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no. 18, pt. 3
1896-97

EIGHTEENTH ANNUAL REPORT

OF THE

UNITED STATES GEOLOGICAL SURVEY

TO THE

SECRETARY OF THE INTERIOR

1896-97

CHARLES D. WALCOTT
DIRECTOR

IN FIVE PARTS

PART III.—ECONOMIC GEOLOGY

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EIGHTEENTH ANNUAL REPORT

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RECONNAISSANCE OF THE GOLD FIELDS OF SOUTHERN ALASKA, WITH SOME NOTES ON GENERAL GEOLOGY.

BY

GEORGE F. BECKER.

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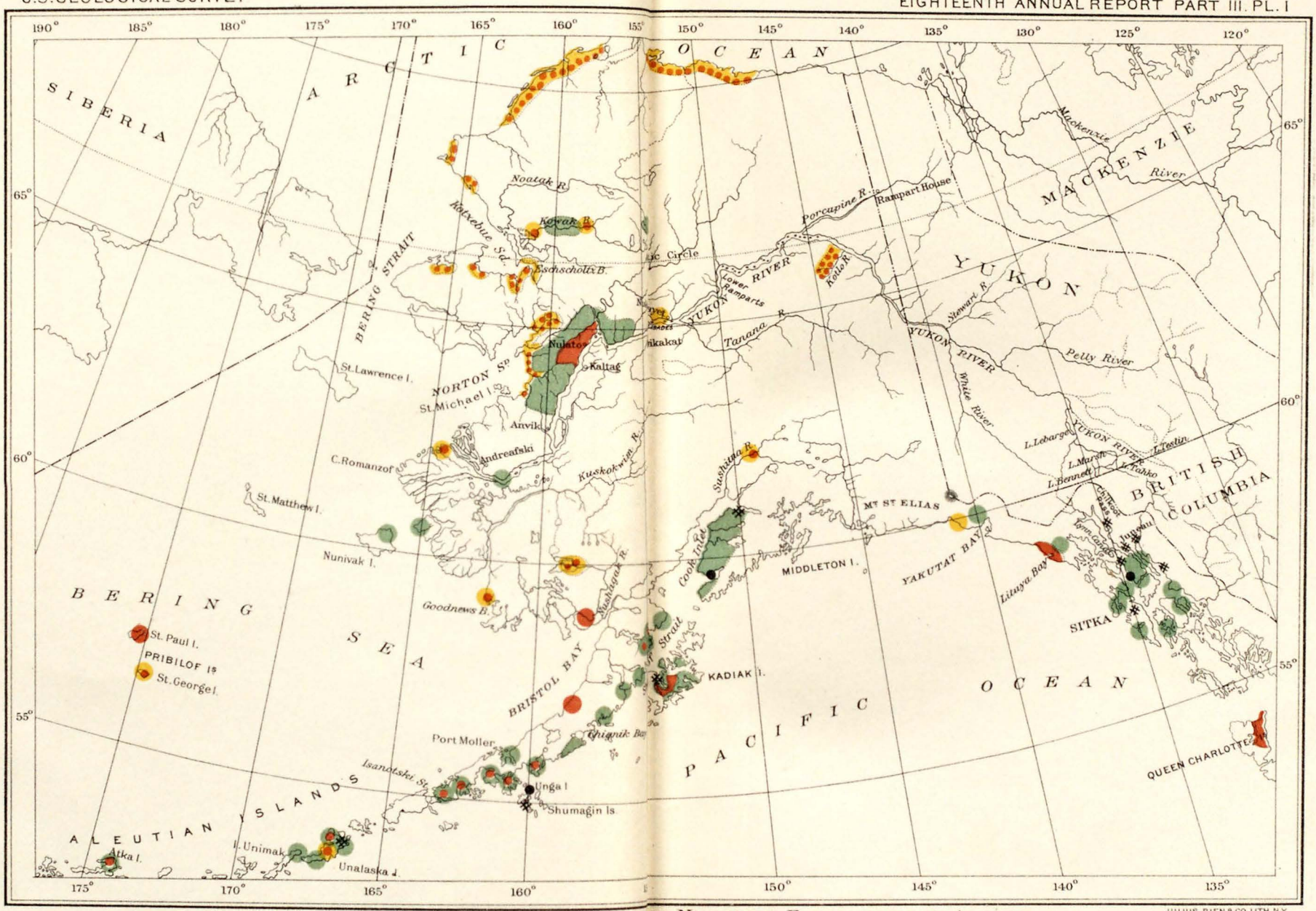

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MAP OF THE KNOWN DISTRIBUTION OF THE NEOCENE FORMATIONS IN ALASKA

W. H. HALL
Sc

0 100 200 300 400 500 600 MILES.

The mineral deposits located by George F. Becker

- ● Coal deposits
- ✱ Gold vein locality
- X Gold placer locality

- Ground Ice formation and Kowak clays with fossil vertebrates (Pleistocene ?)
- Pliocene
- Kenai group (Miocene ?)
- Kenai group capped by Astoria beds
- Astoria group, Miocene, Nulato and Unga beds.

RECONNAISSANCE OF THE GOLD FIELDS OF SOUTHERN ALASKA, WITH SOME NOTES ON GENERAL GEOLOGY.

By GEORGE F. BECKER.

INTRODUCTORY.

Early in 1895 Congress appropriated $5,000 for the investigation of the gold and coal resources of Alaska, to be expended under the direction of the United States Geological Survey. The Director committed the work to my charge. At my desire he requested Mr. William H. Dall to accompany me and make an examination of the coal deposits, with which his former well-known explorations had in large measure familiarized him. Mr. Chester W. Purington also accompanied me as personal assistant.

By the courtesy of the Navy Department, the U. S. ship *Pinta* was placed at our disposal for examinations in the Alexander Archipelago. Thanks to the kindness of Lieut. Commander A. R. Couden, commanding, and his officers, we enjoyed every facility for visiting points accessible by water in southeastern Alaska. All efforts to procure suitable transportation to the westward of Baranof Island failed. We reached St. Paul, Kadiak, by the mail steamer, and there secured a small tugboat of 24 tons, gross, in which, with great discomfort and some risk, a cruise of over 1,300 miles was accomplished. Kadiak was circumnavigated, Chirikof was visited, Cook Inlet, Turnagain Arm, and Kachemak Bay were explored with such thoroughness as time permitted, and landings made at various points on the Alaska Peninsula from Cape Douglas to Unga Island. From Unga to Unalaska the mail steamer was again resorted to. At Dutch Harbor a steamer was chartered for a brief visit to Bogoslof and Grewingk, and the *Bertha*, with a cargo of seal skins, transported us from Dutch Harbor to San Francisco.

Mr. Dall's report on Coal and Lignite of Alaska has already appeared in the Seventeenth Annual Report, Part I. The report on gold, delayed by unforeseen events, is here presented. Besides notes on gold, it has been considered best to include such observations on other matters of geological interest as were made on the trip. Mr. Purington has assisted most efficiently in the elaboration of the material.

GEOGRAPHICAL NOTES.

The well-known gold deposits of Alaska are divisible into two greater groups. Of these one lies upon the Yukon River close to the British frontier and some 300 miles from the coast. The other stretches along the coast from Sumdum Bay westward as far as Unalaska. Gold has also been detected on the Kowak and the Kuskokwim rivers. The examinations recorded in this report were confined to the coastal mines. Pl. I exhibits the general distribution of the deposits, and more detailed maps are given in connection with the detailed descriptions.

The direct distance from Sumdum Bay to Unalaska is some 1,250 statute miles, and the coast line is of course much longer.[1] It is therefore desirable to group the coastal auriferous localities more minutely. The most easterly mines are all either on islands of the Alexander Archipelago or on the adjoining mainland. The largest town of the Territory, Juneau (originally called Harrisburg), is on the mainland. Just opposite the town, on Douglas Island, is the Alaska-Treadwell mine and its extension, the Mexican. On the mainland within a few miles of Juneau are the Silver Bow Basin and the Sheep Creek districts. Sumdum is on the mainland some 55 miles to the southeastward of Juneau; and Seward City, near Berners Bay, is about 50 miles to the northwestward. There are also gold-quartz veins on the northern end of Admiralty Island, 30 miles west of Juneau.

The last district of importance in the Alexander Archipelago is near Sitka, on Baranof Island. Sitka is about 100 miles west of south from Juneau. Another group of deposits lies in the region of the Kenai Peninsula, which forms the southeasterly shore of Cook Inlet. The only deposits actually exploited on the mainland in this region are the stream gravels on Turnagain Arm. At Yakutat Bay there are auriferous beaches, as there are also on Kadiak Island. On this island, too, there is a group of gold-quartz veins, which are being explored and tested.

The Apollo Consolidated mine is on Unga Island, one of the Shumagin group, some 450 miles westward from the Kenai Peninsula. The auriferous area of Unga seems to extend across a narrow strait to Popof Island. Traces of gold are said to have been found on the Alaska Peninsula, and there is certainly a trace of gold on Unalaska, although as yet no valuable deposit has been found there.

The physical conditions of the Alaskan coast can not be said to be unfavorable to mining. In spite of the high latitude, the winter is not severe. The summer is never hot. The precipitation, however,

[1] The coast line of Alaska, including islands, is said to be 26,364 miles, while the Atlantic coast of the United States, including islands, is only 2,043 miles. Eleventh Census, Alaska vol., on authority of Coast Survey.

is great. In the region eastward of the center of Kadiak, timber is extremely abundant, so much so as to make prospecting laborious where it is not fairly impracticable. West of the line indicated there is no timber. The sea, of course, affords ready means of transportation for the entire coast, but navigation is often somewhat perilous.

The meteorological data available, excepting for the port of Sitka, do not accord very well. The averages are probably derived from a number of years too small to eliminate annual variations.

The following little table shows the average temperatures and precipitation, as given to me by the Weather Bureau:

Average temperatures and precipitation in Alaska.

Station.	Mean January temperature.		Mean July temperature.		Annual rainfall.	
	Degrees F.	Number years.	Degrees F.	Number years.	Inches.	Number years.
Juneau	26.9	4	57.8	3	94	2
Sitka	34.2	6	54.4	7	111.7	7
St. Paul, Kadiak	26.6	11	45	9	39.1	6
Unalaska	33.5	5	49.6	4	50.2	5

The observations of Mr. Frederick Sargent at St. Paul, Kadiak, which are recorded in the report of the Eleventh Census, give the following figures:

Mean January temperature for nine years, 31.3° F.; mean July temperature for ten years, 53.4° F.; mean annual rainfall for seven years, 67.1 inches.

The discrepancy between the Weather Bureau figures and those obtained by Mr. Sargent is probably due to the different years included. Mr. Sargent's lowest temperature is − 2° in 1882.

In the Alaska census volume Mr. S. Applegate states the rainfall at Unalaska for the years 1882, 1883, 1884, 1887, and 1888. The average is 118 inches, or considerably more than the Sitka precipitation instead of less than half as much.

The four stations lie at no great distance from the same isotherm, as appears from the data given or from an inspection of Mr. A. Buchan's isothermal chart. Of course the mildness of the winter is due to the effects of the Japan Current.

HISTORICAL NOTES ON ALASKAN GOLD.

If the early Spanish, Russian, and English explorers of the Alaskan coast detected gold in that Territory, they seem to have omitted all mention of the fact, and as such a discovery would have added to the importance of their explorations it may be assumed that they failed to

detect the precious metal.[1] In 1849 Mr. A. Erman published in a Russian journal a map of the world, showing the distribution of gold, which fails to indicate any auriferous locality in Alaska.[2] The Russians looked upon their American possessions as a hunting ground for fur, and had committed its charge to the Russian American Trading Company. In 1848, however, the Government commissioned Mr. P. P. Doroshin[3] to explore for mineral resources about Sitka, the island of Kadiak, and the Kenai Peninsula. He discovered the coal of Cook Inlet and detected gold at several points. In 1851 he again visited the country, but on neither occasion did he find any gold-bearing veins or meet with gravels carrying more than a sixth of a pennyweight per ton. He was afterwards bitterly reproached for not having found more gold, but his failure is not a matter for surprise. He obtained no aid from the natives, who, he declares, had no word for gold, and he was not fortunate in the areas selected for examination. The Kaknu River, which empties into Cook Inlet at Fort Kenai,[4] and Yakutat Bay were among Doroshin's localities.

In 1863 there was considerable excitement about the gold washings on the Stikine River (the Cassiar district), which, however, were entirely in British territory. Gold was reported on the Taku River, not far from Juneau, as early as 1867.[5] In 1873 a gold-quartz vein was found on Silver Bay, 10 miles from Sitka.[6] Fruitless prospecting had been done some years earlier in the same region.[7] The placers of Silver Bow Basin were discovered in 1880 and those of Douglas Island in 1881. In working these last a large body of low-grade quartz was laid bare, which was soon acquired by Mr. John Treadwell. The famous Alaska-Treadwell mine is opened on this body of quartz. Sheep Creek came into notice in 1888, and rich ore was discovered in Sumdum Bay in 1889. In this same year only assessment work was being done at Berners Bay.[8]

On Kadiak Island production can hardly be said to have begun at the time of the examination described in this paper, but the late Prof. J. S. Newberry long since reported gold in specimens from Kadiak.[9]

On Turnagain Arm, at the head of Cook Inlet, there are auriferous stream gravels. At Bear Creek active operations were begun in 1894. In August, 1895, further discoveries were made near the head of the arm.

---

[1] According to C. P. C. Fleurieu (1797), Juan de Fuca reported gold, silver, and pearls on Puget Sound, but little credit seems to have been given to the statement. Possibly the natives may have had trinkets obtained by barter.

[2] Archiv für wissenschaftliche Kunde in Russland, vol. 7, 1849.

[3] Idem, vol. 25, 1866–67, p. 225. Doroshin published several other papers.

[4] C. Grewingk, Beiträge zur Kentniss der Nordwestliche Küste Amerikas, 1850.

[5] U. S. Coast Survey Rept., 1867, p. 290.

[6] Mr. Henry Boursin, Eleventh Census U. S., Alaska vol., p. 229.

[7] Russian America, House Ex. Doc. 177, Fortieth Congress, second session, 1867, p. 253.

[8] Mr. J. H. Burfeind, Eleventh Census U. S., vol. Mineral Resources, 1892, p. 101.

[9] An unpublished report to the Secretary of the Smithsonian Institution; cited in Coast Pilot of Alaska, 1869, App. 1, by W. H. Dall.

The beach sands at Yakutat Bay, on the west coast of Kadiak, and in other localities contain gold, and small parties of miners sometimes engage in its extraction without any brilliant success. To the west of Kadiak the Apollo Consolidated mine is the only one which has yielded any large quantity of gold. It was opened about the year 1886. Prospecting has been done at Unalaska and to some extent on the Alaska Peninsula with insufficient success.[1]

On the Yukon gold was first discovered by members of the Western Union Telegraph Expedition. The first mention of this gold field is by Mr. F. Whymper, in 1869.[2] It was also referred to by Mr. William H. Dall in 1870.[3] The first mining excitement on the Yukon was in 1886.

STATISTICS OF GOLD PRODUCTION.

The figures for the gold product of Alaska are necessarily mere approximations in most cases, since no efficient means exist for obtaining accurate returns excepting in the case of a few companies. In the following table the product of the Alaska-Treadwell from 1882 to 1889, inclusive, is taken from the report of the company for 1894. After 1890, the published reports show the products for the year ending June 1. The figures for the Apollo Consolidated for 1891 to 1894 are taken from a table kindly communicated to me by the company, and represent the net proceeds or returned value of concentrates and bullion shipped in these years. All the other figures are taken from the reports of the Director of the Mint. The details of production are on the authority of Mr. C. G. Yale. The last column shows the estimates of the Director of the Mint, based only in part on the direct returns of his agents, for the entire territory.

The silver product of Alaska is not included in the table. Prior to 1894 the Director of the Mint did not estimate as much as $11,000 coining value in any year. His estimates for 1894, 1895, and 1896 are, respectively, $28,782, $86,880, and $187,867. The Apollo Consolidated produced $39,620 in silver, coining value, in 1896, mainly from the sulphurets, which contain much galena. The remainder for the same year seems to have come from the mines of the Alexander Archipelago, the estimate being founded on returns from the smelting works of the Pacific Coast.

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[1] Mr. Henry Boursin, Eleventh Census U. S., Alaska vol., 1893, p. 236.
[2] Travels in Alaska and on the Yukon, 1869, p. 258.
[3] Alaska and its resources, 1870, p. 477.

Statistics of gold production in Alaska.

[Stated in dollars.]

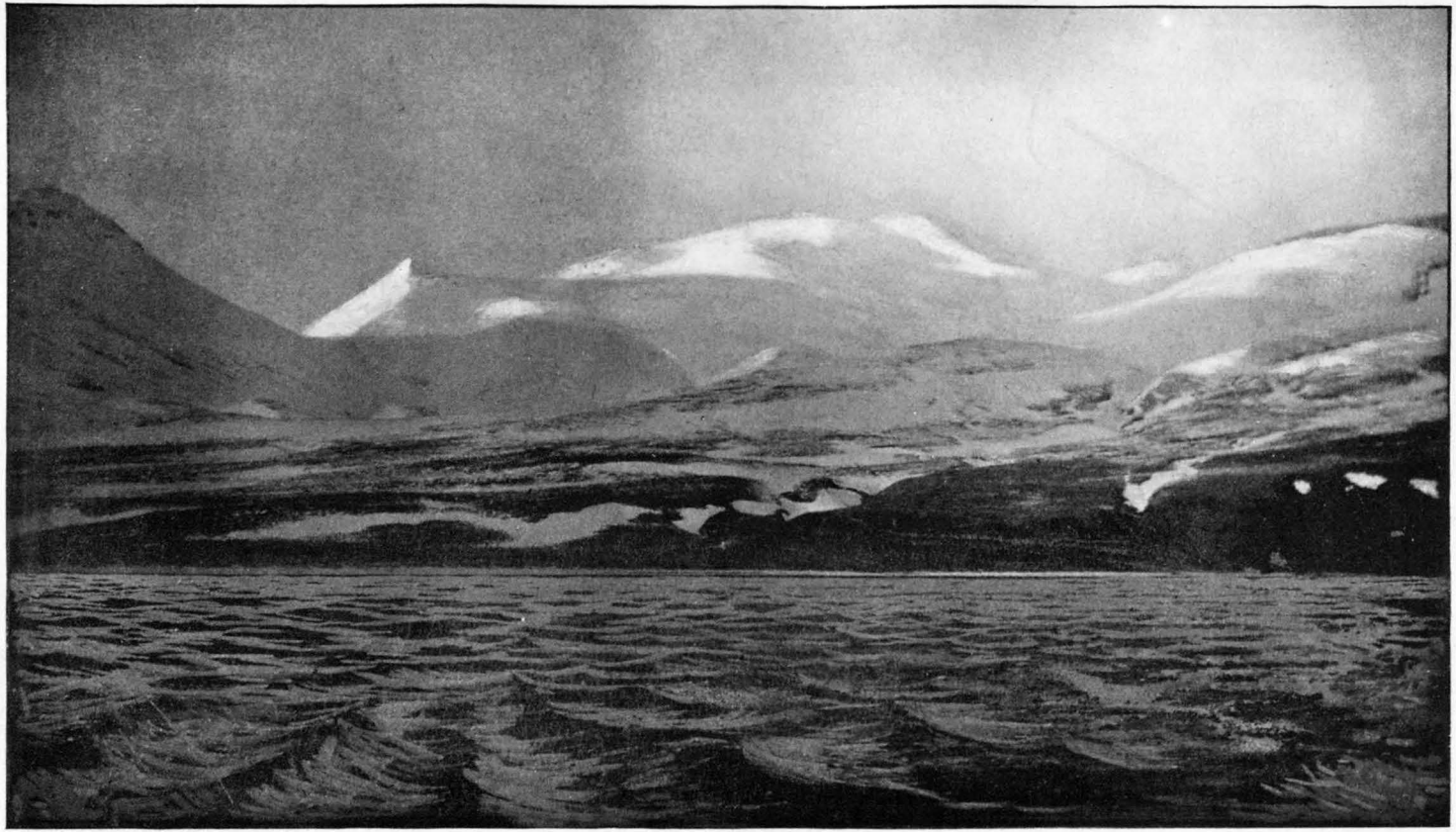
Year.	Alaska-Treadwell mine.	Mexican mine.	Other quartz mines of southeastern Alaska.	Stream placer mines of southeastern Alaska.	Apollo Consolidated mine.	Beach placers.	Cook Inlet placers.	Yukon placers.	All Alaska; estimate of the Director of the Mint.
1880	.....	.....	.....	6,000	.....	.....	.....	.....	6,000
1881	.....	.....	.....	13,374	.....	.....	.....	.....	13,374
1882		.....	.....	20,000	.....	.....	.....	.....	150,000
1883	10,903	.....	2,000	140,000	.....	.....	.....	.....	300,000
1884		.....	100,000	50,000	.....	.....	.....	.....	200,000
1885	242,319	.....	.....	.....	.....	.....	.....	.....	300,000
1886	366,180	.....	.....	.....	.....	.....	.....	.....	446,000
1887	476,934	.....	.....	.....	.....	.....	.....	.....	675,000
1888	429,889	.....	.....	.....	.....	.....	.....	.....	850,000
1889	652,491	.....	250,000	25,000	.....	.....	.....	.....	900,000
1890	613,191	.....	68,238	25,000	.....	.....	.....	50,000	762,500
1891	765,673	.....	21,843	120,000	780	.....	.....	100,000	1,020,045
1892	676,226	.....	110,820	180,900	30,216	2,500	.....	110,000	1,080,446
1893	779,782	.....	7,400	.....	47,847	6,000	.....	200,000	1,000,000
1894	555,307	204,042	19,400	.....	35,297	.....	.....	409,000	1,113,550
1895	818,690	226,258	277,676	2,265	225,395	17,854	50,000	709,000	1,615,300
1896	693,576	245,861	482,382	40,000	400,313	39,000	120,000	800,000	2,055,710

VOLCANIC ACTIVITY AND CHANGES OF LEVEL.

It is very certain that volcanic activity has existed at numerous points along the northwestern coast of America from the Golden Gate northward in comparatively recent times. Less certainty exists in this newly settled region as to historical outbursts. It has been reported on seemingly credible authority that Mount Baker was in eruption in 1843, and the statement has been accepted by Grewingk,[1] Davidson,[2] Whitney,[3] Dana,[4] and Diller.[5] The evidence of a simultaneous outbreak at Mount St. Helens is of the same order of credibility, and it is certain that several of the volcanic cones from Mount Shasta northward still emit small quantities of vapor.

In eastern Alaska, Mount Calder, at the north end of Prince of Wales Island, Mount Edgecumb, close to Sitka, and Mount St. Elias have been reported in action. The only authority for the Calder eruption, supposed to have occurred in 1775, is F. A. Maurelle, and

[1] Verh. Rus. min. Gesell. 1848-49, p. 269.
[2] Russ. Amer., House Ex. Doc. No. 177, Fortieth Congress, second session, 1867, p. 289.
[3] Enc. Brit., 9th ed., vol. 23, 1888, p. 800.
[4] Manual of Geol., 4th ed., 1895, p. 296.
[5] Nat. Geog. Mag., vol. 5, 1893, p. 93.



MAKUSHIN VOLCANO.

Grewingk[1] rejects the report on the ground that if it had been correct it would have been confirmed by other nearly contemporaneous witnesses. The alleged eruption of Mount Edgecumb in 1796 also rests mainly upon the authority of a single witness, E. H. Hoffmann.[2] Sir George Simpson, however, asserts that in 1841–42 there were inhabitants of Sitka who had seen Edgecumb active.[3] On the other hand, had there been an eruption in so conspicuous a position it could hardly have escaped the attention of the Russians.[4] Mount Edgecumb is manifestly a volcanic cone, and smoke from a fire, or even a persistent fog streamer, may have been interpreted by Hoffmann as volcanic smoke.

Mount St. Elias was reported as active in 1839, and again in 1847, and many references to this mountain as a volcano are to be found in literature. Its eruptions were not detected by the sharp and well-trained eyes of the natives,[5] and it is now well known that the mountain is neither a volcano nor even of volcanic origin,[6] a conclusion to which Grewingk came from mere study of the descriptions.

The belt of the present volcanic activity in Alaska begins on the Copper River near Mount Wrangell, and extends along the peninsula of Alaska and the Aleutian Islands to beyond Amchitka Island. Its length is nearly 1,700 miles, which is about the distance from Cape Sable, Florida, to Halifax, Nova Scotia, or from Gibraltar to the Shetland Islands. The ejecta are mainly andesitic. Eruptions have been observed at scores of points, and the intervals are dotted with cones, showing the continuity of the zone of vulcanicity. Mount Wrangell lies at a distance of about 134 miles from the head of Prince William Sound, and, according to Lieut. H. T. Allen,[7] it reaches the great height of 17,500 feet. It was steaming at the date of his visit. It is the loftiest of a group of high mountains, one of which, named Mount Blackburn by Mr. Allen, is only 30 miles from the junction of the Copper River and the Tschichitna, Chechitna, or Chittyna River. I suppose this latter mountain to be that called by earlier writers the Chechitno volcano.

In the following table such records as I have of eruptions on the volcanic belt are arranged according to longitude. The earlier observations were compiled by Grewingk[8] and translated by Mr. William H. Dall, who added data up to 1867. A few more observations, compiled from various sources, are here included, but the list is at best a very partial one. The region is without newspapers, and the seamen or hunters who witness the outbursts are accustomed to the sight.

---

[1] Verh. Rus. min. Gesell. 1848–49, p. 273.

[2] Geog. Beob., gesammelt auf einer Reise um die Welt, 1829; quoted by Grewingk.

[3] Journey round the World in 1841–42, vol. 2, 1847, p. 175.

[4] Grewingk, op. cit., p. 272.

[5] P. P. Doroshin, Erman's Archiv. für wiss. Kunde in Russland, vol. 7, 1849, p. 230.

[6] I. C. Russell, Nat. Geog. Mag., vol. 3, 1891, p. 167.

[7] Exped. to Copper River, Rept. Secy. of War, 1887, p. 59.

[8] Loc. cit., p. 277. A few of Grewingk's data must have been obtained from the natives, for the Russians do not appear to have sighted the Alaskan coast till 1741.

Volcanic eruptions in Alaska.

Locality.	Approximate longitude.	Year.	Phenomena.
	°		
Calder, Mount	133½	1775	Reported active.
Edgecumb, Mount	135½	1796	Said to smoke.
Chechitno, Mount	144½	1760	Smoked.
		1784	Erupted.
Chugach, Gulf. (Prince William Sound.)	146 to 149	1790	Eruption near.
Wrangell, Mount	145	1819	Emitted fire.
		1884	Eruption.
Redoubt, Mount	152½	1819	Smoked.
Iliamna, Mount	153	1741	Grew quiet.
		1778	Resumed action.
		1779	Active.
		1876	Eruption.
St. Augustin, Mount	153½	1883	Violent eruption.
		1885	Steaming, shore to summit.
		1895	Crater steaming.
Veniaminof, Mount (Black Peak).	159	1830–1840	Smoked.
		1892	Violent ash outbreak.
Pavlof, Mount	162	1762–1786	Active.
		1790	Do.
		1838	Smoked.
		1880	Red glare.
		1892	Smoke.
Medviednikof, Mount	162	1768	Active.
Walrus Peak	163	1768	Do.
Amak Island	163	1700–1710	Do.
		1796	Unquiet.
Termination Alaska Peninsula, 163½°.			
Unimak Island	164	1690	Crater formed on Mount Khaginak.
		1775–1778	One volcano active, (probably Shishaldin).
Shishaldin, Mount	164	1778	Smoked.
		1790–1825	Active.
		1824	Flames.
		1827–1829	Fire.
		1830–1831	Very active.

Volcanic eruptions in Alaska—Continued.

Locality.	Approximate longitude.	Year.	Phenomena.
	°		
Shishaldin, Mount	164	1838	Fire.
		1865	Smoked.
		1871–1874	Steamed.
		1880–1881	Smoked.
		1883	Steam and ashes.
		1895	Steamed.
Isanotski, Mount (a little east of Pogrumnoi).	164½	1795	Exploded.
		1825	New crater, ashes.
		1830	Flames.
Pogrumnoi, Mount	164½	1795	Active.
		1827–1829	Fire.
		1830	Ashes.
Akun Island	165½	1828	Smoked.
Akutan Island *a*	166	1790	Do.
		1828	Do.
		1838	Do.
		1883	Steam and ash.
		1887	Lava eruption.
Makushin, Mount, Unalaska Island.	167	1768	Active.
		1790–1792	Do.
		1802	Vigorous.
		1826–1838	Smoked.
		1844	Do.
		1865	Active.
		1871–1874	Steam.
		1880	Do.
		1883	Ashes.
		1891	Steam.
		1895	Do.
Unalaska Island	167	1768	A second volcano active.
Bogoslof Island	168	1796	Rose.
		1806	Emitted lava.
		1814	Threw out stones.
		1820	Smoked.
Grewingk, or New Bogoslof	168	1883	Rose; ashes and lava; has steamed ever since.

a Mr. Dall regards this volcano as usually active and as emitting more lava than any other in the chain.

Volcanic eruptions in Alaska—Continued.

Locality.	Approximate longitude.	Year.	Phenomena.
	°		
Grewingk, or New Bogoslof	168	1890	Emitted ashes.
Vsevidof, Mount	168½	1784	Smoked.
		1790	Active.
		1817	Great eruption north peak.
		1830	Eruption southwest end.
Tanak-Angunakh Island	170	1774	Active.
		1828	Smoked.
Four Craters Islands	170	1796–1800	Active.
		1838	Smoked.
		1871	Steaming.
		1874	Do.
Yunaska Island	171	1817	Smoked.
		1824	Great eruption.
		1830	Eruption.
		1873	Steamed.
Amukta Island	171	1770	Became quiet.
		1786–1791	Active.
Seguam, Mount	172½	1786–1790	Do.
		1827	Smoked.
		1873	Steamed.
Atka Island	174½	1760	Smoked.
		1828	Do.
		1830	Do.
Kluchefskoi, Atka Island	174	1873	Steamed.
Korovin, Mount, Atka Island	174	1830	Smoked.
		1844	Do.
		1873	Quiet.
Sarychef, Mount, Atka Island.	175	1812	Violent eruption.
Koniuji Island	175	1760	Rose.
		1827	Smoked.
		1828	Do.
Great Sitkin Island	176	1792	Fire.
		1829	Smoked.
Adakh, Mount	177	1760	Active.
Kanaga, Mount	177	1763	Solfataras.
		1786	Flames.
		1790	Active.

Volcanic eruptions in Alaska—Continued.

Locality.	Approximate longitude.	Year.	Phenomena.
	°		
Kanaga, Mount	177	1791	Smoked.
		1827	Do.
Tanaga, Mount	178	1763–1770	Constantly active.
		1791	Smoked.
Gareloi Island	179	1760	Do.
		1792	Emitted lava.
		1828	Smoked.
		1873	Active.
Semisopochnoi Islands	180½	1772	Smoked.
		1790	Do.
		1792	Do.
		1830	Do.
		1873	Active.
Sitignak Island (near west end of Amchitka).	181	1776	Do.
Little Sitkin Island	181½	1828	Smoked.

No active vulcanicity is recorded west of longitude 180½°, but Buldir Island, in 184°, is described by Dr. Dawson[1] as a once symmetrical volcanic cone much eroded by the sea. The Semichi Islands are low and flat. Attu, Bering, and Copper islands are reported to consist largely of pre-Tertiary igneous rocks, but Dr. Dawson reports basalt also on Bering Island. On the mainland of Kamchatka there are, as is well known, many finely developed volcanic cones forming a chain with a northwesterly trend, and several of them have been observed in activity.

Whether there is an immediate and direct connection between the volcanic belt of Alaska and that of Kamchatka is questionable. The distance from Buldir to the Alaskan coast is nearly 600 miles, and between them is a deep submarine channel. Even if the basalt which Dawson noted on Bering Island is a recent rock, a break of over 400 miles spanning the channel remains. On the other hand, the eruptive character of the more ancient rocks on Attu and the Commander islands indicates that vulcanicity once existed in the interval, though now totally extinct. A very handsome diorite is also abundant in Unalaska, and fragments of diorite have been brought up by the eruption of Bogoslof. But ancient eruptives are so widely disseminated that it is not justifiable to associate the earlier and later extrusions without further evidence. That which is available is of a very

[1] Bull. Geol. Soc. America, vol. 5, 1894, pp. 117–146.

general character. The connection between the Alaskan volcanic belt and that of Washington, Oregon, and California, so recently extinct, is also interrupted, and to the southward of this series of volcanoes there is another break before the volcanoes of Mexico and Central America are reached. In short, the shores of the Pacific seem marked at intervals by belts of volcanoes nearly parallel with and at no great distance from the edge of the continental plateau.

The geological structure and the fossil fauna of the Pacific coast manifest a marked tendency to parallelism nearly on the present lines. The Mesozoic upheavals and eruptions were substantially parallel to the present edge of the plateau, and characteristic fossil shells stretch along the coast for great distances. The Pacific coast of the Americas lies along a line of weakness in the earth's lithoid shell, upon which movements seem to recur as often as the tendency to isostasy is brought into action by redistribution of matter on the earth's surface, or by other causes. Such lines of weakness seem to be of great antiquity and, as has been suggested before now, may have been outlined early in the Archean. In accordance with Dana's theory of the permanence of continental areas, the shore line from time to time comes back nearly to the edge of the abysmal submarine plain of the North Pacific, now lying nearly 3 miles below the surface of the ocean.

To me it would appear that there is a close relationship, though no direct continuous connection, between the modern volcanic belts; and that in past geological periods also there have been various stretches of the coast similarly affected by vulcanicity, these sometimes overlapping the present volcanic belts. The Alaskan belt seems to have existed since the late Eocene or early Miocene, and may coincide with still earlier lines of activity.

During the Oligocene (Kenai Group) something like one-half of the Territory of Alaska was submerged.[1] In the late Pliocene a great uplift took place in British Columbia,[2] and about the same time the Mount St. Elias Alps were formed.[3] This uplift probably affected western Alaska, and united the Asian and American continents. A partial subsidence seems to have followed,[2] succeeded by a gradual rise, still in progress, from about longitude 145° W. to Bering Sea. The limits of time just indicated correspond to the period during which it is known from fossil evidence that volcanic activity has been in progress. To me it also seems most natural to conceive of vulcanicity as due to the active progress of upheavals and subsidences, the fusion of the lava being ascribable to the dissipation of the energy of uplift.[4] The immediate disturbance of equilibrium which gives

[1] W. H. Dall, Bull. U. S. Geol. Survey No. 84, 1892, p. 251.
[2] G. M. Dawson, Trans. Royal Soc. Canada, vol. 7, sec. 4, p. 54.
[3] I. C. Russell, Nat. Geog. Mag., vol. 3, 1891, p. 174.
[4] If the rocks at a certain depth are near the point of fusion, but are solid on account of the pressure to which they are subject, the principal expenditure of heat would be in supplying the "latent heat of fusion."

rise to the recent uplift is perhaps in part due to the erosion of the Yukon and the Kuskowim rivers.

The effects of uplift are manifest all along this part of the southern coast of Alaska, and were familiar to Grewingk, as well as later writers. Raised beaches and almost unscarred baselevels at elevations of 100 feet, more or less, are very abundant. The Tertiary beds are usually raised to a height of some hundreds of feet, while the western end of Kadiak, Chirikof Island, and other localities seem to represent very modern elevations. Grewingk suggests that the peninsula of Alaska may have been a series of islands comparable to the Aleutians, and certainly if the coast were now to sink 200 or 300 feet the peninsula would be resolved into several insular masses.

A portion of the uplift seems to be historical. At a slight earthquake in 1868 the elevation is said to have amounted locally at Unga to over 20 feet; the Isanotski Strait has become impassable; near St. Michael, windrows of rotten driftwood lie far above the reach of storm waves, and barnacle shells are found 15 feet above high-water mark.[1] Dr. Dawson records evidences of recent elevation amounting to from 10 to 30 feet at Unalaska, Attu, Bering Island, St. Paul Island, and St. Matthew Island, while concluding that the Aleutian Islands as a rule have been unsubmerged since the Miocene.

Possibly the recency of the last uplift may explain the treelessness of western Alaska. One of the most striking contrasts which the country affords is that between the exceedingly dense forests of the east and the absolute treelessness of the west. There is no apparent climatic cause for the sudden disappearance of the spruce west of a line passing through Kadiak. The temperature scarcely changes on a course following the coast along this line. The rainfall maintains the same superabundance, the winds are not severe enough to explain treelessness excepting in very exposed places, and the soil of wooded Edgecumbe can not be very different from that of the treeless Alaska Peninsula. On the other hand, salt-water straits with heavy tidal currents might prove very effectual barriers to the advance of the forests. If Bristol Bay was connected with Cook Inlet by the way of Iliamna and Clark lakes in recent times, and if the western portion of Kadiak was then under water it would be quite intelligible that the spruce should not have made its way to the westward of the meridian of Redoubt, or 153°.

Bering Sea is, on the whole, a very shallow one. About one-half of its area is within the 100-fathom contour, but there is a deeper basin to the northward of the western end of the active volcanic belt, which seems to connect by a deep channel with the adjacent floor of the Pacific Ocean. Bering Strait is so extremely shallow that a further rise of the country of less than 200 feet would connect the continents of Asia and America. Were such an uplift to occur the

[1] W. H. Dall, Alaska and its Resources, 1870, p. 465.

land would be continuous from the Cape of Good Hope to the Straits of Magellan, excepting for the Suez Canal, or to the east coast of Labrador and to Cape Finisterre. The continental area would then be unbroken except by man over more than 130° of latitude and 313° of longitude. In the more philosophical sense of the word "continent," in which the shoal-water plateau is recognized as continental, Asia and America are already united, while Newfoundland and Ireland are not insulated. There is no doubt that the two continents were united by dry land, perhaps more than once, during the Tertiary.

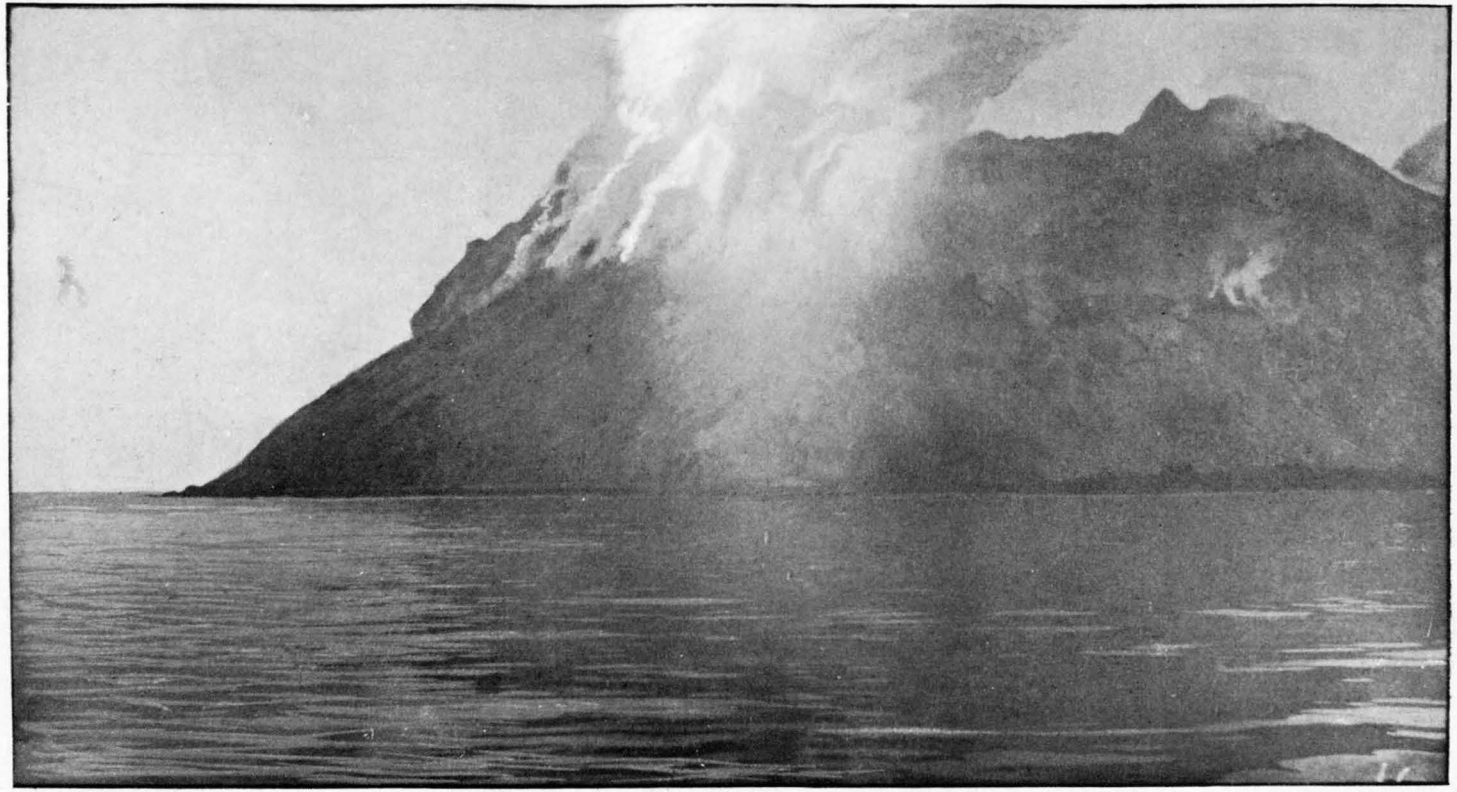
So far as the ocean currents and the climatic features dependent upon them are concerned, the union of Asia and America would make little or no difference. Mr. Dall has shown the commonly received opinion that a branch of the Japan Current flows through Bering Strait to be erroneous. His own observations and a careful discussion of all the known records show that the currents in the strait are chiefly tidal and that they are cool. "The strait is incapable of carrying a current of warm water of sufficient magnitude to have any marked effect on the condition of the Polar basin just north of it."[1] When the land in this region was at a considerably lower level, so that a free and ample communication existed between the Pacific and the Polar basin, more warm water must have reached the Arctic, and the climate of northern Alaska must have been relatively mild, as was long since pointed out.

FORM OF VOLCANIC CONES.

The volcanic belt of Alaska shows many symmetrical cones of the type of Fujisan. There are at least equally numerous cases in which the eruptions have produced masses without marked symmetry. It is quite conceivable that when the volcanic conduit is vertical, its cross section being nearly round and the ejecta mainly ash, the ejecta should be symmetrically disposed about the orifice. When such symmetry of conditions is wanting, it is highly improbable that symmetry of form would result. Hence similar lavas, under circumstances which differ only accidentally, may produce mountains of very regular or of very irregular geometrical character. While the conditions broadly considered or on a large scale may nearly approach symmetry, it is substantially impossible that circumstances should be sensibly uniform when the minuter details are considered. Hence regularity, resulting from general average, can reasonably be looked for in the larger features of a volcanic cone.

When volcanoes are symmetrical—and such volcanoes are extremely numerous—the form is found to correspond, except in scale, to the well-known outline of Fujisan, in Japan. The generating curve is a continuous one, so far as can be judged by inspection. Mount St. Augustine, a view of which is given on Pl. X, is of this type.

[1] Coast and Geodetic Survey Rept. for 1880, App. 16.



GREWINGK, BEARING NW. BY N., IN 1884.

Volcanic cinder cones a few score feet in height are comparable with artificial heaps of loose material sloping at the "angle of rest." The problem might be proposed to find, for a mass of loose, dry material, with a circular horizontal cross-section and an indefinite volume, the loftiest continuous geometrical form consistent with stability. The solution, however, would not answer exactly to a volcanic cone with a very small crater. Even damp ash behaves differently from dry material, the film of water between adjacent grains producing a powerful adhesion through capillary attraction,[1] and there is no doubt that wet volcanic ash hardens, or "sets," to a relatively firm continuous mass. Volcanic cones are also composed in part of lava streams which have solidified from the liquid state. The volcanic cone, therefore, seems to me to be substantially a continuous solid of finite height. In such a mass the pressure per unit area on any horizontal cross-section may be assumed to be uniform over the whole cross-section, while a conical heap of loose material exerts a pressure on the base which is very far from uniform, being greatest at the axis.[2] But while the mountain as a whole is to be regarded as continuous, its external form is determined very largely by the fact that it is built up of layers, each of which consists mostly of ash at the time of precipitation, though it subsequently consolidates to firmer material.

A mountain thus formed must be subject to many vicissitudes, and it is not to be supposed that such a method of genesis can lead to an invariable form. Neither does observation show that volcanoes are all of one shape, as was stated above. Thus Makushin, Pl. II, and Bogoslof, Pl. VII, are irregular masses. On the other hand, there may be a theoretical form to which volcanoes will approach under favorable conditions of symmetry and when the ejecta are mainly ash.

The problem which seems most nearly to correspond to the case of the well-formed volcanic peaks seems to be this: To find the loftiest figure of given volume and continuous curvature which can be built up of successive showers of ash, each ash layer being supposed to become indurated after its deposition. Near the summit the slope will be determined by the angle of rest of the cinder, and the radius of curvature of the generating curve must be infinite at this point. In lofty volcanoes the slope can not be uniform throughout, because the pressure per unit area on a horizontal cross-section of a rigid right cone would be simply proportional to the height of the cone, and the pressure would thus ultimately exceed the resistance. At a great distance from the summit the load per unit area may approach

[1] Everyone is aware that two wet glass plates adhere strongly. The points of contact of moistened sand grains are held together in the same way. Compare. Am. Inst. Min. Eng., 1894, p. 131.

[2] In a right cone of loose material sloping at 45° it is easy to show that the pressure at the center of the base would be proportional to half the height, while the average pressure on the base would be proportional to one-third of the height.

the limit of resistance, and in the loftiest possible volcano of given volume this limit must be approached.

Let the summit be taken as origin, and let the distance from the summit, measured parallel to the axis of the mass, be x. Then y being the radius, y' y'' its differential coefficients with reference to x, and ρ the radius of curvature of the outline, it is well known that

$$\rho=\frac{(1+y'^2)^{3/2}}{y''}.$$

At the summit ρ is to be infinite, while y' for $y=0$ is the cotangent of the angle of rest and is finite. Hence y'' must be zero, when $y=0$ and $x=0$. Now, assuming the curve to be continuous, it must also be possible to express y'' in terms of y, or, by Maclaurin's theorem,

$$y''=f(y)=ay+by^2+cy^3+\ldots \tag{1}$$

a, b, and c being constants of the form $d^n f(0)/\ n!\ dy^n$.

When x is great, the load on a horizontal section is to approach the limit of resistance, so that if σ is the specific gravity of the material and $\varkappa$ the resistance per unit area at the elastic limit

$$\sigma\int y^2dx=\varkappa y^2.$$

The corresponding value of y'' is, by simple differentiation,

$$y''=\frac{\sigma^2}{4\varkappa^2}y, \tag{2}$$

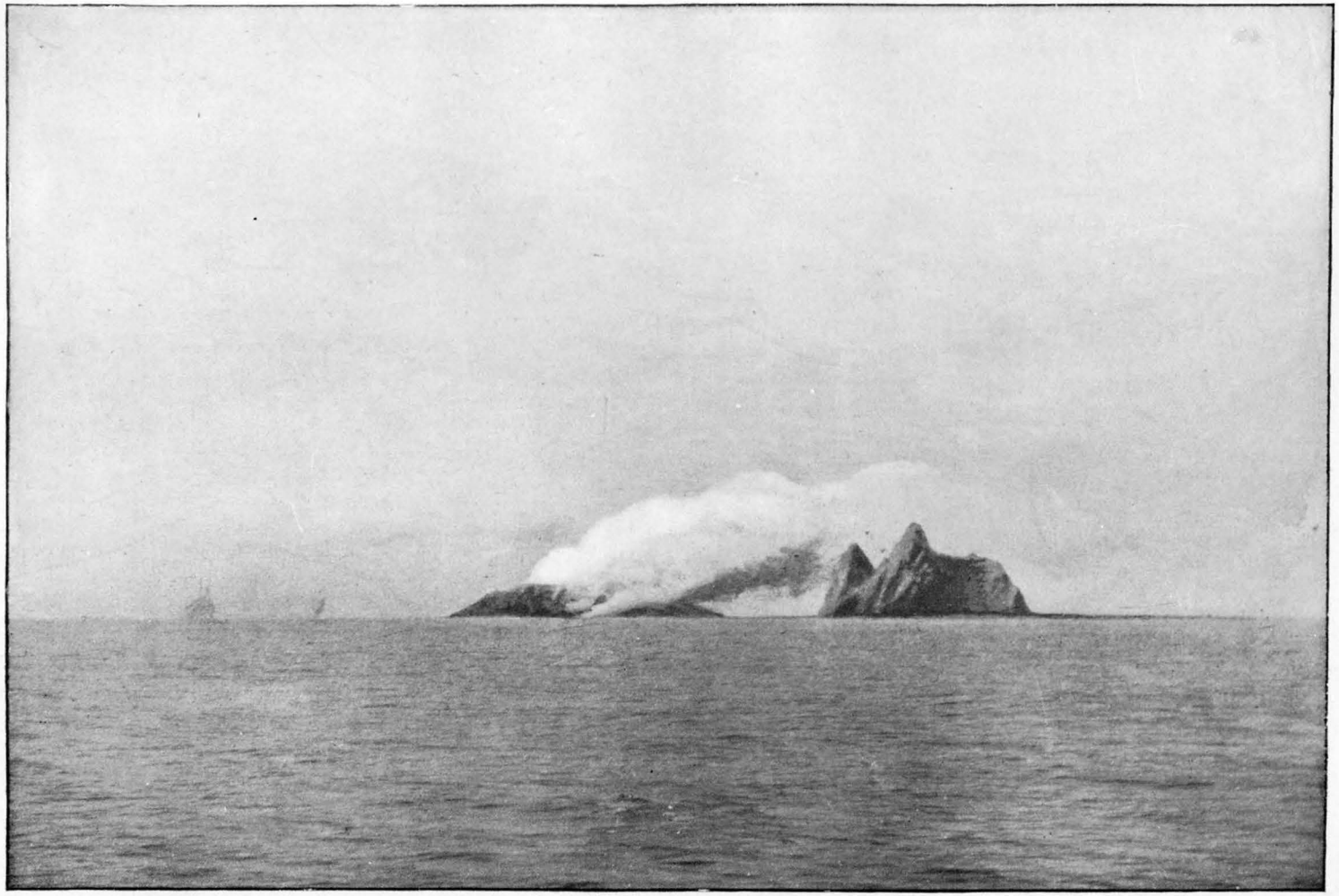
and this is the form which (1) must assume when x and y are sufficiently large. But (1) can not possibly assume this form for large values of y unless b, c, etc., are all zero. Hence, if there is any continuous curve which will express the conditions postulated, its differential equation is of the form (2).[1]

A first integration of (2) gives

$$y'^2=\frac{\sigma^2y^2}{4\varkappa^2}+\frac{1}{a^2}$$

where a is the tangent of the angle of rest. Now, this tangent is by definition the ratio of the frictional resistance of a surface to the normal pressure of a body resting upon it. This resistance can not exceed the pressure which excites it, and the ratio can not exceed

[1] It is not worth while to regard σ as variable; for, excepting near the summit of a volcano, the cubical compression will be nearly uniform and for such material as rock the variation of density is extremely small within the elastic limit.



BOGOSLOF AND GREWINGK, BEARING N. ¼ E., IN 1891.

unity. Hence the maximum possible value of the tangent of the angle of rest is unity,[1] or, for the present case, $a=1$. This gives

$$\frac{y}{c}=\frac{\varepsilon^{x/c}-\varepsilon^{-x/c}}{2}=\sinh\frac{x}{c}, \tag{3}$$

where for brevity c is written for $2\varkappa/\sigma$.

It is easy to see that this curve answers the conditions postulated. The ratio of pressure to resistance for (3) may be written

$$\frac{\sigma\int_0^x y^2\,dx}{\varkappa y^2}=\frac{2\varkappa}{\sigma}\frac{yy'-x}{y^2}=\frac{\sinh\frac{2x}{c}-\frac{2x}{c}}{\cosh\frac{2x}{c}-1} \tag{4}$$

which continually approaches unity for increasing values of x. At the summit y and y'' vanish, so that the radius of curvature at that point is infinite. Both conditions therefore are fulfilled.[2]

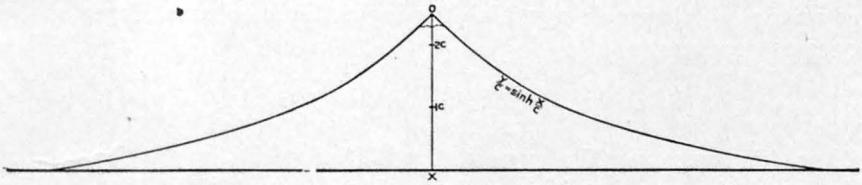


FIG. 1.—Form of volcanic cones.

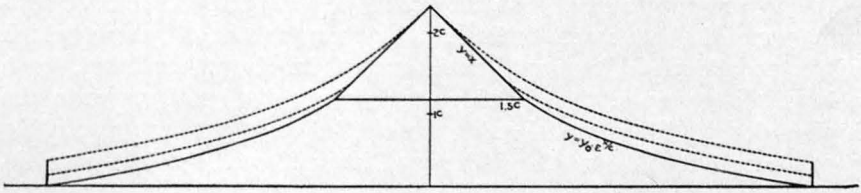


FIG. 2.—Form of volcanic cones.

The curve $\sinh\frac{x}{c}=y$, shown in fig. 1, agrees remarkably well with the form of volcanic mountains as displayed in photographs, and the

[1] According to Weissbach, the maximum angle of rest for sawdust is 44°.

[2] The expression for the volume in (4) is found without labor, as follows: To each member of the first integral of (2), viz, $y^2/c^2=y'^2-1$, add $y^2/c^2=y\,y''$, which is merely equation (2) multiplied by y. Then

$$\frac{2y^2}{c^2}=y\,y''+y'^2-1=\frac{d}{dx}(y\,y'-x).$$

This is one integral of a differential equation of the second order which includes (2), but is more general. It is of the form,

$$y''=\frac{y}{c^2}+\frac{b}{y^3}.$$

If $x=2.5\,c$, the case illustrated in fig. 1, the load on the base is about 19/20 of the resistance.

values of $\varkappa$, deduced from cases where the scale is known, are reasonable,[1] being comparable with those of brickwork and rubble masonry.

It may reasonably be asked why a volcanic cone might not be composed of two distinct portions: first, a right cone near the summit, of such dimensions as to exert upon its base a pressure per unit area equal to the resistance of the material; and, second, a pedestal of logarithmic form and such dimensions that the pressure per unit area at any level is the maximum which the material will bear.[2]

The elements of such a figure are easily computed. Suppose a logarithmic column generated by the revolution of

$$y=y_0\varepsilon^{x/c}$$

truncated in such a manner that the tapering portion cut off will be of volume just sufficient to form a right cone of base πy_0^2 having a slope of 45°. Then the volume of the cone must be $\pi y_0^2\, c/2$, and if h is the height of the cone, $\frac{h}{3}\pi y_0^2=\pi y_0^2\frac{c}{2}$ or $h=3c/2$. The height and radius in a cone sloping at 45° are the same, so that $h=y_0=3\ c/2$. The cotangent of the angle at which the logarithmic column slopes at the base of the cone is

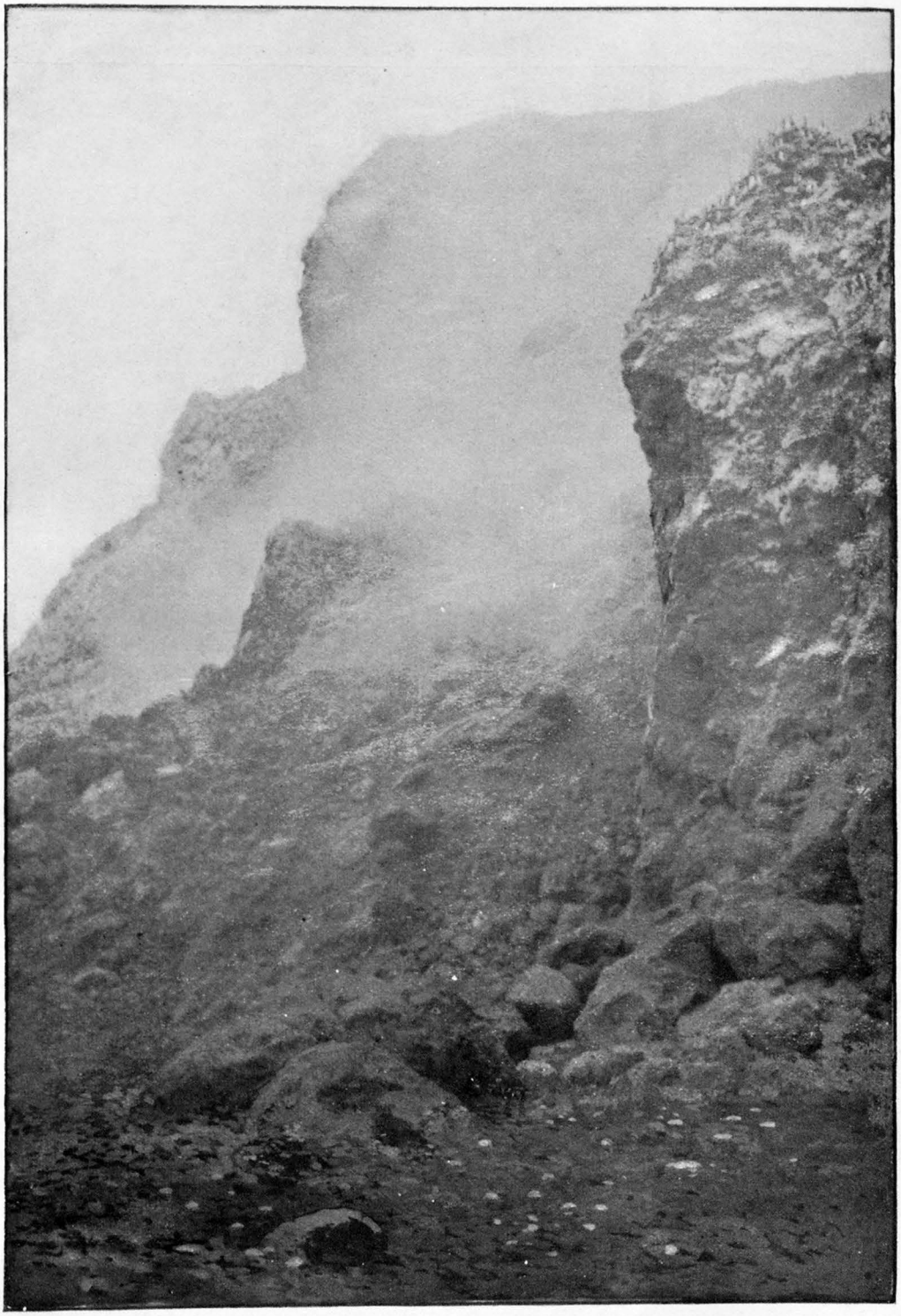
$$y'=\frac{3}{2}=\cot 33^\circ\ 40'.$$

Thus this figure would show an abrupt change of slope at the base of the cone, the angle suddenly diminishing from 45° to 33° 40′. The outline of this mass is shown by the full line in fig. 2 (p. 23).

If one now supposes a fresh shower of ashes to fall on such a mountain, none of the new material can lodge upon the 45° slope, which offers no adequate frictional resistance. On the other hand, fresh ash will lodge upon the shoulder and gradually back up onto the higher slope. Thus the shoulder would be built out into a sensibly continuous curve. But the additional load, if confined to the neighborhood of the shoulder, would overweight the lower portion of the pedestal, which would then yield and broaden. The mass as a whole would not necessarily yield if the fresh ash were distributed over the whole surface below the shoulder. Now, such a layer would evidently build up the mountain to a form closely resembling the dotted lines in fig. 2, which are in fact drawn from the equation $\frac{y}{c}=\sinh\frac{x}{c}$, the locus of which is shown in fig. 1. Thus the discontinuous hypothesis of the volcanic cone leads to results ultimately indistinguishable from the continuous hypothesis, but it serves to throw light on the

[1] A graphic comparison of the continuous curve with the outlines of Fujisan and several other volcanoes will be found in the Am. Jour Sci., vol. 30, 1885, p. 289. Prof. John Milne has also made such comparisons, Trans. Seism. Soc. Japan, vol. 9, part 2, 1886, p. 179.

[2] In the logarithmic column the pressure per unit area at any level is constant, or, in other words, the area of the cross-section is proportional to the volume of the overlying mass.



GREWINGK, WEST SIDE, IN 1891.

process of evolution of the mountains. It appears that if a peak like Fujisan were carved by erosion or other means into any form not inconsistent with stability, fresh eruptions of ash would tend to restore its present symmetry.

In discussing the form of the volcanic cone I have assumed the angle of rest as the maximum possible, i. e., 45°. This angle can never be quite reached, and, as a matter of fact, the steepest talus slopes dip at about 40°. This is of little consequence so far as the theory of a continuous cone is concerned, because on the hypothesis of continuity the maximum angle would then be found only at the sharp apex of the mountain, while real volcanoes have craters of finite size at their summits. In the discontinuous hypothesis there is a long straight slope, and this would necessarily fall as low as 40° if the material were loose. The right cone would then intersect the logarithmic pedestal at a point where its radius is $1.79c$ and where the dip of the surface is 29° 10′. The average energy potentialized in the continuous mountain for $x = 2.5c$, the case shown in fig. 1, would be about nine-tenths of that potentialized in the mountain composed of cone and pedestal, the volume being the same in each.

BOGOSLOF AND GREWINGK.

The island of Bogoslof appeared above the sea in 1796, and a neighboring island, sometimes called New Bogoslof, but for which Mr. Dall has proposed the name Grewingk, rose in 1883. Each island has undergone changes, and the more recent one has been photographed at various intervals. The history of these islands is a very interesting subject, but the data are by no means precise. Estimates of the height of an island made from the deck of a vessel are very untrustworthy, and the fact that successive observers give different altitudes is not valid evidence that a change in elevation has intervened. Even the photographs are unsatisfactory, since the precise position of the camera is generally unknown and the different photographs are not immediately comparable. Mr. Dall[1] has condensed the description of the birth of the earlier island as follows:

On the first of May [1796], according to Baranoff, a storm arose near Umnak, and continued for several days. It was very dark all this time, and low noises resembling thunder were continually heard. On the third day the sky became clear very early, and a flame was seen arising from the sea between Unalaska and Umnak. North of the latter smoke was observed for ten days. At the end of this time, from Unalaska a round white mass was seen rising out of the sea. During the night fire arose in the same locality, so that objects 10 miles off were distinctly visible. An earthquake shook Unalaska, and was accompanied by fearful noises. Rocks were thrown from the new volcano as far as Umnak. With sunrise the noises ceased, the fire diminished, and the new island was seen in the form of a black cone. It was named after St. John the Theologian (Joanna Bogoslova). A month later it was considerably higher, and emitted flames constantly. It con-

[1] Alaska and its Resources, 1870, p. 467.

tinued to rise, but steam and smoke took the place of fire. Four years after no smoke was seen, and in 1804 the island was visited by hunters. They found the sea warm around it, and the soil in many places too hot to walk on. It was said to be 2½ miles around and 350 feet high. The soil emitted an odor of bitumen. It is 45 versts, or nearly 34 miles, due west from the north point of Unalaska. In 1806 lava flowed from the summit into the sea on the north side. Fissures appeared, lined with crystals of sulphur. Veniaminoff says that it ceased to enlarge in 1823, when it was of a pyramidal form and about 1,500 feet high. There are many strong currents about it, and a reef extends from a rock west of it to Umnak.

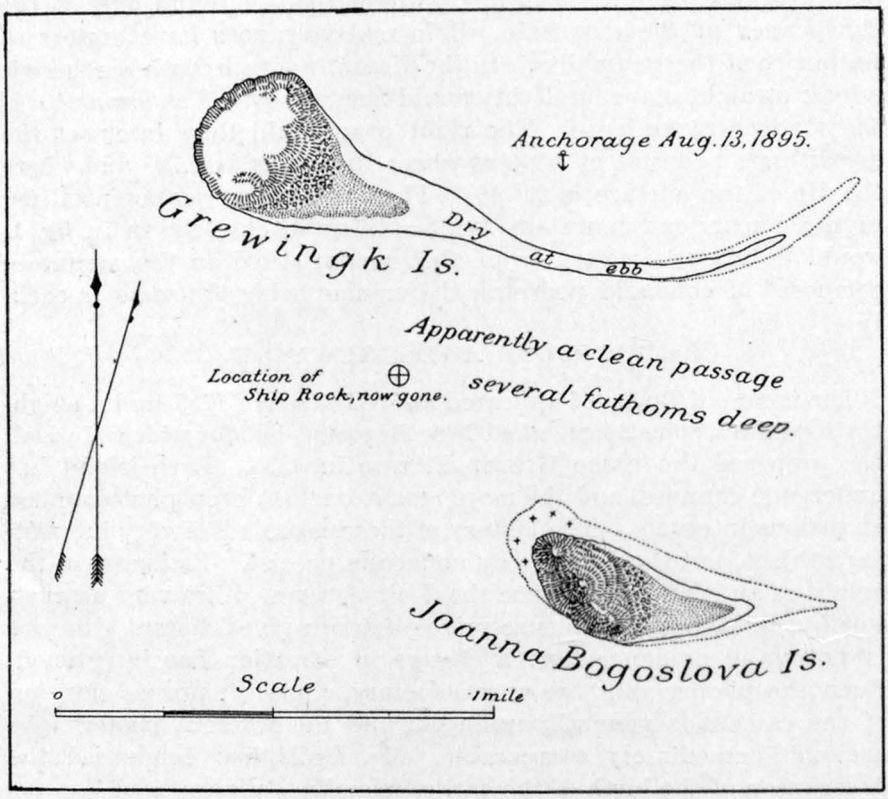
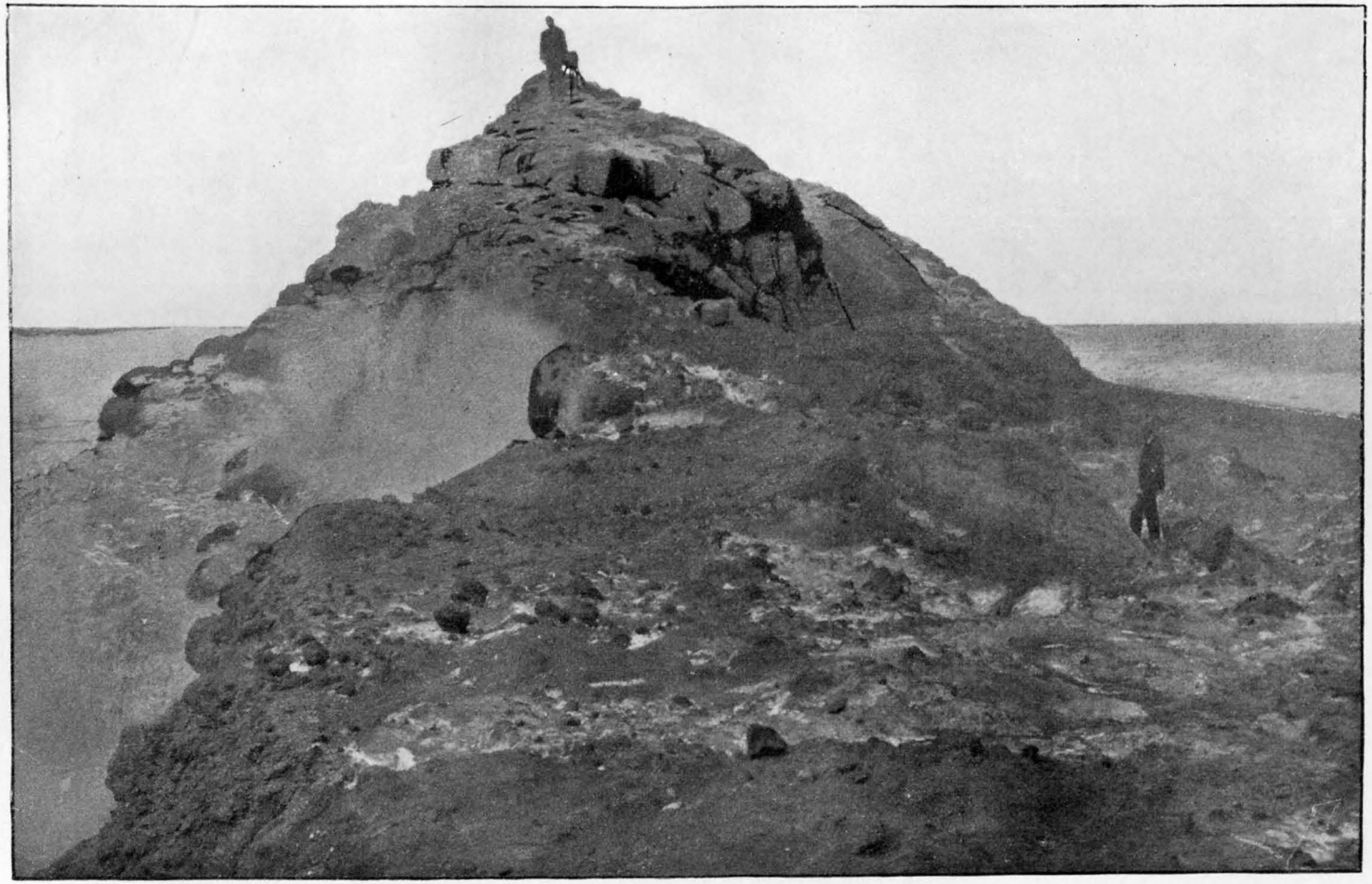


FIG. 3.—Sketch map of Bogoslof and Grewingk.

About half a mile north and west from the island was a perpendicular square-topped pillar, called on modern charts "Ship Rock," possibly, but not certainly, identical with that so named by Cook.

Mr. Dall gathered such information as was available concerning the new island in 1884.[1] Captain Hague, of the *Dora*, observed eruptive action in the locality in the summer of 1883, but the maximum activity occurred in October of that year. Soon after Captain Hague reported the island as three-quarters of a mile in diameter and from

[1] Science, Jan. 25, 1884. Prof. Geo. Davidson also described it in the same journal, March 7, 1884.



GREWINGK, WEST SPUR, FROM ABOVE, IN 1891.

500 to 800 feet in height. Since that time it has undergone various changes.

The island was visited by the U. S. revenue cutter *Corwin*, Capt. M. A. Healy commanding, in 1884, and in the report of that cruise six photographs are published. Comparing these views with those taken in 1891 and 1895, it appears that Bogoslof, the old island, has since undergone no visible change in outline or in apparent elevation since the appearance of the new island, but it seemed to Mr. Dall less lofty than in 1880.

In 1884, however, Grewingk was considerably higher than it now is or than Bogoslof. It was rough and pinnacled and from one point of view dome-shaped. In 1891 it had assumed the flat-topped form, which it still preserved in 1895. In 1884, as shown by the *Corwin* photographs and as mentioned by Mr. Dall, Ship Rock had not disappeared, and a sand spit enveloping Ship Rock extended between the two peaks. This beach was reported continuous in ordinary weather, though showing evidence of submergence in storms. In 1887 the conditions seem to have been unchanged, as is shown by a rough sketch

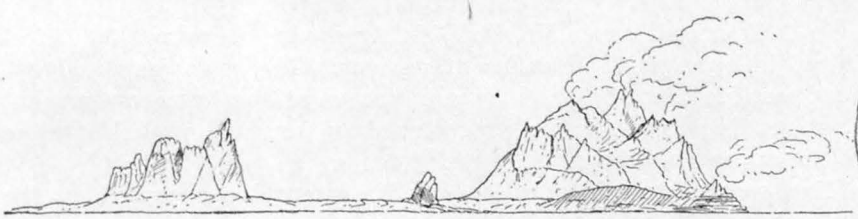


FIG. 4.—Sketch of Bogoslof and Grewingk in 1887, by Mr. William C. Greenfield.

by Mr. William C. Greenfield, kindly given me by him and reproduced in fig. 4. In 1891 Ship Rock had disappeared, and the photographs do not seem to indicate continuous beach between the peaks. In 1895 an apparently clean passage nearly three-quarters of a mile in width separated the two islands. The new island then appeared to be not more than some 300 feet in height. It still steamed vigorously, though not violently, and was colonized to some extent by solan geese. Solfataric decomposition was progressing, with some deposition of sulphur. There was no trace of present or recent volcanic activity on the old island, on which every available nesting place was occupied.

The sketch map of the islands as they existed in 1895 was prepared by Mr. Dall from inspection and some logging, but without survey. Pl. III is from a photograph by Chief Engineer A. L. Broadbent, of the *Corwin*. It is believed to have been taken either in 1884 or in 1885, probably the former, and represents the southerly side of Grewingk. Pls. IV, V, and VI are from photographs taken by Messrs. N. B. Miller and C. H. Townsend, of the United States Fish Commis-

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sion steamer *Albatross*, in 1891. Pls. VII, VIII, and IX are from photographs by Mr. Purington in 1895.

The islands seem to be composed entirely of hornblende-andesite, with some included fragments of diorite. Nothing sedimentary was detected. The igneous material is ash, agglomerate, and tuff, no solid flows being anywhere observed. The rocks will be described in detail in another portion of this report.

ST. AUGUSTINE VOLCANO.

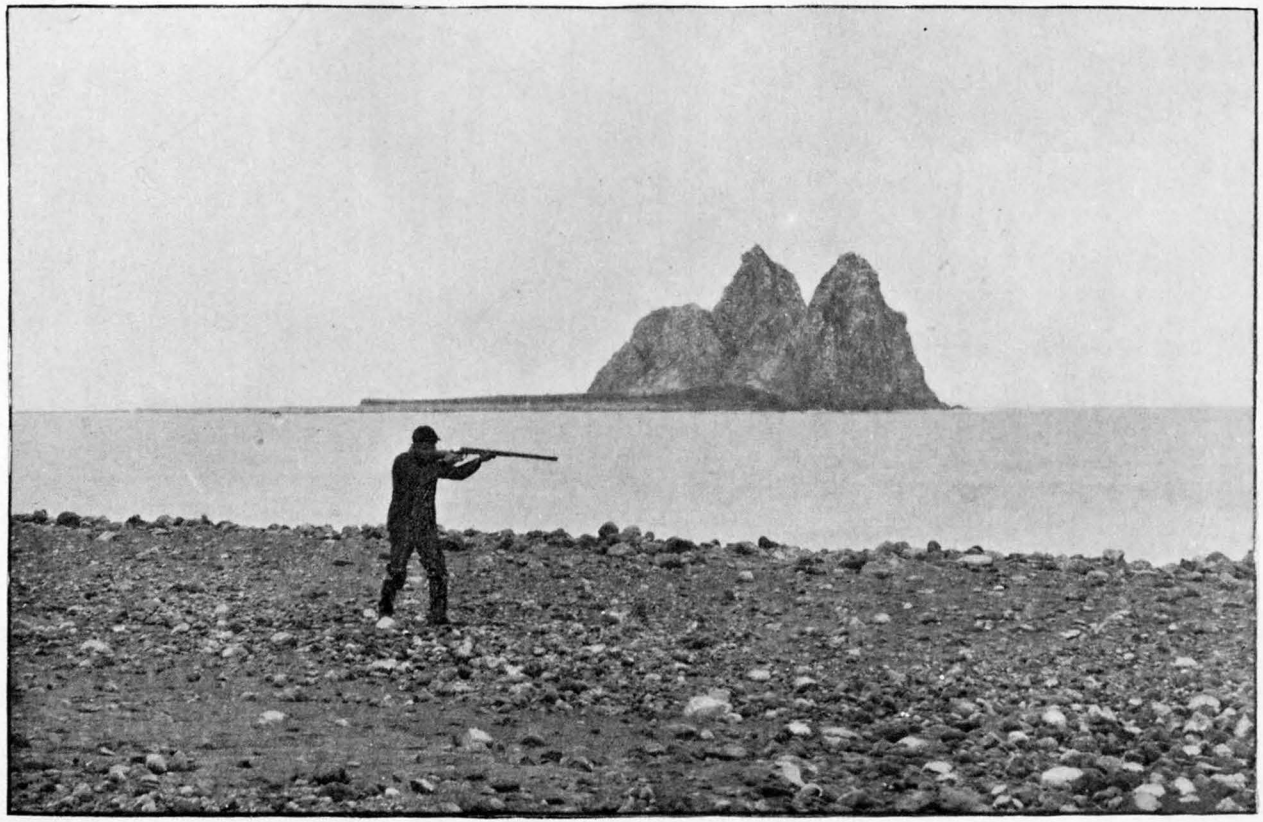
Mount St. Augustine is a volcanic mountain forming an island in Cook Inlet. It is charted as lying in latitude 59° 23′ and longitude 153° 31′ W. It was discovered and named by Captain Cook, who describes it as of conical figure and of very considerable height. In May, 1794, Vancouver[1] wrote:

> This island is stated by Mr. Puget to be about 9 leagues in circuit; toward the sea side it is very low, from whence it rises, though regular, with a rather steep ascent, and forms a lofty, uniform, conical mountain, presenting nearly the same appearance from every point of view, and clothed down to the water's edge with snow and ice, through which neither tree nor shrub were seen to protrude.

In 1880, according to Mr. Dall, St. Augustine measured 3,800 feet in height by angles from different stations. The peak was not sharp. It is possible that the height was increased at the last eruption, but the rounding of the summit mentioned by Mr. Dall probably refers to the appearance from the south.[2]

The only historical eruption of St. Augustine occurred in the autumn of 1883, being contemporaneous with the rise of Grewingk or New Bogoslof from Bering Sea. On the morning of October 6, the atmosphere being very clear, the people at Port Graham heard a loud report and saw dense volumes of "smoke" issue from the top of St. Augustine. A column of steam is also said to have arisen from the sea near the island, and the water was so agitated as to make landing or embarkation there impossible. Twenty-five minutes after the explosion a great earthquake wave, 25 or 30 feet high, came in upon Port Graham, and it was followed by others. The fall of ash at this point, 60 miles from the volcano, amounted to 4 or 5 inches. A new island, 1½ miles long and 75 feet high, rose between St. Augustine and the mainland, and a little harbor on the west side of the island was filled up. It was reported immediately after the eruption that the mountain had been split from base to summit in an east-west direction. This last statement is certainly an exaggeration. Mr. Ivan Petroff made drawings of the mountain from three sides eight months after the eruption. They represent it substantially as it existed in 1895, and show that only a shoulder of the mountain had been blown

[1] A Voyage of Discovery to the North Pacific Ocean, book 5, chapter 5.
[2] Science, vol. 3, 1884, February 25.



BOGOSLOF, FROM THE NORTHWEST, IN 1895.

out, exposing a secondary cone within the remaining portion of the outer crater rim.[1] The view given on Pl. X partially shows this break and gives a good general idea of the form of the mountain.

In 1895 the mountain was still emitting steam in varying quantities. The variation could be observed in watching particular vents, but doubtless the apparent quantity was affected by the relative humidity of the atmosphere. At a distance of a few miles the steam was sometimes scarcely visible, while at one time it ascended to fully twice the height of the mountain above the summit. On ascending to the edge of the crater it was found that steam escaped from countless crevices, most of them on the inner cone. This was blanched and reddened by solfataric action, and masses were from time to time detached, rolling down to the bottom of the deep moat which separates the outer crater wall from the inner cone. So continuous was this disintegration as to excite wonder that any moat remained. During the two hours which I spent in watching on the outer edge of the crater, it was estimated that not more than thirty consecutive seconds elapsed during which masses of rock were not clattering down that portion of the inner cone which was in sight from my station. Though relatively small, these pieces of rock were often many tons in weight. The inner cone being nearly as high as the outer rim, not more than a third of its surface was visible.

The outer crater rim was estimated at about 1,200 feet in diameter, but was perhaps wider than this. The inner wall of the outer rim was nearly vertical, and showed well-developed columnar structure. The moat was 600 or 800 feet deep. The northwestern side of the outer crater was broken through, and a solidified lava stream extended from it nearly to the water's edge. Evidently the ash must greatly have exceeded the liquid ejecta in quantity at the eruption of 1883.[2] The new island has entirely disappeared. It may have been a mass of floating or lightly grounded pumice.

The mountain is very largely composed of ash, but solid lava is by no means lacking. The prevalent type is apparently an asperite, or andesite of trachytic texture, and clearly in the main a pyroxenic rock. Portions of the rock are black and glassy, and on many masses shrinkage cracks are very apparent.

The form of the mountain, as seen from the south at a distance of a few miles, is very symmetrical, and corresponds closely to the locus assigned to such mountains in another part of this report. From this point of view the actual summit appears rounded, a fact due to an accidental irregularity in the lip of the outer crater wall. When

[1] Prof. George Davidson collected the accounts of this eruption (Science, vol. 3, February 15, 1884). He also showed me Petroff's drawings.

[2] It is possible that Mr. Purington and I were the first human beings to ascend this peak. The natives avoid such places with superstitious dread, and fur hunters are generally too busy. I could not learn that the ascent had ever been made. It had once been attempted without success.

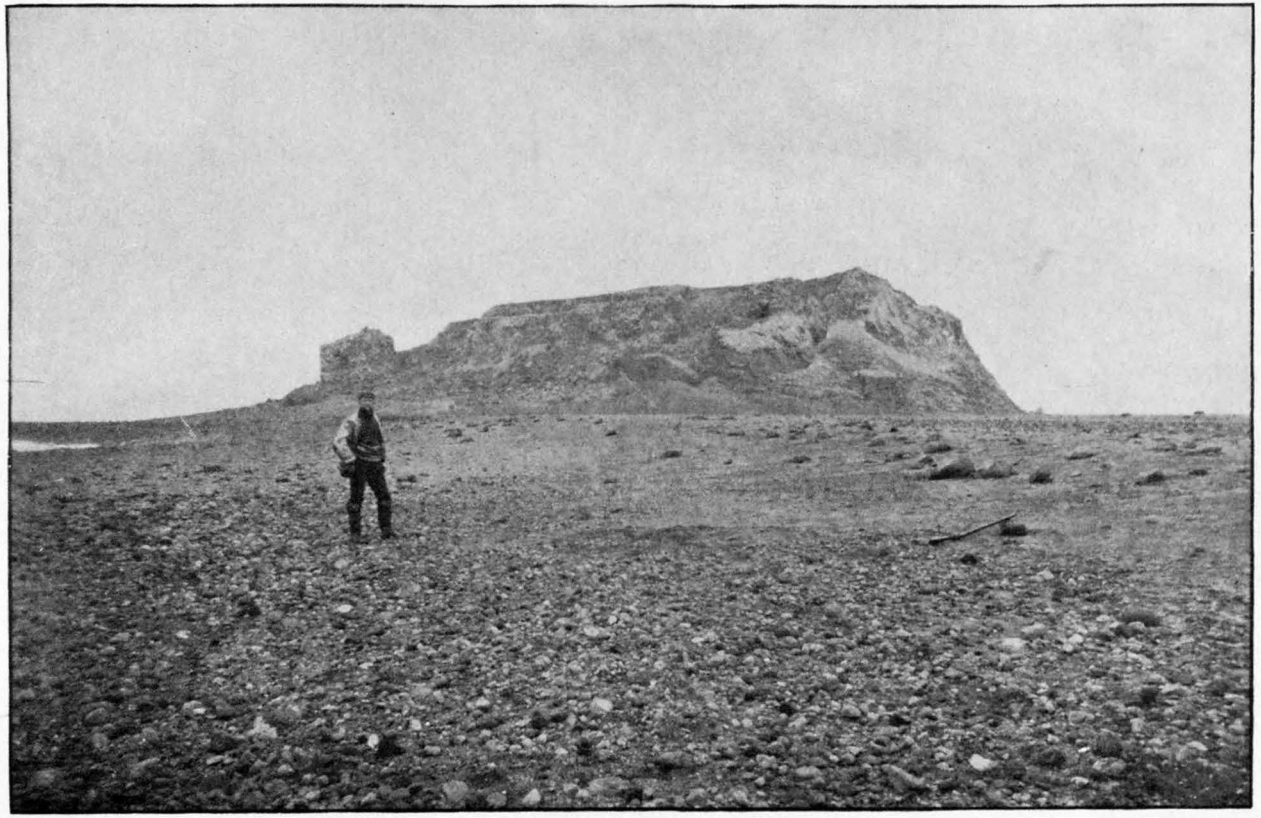
ascending the mountain the local topography is found to be very irregular, and it strikes the climber with astonishment that the distant view can bring general order out of such chaotic details. When seen at a distance from other points of view, St. Augustine is less regular. There is a bit of a shoulder on the southern side, and the broken crater mars the symmetry from the north, but from all points the tendency toward a symmetrical form is apparent.

PLAGIOCLASE DETERMINATIONS.

In examining the rocks described in this report pains was taken to determine the species of the lime-soda feldspars by modern methods. The difference of refraction between a mineral and the balsam or between two minerals in contact, according to the method of Prof. F. Becke, is often useful, and Prof. J. E. Wolff was good enough to determine for me the index of refraction (1.5393) of the Canada balsam used in the final mounting of the slides of this Survey. Much more useful still is the method which Prof. A. Michel-Lévy has developed in two memoirs which should be in the hands of all petrographers.[1] It was intended also that the Fédoroff table should be used in connection with the examinations, but unforseen delays in procuring this bit of apparatus prevented its application on an extended scale. The method of Professor Michel-Lévy does not necessitate the use of the Fédoroff table, at least in rocks which show an abundance of well-developed feldspars.

In such rocks it is usually sufficient to deal with the feldspars, which are cut nearly perpendicular to the brachypinacoid (010) or g^1 or $\infty P \bar{\infty}$. When a crystal is cut in this zone, of course the albite twin lamellæ extinguish at equal angles on opposite sides of the cross-hair of the microscope. When a crystal is twinned both according to the albite law and the Carlsbad law, this fact can be detected by placing the trace of the twinning plane at an angle of 45° to the principal sections of the nicols. The associated albite twins are then equally illuminated and cease to be apparent. On the other hand, the Carlsbad twins are not then equally illuminated, so that a crystal twinned according to both laws seems to resolve itself into a mere Carlsbad twin. The Carlsbad junction commonly shows signs of interpenetration, and is broken or irregular, while the albite junctions are straight. Supposing such a section in the zone under discussion, one has in general two sets of albite lamellæ, each extinguishing at an equal angle to the cross-hairs, but each pair at a different angle; and furthermore, the orientations of the two pairs of albite lamellæ bear a definite relation to each other, because the difference of orientation is due to Carlsbad twinning. If angles in the zone are counted from the front edge of the prism, and if one pair of albite lamellæ is cut by a plane making an angle φ with the front edge, then the other pair of

[1] Étude sur la détermination des feldspaths, 1894. Same, second fascicle, 1896.



GREWINGK, FROM THE SOUTHEAST, IN 1895.

lamellæ is cut at an angle of $180°-\varphi$ to the same edge. Professor Michel-Lévy's beautiful stereographic projections (first fascicle) show how the extinctions in such cases will arrange themselves. He has also plotted the extinctions for this particular zone, and shows that when a compound albite-Carlsbad twin is cut in this zone it can in almost all cases at once be referred to its proper species and its proper orientation.

By some mischance errors have crept into this diagram of the extinctions of the feldspars in the zone of symmetry, and I have taken the liberty of replotting it on Pl. XI (p. 36) from the stereographic projections. I have also added plots of the extinctions at 10° from the zone of symmetry in either direction. In a thin section of a rock the chances are infinitely against any feldspar being cut with mathematical precision in the zone of symmetry. Hence the question at once arises how the extinctions will vary in case the plane of symmetry is slightly inclined. These supplementary diagrams give this information at a glance and assure the observer whether or no the variation of the orientation from the position of exact symmetry precludes precise determination.

In a very great number of cases feldspars exhibit traces of zonal structure due to gradual variation in the composition of the successively deposited layers of the crystal. Professor Michel-Lévy has shown in his second fascicle that if one regards the several plagioclases as mere mixtures of albite and anorthite, instead of as independent species, the position of equal zonal illumination is absolutely characteristic of the orientation of a feldspar in the zone of symmetry. There is only one angle in each quadrant at which equal zonal illumination occurs. This method can be used, for example, in determining when a crystal is cut so nearly perpendicular to the prismatic axis that the extinction of Carlsbad lamellæ should be taken upon opposite sides of the cross-hair. In that case the angle of equal zonal illumination can not exceed 11°. The angle of equal illumination as a rule is less sharply determinable than, for example, that of equal illumination of albite lamellæ.

In his second fascicle Michel-Lévy regards all the plagioclases as mere mixtures of albite and anorthite, and defines the special occurrences in percentages. There is, of course, a very great amount of evidence for this position, and, so far as the needs of the working lithologist are concerned, it is probably without sensible error. At the same time it may be remarked that were there no dissipation of energy accompanying the union of the albite and anorthite they would not tend to unite. The liberation of energy corresponding to their actual tendency to union must, one would think, be accompanied by some modification in physical qualities; but this change, so far as known, is negligibly small.

Michel-Lévy's new attitude toward the feldspars involves some

slight changes in the diagrams. He has given a new diagram for the extinctions in the zone of symmetry, showing the zero angle for the same orientation in all varieties. He does not give a new set of stereographic projections for the several species, and the means are therefore not at hand for plotting the extinctions at 10° from the zone of symmetry. For this reason I have not redrawn the diagram given above of the extinctions. The changes which would be involved appear inconsiderable, and I have found the diagrams for what may be called latitude ±10° too useful to be willing to abandon them. It should be noted that Michel-Lévy's new fascicle gives stereographic diagrams for microcline.[1]

While the zone of symmetry is the most useful one, and is usually sufficient where material is abundant, cases also arise in which other parts of the stereographic projections are indispensable. When needful, a skillful use of the stereographic projections will suffice to determine almost any doubly twinned phenocrysts, however cut, and sometimes mere albite twins. With the aid of the Fédoroff or Klein stages any phenocrystic albite twin can be determined, but the use of such a table involves the application of low powers only.

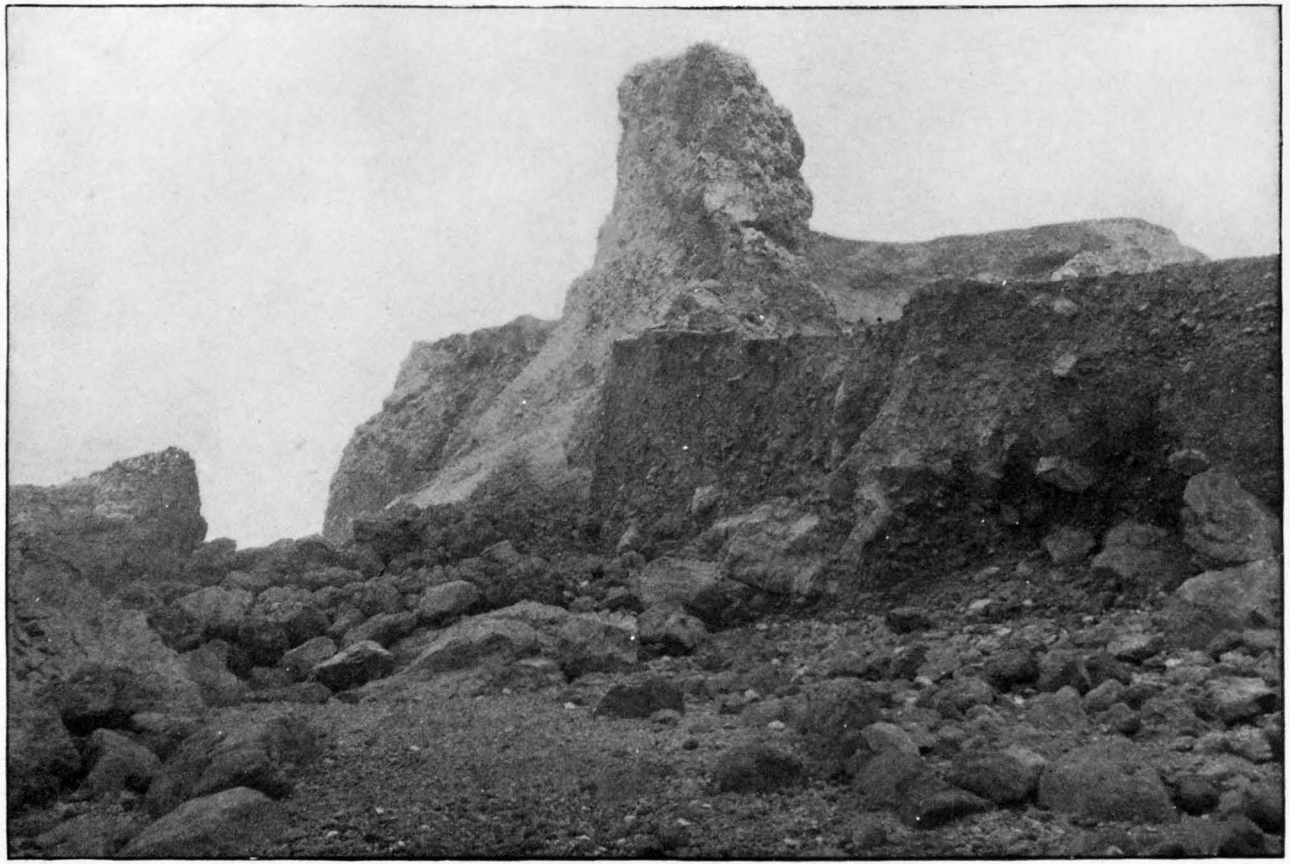
While Michel-Lévy's method of Carlsbad twins, referred to above, is usually sufficient to determine the species of the feldspars of primary generation in porphyritic rocks, it is not easily applicable to the microlitic feldspars of secondary consolidation. Such microlites are twinned, according to both the albite and Carlsbad laws, less frequently than are the phenocrysts; they are also often entirely embedded in groundmass which obscures the extinctions, and relatively high powers must be employed in examining them. Nevertheless, with patience and good eyesight, determinations can often be made. Such determinations have been used as a check upon another method which presents no difficulties, and which will now be described.

In studying the groundmass of lavas from Alaska and California, I have observed many minute, nearly square, sections of plagioclase microlites.[2] These sometimes show albite twinning parallel to one pair of sides, while in more numerous cases no twinning is visible.

[1] Taking albite as $NaAlSi_3O_8$, molecular weight 263.36, and anorthite as $CaAl_2Si_2O_8$, molecular weight 279.09, I find the following percentages of anorthite in the several feldspars. Michel-Lévy gives somewhat different values in his second fascicle, page 107.

Feldspar.	Symbol.	Percentage of anorthite.
Albite	Ab	0
Sodic oligoclase	Ab_4An_1	20.95
Calcareous oligoclase	Ab_3An_1	26.11
Andesine	Ab_5An_3	38.88
Sodic labradorite	Ab_1An_1	51.45
Calcareous labradorite	Ab_3An_4	58.55
Anorthite	$Ab_{11}An_{200}$	95.06

[2] The length of a side is usually less than two one-hundredths of a millimeter. Sometimes there are two generations of microlites.



GREWINGK, WEST SIDE, IN 1895.

They also in some cases exhibit a truncated corner. It appears probable that these microlites are elongated in the direction of the edge between the base and the brachypinacoid, and that they are cut nearly at right angles to this edge, being occasionally truncated by a hemi-domal face. This suspicion is confirmed by comparison between the extinctions of such square sections and those of microlites in the same slides which show both albite and Carlsbad twinnings. An elongation in the direction of this edge is also to be expected from Bravais's theory of crystallization; the two faces, base and brachypinacoid, being those of perfect cleavage. Where such microlites present themselves it is easy to see whether they are cut perpendicularly to their axes by following the microlite through the slide; for if the little prism is inclined, the image in focus will shift laterally as the objective moves.

Now it happens that prisms bounded by these faces, and in a vertical position, are very favorably situated for discrimination. This will appear by examining Michel-Lévy's stereographic projections of the various feldspars at 90° to the pole *p*. In this neighborhood there is a saddle in the extinction surfaces of the feldspars (the central point of the saddle answering to Michel-Lévy's "most frequent extinction"), and the consequence is that an inclination of even 10° affects the extinction of a square microlite section very little. Furthermore, the difference between the behavior of different feldspars is great, so that a confusion between the different species is almost impossible, as may be seen from the little table below.[1]

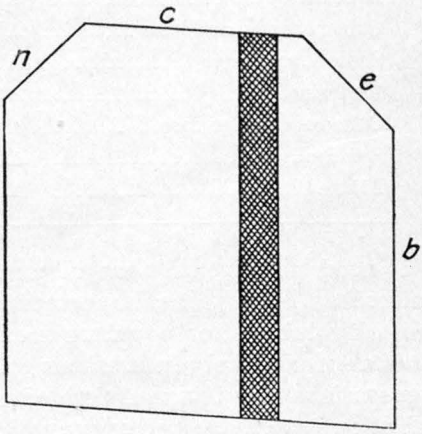


FIG. 5.—Cross-section of bacillar feldspar microlite.

In favorable cases the sign of the extinction can be made useful in the determination of these microlites, which are not really square. In albite the faces *c* (001) and *b* (010) make an angle of 86° 24′, while in anorthite this angle becomes 85° 50′. The divergence from rectangularity is thus sensible, and the proper position of the crystal is then with an acute angle in the upper left-hand quadrant (fig. 5). When the hemi-domal faces appear, *n* (021) truncates the acute angle, making sensibly equal angles of between 46° and 47° with the adjoining faces. The other corresponding hemidome, *e* (021), truncates the

[1] In this table the percentages of anorthite are given as they appear in Michel-Lévy's work. As is mentioned above, these do not answer precisely to the molecular formulas, but whether the formulas or the percentages need correction I am not certain.

obtuse angle and makes angles of from 42° to 43° with the adjoining faces. Andesine and albite can thus be discriminated when orientation is practicable. This discrimination can be confirmed by testing the index of refraction. Andesine has about the same index of refraction as quartz, and a higher index than balsam, while albite has a lower index than either.

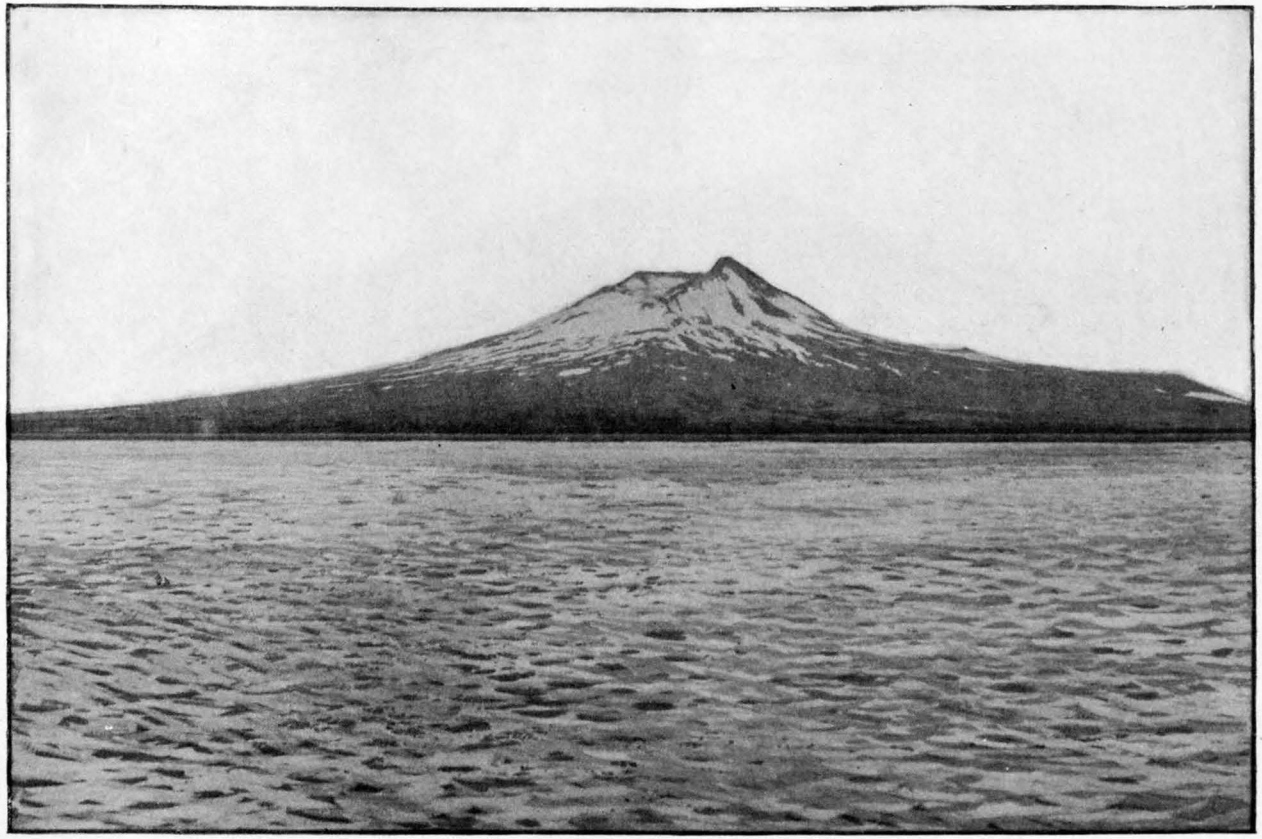
Orthoclase microlites would be exactly square; they would not show polysynthetic twinning, and the index of refraction is much lower than that of oligoclase, which, like orthoclase, extinguishes at 0°.

Extinction of nearly square sections of feldspar microlites cut within 10° of the perpendicular to the edge (001) (010).

Feldspar.	Composition.	Extinction.
		° °
Anorthite	Ab_{11} An_{200} =96 % An	+42½±3½
Calcareous labradorite	Ab_8 An_4 =60 % An	+38 ±3
Sodic labradorite	Ab_1 An_1 =47 % An	+26½±2½
Andesine	Ab_5 An_3 =34 % An	+16 ±2
Calcareous oligoclase	Ab_3 An_1 =28 % An	+ 4 ±1½
Sodic oligoclase	Ab_4 An_1 =18 % An	+ 0 ±1½
Albite	Ab = 0 % An	—13 ±2½

It need not be said that in many rocks the determination of the microlites is quite as important as that of the phenocrysts, their united volume often equaling or exceeding that of the larger crystals. It is also extremely interesting to compare the character of the two generations. It is usually stated or assumed that the microlites are all of one species. The examination of the square sections, of which a dozen or two are often visible in a single slide, leads me to a different conclusion. As a rule the majority do belong to a single species, but it is seldom that two or three out of ten do not belong to a different species; in short, the microlites in the slides I have examined show an irregularity of species of the same order as, and often greater than, that of the phenocrysts. The square sections often show zonal structure, and nearly always the exterior portion is more alkaline than the inner portion; but in a couple of cases this order was found to be reversed. Occasional reversals of this sort are to be found among phenocrysts also. These facts clearly show that even the residual mother liquor of a consolidating lava is far from homogeneous, even over the area of a square centimeter, and therefore, also, that diffusion in such a liquid must be extremely slow, since diffusion would bring about homogeneity.

The existence of rod-shaped microlites, in connection with the fact that some of them show Carlsbad twinning, throws some light on the



MOUNT ST. AUGUSTINE, FROM THE SOUTHWEST, IN 1895.

origin of twinning. If Carlsbad lamellæ of bacillar shape developed in contiguity but independently, they would form X-shaped crystals. These are said to occur, but are not common in my experience.[1] In the bacillar microlites under discussion one lamella has controlled the development of the rod, and the other lamella has accommodated itself. It is difficult to see how this could happen in mere crystallization, for why should one part resign its tendency to elongation in the direction of the cleavage edge? On the other hand, it is well known, from the investigations of Messrs. Max Baur, O. Mugge, L. van Werweke, J. W. Judd, and others, that there is much reason to ascribe polysynthetic structure largely to stresses called in play by the cooling process. This theory would fully explain the bacillar microlites as well as some beautiful cases of bent phenocrysts where twinning by various laws stands in manifest relation to flexure. It would also afford an explanation of the fact, of which comparison has convinced me, that twinning is less frequent in the microlites than in the phenocrysts, for the smaller the crystal the less is the chance that external stresses upon it would reach the intensity needful to produce mechanical twinning.

In the same connection it may be noted that stresses such as would lead to the mechanical twinning of plagioclases would also set up a mechanical æolotropy in glass. As a matter of experience, I have found it extremely difficult to detect any absolutely isotropic base in some lavas which I had reason to believe contained a small amount of glass. The faint variation of tints observed with the gypsum plate between crossed nicols in such cases may, perhaps, have been due to strain and not to crystalline symmetry of structure.

LITHOLOGICAL NOTES.

GRANITE.

True granite is widely distributed in southern Alaska, but so far as the observations recorded in this report go this rock is of small relative importance. The rocks which in the field might be taken for granite are more often diorities. Dr. George M. Dawson reports that the hornblende-granites of the coast ranges extend in two, and perhaps in three, parallel ranges, with intervals, as far northward as Fortymile Creek. Some of these granites have been described petrographically by Dr. F. D. Adams.[2] Dr. Dall mentions granite as occurring on the Yukon River at the mouth of the Tanana, and Lieut. H. T. Allen vaguely mentions granite on the Tanana River.[3] Mr. C. W. Hayes[4] also refers to rocks regarded in the field as granite, at

[1] That phenocrysts often take the form of fully developed Carlsbad twins is well known.
[2] Geol. Nat. Hist. Survey, Canada, Ann. Rept., vol. 3, part 1, 1887, p. 31 B.
[3] Reconn. Tanana, Copper, and Koyukuk, 1887.
[4] Nat. Geog. Mag., vol. 4, 1892, p. 139.

different points on the Taku River and along his path to the Copper River, including the region northeast of Mount St. Elias range.

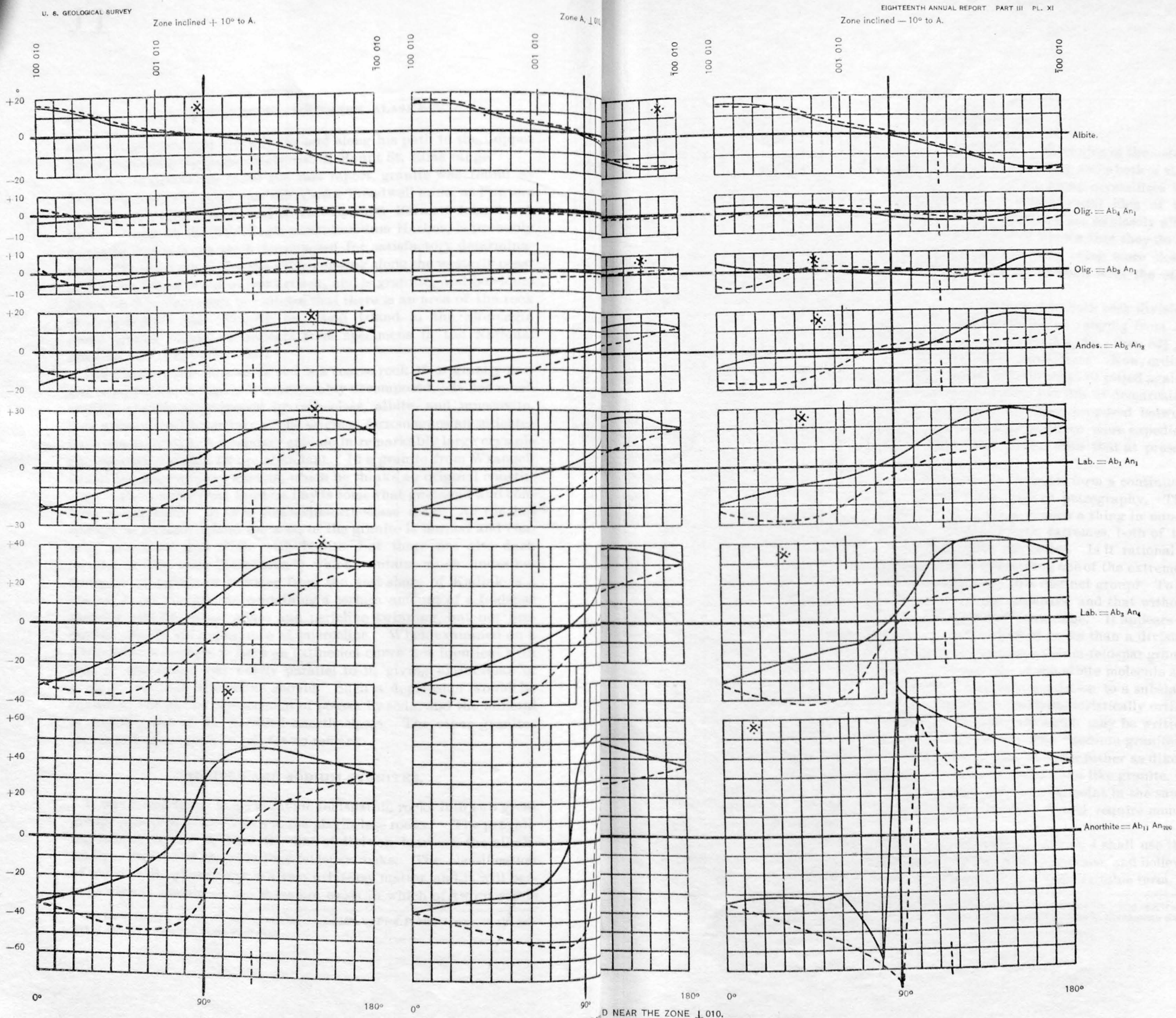
In the examinations made for this report, granite was found at Juneau Island, which lies near the Alaska-Treadwell mine, at Funters Bay on Admiralty Island, and at Hot Springs, Baranof Island. A rock collected at the Bald Eagle mine, Sumdum Harbor, is probably a granite, but it is too much decomposed for satisfactory determination. The southern end of the ridge running along the westerly coast of Kadiak Island is called Saddleback, and is granitic, and bowlders found on this coast seem to indicate that there is an area of the rock of considerable size. Finally, on Nagai Island in the Shumagin group granite occurs, as appears from specimens in the National Museum collected by Mr. Dall.

The granite from Juneau Island is a coarse rock of originally normal composition, though now considerably decomposed. It has much original quartz, accompanied by orthoclase, albite, and muscovite, both primary and secondary. The original ferromagnesian silicates have disappeared, but secondary epidote in remarkably large crystals and secondary muscovite are abundant. In a granite from Wrangell Island Dr. Adams found epidote, which he thinks an original constituent. The granite from Funters Bay is somewhat gneissoid and contains much rutile. It is a muscovite-orthoclase rock. At the hot springs on Baranof Island the mass of the granite is normal and contains orthoclase and albite with biotite, but there are also dark streaks in the rock ("schlieren") which contain much andesine-feldspar. A pebble or bowlder from the west shore of Kadiak is a normal muscovite-granite containing a certain amount of a feldspar showing well-developed albite and pericline twinning, but not presenting exactly the appearance of microcline. When examined on a Klein table it appears to have an extinction curve not identical with that of microcline, but nearly parallel to it, giving extinctions of 4° or 5° less than microcline should. Such a depression would be caused by the partial replacement of potash by soda, and the mineral is probably one of the so-called anorthoclases. The other granites mentioned above seem to call for no remark.

DIORITES AND SODIUM-SYENITES.

It was formerly the habit to divide feldspathic rocks into two great groups—the orthoclase rocks and the plagioclase rocks.[1] The prevailing custom is now to draw the line of division between the alkali-feldspar rocks and the soda-lime-feldspar rocks. The classification of rocks at the present day is a very arbitrary matter, and it will perhaps always remain so, yet there are cases in which of two possible

[1] See for example U. S. Geol. Expl. Fortieth Par., vol. 6, 1876, by Prof. F. Zirkel, who, on the subject of definitions, is an excellent authority.



EXTINCTION OF TRICLINIC FELDSPATHS NEAR THE ZONE ⊥ 010.

Compiled from M. Michel-Lévy's Étude sur la détermination des Feldspaths, 1894, Plates I–VII.

The extinctions are referred to the trace of the twinning plane and are represented by ordinates. The zero point answers to the front edge of the prism.
The full line shows the extinction of an untwinned crystal, or of *one* lamella of an albite twin. The dotted line shows the extinction of an associated lamella rotated according to both the albite law and the Carlsbad law.
The stars (*) are placed on ordinates answering to ***most frequent extinctions***, the abscissas corresponding to the crystallographic position of these points.

groupings one has advantages over the other. The union of the sodium and potassium feldspars preserves a chemical type, since both of them are polysilicates, although one member of the group crystallizes in a different system from the others. The fundamental idea of this grouping seems to be that sodium and potassium are so closely allied hat they should not be divided, yet it is well known that they do not form parallel series of compounds, sodium salts being more closely isomorphous with those of lithium and silver than with the other alkalies, K, Cs, Rb, Am.[1]

But even the chemical type is not preserved in both rock divisions by this classification. Schuster defined albite as ranging from Ab_5 An_1 to Ab_2 An_1. If the feldspar of a diorite is Ab_5 An_1, then $82\frac{1}{2}$ per cent of this feldspar is sodium-aluminium polysilicate. Now, ordinarily, majorities rule in lithology; and if alkalis are to be pitted against calcium, it would seem more rational to draw the line of demarcation at $(Ab, Or)_1$ An_1. Such a distinction has been proposed between andesites and basalts, and in my opinion it would be more expedient in the case of granites or syenites and diorite than that at present received.

On the other hand, the calcium-sodium-feldspars form a continuous series, the most important in the whole field of petrography. This group of minerals forms an entity, if there is such a thing in mineralogy, and naturally this entity embraces both extremes, both of the two components which in mixture form the series. Is it rational to make a single group of all of this series excepting one of the extremes, and to class this indispensable component in a distinct group? To do so is to ignore the serial character of the feldspars, and that without any compensating theoretical or practical advantage. It appears to me also less consistent with the occurrence of rocks than a division into a potassium-feldspar group and a sodium-calcium-feldspar group. Normal diorites with a large predominance of the albite molecule are common, and there seems to be a complete gradation to a substantially pure albitic rock. Normal granites are characteristically orthoclastic or microclinic; granites with feldspars which may be written Ab_3 Or_1, Ab_4 Or_1, Ab_5 Or_1 are not common. The "sodium-granites" and "sodium-syenites," furthermore, appear to occur rather as dikes, and in regions where diorite dikes are abundant, than like granite, in vast massifs; and there are other indications which point in the same direction. This aspect of the matter, however, would require monographic treatment.

While, then, in compliance with prevailing custom, I shall use the term sodium-syenite in this paper, I do so with reluctance, and believe that sodium-diorite or albite-diorite would be a more suitable term.

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[1] Among other instances in the mineral kingdom, consider leucite and jadeite. The empirical formula is the same, excepting that one is a sodium compound and the other is a potassium compound, but there the likeness ends.

TREADWELL SODIUM-SYENITE.

From an economic point of view the syenite of the Treadwell-Alaska mine is the most important in the Territory, for it is in this rock that the greater part of the famous gold deposit occurs. The mass is fissured or reticulated; the fragments are surrounded by ore, and are impregnated with it, as will be more fully set forth in describing the mine. Most of the rock is greatly decomposed, as may be inferred from its relation to the ore, and it is not an easy matter to ascertain its original character.[1] Much pains was taken to collect the best material available for examination. In an unaltered state this granular rock consisted mainly of albite. A considerable amount of oligoclase was intergrown with the albite, and more basic plagioclases existed in very subordinate quantities. The ferromagnesian silicates have disappeared from most of the specimens, and it is impossible to say in what proportion the various minerals of this group were originally present, but the indications are that augite predominated over hornblende, with some local exceptions. Biotite was also an original constituent. As accessory constituents, the rock contains apatite, zircon, and (in association with biotite) rutile.

The freshest specimen of the rock obtained is a fragment included in gabbro (specimen 90). It contains more quartz than most of the rock, and the albitic feldspars are often broken into fragments, as if the specimen represented a pyroclastic facies of the syenite.

Quartz is not abundant in the slides, and in almost all cases in which this mineral is determinable by the help of Becke's method it appears to be secondary. There is a considerable amount of unstriated feldspar, all of a smaller refractive index than Canada balsam. This feldspar, however, does not present the typical appearance of orthoclase under the microscope, and chemical tests appear to preclude its determination as orthoclase. The following is a complete analysis, by Dr. W. F. Hillebrand, of specimen 95, which is one of the freshest in the collection. The analysis, when reduced to molecular terms, shows that the feldspar should be almost pure albite.

[1] This rock was described by Prof. F. D. Adams from a few small specimens as granite. The scantiness of the material and its decomposed character no doubt account for this reference. Am. Geologist, August, 1889.

Analysis of Alaska-Treadwell syenite, No. 95.

[By Dr. W. F. Hillebrand.]

	Per cent.
SiO_2	63.01
TiO_2	.13
Al_2O_3	18.48
Fe_2O_3	.06
FeO	.32
MnO	.06
CaO	2.66
SrO	trace
BaO	.02
MgO	.06
K_2O	.39
Na_2O	10.01
H_2O, below 110° C	.05
H_2O, above 110° C	.27
P_2O_5	.06
FeS_2	2.10
CO_2	2.01
Total	99.69

There is thus twenty-five times as much soda as potash in the rock, and even if the whole amount of potash were present as pure orthoclase the quantity of this mineral would be trifling. On the other hand, most albite contains as much potash as this analysis shows. The analysis also indicates that there is a deficiency rather than an excess of silica, so that the effect of the partial decomposition of the feldspar has been to remove silica. Another specimen (76) shows feldspars similar to those of the rock analyzed. A test was made on the thin section with hydrofluosilicic acid, the result of which was to show abundant soda but no sensible amount of potash. Tests by the same chemical method were made also on doubtful feldspars in other slides of this rock, and specific gravity determinations of the mineral were resorted to in still other cases. All gave accordant results.

The decomposition which this diorite has undergone is manifold. The large amount of calcite present can hardly have been derived from the decomposition of the plagioclases, for the anorthite molecule plays a very subordinate part in the composition of the rock. On the other hand, in the reticule of stringers intersecting the rock quartz vastly predominates, though not to the total exclusion of calcite. Hence, just as in the Ophir district, studied by Mr. Lindgren, it seems

that calcite in solution has probably permeated the rock, leaving the silica mainly in the fissures.[1]

Pyrite is abundant in the rock as a secondary mineral, and is often intimately associated with the calcite. This pyrite might have entered the rock as a solution of iron sulphide; or it may be that it is the result of the action of a solution of sulphydric acid on the ferrous-rock components. I incline to believe that the pyrite is mainly due to the latter process, for reasons which will be stated in discussing the ore. That epidote and chlorite should be found in the decomposed rock is almost a matter of course. Zoisite also occurs in some slides as a decomposition product. A green mica is found in some of the slides in such intimate association with the calcite and pyrite as to leave no doubt as to its secondary character.

Mr. Turner informs me of an occurrence in California which deserves to be noted in comparison with that of the Treadwell. It is a sodium-syenite dike to the eastward of Moccasin Creek, Tuolumne County, which is mineralized to a considerable extent, portions of it containing low-grade gold ore.

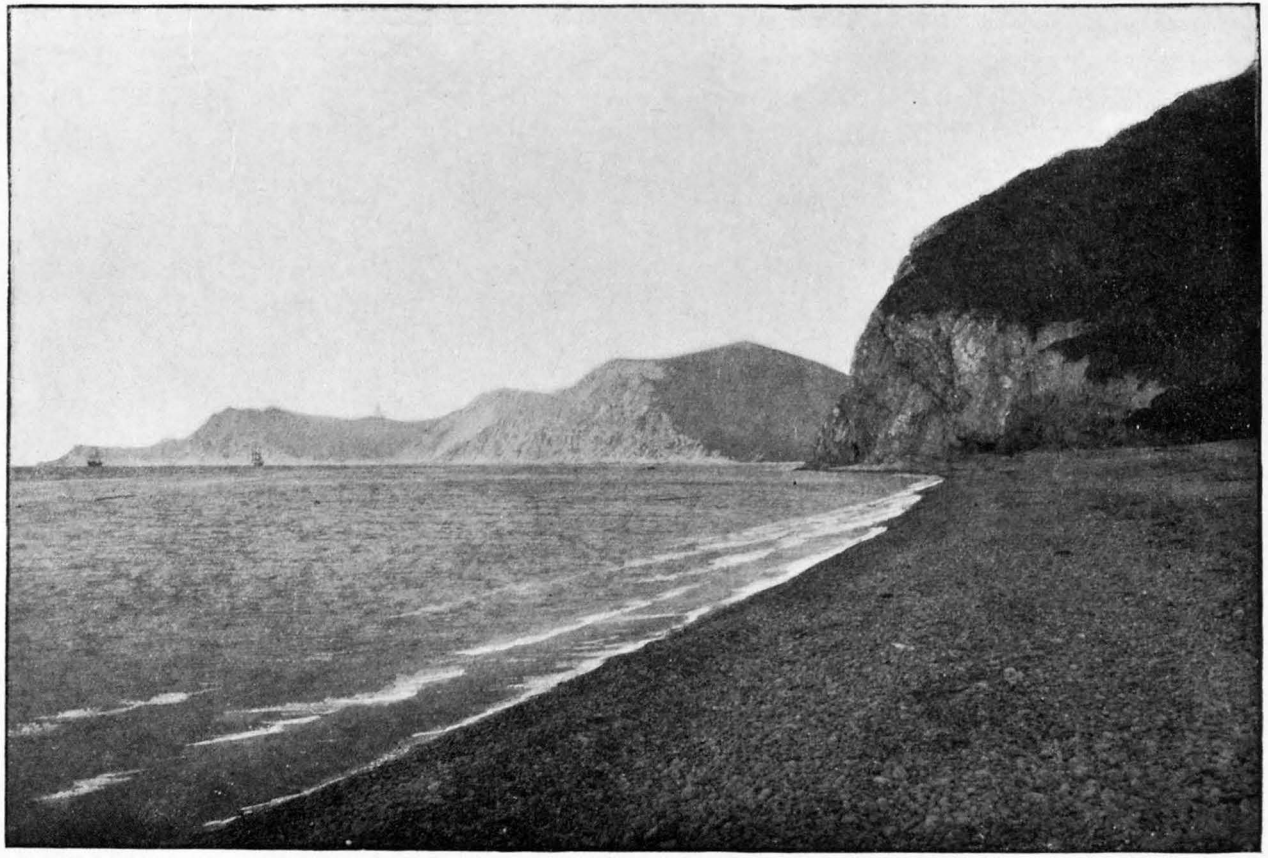
OTHER OCCURRENCES.

Besides the Treadwell rock the only albitic syenite met with occurs as a dike in the granite near Hot Springs, on Baranof Island. This dike presents a somewhat peculiar appearance under the microscope, the feldspar being very imperfectly striated and being mingled with the hornblende in ragged shreds and patches rather than in defined crystals. The hornblende is present in greenish-brown needles, many of them being skeleton crystals, and usually possessing sharp outlines, indicative of early crystallization. The only other original constituent appears to be iron ore, mostly octahedral in form, but seemingly accompanied by a certain amount of leucoxene. The rock appears to have chilled rapidly and the feldspar is clearly the youngest constituent. It has a lower index of refraction than balsam and gives extinctions appropriate to albite.

At the Lane and Hayward, and the Bennet properties in Silver Bow Basin, there are three dikes parallel to one another and about 6 feet wide. The rock is a diorite, the feldspars showing an ophitic structure, though there is no augite present. Hornblende and biotite are the ferromagnesian silicates, and magnetite and quartz in small grains fill the spaces between the larger crystals. Chlorite, epidote, and muscovite are present as decomposition products. The feldspars are not well twinned and do not show good crystal outlines; a few, however, are in a position to be determined and prove to be more or less calcareous labradorite.

The diorite from the Bear mine, in Berners Bay, is coarse and granular, and bears considerable resemblance in hand specimens to the

[1] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, p. 276.



DIORITE CLIFFS AT KARLUK.

rock of the Treadwell mine; under the microscope, however, it appears considerably more idiomorphic and the feldspar is much more anorthitic, ranging from acid labradorite toward albite. The ferromagnesian silicate is chiefly hornblende, which is present in very considerable quantities. There is a small amount of original quartz in this rock. Zoisite and the usual decomposition products of ferromagnesian silicates are present. The rock at the Comet mine is similar to that of the Bear.

At Karluk, on the northwest coast of Kadiak Island, there are magnificent cliffs of an interesting hypidiomorphic diorite. The face of the cliffs, of which a general view is given on Pl. XII, is partly gray and partly black, the two colors manifestly belonging to allied rocks, which, however, are so mingled that it seems impossible to determine by mere inspection whether they represent successive intrusions, imperfectly separated masses, or a partial solution of one material in the other. The rock is extremely fresh, and under the microscope is seen to vary in composition with the color. The gray rock is a quartz-diorite containing hornblende, biotite, and labradorite. The analysis of this rock given below, made by Dr. W. F. Hillebrand, evidently answers to the composition ascertained under the microscope. The dark streaks and patches are more porphyritic than the gray portions just described. They consist of a peculiar reddish feldspar with the optical qualities of anorthite, embedded in a groundmass composed mainly of green hornblende, a little biotite, and quartz mingled with some feldspar. The microlites of the groundmass as well as the phenocrysts are anorthite. Needles of apatite and grains of magnetite are also present. The black diorite contains much more lime and much less soda than the gray material, as the partial analysis given below shows. Considering the relations of the chemical composition, it appears to me probable that the dark material in this diorite corresponds to the blebs so often found in granite and granodiorite, and that while the two materials have always been associated they have never been thoroughly mingled.

Analysis of Karluk diorite.

[By Dr. W. F. Hillebrand.]

	Karluk diorite No. 213.	Karluk diorite No. 211 (ferromagnesian facies).
SiO_2	61.58	54.26
TiO_2	.63	----------
Al_2O_3	15.89	----------
Fe_2O_3	2.19	----------
FeO	5.50	----------
MnO	.20	----------
CaO	6.49	8.88
BaO	.06	----------
MgO	2.69	----------
K_2O	.51	.64
Na_2O	3.04	1.99
H_2O, below 110° C	.16	----------
H_2O, above 110° C	1.26	----------
P_2O_5	.12	----------
FeS_2	.06	----------
Total	100.38	----------

A very handsome diorite occurs abundantly in and about the island of Unalaska. This rock has often been referred to by previous visitors as a granite. It occurs at Captains Bay and on Amaknak Island, and seems to be abundant through the interior of the larger island, occupying a considerable area in the Amber Range east of Makushin Bay. In its typical occurrences this rock is remarkably fresh. The feldspars were found to range from andesine to bytownite, the majority lying between acid and basic labradorite. The ferromagnesian silicates include biotite, hornblende, and augite, of which the first is the most abundant. The hornblende and augite are frequently intergrown. The rock contains a very moderate amount of quartz, most of which occupies interstices between the hypidiomorphic silicates. The various occurrences differ from one another chiefly in minor variations in the relative quantities of the constituent minerals.

On the island of Bogoslof a fragment of granular rock was found included in the andesitic lava. This inclusion is a diorite of the same general appearance as that just described, and showing under the microscope a composition indistinguishable from that of the Unalaska rock. No doubt the andesite broke through earlier intrusions of this rock, which is, of course, allied in composition to the

more recent lava. It is probable that the two rocks represent recurrent phases of eruptivity.

Another rock similar to that of Unalaska was collected by Mr. Dall many years since at Nushagak, on the north shore of Bristol Bay. Some of the feldspars in this rock appear to be somewhat more alkaline than the diorite of Unalaska. Mr. Dall's collection also contains a diorite from Saranna Bay, on the island of Attu, the westernmost possession of the United States. It is a fine-grained granular rock consisting chiefly of labradorite, hornblende, and augite.

PYROCLASTIC DIORITE.

A very peculiar rock occurs in the neighborhood of Sitka, and appears also to be of very widespread occurrence throughout the Territory of Alaska. So far as the neighborhood of Sitka is concerned, this rock long ago attracted the attention of geologists. The first description appears to be by E. Hoffman, in his Geognostic Observations, collected on a journey around the world in 1829. He says, in substance: In the neighborhood of New Archangel the rocks consist of a fine-grained, siliceous graywacke, which contains clay-slate in long and short strips, and sometimes alternates with this rock as if interbedded. This remark apparently refers to the occurrences at the mouth of Indian River, on the easterly side of the river, where there are a number of tidal islets upon which the rock can be observed with great facility. At this locality the material is rather fine-grained, and exhibits no schistosity, though showing many irregularly distributed joints. It contains blebs similar to those found in diorites, andesites, and other igneous rocks, distinguished from the main mass by their darker color and finer grain. The rock here contains numerous masses of slate, which is thoroughly cleavable and often coal-black in color. These masses of slate vary in size from 10 or 20 feet in width to the smallest dimensions; indeed, in portions of the rock the mass is peppered with minute chips of slate no more than a quarter of an inch thick. The larger masses of slate strike with very considerable regularity about N. 40° W., true, and they contain stringers of the imbedding material. It is proper to observe that the complete cleavage of the included masses of slate indicates that the intrusion of the pyroclastic mass occurred after the country had been affected by the slaty structure.

The same rock is found in very widely dispersed localities elsewhere. It constitutes the main part of the country near Silver Bay, where it is clearly intrusive. It was found on the little island of Ugak, near Kadiak Island; it is believed to exist at the mouth of Copper River, Prince William Sound; it was found at the head of Cook Inlet, on Turnagain Arm; there is a probable occurrence of it on the northwest side of Red Cove, Popof Island, and a specimen has been inspected from Nushagak, on the north shore of Bristol Bay; it occurs

in pebbles on the west shore of Kadiak Island and on the south side of Kachemak Bay, Cook Inlet. It would seem from the descriptions by Mr. H. P. Cushing[1] that the same rock occurs on the north shore of Glacier Bay near the Muir glacier. Specimens of this rock, however, were not submitted to Prof. George H. Williams for microscopic study.

While the field occurrence of this rock seems to leave substantially no doubt of its intrusive character, slides examined under the microscope present an extremely unusual appearance for an igneous rock. Specimen 172, from the mouth of Indian River, has been selected as a type. The hand specimen shows a blackish-brown mass with an almost equal proportion of white grains, which under a lens are seen to be incomplete grains of quartz and feldspar. Under the microscope it is found that this rock contains phenocrysts retaining to a considerable extent the form of dihexahedra.

This mineral is accompanied by striated and unstriated feldspar in small amount, together with relatively few pyroxene crystals and irregular fragments of black slate. The groundmass forms a relatively small proportion of the slide. The augite phenocrysts, which are few in number, have idiomorphic form in only one or two cases. There is also one remnant of dichroic brown hornblende. Biotite existed in the rock when fresh, but it is now almost converted into chlorite. The rock contains chlorite, calcite, and muscovite as secondary products. The feldspars are partly striated, and all such refract more highly than Canada balsam. The feldspars can be determined only with difficulty by their optical characters, but one sharp determination was made for oligoclase. They are faulted to a very great extent, and in one case a very beautiful micropegmatitic structure is visible. They are also to a considerable extent decomposed, and some of their outlines are entirely filled with decomposed products. The unstriated feldspar, if there be any such, is indeterminable on account of decomposition. The most numerous phenocrysts are those of quartz. These have undergone no decomposition, and in some cases have retained their original outline, namely, that of short, doubly terminated prisms. The quartzes are much the most remarkable of the rock components. In a great majority of cases they have been crushed and exhibit a fairly regular dynamic cleavage, the planes being apparently parallel to the pyramidal faces *r* or *z*, these cleavages being nearly at right angles to one another. These appear to correspond to Reusch's Gleitflaechen, which Professor Judd has described as developed in crushed or strained quartz. The groundmass of the rock is difficult to distinguish from areas of decomposition and accumulations of fragments due to dynamic action. Areas of closely packed feldspar microlites with low-angle extinction seem, however, to represent the real groundmass.

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[1] Nat. Geog. Mag., Vol. IV, 1892, p. 57.

From the above description it appears that the microscopic character of this rock resembles that of a sandstone almost as much as it does that of an igneous rock. Nevertheless, it presents features which seem to be clearly igneous, and taken in connection with the field occurrence, the only explanation seems to be that the mass has been intruded, not in the condition of an ordinary fluid magma like that of modern lavas, but in a semisolid, more or less pasty state, an emulsion so stiff as to permit of rupture of the minerals in the process of forcible injection. Even on this hypothesis it is difficult to comprehend how such minute comminution can possibly have taken place. That an occasional quartz should be broken is not strange, but that so large a proportion of the quartzes should have a superinduced cleavage is extraordinary. It was only after many tests that I was able to convince myself of the true character of this mineral. Two specimens of the rock have been analyzed by Dr. W. F. Hillebrand. One of these is the specimen 172, from Sitka, already described, and the other was collected on Bear Creek, in Turnagain Arm, some 500 miles from 172. The analyses showed the following composition:

Analyses of pyroclastic diorite.

[By Dr. W. F. Hillebrand.]

	Specimen 172.	Specimen 233.
SiO_2	65.94	62.92
TiO_2	.80	.84
Al_2O_3	13.74	14.29
Fe_2O_3	.49	.84
FeO	5.21	4.66
NiO	trace	trace
MnO	.11	.15
CaO	2.87	2.72
SrO	trace	trace
BaO	.12	.10
MgO	2.33	3.14
K_2O	1.63	1.39
Na_2O	2.80	4.30
Li_2O	trace	trace
H_2O below 110° C	.21	.22
H_2O above 110° C_2	2.59	2.84
P_2O_5	.21	.13
FeS_2	.41	.32
CO_2	.59	1.24
Carbon from carbonaceous matter	.20	.....
Fl	?	.....
Total	100.25	100.10

It will be seen that these analyses show a strong likeness to each other. When reduced to molecular terms it appears that No. 172 should contain an average feldspar intermediate between andesine and oligoclase, but nearer the latter than the former. The metasilicates and free quartz should be present in about equal molecular proportions. In No. 233, from Bear Creek, Turnagain Arm, the feldspar is, or should be, oligoclase. The metasilicates and free quartz are present in about the same proportions as in the Sitka rock. The extent of the occurrence represented by No. 233 is quite unknown and may be great.

A few notes may be made on other specimens of this pyroclastic diorite. No. 174 is from a dark, elongated bleb in the rock near Sitka. Its dark color appears to be due to an accumulation of brown hornblende accompanied by very small amounts of augite. The unstriated feldspars in this specimen are less refracting than balsam, and must, therefore, be either albite or orthoclase. In one section a feldspar appears with rectangular cleavages and extinctions parallel to the cleavages, determining it as orthoclase. At least one striated albite also occurs in this slide. There are, furthermore, areas which remain nearly dark between crossed nicols and which seem to represent a partially devitrified glass. Specimen 32 is from the same locality and is chiefly remarkable for the number and variety of the forms of perthitic intergrowths. Micropegmatitic and granophyric structures are not uncommon in this slide. Among the larger feldspars some were found to be oligoclase, and one was determined as andesine. The slides from Silver Bay and its neighborhood call for no special remark, being in general extremely similar to those from the mouth of Indian River. The microgranitic, microperthitic, and granophyric structure of the groundmass in some of these slides is, however, more pronounced than in the Sitka specimens.

The more western occurrences of this rock do not differ in any noteworthy sense from those near Sitka and on Silver Bay. While the pyroclastic diorite at the mouth of Indian River shows little or no evidence of a secondary schistosity, and the included slate is evidently of a totally different origin and greater age, on Silver Bay a considerable proportion of the diorite in question has been reduced to a schistose condition by movements subsequent to this intrusion. The same is true of the occurrence on Cook Inlet and elsewhere; and in many cases, although the diorite seems to alternate with slate, the slate is merely an altered form of the diorite itself. In all cases where the rock could be collected in a state fairly free from induced schistosity, the microstructure was found similar and gave evidence of a very intense comminution prior to the final solidification of the mass.

Concerning the age of the pyroclastic diorite there are few data. That it is pre-Tertiary is certain. On Cook Inlet it certainly appears

much older than the almost unmetamorphosed Jurassic rocks of Tuxedni Harbor. Carboniferous strata are now known to exist at several points in the Alexander Archipelago, and such may be the age of the slates associated with the pyroclastic diorite. This rock may also be as young as the Jura.

GABBRO.

One of the important rocks of the Treadwell mine is a heavy intrusion or dike of a green, granular material, regarded in the field as a gabbro. All of this rock is in so advanced a stage of decomposition that a satisfactory examination is impossible. It is composed chiefly of augite and plagioclase, the feldspar, however, being so clouded that its species is indeterminable. While a majority of the specimens must be classed as granular or hypidiomorphic, a few are distinctly porphyritic. In these last the groundmass has ophitic structure, so that taken alone the term porphyritic diabase would fitly describe them. Considering their relation to the mass as a whole, these specimens must be regarded as a porphyritic facies of the gabbro. The analysis, by Dr. W. F. Hillebrand, given below, is clearly that of a basic rock with feldspars, probably belonging to the labradorite series. The augites are largely decomposed to chlorite and epidote, while the feldspars are replaced by aggregates of muscovite, calcite, etc. The amount of magnetite is, on the whole, small. In some specimens hornblende occurs as an original constituent associated with augite. At one point in the Mexican there is asbestos in the greenstone. In portions of the mine this rock has assumed a somewhat schistose structure.

Analysis of gabbro from the Treadwell mine.

[By Dr. W. F. Hillebrand.]

	Per cent.
SiO_2	48.18
CaO	8.71
K_2O	1.99
Na_2O	3.11

A float rock was found in Sheep Creek Basin which bears much resemblance to the gabbroitic material of the Treadwell mine. It contains some hornblende, as is the case with some of the Treadwell rock.

A gabbro occurs as the southerly bounding wall of the Grewingk glacier on Kachemak Bay. The structure is granular, and the ferromagnesian silicates are olivine and augite. The former predominates, but is largely converted into serpentine. The feldspars in this rock are so clouded with decomposition products as not to be capable of

identification. Doubtless fresher specimens might have been collected in the neighborhood. These were taken at the glacier wall on account of the relations of the glacier to the disintegration of the mass.

DIABASE.

The only porphyritic pre-Tertiary pyroxene rock collected was found on the dump of the Tellurium mine at Funters Bay. The country at that point is so covered in with vegetation and moss that the exposed rock is almost a vanishing quantity, and even the excavation from which this specimen came was filled in. This diabase is in all probability a dike. It shows large porphyritic crystals, recognizable with the naked eye as pyroxene and under the microscope as augite. The rock is somewhat remarkable for the extreme decomposition of the feldspars in connection with the very fresh augites. The feldspars are recognizable only by their outlines, now filled with sericite, calcite, secondary quartz, and other decomposition products. The outlines, however, are entirely similar to those of labradorites in fresh diabase dikes, and there need be little hesitation in asserting that the feldspar phenocrysts belong in the labradorite series. The groundmass still contains augite, but it is naturally more decomposed than the phenocrysts, and shows a considerable amount of epidote and chlorite. This fact and the state of the decomposition of the feldspars make it difficult to study the groundmass, but it appears to me that the last material to consolidate was pyroxene. The slide contain some magnetite.

SCHISTS.

Eruptive schists.—A few schistose rocks were met with which seem to be of unquestionable eruptive origin, though now so thoroughly metamorphosed that the original character of the rock is obscured. The best of these occurs on Bear Bay, an arm of Silver Bay, Baranof Island. It is a saussuritized, plagioclase rock, and the ferromagnesian silicate is hornblende, probably of paramorphic origin. The feldspars which remained intact are labradorites of both varieties, but most of the feldspathic constituents are disintegrated with the development of zoisite and muscovite. Some garnet is also probably secondary. The hornblende is green, coarsely fibrous, ragged, and strongly pleochroic, decomposed in large measure to chlorite. The rock carries magnetite and some pyrite. As is manifest from this description, this schist strongly resembles many hornblendic schists derived from augitic intrusive or eruptive masses. In this case no direct evidence is at hand that the original rock was pyroxenic.

A somewhat schistose rock occurs on the northeast side of Gastineau Channel, along the beach about 2 miles to the southeast of Juneau. As seen in the field, it is a brownish-green rock with veins of calcite, indicating alteration. Under the microscope the schistose structure

is less evident than in the hand specimens. The feldspars, however, are much disintegrated and are determinable only in a few cases. These seem referable to oligoclase. The most prominent constituent is a colorless amphibole (tremolite), occurring in short, rather well-developed prisms which extinguish at about 15°. Nearly every one of these crystals contains flakes of biotite, varying in tint from nearly colorless to deep brown. The amphibole and mica seem to me to be coeval, secondary minerals. The slide contains much calcite and other ordinary decomposition products. The original rock may very probably have been diabasic.

At the Taku mine, Silver Bow Basin, a large mass of pyrrhotite is accompanied by schistose rock similar to that just described, but in a more decomposed state. The amphibole in this rock is light green in color, but is associated with biotite in the same way as in the beach rock. Quartz and magnetite are also intimately mingled with the hornblende. There are remnants of plagioclase, but they are not determinable.

At the site of old Sitka, some 6 miles to the north of the present settlement, a little prospecting was in progress at the time of my visit. The quartz stringers were in an extremely fine-grained, greenish rock, which is composed of minute hornblende needles mingled with tiny grains of quartz. Such schists are known to occur as the result of the alteration of eruptive rocks, and it seems on the whole more probable that this material is igneous than that it is sedimentary.

Sedimentary schists.—The main mass of the country rock in Silver Bow Basin is of sedimentary origin. It is a schistose material, the greater part of which consists of quartz grains. Some of them are probably of granitic origin and are full of inclusions; others have recrystallized. Brown flakes of biotite occur along what I suppose to have been surfaces of relative tangential motion. A carbonate, which is certainly in part calcite, is distributed through the slides in patches. This carbonate probably contains a certain amount of magnesia, corresponding to the magnesian mica. A small quantity of magnetite is present, and a few grains of garnet, partially decomposed. The mica has decomposed in part to chlorite, and the rock carries a little pyrite irregularly disseminated. It is not improbable that this sulphide is due to the action of sulphydric acid on magnetite or biotite.

A specimen of sedimentary schist from the Gould and Curry property in Sheep Creek Basin is amphibolic. Rays vibrating parallel to $\mathfrak{c}$ are of distinctly bluish tinge. The cleavage of the amphibole is very strongly marked, but it can not be called fibrous in the mass of the rock. The slide contains a beautiful little vein, which is filled with quartz, calcite, and fibrous amphibole. All of these minerals seem to have crystallized at the same time, and the amphibole penetrates the others much like the rootlets of a plant, in sinuous lines,

which converge to fairly well-defined centers. This vein amphibole is less blue than is that in the mass of the rock.

A schist collected at Funters Bay resembles that from Silver Bow Basin in its microscopical character.

ANDESITES.

Under the term andesite I understand an effusive plagioclase-porphyry in which the groundmass is composed of plagioclase microlites and magnetite, while the phenocrysts are ferromagnesian silicates and triclinic feldspars. The most important difference between an andesite and a basalt lies in the character of the groundmass, or of that portion of the magma which is the last to consolidate; for the fluidity of the lava and its capacity to form extensive sheets depends wholly upon the properties of this portion of the mass. In basalts the residual fluid, the mother liquor, is augitic and has the properties of a basic slag. In the andesites it is a relatively very viscous mass and the lava flows with much greater difficulty. In my opinion any system of classification which should ignore this distinction in the capacity to flow would be very artificial and inexpedient.

All the specimens of lava collected in the expedition of 1895 from Cook Inlet westward turn out to be andesites. Some of them were regarded in the field as possibly basalts. Grewingk mentions basalts at the Pavlof volcano on the mainland, and on Atka. Dr. Dawson notes the basaltic structure of volcanics on Akutan and the basaltic appearance of little islands in Nazan Bay, Atka Island. Columnar structure is not infrequent in andesites, and in Grewingk's time a confusion between dense andesites, von Gümbel's "basaltic" andesites, and basalt would not have been strange. Nevertheless, there seems no inherent improbability in the occurrence of basalt in the volcanic belt of Alaska. To the northward it is known to occur.

The andesite of this region may be grouped as augite-andesite, augite-bronzite-andesite, and hornblende-andesite. There is also a pyroxenic dacite which is closely affiliated with the andesites. They appear to represent substantially the same magmas as the diorites of the region, and it is interesting to note so close an approach to uniformity in composition extending over something like 1,000 miles in distance and over several geological periods in time.

The feldspar most characteristic of the Alaskan andesites, as seen under the microscope, is basic labradorite, which seems to be present both as phenocrysts and as microlites in every slide. On the whole, the augite-andesite contains somewhat more calcareous feldspars than the augite-bronzite-andesite, while the hornblende-andesite of Bogoslof shows less calcareous feldspars. Nevertheless, in all three varieties anorthites have been found. In hornblende-andesite elsewhere pure lime-feldspar is considered a rarity, and details of these feldspars will be given below. The phenocrystic feldspars are scarcely

ever all of the same species in any slide of the Alaskan andesites, though one species generally predominates very greatly over the others. Careful examination of the square sections of microlite shows that these too vary, and indeed between much wider limits than the phenocrysts. The majority of the microlites in all these andesites lie within the range of the labradorites $Ab_3 An_4$ and $Ab_1 An_1$, but in almost all there are also microlites of andesine and of oligoclase. The average microlite is always more alkaline than the average phenocryst. Both phenocrysts and microlites often show pronounced zonal structure, and in such cases the exterior portion is as a rule more alkaline than the interior; but there are exceptions to this rule both among the larger crystals and among the microlites, showing a very fundamental heterogeneity in the composition of the fluid rock. While the crystals are conveniently classified as phenocrysts and microlites, several distinct sizes may often be observed, and sometimes there seems to be a complete gradation in size, from phenocrysts some millimeters in length to microlites say 0.005 millimeter square. It may be proper to note that most of the slides of andesites afford much irreproachably good material for the determination of feldspars by optical methods.

The pyroxene of the andesites is present in very much smaller quantity than the feldspar; and though pyroxene microlites occur, they are of much less relative importance than the phenocrysts. A large part of the phenocrystic pyroxene is always augite, and no rhombic pyroxene microlites were found. The rhombic pyroxene shows scarcely noticeable pleochroism, and the axial dispersion has its smaller angle perpendicular to the prismatic axis. This characterizes the mineral as bronzite instead of the more usual hypersthene. Basaltic hornblende, with black borders, occurs sparingly in a few of the augite-andesites.

Olivine is rare in the andesites. It occurs in one slide out of five from St. Augustine, and remnants of this mineral are found in the andesite from Makushin.

Primary quartz is rarer than might be expected in the andesites. A few small crystals were found in the rock from Cape Douglass and in an agglomerate from Amelig Harbor. A specimen from the west side of Amaknak Island also shows a few ill-defined grains. Tridymite was detected with certainty in only one specimen, an augite-bronzite-andesite from Coal Harbor, Unga Island (No. 278). Mr. G. P. Merrill also notes it in the Bogoslof lava.

Glass occurs in greater or less quantity in many of the andesites, but it is not always easy to decide on the amount of this substance present. Many areas which between crossed nicols appear black show faint changes of tint when the gypsum plate is employed. It is possible that this behavior merely indicates strain in a mass, which in a state of ease would be isotropic, or it may be that an incipient

crystallization of certain components of the glass has given the mass an optical character.

The order of succession of the phenocrysts appears to be bronzite, augite, feldspar. The feldspars include pyroxene, and when the two pyroxenes are crystallized together, as often happens, the outer portion is augite. The bronzite appears to resist decomposition better than the augite.

The following is an analysis, by Dr. W. F. Hillebrand, of specimen 244 from St. Augustine. The slide shows phenocrysts of augite, bronzite, and plagioclase in a groundmass containing glass, plagioclase microlites, and some magnetite. The feldspar, optically determined, is almost exclusively calcareous labradorite, but there is also a little alkaline labradorite. There is no free quartz.

Analysis of St. Augustine andesite, No. 244.

[By Dr. W. F. Hillebrand.]

	Per cent.
SiO_2	60.40
TiO_2	.61
Al_2O_3	16.89
Fe_2O_3	1.88
FeO	3.72
NiO	.02
MnO	.12
CaO	7.25
SrO	ft. tr.
BaO	.06
MgO	3.82
K_2O	.77
Na_2O	3.80
Li_2O	ft. tr.
H_2O, below 110° C	.09
H_2O, above 110° C	.20
P_2O_5	.16
FeS_2	.08
	99.87
S in FeS_2	.04

It is not easy to offer a satisfactory discussion of this analysis. The calcareous character of the feldspars as determined by optical methods does not seem borne out by the analysis, and although microscopic examination would lead one to expect a fairly high percentage of silica in the thoroughly andesitic groundmass, a silica content of over 60 per cent would not be suspected. By converting the analysis into

terms of molecular weights the difficulties are not diminished. If the alkalies are reckoned as polysilicate feldspars, and nearly all of the residual alumina is regarded as going to form anorthite, then the feldspars would be nearly expressed by Ab_5An_3, or andesine. The microscopic observations must be greatly strained to answer to this result; for all the determinable phenocrysts and nearly all the determinable microlites are more calcareous than andesine. The only possible conclusion seems to be that the glass is very alkaline. The tendency of alkalies to accumulate in the glass is not unknown; but the difficulty does not end here, for after the maximum amount of feldspar and the ferromagnesian silicates are allowed for, there remains a surplus of silica amounting to over a fifth of the total silica, or about one-eighth of the entire weight of the rock. There is no visible free silica in the slides, and the excess must either be present in the glass or possibly in part in a free state, but so finely disseminated as to escape observation.

As a check upon the microscopic work, specific gravity determinations were made of the phenocrystic feldspars in the St. Augustine lavas. Such examinations on specimen 244 gave in mean a density of 2.684. Specimens 241, 237, and 238 were also examined. The densest feldspar found had a specific gravity of 2.694, and the lightest 2.661. All of these feldspars, judging from their density, were thus labradorites, in entire accord with the microscopic examination. A separation of 244 by the Thoulet solution and analyses of products could hardly throw valuable light on the composition. It is substantially certain that the phenocrysts would prove normal and that the inseparable groundmass would show a large amount of sodium and a great deal of silica.

The composition of this lava is so peculiar that I procured from Dr. Hillebrand the following partial analysis of specimen 241, which is nearly or quite holocrystalline, contains no visible free quartz, and no olivine. The essential components as determined by the microscope are pyroxene, labradorite, and magnetite.

Partial analysis of St. Augustine lava, No. 241.

[By Dr. W. F. Hillebrand.]

	Per cent.
SiO_2	58.98
Al_2O_3, Fe_2O_3, FeO, TiO_2, P_2O_5	24.97
CaO	7.65
MgO	4.15
K_2O	0.93
Na_2O	3.25

Supposing the alumina in this specimen to be present in the same ratio to the iron, titanium, and phosphorus as in specimen 244, the alumina here would be 18.13 per cent. The partial analysis would indicate a sodic labradorite, according in so far approximately with the microscopic examination; but there is again a large excess of silica which one would expect to find separated out as quartz. Thus, supposing all the soda and potash to form polysilicates, there remains a mass in which there are about 3 molecules of SiO_2 to 2 molecules of oxides; in other words, the residue would have the mean composition of a polysilicate. The visible minerals, on the other hand, are ortho-, meta-, and sub-silicates. The only mode of reconciling the analysis with the microscopic work seems to be to assume that films or sub-microscopic grains of quartz are present, or perhaps more probably scales of tridymite, so distributed in the mass as to escape detection. Tridymite is a fairly frequent ingredient of andesites, and occurs in some at least of the Alaskan lavas. When this mineral is present in small patches it is not easily detected on account of its low polarization colors and lack of definite form. It might therefore be present as disseminated scales in considerable quantities without betraying itself.

The similarity in chemical composition between the Karluk diorite and the St. Augustine lava is so great as to render it probable that slow cooling would have produced from the lava substantially the same minerals as the Karluk rock shows. The structure is another matter. In the lava, slow cooling would not have robbed the mass of its porphyritic structure, though a granular groundmass might have resulted. I can not believe that the hypidiomorphic structure of the diorite could result from the consolidation of any truly fluid mass, though it might perhaps be produced by the slow cooling of a mixture of solids with fluids, such as mortar.

An andesite (No. 268) from Delarof Harbor, near which the Apollo mine is situated, forms in some respects a transition between the lava of St. Augustine and the more usual type of pyroxene-andesites. It is a greenish-black, somewhat vesicular porphyry, in which the microscope shows phenocrysts of augite, a rhombic pyroxene, which in this case seems to be enstatite rather than bronzite, and labradorite. The groundmass consists of "felted" feldspar microlites, a little augite, a little magnetite, and a considerable amount of glass. The feldspathic microlites are mainly alkaline labradorite, while the phenocrystic crystals are more calcareous, approaching $Ab_3\ An_4$; but some of the microlites have angles of extinction appropriate to oligoclase. The slide shows decomposition products, especially chlorite, but not in important quantities.

The following is an analysis by Dr. Hillebrand of specimen 268:

Analysis of andesite from Delarof Harbor, No. 268.

[By Dr. W. F. Hillebrand.]

	Per cent.
SiO_2	56.63
TiO_2	.67
Al_2O_3	16.85
Fe_2O_3	3.62
FeO	3.44
NiO	trace
MnO	.23
CaO	7.53
SrO	trace
BaO	.09
MgO	4.23
K_2O	2.24
Na_2O	3.08
Li_2O	trace
H_2O, below 110° C	.80
H_2O, above 110° C	.51
P_2O_5	.16
FeS_2	.06
Total	100.14

When computed in terms of molecules it appears that the feldspars should approach andesine. After deducting the feldspar there remain about 4 molecules of silica to 3 of oxides, indicating that there is either free silica or that the glass is very acid. If about a tenth of the silica were free, the rock after subtraction of the albite and free silica would approach a metasilicate in composition. Thus, although the rock has only the rather moderate silica contents of 56.63 per cent, it is still needful to assume the existence of free silica or a highly siliceous glass.

The only well-developed dacite met with in Alaska occurs at Delarof Harbor, Unga Island, near the Apollo Consolidated mine. As appears from the notes above, dacites are to be expected in the volcanic belt, and some at least of the andesites have a dacitic chemical composition. The rock at Delarof Harbor is much altered and highly "propylitic" in appearance. Only one specimen (collected long ago by Mr. Dall and numbered 28064) is fresh enough to show the ferromagnesian silicates, which are deep-brown hornblende accompanied by a little biotite. In other slides there are patches of decomposition

products which suggest original pyroxene. The quartz grains are often large and seem to be corroded dihexahedra. They are full of inclusions of glass and gas. The feldspar phenocrysts are usually indeterminable from decomposition, but andesine and oligoclase were identified among the larger crystals and oligoclase among the microlites. Some unstriated feldspars occur in the dacite slides. Of these some at least have a higher index of refraction than balsam and are probably oligoclase, but it is possible that some of the unstriated grains may be orthoclases, the optical tests for potassium feldspar being rather negative than positive and unsatisfactory in their character. The groundmass is in part feldspathic and in part spherulitic. The very beautiful spherulites in Mr. Dall's specimen are partially devitrified, and are stained with a brown pigment, probably limonite. The decomposition products are chlorite and epidote, so characteristic of "propylites;" and calcite, too, is abundant.

In comparing this dacite with the andesites it will be observed that the feldspars in the quartzose rock are much more alkaline than in the other lavas. Doubtless there is a connection between the appearance of the quartz phenocrysts and the preponderance of sodium over calcium.

A partial analysis by Dr. Hillebrand of a dacite specimen (271) gave:

Partial analysis of dacite, No. 271.

[By Dr. W. F. Hillebrand.]

	Per cent.
SiO_2	62.32
CaO	3.03
K_2O	2.33
Na_2O	3.92

As compared, in terms of molecules, with the andesite from Unga, No. 268, this dacite contains about the same amount of potassium, more sodium and silica, and less calcium. It would seem to point to a more albitic rock but not to an admixture of orthoclase.

The hornblende-andesites are, so far as is known, much less common in Alaska than the pyroxenic variety. Specimens are at hand only from Bogoslof and Grewingk and from Kiska, one of the Rat Islands. These rocks are for the most part yellowish-gray porphyries with a rough fracture, outwardly resembling trachytes. They belong among the trachytic andesites of von Gümbel, the same group for which I proposed the name asperites. The ferromagnesian silicates are chiefly deep-brown, black-bordered hornblendes accompanied by a very subordinate amount of augite, while orthorhombic pyroxenes

were detected only in the specimen from Kiska. The feldspar phenocrysts are chiefly calcareous labradorite, $Ab_3 An_4$, but in some cases they are anorthite. Thus, in specimen 310, a Carlsbad-albite twin phenocryst gave albite extinctions of 18° and 22° and the Carlsbad lamella extinguished at 43°. This corresponds to anorthite cut at 10° to the zone of symmetry. In specimen 295 there are also unquestionable anorthites, showing Carlsbad and albite twinning and giving characteristic extinction angles. The microlites are also surprisingly calcareous; in one slide (292) 10 square microlites gave an average extinction of 38°, showing that they were calcareous labradorite. A few square microlites in the same slide gave angles characteristic of sodic labradorite. Some of the lath-shaped microlites show Carlsbad twinning, and all such that were examined proved to be $Ab_3 An_4$. The rock contains no visible free quartz. Prof. G. P. Merrill, however, mentions tridymite as one of the components of the rock. The groundmass consists of feldspar microlites, a few augite grains, magnetite, and glass, possibly with more or less admixed tridymite.

Other slides of the Bogoslof lava are very similar to 292, which was selected as a type. The proportion of augite to hornblende, and of the ferromagnesian silicates to feldspars, varies considerably. In some slides apatite and zircon are rather abundant. Most of the feldspars show pronounced zonal structure, and this is the case even with the microlites.

Professor Merrill has described two specimens from Bogoslof, and they were analyzed by Mr. T. M. Chatard. One of them is a gray rock representing the main mass of the islands, and its analysis is given under I, below (p. 58). In mineralogical composition and external appearance it corresponds to the description given above, excepting that according to Mr. Merrill[1] it contains tridymite. The average feldspar may be interpreted from Mr. Chatard's figures as $Ab_2 An_1$, yet basic labradorite is certainly present. The residue, after subtracting the feldspars, contains about 3 molecules of SiO_2 per molecule of basic oxide. Hence it would seem that about an eleventh part of the silica must exist in the free state. Mr. Merrill also examined a dark variety of the lava, which contains more hornblende. The analysis is given under II (p. 58). This analysis does not indicate any free silica.

[1] Proc. U. S. Nat. Mus., vol. 8, 1885, p. 31.

Analyses of Bogoslof lava.

[By Mr. T. M. Chatard.]

	I.	II.
Ignition	.99	.34
SiO_2	56.07	51.54
TiO_2	1.24	.32
Al_2O_3	19.06	20.31
Fe_2O_3	5.39	4.64
FeO	.92	3.56
MnO	.23	.32
CaO	7.70	9.55
MgO	2.12	3.16
P_2O_5	.16	.57
Na_2O	4.52	4.29
K_2O	1.24	2.47
Total	99.64	101.07

The following is a list of the andesite localities in Alaska known to me by specimens:

List of known andesite localities in Alaska.

	Locality.	Longitude.	
		°	′
Augite-andesite	Cape Douglas	153	30
	Belkofski	162	55
	Unga Island	160	30
	Popof Island	160	20
	Unalaska	163	00
	Amaknak Island	163	00
Augite-bronzite andesite	St. Augustine Island	153	30
	Amelig Harbor	154	30
	Unga Island	160	30
Hornblende-andesite	Bogoslof Island	168	00
	Kiska Island	177	30

BASALTS.

Only two basalts were met with in this reconnaissance. One of these is a dike in the Treadwell-Alaska mine; the other occurs on Kruzof Island near Mount Edgecumb. Edgecumb forms a fairly well-developed cone. Of what material the cone itself is composed, I can not say. It is so guarded by a broad strip of forest of almost

GREWINGK GLACIER MOUNTING A MORAINE.

impassable density that no attempt was made to reach the cone. The southeastern shore of Kruzof Island is a beautiful exhibit of basaltic flows, so recent as to show superficial flow structure, scoriaceous masses, and pumice. It is evident that the rock has been of a high degree of fluidity, and hand specimens show abundant olivine phenocrysts.

Under the microscope the rock is seen to be a normal basalt both as to composition and structure. The feldspars are anorthite and labradorite, the microlitic crystals being more alkaline than the phenocrysts. The olivine is very fresh, and several of the specimens show a large amount of glass.

The dike in the Treadwell is less ordinary and more important, since it is seemingly associated with the genesis of the ore body. Though much decomposed, this rock can be fairly well studied under the microscope. It consists of augite, some olivine, a little feldspar, mostly zeolitized, and sensibly isotropic minerals.

A partial analysis of specimen 87 by Mr. George Steiger showed—

	Per cent.
K_2O	2.12
Na_2O	2.39
Water above 110° C	2.41

From these figures it would appear that analcite and leucite are both present, the analcite perhaps resulting from the decomposition of the leucite, perhaps being an original constituent, as in the analcite-basalt first described by Mr. Lindgren. Under the microscope some arrangements of inclusions may be seen which remind one of the symmetrical disposition of such bodies so often seen in leucite, but the minerals do not occur in the slides in such a way as to make it practicable to discriminate the hydrous silicate from the anhydrous one. Mr. Lindgren informs me that the general appearance of the slides is extremely similar to that of his analcite-basalt.

SOME NOTES ON GLACIATION.

Prior to 1895 glacial action on Kadiak and the adjacent smaller islands had not been observed. The topography of Woody Island and the islets which lie between it and the port of St. Paul, however, is strikingly glacial. In particular, the surface shows hummocks and tarns such as unglaciated areas do not exhibit. The rock beneath the grass roots is undecomposed and sometimes nearly smooth, but neither here nor along Narrow Straits was I able to find actual scratches on the rock. Mr. Dall, however, found on Woody Island, in the Mission garden and elsewhere, erratics showing groovings. At the entrance of the southeast arm of the Uyak Bay, about a mile to the westward of the Wamburg and Boyer prospect, there is topography similar to that about Woody Island, but in addition there are scratches and grooves which have been perfectly protected where covered by

moss. The principal set of scratches strikes N. 83° W. (true), and a subordinate one N. 68° W. The steeper surfaces of the roches moutonnées are turned toward the head of the arm.

In considering the glaciers at various points it occurred to me that disintegration must be extremely rapid along the edge of the ice; for the temperature of the ice being zero centigrade, the number of days in the year must be great upon which the adjoining rock is chilled below the freezing point at night and raised above the melting point during the day, and such alternations form a most efficacious means of breaking up solid rock. In such a position, too, the local precipitation of dew must often be sufficient to wet the wall rocks daily.

I had an opportunity of examining such effects on the westerly wall of the Grewingk glacier in Kachemak Bay. The rock here is a gabbro. Within a few yards of the glacier it is full of gaping cracks, dividing the mass into fragments of an average volume of a cubic inch or less, and these are so loose that although nearly in place they can be pulled down with the hand by the bushel. Fifty or a hundred feet away from the ice, on the contrary, the rock was smooth, hard, and so tough that it was difficult to get specimens. It appears to me that all along the edge of a glacier, and along its névé field as well, frosts must be more frequent than, ceteris paribus, at a distance from them, and that disintegration must be correspondingly rapid. The U-shape assumed by glacial gorges and the cirques at the névé basins may be in part explicable in this way.[1]

A somewhat similar action seems to be produced in many parts of Alaska by the ocean spray or the lapping of wavelets. Along many of the shores above high water a groove may be seen in the cliffs which is perhaps a couple of feet deep and in which the rock is cracked and disintegrated, but not in the least waterworn. It seems probable that frequent wetting in frosty weather has caused the disintegration.

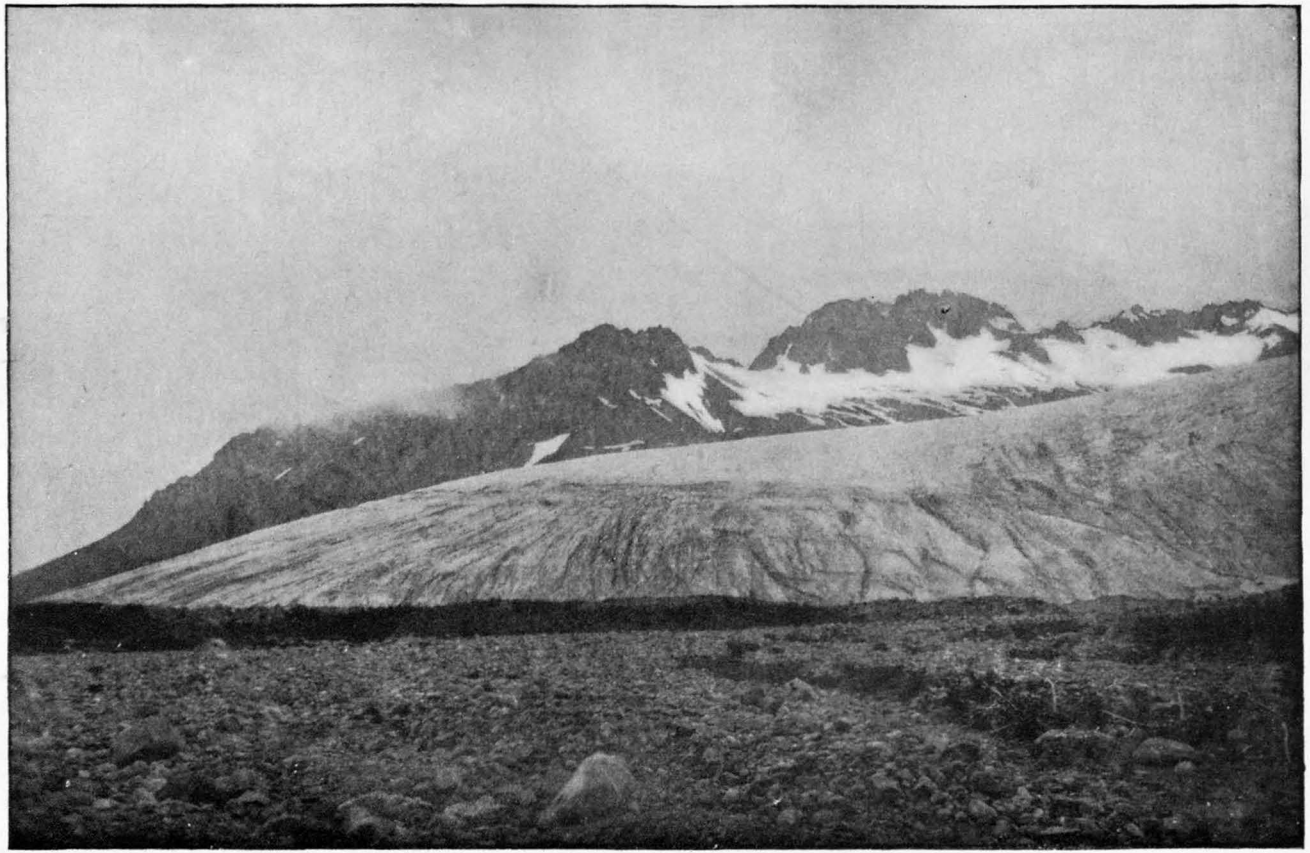
The ability of a glacier to excavate beneath the level of its course depends on the fact that it is a solid and not a fluid. For this reason it can move up hill for a certain distance, depending upon its "solidity" or on the elastic limit of the material. The Grewingk glacier at one point is mounting a moraine, and Pl. XIII shows the ice advancing on a rising grade.

Pl. XIV shows the foot of one of four superb glaciers at Cape Douglas. These, like most Alaskan glaciers, are remarkably free from moraines, and in the clear, dust-free air display their structure in a most diagrammatic fashion.

REMARKS ON DISTRIBUTION OF GOLD IN SOUTHERN ALASKA.

The data which are available concerning the gold are too meager to permit of any very important generalizations. There is a distinct zonal development of the deposits in the Alexander Archipelago,

[1] I am told that Mr. Willard D. Johnson, in an unpublished lecture, gave expression to somewhat similar views, but I am not acquainted with his precise opinion on this subject.



NORTHERN GLACIER AT CAPE DOUGLAS.

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including Sumdum, Juneau, and Berners Bay, and the general direction of this belt is that of the schistosity of this part of the country. Pls. I and XV show the general geographical relation of these localities. The great mine of this belt is the famous Alaska-Treadwell. The ores are normal gold ores, except that calcite is unusually abundant, and there is a sufficient reason for connecting their genesis with eruptive phenomena. The deposits of this belt are so similar in position and character to those of British Columbia and California that, in the absence of direct evidence, they may be regarded as contemporaneous with them and probably of early Cretaceous age.

Further westward occur the deposits near Sitka on Baranof Island, and very possibly the source of the gold of Lituya Bay, in west longitude 137° 30′, may be a prolongation of this group. The mineralizing action on Baranof Island does not appear to have been very vigorous. It seems to be quite as old as the more easterly belt.

At the head of Cooks Inlet, some 14° west of Sitka, are the placers of Turnagain Arm and the Kaknu River, indicating the presence of gold veins which may or may not be strong enough to be worked singly.

The veins on Uyak Bay, Kadiak Island, are few, so far as yet known, and not important.

Next to the Douglas Island deposits the Apollo Consolidated, on Unga Island, in west longitude 160° 30′, is the most important mine in the Territory. It is an extremely interesting occurrence in andesite of Tertiary age, and represents a relatively very modern repetition of the conditions of gold genesis in the northwest. Though there is as yet but one working mine here, it would be strange indeed if no other valuable deposits exist in the same region.

A memoir on the gold deposits of the Yukon region has been prepared by Mr. J. E. Spurr, who made his examinations in 1896, and will appear in the same volume with this report. While together these reports will represent most of what is yet known of the gold resources of the Territory, the reader may be reminded that the area of Alaska is greater than that of all the States north of Tennessee and east of the Mississippi River, more than half a million square miles, and most of it is peculiarly inaccessible. It will be long before any fairly complete view of the resources of this vast region can be presented.

GANGUE MINERALS.

The list of gangue minerals known to occur in the Alaska mines is not a long one. Quartz and pyrite are found everywhere with gold in place. There is possibly an exception in the case of the Taku mine, where pyrrhotite in uncommonly abundant and where I observed no pyrite, but very likely a methodical search for this mineral would reveal it at this locality. Worthy of note is the native copper at the Apollo Consolidated. This metal occurs also in the Smuggler vein, Telluride, Colorado,[1] and was reported long ago (1847) in the property

[1] Mr. Purington saw a specimen at the mine.

of the Orange Grove Mining Company, Virginia.[1] Prof. Henry Howe also mentioned the occurrence of native copper in the gold mines of Nova Scotia, at Oldham and elsewhere.[2] While the list of gangue minerals is not a long one, it includes most of the minerals usual in gold mines. Tellurium and the tellurides are fortunately absent, so far as is yet known.

The following is a list of the minerals, other than quartz and pyrite, thus far detected in the Alaska gold deposits:

List of minerals, other than quartz and pyrite, detected in the Alaska gold deposits during this expedition.

Mineral.	Mine.	Locality.
BIOTITE	Alaska-Treadwell	Douglas Island.
CALCITE	Apollo	Unga Island.
	Bear	Berners Bay.
	Comet	Do.
	Bennet	Silver Bow Basin.
	Liberty	Silver Bay.
	Lucky Chance	Do.
	Mexican	Douglas Island.
	Thetis	Baranof Island.
	Treadwell	Douglas Island.
	Willoughby mines	Funters Bay.
CHLORITE	Apollo	Unga.
	Glacier	Sheep Creek.
	War Horse	Admiralty Island.
COPPER, NATIVE	Apollo	Unga.
COPPER PYRITE	do	Do.
	Bear	Berners Bay.
	Comet	Do.
	Eureka	Silver Bay.
	Glacier	Sheep Creek.
	Gould & Curry	Do.
	Hague	Unalaska.
	Silver Bay	Silver Bay,
	Silver Queen	Sheep Creek.
	Treadwell	Douglas Island.
GALENA	Apollo	Unga.
	All mines of mainland belt except Funters Bay and Taku.	
	Calaveras	Uyak Bay.
	Thetis mine	Baranof Island.

[1] Gold fields of the Southern Appalachians, list of gangue minerals: Sixteenth Ann. Rept. U. S. Geol. Survey, Part III, 1895, p. 275.

[2] Mineralogy of Nova Scotia, 1868, pp. 39-61.

distinct general features. The slates, which are the oldest rocks, acquired their slaty structure prior to the intrusion of the igneous rocks; for the fragments caught up by the intrusions have as well-developed slaty structure as the walls of the deposit. The slaty cleavage is thus an ancient feature of the general structure of the country. Under external pressure the slates have yielded mainly along the cleavage planes, opening up into lenticular spaces, many of which are now filled with ore. These lenticular masses are arranged in overlapping groups, and form ore bodies similar to some in the gold fields of California and the southern Appalachians, for which I have proposed the name stringer lead.[1] The faulting on these slates has been normal, as is shown by the character of the stringers. These have an average dip greater than that of the slate, and the steepest portions of the stringers are the widest.[2]

The gabbro is in some places in contact with the granite, while in others it is separated by more or less slate. In the Alaska-Mexican a considerable amount of slate intervenes. In places the gabbro has been rendered schistose, and near the south pit of the Treadwell the sinuosities of the schistose surfaces seem to follow the undulations of the contact with the syenite.

The syenite has yielded to pressure much more completely than the other rocks. At first glance it seems to have been reduced to mere rubble, but on good exposures it can be seen that the initial yielding has gone on methodically along planes at nearly 90° to one another and at nearly 45° to the horizon. They strike with the lode, and were probably caused by nearly horizontal forces. Crushing, however, was carried beyond the rupturing point, so that the fragments after separation were ground together and some faults were produced in the broken mass.

Such conditions might naturally influence the distribution of ore. While crushing of the mass opens the way for solutions and leaves space for auriferous quartz, the faulting in the crushed rock might give rise to layers of finely packed attrition products, which would affect the course of the solutions and make against uniformity of distribution. Inequalities in richness are known in the mine and are said by some of the miners to be related to such surfaces of motion. A detailed study of this subject with an assay plan would be interesting, but I had not time to make it.

The gangue minerals of the Alaska-Treadwell are not numerous. Quartz is the chief gangue, but it is frequently accompanied in the interstitial stringers by calcite, sometimes ferriferous. In the impregnated rock these carbonates are in excess of the quartz. Pyrite is by far the most abundant associated sulphide or metallic gangue. Professor Adams found free gold in his slides embedded in pyrite,

[1] Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, Part III, 1895, p. 283.

[2] Ibid., p. 271. Compare von Cotta, Erzlagerstätten, 1859, p. 161.

but I was unsuccessful in a similar search. From the assayer, Mr. Booth, I learn that chalcopyrite is more frequent in the Treadwell than in the Mexican, while mispickel is found in the latter mine but not in the former. Pyrrhotite, galena, and zincblende are rare, but are not confined to any particular portion of the deposit.

The ore associated with the syenite is separable into two distinct varieties. Of these one consists of stringers of quartz carrying some calcite and occupying interstitial spaces between more or less decomposed syenite fragments. In such ore the pyrite is often grouped in bunches and at other times is disseminated through the quartz. The distribution of the pyrite seems to be without effect upon the tenor of this variety of ore, which is usually rich in proportion to the quantity of pyrite. The other variety of ore consists of fragments of the syenite which have been, as it were, *soaked* in the auriferous liquid. They are impregnated chiefly with carbonates and pyrite, only a little silica penetrating where there were no open fissures. The pyrite in this variety is also either bunched or disseminated, and all the mine foremen assert that where this pyrite is scattered the ore is nearly or quite worthless. It appeared to me that the disseminated pyrite represents ferromagnesian silicates attacked by sulphydric acid or soluble sulphides, and study of the ore under the microscope lends strength to this hypothesis, though without absolutely proving it.

Wherever the ore is strongly mineralized the ferromagnesian silicates have totally disappeared from the syenite, and the pyrite is scattered in it in about the same manner as the iron-bearing silicates in the fresher material. On the other hand, as the bunches of pyrite are accompanied by much calcite, they could not have been produced from any ordinary accumulation of ferromagnesian silicates, and I think such pyrite must have entered the rock in a state of solution. The association of calcite and pyrite in the wall rock of gold veins in California has been studied by Mr. Lindgren.[1] It appears to be very similar to the association of pyrite with fibrous silica which I have described from the gold mines of the southern Appalachians.[2] Sericite and a secondary green mica are common in the ore.

The impregnation of rocks with various substances seems to be accompanied by a separation of substances, as if certain compounds in solution permeated the rock more rapidly or more completely than others. This would be equivalent to an osmotic separation, and a tendency to such a separation seems almost inevitable when solutions are in contact with dense rocks. I have before called attention to this action,[3] and the theory finds considerable support in the recent investigations of Mr. Lindgren on the alteration of wall rocks.

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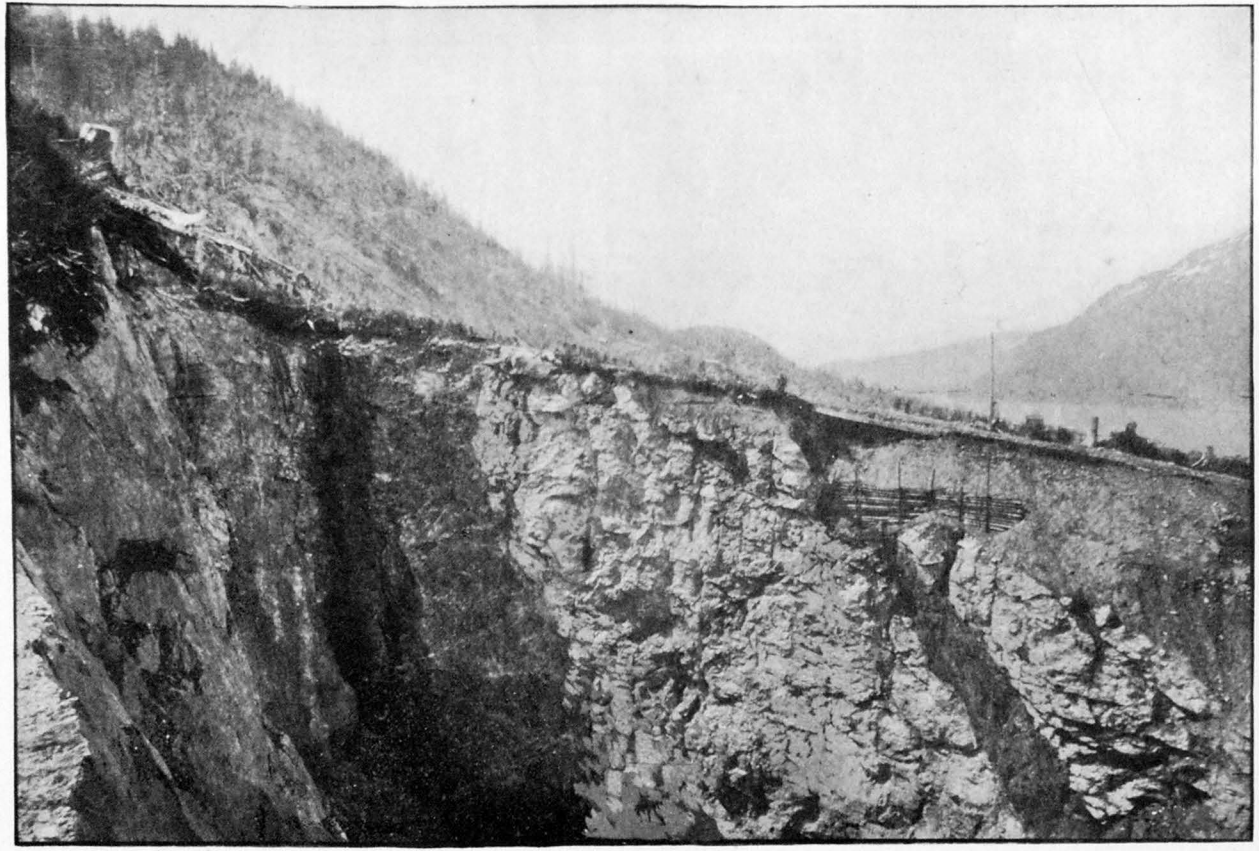
[1] Gold-quartz veins of Nevada City and Grass Valley: Seventeenth Ann. Rept. U. S. Geol. Survey, Part II, 1896, p. 147.

[2] Loc. cit., p. 308.

[3] Quicksilver ore deposits: Mineral Resources U. S. 1892, p. 156.



WEST WALL OF EAST PIT OF ALASKA-TREADWELL MINE.

The genesis of the Treadwell-Mexican deposit is probably connected with the intrusion of the dike of analcite-basalt. This dike must either have accompanied the mineralization of the deposit or have followed close upon it. The dike is not crushed or impregnated with ore to any notable extent, though here and there a few crystals of pyrite are visible. Fragments of the syenite included in the basalt show much crushing, but only a slight amount of mineralization. On the other hand, along portions of the dike small pyritous quartz seams lie between the dike and the surrounding mass, and I was informed that rich ore and free gold are usually abundant near the dike.[1] The preceding intrusion of gabbro has evidently been subjected to intense dynamic and chemical action, and must have antedated most or all of the auriferous injections. Thus, the crushing of the country rock and the deposition of the ore seem to have taken place mainly between the two intrusions, but ore deposition had not entirely ceased when the basalt dike was formed. The basalt was injected after mineralization began, but before it had ceased. The phenomena are not absolutely incompatible with the hypothesis that after the main ore deposition and a period of quiet the basalt was intruded and a fresh, relatively unimportant mineralization ensued, but there is no evidence of such a recrudescence, and the character of the included syenite fragments does not support this more complicated hypothesis.

So far as I know, this is the first known case of an association of analcite-basalt with ore generation. It is worth while to note that in a certain way the gabbro is intermediate in chemical character between the syenite and the basalt. The sodium is least and the potassium greatest in the basalt, which probably came from the deepest couche with the ore-bearing solutions.

The date of the mineralization is uncertain. There is no basalt of any kind known within a long distance of Douglas Island. On the other hand, no analcite-basalts are known to be older than the Laramie, and both in Alaska and California gold deposition has accompanied neovolcanic rocks; but all analcite rocks are not relatively recent, and the general aspect of the deposits in eastern Alaska indicates Mesozoic rather than Cenozoic age. It may be that this basalt is connected with some eruptions concealed from view by the forests, which are of more than tropical density.

The basalt dike occurs near the center of the ore-bearing ground. The most probable hypothesis at the present time seems to be that the ore chute follows downward nearly in the track of the basalt, keeping for the most part to the syenite on account of the superior fragility of that rock, and not because of any chemical influence of the albite rock on ore deposition.

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[1] Rich ore, running up to more than $100 per ton, is occasionally found in small quantities.

THE ALASKA-MEXICAN MINE.

This mine is on the same deposit as the Alaska-Treadwell and shares most of its characteristics. The syenite is much narrower in the Mexican and much of the ore is in "stringer leads" in the slate. The slates show undulating and carunculated surfaces, and are marked by incised grooves caused by the relative motion of the slaty sheets at the time of dislocation. These grooves pitch to the northwest, and the result has been to produce pipes pitching downward to the southeast, which is the pitch of the ore chutes according to the information obtained at the mine. The richest ore is said to occur on the foot wall, or southwestern side. In the proper sense there can not be said to be any foot wall, since the deposit in the slate is a series of imbricating lenses of quartz, and in the syenite a reticulated vein. More generally the deposit occurs on a zone of distributed fracture and not on a single fissure.

The ore of the Mexican has about the same tenor as in the Treadwell, and the gangue minerals are nearly the same. The slate at some points is impregnated with pyrite, which, however, I understand to be of very low grade. The deposit is not so wide, but reaches 100 feet at some points and is amply large for convenient economical working.

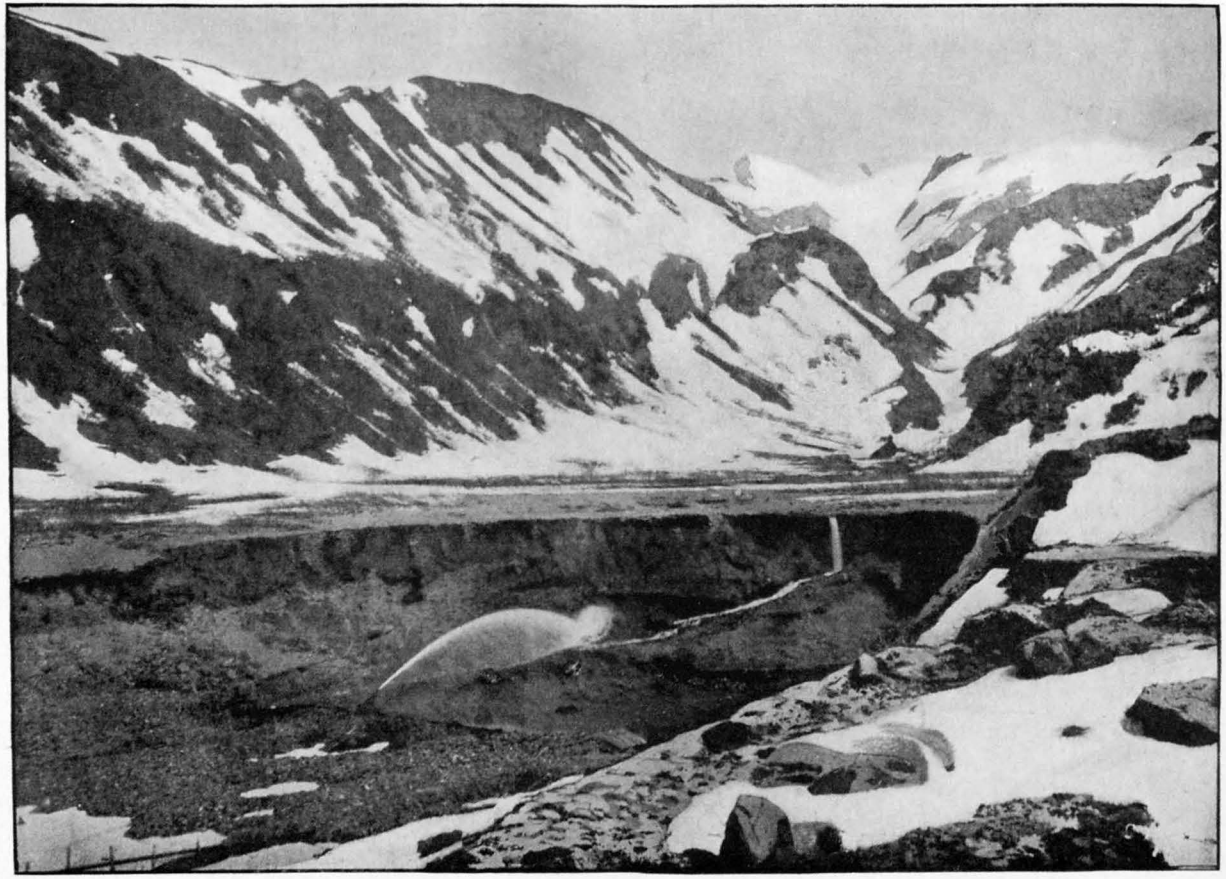
OTHER DEPOSITS OF DOUGLAS ISLAND.

Some excitement was once created by the Bears Nest property on Douglas Island. The ground was not accessible at the time of my visit. I was informed that it was opened on the same sodium-syenite dike as the Treadwell, but that the rock was too poor to pay expenses.

On the shore of the island about 2 miles to the northwest of the Treadwell a very little work had been done on a quartz vein about 3½ feet in thickness, from which some fine specimens are said to have come. The exposure as I saw it was quite insufficient to justify any opinion on my part. The vein carries pyrite and pyrrhotite. Juneau Island is a mere rock near the Treadwell wharf. It is of true granite, containing masses of stratified slate and some quartz veins said to carry a little gold.

SILVER BOW BASIN.

Silver Bow Basin lies about 3 miles from Juneau, a little to the north of east, near the head of a stream called Gold Creek. Its position is shown on the map, Pl. XVI, the topography of which was supplied approximately from local surveys by Mr. C. W. Garside. This basin is the site of considerable mining activity and is a locality of no little geological interest. In the hills to the southeast lies a glacier which formerly extended to the mouth of Gold Creek and



NOWELL PLACER MINE, SILVER BOW BASIN.

built up the moraines, a part of which is now occupied by the outskirts of Juneau. This glacier excavated, or at least swept out, a considerable depression in the position of Silver Bow Basin. The depression was subsequently occupied by a lake separated from the lower stretches of the creek by a solid rock divide.

The excavation of a depression by glacial ice is sometimes referred to as if it implied a paradox in mechanics. Were a glacier a slowly moving fluid mass, however viscous, like sealing wax or asphalt, it could never excavate beneath the level of its course. Ice, however, is not a fluid, but a solid; and it is entirely practicable for a glacier to move uphill provided that the back pressure thus produced does not exceed the limit of solidity of the ice. An opportunity was afforded during the expedition here described of observing the fact that ice may move upward at the Grewingk glacier on Kachemak Bay. The action at Silver Bow Basin was no doubt entirely similar. I was informed that the solid rock of the divide is about 100 feet above the bottom of the lake basin.

The lake-beds of Silver Bow Basin are auriferous, and that to a very considerable extent. It is asserted that no less than $250,000 was extracted from these beds prior to 1895 by the hydraulic process, drainage being secured by a tunnel 3,500 feet long through the schists. The mining operations have made an excellent section of the deposit, a general view of which is given in Pl. XX. Directly upon the bed rock occurs a fine, muddy sand, a foot or more in thickness; next comes a few inches of a black vegetable mold containing a great quantity of leaves which, though blackened, are still tough. Upon this mold rests a layer of large bowlders, some of them 2 or 3 yards in diameter, more or less rudely mingled with gravel and muddy sand. This is illustrated by Pl. XXI. The topmost layer is in some portions a peaty mass, and the entire deposit averages some 50 feet in thickness. The gravel is extremely little rounded and many of the rock fragments are almost sharp cornered. The pebbles are of the most diverse character and many of them are gold-bearing quartz. It is probable that the bowlders in these beds were deposited at a time when the glacier ended in the lake, perhaps after having already once retreated to a higher level. The period during which the glacier supplied the lake with bowlders was probably brief, since otherwise the bowlder layer would be heavier. The upper portions of the beds seem to have been filled in, in the ordinary way, by wash from the surrounding slopes. It is believed to be only the southwestern side of the lake deposit which is auriferous, this side having received the drainage from the area containing the gold-bearing veins to be described presently. This is almost the only case known to me in which lake-beds have proved auriferous to a remunerative extent, though gold-bearing lake-beds are not very uncommon.

It is a remarkable fact that although ice has filled Gold Creek,

patches have been left near Silver Bow Basin which have never been subjected to glaciation; in fact, in the higher portion of the Lane and Hayward property there are left considerable areas of decayed rock, or saprolite, exactly similar to those so abundantly found in the southern Appalachians. This saprolite also is auriferous, deriving its gold from a very great number of quartz veins, many of them of the most tenuous description. It is the wash from this saprolitic mass which seems to have furnished the gold to the lake-beds.

The saprolite on the Lane and Hayward property has been worked for years as a placer deposit. The best of it is no doubt gone, but enough remains amply to illustrate its character. A little lower down the hill than the saprolite deposit are a couple of open cuts and a short tunnel, also on the Lane and Hayward property, known as the Fuller No. 1 mine.

The country rock is a micaceous schist of sedimentary origin, carrying garnets. The schists strike N. 60° W. (true) and dip about 60° to the northeast. These schists are cut by at least three dikes of a fine-grained diorite. The dikes are nearly vertical, strike north, and are each about 6 feet in thickness. They occur near the western limit of the ore-bearing ground, but do not seem to cut off the ore entirely in this direction. Another and similar parallel dike occurs somewhat farther east in the Aurora claim. There appear to be no large veins on this property; the quartz occurs in innumerable stringers and lenses, varying in width from 2 feet or more to the thickness of a sheet of paper. Many of the veins, especially the smallest of them, are intercalated in the schists in perfect conformity to the cleavage, and many considerable lenses occur in the same manner. Still more numerous and of greater average width are seams cutting upward into the schist and very strikingly displayed on the surface of the smooth rock. The stringers have been opened by normal faulting.

There seems to be no large body of quartz on this property which would pay for underground development; but the rock lies in a position very favorable for quarrying, and it is believed by the owners that a large amount of material carrying $4 or $5 a ton can be cheaply extracted. The maximum value of the ore obtainable in commercial quantities is said to be about $8 per ton. The fineness of the battery plate gold saved is about 0.856. The gangue minerals are calcite, siderite, pyrite, mispickel, galena, and zincblende. As nearly as I could learn, this property has produced by milling something like $40,000 worth of gold. The product of the saprolite workings is entirely unknown.

The Aurora or Bennet mine lies directly north of or down the hill from the Lane and Hayward, and is opened on a portion of the same deposit. The peculiar feature of this mine is that it possesses a well-developed cross-fissure vein from 2 to 6 feet in width, striking at 15° west of north and dipping at about 70° to the southwest. I was

BOWLDERS IN THE NOWELL PLACER MINE.

informed that there is no sensible difference between the ores of this vein and those of the lenses or stringers, and I see no indication that its age or its origin is different. It has an advantage over the stringers in the fact that it lends itself to underground mining with more facility. The gangue minerals are the same as those of the Lane and Hayward, but include also pyrrhotite and muscovite. The ore is reported as milling about $13, and the concentrates are shipped to Puget Sound to be smelted. The vein has been followed for about 200 feet underground, and is said to have been followed on the surface for 200 feet more.

About a mile and a half down Gold Creek from Silver Bow Basin is the Taku mine. The rock at this point is a dioritic schist and has been intruded among the slate, horses of which are included in it. The schistosity of the dioritic mass is of course due to subsequent movements. The ore consists of very irregular quartz stringers intersecting both diorite and slate; they strike about N. 30° E. (true) and dip eastward. This ore is remarkable for the unusual quantity of pyrrhotite which it contains, this sulphuret often occurring in masses several pounds in weight. I had a special test made for nickel in the pyrrhotite, thinking this worth while on account of the very usual association of nickel with pyrrhotite, but none was detected. No other sulphuret was observed at the Taku mine, and the only other gangue mineral noticed was muscovite. The gold is said to be very free, as is usual in pyrrhotite ore, so that the sulphurets after milling have no considerable value.

SHEEP CREEK BASIN.

Sheep Creek Basin lies to the southeast of Silver Bow Basin, at a distance of about 3 miles, and the two areas are separated by a divide. The direction of the mines of the two localities from one another is the same as the strike of the schistosity of the country, or as the course of Gastineau Channel. They are, in fact, on a continuous belt of quartz deposits. Sheep Creek Basin is a picturesque little valley lying 750 feet above sea-level, and it seems to represent a glacial cirque. Even in June masses of snow heavy enough to interfere somewhat with mining remain upon its declivities. A view of the Sheep Creek Mountains, taken from the Treadwell Mine, is shown on Pl. XXII.

In Sheep Creek Basin there are three mines from which there has been a considerable output—the Silver Queen, the Glacier, and the Gould and Curry. Besides these, there are several prospects of minor importance.

The Silver Queen mine is that on which there is most development. It is situated on the northwest side of and about 600 feet above the floor of the basin, which is itself about 750 feet above the level of the channel. A wagon road 2 miles in length runs from the beach

to the foot of the steep slope on which the mine is situated. A track tramway, working by gravity, serves to transport ore from the mine to the end of the road.

The rocks of the basin consist of carbonaceous and micaceous schists, whose strike is 50° west of north and dip 70° north. There are also possibly dikes of gabbro similar to that accompanying the Treadwell ore deposit. At the Silver Queen the carbonaceous slate forms the country rock of the vein, while the gabbro is perhaps represented by a decomposed greenstone, which occurs on the foot-wall side a few feet away from the vein. The vein is 5 feet in widest dimension, is intercalated with the laminæ of the slate, and corresponds to the schistosity in strike and dip. It pinches and swells in the manner characteristic of such intercalated veins. Vein minerals consist of quartz, pyrrhotite, zincblende, copper pyrite, galena, mispickel, a little iron pyrite, and, it is reported, native silver and a little ruby silver. The galena is argentiferous. In fact, the product of this mine and that of the Glacier above has been mostly in silver, and has contributed the major part of the silver hitherto obtained from the Territory. Up to the end of 1895 the Silver Queen had produced about $100,000 in silver and $20,000 in gold. The mine workings consisted of about 800 feet of drifting on the vein, represented by three tunnels of 200 to 300 feet in length. The ore is milled in the basin below, and the concentrates shipped for smelting.

The Glacier mine, situated 800 feet above and to the northwest of the Silver Queen, on the same slope of the basin, has workings on three parallel veins, one of which is the same vein as that worked in the Silver Queen. The most westerly of these three veins is on a contact between two varieties of schist. Its foot wall and the country rock of the two veins lying to the east is the carbonaceous slate seen in the Silver Queen. The hanging wall is, however, a micaceous schist, containing scales of muscovite and of light-green chlorite. The veins all correspond in strike and dip with the inclosing schist, but differ from the veins of Silver Bow Basin in that they do not have so much the character of stringer leads. Faults have been noted in the veins, the fault plane being nearly vertical and directly across the strike. The throw is in each case about 5 feet, the southeast side having slipped downhill. Detailed observations on these dislocations were not practicable, but it seemed more reasonable to refer them to the subsidence of blocks or scales of the rock which had been loosened by surface weathering. Such phenomena are probably much more common than has been generally noted hitherto, especially in regions subjected to the violent action of frost, such as the one under consideration.

The veins of this mine average 3½ feet in width, and are said to have a lenticular character, the long axes of the lenses having a pitch in the plane of the strike downward toward the west. Like the

SHEEP CREEK MOUNTAINS, FROM THE TREADWELL MINE.

Silver Queen, this mine carries more silver than gold, but the ratio between the two is variable. The average tenor is about $40. Minerals found in the vein here, besides quartz and some muscovite, are iron pyrite, argentiferous galena, zincblende, copper pyrite, pyrrhotite, mispickel, argentiferous tetrahedrite, pyrargyrite, and native silver. The mine has been worked for six years and has 1,500 feet of development. No complete statistics as to its product are available. Thirty to forty thousand dollars will probably represent its output.

The Gould and Curry, in the north end of Sheep Creek Basin, at about 2,500 feet above the sea, was a mere prospect in the summer of 1895. Considerable development has since been done on it. The rock, although schistose, appears to be of igneous origin and of dioritic type. The strike of the schistose laminæ is N. 70° W.; dip, 80° to the north. There were three veins exposed in a small crosscut 30 feet long, each vein being about 15 inches in width. Stringers of quartz were seen in the schist between the veins. These cut slightly upward into the schistosity. They are barren of any value. The vein minerals consist mostly of quartz, containing zincblende of the black-jack variety, accompanied by small amounts of pyrrhotite and iron pyrite. The veins are said to show free gold frequently, and specimens containing it were found on the dump. According to the United States Mint report for 1895, the product of this mine for that year was $26,000 in gold.

SUMDUM BAY.

The only mining in progress on Sumdum Bay in the summer of 1895 was at the Bald Eagle, in longitude 133° 30′. The mine is at an altitude of about 1,000 feet above sea-level and 2½ miles from shore. The rocks are green slate, black bituminous slate, and dikes of a massive rock seemingly granite, but too decomposed for satisfactory study. The schists strike and dip very irregularly from N. 45 E. to N. 70 W., and have been greatly disturbed.

The deposit is a stringer lead, following the schistosity with so much regularity in dip that I was unable to observe in the exposures momentarily visible whether the stringers cut upward across the schistose surfaces or not. The foreman, however, asserted that they do so, which would indicate normal faulting. In strike they often break across laminæ, and the lead shows a divergent stringer, so that the deposit clearly occupies an opening due to fracture. The lead lies for the most part along the contact between the two varieties of slate.

The main lens of ore being worked is from 5 feet in width downward. The ore consists of quartz, galena, zincblende, pyrite, and mispickel, and is richest on the foot wall. At the cropping I observed copper stains, so that there is probably some chalcopyrite in the lead. The ore is said to be very rich, averaging, according to the superin-

tendent, Mr. Trowbridge, $40 to $50 per ton. The data obtained indicate that the ore contains about equal quantities, by weight, of gold and silver.

At the time of my visit this property could be regarded only as a promising prospect, but the ore was good and the disturbed condition of the country rock was a favorable indication for further development. From the Director of the Mint I learn that the product of the mine for 1896 was nearly $96,000, so that the favorable impression produced is confirmed.

BERNERS BAY.

The Comet and Bear mines belong to the Berners Bay Mining and Milling Company, but the landing, called Seward City, is on the west side of Sherman Point and not in the bay. The 40-stamp mill is about 2 miles from the landing and 700 feet above tide-water.

The Bear mine is about 500 feet above the mill and a third of a mile away. The country rock is a diorite, which is described on an earlier page. It is irregular in texture and much fissured, but I detected no system in the partings. There are three small tunnels cutting several quartz veins, all of which strike in a westerly direction, but do not seem to be parallel. They also dip at various angles to the northeast. The widest of them is known as the Bear vein. It strikes due west (true) and dips at 60° or 70° to the north. In width it varies from 2½ to 11 feet. The vein contains quartz, calcite, sericite, pyrite, chalcopyrite, and mispickel. The vein also incloses many fragments of wall rock, often sprinkled with pyrite, though embedded in white quartz not visibly charged with sulphurets. The quartz is much broken and disturbed, no doubt by movements of the ground. The direction of movement seems to be indicated by the groovings on the walls, which pitch westward at about 30°. While portions of the Bear ore look fairly well, much of it is sugary, dead, and barren-looking. The mine at the time of my visit had produced no ore.

The Comet is said to be 7,000 feet eastward of the mill, and is about 1,000 feet above it. It lies at least approximately in the strike of the Bear deposit. The development consisted of three small tunnels and one winze down about 100 feet below the lowest tunnel. The country rock is the same as that at the Bear. There are several small veins besides the Comet, and the structure is as irregular as in the other mine. The strike of the Comet varies from N. 15° E. to N. 75° E., but the former course seems to be the more characteristic. The dip also varies from about 70° to 45° to the north. The vein varies in thickness from 8 feet downward, and averages about 3 feet. The quartz, which is usually somewhat broken, carries pyrite, chalcopyrite, and galena. In some portions of the mine there is much free gold accompanied by an unusually small amount of sulphurets, and, judging from the statistics, some of the other quartz must be richer than

THE NORRIS PETERS CO. PHOTO-LITHO. WASHINGTON, D. C.

it looks; the deposit, however, is apparently somewhat "pockety." I was informed that the mine had produced over $200,000 in the year preceding June, 1895, and that the ore averaged $50 or $60. It is said that only 1 per cent of the ore is sulphurets, and that these run about $160 per ton. If so, 97 per cent of the gold recovered is obtained by direct amalgamation, a very unusual state of things. The fineness of the bullion is 0.840 to 0.800. The Berners Bay Mining Company, according to the Director of the Mint, produced $125,000 in 1896.

FUNTERS BAY.

There were two prospects on Funters Bay at the time of my visit, both seemingly on the same series of veins. The more easterly was known as the Tellurium mine, and the other, about a mile distant, as the War Horse. The strike is somewhat different, but there is evidence of curvature on the exposures along the shore, and the discoverer, Mr. Richard Willoughby, informed me that substantial continuity is established by intermediate croppings and what may be called *soundings*.

The surface of Admiralty Island is deeply covered with decaying timber, overlain by a thick layer of moss, and overgrown with bushes and trees. Mr. Willoughby states that he is in the habit of prospecting through this vegetable layer with a steel rod armed with a "carbon." After a little practice it is easy to discriminate the feeling of quartz from that of less gritty rocks. More than 99 per cent of southeastern Alaska is covered by dense moss and decaying wood, and some such method of facilitating prospecting as that described is highly desirable.

The Tellurium Mining and Milling Company is said to possess six parallel veins, striking a little east of north (true) and dipping southward at 70° or 80°. Of these, four were visible, averaging about 3 feet in thickness, but sometimes swelling to 10 feet and occasionally pinching. The country rock is a schist seemingly of eruptive origin, very probably once a diabase, but rendered cleavable by pressure. The present position of the schistose laminæ is nearly horizontal. On a little dump I found fragments of a diabase which seem to belong to a dike not visible in place. This is the only diabase met with during the trip, though the closely affiliated gabbro of the Alaska-Treadwell might at some points be regarded as diabase.

The veins fill cross fissures in the schists. They consist of quartz, a little calcite, and a fair amount of pyrite and pyrrhotite, accompanied by an unusual quantity of chlorite. The chlorite is often intergrown with the quartz so as to produce a somewhat regular mottling. Free gold is sometimes found in the chlorite. Mr. Willoughby asserts that some telluride occurs in the ore in thin silvery streaks, but the specimen given me to illustrate this occurrence contains no tellurium. Free gold is sometimes seen in quartz carrying inappreciable quantities of sulphurets.

It is stated that the pyrite contains $150 per ton, while the pyrrhotite carries only $10 or $15. The ease with which gold entangled in pyrrhotite is extracted is well known, and this fact tends to throw a doubt on the favorite hypothesis that gold in pyrite is altogether free. However, pyrrhotite is so much softer than pyrite that, other things being equal, the monosulphide should be more easily treated. The ore is said to average $10, and there is nothing incredible in this assertion. The proximity of the veins to the water and their nearly vertical position will facilitate the working of the property.

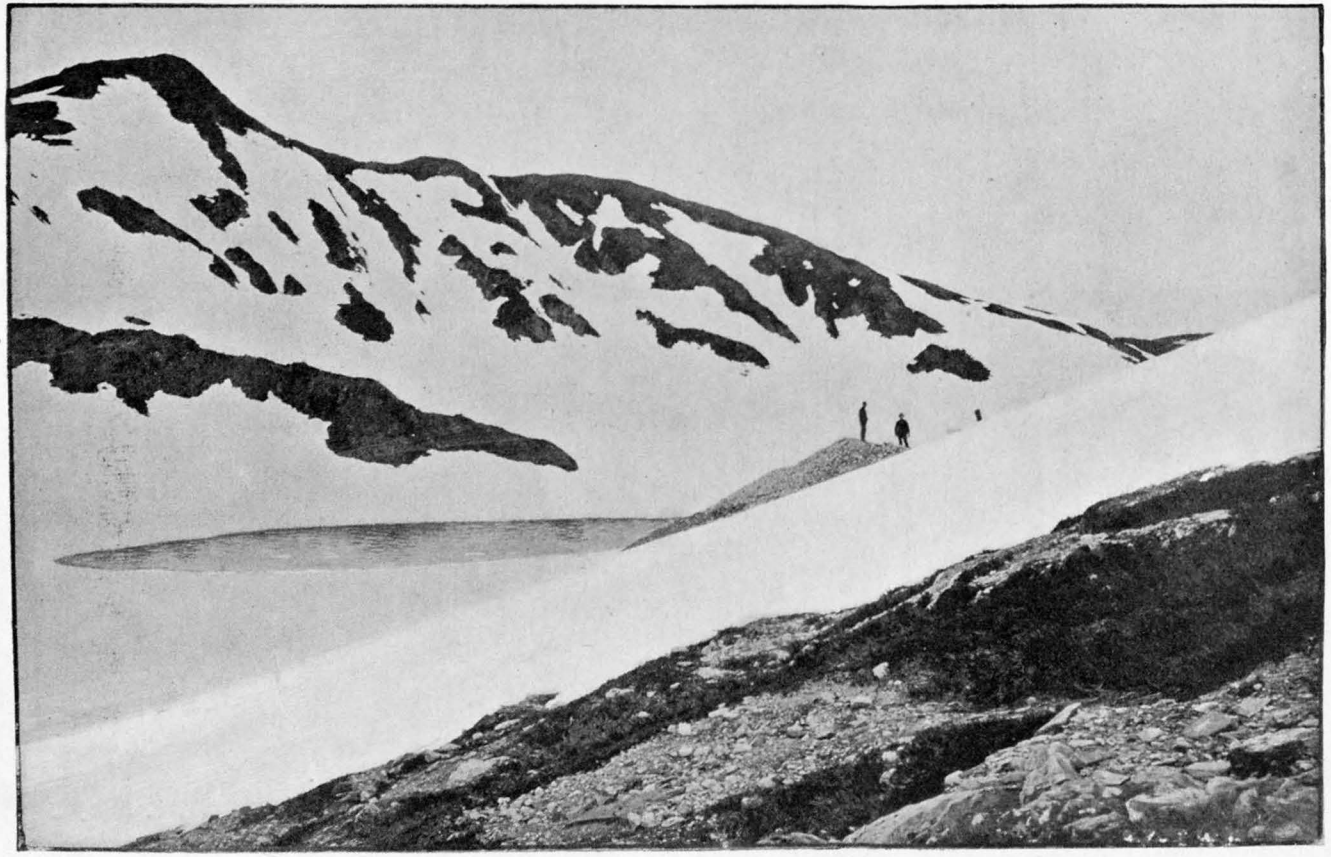
The War Horse veins strike about N. 15° E. (true), and the geological conditions seem similar in nearly all respects to those of the Tellurium property. The veins on the War Horse often send off sheets of quartz into the schists, these sheets following the cleavage surfaces. In this way very pretty illustrations on a small scale of "pipe and rake" veins are produced. It is said that, as one would suppose, the intersection of pipe and rake is often much richer than the average ore. Besides these pipes, there are portions of the slate which show numerous small lenses and stringers of pyritous quartz, and some of the ground thus impregnated is believed to be worth extraction.

The Director of the Mint reports $16,000 from Funters Bay in 1896 credited to the Boston and Alaska Company. Whether this company has acquired the Tellurium claim I am not informed.

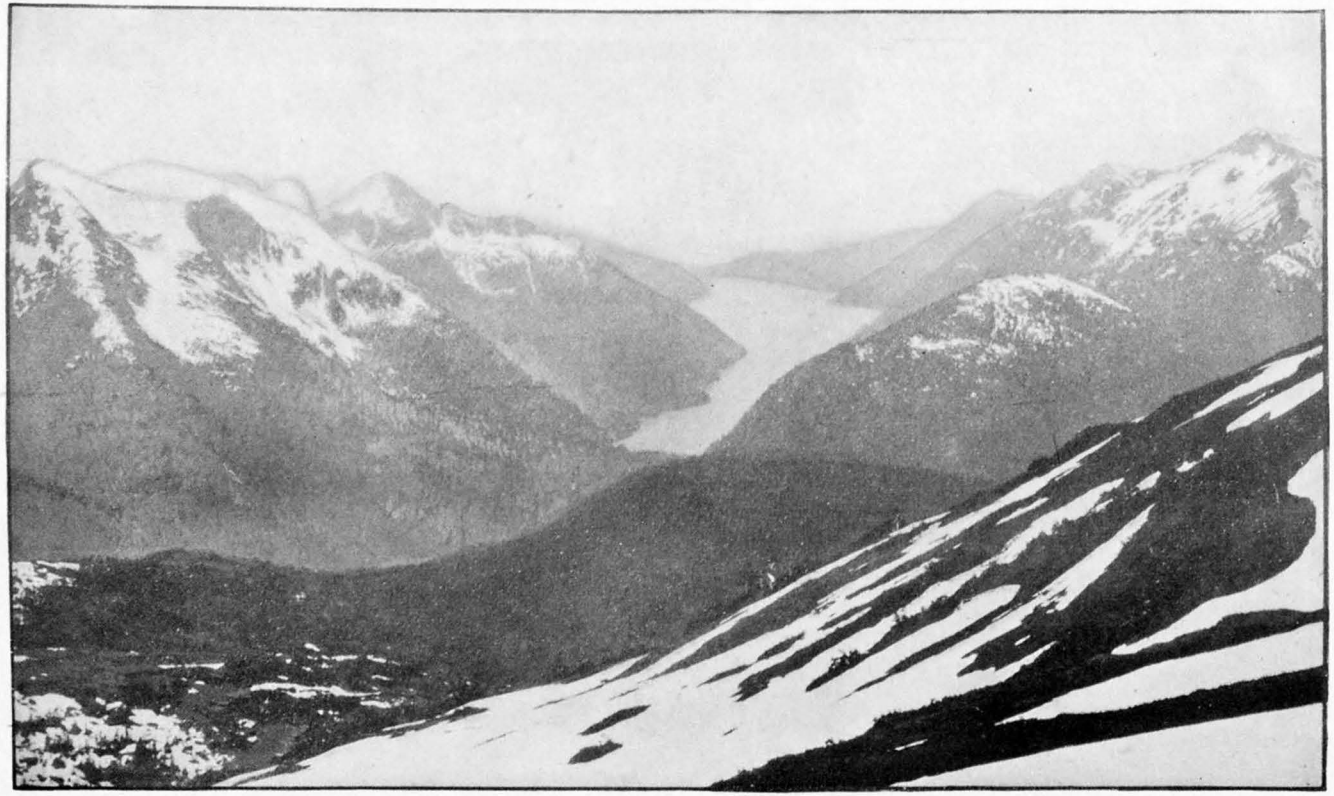
REGION NEAR SITKA.

There is a very considerable number of prospects within a few miles of Sitka. Most of these occur about Serebrennikof Arm or Silver Bay, but the Thetis lies to the eastward of Sitka, and a little (so far as I could see, hopeless) prospecting has been done at the site of Old Sitka on Katliana Bay. Pl. XXIII is an approximate map of this region, the general position of which may be seen on Pl. XV. The rocks associated with ore throughout this region, so far as observed, are carbonaceous slates and the curious pyroclastic diorite described in the earlier portion of this report. The cleavage of the slates antedates the diorite, which is itself more or less schistose at many points. At the hot springs, however, not very far away from Silver Bay, there is granite and a dike of sodium-syenite, and Mount Edgecumb is at least in part basaltic. No product is reported by the Director of the Mint from this region for 1896.

The Liberty mine, owned by Major Turner, lies on the south shore of Silver Bay, about three-quarters of a mile from the indentation called Bear Bay. The country rock is slate, but near by are intrusions of the diorite in the form of dikes varying in width from a few inches to several feet. The slides from these dikes are among the most characteristic of this pyroclastic rock. The slates strike N. 70° W. (true) and dip 80° southward. The ore forms a series of imbri-



VIEW OF THE LUCKY CHANCE MINE.



VIEW OF DEEP LAKE FROM LUCKY CHANCE MINE.

cating lenses, or a stringer lead, in the slates, the quartz conforming as a rule to the carunculated schistose structures, though occasionally breaking across laminæ, and sometimes the slate is so broken as to form a reticulated deposit. The slate fragments are angular, and there is no evidence of substitution. The width of the lead is variable, but reaches 7 feet in maximum so far as explored. The ore consists of quartz, calcite, chlorite, pyrite, chalcopyrite, and mispickel. The ore is said to average $2.50, half of it "over the plates." Milling tests have yielded as much as $5.

The Silver Bay property is nearly on the strike of the Liberty, on the other side of Silver Bay, and shows a vein 8 feet in width in pyroclastic diorite, with the dip and strike of the Liberty lead. Ore on the dump showed pyrite and chalcopyrite. No work was in progress.

The Eureka prospect is about 2 miles southeast from the Liberty, on the westerly side of the bay, and about 500 feet above the water level. It is a stringer lead of pyritous quartz inclosed in slate, but lying close to masses of the diorite, which forms both dikes and brecciated masses. The strike is the same as that of the preceding deposits. The amount of development is insignificant.

The Haley and Rodgers lies east of Salmon Creek, about two-thirds of a mile from the southerly extremity of Serebrennikof Arm, at an elevation of 675 feet. The country rock is slate. The vein is several feet in width, strikes N. 60° W., and dips 70° to the northeast, not conforming to the schistosity of the sedimentary rocks. The vein as a whole is white and unpropitious, but there is said to have been a rich streak on the foot wall. Pyrite is present in the vein, and on the dump fragments of mispickel carrying free gold were observed.

The Stewart is near the last prospect, a little farther from the bay, on the same creek, at an elevation of about 1,000 feet. The deposit is a stringer lead, sometimes developing into a nearly solid vein. A little of the ore is brecciated, and much of it is mingled with slabs of slate. The lead is 15 feet wide at one point, and may average 8 feet in width. It carries pyrite and mispickel. There is a ruined mill at the Stewart, but how much bullion it has turned out I was unable to ascertain.

The Lucky Chance is 2½ miles from the southerly end of Silver Bay as the crow flies, but 7 miles by the wagon trail. It lies on the crest of a ridge, 2,500 feet above water and far above timber, in a very picturesque position. The main country rock is the pyroclastic diorite, carrying, as usual, numerous included fragments of slate. The property is opened by two tunnels, but the entrances to both were deeply buried under snow (June 26), and it was only with much effort that an entrance was effected into one of them, the lower one.

As there seen, the ore forms irregular stringers, each a few inches in width, sometimes massed and sometimes scattered through the country rock, which here consists of diorite mingled with slabs of

slate. If the deposit were a solid vein, it would be perhaps 3 feet in thickness. The strike is irregular, but is approximately N. 45° W. (true), and the dip 80° NE. A peculiarity of the ore seems to be that the sulphurets are massed in contact with the walls or horses, the body of the quartz being nearly free from sulphides. At one point the stringers were so crowded that a stope could be and was carried up to the upper level. The ore contains, besides quartz, calcite, siderite, chlorite, mica, pyrite, and particularly abundant mispickel. Free gold associated with mispickel occurs. A sample taken by a disinterested person is said to have assayed $30 per ton. The upper tunnel is said to look better than the lower one, and the mine is considered the best in the district. While as at present developed it is a very unsatisfactory property, it might pay to follow the lead somewhat farther. A view of the Lucky Chance claim is given on Pl. XXIV, and a view of Deep Lake, taken from the mine, on Pl. XXV.

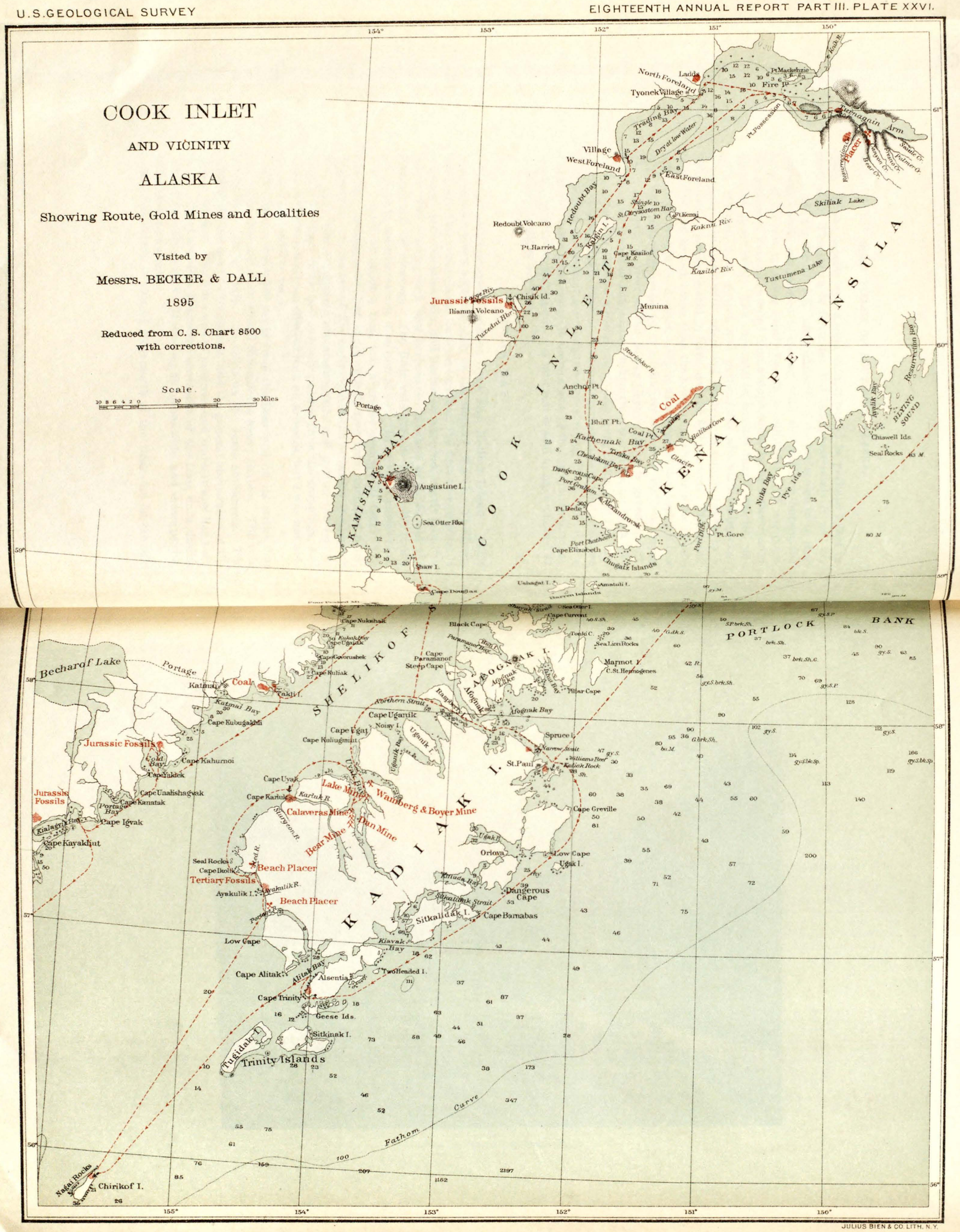
The Thetis is about 5 miles north of east from Sitka, and lies in a locality known as Billys Basin. The country rock is somewhat schistose diorite, and the deposit a reticulated zone striking N. 35° W., with a dip of 40° to the northeast. It shows about 2½ feet of quartz carrying calcite, pyrrhotite, and galena. A mill test is said to have yielded $7 gold and $1 silver per ton.

UYAK BAY.

Several small prospects exist on Uyak Bay, Kadiak Island. Their positions are given approximately on the map, Pl. XXVI. The Bear, Dan, and Calaveras claims lie close together, the first two on what is supposed to be the same vein, and the last on a second, nearly parallel, vein. The country rock is a carbonaceous schist or slate, and the fissures cut the cleavage. The Bear vein strikes N. 25° W. (true) and dips in a southwesterly direction at 40°. In width it varies from a few inches to about 6 feet, and averages perhaps 2½ feet. The quartz is usually solid, but is not entirely free from included schist fragments. A number of fine outlying parallel stringers accompany the vein. The sulphurets are arsenopyrite and pyrite, the former preponderating. Free gold is easily panned from the croppings, and some extraction has been effected with an arrastra, but I was not able to ascertain yield or tenor.

The Dan is about 500 yards from the Bear and on its strike, but the deposit has not been traced through the heavy timber. The vein is about 2 feet in width, and contains the same sulphurets. The mispickel here is well crystallized, and the general appearance of the quartz is good. No work was in progress and scarcely any has been done. The Calaveras lies to the northeast of the Dan, on a similar vein of the same strike. It is about 20 inches wide, and shows pyrite, mispickel, and galena.

The Lake claim is about 4 miles north of the Bear and on the east



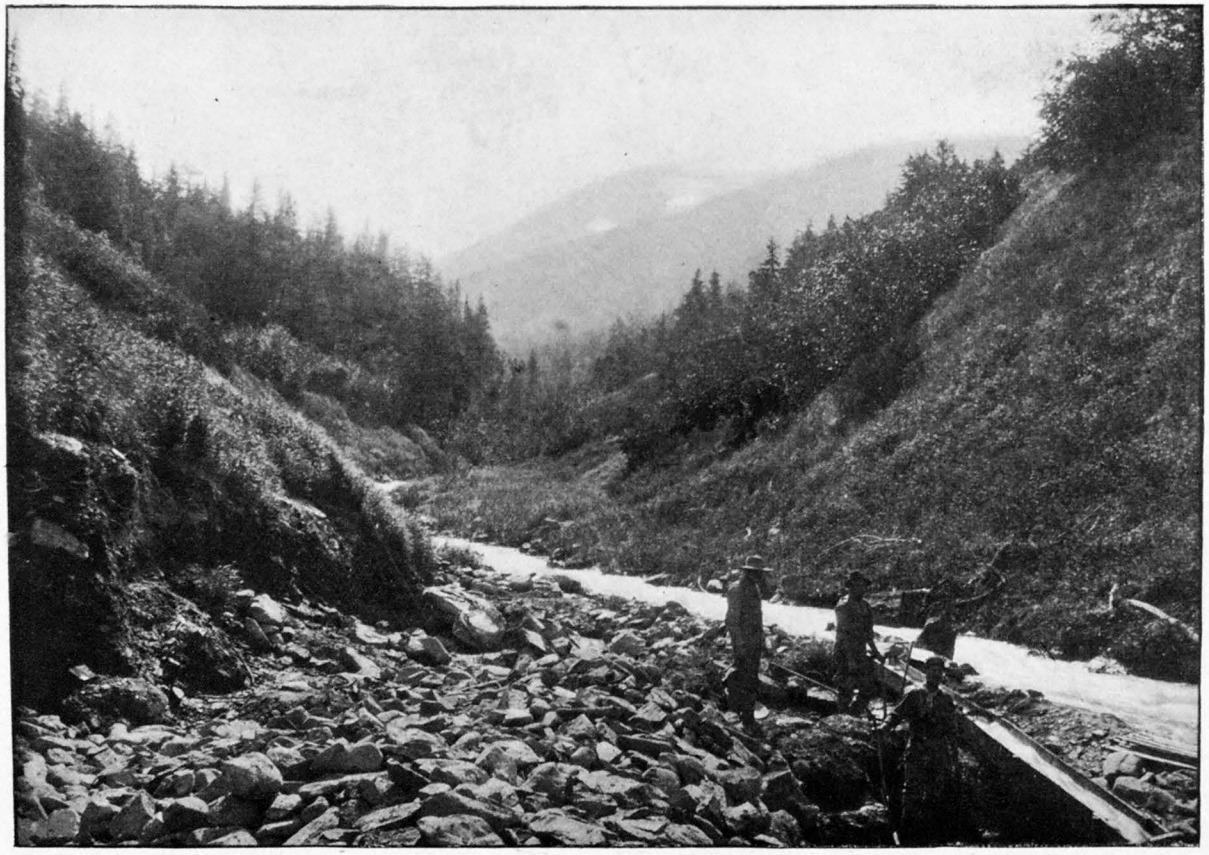
JULIUS BIEN & CO. LITH. N.Y.

THE APOLLO CONSOLIDATED MINE.

This remarkable and important deposit lies on the island of Unga, about 2½ miles west of Delarof Harbor. Unga is one of the Shumagin Islands, and is shown on Pl. XXVIII. Nearly the whole of the exposed rock in this region is andesite and dacite, but on the north side of the entrance to the harbor there are rocks underlying the andesite which from the deck of a vessel look sedimentary. At Coal Harbor, or Zachareffskaia Bay, similar andesites overlie the Miocene. It is reported that there is a belt of granite farther inland than the mine. This is very probable, and it is certain that granite occurs on the Nagai, an island of the same group as Unga, and one of its nearest neighbors.

I saw nothing to lead me to suppose that there is any considerable geological difference between the dacite and andesite of Unga. They seemed at least associated eruptions, if not merely different facies of the same series of eruption. These rocks at some points show well-marked columnar structure. As the mine is approached the decomposition of the rock increases and there is a large amount of "propylite," or chloritic andesite, as pronounced in character as that of the Comstock lode. At the mine itself the rock is so decomposed that it is nearly impossible to decide whether all of the quartz which it contains is secondary. On the whole, it seems probable that at least a portion of the wall rock is dacite. The walls are highly chloritized and charged with pyrite. There is no sensible amount of sericite, nor any conversion to carbonates. The pyrite would seem to have been formed in part from ferromagnesian silicates, and perhaps also from magnetite. In one case a colony of minute pyrites occupies the position of an augite or hornblende.

The ores of the Apollo Consolidated consist of free gold, pyrite, galena, zincblende, copper pyrite, and native copper. Red oxide of copper and malachite are joined as decomposition products. The occurrence of native copper is remarkable, though not absolutely unknown elsewhere. Its usual form is that of fine filiform aggregates. A large part of the gold occurs in the free state, finely disseminated through quartz, and almost wholly unaccompanied by sulphurites. The quartz there often has a yellow stain, not at once recognizable by those unfamiliar with this unusual mode of occurrence. A large part of the value of the mine is said to depend upon kidneys of this free gold ore. A slide from such a specimen shows a few particles of galena with the gold. In some cases, also, the specks of gold are intimately mingled with tiny shreds of native copper, both being embedded in quartz and manifestly contemporaneous. Most of the surfaces of the gold grains are rough, and the metal tends to filiform and scaly configurations. Only occasionally is a plane face visible under the microscope on a gold grain. It evidently requires peculiar conditions to develop good crystals of gold even on a minute scale.



VIEW OF RILEY'S CLAIM, BEAR CREEK.

shore of the bay. The vein at this point strikes N. 70° E. (true) and dips 80° to the southward, cutting the slate, which is here manifestly of sedimentary origin. The vein is only a foot wide, and the only sulphuret observed in it was a very little mispickel. This vein lies on one of a double series of joints forming a nearly rectangular system. On the shore below the vein is a neat illustration of the mechanism of jointing. The partings cross both sandstone and shale. In the sandstone the joints are from one-fourth to one-half inch wide and filled with quartz, but in the shale the same cracks are so narrow as to be scarcely visible, although sometimes carrying quartz. Evidently the shale yielded far more prior to rupture than did the sandstone.

The Wamberg and Boyer is 10 miles north of the Bear and near the entrance of Uyak Bay. The prospect is on a veinlet 7 inches wide, striking about N. 55° E. (true) and dipping to the southeast at 65°. It lies in sedimentary schist, and conforms nearly in strike, less nearly in dip. Near by excellent glacial modeling and scratches were observed.

TURNAGAIN ARM PLACERS.

At the time of my visit stream gravels had been worked for a year or two on Resurrection Creek and Bear Creek, and prospecting was going on at a locality called Sixmile Creek. These localities are shown in fig. 6 (p. 82). They lie on Turnagain Arm at the head of Cook Inlet, shown on Pl. XXVI. Rich gravels were found higher up the arm a few weeks after my departure. The only profitable workings in July, 1895, were on Bear Creek, but I was informed that a "color" could be obtained in any stream for miles about. On Bear Creek, which is a small brook running northwestward, the pay was confined to a length of about 1½ miles, the lower end of the stretch being perhaps 2½ miles from the mouth. The deposit consists of a mass of moderately coarse gravel, composed of pebbles of the size of cobblestones, mingled with a few bowlders. They extend in some cases a couple of rods from the present bed of Bear Creek. The gravel is evidently the result of modern erosion. The bed rock is exposed at Riley's claim toward the upper end of the productive stretch, and consists of slates striking nearly at right angles to the course of the stream and intersected by heavy dikes of pyroclastic diorite. A view of Riley's claim is given on Pl. XXVII. A description and analysis of this diorite have been given on a preceding page. Most of the pebbles are diorite, and this is said to be the prevailing rock at the headwaters of the creek. The rocks, where seen, contain a limited quantity of small quartz veins, and it is probable that the gold is derived from such stringers. Of course, prospecting for remunerative veins would be justified, but the heavy growth of spruce forest renders the search laborious, and hitherto no success in this quest has been attained.

The gold is found mostly in flattened but coarse and slightly worn grains. It is light in color and said to be worth $14 to $16 per ounce. This would correspond to a fineness of about 0.740.

It should be noted that the first discovery of gold in Alaska was made in 1848 by P. P. Doroshin. He found auriferous sands on the Kaknu River, the grains being coarse toward the source, or a region not far from Resurrection Creek, and he speaks of the association of gold with slates and diorite dikes. The miners on the Bear assert that the gravels have been worked to some extent before, and that they find old pick points deep in the gravel. It seems hardly credible, however, that any working in this locality can have antedated the discovery of a couple of years before my visit.

Late in August, 1895, fresh finds were made, particularly on Canyon Creek and Mills Creek, shown on the map, fig. 6. This map I owe

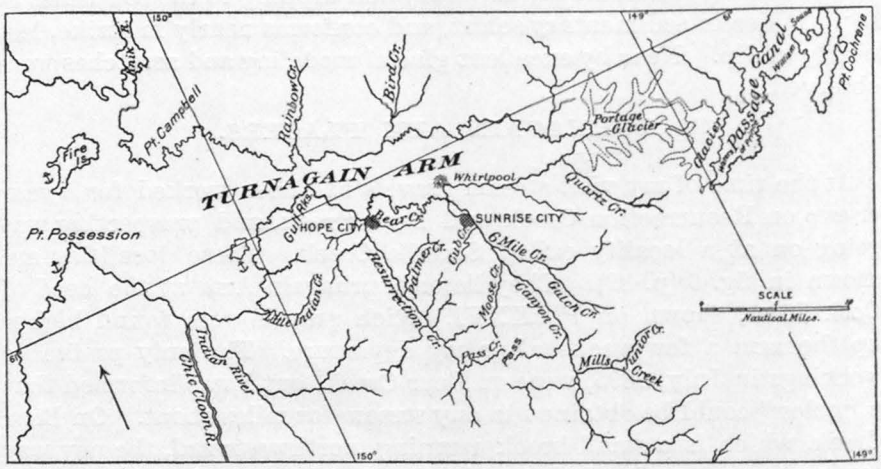
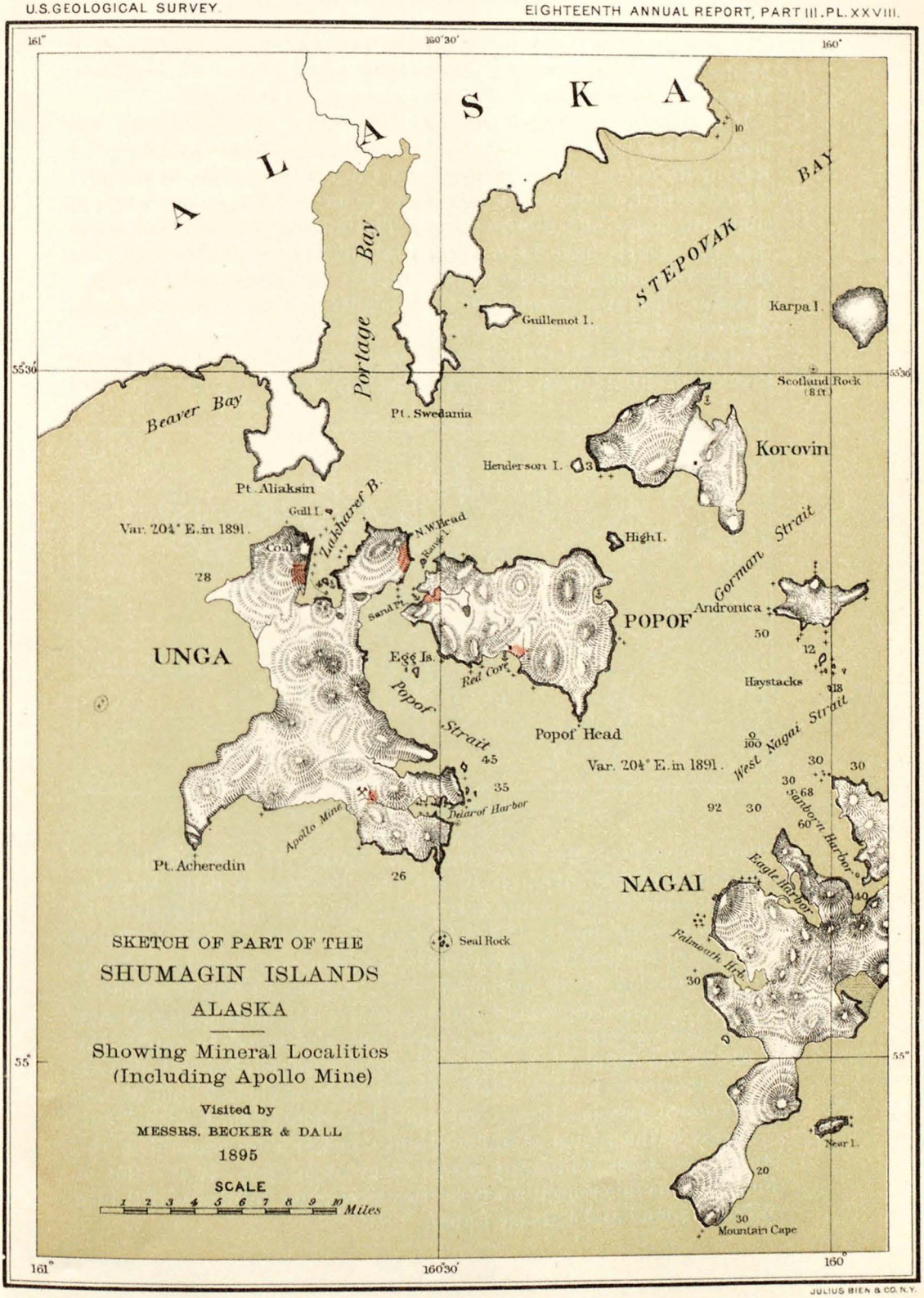


FIG. 6.—Sketch map of Turnagain Arm.

to the courtesy of Mr. J. A. Becker, of Sitka. It is decidedly more accurate than that given on Pl. XXVI. The miners at the new diggings are said to have made over $100 a day, and many slightly worn nuggets were obtained. The richness of the new washings stimulated the placer industry throughout the region, and pay gravel was found on Resurrection Creek and elsewhere. A rush to this region took place in 1896, as one would suppose, and while good diggings were found, not enough auriferous gravel was discovered to supply the needs of the influx of miners, and great disappointment followed. Such a result was sure to occur. Had there been enough gold for last year's crowd, twice as large a one would have sought the fields in 1897.

Access to the region is difficult and dangerous on account of the stupendous tides, which are about as great as those of the Bay of Fundy. For this reason many parties have gone in by way of Prince William Sound and Passage Canal.



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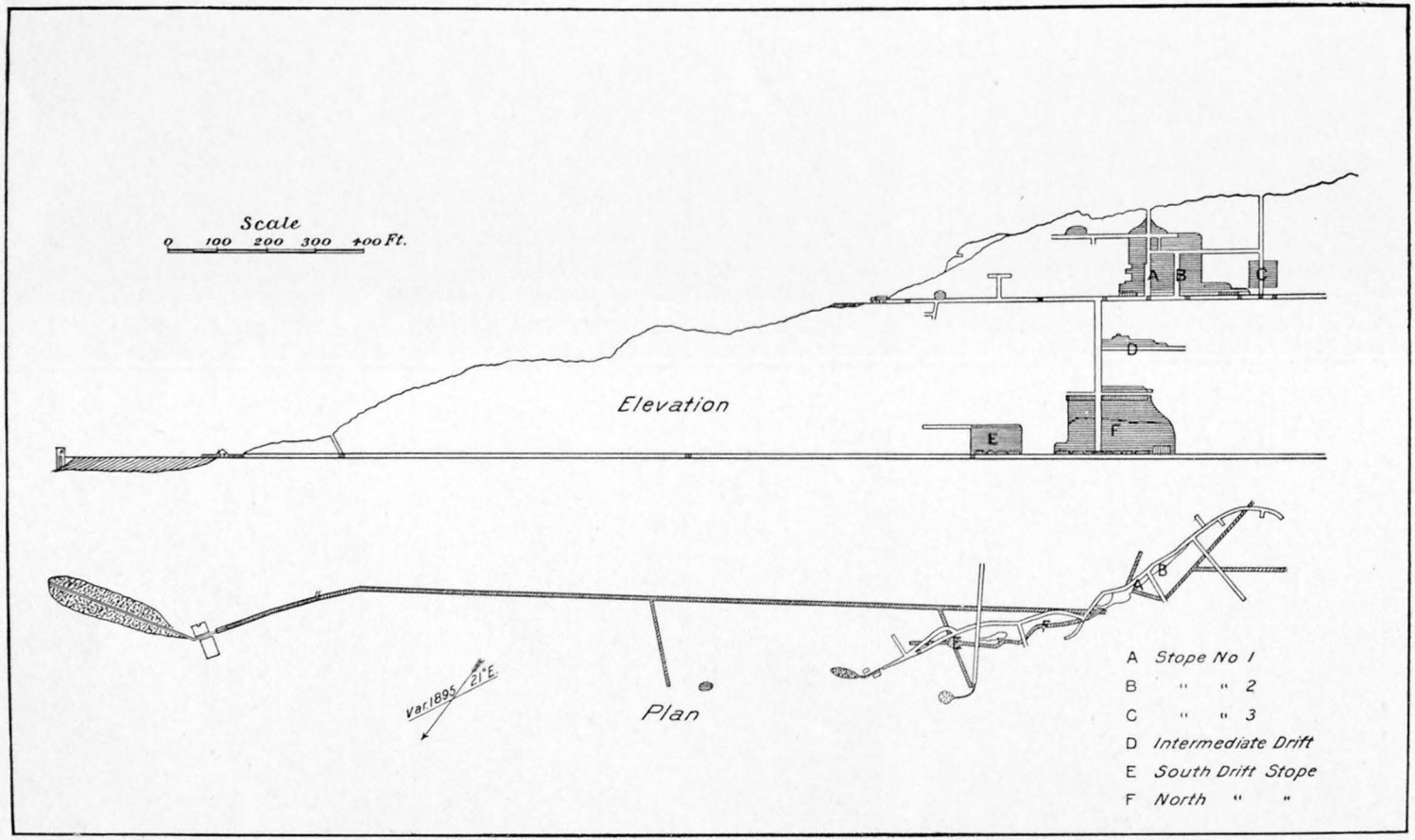

PLAN AND SECTION OF APOLLO CONSOLIDATED MINE.

Much of the quartz is sugary. This condition seems due in part to conditions of crystallization and in part to movements which have taken place since ore deposition. The evidence of such movement is found in thin sections of the ore. One locality in the mine is known as the "Flour Mill," because the ore can be shoveled up as if it were meal. The ore has crystallized on walls and fragments of andesite in a very striking manner. Comb structure appears wherever there were relatively narrow spaces between fragments or along walls. There is not the slightest evidence of substitution; on the contrary, the fragments of rock are as sharp as possible. One of the specimens collected is a piece of andesite with a nearly square cross-section having sides an inch long, the length of the andesite fragment being perhaps 2 inches. The ore has crystallized out from the surfaces of the andesite in all directions, the crystals being arranged like iron filings on a magnet; but the corners of the andesite nucleus are as well defined as if it had been broken but yesterday.

Calcite occurs as a gangue mineral in the Apollo, though in quantities very subordinate to quartz. Much more remarkable is the presence of a mineral believed to be orthoclase. It occurs in small quantities in the stringers of ore, and is of the same age as they. It has a lower index of refraction than the balsam, displays a cleavage like that of orthoclase, and gives a strong reaction for potassium with hydrofluosilicic acid. Mr. Lindgren has more recently found microcline in auriferous veins at Silver Crown, near Cheyenne, Wyoming.

The deposit as a whole is nearly vertical and strikes N. 43 E. (true). It occupies a zone of fracture rather than a fissure, and might be called as a whole a reticulated vein. It is supposed to be bounded by two fissures, often marked by clays. There is often a pay streak at one or both of these fissures, but the pay frequently makes from the easterly fissure into the intermediate ground. So far as I could see, the presence or absence of remunerative ore depends chiefly on the amount of interstitial space present. The included rock fragments often show pyrite, but I could not learn of any more rock which was richly impregnated with gold. The ore-bearing ground is sometimes 40 feet in width, and, on the whole, forms a chute pitching northward. If there are other such chutes, as is to be assumed, they will probably be rudely parallel with this one.

The average yield of the ore is said to be $8, and about four-fifths of this amount is obtained from the plates. The bullion carries 0.767 gold as collected from the plates. The sulphurite contains $50 or $60 per ton, and carries more silver than the plate gold. This is no doubt due to the large amount of galena in the ore. The amount of the production is given in the early portion of this paper under the heading, "Statistics of gold production." In 1896 the Apollo produced over $400,000 gold and nearly $40,000 silver, coining value.

Of course the Apollo Consolidated is a very recent deposit, and

VIEW OF EASTERN PORTION OF UNALASKA.

there has been little erosion since its deposition. In its general features it resembles the deposits of Bodie, California, and the irregularity of the fracturing in both cases is due to proximity to the surface as well as to lack of homogeneity in the rock. Such a mine requires careful management and systematic development. The Apollo also deserves careful treatment. A plan and section of the mine appear on Pl. XXIX.

There are other deposits in the neighborhood of the Apollo. The King mine is about half a mile northward, and is believed to be on the same lead. It is reported to have produced $3,000. Gold has been found at various points east and west of the Apollo, as well as northward, and there is said to be a belt of auriferous ground extending through the island on the strike of the Apollo. Nearly in this direction lies Red Cove, Popof Island, where the andesites are intensely decomposed and heavily charged with pyrite.

UNALASKA.

On the island of Unalaska some prospecting has been done, and one of the tunnels near Pyramid Peak is several hundred feet in length. This tunnel follows fissures on which a little quartz is occasionally seen, accompanied by iron and copper pyrite. This is certainly not a valuable deposit, but it is reported that there are other occurrences of sulphureted quartz on the island. A view of the eastern portion of Unalaska, taken from a hill close to Dutch Harbor, on the little island of Amaknak, is given on Pl. XXX.

AURIFEROUS BEACH SANDS.

As is well known, auriferous beach sands have been worked at various points along the Pacific Coast from lower California northward. Gold-bearing sands are especially abundant from Lituya Bay to Yakutat Bay—that is, between longitude 138° and 140°. According to Mr. Henry Boursin,[1] auriferous black sand was first discovered on the western beach of Khantaak, a small island in Yukutat Bay, in 1887. It is said that $3,000 was extracted from the sands near Yakutat in 1891. In 1890 beach sands were worked a few miles east of Lituya Bay, and in 1891 the yield at this locality is said to have been $15,000, obtained by sluicing. According to the reports received by the Director of the Mint, Lituya Bay sands produced $39,000 in 1896.

Sands from the Khantaak Island have been carefully examined by Mr. J. Stanley-Brown.[2] He found, besides gold, magnetite, garnet, hornblende, pyroxene, zircon, quartz, feldspar, calcite, and mica associated with fragments of a slaty or schistose character. Iron,

[1] Eleventh Census, Pop. and Res. of Alaska, 1893, p. 230.
[2] Nat. Geog. Mag., Vol. III, 1891, p. 196.

platinum, and chromite could not be detected, and only a trace of titanium is present. Mr. Stanley-Brown concludes that the sand is derived from the destruction of metamorphic rocks. The rocks surrounding Yakutat Bay seem to be Pliocene or Pleistocene, but as they are composed of the débris of older rocks, the sand derived from them might bear an older character. There is nothing known to me which suggests that the gold of this region is of recent origin, and it is more probable that it was derived from deposits affiliated with those of Baranof Island, though the croppings may now be concealed by Pleistocene beds. In the expedition here described it was impracticable to stop on this shore compatibly with visiting the more western auriferous districts.

Gold washing was in progress during my visit to the western shore of Kadiak Island, at Portage River and Ayakulik River. The beaches here lie along a bluff, averaging 50 feet or more in height, which limits an extensive grassy plain. This represents a very recent uplift which has been general throughout western Alaska, elevating most parts of Kadiak, Chirikof, Tugidak, and other islands. The recency of the elevation is shown by the fact that the little streams draining the low, flat plateaus have made small progress in cutting back into the bluffs. A view of the Portage River locality is given on Pl. XXXI. At the beach washing, the bluffs as well as the beaches carry streaks of black sand, and those in the bluffs are said to be auriferous as well as those at tide-level. The source of the gold is doubtless in the ranges which lie several miles to the east of the bluffs. Pebbles of granite and metamorphic rock are found on the shore, and have accompanied the gold from its original position. The gold-bearing sands do not occur in masses, but in patches, perhaps an inch in thickness and extending over a few square yards. When such a patch is found the material must be gathered and carried out of reach of the waves, which constantly shift the sands from place to place. The Kadiak sands consist of magnetite, garnet, quartz, slate, serpentinoid material, and very light, scaly gold. The gold floats easily and does not seem to amalgamate well. No doubt much of it is lost, and some new process, such as cyaniding, must be adopted before large profits can be made from any but exceptionally rich beach sands.

While on Kadiak and elsewhere the gold is associated with magnetite, I do not regard this as necessarily any evidence of a common origin. The two minerals would be found together, because both are denser than quartz, whenever both gold and magnetite exist in the rock undergoing degradation. As is well known, volcanic rock usually contains much magnetite, so that an area consisting of schists carrying gold-quartz veins, and basalt carrying no quartz, would yield an auriferous magnetite sand.

BEACH WASHINGS AT PORTAGE RIVER, KADIAK ISLAND.

GEOLOGY OF THE YUKON GOLD DISTRICT, ALASKA,

BY

JOSIAH EDWARD SPURR;

WITH

AN INTRODUCTORY CHAPTER ON THE HISTORY AND CONDITION OF THE DISTRICT TO 1897,

BY

HAROLD BEACH GOODRICH.

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UNEXPLORED
Ngatak R.
Kowak R.
Koyukuk R.
Porcupine R.
MACKENZIE RIVER
Arctic Circle
Melbrikakat R.
Nulato
YUKON RIVER
Sonkakat
St. Michael
Andreafski
Holy Cross Mission
Kuskokwim R.
UNEXPLORED
Tanana R.
Birch Cr.
Circle Cy.
Forty Mile
Forty Mile Cr.
Stewart R.
Mc Millan Riv.
Pelly R.
Ft. Selkirk
Lewes R.
Teslin R.
White R.
Sushitna R.
Copper River
Cook Inlet
Logan
St. Elias
Chilkat Pass
Chilkoot Pass
White Pass
Taku Pass
Dease R.
Liard R.
Juneau
Stikine R.
SITKA
MAP OF ALASKA
Modified from U. S. Coast Survey Chart T according to explorations by U. S. Geological Survey Party in charge of J. E. Spurr – 1896
Red dotted lines denote routes followed
Dashed lines denote areas shown on larger scale maps
Scale
40 0 120 200 Miles
1897

GEOLOGY OF THE YUKON GOLD DISTRICT, ALASKA.

By J. E. SPURR.

INTRODUCTION.

The field work on which the accompanying report is based was done in the summer of 1896 by a party consisting, besides the writer, of Messrs. H. B. Goodrich and C. F. Schrader, assistant geologists. This party left Washington at the end of May and returned about the middle of October, and thus was enabled to spend nearly four months in actual field work in Alaska and adjacent portions of the Northwest Territory. The route pursued is shown on the general map of Alaska (Pl. XXXII) which accompanies this report. From Juneau our way led up Lynn Canal and thence across Chilkoot Pass to Lake Lindeman, which is near the headwaters of one of the several great rivers which unite to form the Lower Yukon. From Lake Lindeman we traveled in a small open boat through lakes and rivers to the gold-mining districts. After examining these we rowed and floated down to Nulato, where we obtained passage on a trading steamer to St. Michael, and at St. Michael took passage on the Alaska Commercial Company's steamship *Bertha* to San Francisco, via Unalaska and Unga. On the trip from Juneau to Fortymile Post, which occupied about four weeks, we were accompanied by Mr. P. A. Wiborg, an Alaskan pioneer miner; otherwise the journeys made were without assistants or camp hands.

In the preparation of this report valuable assistance has been rendered by Messrs. Goodrich and Schrader. The published maps were prepared largely, and in some cases wholly, from our field sketches; although in those covering considerable areas the Coast Survey map has been used as a basis. This work was done by Mr. Goodrich, who has also prepared the preliminary chapter on the history and present condition of the Yukon gold district, as well as a discussion of the drainage peculiarities of the gold belt, which appears as part of the chapter on movements in the earth's crust (Chapter IV, p. 251), and reports on gulches in the placer districts visited by him. Mr. Schrader has prepared separate reports on gold-producing gulches and has given help in the microscopic study of rocks, in obtaining a full knowledge

of the literature of the subjects treated, and in many other ways. Messrs. F. H. Knowlton, W. H. Dall, Charles Schuchert, David White, T. W. Stanton, F. M. Lucas, and Bashford Dean have rendered paleontological assistance, and Messrs. W. F. Hillebrand and H. N. Stokes have aided by their chemical work.

In the field, where the most difficult part of the work was performed, courtesies were rendered by the Alaska Commercial Company and the North American Transportation and Trading Company, to whom thanks are due. Sincere acknowledgments are also given to the Alaskan pioneer miners, open-hearted and open-handed, to whom we are indebted for many a lodging and many a meal. Finally, and above all, the writer records his thanks to his friends and coworkers, Messrs. Goodrich and Schrader, to whose personal support and endurance of physical discomfort and danger a large part of the success of the undertaking is due.

CHAPTER I.

HISTORY AND CONDITION OF THE YUKON GOLD DISTRICT TO 1897.

By HAROLD B. GOODRICH.

EARLY EXPLORATIONS.

It was the fur trade that led the Russians step by step along the Aleutian Islands from the first discoveries of Bering and Chirikof, in 1741, until the time of Baranof and the great Russian-American monopoly. With the organization of the latter and the rights of exclusive trade granted it the Russians, obtaining a foothold on the southeast coast, advanced into Bering Sea and even up the Kwikpak (Yukon) River some 500 miles. While this company was spreading eastward from the Pacific and Bering Sea, the English, represented by the Northwest Company and later by the Hudson Bay Company, were simultaneously pushing their trade westward. In 1821 the Northwest and Hudson Bay companies formed a union. They had posts on the Mackenzie River, where their servants lived and carried on business over 1,000 miles from the nearest civilization, receiving in return salaries hardly large enough to buy the ordinary necessities of life. The hardships of these pioneers were many, but they pushed onward in the face of all difficulties, looking for new fields where a lucrative fur trade could be carried on; and in this extension of the fur trade the idea of another passage to the Pacific was kept constantly in mind. As early as 1786 La Perouse had, in behalf of the French Government, undertaken to solve the problem of a northeast passage to the Canadian lakes or Hudson Bay from the western shore of America; but after sailing as far as Litua Bay he became convinced that the northeast passage had no existence. In 1816 Kotzebue sailed on the same quest, and for a time thought himself successful.

In 1834 J. McLeod explored the Liard River above Fort Halkett in the endeavor to discover some westward-flowing stream that might lead to the Pacific coast. On this trip he discovered Dease Lake,

and crossed to the head of the Stikine, which he called Pelly River, but which was afterwards named Frances River, in honor of Lady Simpson.

In 1838 Robert Campbell volunteered to establish a fort on Dease Lake. He passed the winter there, during which he was reduced almost to starvation; but subsequently the post was abandoned, because in the meantime Sir George Simpson had secured from the Russian Government the lease of the "coast strip" of Alaska in favor of the Hudson Bay Company, and all the furs of the Stikine River found their way to market more easily at the post built at the mouth of that river. For this privilege $2,000 annual rental was paid by the company.

In 1840 Dease and Simpson, having recently discovered the mouth of the Colville River on the Arctic coast, wished to find its headwaters. It was supposed that this river's course was parallel with that of the Mackenzie, and that therefore waters flowing into it would be found in about the latitude of the head of Frances River; accordingly, in the spring of the year an expedition in charge of Robert Campbell started from Fort Halkett, on the Liard, ascended the stream, and discovered and named Frances Lake. He further ascended Finlayson River to the lake of the same name, and from there crossed to the Pelly, which he named in honor of a governor of the company. In 1842 Pelly Banks Post was established at a point near the head of the Pelly River. In June of the following year Campbell descended the Pelly as far as the mouth, and the Lewes River was named, but it was not until 1849 that Fort Selkirk was founded at the junction of the two rivers.

While Campbell was opening the Lewes River country, voyagers were also busy in the country to the north, and another post had been established by the company on the Yukon. In 1842 J. Bell made a journey across the divide between Peel River and the Porcupine, and descended the latter a short distance. He returned to Fort McPherson, on the Peel River near the mouth of the Mackenzie, and was in charge of that post in 1846, when, pursuant to orders from the trading company to repeat the trip, he descended the Porcupine to its mouth, and in 1847, two years before Campbell had settled at Fort Selkirk, Fort Yukon was built. It was not even known that the two were upon the same stream until 1850, when Campbell descended to Fort Yukon, and was much surprised to find a white trader at the latter place. During this and subsequent journeys Campbell named many of the tributaries of the Yukon, generally in honor of friends and associates, and most of these names have become fixed by common usage. Among these were the Stewart and White rivers, the former named for one of his assistants and the latter on account of the muddy character of its water.

From Fort Yukon Campbell made his way up the Porcupine, crossed to the Mackenzie, and returned to Fort Simpson, proving that the

route to the Yukon by way of the Porcupine was much easier and less dangerous than that by way of the Frances to Fort Selkirk; accordingly, in 1850 and 1851 the posts at Fort Frances and Pelly Banks were abandoned. Fort Selkirk was, however, still maintained as a trading post until 1852. In this year the coast Indians, enraged at the serious inroads whsch the posts of the interior were making upon the trade they had previously monopolized, determined upon a raid. The Chilkats crossed the divide in August, surrounded Fort Selkirk, and, in the absence of the friendly Indians, the inmates were driven out and the buildings sacked. Campbell, having gathered his forces, tried in vain to apprehend the robbers; after which, being out of provisions, he was obliged to float down the river to Fort Yukon, whence he returned to Fort Simpson late in the fall. The same winter he traveled to Minnesota on snowshoes, accomplishing a journey unparalleled in the annals of the Hudson Bay Company. Thence he went to Chicago and the East and sailed to London, where he placed the matter before Sir George Simpson and asked for permission to reestablish the demolished post. This was not allowed him, and until comparatively recently the site of Fort Selkirk was marked only by the ruins of the old buildings. At present Mr. Harper manages a trading post at this locality—the first one which the traveler meets on descending the river.[1]

Fort Yukon was occupied as the westernmost post of the Hudson Bay Company until after the transfer of the Territory to the United States. The trip to this point from the western coast was not made till 1863, when it was accomplished by an employee of the Russian-American Company, Ivan Simonsen Lukeén. According to Dr. W. H. Dall,[2] Lukeén was sent by the Russian-American Company to investigate rumors of the existence of an English trading post far up the river, which they knew by the name of Kwikpak. It seems that even before this time trips had been made by Russians up the river to Nowikakat and by the English down to that point, but the men had never met, and the Yukon and Kwikpak were supposed to be distinct streams, the one entering the Arctic Ocean and the other entering Bering Sea. In 1866 Ketchum and Lebarge, of the Telegraph Expedition, ascended from St. Michael as far as Fort Selkirk, and proved conclusively that the Kwikpak and the Yukon were identical.

Previous to the transfer, the Russian-American Company had occupied trading posts on the river as far up as Nulato, having entered the Yukon country from the Kuskokwim, near the head of which Kolmakof had established the redoubt, but with the opening up of the Territory that company yielded in favor of the Americans, and several companies immediately entered the field. The English were accustomed to send men down to Nuklukayet every spring to gather in the

[1] It is reported that Mr. Harper, one of the oldest pioneers of the Yukon, died of consumption, after his return to the United States, in December, 1897.

[2] Alaska and Its Resources, Boston, 1870, pp. 276-277.

furs that had been collected during the winter, but in 1868, when they made their usual annual trip, they found an American company, which had ascended the river the summer before and located there. The latter informed them that they could no longer pursue their trade upon American soil. It had been suspected that Fort Yukon was well within the Alaskan boundary, although its location had never been actually determined; so in 1869, when a company of American capitalists had formed the project of trading on the Yukon, it was thought best to determine once for all whether any English company had the right to carry on trade at the mouth of the Porcupine River. To this end Capt. Charles W. Raymond was detailed to make observations of latitude and longitude at the confluence of the two rivers. The party ascended the river in a steamboat—the first time that one had floated on the Yukon. On the 31st of July, 1869, they arrived at the post, having accomplished the journey from St. Michael in twenty-three days; and on the 7th of August observations of the solar eclipse were made, which settled the question finally. Fort Yukon was found to be in American territory, and a few days later the Hudson Bay representatives were informed that it was illegal for them to trade with the Indians on United States soil, and that they must vacate their buildings. Captain Raymond then took possession in the name of the United States.

In reporting upon the resources of the country from observations made on this trip, Captain Raymond concludes that the importance of the fur trade had been greatly exaggerated. As far as mineral wealth is concerned, he dismisses it with a single sentence, "No valuable mineral deposits in workable quantities have been found up to the present time." In this is shown the attitude which the trading companies had maintained and the policy they had pursued in the development of the country. Their attention had been directed entirely to the fur trade, to the exclusion of all other resources. Nor was this attitude always a passive one. The story is told [1] that when Baranof was chief manager of the Russian-American Company, a Russian who had been exploring the mountains back of Sitka found several pieces of rich quartz. Baranof assayed the specimens, but told no one of the result, and ordered the finder to do no more prospecting. The idea that the mountains of the coast of Alaska contained mineral wealth had been suggested; but even against the repeated efforts of the Emperor to have his realms investigated, the agents of the company interposed objections, their real reason probably being that an increase of population resulting from a discovery of precious metals would have greatly lessened their profits. Finally, in 1855, an engineer, Darrehan,[2] was sent by the Emperor to examine the shores. For some reason this officer made no examination of Baranof Island, where

[1] Rept. Director U. S. Mint upon production of precious metals in U. S. during 1883, p. 19.
[2] This name is a misprint for Doroshin, or Doro[illegible], in the report cited.

gold was afterwards found, in 1858, and his other investigations having proved unsatisfactory, he made an unfavorable report. While the English company took no such positive stand as this, it never did any prospecting nor in any way encouraged others to do so.

But it was soon seen that there were other resources besides furs, and a new element began to come into prominence. In 1857 the Hudson Bay Company had received from its agents on the Fraser and Thompson rivers in British Columbia, or New Caledonia, 300 ounces of gold which had been collected almost exclusively by the Indians, who were very jealous of the white men. The report sent by Governor Douglas caused the greatest excitement among the hordes of miners in California who had not recovered from the attack of "gold fever" produced by the discovery of 1848. As one writer has said, "The third great Devil's Dance of the nations within the decade seemed about to begin." Thirty thousand miners went immediately to the scene of the excitement. Harassed by the Indians along the route, they were obliged to fight frequently for possession of the land; suffering was great and the riotous scenes of the gold craze in California were to a certain extent repeated. In 1859 the Fraser River district was occupied, but all except 3,000 of those who had entered the country returned. The following year the Cariboo district was discovered, and after that the Omenica, although but little work was done in the latter until 1867; and in 1874 came the Cassiar, and later the discovery of gold in the vicinity of Sitka. The tide of gold seekers was setting steadily toward the north, and it is not surprising that, having found gold along all these mountain ranges, prospectors should begin to think of the vast unexplored interior.

PROSPECTING OF YUKON DISTRICT UP TO 1887.

The first prediction of the discovery of gold in the interior of Alaska had been made by Mr. W. P. Blake.[1] In 1863 he visited the Stikine River, in what was then Russian America. At this time, although placers were being worked near the mouth of the Stikine and gravel bars were paying as high as $10 per day to the man, the region which was afterwards known as the Cassiar district had been little prospected; but, on making an examination extending 50 miles up the river, he came to the conclusion that "there is every reason to believe that the gold region of the interior extends along the mountains to the shores of the icy sea, and is thus connected with the gold regions of Asia.[2] This may seem a very sweeping generalization on slight grounds, but coming from such a source it undoubtedly exerted an influence in turning the attention of prospectors toward the interior. Another prediction—though not intended to apply especially to the

[1] House of Rep. Ex. Doc. 177, pt. 2, Fortieth Congress, second session, p. 4.

[2] Professor Blake remarks (op. cit., p. 6) that the gold brought by the Indians from the Takoun (Taku) River, farther north, was much coarser than that found upon the Stikine.

Yukon country—was made in a letter of Mr. H. H. McIntyre to the Secretary of the United States Treasury in 1869. Mr. McIntyre came to the conclusion, from the similarity in geological structure of the Sierra Nevada Mountains of California and the Rocky Mountain ranges of Alaska, that it was reasonable to expect mineral wealth in the latter.

A little while before this, however, the finding of "minute specks of gold" by some of the Hudson Bay Company's men on the Yukon, probably in the vicinity of Fort Selkirk, British territory, was reported to the Western Union Telegraph Expedition. But this gold was not in quantities to warrant a "rush" to the locality.[1] About this time Dr. W. H. Dall wrote:[2] "Gold in small quatities is found in the sands of the Yukon near Fort Yukon." In 1867 Ketchum and Lebarge, members of the Telegraph Expedition, ascended the Yukon and found evidences of gold on the upper river.

The foregoing were casual observations, however, and it was not until George Holt's trip that systematic prospecting for gold was begun. The date is somewhat variously given as 1872, 1875,[3] and, by Dawson, 1878. It is certain that Holt made several trips. On his first one he crossed the Chilkoot Pass and descended the Lewes River as far as Lake Marsh; returning from this point by way of the Teslin (Hootalinqua[4]), Dease Lake, and the Stikine River to the coast, he brought back glowing accounts of coarse gold on the upper Lewes. It is said that in 1874 he descended the Yukon as far as the one hundred and sixtieth meridian, and crossed the water portage which begins at the Russian Mission to the Kuskokwim.[5] Holt appears not to have been entirely reliable, and many of his stories of adventure have been discredited, but, be the dates of his journeys correct and his tales true or not, he was the first prospector who reported gold from the Yukon. In 1885 he was the agent of the Alaska Commercial Company at Knik River, on Cook Inlet, when, having incurred the enmity of one of the Indians, he was murdered.[6]

Soon after George Holt's first trip, in 1873, Harper, who was the agent at Fort Selkirk, and Fred Hart, at that time employed by the Alaska Commercial Company, but who has for a number of years been a successful miner upon Fortymile, went on a prospecting tour in the Stewart and White River countries. They found fine gold, but no good prospects on White River, and absolutely nothing on Stewart, which was the scene of later excitement. Hart attributes their failure to discover gold upon the latter stream to the fact that they did not

[1] Travels in Alaska and on the Yukon, Whymper, London, 1869, p. 258.
[2] Alaska and its Resources, London, 1870, p. 477.
[3] Alaska Coast Pilot, 1883, p. 200.
[4] The United States Board on Geographic Names has adopted Teslin as the name of this river and lake, often called Hootalinqua.
[5] Journeys in Alaska, E. Ruhamah Scidmore, p. 119.
[6] Shores and Alps of Alaska, H. W. Seton Karr, London, 1887, p. 131.

ascend the Stewart far enough. Had they made the discovery the rush to the country would have occurred twelve years earlier.

From time to time reports were brought out by such men as Holt which stimulated miners and prospectors to a rush for the interior. The only practicable routes lay over the passes in the Coast Range to the great watercourses. These passes are four in number; from northwest to southeast: the Chilkat, Chilkoot (Perrier Pass of Schwatka), White, and Taku. Of these the Chilkoot and White are the nearest in direct line with the headwaters of the Lewes, the former being 3,500 feet above sea level, while its neighbor to the south is fully 1,000 feet lower. However, notwithstanding the greater roughness of the journey, the Chilkoot Pass has been almost invariably selected, probably because it is less interrupted by portages, and the journey from salt water to the lakes at the head of the river, only 27 miles, is much shorter than by any other route.

It is related[1] that the first passage of the Chilkoot Pass was made in 1864 or 1865 by an employee of the Hudson Bay Company, who started from Fort Selkirk, was imprisoned by the Chilkoot Indians, and was finally delivered to Captain Swanson, who then had command of one of the company's steamers in Lynn Canal. Dr. G. W. Dawson does not credit this story, because at the time of the alleged trip Fort Selkirk was in ruins and had been so for twelve years; but traces its origin to the fact that shortly after the raid upon the fort a gun and several other articles belonging to Campbell's party were recovered on the coast by servants of the company.[2]

From time immemorial the Chilkoot and Chilkat Indians inhabiting the coast had maintained a monopoly of the trade with the Wood or "Stick" Indians of the interior. In bartering, the latter were allowed to come as far as the pass, where they were met by the Chilkoots and exchange was made. Their position as intermediaries between the interior Indians and the whites was greatly to the profit of the Chilkats, and they appear always to have resented any interference with this position. In writing on this subject in 1869 Mr. W. S. Dodge says: "Nor will the coast Indians permit any white man to pass to the upper country to trade; the penalty they threaten is death. All trade must be made with them and through them. Hence is evinced a monopoly powerful and extensive in character."[3] This attitude of the Indians undoubtedly delayed the development of the country several years, for all parties which started out for the interior with the purpose of prospecting were prevented from crossing the Coast Range, with the exception of George Holt, who, as mentioned above, made the passage.

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[1] E. R. Scidmore: Alaska, its Southern Coast, and the Sitkan Archipelago, p. 119 and elsewhere.

[2] Ann. Rept. Geol. Surv. Canada 1887–88, Vol. III, Part I, 1889, p. 179 B.

[3] Senate Ex. Doc. No. 59, Forty-fifth Congress, third session, p. 97.

In September, 1879, the Indians removed all their objections to the white men entering their country, owing to the diplomatic intercession of Captain Beardslee, who was then in charge of the Government vessel *Jamestown*, stationed at Sitka. During the winter a party of nineteen organized in Sitka under the leadership of Edmund Bean, the same who with a party had landed at Taiya (Dyea[1]) in May, 1878, and had been prevented from proceeding to the interior at that time. They were furnished with an escort and bore letters to be presented to the chief of the tribe, Klotz-Kutch by name, whose father had been instrumental in the raid upon Fort Selkirk in 1852, and who himself had recently given some trouble to the Government representative.[2] The party, increased to the number of 25, landed safely at Taiya. The Indians, recognizing the authority and letters sent to them by Captain Beardslee, helped the prospectors by supplying packers, and on June 17, 1880, the company had crossed the divide. The discovery of gold-bearing ledges near Taku and the development of rich gold placers and ledges discovered by Joseph Juneau in Silver Bow Basin, just above the town which now bears his name, occurred in the same year. The removal of the embargo furthermore opened the interior of Alaska, which before this had been a terra incognita. From this time, then, dates the development of gold mining in Alaska.

As a result of this first prospecting party's work, the finding of gold-bearing bars in a small stream which flows into the Lewes 15 miles above the canyon was reported. The stream referred to is probably Cummins Creek, which in 1893 was worked and yielded $3 to $5 per day per man. R. Steel, one of the members of the prospecting party, reported on this creek $2.50 per day per man. Their movements after this are uncertain. In the Alaska Coast Pilot for 1883 Captain Carroll states that some of the members went down as far as Fort Yukon; others went up the Pelly River 200 miles to the Pelly Banks trading post of the Hudson Bay Company. Here the latter party separated again, some taking the northern branch to Pelly Lakes, and others going to Frances Lake, in the Cassiar country, where they fell in with several other prospectors and presumably stayed for some time.[3] Dr. Dawson's version is that they ascended the Tes-lin-too (Teslin, or Hootalinqua), and prospected its bars, returning by the same route.[4] In the same year at least one other party crossed the Chilkoot Pass.

In 1881 four miners crossed the pass and prospected the Big Salmon River, and these may be said to be the first producing miners in the Yukon district. Gold was reported the whole length of the Iyon, or Big Salmon, and two of the members, Langtry and McGlinchey, did considerable placer mining in the river bars of that stream.

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[1] The United States Board on Geographic Names has adopted Taiya as the form of this name.
[2] Senate Ex. Doc. No. 71, Forty-seventh Congress, first session, p. 60.
[3] Alaska Coast Pilot, 1883, p. 200.
[4] Ann. Rept. Geol. Surv. Canada 1887-88, Vol. III, Part I, 1889, p. 180 B.

In the following year, 1882, an excellently organized expedition attempted to prospect the Yukon from the other end. In June the party, consisting of 45 prospectors under the leadership of Edward and Eff Schiefflin, discoverers of gold at Tombstone, Arizona, went to St. Michael, bought the steamboat *New Racket*, and ascended the Yukon as far as Nuklukayet, where they wintered. About 300 miles above the mouth they are said to have discovered a "mineral belt." That fall they prospected some small creeks and rivers 80 miles above the trading post at Nuklukayet, where they found bars yielding $10 a day per man, and in prospect every pan showed gold. "There were many good indications of gold, especially in the region where a range of hills known as the Lower Ramparts are aligned with the river's course."[1] They returned to winter quarters at Nuklukayet, but in the spring of 1883 started up the river again and found placers paying $10 to $15 at Rowetka.[2] (The latter point I have been unable to identify.) During the summer they returned to St. Michael, sold the *New Racket*, and reached San Francisco by the revenue steamer *Corwin*. Their conclusion in regard to the country was that it would never pay for mining operations on account of the severity of the winter and the shortness of the open season, but, while dissatisfied with the opportunities afforded for mining, the Schiefflins must have been much gratified at proving to their own satisfaction, at least, their theory that there is a great "mineral belt" encircling the world from Cape Horn through Asia and the New World. They had found this mineral belt at several points along the Yukon.

This trip is interesting mainly because, while all the former prospecting tours had been in British territory, this was the first report of the finding of gold in the United States possessions. Further, the creeks and rivers referred to were without doubt Mynook and Hess creeks, which have been rediscovered comparatively recently and have been worked only during the past season. Thirty miles above the mouth of the Tanana River a large creek enters the Yukon from the east. It is called by miners and traders Shevlin Creek, and so spelled. This is probably named after the leader Schiefflin.[3]

In 1882 it was reported that a company of 45 miners found gold 150 miles east of the Copper, or Atna, River.[4] This is probably a reference to Schiefflin's party, which consisted of about that number. In the same year many miners crossed the Chilkoot Pass, and one party in which was Frank Densmore, a man now famous through the whole Yukon country, ascended the Pelly as far as Hoole Canyon.[5] The results of this trip were not especially encouraging.

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[1] Rept. Director U. S. Mint, 1884, p. 29.

[2] Op. cit., p. 29.

[3] On May 16, 1897, Edward Schiefflin died at Canyonville, Oregon. Although he made over half a million dollars out of his discoveries in Arizona, he died in poverty, having squandered his money in various mining ventures.

[4] Ann. Rept. Director U. S. Mint, 1883, p. 34.

[5] Ann. Rept. Geol. Surv. Canada 1887–88, p. 180 B.

In 1883 there was some mining in river bars on the Lewes, but reports are very meager. This was the year that Schwatka made his trip on a military reconnaissance. He notes the presence of gold in placer deposits, beginning at the mouth of a river which he called the D'Abbadie, but which is now known by the name Big Salmon, and continuing almost to the mouth of the great Yukon. He says that "a panful of dirt taken with discretion from almost any bar or bank will, when washed, give several colors."[1] At Von Wilczeks Valley, 20 miles south of the Pelly River, colors were found in the high bank near the river.[2] The author concluded that most of the gold came from the Pelly River, because the bars at the mouth of that stream were a little richer in placer gold than others on the Yukon; also because reports of successful small mining on the Pelly, probably referring to the party mentioned above, had been brought down to Fort Selkirk.

Among the 200 or more miners who crossed the pass in the spring of 1883 was a prospector named Dugan, who, with his party, was so well satisfied that he sent out to Juneau in the middle of the season for a year's supplies, intending to remain that time. His messenger made extravagant reports of placers yielding $150 a day to the man. A later party, again, told of gravel bars yielding $25 a day.[3] Several parties besides that of Dugan spent the witner of 1883 in the interior, among them being one on the Copper River, reported by Captain Carroll,[4] who failed to state whether they had found any good prospects.

In the fall of 1883 some miners brought into the town of Juneau, which was by that time a flourishing community, $1,000 of coarse gold, which they asserted came from the Yukon. This caused great excitement, especially as there were then at Juneau many miners who were out of work, owing to the recent abandonment of the Cassiar district in British Columbia, and was one of the causes of the rush of the following spring, when over 300 men crossed the summit.

The Cassiar district was, in a way, the training school for Yukon miners, and to the experience gained there the latter owe to a great extent their ability to cope with the natural disadvantages, for the conditions are similar in each. The early miners were obliged to enter the Cassiar field over a steep mountain trail more than 150 miles long, bringing all their provisions with them, and when they arrived had to contend against severe winters and short working seasons, in a country far from the base of supplies. Cassiar traditions, then, had great weight among the first miners of the Yukon, and Cassiar methods were followed; therefore it may not be out of place to give a short history of the growth and decline of the Cassiar[5] district.

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[1] Along Alaska's Great River, p. 190.

[2] Ibid., p. 203.

[3] Ann. Rept. Director U. S. Mint, 1883, p. 34.

[4] Alaska Coast Pilot, 1883, p. 200.

[5] Cassiar is a corruption of the name Kaska, applied to two tribes of Indians inhabiting this region.

The district lies in the drainage basin of the Liard and Dease rivers, in British Columbia. Dease Lake is situated at about the center, and the area is also considered to include the Stikine River. In 1799 the fur traders first discovered the Stikine River, which had not been recognized by Vancouver in 1793. In 1834 the Hudson Bay Company sent out a vessel with supplies for a post at its mouth, but were prevented from establishing the post by the Russians, who erected Fort Dionysius on the spot now occupied by Fort Wrangell; finally, however, in 1837, a compromise was arranged and the fort passed over to the possession of the English company with the lease of the "coast strip" of Alaska. Several times Fort Stikine, as the post had been renamed, suffered attacks from the Thlinkit Indians, once narrowly escaping destruction, but it was still held as a trading station for many years.

In 1861 two miners, Choquette and Carpenter, discovered gold on the bars of the Stikine. Excitement was great, mining parties were outfitted at Victoria, and river-bar placers began to be worked. Two years later a Russian expedition was sent to ascertain whether the mining operations were being carried on in Russian territory. Mr. W. P. Blake accompanied this expedition and embodied his observations in a report from which we have quoted above (p. 107).

In 1834 McLeod entered the upper Stikine near Dease Lake, having come overland from Mackenzie River. Afterwards Mr. R. Campbell, noted in the records of the Hudson Bay Company, wintered on Dease Lake, but the post established there being rendered unnecessary by the lease above mentioned and the consequent control of the fur trade from the mouth of the Stikine, it was abandoned in 1839. From that time until 1872, when Thibert and McCulloch discovered rich bars on the Liard, no white men entered the country. These two men were trappers who had come from the East and had wintered near Fort Halkett in 1871, where they found coarse gold and worked a bar known afterwards as McCulloch's bar. The next year they reached Dease Lake, and descending to the mining localities at which men were then at work, reported the news of gold discovery. In 1873–74 there was a rush to the country; production reached its highest point, a small town was built, and cattle were imported, but the supply of gold was not found sufficient for the support of any large number of people, and from year to year the product fell off, as is shown by the following table (p. 114).

Mining population and production of gold in the Cassiar district from 1874 to recent years.

Year.	Mining population.	Production of gold.
1874	2,000	$1,000,000
1875	800	830,000
1876	1,500	556,474
1877	*a* 1,200	499,830
1878	1,800	519,720
1879		405,200
1880		297,850
1881		198,900
1882		182,800
1883	1,000	119,000
1884		101,600
1885		50,600
1886		63,610
1887		60,485
1888		43,325
1893		22,935
1895		22,575

a One-third Chinese.

When the placer deposits had become exhausted it was found impracticable to work the auriferous quartz veins, on account of the great cost of importing machinery; so, in 1884, as has been said, the diggings were abandoned, only a few Chinese being left to work over the rich tailings. Dr. Dawson, writing in 1888 of the Stikine River, says: "Not more than $1 to $3 per day can now be got [from the river bars], and work has practically ceased." And since that time the decrease has been steady until now, when the district has no importance. The abandonment of the Cassiar region, then, gave an impetus to travel over the Chilkoot Pass, and during the year 1884 there was some mining on the Pelly and Teslin rivers, and on the former one party, it is said, took out $700 by bar washing. There were several other encouraging reports by prospectors and travelers in the interior that year. Among them was that of S. B. McLenegan, who was detailed for duty in the exploration of the Kowak River in 1884.[1]

He says: "In regard to the existence of gold in this region, there seems to be little doubt. In almost every stream, large and small, we found the color of gold." He refers to the prospecting of the Yukon, which had then but just begun, and, like Schiefflin, came to the conclusion that mining could never be successfully carried on, although

[1] Cruise of the United States Revenue Steamer *Corwin*, 1884, p. 107.

at the same time admitting that placer mining might be made remunerative if large deposits could be found.

In 1885 the rush to the interior continued. On Stewart River five parties prospected and worked placers on the river bars. All took out some gold, and good prospects were found, the best results, however, being those of one party of two men who worked for four months "rocking" on a bar about 100 miles from the mouth and succeeded in making $25,000. When this big find was reported an influx of miners occurred and much placer work was done on bars along the Upper Yukon. The more advanced stage of gulch mining had not been tried. The method followed was by rocking, the implement used being the same as the California cradle—a bottomless box set upon rockers and divided into three compartments. In the upper one the gravel was thrown and, by setting the rocker in motion, was sifted through a sheet-iron mesh into the lower compartment, in which a cloth caught the finer sand and gold and strained the water. The material thus collected was then taken out and panned with the ordinary hand gold pan. With slight variations this is the process still wherever bar placers are being worked.

With this primitive method of working, Stewart River was prospected for 200 miles from its mouth, and while no well-defined quartz ledges were found, placers were discovered that are estimated to have yielded $60,000; which, in addition to all other placers on the Yukon ($15,858.88), made the total for the Yukon country for the year $75,858.88.

The successes upon Stewart River were followed in the spring of 1886 by the discovery of Cassiar bar, 10 miles below the mouth of the Big Salmon River. Fifteen dollars per day per man was reported, and the output has been estimated at $20,000. Stewart River still continued to produce well, but in 1887 its yield decreased to $5,000, and the placers were almost deserted.

DISCOVERY OF FORTYMILE DISTRICT AND SUBSEQUENT HISTORY TO 1893.

The reason for the desertion of the Lewes River and Stewart River diggings was that late in the autumn of 1886 a miner named Franklin had discovered gold near the mouth of Shitando River, called Fortymile Creek by the miners, on account of its being 40 miles below the old Hudson Bay Post, Fort Reliance. As soon as the news was reported a stampede followed; the center of population was transferred and the camp of Fortymile was founded. In anticipation of the great rush that would follow the announcement of the discovery in the spring, it was thought best to send a letter to Mr. McQuesten, the agent of the Alaska Commercial Company, who was wintering in San Francisco, asking for an increased shipment of supplies to meet the increased demand; and, although it was the middle of winter, one George Wil-

liams volunteered to carry this letter over the Chilkoot Pass. Williams had been a river captain and knew nothing whatever about winter traveling; but, although his friends tried to dissuade him from the attempt, he persevered, and with one Indian accomplished the trip, one of the most dangerous ever made in Alaska. He had many accidents, owing to his inexperience, and when finally he was nearly at the end of his journey a blizzard arose, which prevented him from crossing the summit. He was therefore obliged to build a snow hut and live there until threatened starvation forced him to cross the pass, although the storm was still raging. At the summit his strength gave out and he was carried to Sheep Camp on the Indian guide's back. There they met some Chilkat Indians, who sledded him the rest of the way to Taiya, where he died from the effects of the exposure a few days later. The letter, however, was delivered and sent to McQuesten.

In the latter part of 1887 Franklin Gulch was struck and named in honor of the discoverer of Fortymile. Cabins were built, work was begun, and during the first year the creek is estimated to have produced $4,000. Ever since it has been a constant "payer." The character of the gold found here is nuggety, masses of $5 weight being very common; and Franklin Gulch has the reputation of having produced the two largest nuggets in the Yukon, one worth $500 and the other $239. The first was found by Conrad Dahl in 1894. The discovery and working of Franklin Gulch marks an advance from the primitive bar working to the gulch diggings, in which sluice boxes are used, and the current of the stream is made to perform most of the work. However, bars were still worked all along Fortymile, and the product therefrom forms a large proportion of the total.

The yield the first year after the discovery of Fortymile has been variously estimated at from $75,000 to $150,000 but $60,000, given in the table, probably covers the production.

The discovery of Davis Creek and a stampede from Franklin Gulch followed in the spring of 1888. The finding of other creeks and the wholesale working of river bars probably increased the yield by at least $15,000. Data for 1888 and 1889 are, however, lacking. At the time reports were extravagant, but in retrospect it seems that the amount given in the table is not far from right.

In 1889 Poker Creek and the headwaters of Walker Fork were staked out in claims, but while there has been some placer working on the latter stream ever since, it was not until last spring that the claims of Poker Creek were worked.

The first estimate of the production of the Yukon placers appears in the report of the Director of the Mint for 1890. It is placed at $50,000, which is in all probability too small a figure. In the report of the governor of Alaska for the following year it is said that the Yukon placers produced one-third more than in any other year.

In 1891 Dr. C. W. Hayes, who went down the Lewes to Fort Selkirk

and crossed up the White River to the Copper, reports that 10 men were at work on river bars. Apparently the days of the river bars were passed. On Cassiar Bar 4 or 5 men were not producing much. On the other hand, the reports from Fortymile were very encouraging. On the ocean trip back to Seattle several miners brought with them about $900 apiece. Two new creeks were struck in this and the succeeding year.

According to an estimate by the governor of Alaska, based on conversation with miners who had come out and reported great richness, the product of the Yukon district was $275,000. We have taken the mint estimate, showing double the output of 1890, as being the more conservative of the two, although this, on the other hand, is probably too low. Certain it is that in this year gold mining in the interior, as well as on the coast, at Silver Bow basin and Treadwell, received a great impetus.

The event of 1892 was the discovery of Miller Creek by O. C. Miller, a noted prospector in the Yukon country. It had been prospected a great deal before, but had always been given up because the gravel was so deep that the labor involved in stripping made it unprofitable working. In the first year of actual work, however, one claim is said to have yielded $30,000. In the spring of 1893 many new claims were staked, and it is estimated that 80 men took out $100,000. Since that time Miller Creek has been the heaviest producer of the Fortymile district, and, until recently, of the whole Yukon. Its entire length lies in British possessions.

About the same time Glacier Creek, which lies next to the north of Miller Creek, also in British territory, was discovered. Its product was probably not great during that year, the same difficulty of deep gravel obtaining there as upon the former. The total output of the Yukon placers for 1892 shows an increase of $10,000 over 1891.

In the spring of 1893 the reported richness of the interior caused a rush of miners, over 300 men being employed in the Fortymile district alone, and a result of this increase in population was that prospecting was more vigorously undertaken. Many parties made long trips of discovery, and among these was one in which were such men as O. C. Miller, Langford, Sinclair, and Mynook, all noted pioneers, who prospected the Koyukuk River for many hundred miles from its mouth and brought back favorable reports.

An estimate of the output is given in the report of the Director of the Mint, as follows (p. 118), all the gulches and creeks named being in American territory, with the exception of Miller Creek.

Mining population and gold production of Alaskan creeks in 1893.

	Mining population.	Product.
Fortymile	35	$25,000
Nugget Gulch	3	1,500
Franklin Gulch	40	35,000
Davis Creek	35	30,000
Miller Creek	80	100,000
Bettle's Mine	(?)	2,500
Gold Hill Mine *a*		
Pilker Gulch	3	4,000
Total	196	198,000

a Not worked.

DISCOVERY OF BIRCH CREEK DISTRICT AND SUBSEQUENT HISTORY TO 1897.

In the summer of 1893 Pitka and Sorresco, Russian half-breeds who had formerly worked in the diggings on Fortymile Creek, reported the finding of gold on Birch Creek. At the time that the news was received at Fortymile Post there were many discouraged miners to whom the possibilities of a new district offered chances to retrieve their fortunes. Many of them did not have enough money to buy outfits for any new ventures, but the difficulty was obviated by the generous action of Mr. McQuesten, who offered the goods then in the warehouse to outfit all who cared to make a trial in the new district. Eighty men took advantage of his offer and, proceeding down the river, built cabins at a point on the Yukon 12 miles above the present site of the town, called the settlement Circle City, from its proximity to the Arctic Circle, and wintered there. During the ice jam in the breaking up of the river that spring the ponded water overflowed its banks and swept away a few cabins; so, warned by this accident, the inhabitants moved farther down the river to a little higher ground and built the new town of Circle City in its present situation at the head of the Yukon Flats.

In the early spring the prospectors had crossed the old Indian trail over Medicine Lake to the head of Birch Creek, had discovered and staked claims on Mastodon, Hog'em, Miller, Greenhorn, and Independence creeks. It was soon seen that Birch Creek was a paying district, and that there was room for a large number of miners; consequently almost all of the newcomers went to the new camp; the branches and gulches of Birch Creek were traveled by prospectors, and Circle City became the most important settlement in the interior.

In the Fortymile district the best producer was still Miller Creek; Franklin Gulch and Napoleon Creek were making good yields; Glacier

Creek was bidding fair to equal Miller; Gold and Bedrock creeks had also been prospected but pronounced unsatisfactory, and the bars on the main creek and the river, while not by any means worked out, had fallen off in production. In the meantime the Koyukuk was being prospected to some extent, and $30,000 worth of gold is said to have been taken out and shipped from Tanana trading post, at the mouth of the Tanana River.

The total amount produced by the Yukon placers in 1894 was double that of the year before, and was divided between the two larger districts as follows:

Fortymile	$400,000
Birch Creek	9,000
Total	409,000

With the gold from the placers was brought out $490.36 in silver.

In 1895 the output had doubled again. Birch Creek discoveries on Mastodon, Miller, and Hog'em creeks were paying well. Eagle Creek was opened up and work begun, showing the prettiest gold on the Yukon. Harrison Creek was prospected from end to end during the winter, and a little prospecting was also done on Porcupine Creek, where a result of 10 cents to the pan was obtained. Beaver Creek, which flows into the Yukon 150 miles below Circle City, was examined, and a few men took out some gold from Preacher Creek.

The center of the mining population had by this time been transferred from Fortymile to Circle City; for, as estimated by the statistician at San Francisco, the population of Fortymile was 600; of Circle City, 700. Birch Creek had also become the more important producer, although the older creeks on Fortymile were paying well.

MISSION CREEK.

About this time gold was discovered about 70 miles below Fortymile Post, in the drainage area of Mission Creek (so called because an old mission is located just above its mouth). Mission Creek is a considerable stream flowing in a general easterly direction; 2 miles from its mouth American Creek comes in from the south, and it is upon the latter creek that all the claims are located. At the time of visit there were 25 men at work 12 miles from the mouth.

Output of the Yukon placers in 1895.

District.	Population.	Product.
Fortymile	600	$300,000
Birch Creek	700	400,000
Koyukuk	30	8,000
Beaver Creek	10	1,000
Total	1,340	709,000

All other placers in Alaska, outside of the Yukon, produced in 1895 $69,689.54.

MYNOOK CREEK.

One of the latest developments is Mynook Creek, so called from its discoverer, John Mynook. It is situated in the Lower Ramparts, 60 to 70 miles above the mouth of the Tanana. Its original Indian name is Klanarkakat, meaning "creek suitable for small boats," and so it appears on the older maps of the region. Inasmuch, however, as the names in common use by the miners and traders of the country are certain to supersede those given by the natives, we have used the latter nomenclature in all cases. The creek rises in the high mountains forming the Tanana divide, and flows in a general northward direction. Four miles from its junction with the Yukon comes in Hunter Creek, 30 miles long, which rises near the head of Mynook Creek proper, and flows first north, then bends westward around the head of Little Mynook, another branch of the main creek. Still another large branch, about 20 miles long, enters from the southwest, 10 miles above Little Mynook. On the United States Coast and Geodetic Survey map the name Whymper River, given by Schwatka to the stream next north of Klanarkakat appears. The native name is Yukutchkakat, meaning "big shallow creek," but later it has come to be known by the name of Mike Hess Creek, or Hess River, in honor of a pioneer miner, who did much for the development of the country, died in 1892, and is buried at Fortymile. Hess River, then, and Mynook Creek, are probably the streams referred to above as having been prospected by the Schiefflin Brothers as early as 1882.

Late in the spring of 1893 John Mynook, a half breed, prospected on Mynook, Hess, and Tanana waters, and found coarse gold. About the same time O. C. Miller prospected Hess Creek and did a little mining in a gulch near its head, but it was not until the spring of 1896 that active mining was begun. Several claims were located at that time, and work was begun on two of them.

Mynook Creek is the only one in the country upon which Indian labor is employed, for it is the general experience that the Indian is not worth much as a miner or prospector. He lacks the perseverance and steadfastness of purpose which sustains the white man under difficulties and reverses; even when successful he has not the necessary ambition; and however willing he may be, as soon as he gets a little money he will stop work and spend his entire fortune, with no thought of to-morrow. For this reason, therefore, having been tried in different parts of the country, Indians have been given up as unreliable. On Mynook Creek an Indian staked out a claim last spring, but was not allowed to hold it, on the ground that it is illegal for a native to own mining land. As far as we were able to observe, the Indians

bore no ill will toward the usurpers, but rather took it as a matter of course that the white man should take possession.

In 1895–96 much new ground was prospected in the Lower Ramparts. Mynook and others, having examined the Hess River country and the Tanana waters, reported fine gold on all the streams that head in the Tanana hills, but little coarse gold, 5 cents per pan being about the best prospect. On the Koyukuk there were several men who stayed on until the summer. Another party of three men started from Circle City in the late winter, crossed the mountains near the head of Crooked Creek, reached the Tanana 200 miles from its mouth, and having built boats, floated down to the Yukon. Along the way they prospected side streams and gulches, but found nothing much.

CONDITION OF FORTYMILE DISTRICT.

The condition of the Fortymile district in the summer of 1896 was not so good as formerly. It looks very much as if it had seen its best days, and unless several new creeks are discovered it will lose its old position. Chicken Creek, discovered in the spring of 1896, caused a sensation for a time, but in the end more men left Fortymile than came into it during the summer. John Müller's big strike undoubtedly served to retain claim owners on Miller Creek, but, on the whole, the exodus to American Creek and the Birch Creek diggings was very noticeable. On Glacier and Gold creeks about 100 men were working. The district was particularly unfortunate in the long drought which lasted for six weeks. In almost all of the gulches there was not enough water to run the sluices, and the men were forced to idleness. For bar working a low stage of water is the most favorable, but, as has been said before, the bars are nearly worked out, very few yielding over $8 a day, which, at the prevailing prices, would entail a loss. In all there are probably 35 men at work on the bars.

CONDITION OF BIRCH CREEK DISTRICT.

In the summer of 1896 the Birch Creek district, partly owing to the fact that on the whole lower river considerable rain fell during the spring and summer, was in a flourishing condition, and formed a contrast to that of Fortymile. Most of the gulches were running, miners were working on double shifts, night and day, and many large profits were reported. On Mastodon Creek over 300 miners were at work, many of them expecting to winter in the gulch. Thirty-six claims of 500 feet front were being worked, the most important being the Discovery, one-half mile from the mouth, where 20 men were shoveling in, in double shifts.

But while Mastodon, one of the first-discovered creeks, has heretofore been the best producer, it is thought that the comparatively new creeks, Eagle and Harrison, will in a short time become more impor-

tant. From time to time, too, new creeks are discovered in this district, the latest being Carter or Butte Creek, which is one of the tributaries of the main Birch Creek. It rises about 10 miles southeast of Mastodon Dome, and is 10 to 15 miles in length. The first rumors started 30 men across the mountains in August, 1896, and they staked most of its length; but, according to one man who returned to Harrison after the first rush, its richness has been greatly exaggerated.

PROPOSED HYDRAULICKING.

On Mammoth Creek little work has been done. A short distance below the mouth of Mastodon, on the right-hand side, the pay has been followed under a heavy depth of gravel, but the breadth of the valley lower down prevents its location. Bars have been washed for gold on the meanders of this creek, and $4 to $5 a day made. With the slow method of rocking and the existing high price of the necessities of life, this return would not be profitable, but it is thought that much of the ground now too poor to work might give good returns with the use of some method of wholesale stripping and washing. Some of the miners have planned to work this and other good ground which is supposed to exist under the deep covering of moss and gravel in the wide valley of Mammoth and Crooked creeks by hydraulicking, the water to be obtained by tapping Miller or Mastodon Creek near the head. They realize, however, that it will be several years before their scheme can be put into operation, because at present both of the gulches are paying well, and they will continue to do so for the next five years at least. About that time the placer claims will be worked out, and it is thought that then owners will have no objection to any usage of the water.

There are several disadvantages which may render this scheme impracticable. First and foremost is the high cost of all the necessary implements and materials. Again, it has been found by experience that a constant supply of water is necessary to the success of hydraulic operations, and in this region the amount is far from constant. For almost eight months in the year it is nothing, and for a period from the middle of May to the middle of June, the season of floods attendant upon the melting of ice, it is at a maximum that sometimes causes inconvenience. From June until the freezing, late in September, the amount is variable, generally diminishing gradually, and late in the summer there is little running water in some of the gulches. One of the results of the inconstancy of the water supply would be the damaging of the flumes, for boxes that are full at one time and empty at another soon go to pieces. The snow is not deep, nor is there much wind, so that the damage by drifting can be disregarded; however, that by freezing would be considerable. Two other factors are to be considered—the head fall of the stream and the possibility of disposing of the tailings. To calculate the first exactly requires an accurate topographic survey and a series of levels from

the reservoir to the outlet. We have not made such a survey, and our aneroid elevations must be taken merely as an approximation to the truth. From them, however, we would say that there is available an 800-foot fall in 8 miles on either Miller or Mastodon, or 100 feet to the mile, taking as a starting point the highest position in which a dam restraining any quantity or constancy of water could be built. Such a head of water would give sufficient pressure, amounting, as it does, to something over 600 pounds per square inch, for in hydraulicking in California often only 100 to 450 pounds per square inch are used.

As regards the disposition of tailings, there is apparently no reason why they could not be run off into Crooked Creek. This stream has considerable volume and velocity at the mouth of Mammoth, and from this point to its mouth there is an average grade of 37 feet per mile, sufficient to carry off an immense amount of refuse.

It has been erroneously stated in one of the late mint reports that hydraulicking with small hose has been employed in several localities. At no district visited by us was there a hose in use, nor could we learn of there ever having been any. The miner's implements are always the simplest, consisting generally of a hand gold pan, spade, whipsaw, and ax. These, with his blankets, provisions, and enough money for a year ahead, constitute the sum total of his capital. In fact, it is a well-worn saying that Alaska is "a poor man's country," almost no capital having been invested up to this time; but if this plan should be successfully carried through, the application of hydraulics to other portions of the country would give the industry of placer mining greater permanence and stability.

THE UPPER YUKON.

On the Upper Yukon and on Lewes River, territory properly out of the scope of this report, the old rock piles and a few ruined cabins are still to be seen on the site of the Cassiar Bar excitement, but all the bar workings are deserted, the gulch diggings lower down being more attractive.

At the mouth of Stewart River a few miners were in camp preparatory to a trip up the river. It is thought that Stewart River has not been given a fair chance since the first year of the excitement. Just at the time when good gulches might have been discovered came the reports from Fortymile, which drew all the miners away. It is known that for 200 miles from the mouth the bars contain quantities of gold, and for this reason it is the general opinion of the miners that more systematic prospecting should be done along both branches of this stream. It is very probable, indeed, that many parties will winter there this year for that purpose.

KLONDIKE DISTRICT.

The latest excitement in the country occurred during the latter part of August, 1896, when it was reported at Fortymile that rich placers

had been discovered upon the waters of Klondike River. Klondike, a miner's corruption of the Indian name Thronduik ("water full of fish"), enters the Yukon 45 miles below the mouth of Sixtymile and 15 above the old Fort Reliance. Upon the Coast Survey chart it is given as Reindeer River, but no one except Schwatka, who christened it in 1883, has ever known it by that name. On a bar at its mouth was located an Indian fishing village of perhaps 100 population during the salmon season, for, as its name signifies, it has long been a favorite fishing ground for the Indians, but until late years it has not been invaded by the miners. With the announcement of gold there was a genuine stampede to the new region, so that, while in the winter of 1896–97, Fortymile was almost deserted, it is estimated that 350 men spent the winter on the Klondike, in the gulches, and at the new town of Dawson, established on the banks of the Yukon at its mouth. Messrs. Harper and Joseph Ladue, traders at Fort Selkirk and Sixtymile, are the founders of the new camp, which is expected to rival the older settlements.

The district properly includes Klondike River, with its main branch, Bonanza, which is 24 miles long and enters the Klondike 3 miles from its mouth; Hunker Creek, flowing into the main creek not far from the mouth; and the drainage of Indian Creek (native, "Sugachuk"). Kettlesons Fork rises in a mountain divide opposite the head of Bonanza Creek and flows into Quartz Creek, which is described as being a very long branch of Indian Creek. At least 10 miles below Kettlesons Fork, Phil Creek comes in from the east, and still farther down, perhaps 4 miles, the main Indian Creek is met with, and 5 miles up this is Cultus Creek. But the more important parts of the district are, at present, upon Bonanza and Hunker creeks. Upon the former the discovery was made, and $1,000 was taken out in August and September, 1896. Since that time, according to last information, 400 claims had been located to January, 1897, and about half as many upon Hunker Creek, and the indications at the time of writing are that there will be a great increase in population in 1897–98. But there appears to be plenty of room for many more prospectors and miners, for although it is difficult to state the area of the new field from data at hand, it is not far wrong to say that gulches and creeks which have shown good prospects are spread over an area of 700 square miles.

An estimate of the gold production for 1896, which appeared in the Alaska Mining Record for January, 1897 (Juneau, Alaska; editor, G. B. Swinehart), follows:

Alaska Mining Record's estimate of Alaskan gold production in 1896.

Birch Creek	$1,300,000
Other districts	800,000
Total	2,100,000
All other placers outside of the Yukon	215,000
Cook Inlet placers, included in the last	175,000

Our own estimate is also here given:

Authors' estimate of Alaskan gold production in 1896.

District.	Population.	Output.
Fortymile	700	$460,000
American Creek	35	15,000
Birch Creek	900	900,000
Mynook Creek	25	10,000
Koyukuk River	25	5,000
Other districts	75	10,000
Total	1,760	1,400,000

While much more conservative than the former, this, too, is greatly in excess of the figures given by the Director of the United States Mint, for several reasons. One is, that $1,400,000 represents not only the product of Alaska proper, but the added output of British creeks; another is, that while the figures given below are compiled from the returns of bullion which has found its way to market, our figures express the amount actually turned out.

The estimate furnished by Charles G. Yale, statistician at San Francisco, is as follows:

Charles G. Yale's estimate of Alaskan gold production in 1896.

Birch Creek	$600,000
Other creeks	200,000
Yukon River total	800,000
Cook Inlet placers	120,000
Total production of Alaska	2,861,306.61

This last total has been further corrected by the Director of the Mint to $2,014,263.

DIFFICULTIES OF DEVELOPMENT.

The difficulties in the way of speedy development of the country are many. First and foremost is the climate—the short summer season, during which work can be done, and the long, cold winters. The ice breaks up in the interior about the middle of May, and by the 1st of June, the flood season having passed, the miners are at work. Winter comes on again about the last of September; the ground freezes, the creeks and rivers stop running, and under old methods very little work could be done. At present, however, in a great number of gulches, especially where the gravel is deep and timber plentiful, the process of mining by burning and drifting is employed to advantage. The frozen ground is thawed by fires built upon the surface, shafts are sunk until the pay streak is struck, when the rich gravel is taken out and laid by until the spring.

Prospectors have also found it advantageous to make their search for favorable localities at the time when the frozen ground renders traveling through the swampy, moss-covered country easier, and for this reason, more and more every year, prospecting is done in the winter. The claims are thus located and the miner is ready to begin work with the first spring thaw. Frosts are frequent during the summer, and it is stated that in the winter the temperature has often fallen as low as —76° F. in the vicinity of Fortymile. It is easily seen, therefore, that, in spite of the richness of the soil, the Yukon district can with difficulty become an important vegetable-producing country. Root crops have been tried with encouraging results in many localities, especially at Fort Selkirk, where last year potatoes of a pound weight were raised. A small garden near Cone Hill on Fortymile Creek also produced a good crop of cabbages and turnips, and at missions on the lower river turnips of great size were seen. However, there is always an uncertainty in the crop. To insure it against freezing it must be blanketed many nights during the year, and in this country the high price of even the commonest, cheapest kind of drilling precludes the protecting of areas large enough to produce crops sufficient to sustain even this small population through the long winter.

The introduction of beeves has been tried on a small scale, but it is a question whether great numbers could be provided for. In the swamps about Circle City grass grows to the height of 3 or 4 feet in summer time and makes excellent hay. All other feed must come in by way of the mouth of the river, and in small quantities at that.

It is seen, therefore, that whatever Alaska may be in the future it is not now self-supporting from an agricultural point of view. Moose, caribou, and hare vary in quantity, one year abounding, and again disappearing from the region for twelve months at a time.

The high cost of living has been referred to before. Because of the great distance which all supplies must be brought (over 4,000 miles by ocean and river) and on account of the risk involved in carrying such great distances and in such dangerous seas, even the commonest necessity of life sells at the point of delivery at a price that would seem ridiculously high in the States and which is maintained at the highest point by the almost entire absence of competition in trade. As a slight compensation the rate of wages is much higher than in any other part of the continent, $10 a day being the general wages, and in some of the more remote gulches $12 a day of ten hours. In winter the price for labor is $5 to $8 per day of six hours. But this compensation is only partial, for often the delivery of provisions is delayed by some accident, and the miners, entirely dependent upon the outside world 4,000 miles away, must either leave the country or must stop working long enough to replenish their stock of provisions by hunting. The loss from this cause is often appreciable. Many

times the miners have been at the point of starvation, and there is hardly a winter when they are not put on rations—so many pounds of bacon and so much flour to the man.

The almost entire lack of division of labor is also detrimental to progress. At present a man must not only be miner, but house-builder, carpenter, and cook. To a great extent this is due to the absence of invested capital, which has been alluded to above, but it is being remedied by the immigration of laborers attracted by the high wages of the country.

GOVERNMENT.

MINERS' MEETING.

The miners' meeting is the only government in the interior of Alaska, but it appears nearly to have outlived its usefulness, and with the growth of the country and the introduction of a class of nonproducing adventurers, attracted by the hope of making fortunes at the expense of the producers, it is fast becoming a mockery. The better class of miners have already objected to having disputes occurring in the gulches settled in town, for the greater preponderance of the disreputable class in the latter makes it almost impossible to obtain justice there. Again, while perfectly well intentioned, the miners are often not the ones best fitted to decide cases impartially.

The powers of the miners' meeting are threefold—legislative, judicial, and executive. No provision is made for a governing officer, the whole fabric resting on the great American principle, "majority rules." Universal suffrage is given, and all have an equal vote. The method of procedure is as follows: If a man has a grievance, he posts a notice to that effect and calls a meeting for a certain date. At the appointed time the miners of the locality assemble, generally in the open air, and a moderator from their number is appointed. Then the prosecutor presents his case; the defendant answers. There is cross-questioning, speeches pro and con are made, and in the end someone puts a motion, which is either carried or defeated. If carried, the penalty is imposed without delay. As expressed by one who thought he had been wronged by one of these meetings, "The man who puts his motion first wins." However, sometimes now, and generally in the early days, the decisions have been remarkable for their rigorous justness. Some of the penalties are: For stealing, banishment from the country. Even if it is the dead of winter, the culprit is given enough provisions and put on a sledge and started on his way. In some parts of the country the additional punishment of whipping at the post is inflicted. Stealing has been remarkably infrequent. For threatening with weapons the punishment is the same. There have been no murders in the country, but for the offense death by hanging is the penalty provided. Gambling is a legitimate amusement, and has no place in the catalogue of misdemeanors.

MINING LAWS.

The mining laws as established by the miners are slightly different from those of the United States or Canada; in fact, they differ for different gulches. Generally the claim is 500 feet for gulch diggings, from rimrock to rimrock, but in some gulches that do not pay well enough with small diggings an effort is being made to stake claims 1,320 feet long. On the other hand, creeks which are becoming crowded are staked 300 feet to the claim. No one man is allowed to stake more than one claim in his own name, with the exception of the discoverer, who is allowed 1,000 feet instead of 500. If more than one miner made the discovery, still only the amount of an extra claim is given to the discovery claim.

The only officer in the republic of miners is the recorder (one in each gulch or creek), who is appointed by popular vote. He is without executive powers, his duties consisting in recording the names of claimants and the locations of their claims, for which he receives a fee established for the particular gulch in which he holds office. The amount generally received is $2 for every claim registered, although in some localities it is as high as $5. Sales of claims are also recorded with this officer, who collects a fee therefor, but here his duties end, or, rather, beyond this point they are not well defined. It has been maintained by some that he has the right to refuse to record claims if, in his judgment, to record them would work injustice to another claimant, while others say that the power of deciding the question of ownership between different parties belongs entirely to the miners' meeting. In the latter case it is obviously the duty of the recorder to inform the prospective victim of a claim-jumping scheme; nevertheless, he must make a record of all notices of occupancy.

The law provides that for the month of July the miner must do "assessment work," as it is called, and failing this, the claim is once more thrown on the market. In case a miner is prevented from doing this work himself, his title may be held good by proxy. So it happens very often, when a man goes out of the country for the winter, that he hires some man to take his place on the claim during the assessment month.

These are the placer laws as applied in the American territory. Those which are beginning to be enforced on the British side of the line and are crowding out the ones formulated by the miners are the regulations already in force in other parts of Canada and British Columbia. The laws governing quartz claims in all parts of the Territory are the same as the quartz-mining laws in the States.

It will be seen that we have here a society in the first stages of formation. Up to this time the people have governed themselves and have done so very well, but there will come a time, and it is not so far distant, when the need for better government will be felt.

Canada has appreciated this need, and has stationed a garrison at Fort Cudahy to maintain law and order in her territory. On the American side the miners still frame their own laws. Two customs inspectors are stationed at Circle City, but they are the only representatives of the United States in the interior. With closer connection with the home Government, through some civil or military representative, the better protection would have an important economic effect.

POPULATION.

The inhabitants of the Yukon district and Alaska may be divided into three classes: First, the natives; second, the employees of the two trading companies, and third, the miners. With the first and second classes we have little to do, since our interest is mainly in the producers of gold; nor shall we attempt to make any estimate of the number of people now engaged in mining along the coast. According to Bishop Bompass, in charge of the Church of England missions in the Yukon district for the last twenty-eight years, the Indian population of Alaska is not over 10,000. The Indians subsist by hunting and fishing, and are only just beginning to learn the value of the precious metals. The members of the two companies which trade with the natives and furnish supplies to the miners in the gold districts number in the neighborhood of 200.

The other class, the miners, is of a transient character, including but few who intend to stay all their lives in the country; in fact, it may be said that every man expects to return to civilization sooner or later. Of those who do stay from one year to the next it is nearly impossible to make an estimate, on account of their wandering habits, which lead them sometimes hundreds of miles from the mining camps, so that they may not be heard from for many months. Again, the mining camps now established are not by any means stable. One year the center of population may be at one point, and the next, because of some rumor of rich finds, it is transferred to an entirely new region.

Nor can an exact estimate be made of the number of men that come in every year, for of those who cross the Chilkoot Pass and float down the river a large number stop at Fortymile Post only long enough to exchange greetings with those on shore. It may be that they stay also a few days in Circle City. They then either float down to St. Michael in small boats or take the river boat out of the country.

It is impossible, therefore, to make anything more than a rough estimate of the number of miners who are comparatively fixed, and it should be borne in mind that even in a few days the distribution may be entirely changed. The table on page 132 shows the number of workers from year to year, and an attempt has been made to distinguish between those wintering in the British territory and those on the United States side of the boundary line.

PRODUCTION.

In compiling the statistics given below (p. 132), the estimates of the product of gold and silver of Alaska and the output of the Yukon placers given in the annual reports of the Director of the United States Mint have been followed, except where otherwise stated. These are based on the amount of gold turned in at the mint at San Francisco, which amount is compared with the returns from smelters and refiners all over the country; so that in the case of organized companies, such as the Treadwell mine on Douglas Island and other large corporations, the stated output is very nearly correct.

But in the case of the Yukon placers several factors modify the accuracy of the mint returns. Some of the miners upon returning from the gold fields place their gold in the mint directly or with the refiners who make returns to the San Francisco mint; others, however, go East or South, and their gold is not turned in for some time. Again, it is stated that a certain amount of bullion, probably very large, is shipped abroad direct without ever being deposited in any mint in the United States. Furthermore, much gold remains in Alaska for many years after its production. Taking all these facts into consideration, we think it conservative to add one-third of the total as given in the table in order to complete the actual production of the Yukon placers up to 1897.

The corrected figures will then be approximately $13,067,813 for all Alaska, and $3,310,500 for the Yukon placers. These figures represent the product of Alaska alone, and do not include that from gulches, creeks, and bars in British territory.

In the first part of the table, from the year 1880 to 1886, a small part of the production of the Yukon was from American soil, but no returns having been made, I have considered the total as having come from the Northwest Territory.

From 1880 to 1883 the Yukon output altogether was unimportant; but with the discoveries upon Stewart River in the latter year (although, as has been said above, placers had been worked on the Big Salmon River prior to that) production really began, and since then the growth has continued from year to year with scarcely any falling off.

With the discovery of Fortymile in 1886, Alaska began to be important, and the production was about evenly divided between the two countries. For the next four years there may have been a slight decrease, although, from information derived from miners who were in the country at that time, I have made the estimates for 1887, 1888, and 1889 about the same. Unfortunately, however, the data are not very accurate for this period. In the report of the Director of the Mint for 1888 no estimate of the Yukon output was given. In 1889 the

statistician at San Francisco says, in the annual report, that the production of all mines in the Territory, outside of Douglas Island and Juneau, was $300,000. No estimate of the Yukon placers appears, but in the report of the governor of Alaska for that year, including also 1888, it is said that "several parties have returned from the Yukon placer fields, who report limited results, owing to floods, high water, stress of weather, and various accidents." One of the accidents referred to here was probably the delay of the river boat in reaching Fortymile with provisions. The men in the diggings were starved out, and in the first week in October, 1889, there was a general exodus down the river. Nearly a hundred men left the post in small boats, some going all the way down to St. Michael at the mouth, others stopping and wintering at Indian camps or trading posts on the way, wherever food was plentiful. Fortunately the river did not freeze as early as usual that winter, so that there was little actual suffering in the trip, although the journey on the lower river was made in running ice. This winter of 1889–90, known in the annals of the country as "starvation winter," had the effect of reducing the product by reducing the number of producers, and this reduction was felt mainly in the spring of 1890, before the population, decreased by the exodus of the preceding fall, had been replenished by new arrivals.

Since 1890 the increase in production has been rapid, doubling nearly every year the production of the year before. In the report for 1894 Birch Creek showed as a producer for the first time. Its output was not great, only $9,000, but in 1895 it almost equaled that of Fortymile, and in 1896 it far exceeded it.

Production of gold and silver in Alaska.

Year.	Production of gold.	Rank among States and Territories.	Production of silver.	Rank of production of silver.	Rank in both precious metals.	Amount of output from Yukon placers, all gold.	Per cent of gold from the Yukon in Alaska.	Number of Yukon miners.
1880	$6,000	0	$0.00	0	0	$0.00	0	(?)
1881	15,000	14	144.30	0	15	0.00	0	(?)
1882	150,000	12	0.00	0	12	Small.	0	50
1883	300,000	9	0.00	0	10	*a* 1,000.00	.....	50
1884	200,000	10	0.00	0	11	Unknown.	.....	75
1885	282,000	9	2,000.00	11	11	*b* 25,000.00	.....	75
1886	446,600	9	2,000.00	14	11	*b* 75,858.88	.....	200
1887	675,000	9	300.00	.....	11	*c*30,000.00 30,000.00	4	200 50
1888	850,000	8	3,000.00	10	9	40,000.00 35,000.00	4	100 150
1889	900,000	9	10,343.00	14	11	35,000.00 40,000.00	4	150 125
1890	762,500	9	9,697.00	14	11	50,000.00	7	150 150
1891	900,000	10	10,343.00	14	11	100,000.00	11	200 150
1892	1,000,000	9	10,343.00	14	11	110,000.00	11	225 175
1893	1,010,100	9	10,860.00	14	11	200,000.00	20	500 200
1894	1,113,550	9	28,782.00	12	11	409,000.00	37	400 600
1895	1,615,300	7	86,880.00	12	9	709,000.00	44	600 800
1896	2,014,263	.....	45,798.72	.....	.....	800,000.00	39	700 1,000
Total	12,240,313	.....	220,491.02	.....	.....	*d*2,483,000.00	.....	.....
Cor'ct'd	827,500	.....	.....	.....	.....	827,500.00	.....	.....
	13,067,813	.....	.....	.....	.....	3,310,500.00	25	.....

a E. R. Scidmore.
b G. M. Dawson.
c In bracketed figures the upper set refers to British territory; the lower to Alaska.
d Total output from American territory only since 1886.

For the purpose of comparison we give the table of the production of British Columbia from 1858 to 1895, taken from the Annual Report of the Minister of Mines, 1895:

Output of gold and silver of British Columbia from 1858 to 1895.

Year.	Gold and silver, total.	Number of miners.	Yield per man.
1858	$520,353	3,000	$173
1859	1,615,072	4,000	403
1860	2,228,547	4,400	506
1861	2,666,119	4,200	634
1862	4,246,266	4,100	517
1863		4,400	482
1864	3,735,851	4,400	849
1865	3,491,205	4,294	813
1866	2,662,107	2,982	893
1867	2,480,868	3,044	814
1868	2,372,972	2,390	992
1869	1,774,179	2,369	749
1870	1,336,956	2,348	569
1871	1,799,440	2,450	734
1872	1,610,792	2,400	671
1873	1,375,409	2,300	567
1874	1,844,619	2,868	643
1875	2,474,904	2,024	1,222
1876	1,786,648	2,282	783
1877	1,608,181	1,960	820
1878	1,275,204	1,883	677
1879	1,290,059	2,124	607
1880	1,013,827	1,955	518
1881	1,046,737	1,898	551
1882	954,085	1,738	548
1883	794,252	1,965	404
1884	735,965	1,858	396
1885	713,738	2,902	246
1886	903,652	3,147	287
1887	694,709	2,342	296
1888	616,731	2,007	307
1889	636,796	1,929	330
1890	568,419	1,342	423
1891	429,811	1,199	358
1892	399,526	1,340	298
1893	379,535	1,247	304
1864	464,566	1,610	283
1895	636,545	2,030	313
Total	55,115,965		

CHAPTER II.

THE GEOLOGICAL COLUMN.

THE BASAL GRANITE.

The oldest rock formation found in the Yukon gold district is granite. Only in the Fortymile district has this rock been studied in any detail; for in the other gold-mining districts which were carefully examined it does not appear to be exposed, and in the regions which were more hastily passed over there was not sufficient opportunity to separate it clearly from other granite which occurs in the same areas, but which is clearly younger and of intrusive origin.

On the Miller Creek trail, which leads from Fortymile Creek to the diggings on Miller and Glacier creeks, there is exposed, nearly midway between the ends of the trail, a zone of granite about 6 miles wide. This rock is sometimes massive, but usually has a gneissic or schistose structure, and occasionally is altered into mica-schists; the less altered portions, when fresh, are of a gray color and contain porphyritic crystals of feldspar, which in the more schistose zones become lenticular bodies or eyes. In the slightly weathered rock the color changes to a red or brown, which is characteristic of most surface outcrops. Quartz veins, generally of limited length, or of the nature of gash veins, are frequent; they usually conform in strike and dip to the schistose structure of the granite.

MICROSCOPIC DESCRIPTION.

Under the microscope the rock shows the original hypidiomorphic granular structure of granite, but this has been much defaced by crushing. From the effects of this crushing the brittle minerals are broken and elongated, and the flexible minerals, such as mica, are bent. The component minerals are essentially quartz, orthoclase, with frequent microcline and some plagioclase, and biotite, all coarsely crystalline. The feldspar frequently occurs in large perfect phenocrysts; the biotite is comparatively fresh, the orthoclase kaolinized and muscovitized. Accessory minerals are sometimes found in large amount, notably muscovite, calcite, epidote, garnet, micaceous hematite, kaolin, pyrite, and chlorite. Some of these minerals are derived from the decomposition of the feldspar and mica of the granite, while others, such as the garnet, represent constructive processes attendant upon the development of the schistose structure. Since the rock has thus evidently been subjected to great shearing and alteration, bringing about the formation of new minerals, it may be called a schist; yet

the granitic structure is usually quite unmistakable in the field, and invariably under the microscope, so that the term "granite-schist" is most appropriate.

AGE OF THE FORTYMILE GRANITE.

This granite-schist has been spoken of as occupying a belt several miles wide on the Miller Creek trail between Fortymile and Sixtymile creeks. On both sides of this belt are schists which are in part micaceous or hornblendic, and often pass into less common varieties, but which are, in most cases, made up chiefly of quartz; and study, both in the field and under the microscope, makes it clear that they are altered quartzites. These quartzite-schists, as we may call them, are identical in appearance on both sides of the granite belt. On the side toward Fortymile Creek they are continuous from the granite belt nearly to the main creek, when they pass into a formation which is made up very largely of marble; on the side toward Sixtymile Creek a narrower band has been examined which is made up entirely of quartzite-schists. Throughout this whole cross-section from Fortymile to Sixtymile Creek the schistose structure strikes nearly uniformly east and west. In passing from the quartzite-schist to the marble on Fortymile Creek one observes that the two rocks are at first finely interbedded, and that then the marble increases in quantity so as to form very thick beds with bands of schist between, which have been derived from quartzite and other detrital rocks.

The alternation of quartzite and marble in small bands gives the true bedding of the series, especially since this is often found in places where the forces producing the schistosity have acted very little and can not have changed the original order. The microscope, moreover, shows quartzite passing into marble through all transitional stages, a common rock being a calcareous or dolomitic quartzite in which are zones of calcite or dolomite inclosing quartz grains. This alternation of marble and quartzite, giving the true attitude of the beds, conforms exactly in strike and dip to the schistose structure of the quartzite; therefore the movement producing schistosity seems to have operated in planes mostly parallel to the original bedding of the sedimentary series. Along Fortymile Creek from Moose Creek to the Forks the structure is generally plainly discernible by means of the alternation of marble and quartzite; these show that the creek flows parallel with the strike of the formations, keeping generally in the marbles close to their contact with the massive quartzite-schists. The beds have a general east-west strike, and, although in places much contorted into minor folds, have a very marked general northerly dip, averaging 30° or 40°. The series of interbedded marbles, quartzitzes, and schists of various kinds will be called the Fortymile series, while the quartzite-schists lying between the Fortymile series and the granite will be called the Birch Creek series, on account of their being so well shown in the Birch Creek district.

From the general attitude of the beds, which we have noted as having been ascertained from the interbedded quartzite and marbles along Fortymile Creek from Moose Creek to the Forks, it will be seen that the Miller Creek trail is a cross-section, cutting very nearly at right angles to the formations. From the attitude of the marbles and interbedded quartzites on Moose Creek, it follows that the quartzite-schists of the Birch Creek formation underlie the marble beds of the Fortymile formation. It has also been shown that at the contact of these two formations the actual attitude of the rock conforms to the schistose structure of the quartzite, so that the schistose structure of the quartzite represents at that place the true bedding. Between the Fortymile formation and the sheared granite zone the strike and dip of the schistose planes in the quartzite remain the same, so that the granite has the appearance of underlying the quartzite-schists. On the south side of the granite, however, the quartzite-schists, while having a general east-west strike, like that of the same formation on the other side of the granite belt, have a general dip to the south instead of to the north as before. This dip is comparatively flat, averaging between 10° and 20°. The east-west strike and the southerly dip are practically uniform, except where disturbed by minor folds. If the schistosity in the quartzite-schist on both sides of the granite belt is parallel with the original planes of sedimentation, as has been shown to be the case on Fortymile Creek where a test can be applied, then the northerly dip of the quartzite-schists on the Fortymile Creek side and the southerly dip of those near Sixtymile Creek indicate an anticlinal fold.

Besides the Miller Creek trail cross-section, another section across the general strike of the beds is afforded along the South Fork of Fortymile Creek, between its junction with the North Fork, and the country around Franklin Gulch and Chicken Creek. This section is, however, not so satisfactory, for there is a great amount of intrusive rocks, which have distorted and altered the sedimentary schists so that the general structure is often doubtful, and even the nature of the schistose rock is not always clear. Near the Forks, however, the general dip of the beds, as before, seems to be to the north. These beds are the marbles and quartzites of the Fortymile formation. South of the Forks there is a broad belt in which the intrusive rocks are so abundant and cause such disturbance and alteration that the structure of the sedimentary rocks is uncertain. On the south side of this belt are marbles with intercalated siliceous schists, which have as before, a general east-west strike, but a uniform southerly dip, so that they pass down under younger rocks.

These two cross-sections establish the existence of an anticlinal fold with an east-west axis parallel to Fortymile Creek between Moose Creek and the Forks. The section on the South Fork compared with that of Miller Creek trail shows a closing of the fold toward the west,

for here the distance between corresponding formations across the fold is much less than in the other cross-section, as is shown on the map, Pl. XLVII, p. 318. In this section the quartzite appears to be confined to a narrow zone and to form the summit of the anticline, no sheared granite belt having been observed, although the many dikes and the consequent metamorphism make the matter doubtful without more study.

As far as can be seen, however, the contact of granite with the sedimentary schists roughly corresponds in outline with the strike of these schists and with the contact of the quartzite-schists with the overlying marbles of the Fortymile formation. This granite therefore has the form of outcrop characteristic of a rock lying stratigraphically beneath the sedimentary schists. On the Miller Creek trail no intrusive phenomena were noted near the contact of granite with other rocks, but on account of the schistosity of both formations such phenomena might easily be obscured.

The possibility still exists, therefore, that the granite may be intrusive, having broken through the sedimentary rocks in a massive body and dragged up the beds so that they lie on its flanks, dipping away in all directions. Throughout the gold district there are large quantities of granite which have cut through rocks in this fashion, as is abundantly proved by the contact phenomena. At the same time, these plainly intrusive granites are ordinarily massive and have no schistose structure, being, therefore, later than the disturbance which brought about this structure, while the granite lying along the axis of the Fortymile anticline is markedly schistose and can not be referred to the same period. Another theoretical consideration is in regard to the nature of the rocks which lie on both sides of the schistose granite of Fortymile Creek. These schists, as has been said, are beds of altered quartzite, and the plainly detrital grains of which they are composed are chiefly quartz. In some cases, however, other materials are present; rounded grains of feldspar are found, both orthoclase and plagioclase, containing sometimes flakes of biotite and grains of epidote; detrital grains of zircon, apatite, and magnetite have also been observed. These minerals must necessarily have come from the denudation of some older rock, and their nature suggests derivation from granite. It may therefore be concluded that the Fortymile granite is older than the schistose sedimentaries and underlies them.

EXTENT OF THE GRANITE AREA.

As stated, this granite occurs along the axis of a fold whose trend corresponds in a general way with the schistosity. This same east-west trend of schistosity is found nearly uniformly in the schists from Fortymile Creek along the Yukon to near the junction of the Lewes and Pelly, and throughout this distance belts of granite alternate

with belts of schist corresponding to the Birch Creek and Fortymile formations. There is also much intrusive granite, but this is solid and comparatively fresh, while the basal granite is altered and schistose. A specimen of this schistose granite collected by Mr. Ogilvie on the Yukon near the mouth of the Stewart River is described by Mr. F. D. Adams,[1] under the head of "Quartzose biotite-gneiss." This granite becomes more abundant to the south, so that Fortymile Creek seems to be on the northern border of the area in which it appears. Dr. C. W. Hayes[2] notes that the prevailing rock of the greater part of the region between the Yukon and the St. Elias Mountains, along the White River, is a reddish granite, quite free from hornblende, and frequently containing large porphyritic crystals of feldspar. This red granite he judges to be Archean, and to be the floor on which later sedimentary rocks have been deposited. Granite also appears to cover a very large area along the Tanana River.

According to Lieut. H. D. Allen,[3] "the banks of the Upper Tanana, where there is rock, are generally composed of a yellowish granite, fast undergoing disintegration, as evidenced by the innumerable particles of mica suspended in the river and the ever shifting quicksands." Prospectors who have crossed from the Birch Creek district over to the Tanana also report that the rock along a considerable part of this route is granite, although it may be remarked that their separation of granite from other rocks is by no means accurate; and from other men it has been learned that a prominent mountain above the headwaters of Sixtymile Creek, called Sixtymile Butte, is of granite.

This same belt of granite has been shown by the observations of Dr. G. M. Dawson[4] to extend in a southeast direction from the Yukon, where it has already been noted, along the Pelly, where it has been found at various places, and to be roughly continuous as far as the Dease River, a short distance below Dease Lake. The total length of this northwest-southeast granitic belt from Dease River to the localities where it has been reported on the Tanana is not far from 800 miles in a straight line. The observations made during the last season, however, show that this belt probably does not cross the Yukon below its great bend at the Lower Ramparts, for although granites are found at this point they appear to be intrusive and younger.

The schists which overlie the basal granite are found continuously along the northeast side of the granite belt in the Yukon district of Alaska, being exposed notably in the Fortymile and Birch Creek mining districts. On the northeast this belt of schists passes under successively younger rocks, so that in a short distance there is a continuous belt of Tertiary strata running parallel with the schists. In

[1] Ann. Rept. Geol. Nat. Hist. Survey Canada, new series, Vol. III, Part I, p. 239B.

[2] Expedition through the Yukon district: Nat. Geog. Mag., Vol. IV, p. 139.

[3] Expedition to the Copper, Tanana, and Koyukuk rivers: Senate Doc., Washington, 1887, p. 159.

[4] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1887-88, new series, Vol. III, Part I, p. 34B.

British territory Dr. Dawson[1] has noted the close association of the granite belt with gneissic rocks and hornblende- and mica-schists, which, from his descriptions, are probably identical with the schistose rocks already mentioned. On the south side of the granite belt, along the White River, Dr. Hayes[2] found marbles and schists lying upon the granite, which are evidently similar to the schists of the Birch Creek and Fortymile series. Farther south Dr. Hayes found that these schists pass under younger rocks of Carboniferous, Triassic, and Cretaceous age; and above these again lie still younger rocks, which may be Tertiary, possibly corresponding in part with the Tertiary beds noted a short distance farther east by Prof. I. C. Russell[3].

The position of the rocks on both sides of the granitic belt, which is such that successive younger formations occur as the distance from the granite increases, both on the northeast and on the southwest, evidently points to an anticlinal ridge of such vast dimensions that it could not have arisen from any local cause, but must have originated in the main crust of the earth; it may be called, therefore, the Yukon geanticline. Following the general trend of this geanticlinal ridge, as shown by observations on the Pelly, Yukon, and Tanana, it will be seen to cut the Yukon at the Lower Ramparts. At this point, however, as already noted, the basal granite does not appear, although the sedimentary schists which overlie it are present. The width of the schists is much lessened in comparison with that at other points farther southeast along the belt, and this narrowing, with the absence of granite, indicates that the fold has closed considerably.

If the geanticline persists beyond this point in a northwest direction, the basal granite and associated schists should cross the Koyukuk. Concerning this river very little is known. Lieutenant Allen,[4] however, reports that the country drained by it is composed of rocks similar to the Tertiary strata on the lower Yukon, and what vague reports are brought out by prospectors seem to confirm this statement. If this is true, the northwestern extension of the Yukon geanticline diminishes rapidly near the point where it cuts the Yukon at the Lower Ramparts, till the younger Tertiary strata, which lie on its flanks, approach from both sides, and finally meet, cutting off the northwestern extension of the schistose formations.

CORRELATION.

Concerning the age of this basal granite, we may term it, by analogy with fundamental granites in other regions, Archean. This is the name given it by Dr. Hayes,[5] and Dr. G. M. Dawson[6] points out the

[1] Op cit., p. 34B.
[2] Op. cit., p. 140.
[3] Bull. U. S. Geol. Survey No. 84; Correlation Papers, Neocene, p. 259.
[4] Expedition to the Copper, Tanana, and Koyukuk rivers. Senate Doc., Washington, 1887, p. 159.
[5] Op. cit., p. 139.
[6] Op. cit., p. 35B.

great age of the granites of this belt as compared with the intrusive granites of the Coast Ranges, and remarks the resemblance to the probable Archean granites in the Gold Ranges in southern British Columbia.

THE BIRCH CREEK SERIES.

Lying on both sides of the belt of sheared granite which occupies a position between Fortymile and Sixtymile creeks is a series of schists of nearly uniform appearance. This granite has been described as being probably the fundamental rock in the region, and as forming in the Fortymile district the axis of an anticlinal ridge. The schists which lie on both sides are therefore younger than the granite and older than the other rock formations, which will be described later.

GENERAL CHARACTERISTICS.

Composition of rocks.—These schists are of a general light-gray color and are chiefly made up of quartz, though locally they pass into darker and even graphitic varieties. The typical rock is a quartzite, of which the grain is often coarse enough to be distinguished in the hand specimen, and of whose detrital origin the microscope leaves no doubt. In the less-sheared portions the quartzite is hard and white, and shows very little the effects of pressure; usually, however, a decided schistosity has been produced, evidenced by parallel cracks and shear-planes, along which metamorphic minerals have been developed. In the more intensely sheared portions the planes of schistosity are set closely together, and the rock appears to be made up largely of mica; but even in such rocks the microscope ordinarily shows that the chief constituent is quartz. From these types, which are derived from the alteration of quartzite, there are local gradations into schists, which are plainly derived from finer siliceous and carbonaceous sediments. These schists are met with in small amounts at various points in the series, but especially in its lower portions. There are also found, although rather sparingly, schists of igneous origin, being dikes which have intruded into the sedimentary series previous to the shearing. In some places the contact between this igneous schist and the sedimentary quartzite-schist was seen, proving its dike-like nature. So far as noted, these intrusions were of granite in its various phases, although the original structure of the rock has often been obscured by the subsequent metamorphism.

Dikes of various kinds, later than the development of schistosity, are also frequent.

Correspondence of schistosity and stratification.—The planes of schistosity have been described as probably conforming, in a general way at least, to the actual stratification of the rock, for in the Fortymile district the schistosity dips away from the underlying granite on both sides of the anticlinal axis and dips down under the overlying

marble and schist formation which is exposed on Fortymile Creek; and in the Birch Creek district, where the same rocks are exposed, the conditions seem to be the same, since the dip of the schistosity in the quartzite-schists carries them down below the marble and schist formation which is reported by prospectors as lying to the south of the gold-bearing district. It is in the Birch Creek district that this series, composed of quartzite-schists, is shown to the best advantage, and therefore to these rocks may conveniently be given the name "Birch Creek series." To the overlying series, consisting of marbles with interbedded quartzite-schists and garnetiferous, micaceous, and hornblendic schists the name "Fortymile series" will be given, on account of their being so well exposed along the canyon-like valley of this stream.

The parallelism of the schistosity planes with the original bedding on Fortymile Creek is further shown by the close correspondence of the strike of the schistosity with the line of contact between the Birch Creek and Fortymile formations and with the strike of the alternating beds of marble and quartzite-schist, which plainly show the original stratification. In attempting to estimate the thickness of the Birch Creek series of schists on Fortymile Creek, moreover, the planes of schistosity were taken as representing the actual bedding, and from this datum and from the known width of the belt occupied by the rocks of this series in the Fortymile district the calculation was made. In the Birch Creek district the same method was applied, and here the dip of the schistosity was greatly different from that in the Fortymile district, as was also the width of the belt of the Birch Creek series; yet the total thickness of the series was computed to be very nearly the same in both districts. This of itself is strong evidence for regarding the schistosity as nearly approaching the original bedding.

Quartz veins.—Another distinctive feature of the schists of the Birch Creek series, and one of great economic importance, is the occurrence of quartz veins in nearly every rock exposure. Most of these veins are small and nonpersistent. They lie typically parallel with the schistosity, although occasionally they cut across it at varying angles; and most of them have plainly been affected by the same dynamic disturbances which have produced the schistose structure in the inclosing rock, for they have been bent, broken, shredded, and fractured, both megascopically and microscopically. There are also other veins, which are later than the shearing. These veins are the chief source of the gold throughout the district, and occasionally show free gold in the crevices of the quartz. Pyrite is very abundant and galena not infrequent. Pyrite and galena are also sometimes found impregnating the more schistose portions of the rocks without abundant gangue material.

Summary.—The Birch Creek series may then be summed up as con-

sisting mostly of quartzite-schists, grading into finer-grained, often graphitic schists. All these rocks contain dikes, and quartz veins carrying gold and various metallic minerals. The slipping in the rocks consequent upon the pressure which produced the development of metamorphic minerals seems to have followed in a general way the original bedding planes, so that the planes of schistosity may be taken guardedly as indicating the true attitude of the beds.

DISTRIBUTION OF BIRCH CREEK SCHIST.

The Birch Creek series, as already defined, is apparently shown in its entire thickness in the Fortymile district. Above Fortymile Creek, on the Yukon, this same series outcrops for a large part of the distance nearly to the junction of the Lewes and the Pelly. Along this line the sheared quartzites contain belts of granite, some of which is schistose and very likely belongs to the fundamental granite, while in other places it is fresh and massive and shows plainly an intrusive character. There are also occasional belts of marble belonging to the Fortymile series. The schistosity in all these rocks has a general east-west trend or strike, and the alternating bands of different rocks appear to follow this same trend. Judging from the attitude of their schistosity, these rocks are considerably but not intensely folded, and their thickness must be very great, since a uniform strike and dip are maintained for long distances without any great change in the nature of the rock. Specimens of schists collected about 10 miles above the mouth of the White River, on the Yukon, and about 25 miles below Sixtymile Creek, on the same river, which have been examined microscopically, are essentially schistose quartzites, containing grains of zircon and a variable amount of muscovite and biotite, formed in consequence of shearing.

Below Fortymile Creek the Birch Creek formation was not encountered until the upper part of Birch Creek was reached, where the series is found to the exclusion of other rocks. The strike and dip of this series in the Birch Creek district are consistent at different points. The general strike is nearly east and west, changing in the western part of the area, in which active mining is carried on, to northwest, and in the eastern part to northeast. The dip is almost invariably to the south at a comparatively gentle angle, ranging between 5° and 30°, and perhaps hardly averaging more than 10°. The nearly semicircular course of the strike shows a broad, gentle fold, and since the dip is uniformly to the south, it is natural to suppose that in this direction the Birch Creek series passes under the Fortymile series. In fact, the existence of much marble has been reported by a prospector at some distance farther south, on the southern side of the divide between the Birch Creek waters and those of a tributary of the Tanana. This information, however, is not necessarily accurate. Cliffs of white rock, apparently dipping northward, were also

seen on the south side of the Crazy Mountains, between Circle City and the Birch Creek gulches. According to a prospector, these cliffs are of marble. Owing to the very gentle dip of the series in the Birch Creek district, it here occupies a broader belt than at any other point examined.

Below Circle City the Birch Creek series was not encountered on the Yukon until a point was reached just above the mouth of the Tanana, where a schistose, calcareous quartzite, carrying quartz veins, was found outcropping. From this point it outcrops frequently along the river nearly to the mouth of the Nowikakat, although it is frequently concealed by the overlying conglomerates and sandstones of the Tertiary, and by the silts and clays of the Pleistocene.

Along the right bank of the Yukon, between the mouth of the Tanana and that of the Nowikakat, is a range of low mountains running parallel with the river. On these mountains the bare rock seems to be light bluish-gray in color, and although the structure of the mountains is massive, structural planes seem to be visible. The fact that the outcrops along the river at the base of these mountains are for a long distance of micaceous and garnetiferous quartzite-schists, lends probability to the belief that the mountains themselves are composed of schists belonging to the Birch Creek formation, or to the Fortymile formation, which is also cut by the Yukon above the Tanana. This lower belt of Birch Creek rocks, running parallel with the Yukon below the Tanana, has exactly the same characteristics as the rocks in the Fortymile and Birch Creek districts. It has the same rock types, the same schistose structure, and the same quartz veins which have ordinarily been sheared with the inclosing rock. The series here also contains gold, and about the mouth of the Tozikakat a large sheared vein of quartz, carrying gold, has been worked a little by Mr. G. C. Bettles, the trader in charge of the post at Tanana.

THICKNESS OF THE BIRCH CREEK SERIES.

From the area which the Birch Creek rocks occupy between the Pelly River and Fortymile Creek it is clear that their thickness must be very great, even if much folding is assumed. In the Fortymile district a cross-section was obtained along the Miller Creek trail, where the series forms a belt about 8 miles in width. Along this belt the dip of the schistosity was observed at numerous points, being on an average about 40°, which was also the dip of the intercalated marbles and quartzite-schists of the overlying Fortymile series on Fortymile Creek. Inasmuch as the dip is uniformly to the north, there seems to have been no great amount of minor folding, and the 8 miles of outcrop with an average dip of 40° gives a total thickness of about 25,000 feet.

In the Birch Creek district, as already stated, the dip is much

slighter, averaging perhaps in the neighborhood of 10°. The width of the belt in which the series outcrops, however, is much greater as measured from the mountains just north of the Birch Creek gulches in a southerly direction to the locality where marble has been reported by prospectors. This is probably the total width over which the series crops with a uniform dip; for north of the Birch Creek gulches, on the trail to Circle City, schists similar to those in the Fortymile formation are found cropping, and fragments of marble in the coarse gravels; and marble is said to outcrop on the northern end of the ridge of mountains lying just west of Birch Creek. The semicircular curve in the strike of the Birch Creek quartzites, as detected in the mining district, joined with this evidence of the cropping of the Fortymile series farther north, goes to show that the fold is in the nature of a comparatively gentle dome from which the strata dip away on three sides at least—to the north, south, and east. It is at the probable summit of this dome that one end of the line measuring the width of the belt occupied by the Birch Creek series is taken. At the other or southern end the marbles reported apparently indicate the existence of the Fortymile formation, under which the Birch Creek formation passes. The total length of this line as thus measured is about 25 miles, and this width, with an average dip of 10°, gives a total thickness to the rocks of the Birch Creek series of not far from 25,000 feet, which is the same result as that reached independently, with quite different data, in the Fortymile district.

MICROSCOPIC STUDY OF BIRCH CREEK ROCKS.

The igneous rocks which are intrusive into the altered sedimentaries of the Birch Creek series will be described later, and for the present only the nature of the original sediments and the derived schists will be considered.

As already stated, the nature of the rocks in the Birch Creek series is comparatively uniform throughout its whole thickness, and the rocks are also identical in appearance at the different localities mentioned above, which are hundreds of miles apart. Nearly all specimens appear in thin section as slightly altered quartzites, composed of interlocking grains of quartz of nearly uniform size. In many cases the outlines of original detrital grains are plainly visible, being shown by a faint ring of indeterminable dirty material, which must have coated the surface of the original grains. In other cases the outlines of the original grains are very faint and often can not be discerned. This is probably due to the circumstance that the surface of the grains was entirely clean before the addition of the second quartz. In all cases the interstices between these original grains have been filled by crystalline quartz, which has grown onto the grains in crystallographic continuity, as is usually the case in quartzites; so that the rock is now composed essentially of irregular interlocking grains.

Besides quartz there are rarer minerals, which occur in rounded grains and are plainly of detrital origin. Small fragments of zircon are common; feldspar is sometimes found, and occasionally apatite, epidote, and calcite. By increase in the amount of calcite the quartzites gradually pass in the upper part of the series into the marbles of the Fortymile formation. In some of the Birch Creek schists there is a large amount of carbonaceous matter, sometimes completely altered into graphite, which is also evidently an original constituent.

Metamorphic minerals are usually much less in amount than the original detrital material, but are present in nearly every section. The most common metamorphic mineral is muscovite, which occurs especially on the slipping surfaces, or planes of schistosity. Biotite is often found, sometimes inclosing zircon or sagenite webs; tourmaline is very common, and garnet is conspicuous in some of the rocks; green hornblende and actinolite are occasionally met with. Another class of secondary minerals which probably have a slightly different origin, being due to aqueous rather than to dynamic action, consists of occasional, sometimes abundant, crystals and grains of pyrite, and iron in other forms, such as specular iron, limonite, and siderite. Marcasite is frequent in perfect crystals, and copper pyrite, often yielding a green stain from decomposition, is not unusual; galena is sometimes found in grains in the schist as well as in quartz veins which the schist incloses. All these secondary minerals, whether the result of shearing or dependent upon aqueous causes, occur in evident relation to the slipping planes in the rock, as can be seen in thin section, and all often form perfect crystals or irregular plates which have grown around and inclosed the original detrital grains.

THE FORTYMILE SERIES.

GENERAL DESCRIPTION.

Overlying the schistose quartzites of the Birch Creek series is a considerable thickness of intercalated marbles and quartzites, with hornblendic, micaceous, garnetiferous, and sometimes graphitic schists. The marble beds, however, are found in all parts of the formation and form its chief distinctive feature. To these rocks are given the name "Fortymile series," since they are exposed in great detail along Fortymile Creek, and there afford better opportunities for study than at any other place visited.

The Fortymile series seems to pass gradually into the Birch Creek series, for in the upper part of the latter the quartzites grow calcareous and pass into the banded marbles and quartzites which are found at the bottom of the Fortymile rocks. Often these rocks have been so little altered that their original sedimentary nature is clearly discernible in the field. This is well shown at the junction of Moose

Creek with Fortymile Creek, where there occur interbedded marbles and quartzites which are only locally sheared to any great extent. These quartzites and marbles alternate in beds, often 40 or 50 feet thick, but frequently the thickness diminishes to a few inches. From the quartzite there is a gradual transition to more altered rocks, such as mica- and hornblende-schists, often garnetiferous. These schists are often so metamorphosed that were it not for the fact that the marble remains the same and occurs interstratified with the schists in a very intimate way, just as it does with the quartzites, it would be difficult to recognize their original sedimentary nature.

The gradual transition from the quartzites and quartzite-schists to the hornblende-, mica-, and garnet-schists suggests that the latter are altered from sediments containing more basic material than the quartzites, and so are capable of forming a greater variety of new minerals under the stress of dynamic action. The hornblende- and mica-schists, again, pass into very black graphitic schists, often pyritiferous, which appear to be altered argillites, and which are still interbedded with marbles. The graphitic schists seem to occur most abundantly in the upper part of the series, as the pure quartzites do in the lower part, while the bulk of the rocks consists of hornblende-, mica-, and garnet-schists. The marble is everywhere present, often in thin layers, but increasing in some beds to a thickness of several hundred feet.

DIKES.

Intrusive igneous rocks are abundant in the Fortymile series, and are of different ages. Some have been so altered by the same processes which have produced crystallization in the sedimentary series that their igneous nature would often hardly be recognized without the aid of the microscope. These rocks appear to belong mainly to the granitic and dioritic families. Other dikes which have been only slightly sheared show much less metamorphism than the inclosing rocks, and leave no doubt as to their igneous and intrusive nature. Finally, there are dikes which show no metamorphism whatever, and which must have entered the rocks subsequent to all important movements and strains.

On Fortymile Creek these dikes are everywhere abundant in the banded marbles, quartzites, and schists, especially on the South Fork of Fortymile Creek, between the junction with the North Fork and with Franklin Gulch. Here they often form immense masses, the different varieties cutting across one another in a confused manner; and the sedimentary rocks are disturbed and metamorphosed so that the general structure was not surely made out.

In composition these dikes show a great variety, but they do not admit of any strict classification, since they grade into one another, and the rock of any one dike is rarely exactly like that of any other. There are variations from the most basic to the most acid, and the

chief forms may be enumerated, commencing with the most basic, as pyroxenite, hornblendite, diorite, diorite-porphyry, quartz-diorite, syenite, hornblende-granite, porphyry, and aplite. The most basic varieties, pyroxenite and hornblendite, contain considerable quantities of pyrrhotite and other metallic minerals, while the extremely acid aplites change gradually into pure quartz veins. Both acid and basic rocks often occur in great masses, on the borders of which are abundant fine stringers into the sedimentary schist, showing their intrusive nature. The different dikes often cut one another, and it is usually the case that when two dikes of different varieties intersect, the phenomena show the more acid dike to be the younger. The more basic varieties of the dike rocks are in some places schistose and in other places massive, while the extremely acid rock, such as the aplite, shows no schistosity or other deformation. Some of the highly metamorphosed igneous rocks, which are evidently the oldest, contain quartz veins, but the younger rocks, even such as are often markedly schistose, contain none.

QUARTZ VEINS.

Two sets of quartz veins are clearly distinguishable in the Fortymile formation. Of these two the less abundant has an intimate connection with the aplite dike, for it grades into these rocks in structure and composition, and can often be traced into it in a single outcrop, the aplite changing to a vein composed of quartz and feldspar, and this, by disappearance of the feldspar, into one of quartz alone. These veins cut across the schistosity in the fashion of dikes, and have not been disturbed by any movement in the rocks.

Veins of the other set are very abundant, both in the Fortymile series and in the underlying Birch Creek series. They occur sparingly in the oldest and most schistose dike rocks, and not at all in the younger rocks, such as aplite. Moreover, they afford abundant evidence of having been subjected to great crushing and deformation together with the inclosing rock, and it has already been mentioned that these disturbances have not acted at all upon the younger dike rocks. This set of abundant quartz veins, therefore, is quite distinct from that which is connected with the dikes and has a considerably greater age. These veins are usually nonpersistent, so that both ends of a given vein can usually be found in a large outcrop. This nonpersistence is probably partly original and partly due to faulting subsequent to deposition. In general the veins are parallel with the schistosity, although sometimes they cut across it at varying angles. Whenever the inclosing rock has been much disturbed and rendered markedly schistose the effects of the movement are shown in the veins also by a stretching of those which are parallel to the schistosity, and in extreme cases by a veritable shredding; while those veins which cut across the schistosity are faulted and dragged along

the planes of movement. The effect of this shearing is seen in all microscopic sections of the veins, being manifested by numerous intersecting sets of parallel fractures, and in the wavy extinction of the quartz, and often by more or less complete granulation. Where there has been folding as well as shearing in the rocks the inclosing quartz veins are often violently contorted. These veins, whether occurring in the Fortymile series or the Birch Creek series, often contain pyrite, sometimes galena, and occasionally free gold. They are probably among the chief sources of the gold in the Yukon district.

SCHISTOSITY.

Some parts of the Fortymile series, as, for example, the interbedded marbles and quartzites on Fortymile Creek, near the mouth of Moose Creek, are not greatly sheared; from this there are all transitions up to highly crystalline schists. As suggested in considering the Birch Creek schists, it is probable that the movement producing schistosity took place mainly along the original bedding planes, for the interbanded marbles and quartzites pass into interbanded marbles and crystalline schists without breaks or discordance in the attitude of the rocks. The effects of the shearing are shown by the development of metamorphic minerals of evidently secondary nature, such as hornblende, mica, and garnet. The quartz veins, which have formed chiefly along the planes of schistosity, may also be regarded as a result of metamorphism. Although these quartz veins were probably formed subsequent to the initial shearing of the rock, and along channels conformable with the schistosity which were opened up by the movement, yet the veins themselves are generally strained, faulted, and even shredded. Moreover, microscopic study shows that many undoubtedly metamorphic minerals, such as garnet, have very often been sheared, sometimes violently, so that in their present condition they are broken and elongated. It therefore appears that subsequent to the initial shearing which produced the metamorphic minerals and gave rise to the quartz veins the movements in the rocks continued along the same planes, producing greater metamorphism and defacing, in part, the results of the earlier movement. It has already been stated that some of the dike rocks are profoundly sheared and others only slightly, while those which are evidently youngest have undergone no deformation whatever. It is probable, then, that the movement which produced the present schistose structure continued in operation a very long period of time, during which period many other changes occurred in the rocks.

FOLDING AND FAULTING.

As a rule the rocks of the Fortymile series are not greatly faulted. From a point on Fortymile Creek about 12 or 15 miles above Fortymile Post, as far as O'Brien Creek—a distance in a straight line,

disregarding the sinuosities of the river, of 25 or 30 miles—there is a nearly uniform strike and dip; this strike is northeast, nearly parallel with the general course of the river, while the dip is northwest at an average angle of 30°. Along this part of the river, therefore, the Fortymile series has a general dip away from the axis of the Fortymile anticline. Above O'Brien Creek, especially on the South Fork, the rocks have been greatly disturbed by dikes of immense size, so that there is no uniformity, and the general structure can not be clearly made out. The accompanying figure (fig. 7) shows an outcrop of marble with some interstratified schists on Fortymile Creek below O'Brien Creek, the rocks as exposed having a uniform dip.

Minor folding, even crumpling, is locally found, especially in that part of the series which is most traversed by dikes. This minor fold-

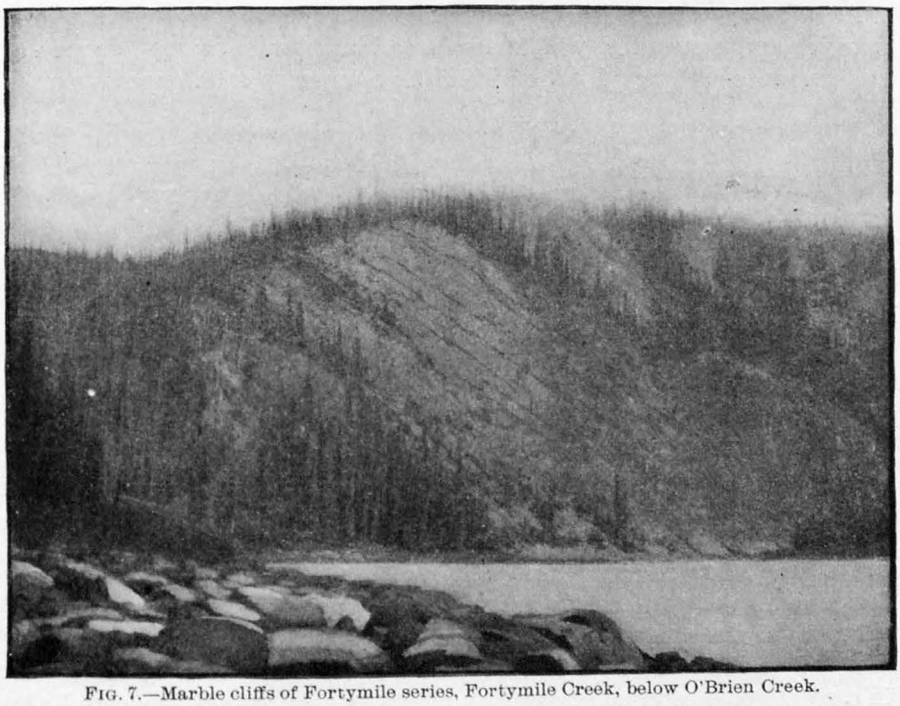

FIG. 7.—Marble cliffs of Fortymile series, Fortymile Creek, below O'Brien Creek.

ing has often come about later than the movement producing the planes of schistosity, for these schistose planes follow all the curves in the folds. A specimen of contorted quartzite-biotite-garnet-schist, exhibits some bands essentially of pure quartzite, while darker ones contain also much biotite and garnet with muscovite. The schistosity appears to follow all the curves of the folds, and microscopic study shows that biotite and garnet, both metamorphic minerals, have been broken and stretched by shearing previous to the folding.

At various points on Fortymile Creek faults are often shown diagrammatically in the cliffs, but the amount of movement could not be

ascertained by such cursory observation as the limited time permitted. Fig. 8 is from sketches of such faults.

JOINTS.

There is no universal jointing in the rocks of the Fortymile series, but in the most altered portions there is often found a very prominent set of joint planes, which cuts the schistosity and the folding and is probably due to local causes. At two points on Fortymile Creek where these joints were especially well developed their attitude was taken, and was found to be in one case, strike N. 85° W., dip 30° N., and in another strike, N. 75° E., dip 75° SW.

COMPOSITION OF FORTYMILE ROCKS.

As already stated, the Fortymile rocks consist essentially of marbles and quartzites, which pass into hornblende-, mica-, garnet-, and graphite-schists. By the aid of the microscope the exact struct-

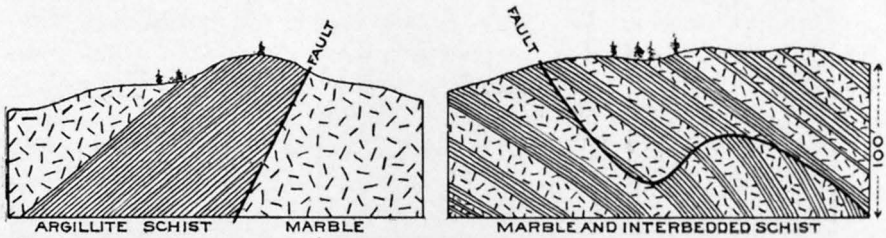

FIG. 8.—Faults in Fortymile series.

ure of these different varieties and the fine gradations into one another which they exhibit may be accurately studied.

Marble.—The marbles are often quite pure, being made up entirely of coarse, interlocking plates of crystalline calcite. These plates often show bending and sometimes crushing as the result of shearing, but scarcely any development of new metamorphic minerals. The first stage in the transition of marbles to quartzites is shown by the presence of more or less numerous detrital grains of quartz, which are inclosed in the calcite plates; very often grains are entirely inclosed in a single calcite crystal, showing that the calcite is regenerated or recrystallized from its original form. In other parts the quartz grains increase in number until the rock is essentially a calcareous quartzite, being made up chiefly of quartz grains cemented by calcite; and in some sections there are alternating zones, some of which are true quartzite, being composed of detrital quartz grains, cemented by secondary quartz, while others contain less numerous quartz grains inclosed in calcite, thus showing a perfect transition between the two rocks.

Quartzite.—The pure quartzites show their true nature quite well in the field, and under the microscope exhibit comparatively little

metamorphism. Very often the rounded forms of the original detrital grains of quartz may be discerned by the faint line of dirty kaolinic material which bounds them. Besides the quartz grains there are also occasionally other detrital fragments, among which feldspar, zircon, and apatite may be noted. As a rule the quartzites are traversed by many parallel microscopic cracks, which are plainly the result of shearing, and in evident connection with these shear zones are metamorphic minerals in varying amount, such as muscovite, tourmaline, and garnet. Pyrite is also frequent.

Quartz-mica-schist.—These schistose quartzites change very gradually into more metamorphic rocks by an increase in the amount of metamorphic minerals. Among these an important class is distinguished by the great development of mica, which is chiefly biotite, although sometimes muscovite predominates. In these rocks some zones ordinarily retain the structure of the purer quartzite-schist, while in others the secondary minerals are greatly developed. These latter apparently represent impure bands in the original sediment. Besides quartz and biotite, there is generally green hornblende, pyrite, and magnetite. A very characteristic mineral is epidote, which often occurs abundantly in perfect crystallographic development, forming long prisms, varying in color from pale yellow to nearly colorless.

Quartz-hornblende-schist.—The quartz-hornblende-schists are essentially like the quartz-mica-schists, except that the hornblende predominates in amount over the other metamorphic minerals. In some forms the rock is essentially a quartzite, in which the shapes of the original grains are plainly discernible. In this rock light-green hornblende is often present in considerable quantity, in plates of rather large size, roughly arranged in zones. With the hornblende is generally associated fresh brown biotite. Neither of these minerals have definite crystallographic boundaries, but they inclose detrital quartz grains in such a way as to prove their secondary origin. In other specimens the quartz becomes less in amount and the hornblende greater, so that the rock assumes megascopically a dark-gray, often nearly black, color, with a peculiar luster due to the minute grains of hornblende; and in some cases the hornblende makes up a large part of the rock, the rest still consisting mainly of quartz. Biotite is, however, always present in small amount, and the metallic minerals, such as pyrite, magnetite, specular iron, micaceous hematite, pyrrhotite, and ilmenite, are usually present, often abundantly; they generally form nearly perfect crystals, but sometimes are in irregular grains.

Epidotic schist.—The quartz-mica-schists and quartz-hornblende-schists sometimes contain epidote in such large quantity as to merit special attention. This epidote occurs in long, nearly perfect crystals, which cut across the different grains of the original rock without disturbance, and thus show clearly a secondary origin. Like the biotite, hornblende, and other metamorphic minerals, the epidote is

ordinarily most abundant along certain zones where the alteration has been greatest. In these epidotic schists, as in other schists which have been mentioned, there are frequent portions which still retain the structure of a sedimentary rock, being composed mainly of detrital quartz grains, with occasional feldspar, zircon, apatite, and other minerals.

Garnetiferous schist.—Another variation in these crystalline schists is marked by the increase of the garnet, which is nearly always present, so that it forms a very conspicuous part of the rock. These garnets vary in size from extremely small, microscopic dimensions to an inch or so in diameter in the highly metamorphosed schist. The garnetiferous schists contain also abundant mica and generally considerable hornblende and epidote, which have the same habit as in the other varieties; the transition, therefore, into the rocks which are distinguished by the predominance of biotite and hornblende among the dark-colored minerals is very gradual.

Garnet-muscovite-schist.—A comparatively rare type of rock is composed essentially of muscovite and garnet, the latter being in quite large crystals; it is highly metamorphosed and shows microscopically no evidence of its original nature, although by analogy with other rocks it is probably sedimentary in origin. This rock is found in portions of the series which have evidently been subjected to great pressure.

Graphitic schist.—In some places, especially in the upper part of the series, are schists which are distinguished by the presence of abundant carbonaceous and graphitic material. This gives the rock in the hand specimen a lustrous, dark-gray color, and under the microscope shining particles of graphite are everywhere seen. Besides the graphite, which is subordinate in amount to the other minerals, the rock consists mostly of quartz, biotite, and muscovite, so that it is really an impure carbonaceous form of the quartz-mica-schist.

Cyanite-schist.—A variety of the graphitic schists found in the Birch Creek district, along the trail leading from Circle City to the gulches, is marked by abundant cyanite, in short, stout prisms. In other respects the rock is essentially a graphitic quartz-mica-schist, like others already described.

Schistose igneous rocks.—There are sometimes observed dike rocks which have been so metamorphosed by shearing that their true nature can often not be certainly told in the field, although generally determinable under the microscope. In these rocks the original minerals are preserved, although a marked and in places a profound cataclastic structure defaces their arrangement. Among these dikes varieties of the granite, diorite, and syenite families are most abundant.

ORIGINAL NATURE OF FORTYMILE ROCKS.

Those portions of the Fortymile series which are least metamorphosed are plainly sedimentary rocks, being interbedded marbles and

quartzites. In the more altered rocks, which become schistose, the marbles still alternate with the schistose bands, showing that even these are of sedimentary origin. Moreover, the microscope shows a gradual transition from the nearly pure quartzites to the high crystalline schists in which the gradual change by the development of metamorphic minerals may be observed. In these transitions the alternation of bands of pure quartzite-schist with other bands containing darker metamorphic minerals, such as mica and hornblende, suggests that these darker bands represent impure parts of the original sediments which contained a large proportion of basic detrital material. The occurrence of quartz, feldspar, zircon, apatite, pyrite, and some biotite among the grains of the original sedimentary rocks has already been spoken of as indicating that the rock from which the sediments were derived was of granitic nature. We may therefore consider that the bands which are now changed into mica- and hornblende-schist contained originally much detrital material derived from the darker minerals in the granite, while the pure quartz-schists were made up chiefly of granitic quartz. There is also evidence, in various parts of the series, of conglomerates which are in general considerably metamorphosed. In the upper parts of the series the graphitic schists indicate a still more impure sediment and probably the presence of organic life. The series, then, originally consisted of alternating bands of limestone, sandstone, conglomerate, and shale, and it appears probable that the lower part consisted chiefly of pure sandstone while the upper part was more impure and carbonaceous.

DISTRIBUTION OF FORTYMILE SERIES.

On Fortymile Creek the rocks of the Fortymile series outcrop continuously from a point 6 or 7 miles above the post up to a point beyond Franklin Gulch, which empties into the South Fork. Between Franklin Gulch and Chicken Creek, and between Franklin Gulch and Napoleon Creek, the Fortymile series is overlain by green slate and impure calcareous grits belonging to a younger formation, which will be described as the Rampart series; and also by conglomerates, grits, and sandstones, with shaly and coaly beds, which will be described as the Mission Creek series and which appear to overlie unconformably both the Fortymile series and the younger green slate and grit formation. A short distance above the junction of Fortymile Creek with the Yukon the rocks of the Fortymile series are overlain by sandstones and shales which are considerably altered in places but which are still distinctly younger, and are also referred to the Mission Creek series.

On the Yukon, 5 or 6 miles above the mouth of Sixtymile Creek, a series of pure white marbles interbanded with micaceous schists was noted. These undoubtedly belong to the same formation as the beds which have been described on Fortymile Creek. McConnell[1] also

[1] Ann. Rept. Geol. Nat. Hist. Survey, Canada, 1888-89, new series, Vol. IV, p. 142D.

notes that some miles above Fort Reliance a band of limestone and dark argillites, traversed by numerous quartz veins and associated with micaceous schists, crosses the river. These are probably also to be assigned to the Fortymile series.

In the Birch Creek district no opportunity was had to study the Fortymile series to any extent. On the trail between Circle City and the gulches, however, marbles and highly metamorphosed mica-schists are found in the débris, and this débris is evidently derived from the hills immediately adjacent. At one point also a micaceous schist, carrying much cyanite and belonging to a group which occurs abundantly in the Fortymile series, was found in outcrop; and along the Crazy Mountains, which lie to the west of this trail, marble is reported to occur in outcrop. The quartzites and quartzite-schists of the Birch Creek formation, which form practically the only rocks outcropping in the gulches, appear by their strike and dip to form a dome-like uplift, from the center of which the strata dip away in nearly all directions, thus passing under the Fortymile series, as here noted. On the south side of the gulches marble is reported by prospectors as occurring near the divide between the Yukon and the Tanana waters.

In the Lower Ramparts of the Yukon, about 15 miles above the mouth of the Tanana, are outcrops of calcareous quartzite-schists. These rocks are overlapped by the unconformably overlying conglomerates and grits of the Tertiary, so that continuous observation can not be made, and the appearance of the mountains suggests that there has been considerable faulting on a large scale. Below the Tanana, however, the quartzites and quartzite-schists of the Birch Creek formation outcrop for many miles along the Yukon, except where overlain by Tertiary or Pleistocene beds; showing that the outcrops first alluded to are probably to be assigned to the Fortymile series.

Along the Pelly River, which runs close to the axis of the great geanticline, Dawson[1] has noted limestones and micaceous schists, which probably belong to the same series as has here been described. On the White River, Dr. Hayes[2] states that on the southwestern side of the great belt of granite which covers most of the district through which the lower White River flows there is, between the Donjek and Koidern rivers, an area composed almost entirely of white marble and talcose schist. It is probable that these rocks are to be correlated with the Fortymile series, and it may be noted that they lie on the opposite side of the Yukon geanticline from the rocks along Fortymile Creek.

THICKNESS OF FORTYMILE ROCKS.

No satisfactory cross-section of the Fortymile series was obtained, so the thickness can not be given; it is probable, however, that it is somewhat less than that of the Birch Creek series.

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[1] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1887-88, new series, Vol. III, Part I, p. 32B.
[2] Nat. Geog. Mag., May 15, 1892, p. 140.

RÉSUMÉ.

The Fortymile series consisted originally of a considerable thickness of limestones, sandstones, shales, and conglomerates in alternating beds, the series being calcareous at the bottom and becoming rather shaly at the top. These rocks overlie the Birch Creek quartzites, into which they exhibit a gradual transition. Together with the Birch Creek rocks, they have been folded, faulted, and sheared. The first alterations which probably accompanied the folding which gave rise to the Fortymile anticline were movements producing schistosity, the intrusion of dikes, and the formation of quartz veins. It is probable that about the same time the gold which is found in connection with the quartz veins was introduced. Subsequent to this folding the movements in the rocks continued, and certain portions became more schistose, so that the veins already mentioned were sheared, and metamorphic minerals formed in the initial disturbance were broken and drawn out. Subsequently numerous dikes cut their way into the series. Some of these dikes exhibit slight schistosity, showing that movement in the rocks still continued. There are, however, a final set of dikes which show no effects of shearing whatever, and which are therefore subsequent to the last important movement in the rocks. Connected with these last dikes and grading into them are quartz veins which differ from the original veins in being unbroken and persistent. From this it appears that the movement in the rocks, producing various deformations, lasted for a long period of time, and that during all this period dike rocks were intruded into the series at intervals.

THE RAMPART SERIES.

PRELIMINARY STATEMENT.

At a higher horizon than the rocks of the Fortymile series, and probably directly overlying them, is a series of great thickness, whose rocks are characterized throughout by nearly constant lithological peculiarities. These peculiarities give a certain uniformity of appearance in the field, and, when carefully studied, point to a similarity of origin; and on these lithological grounds alone the rocks have been grouped together and the name Rampart series given them, from the fact that they are exposed in the Lower Ramparts of the Yukon.

One of the most common characteristics of this series is a general green color, which is possessed by different rocks which may otherwise show little resemblance to one another. The presence of volcanic material is likewise a distinguishing feature, and these lithological characteristics are identical in the different localities where this series has been examined, which are hundreds of miles apart. A

common rock is diabase, often olivine-bearing, and varying but little in composition and appearance in different localities. From the way in which this diabase occurs it probably represents for the most part surface flows, although it also is found in dikes cutting the associated rocks. With the diabase are found tuffaceous sediments, which are derived entirely from the diabase, and these form a very large and important part of the series. They grade into impure limestones, often glauconitic, and hard green shales. The general green color of the formation is due partly to the development of glauconite in the tuffs and impure sediments, but chiefly to the presence of serpentine, chlorite, and other green minerals arising from the decomposition of the igneous rocks which have contributed toward the upbuilding of the entire series.

DISTRIBUTION AND GENERAL DESCRIPTION.

Fortymile Creek, South Fork.—On the ridge dividing Chicken Creek from the South Fork of Fortymile Creek, and in a corresponding position in the bed of the South Fork itself, the marbles, hornblende-schists, and quartzite-schists of the Fortymile formation are overlain by rocks of decidedly younger appearance. These rocks vary in structure from massive to shaly. They are well indurated, and sometimes sheared, but only rarely have metamorphic minerals been developed in consequence of the shearing, so that true schists are uncommon. Small quartz veins are occasionally found, but are conspicuously few as compared with the veins in the Fortymile series. The rocks are microscopically determinable as diabasic tuffs, calcareous grits, often glauconitic, and compact green slates. This sedimentary series is cut by dikes of granite, often dioritic, and so changing to quartz-diorite, and also by dikes of porphyry. As a whole, the series is characterized by a general greenish color, which the microscope shows sometimes to be due to glauconite, but oftener to chlorite, serpentine, and other minerals derived from the decomposition of minerals in igneous rocks. On Napoleon Creek this series is unconformably overlain by conglomerates, sandstones, and shales, which carry coaly layers and which are subsequently described under the name of the Mission Creek series. The black carbonaceous shales of this later series also appear to overlap the green rocks in the lower part of Chicken Creek, so that the older series occupies a comparatively narrow band.

Between Fortymile Creek and Mission Creek.—Along the Yukon for about 25 miles below Fortymile Creek are black shales and thin-bedded sandstones, which are considerably faulted and folded, and which are locally slightly metamorphosed, but never so much so as the other formations which have been described. These black shales and sandstones appear to belong to a younger formation, and have been correlated with the conglomerates, sandstones, and shales which

overlie unconformably the green rocks of the Rampart formation on Napoleon Creek and Chicken Creek; and to these rocks has been given the name Mission Creek series.

At a point about 25 miles below Fortymile Creek the shales and thin-bedded sandstones are succeeded by massive dark-green rocks, which change in places to dark-gray or dark-blue color, but still retain their massive structure and their peculiar lithological characters. At first these rocks alternate in broad bands with the black shales which have already been mentioned, and then they come in continuously until about 5 or 10 miles above Mission Creek, where they are again succeeded by black shales and thin-bedded, gray, shaly limestones, which probably belong to the series exposed directly below Fortymile Creek. The belt of massive dark-green or dark-blue rocks exposed between these shale areas is cut by occasional dikes, some of which are very light yellow in color, and probably correspond to the aplite dikes on Fortymile Creek. The rock becomes schistose in bands or zones, and in these portions contains quartz veins, although always in much smaller amount than the rocks of the Fortymile and Birch Creek series. Some of these veins are of quartz, some of calcite, and some of quartz and calcite crystallized together. They nearly always cut across the rock, and show no evidence of shearing, thus forming a strong contrast with the veins of the underlying series.

The nature of these massive green and dark-blue rocks is not always apparent in the field, but microscopic examination shows that they are in part coarse tuffs containing frequent large fragments of olivine, plagioclase, and augite in a confused groundmass made up in part of serpentine, which gives the green color to the rock. These tuffs, therefore, appear to be derived from an olivine-diabase or a closely related rock. They pass into fine-grained shaly rocks which are of the same character but have a grain so fine that the component minerals are indistinguishable. The lithological characters of these rocks, therefore, are exactly those of the similar rocks described in the neighborhood of Franklin Gulch, on Fortymile Creek, and the two formations may be correlated.

Mission Creek.—The main branch of Mission Creek is called American Creek, and flows into Mission Creek only a short distance above its mouth. On American Creek, at a point about 2 miles above its junction with Mission Creek, the black shales and thin-bedded limestones which outcrop at the mouth of Mission Creek are underlain, in apparent unconformity, by dark-green and dark-gray massive rocks, which locally become shaly and which are evidently in the same belt as the similar rocks which have just been described along the Yukon River above Mission Creek. From this point along the trail which leads to the gold diggings on American Creek the chief rock exposed is dark gray or dark blue in color, locally greenish, and apparently is

largely an impure shale, changing into shaly limestones and tuffs. In this rock are everywhere zones of shearing, along which the limestones have been silicified, producing siliceous limestone and jasperoid. There are also, locally, true quartzites, which along shear zones become slightly metamorphosed and are characterized by the development of muscovite. On the upper part of American Creek, at the end of the trail shown on the map (Pl. XLVIII. p. 337), the rock is very massive and dark-green in color. It is generally much jointed, and at one point where these joints were remarkably well developed the chief set was nearly horizontal; at the same place were well-developed shear zones with a strike of N. 75° E. and a dip of 75° NW. Along these shear zones veins of quartz and calcite parallel with the shearing have been formed. These veins often contain copper and iron pyrite. In the gravels are abundant magnetite and barite, often in large pebbles, indicating the presence of rarer minerals in some of the veins farther up the creek. As noted in other localities where the rocks of this series are found, the veins are hardly ever broken or sheared, but cut across the rock without displacement. Microscopic study shows that these rocks are largely of undoubtedly tuffaceous origin, some of them consisting chiefly of serpentine which contains fragments of residual olivine, while others are made up of finely comminuted fragments of quartz with extremely abundant chlorite and other decomposition products. These rocks are cut by occasional dikes, among which aplite and mica-lamprophyre have been identified.

Between Mission Creek and Circle City.—Some 30 or 40 miles above Circle City, on the Yukon, a series of thin-bedded limestones, gray and often lithographic, which change locally into black shales, and which will be described later, is succeeded by massive dark-blue and dark-green rock, weathering red, and therefore conspicuous from a distance. This red color from weathering is characteristic of the rocks of the Rampart series, being due to the oxidation of the abundant iron, which in the protoxide condition, in combination with other elements, gives the green color to the fresh rock. These massive dark-colored rocks are continuous until the beginning of the Yukon Flats, a short distance above Circle City, and their appearance and lithological composition seem to warrant a correlation with the rocks of the localities which have just been described. They have been studied microscopically, and are found to consist in part of diabase, which occurs in such a way as to show it probably to have been mostly surface flows. These diabases change to waterlaid tuffs, whose materials are plainly derived from the diabase; and these tuffs become glauconitic and calcareous, sometimes containing traces of organic remains, and so pass into impure and sandy limestones. As in the rocks of this same series from other localities, the typical tuff has a groundmass consisting largely of serpentine and other indistinguishable components, which incloses frequent fragments of olivine, augite, and feldspar.

On Birch Creek.—On the trail which leads to the gold diggings from Circle City, at the point where it crosses Birch Creek at the Twelvemile Cache, there is exposed in outcrop a typical diabase of the Rampart series. This was the only outcrop noticed along here, the rock in general being concealed by gravels.

Fort Hamlin to Mynook Creek.—Below Circle City the Yukon flows for several hundred miles through a perfectly flat region, covered by silts and gravels which are mostly of Pleistocene age and which were probably formed as sediments in the bed of a great lake. In all this region no outcrops of solid rock were found. The end of this level country, which goes by the name of the Yukon Flats, is at Fort Hamlin, where the river narrows and enters a canyon-like channel through a range of low mountains which lie between this point and the junction of the Yukon with the Tanana. This portion of the Yukon valley is called by the name of the "Lower Ramparts."

The first rock found outcropping at the end of the Flats just above Fort Hamlin has the same peculiar lithological characters as the rocks of the localities already described. From this point similar rocks are exposed continuously along the Yukon for nearly 100 miles, as far as the bend in the river above the junction with Hess Creek, where this series is overlain by conglomerates, sandstones, and grits, which are made up largely of pebbles and smaller fragments derived from the underlying rocks. The younger formation contains seams of lignitic coal and abundant plant remains, which show its age to be probably Eocene. Between Fort Hamlin and this locality the older rocks contain a great deal of diabase, varying in texture from very fine to coarsely crystalline, and being often very fresh in appearance. This diabase changes gradually into finer-grained, green rocks, which in turn pass into gray, smooth-textured rocks, and these into thin-bedded or argillaceous and slaty rocks, often calcareous. Although the diabase is a typical igneous rock in appearance and structure, the rocks into which it passes with no abrupt transition have well-marked sedimentary characteristics, and although many opportunities for observing the change from igneous into sedimentary rock were afforded no exact line of demarcation could ever be found.

All observations go to show that the diabase forms many sheets of variable thickness, which lie conformably with the waterlaid rocks, and the usual absence of contact phenomena between these sheets and the adjacent sediments, as well as the nature of the sediments themselves, points to the conclusion that the sheets were surface flows. On careful study it is found that the rocks constituting the transition between the typical igneous rock and the typical sedimentaries are really tuffs of varying texture, which are derived from the minerals of the diabase, the coarsest being made up of large fragments, so that it is with difficulty distinguished from the unaltered igneous rock in the field, while from this coarse rock there are gradations depending upon the comminution of the component materials down to very fine-

grained tuffs and argillaceous rocks, in which the fragments are so small as to be indistinguishable. Along this part of the river the most common rock besides true diabase is a massive, dark-green, medium-grained tuff, having a trap-like appearance, whose true nature is often not determinable except under the microscope. In places this becomes finer-grained and changes to a dark-green, smooth-textured slate, which is often calcareous in zones. In these waterlaid rocks glauconite is abundant, and on alteration produces siliceous and ferruginous rocks, and even true cherts or jasperoids, red, green, brown, and black in color. Jasperoids having less varied color are also formed along shear zones by deposition of silica by percolating waters, and some close-textured rocks having a similar appearance are very fine-grained siliceous sediments.

The rocks of the Rampart series in this region contain frequent, though not abundant, veins of quartz and calcite, which are usually unbroken and apparently of comparatively late origin. They are nonpersistent and are associated with joint planes and shear zones which are older than the veins, and have, indeed, been the cause of their formation. The evidence of earlier motion is shown by slipping planes with striated surfaces and by local slight stretching or shearing; in places, also, there are frequent breccias cemented by quartz and calcite. These shear zones, however, though frequent, are only local, most of the rock being quite massive.

Occasional dikes are found cutting this series, and among these aplite has been determined.

Mynook Creek.—The Tertiary conglomerates, grits, and shales which overlie the rocks of the Rampart series above Hess Creek seem to be only a comparatively small patch, for on Mynook Creek, a short distance above its mouth, typical rocks of the Rampart series again come in. These are essentially the same as found below Fort Hamlin, since they consist of diabase changing into sedimentary rocks, some of which become very fine-grained and shaly. One variety is a green, aphanitic, smooth-textured slate, which becomes red on oxidation; other slates are dark-gray or black from the presence of carbonaceous matter. The rocks are well jointed, and in places the joints are set so close together as to form shear zones, along which there has often been silicification and the deposition of metallic sulphides; and along crevices have been formed quartz veins, a few of which are very wide and persistent and appear to contain gold in small amount.

Between Mynook Creek and the Tanana.—For 18 or 20 miles below Mynook Creek there outcrop at intervals coarse green diabase and the associated rocks of the Rampart series; and the hills a short distance from the river show the dark-red color which the rocks of this series assume on oxidation. Below these rocks, and apparently overlying them with approximately the same strike and dip, come limestones, gray, lithographic, and often carbonaceous, associated with shales. These shales carry indistinct plant remains which suggest

Devonian age. Fifteen or 20 miles below this place the green rocks of the Rampart series again appear, being probably brought up by a fault, since no change in the dip is apparent. At this point the series is cut by great dikes of granite and occupies a belt 15 or 20 miles wide along the river, below which it is overlain unconformably by Tertiary sandstones and conglomerates composed largely of material derived from the Rampart rocks. Below this patch of Tertiary rocks there are exposed, a few miles above the mouth of the Tanana, underlying calcareous quartzites, which probably belong to the Fortymile series; and below the Tanana the Birch Creek series is exposed, as already described. Between the Tanana and the sea the rocks of the Rampart series are not exposed along the Yukon.

MEGASCOPIC CHARACTERISTICS OF THE ROCKS OF THE RAMPART SERIES.

The rocks which have been described from widely separated localities, and which have been correlated as the Rampart series, are characterized throughout by a general dark-green color, which changes to dark red on exposed surfaces, by a peculiar massive structure and firm texture, and by the constantly recurring evidence of volcanic agencies. Throughout these rocks are masses of diabase, which apparently have the characters of volcanic flows; there are also great thicknesses of tuffs derived from these diabases. Transitions from the solid diabase to the coarse fragmental rock, made up of diabasic detritus, have often been observed, and rarely is there any contact phenomena or any line of separation between the diabases and the tuffs. The coarse tuffs pass gradually into tuffs of finer grain, and these in turn into fine-textured gray slates, which become calcareous, and so pass into impure limestones or become carbonaceous. Glauconite is very abundant in these sedimentary rocks, and gives rise by its alteration to jasperoids of brilliant colors—green, brown, red, and gray. Jasperoids also arise from the deposition of xenogenous silica in the impure limestones by water percolating along shear zones. Some of the finer-grained feldspathic rocks are also indurated in the same manner. Other rocks which also have nearly the same appearance are chiefly light-gray in color and appear to be very fine-grained siliceous sediments or novaculites. These fine-grained siliceous rocks are the hardest rocks in the formation, and so are most persistent in detrital rocks which are derived from the disintegration of the rocks of the Rampart series; therefore pebbles in the younger overlying conglomerates are often almost exclusively of varicolored jasperoids, cherts, and other siliceous rocks.

CLASSIFICATION OF THE ROCKS OF THE RAMPART SERIES.

Diabase.—The diabase is everywhere remarkably uniform in appearance and composition. It is generally dark-green in color, with a

texture varying from fine or nearly aphanitic to rather coarse and granular, and sometimes has a tendency toward a porphyritic structure. The feldspars in the coarse rock are light-gray in color, while the rest of the minerals are of a general dark green.

Microscopically the structure is holocrystalline and often ophitic, the minerals being well crystallized and interlocking. The essential minerals are plagioclase and augite, with often much orthoclase and diallage. Accessories which often become very important are olivine, hornblende, serpentine, epidote, calcite, magnetite, ilmenite, and pyrite. Of these the olivine is always a primary mineral, and the magnetite and ilmenite probably nearly always; quartz is sometimes primary and sometimes evidently secondary, while the calcite, epidote, and pyrite seem to depend upon the decomposition of the essential constituent minerals; the hornblende is nearly always derived from the augite, and the serpentine usually from the olivine, frequently from the augite.

Quartz-diabase.—Quartz-diabase differs from the typical rock just described only in the increase of primary quartz to such a quantity as to form an essential constituent. This gives the rock in the hand specimen a lighter and grayish color.

Olivine-diabase.—This variety is very common and is the same as the typical diabase, except that the olivine becomes an essential mineral. There is sometimes a tendency toward a porphyritic structure.

Quartz-olivine-diabase.—In the single thin section examined both quartz and olivine were so abundant as to be essential minerals, while the structure of the rock was otherwise the same as that of the ordinary type.

Gabbroid olivine-diabase.—In a single specimen picked up in the "float" on Hunter Creek, which is one of the branches of Mynook Creek, the essential constituents are augite, diallage, and olivine. Plagioclase is present in small amounts, and there is a decided pœcilitic structure. The olivine is greatly altered to serpentine in fibrous and spherulitic masses. There is a remarkably large proportion of metallic sulphides in the rock, among which are marcasite, pyrite, chalcopyrite, and pyrrhotite. These sulphides, judging from their habit, are probably indigenous and primary. The pyrrhotite contains a trace of nickel, as determined by Dr. Stokes, of the Survey.

Serpentine-tuffs.—Under this heading are classed certain rocks which were collected on the Yukon River above Mission Creek and on American Creek. In the hand specimen they are dark-green, heavy and massive, with the color and greasy feel of serpentine. Under the microscope they are seen to be made up chiefly of serpentine which has no special structure. In one of the sections, however, are broken and irregular grains and shreds of olivine, which pass into serpentine by a process of alteration; there are smaller fragments of plagioclase feldspar. Besides the serpentine in the groundmass there are chlorite

and other decomposition products, and often abundant magnetite and other iron oxides, which also appear to be decomposition products and to be derived from the same source as the serpentine.

Diabasic tuffs.—These rocks are sometimes coarse-grained and contain angular fragments of igneous rocks, which are very noticeable in the hand specimen; others are fine-grained or aphanitic. The color is dark-green to nearly black. The typical coarse tuffs are made up of large fragments of augite, olivine, and feldspar, all more or less decomposed, and arranged without order; the groundmass is fine-grained, and consists largely of serpentine. In another type the groundmass is predominant; it is a fine microcryptocrystalline aggregate, largely kaolinic and serpentinous. In this groundmass are many angular or subangular fragments, some of which are several inches in length, and are light-colored and porous in the hand specimen. Under the microscope some of these fragments seem to be glassy, while others vary from microfelsitic to finely crystalline; in the latter case they are apparently made up largely of feldspar and calcite. These fragments seem to represent the groundmass of some volcanic rock—andesite, or basalt.

The finer-grained diabasic tuffs have essentially the same groundmass as already noted, which contains large, broken crystals of augite, hornblende, quartz, feldspar, and actinolite. In one locality above Circle City this dark-green tuff is spotted with many small, white grains of calcite, which under the microscope show a fibrous structure suggesting organic origin. In some of these rocks, also, glauconite has formed abundantly. The decomposition of this mineral to silica, typically chalcedonic, often spherulitic, and to pyrite or siderite, may often be observed.

Indeterminable tuffs.—Those rocks which are clearly of tuffaceous origin but in which the internal evidence is not conclusive as to their derivation from diabase are classed simply as tuffs. They show a gradual transition from the tuffs which are made up of diabasic detritus, and differ from them chiefly in their finer grain. In all these rocks are small detrital fragments, consisting mostly of quartz and feldspar, embedded in a fine-grained, microcrystalline, chloritic and serpentinous groundmass.

Clay-slate.—The fine-grained tuffs pass gradually into the clay-slates by the disappearance of the larger detrital fragments. These rocks vary from light green to nearly black in color, and are smooth-textured, sometimes comparatively massive, oftener fissile or slaty. Under the microscope they are seen to be made up of a very fine aggregate of tiny detrital quartz grains, with much kaolinic and muscovitic, often calcareous and carbonaceous, material.

Carbonaceous slate.—This type differs from the last described chiefly in the presence of abundant carbonaceous material, which gives a dark-green or nearly black color. The rock is generally strongly banded or slaty, and pyrite is generally present in large crystals.

Impure sandstone.—On the south fork of Fortymile Creek and on Mynook Creek were noted beds of impure sandstone in the Rampart series. The detrital fragments are large and easily determinable, and there is considerable calcite, usually present as a cement. The rocks are gray or green in color and granular in texture. They are made up of closely compacted grains of quartz, plagioclase, and orthoclase, with other less-frequent minerals. Much of the feldspar appears to be microcline, suggesting a granitic origin. The rock from Fortymile Creek contains abundant glauconite in irregular grains, with which are associated as a decomposition product numerous crystals of siderite. The interstices between the detrital grains are usually filled with calcite, and in this calcite is generally considerable plainly xenogenous pyrite in perfect crystals. On Mynook Creek, besides the iron pyrite is considerable chalcopyrite, which stains the rock green on oxidation. This green stain was found by Dr. Hillebrand, of the Survey, to be a mixture of calcite and copper silicate. Two assays of rock carrying this copper pyrite were made; one, by Prof. C. E. Munroe, of Washington, gave no gold or silver; and another, by R. H. Officer, of Salt Lake City, gave no gold and two-tenths of an ounce of silver to the ton; a different sample gave Mr. Officer one one-hundredth of an ounce of gold and no silver.

Impure limestone.—Impure limestone is found at intervals throughout the formation, but not in great amount. These limestones are generally dark-gray or dark-blue in color, and are made up mostly of small grains of crystalline calcite. This calcite incloses detrital grains of quartz, feldspar, and indeterminable decomposition products; it also sometimes contains carbonaceous material and glauconite, with secondary silica of the chalcedonic or cryptocrystalline variety, and secondary grains of pyrite and hematite, sometimes partly altered to siderite.

Fine-grained quartzite, or novaculite.—This rock is found at various points in the Rampart series, in comparatively thin beds. Megascopically it is light-green and aphanitic, and generally thin-bedded; microscopically it is seen to be made up of very small, rounded detrital grains of quartz, cemented by secondary silica. There are also occasionally present muscovite, zircon, and kaolinic and ferruginous material.

Jasperoid.—The jasperoids are rocks consisting chiefly of silica, generally chalcedonic or cryptocrystalline, and are plainly derived from the silicification of other rocks. They are formed in various ways, but in all true jasperoids the silica is secondary, and introduced subsequent to the deposition of the rock.

An interesting and important variety is the glauconitic jasperoid or taconite, such as has been described by the writer as occurring abundantly in the iron-bearing rocks of the Mesabi range in Minnesota. In the rocks of the Rampart series it also appears that the glauconitic

limestones pass into jasperoids, which are colored red, green, brown, or gray by iron in its different forms, or occasionally by manganese, or which are light-gray or nearly white, as a result of the separation of the iron. The processes of this change are exactly those which have been described for the taconites of Minnesota.

A rock exhibiting well the transition between the glauconitic limestone and the jasperoid was collected on the Yukon River in the Lower Ramparts. Here in a cliff was seen a thin seam of bright-red jasper, with dark-green fine-grained rock on both sides, which was in immediate contact with coarser-textured green rock shown by microscopic examination to be typical tuff. A thin section of the rock at the contact of the bright-red jasper seam with the dark-green chert is made up mostly of cryptocrystalline silica, which is chalcedonic in places, with spherulitic aggregates showing dark crosses under crossed nicols. Glauconite is abundant in irregular grains of all sizes, and the decomposition of this mineral, forming chalcedonic silica and iron oxide, is seen in all its stages. The process is that observed by the writer in the rocks of the Mesabi iron range.[1] This decomposition accounts for the ragged outlines of the grains of glauconite. The iron is dark-red, apparently ocherous hematite, and occurs everywhere, though it is considerably less in amount than the glauconite. It shows a tendency to accumulate in irregular clumps. Calcite in frequent ragged areas is residual, being encroached on by cryptocrystalline silica, which is evidently replacing it. The silica occurs also in isolated grains sprinkled throughout the calcite. These isolated grains are likewise evidently secondary and are replacing the calcite, this being one of the most ordinary phenomena of the silicification of limestone, as observed by the writer in the rocks of Aspen, Colorado.[2] The residual calcite is often of a greenish-blue color, which is sometimes barely perceptible and again very deep. There is frequently a gradual transition from this color to the deep brownish-green of the glauconite. The greenish-blue color suggests manganese, an element often occurring in small amount in glauconite, from which it may have been separated during the decomposition of this mineral; and a chemical test by Dr. Hillebrand, of the Survey, showed a trace of manganese in the rock sufficient to account for the coloring.

In this thin section also are seen organic remains of complicated structure. The structure is brought into prominence by the increased amount of glauconite and iron oxide which have formed in the canals and other cavities. Mr. Bashford Dean, of Columbia College, has examined this section and has determined the structure as unquestionably that of a fish-tooth.

A section of the bright-red jasper into which the green rock passes, taken only a few inches from the specimen just described, is composed

[1] Bull. Geol. Nat. Hist. Survey, Minnesota, No. 10, p. 133.
[2] See Mon. U. S. Geol. Survey, Vol. XXXI (not yet published).

entirely of very fine-grained silica which is stained throughout with iron oxide so deeply that the rock is aphanitic even under the microscope.

Green and red jasperoids having the same structure as that described above, with the exception of the residual glauconite and calcite, are frequent in the rocks of the Rampart series, and by reason of their superior hardness are most conspicuous in conglomerates which have been derived from these rocks. They are made up essentially of silica, which varies from phenocrystalline to finely cryptocrystalline, and becomes often chalcedonic, fibrous, or spherulitic. Where the original rock contained impurities, these generally remain in the jasperoid, so that in the silica is frequently found carbonaceous and clayey material.

Schistose rocks.—Along shear zones the rocks of the Rampart series are sometimes slightly metamorphosed and new minerals are produced. On American Creek and on the Yukon River above Mission Creek were collected specimens of such rock, which are apparently slightly metamorphosed, impure, fine-grained sediments. They are dark-green in color and generally fine-grained or aphanitic. They consist of very finely divided quartz, with biotite or chlorite; occasionally there is considerable tourmaline and epidote, and specular iron is present in perfect crystals.

DIKES IN THE RAMPART SERIES.

The rocks of the Rampart series are cut occasionally by later intrusions. The most frequent dike rock is granite, which occurs in immense bodies in the Lower Ramparts below Mynook Creek. Dikes of granite-porphyry and of true porphyry, which are probably closely related to one another, were noted along the divide between Chicken Creek and the South Fork of Fortymile Creek; and in the same vicinity are large dikes of quartz-diorite or granite, which is probably connected genetically with the finer-grained rocks. Dikes of aplite were noted on American Creek and at the end of the Yukon Flats above Fort Hamlin; on American Creek is also a small dike of altered rock, which appears to be mica-lamprophyre.

FOLDING.

Owing to the massive nature of the rocks of the Rampart series the bedding is generally not discernible or can not be distinguished from the jointing and shearing. Judging from the underlying and overlying formations, however, this series must have been considerably folded, although not intensely. Near Fort Hamlin an opportunity was found to observe the true stratification, which was: Strike, N. 50° E.; dip. 20° NW. Farther down the river, in the Ramparts, a strike of N. 25° E. and a dip of 10° SE. were observed. In the green slates of Mynook Creek a strike of N. 30° E. and a dip of 80°

SE. were noted. These observations, taken together with the attitude of the limestones and shales which succeed the Rampart series some distance below Mynook Creek, seem to show that the rocks have a general northeast strike and a southeast dip in the Lower Ramparts.

JOINTS.

At American Creek considerable jointing was noted. One pronounced set is nearly horizontal, while another strikes N. 65° E. and dips 75° NW. Above Fort Hamlin pronounced vertical jointing strikes N. 25° W., and some distance below Fort Hamlin many joints and slip-surfaces, striking north and south and dipping 50° SW., were noted. Above Hess Creek, jointing with a strike of N. 20° E. and a dip of 65° SE. was noted. On Mynook Creek at different localities, only a mile or so apart, was seen jointing with the following attitudes: strike N. 85° E., dip 80° SE.; strike N. 10° E., dip 80° SE.; strike N. 65° W. dip 70° NE. The joints at these different places in widely separated parts of the Rampart series show no uniformity in attitude and suggest no common cause.

SHEAR ZONES.

The shear zones are intimately connected with the joints, and are, in fact, essentially a series of parallel joints, set very close together, along which there has been some movement or slipping in the rocks, producing local alteration. The rock along the shear zone is generally somewhat crushed or stretched, and metamorphic minerals are sometimes developed on a small scale. More important changes are wrought by the introduction of xenogenous materials by waters which find convenient channels along these zones. By the action of these waters the rock is generally more or less silicified, and there is often deposition of metallic sulphides.

VEINS.

Veins of quartz and calcite are frequently found, especially along shear zones, where they are formed in the crevices left by the movements in the rock. They are generally unbroken, since they have formed subsequent to the shearing. On Little Mynook Creek a vein of pure white quartz 6 feet wide was noted, which appeared to be persistent and which was said to yield gold on panning, although none appeared in outcrop.

AGE OF THE RAMPART SERIES.

On Fortymile Creek near Franklin Gulch the Rampart rocks appear to overlie immediately the Fortymile series. This is the only place where the junction of the Rampart series with the underlying formations has been observed. Below Mynook Creek the rocks of this

series appear to be directly overlain by fine-grained, often carbonaceous limestones and shales, which carry plant remains suggesting Devonian age. On the Yukon above Circle City the Rampart rocks are succeeded by probably overlying limestones and shales similar to those just mentioned. In some of these limestones are characteristic Carboniferous fossils. We may therefore conclude that the rocks of this series are younger than the Fortymile series and older than the other formations which will be described. The internal structure of the rocks themselves shows clearly that they are younger than the Fortymile rocks, for even when the two series occur in the same region, as on the South Fork of Fortymile Creek, the Fortymile series shows the results of great disturbances, which have not affected the rocks of the Rampart series, and which therefore occurred previous to their deposition. These disturbances are manifested in the older rocks by the production of highly crystalline schists, the formation of extremely abundant quartz veins, and other phenomena which are wanting or are developed on a much smaller scale in the Rampart series. On the other hand, the formations which will be considered later show somewhat less dynamic disturbance than do the Rampart rocks.

In a specimen from the Rampart series below Mynook Creek, on the Yukon, sections of organic bodies were noticed in thin section, which were identified by Mr. Bashford Dean, of Columbia College, as fish teeth, but no more specific determination can be made. These are the only fossil remains found.[1]

ECONOMIC IMPORTANCE.

The rocks of this series are characterized throughout by great basicity. The diabases contain a large proportion of idiogenous sulphides, and of iron and other metals as component elements of augite, olivine, and other bisilicates. In the tuffs, which make up a large proportion of the rocks, these materials are separated and rendered especially liable to decomposition; afterward the rearrangement of the component elements follows naturally, and the concentration of the metals in favorable localities must be looked for. Such localities are afforded by shear zones, which may form channels for waters bearing metallic solutions derived from the decomposed diabases and tuffs, and along which these metals may be deposited under proper conditions. Many of these mineralized shear zones

[1] Dr. W. H. Dall, in 1867, reported (Am. Jour. Sci., third series, Vol. XLV, p. 96) finding, "just above the Ramparts, pebbles of Niagara limestone with its characteristic fossils." No further mention is made. The pebbles referred to may have been derived from the Rampart series, for these are the only rocks exposed along the Yukon at the locality named. Above this the river flows for several hundred miles through deposits of silt, with few or no rock outcrops. Interbedded with these silts are sometimes gravels, which are, however, made up almost exclusively of quartz pebbles. The derivation of the pebbles mentioned by Dall is therefore probably not from these gravels; and while the meagerness of the information is such that no conclusion can be safely drawn from it, yet, on taking it together with the evidence already brought forward to show that the Rampart series is older than the Devonian and Carboniferous, we may be justified in suspecting a Silurian age for it.

have been observed, but thus far assays show only comparatively insignificant amounts of gold and silver; in the future, however, profitable ore deposits may very likely be found.

PREVIOUS NOTES.

Mr. R. G. McConnell[1] makes mention of this series as follows in summarizing the crystalline schists west of the Rocky Mountains:

> Along the eastern edge of the crystalline belt the rocks are characterized by a general greenish color and consist largely of altered volcanic rocks. The most important variety is a sheared and altered greenish quartzose schist. With this are associated greenish chlorite-bearing schists, lustrous mica-schists, diabases, and serpentines. The schists are interbedded with occasional bands of slates and crystalline limestones, and are broken through in many places by igneous intrusions.

Dr. G. M. Dawson[2] has noted diabases, conglomerates, argillites, and interbedded limestones at various points along the Lewes River above its junction with the Pelly. Concerning the rocks along the Lewes near the junction with the Big Salmon River, he writes:

> From the few exposures which occur on that part of the Lewes which cuts across the Seminow Hills the range would appear to be composed of greenish, altered volcanic rocks, probably diabase, interbedded with gray or whitish marble. Rocks of this character are those which have supplied the material for the conglomerates described before (p. 146B), and are evidently much older than these and doubtless referable to the Paleozoic.

THE TAHKANDIT SERIES.

PRELIMINARY STATEMENT.

Under the name Tahkandit series has been classified a series of white or gray limestones alternating with carbonaceous shales and sometimes with conglomerates This directly overlies the Rampart series and underlies the Mission Creek series, which will be described later. In this series have been found good Upper Carboniferous fossils and plant remains which are probably of Devonian age, but the limits of geological time assigned to it in this classification are not intended to be definite. The name Tahkandit is taken from the Tahkandit River, which enters the Yukon near the locality where Upper Carboniferous fossils are found in white crystalline limestones.

DISTRIBUTION AND GENERAL DESCRIPTION.

ON THE YUKON ABOVE CIRCLE CITY.

At the mouth of Mission Creek are bold cliffs consisting of black shales with thin-bedded sandstones and limestones, which will be described as the Mission Creek series. These are overlain farther

[1] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1888-89, new series, Vol. IV, p. 13D.
[2] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1887-88, new series, Vol. III, Part I, p. 154B.

down by heavy conglomerates, shales, and sandstones, carrying abundant plant remains, the latter belonging to the Kenai series. The underlying shaly rocks alternate in bands with the overlying conglomeratic formation nearly to the Tahkandit River, where another formation consisting of heavy beds of pure white crystalline limestone, weathering yellow on exposed surfaces, comes in.

These white crystalline limestones change into gray, thin-bedded limestones, and alternate with beds of shales and conglomerates. The conglomerates contain pebbles of gray, white, black, and especially green chert, which is similar to that observed in the Rampart rocks, and so suggests derivation from that series.

In one locality where careful study was made the conglomerates become calcareous, and so pass gradually into the white crystalline limestone; and both the calcareous conglomerate and the pure marble are highly fossiliferous. The fossils collected were identified as Carboniferous by Mr. Charles Schuchert, who made the following report, addressed to the Director:

In regard to the fossils sent to me by Mr. J. E. Spurr, and collected by his party on the Yukon River above Circle City, Alaska, I respectfully report the following:

The collection is an excellent one, and is the best collection of Carboniferous fossils from Alaska in the United States National Museum. The age of these fossils is unmistakably Carboniferous, and since no characteristic Lower Carboniferous species are present I infer this fauna to be of Upper Carboniferous age.

This collection also indicated that the Yukon Carboniferous is more closely related to the Nevada Upper Carboniferous than to either the California or Mississippi Valley faunas. The Yukon, Nevada, and Mississippi faunas appear to have more species in common than any of these with that of Northern California.

The following is a list of the species:

Amplexus? Apparently related to A. zaphrentiformis.
Productus multistriatus Meek.
Productus semireticulatus Martin.
Productus punctatus variety.
Productus longispinus Sowerby.
Productus longispinus Sowerby?
Productus like boonensis, but much larger. Cf. P. undatus Defrance.
Spirifer n. sp. It has its nearest relationship in S. scobinus Meek, but differs in having more plications arranged in distinct bundle.
Aviculopecten sp. undet.

These Carboniferous rocks are greatly but not intensely folded, the plications being of about the same degree of intensity as in the overlying conglomerates and shales between the Tahkandit River and Mission Creek. The fossil plants from these overlying conglomerates seem to place the series in the Eocene period, and this shows that the most of the folding which has affected in nearly the same degree all the formations from the Eocene as far down as the Carboniferous was comparatively recent—certainly post-Eocene. This conclusion receives support from the fact that the topography throughout this district shows a very close relation to the structure, in some

places following it faithfully. Fig. 19 is a photograph of the Carboniferous rocks on the Yukon near the Tahkandit River, opposite the spot where the fossils were collected. A broad band of white crystalline limestone makes the structure conspicuous from a distance, and the folding into an anticline and syncline is observable in the picture. It is also seen that the anticline forms a hill and the syncline a valley, the limits of these topographic features corresponding closely to the limits of the folds. In this case there has been no profound erosion since the folding.

Below the Tahkandit River there come in calcareous and carbonaceous shales and thin-bedded limestones, which are probably to be assigned to the same series as the rocks immediately below Mission Creek. These rocks continue outcropping along the river, alternating in bands with the conglomerates, sandstones, and grits belonging to the series which has been noted as overlying the shales between Mission Creek and the Tahkandit River, as far as the junction of the Charlie River with the Yukon. Near this point there come in gray and dark-blue limestones of distinctly older appearance; these are sometimes dark-blue or dark-gray and coarsely crystalline, but are usually very fine-grained or aphanitic and gray or nearly black, the color being due largely to the presence of carbonaceous material. The carbonaceous limestones become thin-bedded and pass into calcareous and carbonaceous shales. The natural gray or black color of the fresh rock becomes in places yellow-brown from iron rust, which is derived from the decomposition of pyrite; this pyrite is disseminated in tiny crystals or nut-like concretions. These rocks outcrop for 30 or 40 miles along the Yukon below Charlie River. At the eastern end of the exposure imperfect fossils were found in rather massive gray limestone, but none good enough for identification. Some 30 or 40 miles above Circle City these rocks are succeeded by the rocks of the Rampart series, already described.

BELOW MYNOOK CREEK.

About 18 or 20 miles below the mouth of Mynook Creek, on the Yukon, the rocks of the Rampart series are succeeded by gray lithographic limestone, which in places has the appearance of having been fossiliferous; but the rock has been so kneaded by dynamic action that the fossils are unrecognizable. There are many seams of novaculite or fine-grained quartzite, which show by their separation and brecciation the movements which have taken place. (See fig. 9, p. 172.) These limestones alternate with carbonaceous slates, which are sometimes schistose and graphitic; the less altered of these carry indistinct plant remains. Some of these were submitted to Mr. David White, of the Survey, who made the following report:

I have carefully examined the three fragments you transmit in graphitic slate from the Yukon River, 20 miles below Mynook Creek. There can be no doubt that the remains are organic, and, while they are not absolutely even generically

determinable, there is room for but little doubt that they represent plant fragments. They seem to be remains of vascular plants.

I should say they might be referable to Psilophyton, or possibly some slender fern rachises. If the former, they might occur anywhere from the Lower Devonian to the Lower Carboniferous (inclusive). From their organization we may conclude that they are probably not older than the Devonian. Such fragments are, in general, more common in the Middle and Upper Devonian; and I more than half expect that the discovery of additional and more complete material will indicate an age in that region of the geological column.

Too much reliance should not, however, be placed on the obscure fragments in hand, since they are hardly generically identifiable, still less specifically so; and while I interpret from them a meaning as above stated, it is quite possible that

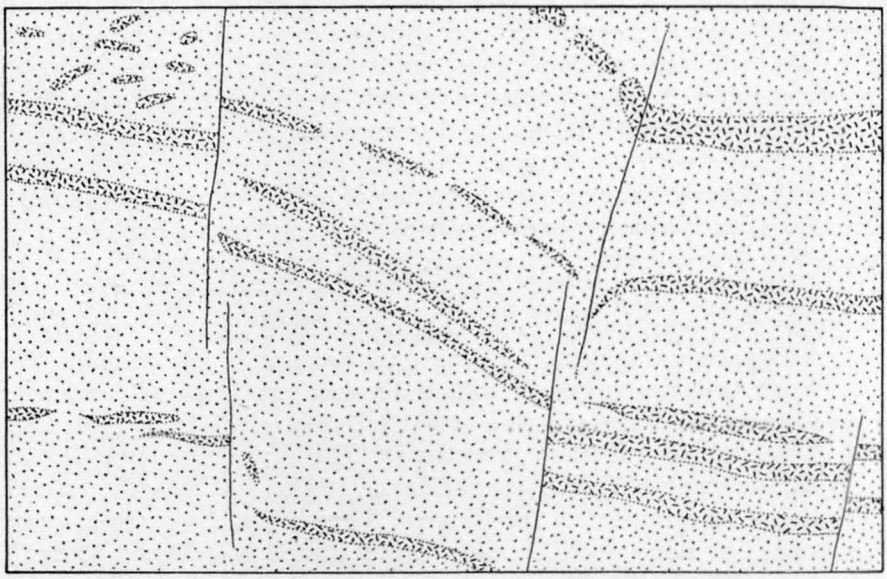


FIG. 9.—Kneading in aphanitic limestone of Tahkandit series, Lower Ramparts.

additional material (which is most to be desired) will necessitate a considerable alteration of opinion. Any expression of opinion as to the age of the fragments before me is hazardous, though they suggest Middle or Upper Devonian to me.

Under the microscope the limestone appears to be very fine grained and comparatively pure, like the gray lithographic limestones described below the Charlie River. The quartz seams are seen microscopically to be fine-grained quartzites or novaculites, although in the hand specimen they often have the appearance of gray chert. In portions of the rock these novaculites are sheared, and sometimes tremolite, green hornblende, and biotite have been developed as metamorphic minerals. Other seams of light-green aphanitic rock, which are nearly like the novaculites in the hand specimen, are seen under the microscope to be compact clay-slates.

NEAR THE MELOZIKAKAT RIVER.

Near the mouth of the Melozikakat River, a locality not shown on the map of the Yukon gold fields, but which may be found on Pls. XXXII and XXXIV, there outcrops for several miles blue-gray crystalline limestone underlain by black slate. In this limestone are thin seams of white marble, and the rock is cut by small stringer veins of calcite and occasionally of quartz. There is some jointing, frequent slipping, and slight shearing, especially along bedding planes; but there is no uniform system in the jointing, nor general schistosity, nor any other other evidence of regional strains. At the eastern or upper end of the exposure the blue-gray limestones outcrop, striking N. 60° E. and dipping 45° SE.; and at the west end of the exposure are the same limestones with the same strike, but dipping 30° NW. Between these two exposures come in the slates. These rocks, therefore, form a syncline which exposes by erosion the underlying slates between the two belts of limestone.

CORRELATION AND NOMENCLATURE.

The rocks already described below Mynook Creek and those between Circle City and Charlie River resemble one another closely in lithological characters and approximately in the amount of metamorphism which they have undergone. Below Mynook Creek the rocks are somewhat more altered than above Circle City, but this may be accounted for by the probability that the Rampart Mountains, in which the former exposures occur, have been subjected to more disturbance than the regions lying to the north and to the south. It is to this disturbance that the existence of the mountains is probably due. The gray limestones and shales below Mynook Creek, moreover, appear to overlie directly the rocks of the Rampart series, while above Circle City rocks which resemble these lithologically are also succeeded by the rocks of the Rampart series in probably the same relation. These rocks, consisting of gray limestones and shales, outcrop below Charlie River on the Yukon, and appear to be succeeded farther up the river by white crystalline limestones with interbedded shales and conglomerates, and these limestones carry Carboniferous fossils; while in the locality below Mynook Creek the shales associated with the gray lithographic limestone carry plant remains which suggest Devonian age. In the rocks noted near the Melozikakat no fossils were found, but the general lithological characters of these rocks and the extent to which they have been influenced by dynamic changes strongly suggest this general Devonian-Carboniferous series.

All these rocks may then be classed together as a single series with somewhat indefinite limits, and may be conveniently called the Tahkandit series, from the Tahkandit River, which enters the Yukon

near the place where Carboniferous fossils were found. This series may then be defined as consisting of limestones, sometimes white, generally green or black, sometimes crystalline, often aphanitic or lithographic. These limestones become thin-bedded and carbonaceous and alternate with shales. The white crystalline limestones of the Carboniferous above Circle City also alternate with beds of conglomerate containing chert.

The Tahkandit rocks overlie the Rampart series directly, and the chert in the conglomerate mentioned above suggests derivation from the rocks of the Rampart series. Thus an unconformity, or at least an erosion interval, in some part of the Tahkandit series may be suspected.

The lower limit of this series is thus fairly definite. The upper limit is not so well marked, but is taken approximately at the bottom of a series of black shales with interbedded impure sandstones and limestones, which is exposed at and below Mission Creek along the Yukon. The fossils taken from various points in the Tahkandit series show a range in age from probable Upper Carboniferous to probable Devonian, but the series may contain formations belonging to other periods. It has no very definite limits in point of age, and has been named merely for the classification of our very rudimentary knowledge, and for convenience in mapping.

OTHER AREAS MAPPED AS TAHKANDIT ROCKS.

Mr. R. G. McConnell[1] notes that on the Porcupine, below the mouth of the Succor River, there outcrop for 15 miles yellowish-weathering limestones which yield *Atrypa reticularis* with fragmentary specimens of corals, and which he refers, in part at least, to the Devonian. Farther down the river, close to the edge of the Yukon Flats (which extend up the Porcupine for a long distance), these limestones are interbedded with dark shales, which Mr. McConnell considers as probably Cretaceous.

Mr. W. Ogilvie[2] has made a traverse from the Yukon up the Tatondu River across to the headwaters of the Porcupine, and so down to the confluence of the Porcupine with the Bell River. On this trip he has noted that dark shales, overlain by fine-grained conglomerates, occur along the Tatondu for 27 miles from its mouth. At two points in this distance limestones rise to the surface from beneath the shales, and in the upper part of the valley of the Tatondu the shales and conglomerates are replaced by these grayish Paleozoic limestones. Similar limestones were also met with all across the watershed separating the Tatondu from the Porcupine, where they form a range of high mountains, and down the Porcupine as far as the Cathedral rocks.

Mr. I. C. Russell[3] notes that the crest of the mountains, a few miles

[1] Ann. Rept. Geol. Nat. Hist. Survey Canada, Vol. IV, Sec. D, p. 133.
[2] Op. cit., p. 138.
[3] Bull. Geol. Soc. America, Vol. I, p. 136.

north of the Yukon, at the international boundary, "is composed of compact earthy limestone in nearly vertical strata, striking nearly east and west, conformably with the trend of the mountains."

THE MISSION CREEK SERIES.

PRELIMINARY STATEMENT.

Stratigraphically above the rocks of the Tahkandit series come black calcareous or feldspathic shales, which alternate with thin beds of impure limestone and with beds of gray sandstone. These rocks are generally considerably and sometimes intensely folded, and are sometimes slightly sheared and altered, but ordinarily are fresh and recent in appearance. They sometimes overlap the rocks of the Tahkandit series, so that in at least two localities visited they lie upon the Rampart series. In both these cases the lowest bed of the younger formation is a conglomerate containing many fragments of the rock on which it rests. This series has been named from Mission Creek, in the vicinity of which it is well exposed. It is probably, in part at least, of Cretaceous age.

DISTRIBUTION AND GENERAL DESCRIPTION.

NAPOLEON AND CHICKEN CREEKS.

According to the observations of Mr. Schrader, the mouth of Napoleon Creek seems to be nearly on the contact of the Rampart series with the Fortymile series. Just above the mouth, however, there is encountered, resting upon these older rocks, a conglomerate, which is made up at the bottom of pebbles ranging in size from mere grains to a foot in diameter. These pebbles are subangular in shape, showing that they have not traveled far, and among them are fragments of quartzite and of vein quartz, probably derived from the Birch Creek or Fortymile series; of aplite and porphyry, similar to the dikes already mentioned in these older rocks, and of compact gray and green slate, identical with the rocks of the Rampart series exposed on the ridge between Fortymile Creek and Chicken Creek, only a few miles away from this conglomerate. The conglomerate is very firm and coherent when fresh, so that the pebbles often break before the cement does. The strike of the rock is N. 25° E. and the dip 65° SE. Farther up the creek this conglomerate is overlain conformably by coarse gray sandstone and grit, interstratified with seams of a black coaly slate carrying plant remains, which, however, are so poorly preserved as to be indeterminable. Above this comes finer sandstone, slightly interstratified with coaly slate and striking N. 49° E., with a dip of 50° SE. There is here considerable slickensiding and jointing; the principal set of joints trend N. 16° W. and dip 80° SW. Higher up in the series the black carbonaceous shales become more abundant, and contain beds of compact greenish clay-slates, while still

higher up comes arenaceous limestone, which is in part marmorized by contact with a body of diabasic basalt. In this marmorized limestone there is a prominent jointing, striking N. 49° E. and dipping 30° NW.

The younger series, consisting of a basal conglomerate passing upward into sandstone, grits, shales, and limestones, is seen at the mouth of the gulch to rest unconformably on the older rocks, of which fragments are found in the conglomerate. In the bed of Napoleon Creek the gravels in the belt occupied by the basal conglomerate and immediately below this belt are rich in placer gold, while above this comparatively narrow zone they are entirely barren and below they are very poor. It is probable, therefore, that the gold is derived from the conglomerate, and from the fact that this conglomerate is composed of fragments of the older auriferous rocks it appears that the gold from these rocks has been concentrated in it, so that it is an ancient or fossil placer.

On Chicken Creek black, carbonaceous, compact shales, containing impure coal seams, form a large part of the bed-rock.

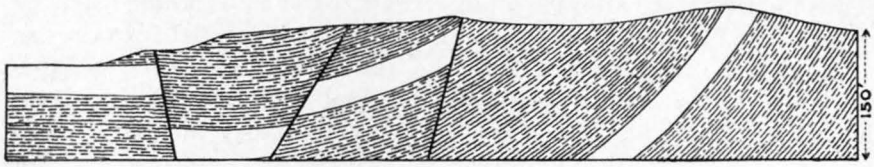
Microscopic characters.—Under the microscope the cement of the Napoleon Creek conglomerate is seen to be essentially like the associated beds of grit; both are made up of fragments of varying size, often angular and ill assorted. These fragments are of quartz and feldspar, both plagioclase and orthoclase, with biotite, often altered to chlorite. The finer material inclosing these grains is a calcareous and muscovitic aggregate, containing tiny grains of crystalline specular iron, which are often altered in part to siderite and limonite. In many cases these iron minerals are seen to be derived from the biotite in the process of its decomposition. The microscope also shows the shales to be composed of tiny particles of quartz and submicroscopic aggregates of decomposition products, with much carbonaceous material in the black varieties.

BELOW FORTYMILE CREEK.

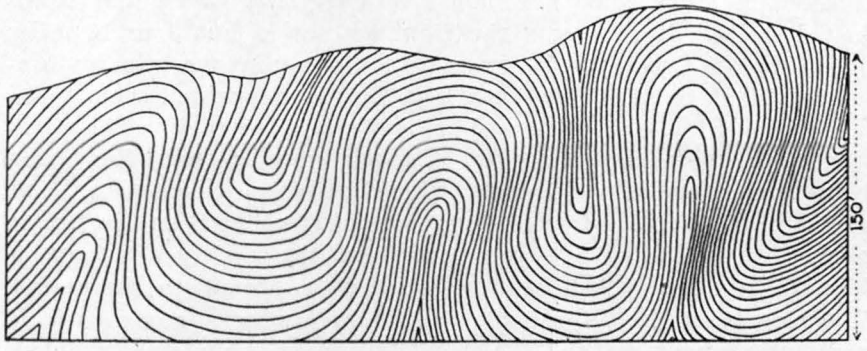
On Fortymile Creek, about 3 miles above its mouth, the schists of the Fortymile series are succeeded by black shales and sandstones, striking east and west and dipping 10° N. These rocks are traversed by shear zones, along which there has been some metamorphism, partly dynamic, but principally aqueous, evidently resulting from waters which have coursed along these zones. As the result of this action, the rock in the neighborhood of the shear zones is often somewhat impregnated with sulphides, and frequently small quartz veins have been formed. On Cone Hill, opposite the mouth of Clinton Creek, one of these altered zones has been exploited for ore. The rock is a fine-grained impure limestone, rendered schistose in narrow belts. From the alteration of the minerals which have been deposited along these belts the outcrop appears dark-red and sometimes green, the red

color being probably due to iron and the green to chromium. The altered rock is said to show the presence of precious metals on assaying, but an assay made in the laboratory of the Survey shows no appreciable amount of either gold or silver.

This rock series is exposed from the point above mentioned to the mouth of Fortymile Creek, and from here down the Yukon for about 25 miles. For the whole distance the rock consists of black shales alternating with thin-bedded gray sandstones and limestones. The beds are bent into broad, open folds, which grow more pronounced as one goes down the Yukon from the mouth of Fortymile Creek and approaches nearer the Mammoth Mountains. There is also slight faulting. Fig. 10, *A*, shows the structure of a high and long section of



A.



B.

FIG. 10.—Sketches of disturbed strata of Mission Creek series.

these beds exposed in a vertical cliff on the river about 10 miles below Fortymile Post.

These rocks are cut by occasional dikes, which are generally light-yellow in color. Specimens of a dike rock collected at the mouth of Coal Creek have been found to be porphyry.

Microscopic characters.—The thin-bedded limestones found near the mouth of Fortymile Creek, and below that creek along the Yukon, are ordinarily dark-gray in color, and under the microscope are seen to be made up of very small calcite granules with no evident regeneration or crystallization. Along the sheared and altered zones a short distance above the mouth of the creek, however, the limestone has been partly recrystallized and dolomized, and the microscope shows the development of occasional metamorphic minerals. There are also

small masses of a dark-brown metallic mineral, which are surrounded by a slight stain of green. Chemical tests made by Dr. Hillebrand, of the Survey, show that the dark-brown mineral is probably chromite, and that the green stain which surrounds these grains, and which gives a general color to the rock in the field, is due to chromium.

From the limestones there is a transition to coarse calcareous shale, which is often dark-gray in color, but on oxidation changes to light red. This shale is made up chiefly of small detrital quartz grains and of mica which is also probably detrital.

The sandstones which are associated with these thin-bedded limestones and shales are locally metamorphosed into quartzites. In a specimen of sheared sandstone from Fortymile Creek, about 3 miles above its mouth, the alteration has given rise to an abundance of felty actinolite. This specimen is traversed by many parallel fractures at right angles to the planes of shearing, and both along these fractures and along the shearing planes a great deal of iron oxide has been deposited, which gives the brown color to the rock in the field.

MISSION CREEK AND BELOW.

About 25 miles below the mouth of Fortymile Creek the series just described gives way to the Rampart series, but 5 or 10 miles above Mission Creek the Rampart series is again overlain by thin-bedded black or gray limestones and limy shales which seem to be lithologically like those exposed below Fortymile Creek. The plication of the beds here, however, is much more intense, the strata being compressed into close folds which are often overthrown. The sketch in fig. 10, *B*, is from an exposure of these beds on the Yukon above Mission Creek. It is to be noted that the locality is in the foothills of the sierras which have been called the Mammoth Mountains. The increase in the intensity in the folding as one approaches these mountains is very marked. Although these rocks are closely folded, there are no schists or quartz veins of any importance, and the whole appearance of the formation is comparatively recent.

These rocks are continuously exposed to the mouth of Mission Creek. On American Creek, which is a branch of Mission Creek, there occurs, about 2 miles above its mouth, the contact of these shaly rocks with the rocks of the Rampart series. The actual contact was not observed, but an outcrop a short distance away is of gray shales with layers of impure coal. These shales strike N. 70° W. and dip 65° SW., and overlie more massive dark-gray or dark-green rocks, much older in appearance. In the bed of the creek were noticed large bowlders of conglomerate, with a hard limestone cement, containing pebbles of quartz and nearly black slate or chert. The size of these bowlders shows that they must be derived from some point close by, and they are probably from the basal conglomerate of the younger shaly series, which rests unconformably upon the older rocks and

corresponds to the basal conglomerate observed on Napoleon Creek. This series is continuously exposed on the main Mission Creek, nearly to its head, and consists of thin beds of conglomerate, black calcareous shale, thin sandstones, and carbonaceous limestone with seams of slaty coal. These rocks are much folded, but are only locally altered by shearing. Near the junction of Mission Creek with Twelvemile Creek the series is overlain unconformably by slightly tilted conglomerates and grits with unconsolidated lignite beds. This later series is probably late Tertiary.

From the mouth of Mission Creek down the Yukon the rocks consist of black shales with thin-bedded limestones and sandstones. These beds are intensely folded, but the folds can be continuously followed in the vertical cliff sections, for there is very little faulting. In these cliffs sharp or gentle anticlines and synclines, occasionally slightly overturned, succeed one another rapidly, for they are ordinarily of no great magnitude.

About 7 or 8 miles below Mission Creek there come in massive conglomerates, containing pebbles of small size, which are apparently almost exclusively of different varieties of chert—gray, white, black, and especially bright-green. The conglomerate passes into sandy argillaceous limestone and into shaly layers, in which are abundant plant remains. This conglomeratic and plant-bearing formation appears to overlie the dark shales and thin-bedded limestone and sandstone which are exposed at Mission Creek and immediately below. It has been separated from the Mission Creek series, and will be described later under the head of Kenai series.

At the locality mentioned above the conglomerates and leaf beds occupy a belt several miles wide, below which again come in rocks like those exposed at Mission Creek—mostly black shales and gray limestones with seams of impure clay. The outcrops are yellow in places from the formation of sulphur on exposed surfaces. Farther down the conglomeratic series comes in again, alternating in broad belts with the underlying shales. These two series present such marked lithological differences that they were classified separately in the field. The fossil leaves which were collected from the upper rocks are stated by Dr. F. H. Knowlton to be evidently Eocene, while Mr. R. G. McConnell, of the Canadian Geological Survey, collected a characteristic Lower Cretaceous fossil from the underlying shale series.

In the neighborhood of the Tahkandit River the dark shales and thin-bedded limestones of the Mission Creek series are succeeded by white limestones interbedded with shales and conglomerates. In the limestone abundant fossils were found. These rocks have already been described as part of the Tahkandit series. No abrupt break was noted between the Tahkandit series and the overlying Mission Creek series, for the rocks of both have undergone about the same slight amount of alteration, and both are folded in about the same degree.

There is a marked lithological resemblance, moreover, for both series contain similar calcareous shales, and the conglomerates of the carboniferous noted above are identical in appearance with the conglomerates of the Cretaceous and Eocene, all being composed of pebbles which have the aspect of being largely derived from the rocks of the Rampart series. So it appears that the Mission Creek overlies the Tahkandit with no enormous unconformity, and that the rocks of both these series have been left nearly undisturbed until a comparatively recent period, when all were folded at the same time. The Yukon River, cutting across the folds, now exposes the different series in alternating broad bands.

Megascopically and microscopically the rocks on Mission Creek and below resemble closely those at the mouth of Fortymile Creek. The thin-bedded limestones of Mission Creek are seen under the microscope to be made up of pure, fine-grained calcite or dolomite, with carbonaceous material in some parts.

Along shear zones tremolite is developed in this limestone, as in the limestone near the mouth of Fortymile Creek. This tremolitic rock has a greenish color and a schistose structure in the hand specimen. A green feldspathic slate, which is sometimes found, is made up of a very fine aggregate of quartz and muscovite, with veins of calcite. Fine-grained sandstone, consisting chiefly of small detrital quartz grains, with some carbonaceous and clayey material, and veins of fibrous chalcedonic silica, is common. Other beds are coarser and more impure, and are to be classed as grits. One specimen examined was made up chiefly of fragments of plagioclase and pyrite, both undoubtedly detrital, and both present in large amount; these were embedded in a cement which was partly calcareous and partly a mixture of indeterminable decomposition products.

KANDIK RIVER AND VICINITY.

In the neighborhood of Kathul Mountain, on the Yukon, calcareous shales come in again with some thin-bedded blue-gray limestone. These beds are closely compressed, often into vertical folds, and are in places much jointed and cleaved; occasionally there are small, nonpersistent quartz veins. Above the Kandik River these beds are succeeded by green grits, sandstones, and conglomerates, with coaly seams and impure plant remains. The beds evidently correspond to the upper conglomeratic series noted farther up the river. At the Kandik River closely folded, black calcareous shales and thin-bedded limestones again come in, exactly like the rocks observed near Kathul Mountain. Farther down the Yukon, above Charlie River, these rocks are succeeded by massive gray limestones carrying obscure fossils. These limestones have already been described as part of the Tahkandit series.

CORRELATION.

The occurrences just described from Napoleon Creek, Chicken Creek, the mouth of Fortymile Creek and below, Mission Creek and vicinity, and near the Kandik River, are all of rocks having similar lithological characters, being composed of dark calcareous and carbonaceous shales with thin-bedded impure limestones and sandstones, and occasional thin beds of grits and conglomerates. These rocks carry impure coal seams and plant remains, which, so far as found, were not identifiable. In all the different localities the rocks described have been considerably folded, but only slightly faulted, and only locally have they been sheared, cleaved, or metamorphosed. In all these rocks veins of quartz and calcite are found, but they are usually small and nonpersistent, and do not form a distinguishing feature of the rocks. Wherever the base of these beds was observed, as on Napoleon and American creeks, there has been a basal conglomerate containing pebbles of the rocks on which it rests. On Napoleon Creek this conglomerate rests unconformably on the rocks of the Rampart series and of the Fortymile series; on American Creek it rests unconformably on the Rampart series. Below the Tahkandit River, however, and also below the Kandik River, the series which at Mission Creek rests upon the rocks of the Rampart series is underlain by the Tahkandit series, with no appearance of great unconformity. This shows that the Mission Creek series must overlap the edge of the Tahkandit series, and some slight unconformity is probable. This unconformity is also hinted at by the conglomerates occurring in this and in the underlying Tahkandit series.

Below Mission Creek the shale series is overlain by a conglomeratic series carrying abundant plant remains. Above and below the Kandik River shales and limestones having the same lithological characters as the Mission Creek rocks are also overlain by the plant-bearing conglomeratic series. The correlation of the rocks in the vicinity of Mission Creek and those in the neighborhood of the Tahkandit River is, therefore, strongly supported by lithologic, dynamic, and especially by stratigraphic evidence.

The strata at the mouth of Fortymile Creek and below are separated from those near Mission Creek by a belt of older rocks, which is probably mainly referable to the Rampart series. Between the rocks at these two localities, however, the lithological resemblance is great, and they have both been affected to nearly the same extent by dynamic action. On Fortymile Creek, just above the mouth, there appears to have been slightly greater alteration than is usually shown in the rocks near Mission Creek, but this is probably due to local shearing, which gives the formation in places an older appearance than have most of the rocks correlated with it. On Coal Creek, however, about 12 miles above its mouth, are found beds of hard lignitic

coal, with brilliant luster and conchoidal fracture and containing grains of amber. Coal of this nature is often found in the upper conglomeratic series, and is not, so far as observed, found in the lower shale and carbonaceous limestone series. On a small creek a few miles below Coal Creek, a short distance up, the same coal is found. It is probable, therefore, that at this point the upper conglomeratic (Eocene) beds come in, overlying the rocks exposed at the mouth of Fortymile Creek; and this seems to furnish stratigraphical evidence for the correlation of these latter rocks with those at the mouth of Mission Creek. The formations exposed along the Yukon, in the vicinity of Fortymile Creek, Mission Creek, and Kandik River, therefore, seem to form a continuous belt infolded with the overlying conglomerate series and the underlying Tahkandit series, so that the river cutting across the folds exposes all these different series, together with the older rocks, in alternating belts.

The Napoleon Creek and Chicken Creek occurrences are separated from the other localities, but these rocks have close lithological and structural resemblance to the others, and like the rocks on American Creek, are characterized by a basal conglomerate which rests unconformably upon the Rampart and Fortymile series. All these rocks may then be provisionally correlated as a single series, which may be called the Mission Creek series. The upper limit of this series may be regarded as the heavy beds of conglomerate, sandstone, grit, and shale, which carry abundant plant remains and beds of pure lignitic coal, with brilliant luster and conchoidal fracture and frequent grains of amber. The lower limit of the series is not so clear, but is approximately the heavier and purer limestones, with some conglomerates and shales. In some of these limestones Carboniferous fossils are found.

The lithological and structural resemblance between some rocks which have been classified as part of the Tahkandit series and some which have been put into the Mission Creek series is very strong. For example, the rocks near the mouth of Fortymile Creek strongly resemble lithologically and structurally the rocks below Mynook Creek, which carry plant remains suggesting Devonian age. Possibly further evidence may show that some of these rocks should be put into divisions different from those which are now considered best; the point aimed at is simply to make a provisional classification.

AGE OF THE MISSION CREEK SERIES.

In the Mission Creek series no fossils were found by the United States Geological Survey party except indeterminable plant remains. Mr. R. G. McConnell,[1] of the Canadian Geological Survey, discovered below the mouth of the Tatonduc River, in the shales underlying the heavy conglomerates, specimens of *Aucella mosquensis* var. *concen-*

[1] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1888-89, Vol. IV, pp. 21D, 138D.

trica. Concerning the stratigraphical significance of these fossils, Mr. T. W. Stanton, of the United States Geological Survey, has kindly supplied the writer with the following note:

The genus Aucella is with very few doubtful exceptions confined to the Upper Jurassic and the Lower Cretaceous. The forms that Whiteaves called *Aucella mosquensis* var. *concentrica* certainly do not have a greater range than that, and they are probably Lower Cretaceous. (See Bull. U. S. Geol. Survey, No. 133, pp. 40–47.)

DEFINITION OF THE MISSION CREEK SERIES.

The Mission Creek series may then be described as a succession of calcareous and carbonaceous shales with thin-bedded limestones, sandstones, and conglomerates, of considerable but not enormous thickness. This series often rests unconformably upon the Rampart series and older rocks. It is normally underlain by the Tahkandit series, the edges of which it overlaps and from which it is probably separated by a slight degree of unconformity. McConnell[1] notes on the Porcupine River, below the mouth of Driftwood River, the exposure of a contact between sandstones and quartzites with underlying compact bluish limestone. The sandstone and quartzites are overlain by soft bluish shales with harder calcareous layers, and are supposed by Mr. McConnell to be Cretaceous. The compact bluish limestones are filled in places with broken crinoid stems and other fossils, and are referred to the Paleozoic. The contact between the limestone and the overlying rocks has the appearance of being slightly discordant.

The Mission Creek series is directly overlain by conglomeratic beds carrying abundant plant remains which indicate Eocene age. The sudden abundance of these conglomerates gives some reason for suspecting a slight unconformity, but it certainly is not great.

The occurrence of the genus Aucella in the Mission Creek series shows that it is, in part at least, lower Cretaceous, although other periods may be represented. The series is more closely related to the Tahkandit series than to any other, and the lithological and paleontological boundaries between the two are not well determined. They may be collectively considered, however, as a grand series of sediments ranging in age probably from Devonian to Cretaceous, and of this the Tahkandit series forms the lower and the Mission Creek series the upper division.

CORRESPONDING STRATA IN OTHER LOCALITIES.

Mr. R. G. McConnell[2] notes at various points on the Porcupine River bluish shales with sandstones and conglomerates, which carry at different points *Aucella mosquensis* var. *concentrica* and Inoceramus. At the ends of the Lower Ramparts on the Porcupine, just above the

[1] Op. cit., p. 126D.
[2] Op. cit., p. 125D, 127D.

beginning of the Flats, rocks having these same lithological features occur, but from them no fossils were collected. They overlie here yellowish-weathering limestones which carry *Atrypa reticularis* and fragmentary specimens of corals, and which are considered by Mr. McConnell as referable, in part at least, to the Devonian. These overlying rocks are represented on the map of the Yukon gold district as belonging to the Mission Creek series, while the underlying limestones are mapped as part of the Tahkandit series.

Prospectors who have passed up the Kandik River, and thence across to the Big Black River and down to the Porcupine, report the occurrence of coal on the Big Black River. It is probable, therefore, that the Mission Creek series or the overlying Kenai series, or both, are there exposed. The locality of these occurrences, however, can not be ascertained from the prospectors, and therefore the boundaries of the formations as drawn along the Big Black River on the map are hypothetical.

Mr. W. Ogilvie[1] states that along the Tatondu River for 27 miles above its mouth are dark shales overlain by fine-grained conglomerates, these beds being similar to those observed on the Yukon. At two points in this distance limestones rise to the surface from beneath the shales. In the upper part of the valley of the Tatonduc the shales and conglomerates are replaced by grayish Paleozoic limestones. Similar limestones occur on the watershed separating the Tatondu from the Porcupine, and here form a range of high mountains; they also occur down the Porcupine as far as the Cathedral rocks, where they are again overlain by dark shales.

THE KENAI SERIES.

PRELIMINARY STATEMENT.

The name Kenai is given by Dr. W. H. Dall to a thick series of fresh-water beds carrying abundant plant remains and frequent seams of lignitic coal, which is often flecked with amber or amber-like resin. The name is derived from the Kenai Peninsula, on Cook Inlet, where these beds are well exhibited. For the full description of the series and for the details of the different occurrences, Dr. Dall's work should be consulted.[2] The determination of the age of these beds depends upon the determination of the age of the fossil flora, which was formerly regarded as Miocene, but is now considered to belong to the Eocene. In the following pages are described certain rocks which appear to belong to this series. These are all in localities examined by the United States Geological Survey party along the Yukon River in the summer of 1896.

[1] Am. Rept. Geol Nat Hist. Survey Canada, 1888-89, Vol. IV, p. 138D.
[2] Bull. U. S. Geol. Survey No. 84, Correlation Papers, Neocene, p. 234.

DISTRIBUTION AND GENERAL DESCRIPTION.

Below Mission Creek.—About 7 or 8 miles below Mission Creek, on the Yukon, the thin-bedded limestones, sandstones, and carbonaceous shales of the Mission Creek series are succeeded by overlying massive conglomerates. The pebbles in these conglomerates are small, and are mostly made up of different varieties of quartz and chert or jasperoid—gray, white, black, and especially pale-green. These rocks pass into sandstones and coarse grits, almost invariably green in color, and these into sandy argillaceous limestones and carbonaceous shales which contain frequent seams of impure, lignitic coal. This conglomeratic series is infolded with the underlying Mission Creek series, and the Yukon cutting across these folds exposes the two in alternating belts nearly to the Tahkandit River, where the pure-white limestones of the Tahkandit series, some of which carry Upper Carboniferous fossils, come in beneath the Mission Creek series.

In the conglomeratic series overlying the Mission Creek series the sandstones and shales very generally contain abundant leaf impressions, and about 25 miles below Mission Creek a collection of these fossils was made, from which the following species were identified by Dr. F. H. Knowlton:

Sequoia langsdorfii.
Ficus? alaskana? Newb.
Corylus macquarrii? (Forbes) Heer.
Pterospermites dentatus Heer.

These fossils are considered by Dr. Knowlton to belong to the Eocene. At the same place where they were collected a pebble of fine, dense, gray, calcareous sandstone, like the gray sandstones of the underlying Mission Creek series, was found in the conglomerate, suggesting some slight unconformity, or at least an erosion interval, between the two series. The upper plant-bearing series is very thick, and although no actual measurement was undertaken, the impression given is that it is several times as thick as the underlying Mission Creek series. A rough estimate in the field made the thickness of the upper series about 10,000 feet, and that of the Mission Creek series about 1,000 feet. This estimate, however, was based on no data whatsoever, but simply expressed the impression gained after seeing the continuous and numerous rock exposures for many miles along the river. Both the upper and the lower series have been folded at the same time and in approximately the same degree. The stresses appear to have been local, for in one exposure the strata are horizontal and in the next vertical or violently contorted. No veins worthy of mention were seen in these rocks and no dikes were actually observed, although certain objects seen at a distance were suspected to be dikes.

Above Kandik River.—Several miles above the Kandik River occur again green grits, sandstones, and conglomerates with black shales containing coaly seams. All these rocks contain badly preserved plant remains. Lithologically these beds are exactly like those in the locality just described below Mission Creek. As in the last-named locality, the pebbles in the conglomerate consist mostly of silica in its various forms, but a specimen of dark greenish-gray grit is seen under the microscope to be made up of irregular and often sharply angular fragments of feldspar and quartz. The feldspar, which is plagioclase, is the predominating material, and occurs in broken, lath-shaped crystals. The grains of quartz are not much rounded, and there is some orthoclase, augite, hornblende, and mica, with fine calcareous and kaolinic material. The nature of this grit shows that it has been derived from some basic igneous rock, probably a diabase or diorite, and the diabases of the Rampart series may be suspected of having furnished the material. The richness of the rock in highly perishable minerals, moreover, and the angularity of the grains show that the material has not traveled very far from its original source.

On the river above and below the locality just mentioned come the underlying darker, thin-bedded limestones and shales of the Mission Creek series.

Coal Creek.—On Coal Creek, which enters the Yukon a few miles below the mouth of Fortymile Creek and on the opposite side, coal occurs some 12 or more miles above the mouth, as Mr. Ogilvie, of the Canadian Geological Survey, has informed the writer. One specimen given by Mr. Ogilvie was a pure, hard, black lignitic coal with brilliant luster and perfect conchoidal fracture, and contained tiny flecks of pyrite and larger grains of amber or amber-like resin. This coal is like that found so frequently in the rocks of the Kenai series, and it is probable, therefore, that these rocks cross Coal Creek some miles above its mouth.

On a small creek a few miles below Coal Creek, on the same side of the Yukon, coal is also found, identical in appearance with that on Coal Creek.

The existence of fine-grained conglomerates overlying dark shales along the Tatonduc for 27 miles above its mouth has already been referred to under the head of the Tahkandit series. These beds are considered by Mr. Ogilvie to be the equivalent of beds observed on the Yukon. In the upper part of the valley of the Tatonduc they are replaced by grayish Paleozoic limestones.

Above Mynook Creek.—About 25 miles above Mynook Creek the green diabases and tuffs of the Rampart series are overlain unconformably by conglomerates and grits, with some limestones and shales, all thin-bedded. The grits are green in color, owing to their derivation from the underlying rocks of the Rampart series; the matrix of the conglomerates is also green, and the pebbles are made

up of varicolored chert or jasperoid, and also of diabase and diabasic tuffs from the underlying rocks. The limestone is in thin layers, gray or greenish in color, very fine-grained, and with a smooth conchoidal fracture. In the shale are frequent seams of rather impure lignitic coal; three distinct seams are exposed on a cliff here just below the mouth of Whymper River, or, as it is ordinarily called by Alaskans, Hess Creek. Along one of these seams a tunnel has been driven by Oliver Miller, the discoverer of gold on Miller Creek, in the Fortymile district. The coal, when pure, is of brilliant luster and conchoidal fracture, like that on Coal Creek, and is lignitic. The thickest seam of pure coal noted was 18 inches thick, and there are many thinner seams alternating with impure bands, or "bone," and with clay partings. The pure coal contains amber, like the coal of Coal Creek and vicinity. The beds at this point are nearly vertical, and are even locally overturned; the general strike is N. 65° E. Plant remains are everywhere, and some were collected and have been identified by Dr. F. H. Knowlton. These will be referred to later.

About 15 miles below this locality the same series has a strike due north and a dip 45° W., and about 5 miles farther below, the contact of coarse green diabase belonging to the Rampart series with the overlying basal conglomerate of these plant-bearing rocks is shown. The pebbles in this conglomerate are not usually more than 2 or 3 inches in diameter, and consist very largely of the different varieties of silica; some, however, are coarse diabases and tuffs, like those of the Rampart series. Above the lowest bed the conglomerate becomes finer-grained and alternates with thin-bedded grits and black carbonaceous shales. The shales contain indistinct plant remains.

At the mouth of Mynook Creek are exposed conglomerates, grits, and shales similar to those just described. The beds are fairly well consolidated, although some layers are loose and incoherent. The conglomerates are generally fine-grained, and often contain nodules of limonite and silica; the shales carry small seams and fragments of lignitic coal, which often contain specks of amber. The pebbles in the conglomerate are partly derived from the diabases and tuffs of the Rampart series. At the mouth of the creek the beds strike N. 80° E. and dip 60° NW. Above this point a continuous section is exposed along the bank of the Yukon for nearly 2 miles. In all this distance the strikes remain the same, while the dip is steadfastly to the north, so that continuously higher and higher beds are exposed as the distance from the mouth of the creek increases. Toward the end of the section, however, the dip becomes gradually shallower, and at last is in places as small as 20°. The thickness of these uniformly dipping beds must be very great, unless there exist faults which were not noted, and which may possibly operate to increase the apparent thickness. The uppermost beds exposed have a character and a composition substantially like those of the lowest beds,

but there is a marked difference in the degree of consolidation or coherency. The lowest beds near the mouth of Mynook Creek contain sometimes loose layers, yet are ordinarily firmly consolidated conglomerates, grits, and shales. In the higher horizons, however, this consolidation becomes very gradually less, until the uppermost beds are of little coherent clays and shales with loose sand and gravels. Although these gravels correspond in composition to the conglomerates in the lower beds, they are so little indurated that the pebbles can be easily and cleanly picked out of the matrix and the whole rock can be removed with a shovel. The general appearance of the upper beds, therefore, is decidedly different from that of the lower ones, and if the two localities were not connected by a continuous exposure, the sands and gravels would undoubtedly be considered as belonging to a decidedly younger series than the conglomerates.

Throughout this series, from top to bottom, are frequent seams of lignite and lignitic coal which contains specks of amber. The coal seams are generally overlain and underlain by sandy clay, and are associated with carbonaceous shales containing plant remains, stems, and often large fragments of trees. The best leaf impressions were found in the upper, less consolidated part of the series, and these are regarded by Dr. Knowlton as Eocene. The species identified are also found at Miller's coal mine. The correspondence of the lowest part of the series, with the beds at Miller's coal mine, is beyond a doubt, and therefore the whole series appears to belong to the Eocene. Still, the loose, incoherent nature of the upper strata, compared with the compact, well-consolidated condition of the Eocene in other localities, gives rise to the doubt as to whether all should be classified under exactly the same head, and whether the unconsolidated beds may not belong to a somewhat more recent period.

Above the Tanana.—About 35 miles above the mouth of the Tanana, on the Yukon, come in coarse conglomerates, green grits, and micaceous shales only partly consolidated. The grits and the finer material of the conglomerates are evidently made up chiefly of detritus from the diabasic rocks of the Rampart series, while the pebbles in the conglomerate are largely of the varicolored chert or jasperoid, which occurs so abundantly in the same rocks. There are also occasional pebbles of white crystalline quartz which may be derived from the veins of the Birch Creek or Fortymile series; and in some of the coarse grits there is much fine granitic detritus. This conglomerate overlies the Rampart rocks, which are exposed farther up the river, and for some distance below the contact has a general southwest dip, which it changes farther down for a northeast one. The strike is usually north or northwest, so that the whole belt seems to have a general synclinal structure. Farther down the river these conglomerates are succeeded by older rocks, consisting in part of micaceous and calcareous quartzite-schist with quartz veins. These schists have been referred to the Fortymile series.

BOWLDER OF KENAI CONGLOMERATE NEAR MOUTH OF TANANA.

Nearly opposite the mouth of the Tanana River, about 3 miles above the trading post known as Tanana, are again found outcrops of coarse conglomerates similar to those last described but separated from them by the belt of older rocks. At this point the conglomerates lie nearly horizontal and are interstratified with layers of green grit which contain plant remains. The pebbles are large, being often 5 or 6 inches in diameter, and are commonly subangular in shape. One bowlder of quartz noted was over a foot in diameter. Green diabase and other characteristic rocks of the Rampart series make up a large proportion of the pebbles and bowlders. The micaceous quartz-schists of the Birch Creek or Fortymile series also make up a very large part, and there are quartz and chert or jasperoid of all varieties and of all colors. Granite pebbles, however, could not be found in this locality. Pl. XXXIII is a photograph of a mass of this conglomerate newly fallen from the face of a cliff.

Below the Melozikakat.—A few miles below the Melozikakat (see Pl. XXXIV) the gray limestones and indurated shales which have already been described under the head of the Tahkandit series are overlain by conglomerates, green grits, and shales containing plant remains. The pebbles in the conglomerate are mainly of diabase and diabasic tuffs from the Rampart series, of micaceous schist from the Birch Creek or Fortymile series, and of coarse granite like that of the great intrusive masses observed in the Lower Ramparts of the Yukon; there are also fragments of fine-grained, greenish limestone, like the limestones of the Tahkandit series, exposed immediately above. About 6 miles below the Melozikakat these conglomerates strike N. 70° E. and dip 20° SE.; about 6 miles farther down the river the same rocks strike N. 60° W. and dip 35° SW., and the folding at this latter point is more marked. In both these localities the conglomerates are very coarse, the pebbles being as much as 6 or 8 inches in diameter, especially those of granite. About 7 miles below the last-named locality were found sandstones and soft clay-shales, both being plant remains. The sandstones are greenish in bands, like those above described, but are mostly gray and of pure composition, being made up chiefly of quartz grains, while the ordinary green sandstone is largely composed of feldspar. These rocks strike N. 60° E. and dip 35° NW., and are continuously exposed, with a uniform dip, for 5 or 6 miles along the river, thus affording a fine cross-section.

The thickness of strata exposed in this section is apparently very great, but it is probable that this appearance is largely due to faulting, as noted by Prof. I. C. Russell.[1] Of this Professor Russell speaks as follows:

> The finest example of monoclinal structure seen in ascending the Yukon, though on a comparatively small scale, was in cliffs of sandstone and slate bordering the right bank of the river for several miles, at a locality some 15 or 20 miles below

[1] Notes on the surface geology of Alaska: Bull. Geol. Soc. America, Vol. I, p. 108.

the mouth of the Melozikakat, or midway between Nulato and Nowikakat. These sandstones contain the leaves of deciduous trees, and belong to the same system as the rocks at Nulato, which have been described by Dall.[1]

The river bank at the locality referred to is extremely precipitous, and exposes a fine section of the rocks, which dip, in general, northwest 25° to 30°, except where disturbed by faults. The displacements trend nearly north and south, and appear in the cliffs as in a diagram. In the best-exposed portion of the section there are six or eight important faults within a space of about 2 miles. These are parallel, and head to the east at an angle ranging from 25° to 40°. In each instance the strata are disturbed on approaching the breaks, but soon return to their normal dip. At each fault a lateral valley has been excavated, the west side of which is a smooth, even rock slope, frequently slickensided, and is in reality the heaved side of the fault. The east wall of each of the valleys is rugged and broken, and the strata in the projecting ledges usually show a high dip toward the east. In other ravines, where the structure was not clearly visible, the peculiar topographic conditions indicated a similar origin. These faults are instructive for the reason that they illustrate the manner in which a series of displaced blocks sometimes present a nearly uniform dip, so as to appear as a single monocline when the exposures are not sufficient to show the true structure.

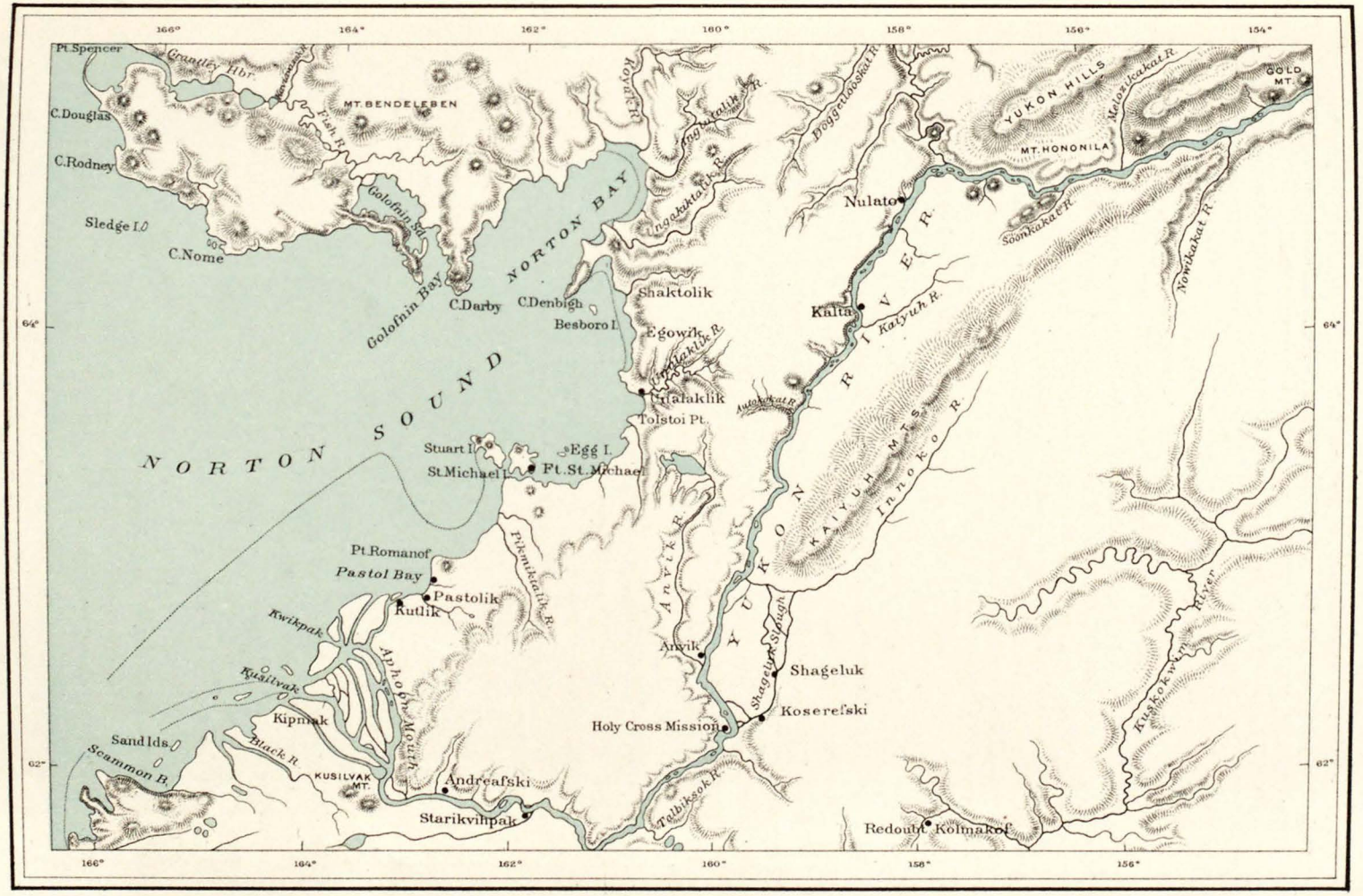
Plants collected from these beds have been provisionally referred by Dr. F. H. Knowlton to the Eocene.

About 6 miles farther down the river were noted the same greenish sandstones and soft shales, carrying leaves, stems, and small chunks of hard, black lignite. In these beds, mingled with the plant remains, were found fresh-water shells, which, however, are not characteristic enough to determine the horizon. At this point the beds strike N. 70° E. and dip 40° NW.

At a point some 6 or 7 miles beyond that last mentioned were examined bluish-gray and brown sandstones, grits, and conglomerates, differing considerably in appearance and color from the rocks in the localities farther up the river. These beds are considerably folded, and even slightly overturned. There is a strong jointing, trending due north and varying in dip from vertical to 60° E. Along these joints and other fracture planes are slickensiding and slight faulting, and there are small stringer veins of calcite, often cutting across the stratification at right angles. The conglomerate contains pebbles of schist like that of the Birch Creek series; of diabases, tuffs, and chert from the Rampart series, and also of shaly green limestone in large pebbles, the derivation of which is uncertain. The general strike here is N. 60° E., while the dip varies from 30° NW. to vertical, or is even locally reversed. About 6 or 7 miles farther down come bluish-gray sandstones and sandy shales, striking N. 70° E. and dipping 50° SE. These contain many plant remains similar to those collected in the other exposures between here and the mouth of the Melozikakat, and the sandstones are ripple-marked.

A few miles below this last exposure come in high bluffs of horizontally bedded silt which conceals the other formations. This silt is

[1] Am. Jour. Sci., 2d series, Vol. XLV, 1868, pp. 97-98.



OUTLINE MAP OF THE LOWER YUKON RIVER AND VICINITY ADAPTED FROM U.S. COAST SURVEY CHART-T

Scale

20 10 0 20 40 60 80 Miles

Area occupied by this Map is shown by dashed lines on Pl. XXXII (General Map of Alaska)

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the only deposit exposed along the banks for about 35 miles, and it apparently extends away from the river on both sides for a number of miles, for the country is composed of broad, level flats, which form a marked contrast to the rougher topography above and below, and which stretch away to the distant hills. It seems probable that this silt was deposited in the bottom of a lake which occupied the region of the flats and which was drained in comparatively recent time. At the end of the flats are two eminences, which are called the Twin Mountains; they are close together, on the left-hand side of the river. Nearly opposite these mountains, on the right-hand side of the river, is a steep rock cliff, about 300 feet high, composed of compact, blue-gray shaly limestones and sandstones. These rocks resemble, lithologically, those seen farther up the river, and contain indistinct plant remains, but they also contain marine fossils, which Dr. Dall considers to be probably of Miocene age. An estimated thickness of about 600 or 700 feet of strata is exposed in this cliff, and the beds are well folded. The general strike is N. 80° W. and the most important dip 30° SW.

Between the Koyukuk and the sea.—At the mouth of the Koyukuk is a sheer cliff of magnificent height rising directly from the river and known as Koyukuk Mountain. This rock is of basalt, and shows on its naked face very beautifully and regularly two different sets of joints, due to contraction in cooling. The basalt has burst through conglomerates and sandstones, which it incloses in large masses. A short distance below the mountain the sedimentary rocks are exposed in a comparatively undisturbed condition. They consist of black shales with beds of brown-weathering sandstone, and extend from here at least as far as 50 miles below Nulato; according to Dr. Dall, as far as Kaltag. These rocks are referred by Dall to the marine Miocene.

At the Holy Cross Mission dark-blue sandstones and conglomerates were noted, and at a village 18 miles above Andreafski are impure sandstones. All these rocks are well folded, although not intensely, and are mingled with intrusions of basaltic nature. Below Andreafski no outcrops were noted as far as the mouth of the Yukon. St. Michael Island is purely volcanic, being made up of basaltic lava and ash.

The Koyukuk River.—Concerning the rock formations along the Koyukuk, Lieut. H. T. Allen[1] notes that "the geological formation of the country drained by this river is in appearance very similar to that of the Yukon from Yakutskalitnik up, so that what may be written in respect to the geology of the Yukon will in a large measure apply to it." He also notes that "on the northern bank of the Koyukuk are indications of coal beds." According to this report, those portions of the Koyukuk which have been explored probably flow mostly through Tertiary strata, like those which have just been described. A few years ago considerable prospecting was done on the Koyukuk

[1] Report of an Expedition to the Copper, Tanana, and Koyukuk rivers, Senate Doc., 1887, p. 159.

and some gold was taken out. A post was established on this river at Arctic City, northwest 100 miles or so from Tanana station, on the Yukon, but has lately been abandoned. According to the reports of prospectors and traders the gold is contained in beds of conglomerate.

CORRELATION AND AGE.

The conglomeratic series exposed below Mission Creek and that found above the Kandik River evidently are the same, since they are identical lithologically and stratigraphically, contain the same plant remains, and have the same amount of induration and folding. The strata above Mynook Creek, at Miller's coal mine, have the same characters as in the two localities last mentioned, corresponding closely in nature and composition of the beds, in the degree of consolidation, and in the lignite seams and plant remains. Immediately above the mouth of Mynook Creek the lower beds in the section exposed have the same character as those at Miller's coal mine, but are less consolidated. Toward the top of the thick series exposed along the banks of the Yukon at this point the beds become progressively less consolidated, until finally they are only gravels, sands, and slightly indurated clays; yet these upper beds are conformable with the more consolidated ones below, and contain lignite seams and plant remains similar to those found in other localities. From these loosely consolidated beds specimens were collected which were identified as *Ficus? alaskana?* Newb., and *Corylus macquarrii* (Forbes) Heer. From the beds at Miller's coal mine were identified—

Phragmites alaskana? Heer.
Ficus? alaskana? Newb.
Corylus macquarrii (Forbes) Heer.
Quercus? sp.
Populus balsamoides Heer.
Platanus sp.
Vitis crenata? Heer.
Carpites sp.;

and from the locality below Mission Creek—

Sequoia langsdorfii.
Ficus? alaskana? Newb.
Corylus macquarrii? (Forbes) Heer.
Pterospermites dentatus Heer.

Since these three localities have at least two species in common, Dr. Knowlton considers them as approximately equivalent in point of age, and the combined collections from the three localities give 7 species which are characteristic of a horizon formerly known as the "Arctic" Miocene, but which is now considered to belong to the Upper Eocene.[1]

The beds brought together in this correlation are closely alike lithologically, with the exception of the upper beds of the series exposed

[1] See Dr. Knowlton's report, page 194; also A review of the fossil flora of Alaska, with description of new species, by F. H. Knowlton: Proc. U. S. Nat. Mus., Vol. XVII, pp. 207, 240.

immediately above Mynook Creek. These are so little consolidated in comparison with the bottom of the same series and with the rocks exposed in the other localities, that they would hardly be correlated with them by their physical characters. Still, the change from the lower rocks to the upper sands and gravels is seen to be very gradual, and the series to be conformable from top to bottom. If this correlation be correct, we have above Mynook Creek a very great thickness of fresh-water strata deposited in the Upper Eocene period. The section exposed must be at least 10,000 feet unless faults exist, which were not noted. If deposits so thick were actually formed in this comparatively short geological time, the difference in the consolidation between the top and bottom of the series apparently depends upon the consolidating influences exerted on the lower beds by the weight of the overlying accumulations, as well as upon the slightly greater age of the lower beds.

In the somewhat loosely consolidated coarse conglomerates in the Lower Ramparts, between Mynook Creek and the Tanana, were collected remains of dicotyledonous plants which were indeterminable, but which were considered by Dr. Knowlton to be probably of the same age as those above noted—Upper Eocene.

Below the Melozikakat the first Tertiary rocks exposed are conglomerates, green grits, and shales. Farther down the river they are overlain by purer and finer sediments, consisting of gray sandstones and soft clay-shales. In the upper beds were collected fragments of wood and indeterminable dicotyledonous leaves and a small fern, which, according to Dr. Knowlton, somewhat resembles *Pecopteris arctica* Heer, but probably represents a new species. Dr. Knowlton says in regard to these beds: "The age is uncertain, but from a number of shells in the same matrix Mr. Stanton inclined to call it, at least provisionally, Eocene." The species containing the fossil shells referred to were submitted to Dr. W. H. Dall, who characterized them as follows:

> Fresh-water sandstone with remains of vegetation, worm (?) tracks, obscure bivalve impressions (possibly a small Unio), a species of Goniobasis, Ancylus, and a very elongated, rather smooth shell, which appears to belong to the genus Campeloma.
>
> None of these is identifiable with any described American species as far as can be judged from the material.

The sandstones below Kaltag and above the Yukon delta are referred by Dr. Dall to the same series as those already described, apparently on stratigraphical grounds and on account of their probable continuity with the beds on Unalaklik River and Norton Sound, which contain fossil leaves characteristic of the Kenai group.

All the occurrences which have been described, therefore, may be correlated with the Kenai series of Dall, and may be referred to the Eocene. The rocks may be summarily described as consisting of a

great thickness of somewhat loosely consolidated conglomerates, sandstones, and shales, all generally greenish in color. They contain everywhere plant remains and frequent seams of lignite, and rest unconformably upon the older formations.

THICKNESS OF THE KENAI SERIES.

The leaf-bearing conglomerates, sandstones, and shales overlying the Mission Creek series below Mission Creek on the Yukon were roughly estimated, without any actual data, as being 10,000 feet thick, and as being several times as thick as the underlying Mission Creek series. This is a mere guess, but serves to convey the impression formed after viewing numerous extensive exposures along the bank of the river. Just above Mynook Creek the section of beds containing the same species of fossil plants is at least 10,000 feet thick if there is no faulting. Below the Melozikakat, also, these beds occur for many miles with a general northwest dip, passing upward from conglomerates to finer-grained sandstones and shales; and even allowing for a great deal of faulting, the actual thickness of strata exposed here must be very great.

REPORT ON A COLLECTION OF FOSSIL PLANTS FROM THE YUKON RIVER, ALASKA, OBTAINED BY MR. J. E. SPURR AND PARTY DURING THE SUMMER OF 1896.

By F. H. KNOWLTON.

DESCRIPTION.

This collection, as submitted to me, consisted of about 125 specimens, and represents 10 localities at various points along the Yukon from Walkers Fork of Forty Mile Creek to the vicinity of the mouth of the Koyukuk, a distance of some 800 miles. The entire collection was carefully arranged by Mr. Schrader by localities, and the position of each indicated on a map of the Yukon, together with the provisional determination of the geological horizon.

The material is, unfortunately, very imperfect, the plant remains being in almost all cases only fragments. The determinations, therefore, are more or less doubtful, and can not have the value that is necessary for satisfactory identification of horizons. The report is therefore to be regarded as provisional, and subject to revision when more perfect material can be obtained.

I have given first a list of the localities, with the plants from each, relegating the discussion of their age to the end of the report.

1. FORTY MILE. NAPOLEON CREEK.

Material a black carbonaceous shale. Contains plant fragments, but so imperfect as to be of no value.

2. MISSION CREEK.

Material a very black carbonaceous shale, with minute, wholly undeterminable plant fragments.

3. BELOW MISSION CREEK

Sequoia langsdorfii.
Ficus? alaskana? Newb.
Corylus macquarrii? (Forbes) Heer.
Pterospermites dentatus Heer.

4. TWENTY-FIVE MILES ABOVE MYNOOK CREEK; MILLER'S COAL MINE.

Phragmites alaskana? Heer.
Ficus? alaskana? Newb.
Corylus macquarrii (Forbes) Heer.
Quercus? sp.
Populus balsamoides Heer.
Platanus sp.
Vitis crenata? Heer.
Carpites sp.
Wood.
Stems and fragments.

5. NINE MILES ABOVE MYNOOK CREEK.

Nothing can be made out from this material.

6. JUST ABOVE OR NORTH OF MYNOOK CREEK.

Ficus? alaskana Newb.
Corylus macquarrii (Forbes) Heer.
Wood, apparently coniferous.

7. BELOW MYNOOK CREEK, OR BETWEEN MYNOOK CREEK AND TANANA.

Several small specimens showing fragments of dicotyledonous leaves, but wholly indeterminable.

8. THIRTY-FIVE MILES BELOW TANANA.

Dicotyledonous leaves; fragments.
Pinus macclurii? Heer.

9. BELOW MELOZIKAKAT.

Pecopteris arctica Heer.
Dicotyledonous leaves, indeterminable.
Wood.

10. MILES ABOVE THE MOUTH OF THE KOYUKUK.

Traces of organic remains, but doubtful plant fragments; of no value.

DISCUSSION OF AGE AS INDICATED BY PLANTS.

In regard to localities 1 and 2, obviously nothing can be said. They are plant fragments, but without characters. The same may be said of localities 5 and 10.

The localities 3, 4, and 6 may be considered together. From the first of these (3, below Mission Creek), four species have been identified. Locality 4 (Miller's coal mine) has yielded five species and five or six questionable fragments, while locality 6 (above Meynook Creek) has afforded two species. The combined list from these three localities is only seven named species, as follows:

Sequoia langsdorfii.
Phragmites alaskana.
Corylus macquarrii.
Populus balsamoides.
Ficus alaskana.
Pterospermites dentatus.
Vitis crenata.

These three localities appear to be similar in age, since at least two species *Corylus macquarrii* and *Ficus alaskana*) are found in all of them. These seven species are all well-known forms, being found in abundance in the vicinity of the Mackenzie River and various parts of Alaska. In age they belong to what has long

been called the Arctic Miocene, but which late investigations have shown is probably Upper Eocene. A majority of these species were also found by McConnell in his explorations in the Yukon and Mackenzie basins near the mouth of Bear River.[1] They were referred by Sir William Dawson to the Laramie, but it should be remembered that the Canadian Laramie corresponds to the Fort Union group of United States geologists and not to our Cretaceous or true Laramie. There is undoubtedly a strong resemblance between the flora of Alaska, Mackenzie, etc., and the Fort Union flora, but I incline to regard the northern floras as a little higher, therefore probably Upper Eocene in age. They can not possibly be Cretaceous.

Locality 7 (below Mynook Creek) affords only fragments of dicotyledons, but the age is probably similar to the age of those last considered.

The specimens from locality 8 (35 miles below Tanana) are also fragments of dicotyledons, but none sufficient for identification. There are several finely preserved cones that appear to be the same as Heer's *Pinus macclurii*. The age is Pliocene, or possibly upper Miocene.

The only form from locality 9 (below Melozikakat) that I have been able to determine is a small fern somewhat resembling *Pecopteris arctica* Heer, but probably representing a new species. The age is uncertain, but from a number of shells in the same matrix Mr. Stanton inclines to call it, at least provisionally, Eocene.

THE NULATO SANDSTONES.

The Nulato rocks have already been described by Dr. Dall.[2] They consist of marine Miocene sandstones and shales which overlie the rocks of the Kenai group and are exposed along the Yukon from near Kaltag to the Koyukuk Mountain. These beds are often ripple-marked, and contain vegetable fragments. In 1886 Dr. Dall obtained fossils representing the genera Modiola, Tellina, Mytilus, Gastrochæna, and Mya.

About 20 miles above the mouth of the Koyukuk, nearly opposite the Twin Mountains, is a steep cliff on the right-hand side of the Yukon rising to a height of 300 feet or more. Here the beds are well folded and have a general strike east and west. They consist of blue-gray shaly limestones and sandstones, containing doubtful plant fragments and casts of marine shells. Specimens collected from this locality were submitted to Dr. W. H. Dall, who characterized them as follows:

Marine sandstone, probably Miocene, with poorly preserved casts of Thracia, Glycimeris, Tellina (subg. Angelus), Macoma, Yoldia (or a yoldiform Macoma), Nucula, a species with heavy shell, and a partial imprint of a naticoid shell.

THE TWELVEMILE AND PORCUPINE BEDS.

TWELVEMILE BEDS.

Twelvemile Creek is one of the branches of Mission Creek. Near the point of junction of these two streams are exposed in numerous outcrops slightly consolidated and coarse-bedded gravels and sands

[1] Ann. Rept. Geol. Nat. Hist. Survey Canada. Vol. IV, 1888-89, p. 22 D.
[2] Bull. U. S. Geol. Survey No. 84, Correlation Papers—Neocene, p. 247.

which carry seams of light-brown sandy lignite. Fragments of wood, considerably altered, having a diameter of as much as 2½ inches, are found, but no fossil leaves or shells. Occasional pieces of black, shiny lignite, such as is found in the Kenai series, and less abundantly in the Mission Creek series, occur, but in such a manner as to lead to the suspicion that they are fragments derived from these older rocks. The beds are slightly folded, having a dip of about 20°. Near the mouth of Twelvemile Creek the dip is southward, though about a mile above Twelvemile Creek, on Mission Creek, the dip is to the north, though the strike remains nearly the same; thus a shallow syncline is indicated.

The rocks of the Mission Creek series, which underlie these beds, are sharply folded, and although no actual contact was seen, it is probable that an unconformity exists. Below Mission Creek the rocks of the Kenai series are well indurated, forming compact conglomerates and sandstones, and they are apparently conformable with the rocks of the underlying Mission Creek series, with which they are infolded. It appears, therefore, that the Twelvemile beds can not be correlated with the Kenai series, and yet they are older than the horizontal Pleistocene silts and gravels which are exposed all along the course of the Yukon. They may be provisionally referred to the Miocene or Pliocene. From their nature they seem to be fresh-water lake deposits. The marine Miocene sandstones described at Nulato are littoral, as is shown by the vegetable remains, ripple-marks, and mud-cracks which they contain, so that at the time of their deposition it is probable that that portion of the country through which the upper part of Mission Creek now cuts was land, where there may have been lakes in which such deposits as the Twelvemile beds were laid down.

PORCUPINE BEDS.

On Porcupine River, between the mouth of the Driftwood River and the head of the Ramparts, is a series of beds which Mr. R. G. McConnell[1] has described as composed of "yellowish and whitish sands and sandstones, interbedded with a grayish rather hard conglomerate made up of quartz pebbles, fragments of shale, and scales of a silvery micaceous schist;" in other localities these beds consist of "soft scarcely stratified whitish and yellowish clays and sands." No fossils were found in these beds, but they are unconformably underlain by bluish shales and sandstones, which contain numerous impressions of a large Inoceramus, and which are probably, in part at least, of Cretaceous age. From these stratigraphical relations Mr. McConnell correlates the overlying series with the Bear River beds of the Mackenzie. At the lower end of the Lower Ramparts of the Porcupine, just above the termination of the flats which occupy both banks of the river for 60 miles above its mouth, the same series of

[1] Ann. Rept. Geol. Nat. Hist. Survey, Canada, new series, Vol. IV, 1888-89, p. 127D.

yellowish and light-reddish sands and clays was observed by Mr. McConnell, and here also they overlie unconformably dark shales which are probably Cretaceous. The Bear River beds contain abundant remains of flora, which were examined by Sir William Dawson and held by him to indicate a Laramie (Fort Union or Eocene of United States geologists) age for the beds. On stratigraphical and lithological grounds, however, Mr. McConnell appears to entertain some doubt as to the correctness of this correlation. He says:[1]

The beds of this Tertiary basin are evidently lacustral in their origin, and both in lithological character and stratigraphical position have a much closer resemblance to the Miocene (White River) of the Cypress Hills and neighboring areas than to the Laramie with which their fossil flora correlates them. Like the Cypress Hills beds, they are characterized by their irregular deposition, by their slight induration, and by the large proportion of gravel and pebble beds which they contain, and a further degree of relationship is evidenced by the fact that they both rest unconformably on the beds beneath. Mere lithological similarity in the case of two such widely separated detrital terranes is of very little value in determining age, and in the present instance might be disregarded were it not supported by the more important feature of a corresponding structural break. In the area of the Great Plains, and even in the Rocky Mountains, the Laramie is everywhere conformable to the Cretaceous beds below, but sustains a discordant relation to the overlying Tertiaries, and it has been found that its termination was synchronous with a widespread elevation of the land and the formation of fresh-water lakes in which the succeeding deposits were laid down. At the mouth of the Bear River, instead of a conformable passage from the Cretaceous to the Tertiary, we have evidence that the former was elevated and subjected to a prolonged denudation before the latter was deposited. In order to reconcile the stratigraphical position of the Bear River beds with a Laramie age, it will therefore be necessary to assume that this part of the continent was, toward the end of the Cretaceous period, affected by extensive movements of elevation and depression in which the central part did not participate.

CORRELATION.

It is the opinion of the writer that the Tertiary beds on the Porcupine, described by McConnell, are of the same age as the Twelvemile beds just described. Like the Porcupine River and Bear River beds, the Twelvemile beds rest unconformably on the older rocks, in this case upon dark shales, which have been called the Mission Creek series, and in which Mr. McConnell found the fossil *Aucella mosquensis* var. *concentrica*, thus showing that they are, in part at least, Cretaceous. The same fossil is found in certain of the dark shaly rocks which underlie the slightly consolidated Tertiary beds on the Porcupine. Lithologically and in degree of induration the Twelvemile beds resemble closely the Porcupine beds, and in both regions they have suffered a very slight amount of folding or tilting. All, moreover, appear to be lake deposits.

It has already been recalled how below Mission Creek there overlies the heavily folded Mission Creek series, in apparent conformity, a series of heavy conglomerates and shales carrying plants which are

[1] Op. cit., p. 100D.

considered by Dr. Knowlton to identify the series as of the Eocene age. Between these Eocene beds of the Kenai group and the nearly horizontal Twelvemile beds there is therefore an abrupt unconformity, and the difference in degree of consolidation between the two formations is so great that in the field the possibility of their correlation, even in a general way, does not suggest itself, since the Twelvemile beds appear certainly much younger. If the Twelvemile and the Porcupine beds, therefore, are still considered Eocene, we must accept the consequence, already pointed out by Mr. McConnell, of a profound unconformity separating the different epochs of the Eocene period in this region. Since, however, it appears to the writer that the classification of the Bear River beds as Laramie by Sir William Dawson (or as Upper Eocene by Dr. Knowlton) rests on data which, however suggestive, are not finally conclusive, it seems that the evidence afforded by stratigraphy and lithology should be considered, and that at least the possibility of a Miocene age for the Twelvemile and Porcupine beds should be admitted. Certainly, in any division of the rock formations, these beds must be separated from the underlying Kenai series, and they are therefore mapped separately in this report.

THE PALISADES CONGLOMERATES.

On the left bank of the Yukon, about 35 miles below the mouth of the Tanana, cliffs of silt and gravel rise to a height of 150 feet. This

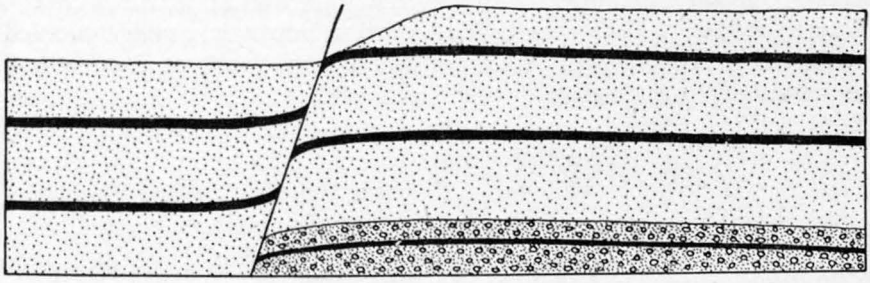


FIG. 11.—Exposure of Palisades conglomerate underlying silts.

locality has been named the Palisades, but on account of the occurrence in the silt of abundant bones of the mammoth and other large mammals, it is more popularly known as the "Boneyard." The silts also contain lignite beds and small land and fresh-water shells, and are of Pleistocene age. About a mile below the beginning of the silt bluffs the height of the vertical exposure changes from 150 to 200 feet, the increase being apparently caused by a fault which is visible in the face of the bluffs, and which upthrusts the down-river portion. The fault is a normal one, and the silts of the upstream side are seen to be upturned against the fault plane. (See fig. 11.) On the downstream side of the fault there is brought up a lower and more consolidated

bed which underlies the silts. This new bed is pure white, being composed of clean sand and well-washed pebbles. It is strongly cross-bedded, and contains much woody matter—sticks, logs, etc.—in a condition between wood and lignite. Many of these woody layers are steeply inclined, being cross bedded with the sandstone. This bed is very gently arched and has a barely perceptible dip downstream. It is partly indurated, so that while it yields with comparative ease to a pick, it is firm enough to stand in solid, nearly perpendicular cliffs, and falls in great slabs.

In the materials collected from the woody layers Dr. Knowlton found fragments of dicotyledons, but none sufficientlly distinct for identification. Many of the layers are full of finely preserved cones, which, according to Dr. Knowlton, appear to be the same as Heer's *Pinus macclurii*, and from these he infers that the age is Pliocene, or possibly Upper Miocene.

THE YUKON SILTS.

YUKON FLATS.

Throughout nearly its whole course the Yukon flows through an unglaciated country. The great cordilleran glacier, which has been made known chiefly by the work of Dr. G. M. Dawson, and which occupied British Columbia west of the Rocky Mountains and the extreme southern part of Alaska, has now shrunk into the many small separate glaciers which form such interesting features in the scenery of the Alaskan coast. This glacier, however, never extended farther north than a point which on the Yukon has been determined as just above the junction of the Lewes with the Big Salmon River. This fact has been confirmed by the observations of Dawson, McConnell, Russell, and Hayes. From its source to its mouth the Yukon flows in narrow, deep valleys; and where the country has been glaciated, as along the Lewes above the Big Salmon River, the hills are somewhat rounded and the topography suggests glacial action. Here also the river sometimes slackens, and forms long, narrow lakes, whose shores are generally steep and often precipitous and whose basins are simply portions of the ancient river valley which have been dammed in one way or another. North of the limit of glaciation the scenery is more bold and picturesque, and the river flows through a deep and often narrow valley with steep and rugged walls which are conspicuously terraced, the lower terraces being formed of gravels or silts, while the higher ones are carved out of the rocks. This is the nature of the valley from the Big Salmon River to Circle City, a distance of 400 miles or more.

About 50 or 60 miles above Circle City the valley of the Yukon enlarges, so that there is often a flood-plain several miles in width, which is swampy and covered with moss and stunted spruce and cot-

THE YUKON FLATS.

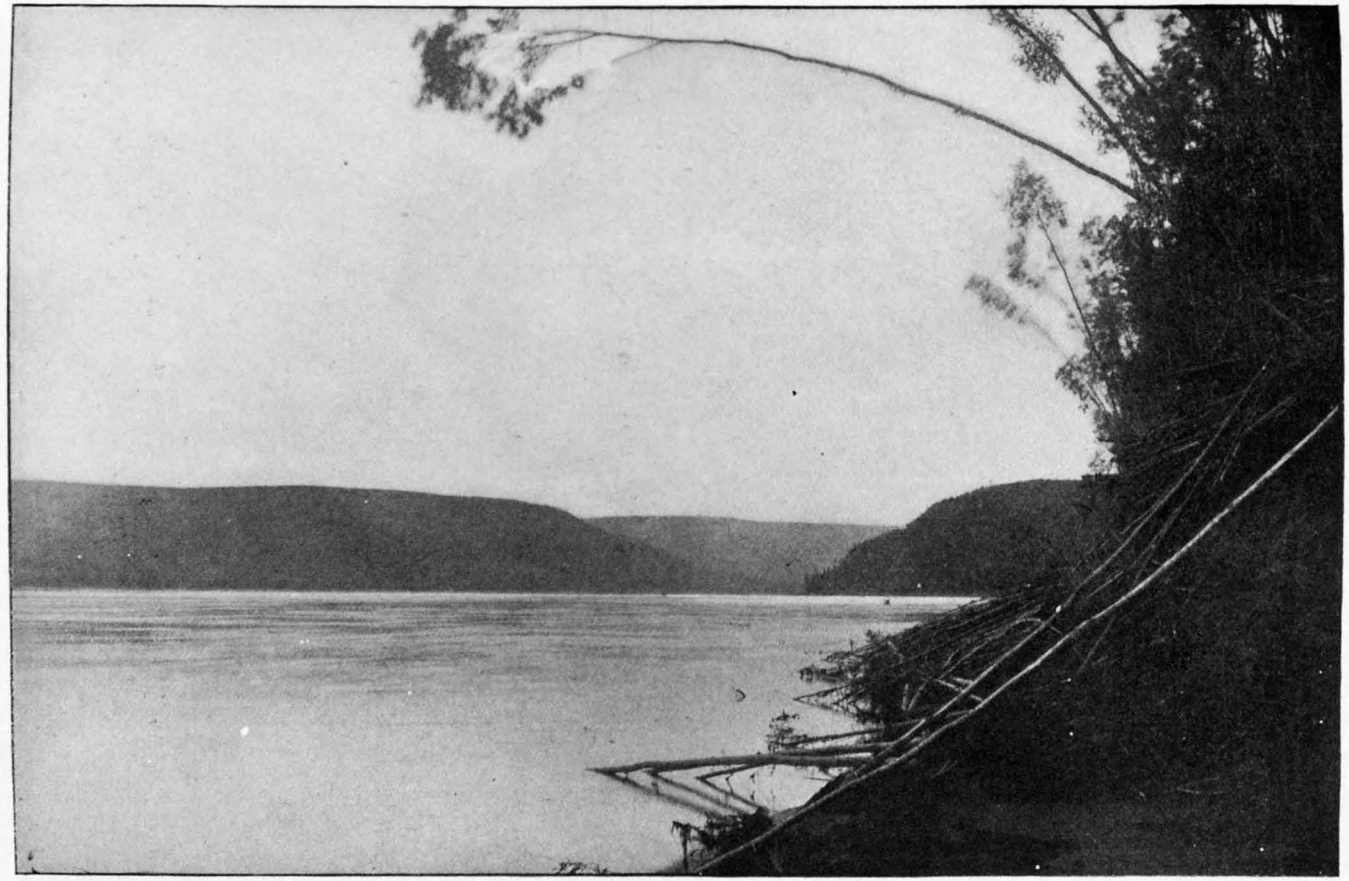
tonwood. The cuts along the bank of the river show that this flood-plain deposit is composed mostly of stratified sands with some gravels. Farther down the river the width of the valley still increases. About 5 or 6 miles above Circle City the steep wall on the left side suddenly disappears, and is replaced by low, perfectly flat banks, which stretch away to the southwest 20 or 30 miles to the distant low mountains. The high rock bluff on the right bank persists a little longer, but near Circle City this too disappears. With the recession of the confining rock walls the river broadens out and wanders slowly through the flats, forming long islands with channels or sloughs between. Thus the Yukon is said to be 7 miles wide at Circle City, and undoubtedly the combined width of its several channels is nearly or quite that. Northeast and northwest from Circle City the sky line is low and perfectly level, being formed, indeed, by swampy land, such as constitutes the banks at this point. To the northwest, beyond the flats, lies a spur of picturesque mountains. Below Circle City the river flows for 250 miles or so through this perfectly level country. For a large part of this distance the higher land which bounds the swampy flats is so far away as to be below the horizon, but at times outlines of hills may be seen. At its junction with the Porcupine the Yukon turns nearly at right angle and flows to the southwest, and the nature of the country on both sides continues the same as far as the trading post known as Fort Hamlin.

In this flat region the river spreads out very broadly, with numerous channels and islands. (See Pl. XXXV.) There was no hard rock observed at any point, the islands and the banks of the river being perfectly level and composed of horizontally stratified sands and fine gravels. The islands are of various heights; at the time of the writer's observation (the latter part of August) the highest ones stood at an average of 6 to 8 feet above the river, and were composed in large part of dark-colored silt with some coarser sands and fine gravels. These higher islands are covered with a heavy growth of spruce; the somewhat lower ones, which are made up of sand and gravel rather than of silt, have a young growth of cottonwood, while the gravel bars and sand spits, which rise only a few inches or a foot above the river, are bare or have but a scanty growth of young vegetation. So numerous are the channels in the river that one is rarely confident of having found the true bank; indeed, between Circle City and Fort Yukon our party was never certain about this point. From Fort Yukon to Fort Hamlin, however, the main current of the river flows along the right bank, which it does indeed for the whole length of the river between Fort Yukon and the sea, as has already been noted by Russell; and in this way the stream is continually eroding deposits which have been undisturbed for a long period. Between Fort Yukon and Fort Hamlin the boatman drifting down the river naturally follows the swiftest current, and therefore keeps always close to the right

banks. The banks are usually higher than any of the islands in the river, reaching often 30 or 40 feet above the water at the time of our observation. Like many of the islands, they are built up mainly of horizontally stratified silt with frequent layers of gravel. They are covered with a thick growth of trees, many of which are evidently of considerable age, and on the surface is a coating of deep moss, which is not found in the lower islands. There also appears to be an absence of the driftwood and other evidences of yearly inundation which characterize these islands.

The flats end even more abruptly than they begin. They terminate sharply about a mile above Fort Hamlin at a line of steep, bare, rock hills which rise to a common level estimated as 600 or 700 feet above the river. There is no noticeable narrowing of the valley as the stream approaches these hills, but the hills lie transversely to the course of the river, like a solid wall thrown up to hinder its advance. Up to the very point of reaching this barrier the river continues to be very broad, with many islands. Both the islands and the banks are low and perfectly level, and are built up entirely of gravel capped with silt, exactly like the banks and islands for 250 miles above. In the silts numerous shells of small gasteropods were found, belonging to land and fresh-water species, all of which are living in this region at present, according to Dr. W. H. Dall. Here, as farther up the stream, the true banks of the river are higher than the numerous islands, and there is no evidence that they have been inundated by the river floods for a long period, since at the time of observation they were about 30 feet above the river, and apparently above extreme high water. On leaving the flats the river immediately enters a narrow canyon, the walls of which rise steeply up to the general level of the hills. Pl. XXXVI is a photograph of the lower end of the flats and the beginning of the Lower Ramparts. In the right foreground is the silt bank of the river. The river, here cutting its right bank as usual, is undermining the silts, so that they fall into the water continually, carrying with them their vegetation. In the center of the picture is the narrow, canyon-like valley into which the river plunges on leaving the flats, and the level top of the hills in which this valley is cut is well shown. Beyond this level surface are low, rounded hills which rise above the usual level to a considerable height, and in the distance are steeper and higher mountains.

Returning now to the upper end of the flats, we find that their boundary on leaving the Yukon runs off at a right angle to the river for a few miles, and then skirts the base of the Crazy Mountains. Eight miles southwest of Circle City is a stream of considerable size, known as Birch Creek, meandering through the flats. This stream, however, continues to hold a course nearly parallel with the general trend of the Yukon, so that the distance is nearly 200 miles from this



END OF YUKON FLATS AND BEGINNING OF LOWER RAMPARTS.

point to where it joins the larger river some distance below the great bend. From the point on Birch Creek directly opposite Circle City the flats extend backward in a southeast direction, forming a long, broad arm, bounded by high and hilly land in all directions except the northwest. As is everywhere the case, the line of junction of the flats with the bounding higher land is very distinctly marked, and has been followed along this arm in some detail, since it is in this region that the placer gravels of Birch Creek, which are the most profitable thus far discovered in the Yukon district, are found. When thus followed, the line is found to be extremely irregular, branching off into arms which run for some distance up valleys deeply cut in the hills. The topographical sketch map of the Birch Creek mining district (Pl. L) gives some idea of the junction of these Flats with the surrounding hills. The bottom of the flats consists of swampy ground, with dry, low swells and small, shallow lakes. Through this level country Birch Creek winds with complicated meanders. Narrow, curving lakes, such as are shown on the map near Twelvemile cache, are old cut-offs of the stream, and are now being gradually converted into swamps by encroaching vegetation. Other lakes, such as Medicine Lake, have had an origin independent of the stream, being shallow bodies of water filling slight depressions in the surface, and these also are surrounded by a thick growth of rapidly increasing moss and water-loving plants.

Between this swampy country and the base of the bordering hills is a belt several miles wide, which has a uniform, very slight slope away from the hills and which is ordinarily dry. This belt occupies the most of the valley of Crooked Creek above Hog'em Junction, and has also been continuously observed along the base of the hills between Central House and the Twelvemile cache. (See Pl. XLIX.) The surface of this belt exhibits very slight undulations, which are not noticed in the perfectly level country more remote from the hills. The materials of which it is composed are schists and granite, like the rocks exposed in place on the adjacent hills, but here these rocks occur only in subangular or slightly waterworn fragments, piled together with often some suggestion of rude stratification. The streams which flow over this belt, such as Hog'em Creek, Boulder Creek, Albert Creek, Quartz Creek, and others, have no definite valleys, but have carved mere furrows on the surface, through which they flow down to the swampy flats. These streams all originate in the hills which rise abruptly from the lowland. Above the line of junction of the flats with the hills each stream, which before has flowed in a little furrow on the surface of the nearly level accumulation of rock fragments, lies in the bottom of a V-shaped valley carved deeply in solid rock; and in this valley there is little fragmental material except a small accumulation of gravels, which lie in the bottom and which are in many places rich in gold.

These flats extend up the Porcupine above its junction with the Yukon for 75 or 100 miles, as noted by Russell[1] and McConnell,[2] and here the characters of the deposit are the same as noted along the Yukon, the material being stratified silts, sands, and gravels, often showing cross-bedding. The extent of the flats is, therefore, not far from that shown on the map, where they are seen to reach in a northeast direction for about 200 miles, while their width, taken in a northwest-southeast direction, is probably over 100 miles.

The shape of the great silt, sand, and gravel deposit as thus outlined immediately suggests the former existence of a great lake, in the bottom of which these sediments accumulated, and the sharply defined hills which rise everywhere distinctly and abruptly from these flat deposits have all the appearance of shore lines. The sudden change in the character of the streams when they enter the flats from the hilly country, or leave the flats and enter the hills again, is also very strong evidence of the existence of such a body of water, for at the junction the canyon-like valleys suddenly and completely disappear and the river wanders far and wide over the sandy deposits, into which it has cut the merest indentations.

The belt of gently sloping, coarse, slightly stratified material, moreover, which has been described as lying between the swampy lowland and the hills in the Birch Creek mining district can be accounted for only by the supposition that it is composed of torrential material, brought down by the mountain streams which have carved such deep valleys in the surrounding hills, and deposited along the shore of a shallow body of standing water. The materials of this fragmental deposit, as has been remarked, correspond with the rocks found in the valleys of the mountain streams.

All the central portion of these flats, which is remote from the shores, is of fine material, chiefly silt. At the present time the Yukon rises annually into floods, and over low islands deposits repeated layers of fine sediment, which in many cases have accumulated to a thickness of several feet. These recent flood-plain deposits are often not distinguishable from the silts which form the banks of the river, but the latter ordinarily form bluffs of greater height. The growth of low islands by yearly additions can be studied in detail along this part of the Yukon, and the evidence of growth is generally seen in numerous layers of woody or peaty matter, which alternate with the layers of silt and represent each a summer's growth of vegetation, while the last layer is quite fresh and is only partially covered by certain rapidly growing plants.

The presence of driftwood and the marks of recent gouging by floating ice are also frequent evidences of late inundation. In the higher deposits along the banks, however, the silt is frequently very

[1] Notes on the surface geology of Alaska: Bull. Geol. Soc. America, Vol. I, p. 112.
[2] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1888-89, Vol. IV, pp. 27D, 133D.

thick, has little evidence of stratification, and is without the numerous little seams of woody matter which mark the annual growth of the lower islands, while the surface is deeply covered with moss and full-grown trees and bushes, and has evidently not been flooded for a very long period. It seems certain, therefore, that if these latter are flood-plain deposits, they were formed at a time when the general level of the river was higher than it now is, or before it had cut so deeply into its channel; and from the characters mentioned it seems probable that they are lake sediments. Mr. Russell has suggested that the whole material of the Flats is a vast flood-plain deposit, spread out by the Yukon in consequence of the river having been dammed up by an elevation of the Ramparts, but the abrupt termination of the upper end of the flats as well as the lower end, and the evidences of shore-lines already given, seem to exclude this hypothesis.

Concerning the flat deposits along the lower part of the Porcupine, Mr. McConnell[1] remarks:

> This plain has a width in its widest part of fully 90 miles. Sections are cut through it in different directions by the Porcupine and Pelly-Yukon, and show it to be underlain throughout by stratified sands and silts, often showing false bedding and with occasional layers of gravel. The latter appeared to become finer grained and of less relative importance toward the center of the area. The size of the plain, its uniformity, and the character of the beds which underlie it, suggest a delta origin, and correlate it with the lowlands at present in course of formation at the mouth of Slave River, in Great Slave Lake.

The period at which this lake existed must be very recent, for the fossils found in the silt all belong to living species. Another piece of evidence is found in the slight amount of erosion which streams have accomplished along the edges of the basin. In the zone of gravels and torrential materials, which has been described as bordering the old shores in the Birch Creek district, the streams which flow from the mountains run in constant narrow channels, yet they have cut only mere furrows, which can not be detected in a general survey of the landscape.

The same phenomenon was noted in the Lower Ramparts, below Fort Hamlin. The river here flows through a narrow valley, with steep walls, which are distinctly terraced all the way up to a nearly level plain 600 or 700 feet above the stream. In these walls lateral gullies running at right angles to the main trend of the valley have begun to form, but they are so imperfect in their development that they must have begun very recently, for the most marked ones are only deep V-shaped notches. Another suggestion is offered by the position of the river in the flats. The erosion of the right bank from Fort Yukon to Fort Hamlin is very rapid, and it follows that the stream must be rapidly pushing northwestward. The rapidity of this progress can be fully appreciated only by one who has traveled

[1] Op. cit., p. 27 D.

along the bank of the river and heard the continual splash of the water, with the rumbling of the silt banks and the crackling of trees as the under-cut portions fall. At this rate it is evident that in a very short time the stream will have pushed its way close up to the northwestern border of the flats, and the fact that it has not yet done so is evidence of the comparatively brief period that it has been working. That it has already traveled some distance is hinted at by the fact that it is at present approximately three times as far from the southeastern side of the flats as from the northwestern side.

FORT HAMLIN TO MYNOOK CREEK.

About halfway between Fort Hamlin and Mynook Creek, in the vicinity of Ray River, the valley broadens out, forming low flats, which stretch 8 or 10 miles away to low mountains, which are distinctly and evenly terraced (see Pl. XL). Below this point the river makes a sharp turn to the left, as shown on the map, and enters a narrow valley. Opposite Mynook Creek are narrow flats again. On the left bank of the Yukon, just above Mynook Creek, is a great thickness of steeply dipping Kenai beds, as already described. These are exposed in a steep bluff about 400 feet high, of which they constitute the lower 100 or 200 feet; unconformably overlying them are 5 or 10 feet of horizontally bedded gravels and mud, and then 200 or 300 feet of silts like those found in the flats. In these silts fossils were collected, which were identified by Dr. W. H. Dall as *Succinea chrysis* West., *Valvata sincera* Say., and *Limnæa palustris* Mull. All these species are found living in the region at present.

JUNCTION OF TANANA AND YUKON.

At the end of the Lower Ramparts, just above the mouth of the Tanana, the river again broadens out into flats. The banks here are of horizontally stratified silt, often 30, 40, or even 60 feet above the water.[1] From the river these flats extend in perfect uniformity on each side 10 or 15 miles back to the hills; but they narrow farther down, till about 25 miles below the mouth of the Tanana the stream again cuts on its right bank the hard schists of the Birch Creek formation. Below this, however, the silts continue to be exposed in places, especially on the left bank. They are also said to extend up the Tanana for many miles, causing constantly shifting channels like those of the Yukon Flats, and rendering steamboating difficult. Lieutenant Allen[2] notes that below the Toclat River the Tanana becomes very wide and sluggish, with sometimes several channels. This is, indeed, the manner in which it enters the Yukon, the various branchings having the aspect of a delta.

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[1] About the 1st of September.

[2] Report of an Expedition to the Copper, Tanana, and Koyukuk Rivers, Senate Doc. 125, 1887, p. 86.

About 35 miles below the Tanana, on the left side of the Yukon, rise perpendicular level-topped bluffs about 150 feet in height. The material in these bluffs is mostly extremely fine silt, greenish-gray in color, forming when wet a fine, sticky clay, and showing scarcely any traces of stratification. At intervals in this deposit are thick beds of vegetable material, containing wood in all stages of change, from pliable sticks to brittle brown lignite. These beds vary in thickness and also in the nature of their material; usually, however, they contain trees, some of considerable size. At the beginning of the exposure, and for some distance farther on, one of the heaviest beds of woody material is from 6 to 20 feet below the top of the bluff and is about 4 feet in thickness, while directly above it lie mixed gravels and silt, with occasional sticks and logs. In this deposit, about 6 feet below the surface, part of the skeleton of a mammoth was found, and tusks and other bones of this and other mammals are so commonly found here that, as has been said, the locality is known among the miners as the "Boneyard," although it is put down on the maps as the Palisades. A tooth picked up here was identified by Mr. F. A. Lucas, of the National Museum, as belonging to the species *Elephas primigenius*. All through the thick silt were found abundant specimens of the land shell *Succinea chrysis* West., which is, according to Dr. Dall, still living in the region.

About a mile below the upper end of these bluffs the silts and lignite beds are displaced by a steep fault, having a throw of about 50 feet, and by this the upper bed of the Palisades conglomerates is brought up below the silts. The contact of the conglomerates with the silt has a slight inclination downstream, showing a scarcely perceptible tilting. (See Pl. XXXIV.)

These bluffs are being continually undercut by the river, and yet the clay is so firm that the upper part of the bank often stands out as a projecting shelf when the lower part has been carried away. When this top part finally falls, therefore, it does so in great masses, and sometimes sinks gradually, with very little breaking, and lodges at the foot of the bluff, where the trees which it bears still continue growing. At the upper end of the silt exposures a large mass, containing part of the uppermost 4-foot bed of lignite above referred to, has sunk down in this manner. The lignite in the fallen portion has taken fire and nearly burned out, although in places it is still smoking and hot. The transformations effected by this burning in the surrounding materials are curious and interesting. In the unburnt lignite are layers rich in bog iron ore, which on burning is fused into a sort of impure pig. Other portions of the clay have been fused into vesicular slag, resembling lava, while a little farther away from the burnt seam bright-red brick has been formed, which is exactly identical in appearance with artificial brick. Other portions of the clay assume various bright colors in different stages of the baking

process—green, orange, yellow, and red—and these baked clays often show beautiful leaf impressions when broken open, which can not be discerned in the unburnt state.

On the face of the bluff from which the mass containing the burning lignite seam has fallen the same seam is exposed 100 feet or so higher up, but here it has not been on fire. In a search for the reason why the lignite in the fallen mass should have caught fire, while that remaining in the bluff escaped, the only important point of difference which could be discerned is that the fallen part of the seam is covered by water every year, while that in the bluff is quite out of reach of the river. In spite of the yearly inundation, the fires have been burning for a very long period, as learned from the natives and miners, and it seems possible that the water may have been the actual cause of the combustion. The process may depend upon chemical action between water and some of the components of the silt or lignite beds. A familiar process of this kind is the alteration of lime to calcium hydrate by the addition of water; the heat developed is sufficient to set surrounding objects on fire, so that to load a ship with lime is especially dangerous.

In the Bear River, on the Mackenzie beds, burning lignite seams were noticed a century ago by Sir Alexander Mackenzie, and they are still burning, as noticed by Mr. McConnell.[1]

ABOVE TWIN MOUNTAIN.

The silt deposits at the Palisades are comparatively narrow and seem to lie in a widening of the old Yukon Valley. They extend for 12 or 15 miles, and are then mainly replaced by solid rock; at intervals, however, are still exposed banks of gravel, sand, and silt 50 or 60 feet high, which rest unconformably upon the upturned conglomerates of the Kenai series. Just below the mouth of the Soonkakat there are exposed on both sides of the river bluffs of evenly and horizontally stratified silt, probably 150 feet in height. In the little depressions on the surface beds of peat are forming, often several feet in thickness, and the river, cutting the banks, exposes sections of this deposit, showing it to be of very much the same character as the beds of lignitic material observed in the silts of the Palisades and at other places. These bluffs soon diminish in height and become uniformly 8 or 10 feet above the water. The river broadens out and the hills recede, giving place to broad flats, whose exact extent could not well be made out. These flats extend for about 35 miles, terminating just above the mouth of the Koyukuk, where they are succeeded by hills and bold, rocky bluffs which are made up, in part at least, of the folded Nulato (Miocene) beds.

[1] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1888-89, Vol., IV, p. 98D.

BELOW THE KOYUKUK.

Below the Koyukuk there occur narrow local flats on both sides of the river, but almost always on the concave side of the curves. The banks are ordinarily not over 12 feet above the river, and their tops are covered with a fresh layer of silt, which bears little vegetation except rapidly-growing, bright-green equisetums, which have evidently all sprung up within a few weeks or months. Sections often show repeated layers of peat alternating with the silt, the successive accumulations of vegetation which were afterwards covered up by flood deposits; and in some layers the trunks of trees which have taken root have been partly covered by silt, while their upper parts still stand erect above the surface. In other cases the dead trees have been broken off at the surface, while 2 or 3 feet of the stump remains buried in the silt. Some of these erect stumps were noted 4 feet below the surface. Shortly below Andreafski the flats of the Yukon delta begin. These are composed of silts like those already described. The banks are low and treeless and are strewn with driftwood, showing that they have been recently inundated.

The silt deposits just described between the Koyukuk and the sea have the same characteristics as the flood deposits in the Yukon Flats. They are built up, by annual depositions of silt from the muddy, flooded river, on a substratum of sand and gravels accumulated by the water in its lower stages, many circumstances, such as the partially buried trees and the fresh silt covering the tops of the banks, showing that their formation is still going on. This is true, however, only of those deposits whose tops are but a short distance above the river-level. At an altitude of 20 or 30 feet the flats along the Yukon are covered with thick moss and are free from evidences of recent inundation. At various points, moreover, beds of silt having the same appearance as those now being formed by the river have an altitude several hundred feet or more above the present stream, and are sometimes as much as 200 or 300 feet in thickness.

These elevated silts are evidently of greater age than those lying only a few feet above the river, but there is a gradual transition from he highest to the lowest, showing that in the Yukon Valley nearly the same sediments have been deposited during a period in which the river has cut down its bed considerably. It is to be remembered, however, that even the most recent of these silts are formed under conditions different from those usually afforded by rivers, since they are built up by deposition from waters which are spread out in time of flood and which have comparatively little movement; so that the conditions are rather those of a lake than of a rapid river. It has previously been suggested that the higher silts of the Yukon Flats were probably deposited in the bottom of a shallow lake, while the more recent ones were formed under lacustrine conditions in time of

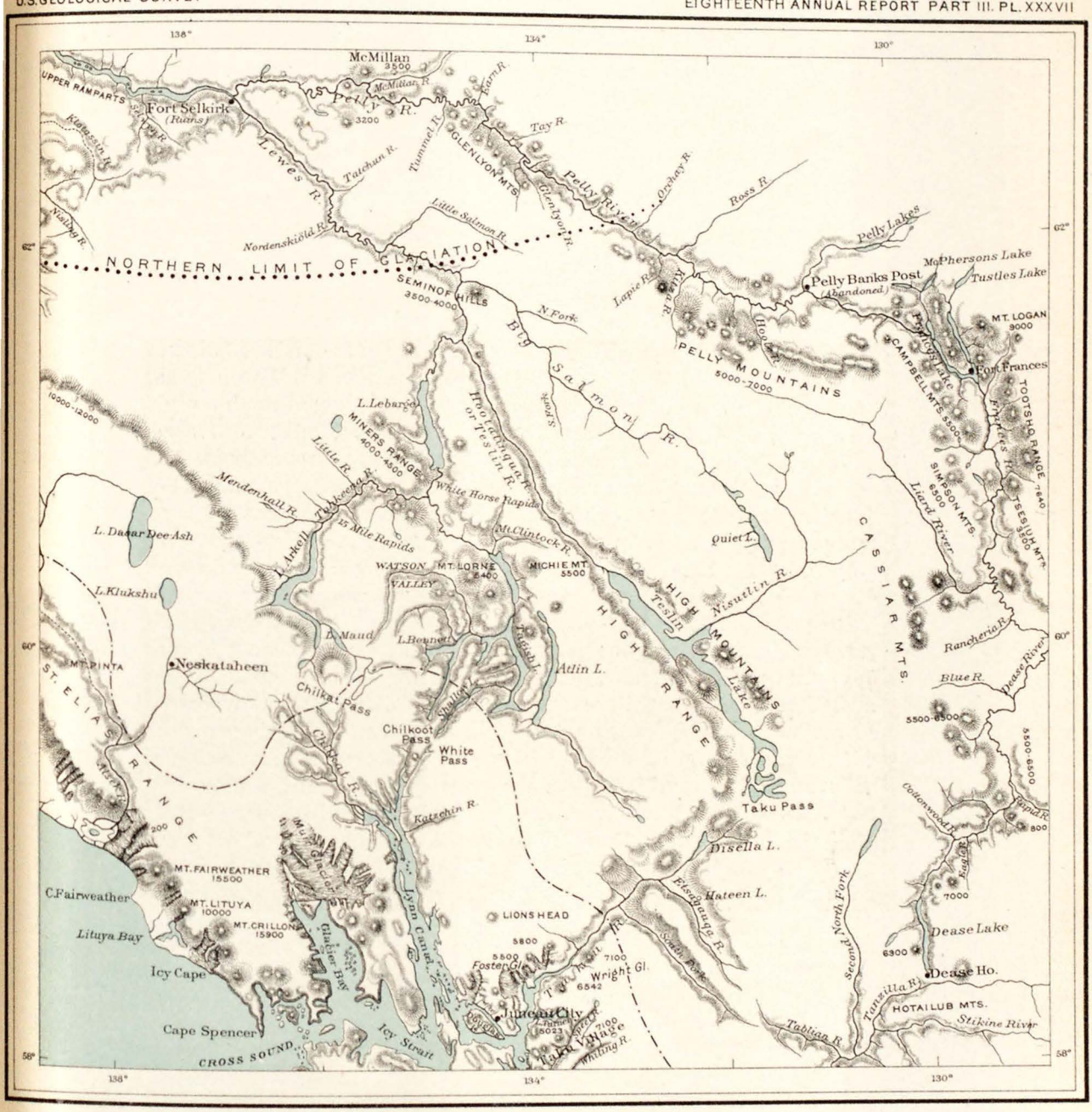
flood, and the step from one to the other condition is very slight. The elevated beds of pure silt at Mynook Creek, the Palisades, below the Soonkakat, and at other places along the river, seem to show that they were formed at a period when lacustrine conditions prevailed for a comparatively long time; for they are often many feet thick, without any layers of vegetable matter or of coarse detritus, and so can not well have been formed in the short space of time allowed by a spring flood. The great thickness of these deposits is also against the idea of river deposition.

SILTS BETWEEN LAKE LINDEMAN AND THE FIVE FINGER RAPIDS.

On the Lewes River, above the junction with the Teslin, is a series of long, narrow lakes. (See Pl. XXXVII.) Four of these, lakes

Fig. 12.—View at the head of Lake Lindeman, looking west, showing the higher rock-cut terrace, its top outlined by snow. On the same level as this is the beginning of a broad valley of comparatively slight gradient, which reaches back some distance from the lake. From the level of the rock-cut terrace the waters plunge suddenly downward, and have carved a small canyon.

Lindeman, Bennett, Tagish, and Marsh are closely connected and have nearly the same level. Lake Lebarge is somewhat over 30 miles long, and is separated from the rest by 60 or 70 miles of rapid river. It is the lowest in the series, being some 30 miles above the mouth of the Teslin. All these lakes occupy portions of the old, deeply eroded river valleys of the Yukon and its tributaries, where



OUTLINE MAP OF THE UPPER YUKON AND VICINITY ADAPTED FROM COAST SURVEY CHART-T

Scale of miles

20 0 20 40 60 80 100

Area occupied by this Map is shown by dashed lines on Pl. XXXII (General Map of Alaska)

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these valleys have been obstructed or deformed so as to dam up the drainage. The river, which occupies its old valley below the lakes and between Lake Lebarge and Lake Marsh, is at present very rapid and is cutting down its channel so that the lakes are being gradually drained; and if present conditions continue they will have entirely disappeared within a comparatively short period of geological time. That this process of draining has gone far is shown by level terraces and deposits of finely stratified silt above the present level of the lakes and in places along the banks of the down-cutting river.

The terraces were first noticed on Lake Lindeman, on the shores of which there are two very distinct benches. One is about 50 feet above the lake, and is composed of sand and gravel which, when undercut by the water, form conspicuous yellow exposures. The second terrace is considerably higher and runs back in some places a long distance from the shores, to a line where the uniform upward slope of the mountains begins. On this upper terrace are bare, rounded rock surfaces which are cut by small valleys of considerable depth. (See fig. 12.) The lower terrace, therefore, seems to be constructional, and to have been built up in quiet waters, while the upper one has the appearance of having been carved out of the rock by a body of water capable of sweeping away the rock fragments as fast as they were worn from the hills.

On Lake Tagish and Lake Marsh there are bluffs of fine, homogeneous silt, horizontally stratified, 20 or 30 feet in height. That part of the Lewes River which connects Lake Marsh with Lake Lebarge is known by the miners as Sixtymile River, it being approximately of this length. On the upper part of this river the silt bluffs are 30 or 40 feet high, and they gradually grow higher farther down the stream. About halfway between Lake Marsh and Lake Lebarge the river valley has been dammed by a flow of basalt, through which the stream has cut a narrow canyon where the water flows very swiftly. Just below the canyon are the White Horse Rapids, which are due to the same cause as is the canyon, the water being here also confined by steep basalt walls. At the White Horse Rapids the basalt is overlain by horizontally stratified silts like those described above. From the White Horse Rapids to below the Tahkeena River (which lies between the rapids and Lake Lebarge) there are no rock exposures, but the river flows through steep banks of silt, which grow continually and gradually in height, till at the mouth of the Tahkeena River their height was estimated at 150 feet. The material shown in these exposures is chiefly fine silt, sometimes with gravelly layers, and generally exhibiting even, horizontal stratification, but often so homogeneous that no trace of stratification could be detected in thicknesses of many feet. The river is continually undercutting the banks, so that everywhere columns of dust are seen ascending like smoke where a portion of the bank topples into the stream. In this way the river becomes

very muddy, and is still more highly charged with sediment from the dirty waters of the Tahkeena. In Lake Lebarge, however, this mud settles, so that the waters of the Lewes, as they flow from the foot of the lake, are comparatively clear and of a greenish color.

The sediments now forming in the bottom of Lake Lebarge must therefore be growing rapidly, and must consist of fine, horizontally stratified silts, exactly like the deposits from which they are immediately derived, and which are now exposed along the banks of the river. If in the geological future Lake Lebarge is drained, as it must be if the present rapid downcutting of the river continues, the material now accumulating will be exposed along the banks of the new stream

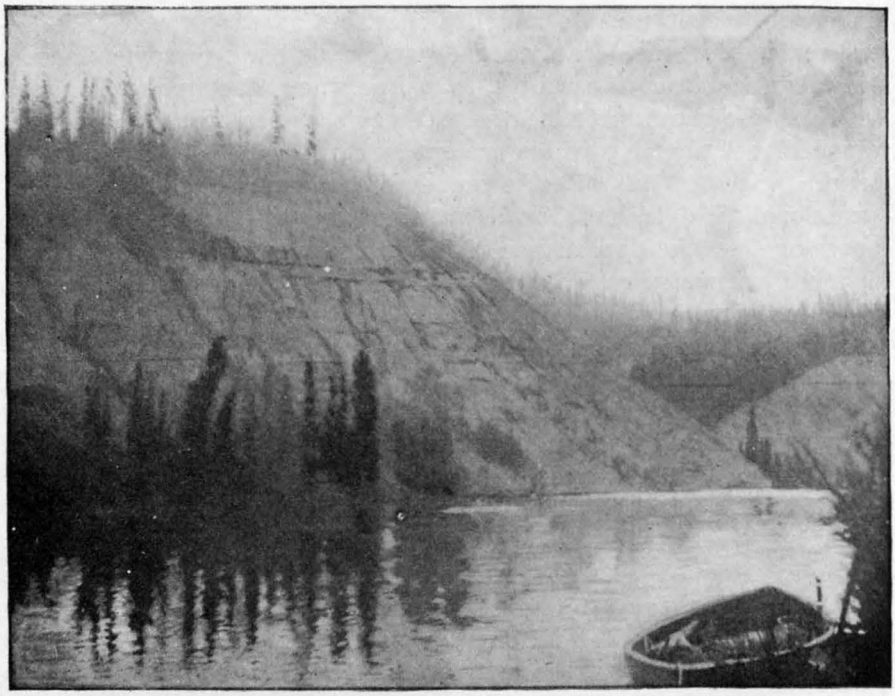

FIG. 13.—Bowlder-clay, silts, and gravels on the Lewes just below the Teslin (Hootalinqua).

and will have the same appearance as the older deposits. The evidence of their later age, however, will be found in their slight elevation above the stream as compared with the greater height of the older accumulations. This would be analogous to the cases already described along the Yukon between Circle City and the sea, and noticeably in the Flats between Circle City and Fort Hamlin, where sediments of nearly uniform appearance are found at slightly different elevations; and of these the higher ones were probably laid down in old lakes of considerable duration, while the lower ones were deposited later, at times of flood or temporary damming of the river.

Lake Marsh, which lies above Lake Lebarge, is called by the miners

Mud Lake, on account of its shallow, muddy bottom and shores. Here again the sediments are exactly like those of the higher bluffs, and the process of their formation is like that at Lake Lebarge. In the bottom of the lake the silt accumulations must be very thick.

The exposures of silt in bluffs cease, so far as observed, at the extreme upper end of Lake Lebarge. The shores of this lake where examined were largely of bare rock. At the lower end of the lake the Lewes River at first flows through banks of gravel and sand 30 feet or less in height. Below these gravels there is often exposed clay containing pebbles and subangular bowlders, the deposit being evidently of glacial origin and having ordinarily the aspect of a true till, though often showing signs of stratification. Near the junction of the Lewes with the Teslin this glacial deposit, capped by gravels and interbedded silts, forms steep scarps 100 feet in height. (See fig. 13). Below the Teslin the top of the bowlder-clay becomes gradually lower, and the banks are made up more and more of stratified silts and gravel, till near the junction of the Big Salmon River they are often entirely of finely stratified material, and are still as much as 100 feet in height. The silts continue to be exposed, alternating

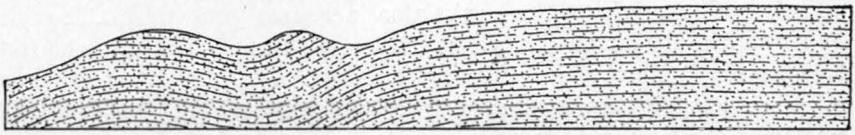

FIG. 14.—Diagram showing folding in silt bluffs on the Lewes above Miles Canyon.

with frequent rock outcrops, nearly to the Five Finger Rapids. In the neighborhood of the rapids they practically stop, and between here and Circle City, a distance of about 450 miles, the Lewes and the Yukon flow past banks of bare rock, except where the stream has formed local deposits of sand and gravels, which it has afterwards cut through.

The silts between Five Finger Rapids and Lake Lindeman are often seen to be very slightly but distinctly plicated in places. (See fig. 14.) This folding is quite recent, for the little synclines in the surface have been adopted as channels for the drainage water, and so have sometimes developed into gullies. Along the river between Lake Marsh and Lake Lebarge, and between Lake Lebarge and the Five Finger Rapids, there is often a layer of river pebbles and sand, horizontally stratified, topping the silt beds and resting unconformably on them where they have been plicated. This layer is never more than a few feet thick, and is often entirely wanting. On top of the river gravels, or, where these are wanting, on top of the silts, is everywhere seen a thin layer of white, gritty volcanic ash, which ordinarily conforms to all the little irregularities in the surface, and which, therefore, has the appearance of having been deposited a comparatively

short time ago. This volcanic ash is widely distributed over this portion of Alaska, and has been described by nearly all travelers who have passed through this region. Along this part of the river the layer is never more than a few inches thick, and is immediately overlain by several inches of vegetable loam, which forms the immediate surface.

The steady increase in elevation of the lowest broad silt terrace from the lakes to the Tahkeena River indicates that the surface of this lowest terrace is very nearly horizontal, so that the river, in cutting down through it, flows between higher and higher banks as it reaches successively lower points. It is probable, therefore, that this deposit was laid down in still water or in a scarcely perceptible current, and the nature of the sediments, which are like those now forming in Lake Marsh and in other places under lacustrine conditions, points to the same conclusion. So far as observed, however, the continuity of the silt deposits appears to be broken at the upper end of Lake Lebarge. At the lower end of Lake Lebarge are low banks of bowlder-clay and gravel; below the mouth of the Teslin the bowlder-clay becomes capped by an increasing thickness of silt and gravel, and the glacial material appears to pass laterally into stratified deposits. The height of the banks also increases somewhat, although not so markedly as on Sixtymile River between Lake Marsh and Lake Lebarge; however, between the mouth of Little Salmon River and Five Finger Rapids the interbedded silt and fine gravels are sometimes exposed in perpendicular bluffs 150 feet in height or more. These deposits often bear evidence of the existence for long periods of uniform conditions, but the narrowing valley and the frequent gravels show that the body of water in which these sediments were laid down was narrower than that which existed above Lake Lebarge, and had probably in places some current.

According to aneroid determinations made by Dr. Dawson's party, the surface of Lake Linderman is 70 feet higher than that of Lake Lebarge, the elevation of the former being 2,170 feet and of the latter 2,100 feet above the sea. The main gravel and silt terrace on Lake Lindeman was estimated by the United States Geological Survey party as being 50 feet above the lake, which would give it an altitude of 2,220 feet. Just above Lake Lebarge the broad silt plain through which the river cuts was estimated as being more than 150 feet above the water, and is therefore at an approximate elevation of 2,250 feet. This elevation is 30 feet above that of the Lake Lindeman terrace. It must be remembered, however, that the elevation of the lakes as determined by the aneroid can be only approximate, and, moreover, that our own estimates of the height of the bluffs at the various places are necessarily inaccurate. Careful surveying might make the difference more or less, but it seems certain that the top of the lowest silt deposit is nearly horizontal.

Above this lowest terrace there are seen on all the lakes, on Sixtymile River, and on the Lewes well-marked benches, which occur up to a considerable height. Dr. Dawson[1] estimates the highest terraces on Lake Lebarge as 400 feet above the lake, while Professor Russell[2] puts their height at 550 or 600 feet. On the lower part of Lake Bennett the higher terraces were estimated by the writer as being 400 or 500 feet above the water. On Sixtymile River, between Lake Marsh and Lake Lebarge, the two best-marked terraces were measured with an aneroid by Mr. Schrader and found to be 175 feet and 300 feet above the river. The upper one was best marked. Of these successive terraces the lowest are in general the most regular, and are made up of silt, sand, and gravel. The upper ones, which were not carefully examined, are more irregular in detail, and often have the appearance of being rock-cut, although encumbered with gravel and sand. On Lake Bennett benches 200 or 300 feet above the lake are strewn with large glacial bowlders of granite, which have been brought from a point some miles up the lake.

The occurrence of terraces or benches is by no means limited to the vicinity of the lakes, for they were observed all along the Yukon River between here and the sea. They have been noted at many points in Alaska and British Columbia by G. M. Dawson and R. G. McConnell, and are found on islands in Bering Sea. These terraces will be spoken of in more detail later in considering the movements of the land, and it need only be stated here that the whole interior plateau of Alaska and British Columbia appears to be distinctly terraced up to a great height, which may be approximately stated as 3,000 feet above the sea. Above this occasional terraces are found up as high as 5,300[3] feet. As pointed out by Dr. Dawson, these higher terraces are distinct from the abundant river terraces in that they do not always follow the river valleys, but skirt the divides and appear far up on the highest hills. They seem to mark the former shore-lines of a great level body of water which flooded the whole country, and from their presence in such places as the mountainous islands of Bering Sea it is evident that they are marine. From the clearness with which they are ordinarily cut, moreover, it is evident that they were formed at no very ancient geological period.

For these reasons Dr. Dawson has considered the terraces, which have been described, above the lakes on the Upper Yukon to be of marine origin. Evidence found at other places shows that the sea probably encroached thus far at least, and when it stood at this elevation it must have formed shore-lines. The character of the upper benches on the lakes, such as the bench described on Lake Lindeman above the gravel terraces, favors the idea of marine origin, for they

[1] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1887–88, Vol. III, Part I, p. 159B.
[2] Notes on the surface geology of Alaska: Bull. Geol. Soc. America, Vol. I, p. 147.
[3] G. M. Dawson, Trans. Royal Soc. Canada, 1890, Vol. VIII, Sec. IV, p. 36.

appear to be carved out of the bed-rock, and such a method of formation involves active erosion and active removal of detritus, such as would be accomplished by the waves and currents of the sea but with difficulty by the quiet waters of a small lake. Dr. Dawson, however, applies the idea of marine origin to all the phenomena, and considers all the terraces as marking marine shore-lines, and the silt deposits as laid down in an arm of the sea, which he proposes to call Yukon Inlet. Previous to the publication of Dr. Dawson's paper containing the above conclusions, Prof. I. C. Russell[1] had traveled through this region and had concluded that the silt deposits were formed in a lake, which he called Lake Yukon.

The characters of the silts are such that they must have originated, if not in a lake, at least in a body of water where the conditions were lacustrine. These characters are identical with those of the lake deposits already described farther down the Yukon. When it is considered that as far down as Circle City the occurrence of the silts is practically limited to the region between the Five Finger Rapids and Lake Lindeman, although the terraces accompanying them in this region continue down the Yukon quite to the sea, and that the district to which they are thus limited corresponds in a general way to the region of the present lakes, it must be admitted that there seems good grounds for belief in their lacustrine origin. The absence of marine fossils in the silts, as Dr. Dawson himself points out,[2] is negative evidence against considering them marine.

The assembled facts which have been cited seem to point to an explanation intermediate between the differing views. The benches or terraces all over the interior plateau of Alaska and British Columbia, fringing the mountains and the mountainous islands in the sea, point to a comparatively recent submergence. This submergence was probably 3,000 feet below the present general level. The sea, therefore, must have invaded the deep, narrow valley which the Yukon had previously cut in the old plateau, and toward the head of this valley must have stood fully as high as the highest of the observed terraces in the lake region.

To marine action at this period the upper rock-cut terraces, often encumbered with gravel, may be assigned, their formation seeming to indicate active erosion and transportation greater than is ordinarily possible in a small lake. When this upper part of the ancient river valley emerged from the waters of the ocean it was slightly depressed relatively to the lower part, so that the drainage waters spread out into long, irregular lakes, stretching over the old channels. Whether the depression which gave rise to the lakes was due to slight deformation attendant on elevation or to other causes is not certain, but similar differential movement is now undoubtedly

[1] Notes on the surface geology of Alaska: Bull. Geol. Soc. America, Vol. I, p. 146.
[2] Trans. Royal Soc. Canada, Vol. VIII, Sec. IV, p. 43.

going on in Alaska. In this case the cause of differential movement or relative depression may have been, as suggested by Professor Russell,[1] the weight of the great cordilleran glacier.

The approximate coincidence of the northern border of glaciation and of the silt deposits in this region seems to favor this hypothesis; but whatever may have been the cause of its origin, it is certain that a basin was formed and still exists, and the lake or lakes which occupied it immediately after the retreat of the sea may perhaps have stood at a level not greatly above that of the present lakes. If it be assumed that the lower gravel terrace on Lake Lindeman was the first deposit of the fresh-water lakes and that the rock-cut terraces above are of marine origin, then the lake may have stood originally only 100 feet or less above the present level of Lakes Lindeman, Tagish, Bennett, and Marsh. On the bottom of this lake the level silt deposit found continuously between Lake Lindeman and Lake Lebarge, but best shown on Sixtymile River, may have been laid down while sandy and gravelly terraces were forming higher up along the shores. The lake seems to have been interrupted or to have greatly shallowed at Lake Lebarge. Here the silt deposits are succeeded by rock shores, and at the foot of Lake Lebarge, where silts and gravels having the appearance of lacustrine origin are again found, they are at a lower level, indicating a somewhat separate and deeper basin. Below Lake Lebarge the silts frequently indicate long-continued sedimentation in quiet waters, but the morainal material found along here has caused irregularities in deposition and variation in the nature of the sediments, so that the characters of the deposits are by no means constant. The narrowing of the old valley in this region is likewise adverse to uniformity of sedimentation. The lower body of water below Lake Lebarge, or the lower extension of the principal lake, must therefore have been narrow and in places like a sluggish river, and must have passed gradually into a swifter river above the Five Finger Rapids.

With the further elevation of the land above the sea, the rivers became swifter and capable of carrying more water within a given time. By virtue of the increased erosive power gained thereby they also began to cut down their channels, and in this way the water of the lakes was gradually drained, so that the narrow lake or lakes below Lake Lebarge disappeared entirely, and the upper lake, which Professor Russell has named Lake Yukon, shrunk to various small connecting bodies of water, now known as Lakes Lindeman, Tagish, Bennett, Marsh, and Lebarge. The stage when the increase in elevation accelerated the movement of waters, so that narrow lakes became transformed into broad rivers, is marked on Sixtymile River between Lake Marsh and Lake Lebarge and on the Lewes below Lake Lebarge by the layer of gravels which overlies the silts, and was the first deposit of the young river. There are evidences that

[1] Op. cit., p. 148.

elevation of the land is still in progress at the present time. The rivers are still rapid and are cutting down their channels, so that the drainage of the lakes is still going on, and in course of time they will shrink to still smaller dimensions, or very likely will be entirely drained, in which event the present shore lines and the silts accumulating on the bottom of the lakes will be exposed along the banks of the future river in silt bluffs and terraces identical in appearance with those now found, and forming a natural continuation of them.

Another factor in the draining of the lakes was probably tilting. So great an elevation (probably at least 3,000 feet) was not without some slight irregularities. Indeed, on the Lower Yukon and its tributary streams, it appears that the land is being elevated more rapidly to the south than to the north, so that the streams crowd over to their northern banks. If this differential elevation extends to the region of the Upper Yukon lakes (where time was not available for investigation), the drainage of the lakes must be accelerated thereby. Moreover, if, as has been suggested, the depression of the ancient river valleys, forming lake basins throughout this region, was caused by a sinking of the earth's crust by the weight of the cordilleran glacier, this same region should now be regaining its former elevation, and in doing so the water accumulated in the depressions would gradually be discharged. That there have been local disturbances during the process of elevation is shown by the slight plication of the silt beds and by the occasional faulting.

INTERIOR PLATEAU REGION OF BRITISH COLUMBIA.

Dr. G. M. Dawson has described[1] silts like those of the Upper Lewes as having a wide distribution over British Columbia, in many valleys and lakes. All these occurrences Dr. Dawson correlates under the head of the "White silts," and, as in the case of the silts of the Lewes, supports the idea of their marine origin, suggesting that they were laid down in fiords connecting with the sea, their materials being derived from the débris of the retreating cordilleran glacier.

PELLY RIVER.

On account of its proximity to the Lewes, the Pelly River may be especially mentioned. Dr. Dawson has noted[2] along the Pelly below Ross River silts like those on the Lewes, often 50 feet thick, and resting upon bowlder-clay and gravel. These silt bluffs are cut out of flats, which sometimes stretch for considerable distances away from the river.

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[1] Trans. Royal Soc. Canada, 1890, Vol. VIII, Sec. IV, p. 44 et seq.

[2] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1887-88, Vol. III, Part I, p. 126B.

TESLIN RIVER.

On the Teslin (Hootalinqua) River, Dr. C. W. Hayes[1] noted continuous level-topped bluffs, consisting mostly of silt, with layers of sand which are often cross-bedded, the whole being capped by a bed of coarse gravel 10 feet or more thick, which is sharply separated from the underlying silt formation. The bluffs increase in height from 100 feet at Lake Ahklen to 150 feet at the mouth of the river, and are frequently cut into a number of terraces.

KOWAK CLAYS AND GROUND-ICE FORMATIONS.

Under these heads Dr. W. H. Dall[2] has described a series of clays, with often interstratified beds of ice, which occur at various points on the Alaskan coast, notably on Kotzebue Sound and the Kowak River, as described by Lieutenant Cantwell. Along the shores of the sea and the banks of the river there are exposed in many places cliffs of solid ice, which sometimes rise to a height of 150 feet and are covered by clays and dark-colored earth, on the top of which flourish trees and moss. This ice therefore plays the part of a rock formation. The clays also occur in places where the ice is absent, and on the Kowak River form in one place a bluff three-quarters of a mile long and 150 feet high. On Kotzebue Sound, at Elephant Point, the beds of blue clay contain numerous bones of Pleistocene mammals, such as the elephant, horse, and buffalo, and in the Kowak clays are also many mammoth tusks. Dr. Dall describes some of the clays at Elephant Point as containing much vegetable matter mingled with the clay or forming distinct layers in it, and in one layer of sphagnum or bog moss fresh-water shells of the genera Pisidium, Valvata, etc., were found. These ice and clay deposits are considered by Dr. Dall as having been formed in vast shallow lakes, and are referred somewhat doubtfully to the Pleistocene.[3]

CORRELATION.

In all the localities which have been described are deposits of silt having similar characters, showing deposition in bodies of still and often undoubtedly shallow water. These silts often contain the remains of the mammoth and other Pleistocene mammals and land and fresh-water shells of living species. Wood and vegetable matter are also abundant in places. In most cases it seems certain that the bodies of water in which the deposits were formed were fresh-water lakes. The silts of the Upper Yukon and the surrounding region have been supposed by Dr. Dawson to be deposits in marine estuaries;

[1] Expedition through the Yukon district: Nat. Geog. Mag., Vol. IV, p. 156.
[2] Bull. U. S. Geol. Survey No. 84, Correlation Papers—Neocene, p. 260 et seq.
[3] Op. cit., p. 266; also Pl. III.

but at present there are numerous lakes in this country, and the raised beaches along the coast and the rapid down-cutting of the rivers in the interior show that formerly these lakes must have been more extensive, so that part, at least, of the silts must be of lacustrine origin.

Considering the problem of correlation in the light of dynamic disturbances, we find that most of the silts when carefully examined show evidences of slight movement. On the lakes of the Upper Yukon the silts are in places slightly but distinctly plicated, so that the later river gravels rest on them with slight local unconformities; in the Palisades the silts have been displaced by a fault of 50 feet, while on the Lower Yukon evidence of tilting is sometimes found in the inclination of the surface of a silt deposit which must originally have been horizontal. In no place, however, have these deposits met with any important disturbance.

AGE OF THE YUKON SILTS.

The silts on the Lewes and Pelly rivers rest upon bowlder-clay, showing that they were deposited in places left by the retreat of the glacier after its maximum extension. On the other hand, above the silts comes a layer of river gravels which marks the point where the elevation which first caused the retreat of the sea became sufficient to convert standing or sluggishly moving water into rivers. The lakes of the Lower Yukon were also formed subsequent to the retreat of the sea, and were also drained in consequence of the increasing elevation. It may be said in general, therefore, that the accumulation of the silts began in shallow lakes and sluggish rivers on the emergence of the land from the sea after the maximum extension of the cordilleran glacier, and has continued on a progressively smaller scale up to the present day, since such sediments are now in process of formation in lakes like those on the Lewes, in sluggish parts of the Yukon and its tributary streams, and on the flood-plains of these rivers. The gradually lessening amount of accumulations is due to the increased elevation of the land and the consequent increased carrying power of the rivers, whereby the silting-up of the river beds is prevented and the channels are cut down so as to drain the water from the old lakes. In the Upper Yukon region the silts seem to have been largely derived from material ground out of the rocks by glacial action, and this material has doubtless contributed very largely to the sediments of all the lakes into which waters rising in this glaciated region empty.

Concerning the origin of these lake basins, it seems likely that slight differential movements in the earth's crust were the most common cause. The elevation of the whole peninsula of Alaska for 3,000 feet or more can hardly have taken place without occasional irregularities, the latest evidence of which are the slight folding, faulting,

and tilting of the silts. Very slight local differences would convert portions of the old river valleys into lakes similar to those now existing in the Upper Yukon region, and in such lakes most of the silt deposits seem to have formed. The broad basin of the Yukon Flats, however, can hardly be considered as having formed part of the pre-Glacial valley of the Yukon, since it stretches out abruptly from the junction with this valley to a great width. It is possible, therefore, that this is an orogenic depression of considerable age.

Other hypotheses have been made to account for the origin of the Upper Yukon lakes which further study may show to be in part or wholly correct. Dr. G. M. Dawson[1] suggests that "the lakes of this region now occupy the place of the last tongues of the great glacier, which in the end disappeared so rapidly that their beds had not time to become filled with detritus." The same view was held for Lake Ahklen by Dr. C. W. Hayes,[2] who considered that "the present lake basin was doubtless occupied by a lobe of the retreating glacier, which prevented the silting-up of the portion of the valley so occupied. On the withdrawal of the glacier at the close of the stationary period the lake was left much as it appears at present, only somewhat larger, its waters being held by the dam of silt which had been laid down in front of the ice." Prof. I. C. Russell[3] suggests as an explanation for the origin of the body of water to which he gave the name of Lake Yukon, that the river valley must have been obstructed and dammed in some way, possibly by the large lava-flow at the mouth of the Pelly, or by morainal material deposited along the northern border of the cordilleran glacier. Professor Russell, however, holds as still more probable the hypothesis that "the weight of ice forming the great cordilleran glacier was sufficient to depress the earth's crust in the manner suggested by students of glaciation in other regions. As the ice retreated the depression thus originated was occupied by a lake, which was slowly drained as the land regained its former elevation."

THE ANCIENT GRAVELS.

ANCIENT ROLLED GRAVELS.

The silts of the Upper Lewes in the vicinity of the lakes are overlain by a few feet of river gravels, as already described, and Dr. Hayes[4] has noted a similar deposit on the Teslin River. All along the Yukon River are terraces at various heights, and on these are rolled gravels which are said often to yield gold in small quantities. The successively higher terraces spread over broader and broader areas, so that it is probable that the distribution of these

[1] Ann. Rept. Geol. Nat. Hist. Survey Canada, Vol. III, Part I, 1887-88, p. 172B.
[2] Expedition through the Yukon District: Nat. Geog. Mag., Vol. IV, p. 56.
[3] Notes on the surface geology of Alaska. Bull. Geol. Soc. America, Vol. I, p. 148.
[4] Op. cit., p. 156.

gravels is very extensive. On Fortymile Creek gravels are found covering the broad, shallow Tertiary valleys, in the bottom of which the later valleys have been cut, so that in the gulches which head in the old valley a considerable amount of gravel is derived from these ancient sources. Gravels also occur on the divides between valleys of considerable depth, such as that between Chicken Creek and Franklin Gulch on Fortymile Creek. On Mynook Creek gravels containing waterworn pebbles of a variety of rocks, especially the quartzitic schists of the Birch Creek series, which are not found in place in the immediate neighborhood of the gulches, come down the sides of the valleys from the level-topped plateau above and mingle with the talus of the rocks which these valleys cut, to form the present gulch gravels. The surface of this level plateau is shown in Pl. XXXVI. It rises 600 or 700 feet above the Yukon Flats, and is everywhere covered, according to prospectors, with these waterworn gravels. Mr. R. G. McConnell[1] has noted on the Rocky Mountains, between the Mackenzie and the Porcupine, terraces up to 1,500 feet above the sea; and along the Porcupine, silts, sands, and gravels, the latter often very coarse, were noticed at various points up to elevations of 400 or 500 feet above the river. The same geologist reports that along the Stewart River there is a constant recurrence of high gravel terraces, most of which are more or less auriferous.

Although the gravels on the lower river terraces are doubtless due to stream action, those which are more elevated, and especially those which lie on rock-cut benches, must be due in large part to marine action; or, if originally river gravels, must have been redistributed by the sea, for these upper levels have not been subjected to river erosion for a long period, while they have been in late geological times under the ocean waters. We may therefore expect these gravels to be almost universally found below a height of 3,000 feet above the sea, in places where they have not been stripped off by recent erosion.

ANCIENT GULCH GRAVELS.

In the bottoms of the narrow gulches which feed the larger streams the accumulations consist chiefly of angular rock fragments, which slide down from the steep gulch walls and form a deposit that shows little of the sorting and wearing action of water. These deposits are therefore distinct in nature from the well-rounded gravels of the larger streams. As the gulches wear down their beds, portions of the older accumulations are sometimes left on the sides of the valley in a manner analogous to the formation of the gravel terraces of the larger streams. Thus on Moose Creek a deposit made up of angular and subangular pebbles and bowlders of schist, schistose granite, and quartz occurs in the bottom of the valley and on its sides up to a height of several hundred feet. The deposit shows little evidence of

[1] Ann. Rept. Geol. Nat. Hist. Survey Canada, Vol. IV, 1888-89, p. 27D.

sorting or wearing by water, the fragments being piled together in such helter-skelter fashion that no stratification can be made out; the material seems to be plastered onto the schist through which the valley cuts, and is sufficiently hard to form sharp ridges and pinnacles 40 or 50 feet high.

VOLCANIC ASH.

In the region of the upper Yukon there occurs, overlying all other deposits except a few inches of vegetable loam, a bed of volcanic ash. This deposit has been mentioned and described by Schwatka,[1] Dawson,[2] Russell,[3] and Hayes.[4] Along the Lewes this ash occurs as a fine, white powder, in a layer only a few inches in thickness, but conforming almost exactly to the surface, being worn away only in little gullies. The maximum thickness appears to be in the neighborhood of the Big Salmon River, and even here it scarcely exceeds 6 or 8 inches. In some places there are two distinct layers, of which the upper is directly at the grass roots and is continuous, while the lower is a foot or two deeper and is separated from the upper one by a foot or two of stratified river gravels. The lower layer is intermittent and often cross bedded with the gravel, and is therefore waterlaid. Some 30 or 40 miles below the Five Finger Rapids the ash grows very thin, and is scarcely noticed at all below the Pelly.[5] On the White River, however, it was found by Dr. Hayes in immense quantities, a thickness of 75 or 100 feet being sometimes observed.

According to Dr. Hayes, the eruption which furnished this ash occurred in the northern part of the St. Elias Mountains, near the source of the Klutlan glacier (shown on sheet 2 of the maps accompanying Hayes's report), and he agrees with Dr. Dawson in considering that the eruption could not have taken place more than a thousand years ago. The remarkably muddy character of the White River, from which it derives its name, is largely due, according to Dr. Hayes, to the ash which it erodes from its banks and carries in suspension. According to Professor Russell, layers of this ash are reported by Arthur Harper and Frank Densmore, well-known Alaskan frontiersmen, as occurring at Fort Yukon and on the Tanana, but in general it is rarely seen in this lower region, and where it occurs it is probably brought down by rivers.

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[1] Along Alaska's Great River, New York, 1888, p. 196.

[2] Ann. Rept. Geol. Nat. Hist. Survey, Canada, Vol. III, Part I, 1887-88, pp. 43, 46B.

[3] Notes on the surface geology of Alaska: Bull. Geol. Soc. America, Vol. I, p. 145.

[4] Expedition through the Yukon district: Nat. Geog. Mag., Vol. IV, p. 146.

[5] On Chicken Creek, at the head of Fortymile Creek, this ash is found on the surface, but was not noted in the lower parts of Fortymile Creek. This is in accordance with the idea of its derivation from near the upper part of the White River.

CHAPTER III.

IGNEOUS ROCKS.

Two sets of igneous rocks having widespread distribution and definite position in the geological column, and so possessing the same value as stratified rocks in the study of structure, have already been described—the basal granite and the effusive diabases of the Rampart series. Besides these igneous rocks there occur in the gold belt many dikes and also later volcanics. It is now proposed to treat these igneous rocks as a whole, passing lightly over those already discussed.

BASAL GRANITE.

Granite is the oldest rock yet found in Alaska. In the Fortymile district it is found underlying the quartzitic schists of the Birch Creek series, which form the oldest sedimentary series known; it is also found along the Yukon between Fortymile Creek and the junction of the Lewes with the Pelly, and along the Pelly to the Dease River, as described by Dr. Dawson. According to Dr. Hayes, it forms the prevailing rock of the greater part of the region between the Yukon and the St. Elias Mountains along the White River, and according to Lieutenant Allen and prospectors it is exposed for a long distance on the Upper Tanana. It thus forms a continuous belt, running in a northwest-southeast direction. This belt has been observed for a distance of not far from 800 miles in a straight line. On both sides of the granite, to the northeast and southwest, successively younger strata occur, so that the exposure of this rock seems to lie along the axis of a geanticline.

So far as observed, the fundamental granite is usually more or less schistose or gneissic, having undergone the same mountain-building stresses which have converted the overlying sediments into schists. Locally this shearing becomes so great that the granite itself is converted into mica-schists. Where moderately massive, the fresh rock is of a gray color, and often contains porphyritic crystals of feldspar, which in the more schistose zones become lenticular bodies or eyes. In the slightly weathered rock the color changes to a red or brown, which is characteristic of most surface outcrops.

Under the microscope the rock is seen to be made up essentially of quartz, orthoclase, and biotite, all coarsely crystalline and with a typical granitic habit. The orthoclase or microcline often occurs in large, perfect phenocrysts. Accessory minerals, notably muscovite, calcite, epidote, garnet, micaceous hematite, kaolin, pyrite, and chlorite, are sometimes found in large amount. Some of these minerals

are derived from the decomposition of the feldspar and mica, while others represent constructive processes which have been consequent upon the shearing. This shearing has also operated to break and stretch the original minerals in greater or less degree, yet the granitic nature is usually quite unmistakable in the field and almost invariably so under the microscope.

From this fundamental granite must be distinguished the intrusive granite, which is of later age, and occurs frequently in dikes or lenses throughout this portion of Alaska.

DIKE ROCKS.

DIKES IN THE FORTYMILE DISTRICT.

Dike rocks are exposed in varying degree of abundance over most of the gold belt, especially in the older formations. On Fortymile Creek, however, they are found in remarkable abundance, and here also are especially open to observation, since continuous exposures are offered along the walls of the canyon-like valley which the stream has cut in late geological times. The relation of these different dike rocks to one another can therefore be carefully studied, and as the observations made in this limited area need not necessarily apply to similar rocks at other points, it is thought best to study the dikes of Fortymile Creek separately.

Between the formation of the sedimentary rocks of the Fortymile series and the rocks of the Rampart series there was a period of great disturbance in this portion of the earth's crust, which is manifested, among other ways, by the development of schistosity in the Fortymile rocks and those underlying. Of the many dikes which are found in the Fortymile sedimentary schists, some have been altered by the shearing almost or fully as much as the inclosing rock. Other dikes have been sheared throughout, but notably less than the sedimentary rocks; others still have been sheared only locally, while a certain class have experienced no disturbance whatever. These phenomena can mean only that the dikes were intruded at different periods, and that the development of schistosity was not sudden, but occupied probably a very long time. A convenient, if somewhat arbitrary division, based on structural features, may therefore be made between the dikes which have been most and those which have been least sheared. This is really a classification between the older and the younger dikes, since those which are most altered were evidently intruded previous to the chief development of the schistose structure, while the unaltered or less altered dikes came in at a somewhat later period.

EARLIER SCHISTOSE DIKES.

Under this head are considered only those dikes which have been so much altered as to become virtually schists, they having experienced

practically the same amount of interstitial movement as the inclosing schists of sedimentary origin. These dikes are not all necessarily contemporaneous in origin, but all are older than the maximum period of shearing. Moreover, there is no sharp line of division between them and the dikes which will be considered later, for there is a perfect transition in degree of schistosity between dikes which are completely sheared and those which have suffered no movement.

Quartz-diorite-schist. — On Fortymile Creek below Brown Creek the lower part of the wall of the so-called "canyon" is made up of a mottled schistose rock of a general dark-green color, which incloses eyes or short seams of crystalline quartz. Under the microscope the rock is seen to have the granular structure, and consists essentially of quartz, feldspar (plagioclase predominating), and hornblende. There is also some biotite and secondary epidote. Pyrite altering to hematite is not infrequent. The whole rock has been sheared, and in places the minerals have been granulated.

Diorite- or syenite-schist.—On Fortymile Creek below the Forks are great masses of a dark-green rock with schistose structure, which, however, in places becomes coarse and massive and carries large phenocrysts of hornblende. Between this massive rock and the fine-grained schist there are all stages of gradation. Certain phases also contain much biotite, which takes the place of hornblende. A specimen of this schist, seen under the microscope, appears to have for the predominating mineral orthoclase, much muscovitized; also some plagioclase and quartz. Fresh brown biotite, very likely secondary, is present in large quantities; and colorless epidote, in small crystals and in irregular grains, forms a large proportion of the rock.

Diorite-porphyry-schist.—On the South Fork of Fortymile Creek are large areas of hornblende-schist, some parts of which are fine-grained, while others become gradually coarse and develop slim hornblende phenocrysts. These phenocrysts are usually arranged in a radiating fashion, and give the rock, when coarse, a very striking appearance. Specimens of the more schistose portions of this rock are not always easily distinguishable from the hornblendic schists which have resulted from the alteration of the impure Fortymile sediments; but the line of contact between the two is ordinarily well marked, and in several cases this line of contact was seen to cut across the schistosity, showing that the coarser and more massive rock was undoubtedly intrusive. A specimen of one of the finer varieties of this dark-green schistose dike rock shows under the microscope phenocrysts of feldspar, which are much altered to epidote and calcite. The groundmass is mostly orthoclase, with plagioclase and green hornblende. There is also considerable epidote, and probably a little quartz.

The few examples which have been cited show that the extremely schistose dike rocks of the older series appear to be different phases of the diorite family. A few dike rocks from other localities which

have experienced the same amount of shearing, and are therefore probably of the same age, will be described later; and it appears that, so far as observed, they are all varieties of the granite and diorite families.

LATER UNSHEARED DIKES.

Most of the dike rocks which occur so abundantly on Fortymile Creek are only slightly or not at all schistose, and often cut directly across the schists, so that they are evidently of later age than those dikes which have been altered at the same time with the inclosing rocks. In these dikes there is a marked variety, and the different rocks seem transitional into one another, so that all stages of change are represented from extremely acid rocks to extremely basic.

EXTREMELY BASIC ROCKS.

Rocks of this character are abundant, and are present in dikes of considerable thickness, also in numerous small dikes and stringers. They are nearly black, and often coarsely crystalline, and so have a striking appearance in the field. They are usually quite massive, with no appearance of schistosity, and yet sometimes show evidence of disturbance by the presence of joints and small faults.

Pyroxenite.—One phase of the extremely basic dikes is black and usually coarsely crystalline, with finer-grained, greenish bands. Much pyrrhotite and other metallic minerals are recognizable in the hand specimen. Under the microscope the structure is seen to be coarse and holocrystalline, and the rock to be made up almost wholly of green or colorless augite, with a small amount of green hornblende and some brown biotite, in irregular strips. Some of the augite shows zonal structure. Pyrite and pyrrhotite are present in considerable quantities. There is no quartz or feldspar.

Another dike which appears originally to have been of pyroxenite is altered so as to consist mostly of fibrous serpentine in radial, parallel, or felty aggregates. In the serpentine are numerous remnants of augite, from which it is undoubtedly derived. Magnetite is present in moderate amount.

Hornblendite.—Another dike having nearly the same appearance and the same habit as the pyroxenite, and occurring so close to it that the two are probably varieties of the same rock, is found under the microscope to consist essentially of green hornblende with very abundant epidote in crystalline prisms and irregular grains. Pyrite, pyrrhotite, and ilmenite are present in large quantities, so that small pieces of the rock are readily attracted by the magnet. No quartz or feldspar is present. In the hornblendite are narrow bands of bright-green rock, which under the microscope are found to be made up entirely of epidote. These bands have probably formed along joint planes. Similar bands are found at the contact of the hornblendite with the aplite which cuts it.

Pegmatitic hornblende-diallage-biotite rock.—On Fortymile Creek above Smith Creek there occur sheets and cross-cutting dikes, often 15 or 20 feet in thickness, of a very coarsely crystalline dike rock, which is made up of uniformly large crystals of hornblende, pyroxenite, and mica, intergrown in pegmatitic fashion, each crystal being an inch or two in length. A specimen taken of this rock consists apparently of idiomorphic crystals of hornblende and biotite intergrown, each crystal being about 2 inches in length. On account of the extremely coarse texture, only a single crystal was shown in the slide, and this was taken from a slightly different portion of the rock. It consists of diallage with pœcilitic structure, containing many small inclusions of brown and green biotite, and crystals of hematite or ilmenite.

INTERMEDIATE ROCKS.

Porphyritic hornblende-syenite.—This rock is dark-colored and basic in appearance, contains much pyrite and pyrrhotite, and also many perfect crystals of feldspar. Under the microscope the structure is seen to be nearly panidiomorphic. The rock consists mostly of dark-green hornblende, with some chlorite. The feldspar is nearly all orthoclase, somewhat altered to muscovite. There is a small amount of quartz as an original constituent, which shows pœcilitic structure and incloses small crystals of hornblende.

Quartz-hornblende-diorite.—This dike rock is dark-colored, massive, and coarse-grained. In the hand specimen it shows phenocrysts of feldspar, white or pink in color, and some quartz. Under the microscope the structure is seen to be coarse and granitoid, with a tendency to porphyritic. The constituent minerals are chiefly feldspar, with plagioclase predominating, considerable quartz, and much hornblende; some augite, magnetite, and chlorite also occur, and an occasional garnet. Often the rock shows a tendency toward the pœcilitic structure, the feldspar phenocrysts containing numerous inclusions of quartz.

This rock and the one last described are probably varieties of the same general type, since they occur close together in a series of dikes of the same age and the same appearance, and since one seems to pass gradually into the other.

Hornblende-granite.—This rock occurs in great dikes in the marble of the Fortymile formation. It is dark-colored and gneissic in appearance, and becomes locally schistose. Under the microscope the structure is granular and hypidiomorphic. The essential minerals are orthoclase, hornblende, and quartz, with considerable plagioclase biotite, muscovite, and epidote.

Fine-grained hornblende-granite (*porphyritic facies*).—On the ridge between Chicken Creek and Fortymile Creek, overlooking Mosquito Fork, is a great dike of dark-gray, mediumly fine-grained rock, having a tendency to a porphyritic structure. Under the microscope the

rock is seen to be essentially a true granite with phenocrysts of feldspar, small and imperfectly developed. The essential constituents are orthoclase, quartz, and hornblende, with some biotite. The secondary minerals are chlorite and epidote in considerable quantities; also hematite, calcite, and actinolite. Magnetite and ilmenite are locally abundant. The rock has the mineral constituents of granite, and yet the proportion of the different minerals is such that the rock is decidedly more basic than typical granite.

Porphyry.—A specimen taken from a dike on the ridge between Chicken Creek and Fortymile Creek is of considerably weathered rock, of a general gray color, with phenocrysts of flesh-colored feldspar. Under the microscope the phenocrysts are found to be much altered to muscovite, but seem to be of predominating orthoclase with some plagioclase. Areas of chlorite probably represent original phenocrysts of biotite. The groundmass is fine-grained and holocrystalline, and seems to be made up chiefly of orthoclase, quartz, and muscovite.

Quartz-diorite, or granodiorite.—On the ridge between Franklin Gulch and Chicken Creek is a great dike of coarse-grained rock which has the appearance of an acid granite, being made up chiefly of feldspar and quartz, with a distinctly subordinate amount of hornblende and mica. This rock has a light-gray color, becoming reddish or pinkish on weathering. Under the microscope the essential feldspar is found to be plagioclase in stout prisms. Next to the plagioclase the most abundant mineral is quartz, and there is also considerable orthoclase. Hornblende and biotite occur sparingly and in small crystals, although regularly enough to be classed as essential constituents. Titanite and magnetite are generally present. In some parts of the rock micrographic intergrowths of quartz and feldspar occur.

ACID ROCKS.

Granitic aplite.—This rock is light-gray in color and fine-grained, and occurs as a narrow dike cutting more basic dike rocks. Under the microscope it is seen to be made up chiefly of orthoclase and quartz in large hypidiomorphic grains. Some plagioclase is intergrown with the orthoclase. Green biotite in hypidiomorphic plates very much smaller in size than the grains of quartz and feldspar is present abundantly and regularly, so that the rock might readily be classed as a phase of granite were it not for its evident relationship in structure and composition to the aplites with which it occurs. Epidote in imperfect crystals and irregular grains is abundant. The rock seems to be an intermediate type between an acid granite and an aplite.

Pegmatoid aplite.—This rock is coarsely crystalline, gray and granular; and the structure as seen under the microscope is highly pegmatoid or micrographic. The rock constituents are chiefly quartz and microcline intergrown; considerable muscovite and some biotite are

also present. All these have the pegmatoid habit; and in strong contrast to them is an idiomorphic mineral which occurs abundantly in perfect crystals, cutting the other minerals and passing from one to another without disturbance. These idiomorphic crystals, however, are usually considerably smaller in size than the individual grains which have the pegmatoid habit; and the mineral, which is probably epidote, is undoubtedly secondary. Occasional pyrite, altering to iron oxide, is present.

Dioritic aplite.—Under this head are classified abundant dikes whose essential constituents are plagioclase and quartz. In texture the different specimens vary from very coarse (approaching pegmatite) to extremely fine. The structure also varies from hypidiomorphic to panidiomorphic granular, and there are great differences in the relative amounts of quartz and feldspar. Some orthoclase is present in these rocks. In some cases biotite in small flakes and crystals is very common, while in others it is entirely absent. Titanite and pyrite are also found. In some of the specimens the quartz and feldspar are intergrown to form the micrographic structure.

Ordinary aplite.—Abundant aplites are found of a very light-gray or pure-white color, consisting essentially of orthoclase, quartz, and plagioclase. Small grains of iron pyrite are usually present. The texture varies from coarse to very fine. The structure is generally panidiomorphic with extremely frequent micrographic intergrowths, and is occasionally granitoid.

Porphyritic aplite.—This rock cuts the hornblendite which has already been described, and the contact between the two is marked by a narrow band of hornblende-epidote rock of a bright-green color. The aplite itself is light-gray and resembles a fine-grained quartzite, except that the glimmer of small feldspar crystals can be seen here and there. Under the microscope the most striking mineral is feldspar in nearly perfect crystals; it is usually orthoclase, but sometimes plagioclase, and sometimes both intergrown. These crystals are scattered rather sparingly through a groundmass which consists almost exclusively of quartz in small, interlocking grains, and so has the exact appearance of a fine-grained quartzite. Small flakes of biotite are abundant, both in the quartz groundmass and in the feldspar phenocrysts, and there is a little epidote.

Pegmatite.—Very little coarse, typical pegmatite, such as is so common in areas of granitic intrusives, was found among the dikes of Fortymile Creek. As already noted, however, the aplites vary in texture from extremely fine to so coarse that the rock might be considered fine-grained pegmatite; and yet the transition is gradual and without appreciable change in composition or structure. In some rocks, however, the quartz and feldspar tend to separate in distinct bodies, so that large bunches of nearly pure quartz occur, while in other portions of the same dike the rock has the appearance and

structure of a coarse-grained aplite or fine pegmatite, being made up of regularly intergrown crystals of quartz and feldspar, with rarely a little biotite. Among the feldspars of these coarse rocks plagioclase is predominant in some cases; in others orthoclase. There is generally a small amount of calcite veining, and in the large masses of quartz which occur in these dikes are frequent small geodes, the walls of which are covered with quartz crystals.

Quartz veins.—The pegmatite or coarse aplite just described can be traced in one and the same dike or vein into solid quartz filling the whole space between the walls. At first the feldspar generally becomes contracted into zones nearest the walls, leaving the central part pure quartz, and finally disappears altogether. These quartz veins under the microscope show the usual coarsely crystalline, interlocking structure, and besides quartz contain only a little magnetite and pyrite, with some calcite veining which is probably secondary.

RELATIONS OF DIFFERENT VARIETIES.

Although the rocks which have been described have been classified under different names, according to their mineral composition, yet as a matter of fact neither field nor laboratory study can divide them into any classification other than an artificial one. On the contrary, they form as a whole a connected series with ordinarily the most perfect and gradual transitions connecting the widely differing extremes, and in this series the line dividing the rocks according to established classifications must be arbitrarily drawn. It thus happens that in the rocks whose mineral composition warrants their being classified under one name according to an established nomenclature, the relative proportion of the constituent minerals varies so that there are greater actual differences than there are between some of these rocks and others which, on account of the slightly different proportion of the constituent minerals, have been classified under a different name. For example, there is a greater actual difference in structure and composition between the acid and basic varieties of the rock which has been classified as hornblende-granite than between the basic hornblende-granite and the hornblende-syenite or diorite, or between the acid granite and the aplite.

So great were the difficulties under which these abundant and highly interesting dikes were observed that only about twenty specimens were collected. Yet in these twenty specimens, which were taken at different times and under circumstances where there was little opportunity for comparison, hardly any two are alike, and the set constitutes a nearly perfect transition from the most acid to the most basic varieties. The most abrupt change was from hornblendite to extremely basic hornblende-diorite or syenite, and between these two rocks more gradual transitions were noted in the field. The nature of the transitions will now be briefly sketched.

The most basic variety is composed sometimes entirely of hornblende, sometimes of pyroxenite, and sometimes of both intermingled, and contains a remarkable quantity of pyrrhotite, ilmenite, pyrite, and other metallic minerals, thus constituting a rock type of extreme basicity. These basic rocks become pegmatitic, with pœcilitic structure, and these portions contain biotite as well as pyroxene and hornblende. In other localities dikes having the same coarse, panidiomorphic structure and made up chiefly of hornblende begin to carry crystals of feldspar, at first very sparingly and then in greater amount. In some varieties quartz also comes in. In other places the hornblende decreases in amount proportionally to the increase of feldspar and quartz, so that the rock becomes first a hornblende-syenite or diorite, and then a hornblende-granite or quartz-hornblende-diorite, or granodiorite. The hornblende-granites and diorites seem to grade into one another in the same dikes, and occur in immense intrusive bodies, often several miles wide, forming probably a greater bulk than either the more acid or the more basic of the allied rocks. In these granites and diorites the hornblende still continues to be the chief prominent dark bisilicate, although biotite, which was noted as being one of the constituents of the extremely basic rocks, seems to increase in importance in the more acid varieties, and in the more acid granites often becomes predominant. By this gradual change the basic hornblende-granite, in which hornblende is the most abundant of the constituents, passes into an extremely acid biotite-granite, in which the biotite forms a comparatively insignificant constituent as compared with the feldspar and quartz.

This acid granite, by a very slight change, passes into a rock of coarse or fine hypidiomorphic-granular structure, composed essentially of quartz and feldspar, the predominant feldspar being generally orthoclase, sometimes plagioclase; there is also some essential biotite and occasionally muscovite; yet these minerals are in scattered plates of very small size. In the next stage the mica disappears almost entirely, being found only in certain areas, so that the rock becomes entirely of quartz and feldspar. There is also a tendency to change from the granitic to a panidiomorphic structure, and the minerals form pegmatoid or micrographic intergrowths. These rocks are sometimes very fine grained, and sometimes are coarse like granites, but all have essentially the same structure and composition, and have been classified as aplites. In these aplites the change continues by the relative increase of quartz and decrease of feldspar. A remarkable phase attending this is a rock consisting of scattered phenocrysts of feldspar with a groundmass of fine quartz in small interlocking grains, which has in the field and under the microscope the exact appearance of a fine-grained quartzite. In coarse varieties of the aplite both quartz and feldspar become more coarsely crystalline, so that the rock approaches pegmatite in structure. The next stage after becoming

coarsely crystalline is the separation of the two minerals into distinct areas. The quartz-feldspar dikes contain large bunches of nearly pure quartz, which has all the characteristics of vein quartz. With the progressive increase in acidity the feldspar becomes restricted to certain parts of the vein, sometimes irregularly and sometimes collecting near the walls, while the pure quartz lies in the center. Finally the feldspar disappears altogether, and the vein becomes pure quartz with occasional pyrite, and now and then a crystal of biotite. Often there is also calcite, especially along the walls. In one and the same vein the transition from the coarse aplite or fine pegmatite into an ordinary quartz vein may be seen in all its stages. In all these rocks, however, the absence of coarse-grained pegmatite is noticeable.

In all the rocks, from the hornblendites and pyroxenites to the acid aplites, epidote forms a constant and important mineral, but is in most cases of secondary origin.

Considering all these dike rocks together, then, we find that they are all made up essentially of a combination of quartz, feldspar, and hornblende, with subordinate biotite and other rarer minerals. By the different proportions which these minerals bear to one another in different dikes all the chief rock types enumerated are produced. When the three chief minerals, quartz, feldspar, and hornblende, with subordinate biotite, occur in about equal proportions, the rock is a hornblende-granite or diorite. From this intermediate phase variations are produced by the increasing abundance of basic minerals to the exclusion of acid ones, or by the reverse process; so that by easy stages one extreme is reached in a rock consisting entirely of hornblende and other dark bisilicates, such as pyroxene and biotite, with large quantities of metallic minerals, and the other extreme in rocks consisting entirely of quartz and feldspar, which by increasing acidity grade into quartz veins.

RELATIVE AGE OF FORTYMILE DIKES.

There are two criteria for determining the relative ages of the Fortymile dikes. The first is the one which depends upon the obvious and elementary principle that if one dike cuts through another without interruption it is younger in age. The other depends upon the relative amount of schistosity which the various dike rocks show, the schistosity being the record of dynamic forces which have operated during a more or less extended period, and whose maximum metamorphism is measured by the alteration into schists and marbles of the sedimentary beds of the Fortymile series. When dikes have experienced the same amount of metamorphism as the inclosing sedimentaries it is certain that they existed in the rock when dynamic disturbances began; and, on the other hand, dikes which show no shearing whatever, but form massive bodies cutting across the schis-

tose rocks, were not present during the period of metamorphism, and so must be distinctly younger than the sheared dikes. Intermediate between these oldest and youngest dikes are some which are slightly sheared throughout, or are locally schistose and locally massive. These must have been intruded during the period of metamorphism, so that they have suffered only the final effects, and therefore they are younger than the completely schistose dikes and older than those which have suffered no metamorphism whatever.

The most schistose dikes found on Fortymile Creek, so far as observed, are various phases of the diorite family, which may be classified as diorite-porphyry, quartz-diorite, or syenitic diorite. Among the rocks which are partially schistose the hornblende-granites are conspicuous, occurring abundantly in immense dikes, and being sometimes greatly and sometimes slightly sheared. Most of the other rocks show very little evidence of shearing, either in the basic or in the acid types. The different varieties of ultrabasic rocks seem to grade into one another, and are usually quite massive. They have in places, however, been jointed and faulted, and in this respect they contrast with the aplite dikes which cut them and which have not experienced the same faulting.

Considering the question of age from the cutting of one dike by another, it was observed that the basic hornblende-granite, which was slightly schistose or gneissic, was cut by dikes of porphyritic hornblende-syenite with granitic facies, a rock markedly more basic than that through which it cut, but not at all schistose. Both of these dike rocks are in turn cut by small dikes of ordinary aplite and of granitic aplite. Thus in this particular case the relative age of the three dikes which intersect one another is basic hornblende-granite, hornblende-syenite, and aplite. The general rule on Fortymile Creek, however, is that when two dikes intersect the more acid one is shown to be the younger. In every case where aplite dikes were observed they cut all others. In one case an extremely acid aplite, consisting essentially of small phenocrysts of feldspar in a groundmass of fine-grained quartz, is found cutting a rock consisting almost entirely of hornblende with much pyrrhotite and other metallic minerals. The quartz veins into which the aplite dikes often change also cut the schists and dike rocks without disturbance, and show themselves likewise to be among the youngest rocks in the formation.

The order of intrusion of these dike rocks seems, then, to be in general: First, a series of dioritic dikes with granitic facies; second, a series of more basic dikes, but still of the granite and diorite families; next, a series of still more basic dikes, which sometimes reach the extreme of basicity, as exhibited in the hornblendites and pyroxenites; and, finally, an abundant series of very acid dikes, belonging chiefly to the aplite group and merging into quartz veins.

RELATIVE ABUNDANCE OF DIFFERENT DIKE ROCKS.

Although nearly all the dike rocks described occur abundantly, the types which are intermediate in chemical composition seem to form the largest masses. Next in relative abundance come the acid quartz-feldspar rocks, which occur in immense dikes; and, finally, the more basic rocks, which, while still very abundant, are apparently somewhat less in amount than either the acid or the intermediate groups.

DIKES OF BIRCH CREEK DISTRICT.

The bed-rock in the Birch Creek mining district is almost entirely quartzite-schist, which contains frequent dikes, although not nearly so many as on Fortymile Creek. Those noted, however, are interesting in that they represent intrusions both earlier and later than the development of schistosity, as in the Fortymile district.

Sheared granite or granitic schist.—In the gray quartzite-schists on Hog'em or Deadwood Creek a mass of darker-colored, more massive schist was observed. The contact between this and the ordinary quartzite-schist was well marked and ran nearly at right angles to the schistosity, and when closely observed the darker rock showed small crystals of feldspar, often elongated into lenticular eyes, so that it was evidently a dike. The planes of schistosity traverse both dike and country rock, passing from one to another without interruption. In the dike, however, they are fewer, so that this has a more massive appearance. In both rocks are quartz veins which are nonpersistent and are often bent and folded.

Under the microscope the dike rock shows a cataclastic structure, but the individual grains are large and uniform and give no sign of detrital origin. The principal minerals are quartz, orthoclase, and biotite, the latter altered to chlorite, actinolite, hematite, and carbonates. The feldspar is somewhat muscovitized. In more schistose portions of the same dike the structure becomes markedly laminated, and the finer materials are arranged in layers inclosing frequent large grains or eyes, which are sometimes orthoclase, much altered, and sometimes crushed quartz. The finer inclosing materials are granulated quartz and fresh biotite, and muscovite in grains; pyrite is also abundant. In this latter case both micas seem to be secondary.

Unsheared granite.—On Hog'em Creek for 6 miles or more above its junction with Crooked Creek there are no rock outcrops, the region being occupied by a nearly level deposit of ill-assorted, angular fragments, which has been described above as probably torrential material brought down by the streams from the hills and deposited along the margin of a great lake which is now drained. On reaching the shoreline of this old lake the valley of the creek changes suddenly and solid rocks appear. The first outcrop is granite, which is exposed for a distance of about 3 miles along the creek and then gives place to

schist. The granite is light gray in color and is of average acidity, containing much quartz. It varies in texture, from rather fine where first noted to coarse, and even porphyritic, farther up. It has experienced no shearing and contains no quartz veins, and is therefore later than the vein-bearing quartzite-schists which are associated with it. The variation in texture also points to the same conclusion. This broad dike runs in a nearly east-west direction, and cuts Boulder Creek as represented on the map. It was not observed on Mammoth Creek, and if it exists at all there it must lie underneath the lake deposits, as represented.

This granite consists essentially of orthoclase, quartz, and biotite; there is also microcline and occasional plagioclase.

Quartz-feldspar dikes.—In some places in the Birch Creek district were found dikes or veins of quartz and feldspar similar to those described on Fortymile Creek. These veins are often cavernous, as in quartz veins which do not contain feldspar, and the feldspar varies in amount, sometimes being equal to the quartz. Under the microscope the feldspar is seen to be mostly orthoclase, although occasionally the multiple twinning of plagioclase is shown. Feldspar and quartz appear to have crystallized in large part simultaneously, since neither has its regular crystal outline. Along strong fractures which traverse both quartz and feldspar small crystals of green biotite have formed which fray out into the quartz. The wall rock of these veins is a micaceous quartzite schist, profoundly altered. Under the microscope many parallel fractures are seen in it, which curve slightly at times, so as to inclose a lenticular area of quartz. Along these fractures green biotite is plentiful, and occasional clumps of iron carbonate and oxide seem to represent the decomposition of pyrite.

Aplite.—As on Fortymile Creek, these quartz-feldspar veins seem to be directly connected with dikes of aplite, which were observed at different places.

DIKES ON AMERICAN CREEK.

On American Creek near the Upper Canyon two dikes cutting the rocks of the Rampart series were noted. Although these occur only a short distance apart, they belong to exactly opposite types.

Aplite.—In the walls of the creek was found a narrow dike of grayish-green, medium-grained rock with occasional small phenocrysts of feldspar. Under the microscope the rock is seen to consist essentially of feldspar (chiefly orthoclase) and quartz, with a large amount of epidote; some pyrite is also present, and calcite in secondary veins. Epidote is in large crystalline masses with perfect cleavage, and also in smaller crystalline grains.

Mica-lamprophyre.—In a small gully which runs into American Creek at the Upper Canyon a dike of a dark-gray, rather fine-grained rock containing small phenocrysts, apparently of feldspar, was noted.

This rock was considerably altered, and under the microscope the phenocrysts were seen to be made up entirely of secondary decomposition products. These phenocrysts are set in a groundmass in which there are many fresh biotite crystals, which are in turn surrounded by a groundmass which varies from faintly microcrystalline to aphanitic. There is some quartz, which may be derived from alteration of the groundmass, and much calcite which apparently has a similar origin; magnetite in crystalline form is also present.

RELATION OF DIKES TO SCHISTOSITY.

The rocks through which both aplite and lamprophyre cut, although not entirely altered, have undergone in zones a local shearing. Both the dikes mentioned seem to be later than the development of this shearing, as is especially well shown in the case of the mica-lamprophyre, which cuts across a zone of great shearing nearly at right angles, but shows no schistosity. In the shear zone, near the contact with the dike, there have been developed veins of white quartz and impregnations of pyrite. It seems plausible that deposition of these xenogenous minerals may have been stimulated by the intrusion of the dike into the preexisting shear zone.

DIKES ON THE YUKON BELOW FORTYMILE CREEK.

In the sedimentary series along the Yukon immediately below the mouth of Fortymile Creek there are occasional acid dikes. One of these collected near the mouth of Coal Creek is very light-gray in color and fine-grained, with small phenocrysts. It is a porphyry of exactly the same type as is found in various parts of the country, and is almost identical with dikes found cutting the Coast Range granite in the vicinity of the Chilkoot Pass. Under the microscope there are seen small phenocrysts of biotite and feldspar, chiefly orthoclase, in a fine-grained groundmass of quartz, orthoclase, and muscovite, with some plagioclase and biotite. The micrographic structure is frequent.

DIKES IN THE LOWER RAMPARTS.

In the Lower Ramparts from Fort Hamlin to the Tanana occasional dike rocks were found, consisting chiefly of schistose granite or quartz-diorite. From the schists of the Birch Creek series on the Yukon, about 15 miles above the mouth of the Tanana, was taken a specimen of fine-grained gray rock with radiating bundles of greenish-black, fibrous hornblende. Under the microscope the rock was seen to consist essentially of quartz and actinolite, with some feldspar and biotite and small quantities of chlorite and hematite. The structure is profoundly schistose, but from the relation of this rock to the inclosing rocks it is probably a dike, and may have been originally a quartz-hornblende-diorite, or a hornblende-granite.

Quartz-mica-diorite.—About 35 miles below Mynook Creek on the Yukon there occurs a fine-grained, very slightly schistose rock, which under the microscope appears to be a typical quartz-mica-diorite. This rock is fresh, but nothing is known of its geological occurrence except that it is cut by the great dikes of granite described below.

Granite or granodiorite.—From 25 to 40 miles below Mynook Creek come in great masses of light-gray massive granite, which are intrusive in the older rocks, as their contact phenomena show. Two chief dikes were noted, one of which was several miles in width. This granite varies from rather fine-grained to very coarse and porphyritic with large phenocrysts of feldspar. It is succeeded farther down the Yukon by the green diabases of the Rampart series, and it is therefore probable that the dikes are intruded into this series. The quartz-mica-diorite above described was found at the contact with the granite, and from its megascopic characters it is probable that it is a local effect of contact metamorphism. The granite consists essentially of feldspar, quartz, and biotite. The feldspar is chiefly orthoclase, although in some cases plagioclase is predominant. Zircon, apatite, titanite, magnetite, and hematite occur abundantly as accessories.

Dioritic aplite.—Cutting the diabases and diabasic tuffs at the beginning of the Lower Ramparts above Fort Hamlin was noted a small dike, which is made up essentially of quartz and plagioclase, the former preponderant. Micropegmatitic intergrowths of these two minerals were remarkably well developed. This dike had not been affected by any of the shearing and jointing which had affected portions of the inclosing rock.

ORDER OF DIKE ROCKS.

The dikes which have been described outside of the Fortymile district, when separated into two main classes in respect to age, as shown by their relation to the schistosity, whose development seems to have been regional, give the same results as those obtained from the study of the Fortymile dike rocks alone. Taking all the dike rocks of the gold district together, then, it may be stated that the earliest series was of slightly differing varieties of granitic and dioritic rocks of intermediate chemical composition. All these rocks are now much sheared, so much so that often their true nature is recognizable only under the microscope or by their relation to the earlier rocks. Subsequently there came about a series of more acid and more basic rocks which are unsheared. The two unsheared dikes of aplite and mica-lamprophyre on American Creek are only an isolated case of what on Fortymile Creek was found to be the rule, namely, that both the very acid and the very basic dikes were later than the development of schistosity.

AGE OF DIKES.

So far as observed, the extremely acid or aplite dikes appear to be the youngest in the series. These dikes are found chiefly on Fortymile Creek, but also, less abundantly, in the rocks of the Rampart series. On Napoleon Creek the conglomerate which overlies the Rampart series and the Fortymile series unconformably contains, among other things, pebbles of aplite and porphyry, so that in this locality the dikes are older than the conglomerate, which has been correlated with the Mission Creek series. On the other hand, acid dikes among which porphyry has been identified are found cutting the sedimentary sandstones and shales on the Yukon below Fortymile Creek; these sandstones and shales have also been correlated with the Mission Creek series. This seems to show either that the sedimentary beds in the two localities are not to be strictly correlated or that the dikes below Fortymile Creek belong to a younger intrusion. It is likely that the former is the case, for although the broad correlation of the beds in both localities may be correct, yet those below Fortymile Creek may belong to an older and those of Napoleon Creek to a younger portion of the series. In the rocks of the Kenai (Eocene) series no dikes were observed.

It has already been stated that the earliest granitic and dioritic dikes were intruded previous to the chief development of schistosity. The shearing took place after the deposition of the Fortymile series, and chiefly before the formation of the Rampart series, since the latter series is only slightly and locally sheared, much less so than many of these earlier dikes, which therefore were probably intruded, in part at least, before the formation of the Rampart series. It has been shown that on Fortymile Creek there is evidence that dikes were intruded at all periods between the youngest and the oldest, so that there is a gradation in point of age, as indicated by relative metamorphism as well as by gradations in structure and composition. We may say, therefore, that in this region there is a series of dikes the first of which were intruded previous to the deposition of the rocks of the Rampart series (pre-Silurian?) and others at intervals up to or into the period of the deposition of the Mission Creek series (Cretaceous?), and that this series began with granitic or dioritic rocks and ended with more acid and more basic rocks.

VOLCANIC OR EFFUSIVE ROCKS.

PALEOZOIC—RAMPART SERIES (DIABASES).

GENERAL DESCRIPTION.

At a higher horizon than the Fortymile series, and probably directly overlying it, are rocks which are largely of volcanic origin. Throughout this series there are great quantities of diabase, generally

olivine-bearing, which varies but little in structure and appearance in widely separated localities. Closely associated with the crystalline rocks are tuffaceous sediments which are derived entirely from the diabase, and which form a very large and important part of the series. These tuffs grade into impure sandstones, shales, and limestones, which are often glauconitic. From the glauconite in the tuffs and impure sediments, and the serpentine, chlorite, and other minerals derived from the decomposition of the igneous rocks, there arises a general green color which characterizes nearly the entire formation. These rocks were noted at the head of Fortymile Creek just above Franklin Gulch, between Fortymile Creek and Mission Creek on the Yukon, on American Creek, and in the Lower Ramparts from Fort Hamlin considerably beyond Mynook Creek. (See "The Rampart series," in Chapter II.)

CONDITIONS OF FORMATION.

The igneous rock occurs in many separate bodies, which are often of immense size. In these masses the texture varies from medium-coarse to very fine or aphanitic. Even in a single body it varies considerably; the finer-grained portions near the borders often grade into tuff so gradually that no contact can be found in the field, and the difference between those rocks which have truly igneous characters and those which are detrital can be made out only by aid of the microscope. In nearly every case observed the sheet of igneous rock was conformable to the overlying and underlying sediments, and the fine tuffs which are composed entirely of diabasic material grade into more assorted sediments, such as impure sandstones and shales. These characters show that the igneous rock occurred as surface flows, and since these sheets recur abundantly at successively higher horizons, the volcanic activity must have lasted for a considerable period of time, during which there must have been sent out sheets of lava of immense size and extending over large areas. During intervals between the eruptions there must have been periods of comparative quiet, when sediments accumulated and life existed in the waters, for in a specimen of glauconitic limestone sections of fish teeth have been identified.

STRUCTURE AND COMPOSITION OF ROCKS.

The igneous rock has a holocrystalline structure, and generally an ophitic arrangement, all the components being well crystallized and interlocking. The essential minerals are plagioclase, augite, and usually olivine, often with much orthoclase, diallage, and quartz. Accessory minerals, which often become very important, are hornblende, calcite, magnetite, ilmenite, and pyrite. The hornblende is a decomposition product of the augite, and the calcite, epidote, and pyrite are also secondary. An extremely common decomposition product both of olivine and of augite is serpentine, to which is due,

partly at least, the rock's green color in the field. The quartz is sometimes secondary and sometimes primary, and occasionally increases in quantity so as to form an essential constituent. In some cases the augite is entirely altered to green hornblende, and there results a hornblende-plagioclase rock, which might be styled epidorite. Its evident derivation from the typical diabase, however, its field relations, and its occasional and restricted occurrences seem to make such distinctive names as this superfluous and misleading, and it is best, therefore, to consider all these rocks as phases of a typical olivine-diabase. In consideration of their enormous bulk and extent, the differences are remarkably slight.

Although even the finest-grained igneous rocks, which are aphanitic in the field, show, so far as observed, a holocrystalline structure under the microscope, yet in the tuffs, which are composed of the same material, fragments of these fine-grained holocrystalline rocks grade into others which in places show a groundmass of cryptocrystalline or nearly glassy structure, and this groundmass contains small phenocrysts of the essential minerals which make up the diabase. Obviously these are to be classed as basalts rather than diabases, and yet they evidently represent only a slight textural and structural change from the fine-grained holocrystalline rock. Specimens of this altered basalt were not found in place, but it is probable that they thus occur.

NOMENCLATURE.

The structure and composition of the coarser types of the igneous rocks of the Rampart series, as well as their appearance in the field, are those of a typical olivine-diabase; yet these rocks grade into finer phases, which are aphanitic in the hand specimen, and probably into rocks with cryptocrystalline groundmass. All of these are undoubtedly surface flows. The Tertiary basalts of this same region are often fine-grained and amygdaloidal, and also often holocrystalline and ophitic, and in structure and composition are sometimes exactly like the rocks of the Rampart series, the difference being that in the older rocks the feldspar, augite, olivine, and other constituents are more decomposed, giving a general green color, while the Tertiary rocks are nearly black. Both, however, are essentially holocrystalline plagioclase-augite-olivine rocks, with cryptocrystalline or glassy phases, and both are surface flows. Originally, therefore, they seem to have been the same. This intimate relationship is not expressed by the terms diabase and basalt, and, as a compromise between existing nomenclature and the actual facts of relationship, the terms basaltic diabase for the Rampart series rocks and diabasic basalt for the coarser portions of the Tertiary lavas are proposed. It is coming to be recognized that the old terms of petrography are incapable of expressing the true relationship of rocks, and no more accurate system

has yet been adopted; but the time for separating rocks as to their age and origin by peculiarities of structure and composition has gone by. In an igneous mass differences in crystallization alone will give rise to varieties which under existing rules of classification will belong to quite different groups.

TERTIARY BASALTS.

At various points along the Yukon and its tributaries are flows of basalt belonging to a comparatively recent geological period.

JUNCTION OF THE PELLY AND LEWES.

On the Lewes, for 10 miles below the junction with the Pelly, the right bank is a perpendicular cliff of vesicular brown basalt, which forms part of a comparatively level plateau, rising 200 or 300 feet above the river. This lava flow has been noticed by Dawson, Russell, and Hayes. Dr. Hayes[1] ascribes it to two or more vents in the immediate vicinity. These vents are supposed to be marked by high hills, one about 10 miles and the other 4 miles from Fort Selkirk. One of these hills is a symmetrical cone, and is said to have on its summit a small lake, which probably occupies the crater. According to Dr. Dawson,[2] this lava field is composed of several superposed flows. Unfortunately no specimen of the rock was collected, so that no detailed description of its nature can be given; but it is undoubtedly the same as the basalt at Miles Canyon and the other flows which will be described.

MILES CANYON.

Occurrence.—The river connecting Lake Marsh and Lake Lebarge, which is that portion of the Lewes called Seventymile River, cuts through a flow of basalt about midway between the two lakes. In this flow the river has cut a gorge about 100 feet wide and half a mile long, with perpendicular basalt walls from 60 to 80 feet high. This is known as Miles Canyon. Through this narrow cleft the whole volume of the river is forced, producing a torrent of excessive turbulence and rapidity, the water being arched up in the center considerably higher than it is at the sides. Midway between the two ends of the canyon is a steep, circular basin, where the water eddies around rapidly before plunging again down its narrow channel. Below the canyon the stream broadens, but is still rapid and full of obstructions for nearly two miles, at the end of which stretch comes a dangerous rapid nearly half a mile in length, known as the White Horse. Here the banks are still of basalt. They are perpendicular and hardly more than 15 or 20 feet high (fig. 15). The channel is full of projecting rocks, so that the whole surface is broken, foaming, and

[1] Expedition through the Yukon district: Nat. Geog. Mag., Vol. IV, p. 150.
[2] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1887-88, Vol. III, Part I, p. 132B.

tossing, and at the end is a narrow gorge, said to be only 20 or 30 feet wide, which can be seen only at extremely low water. From the head of the canyon to the foot of the White Horse the distance, as measured by Mr. Ogilvie,[1] is 2¾ miles.

The basalt at this locality is said not to extend far above or below the points mentioned. It is made up of several successive sheets, which show beautiful columnar structure. It is sometimes massive, sometimes extremely scoriacious or blebby. At the White Horse Rapids stratified silts and gravels lie on top of the basalt at a height of 20 feet or more above the present river.

Structure and composition.—A specimen of dark-brown vesicular

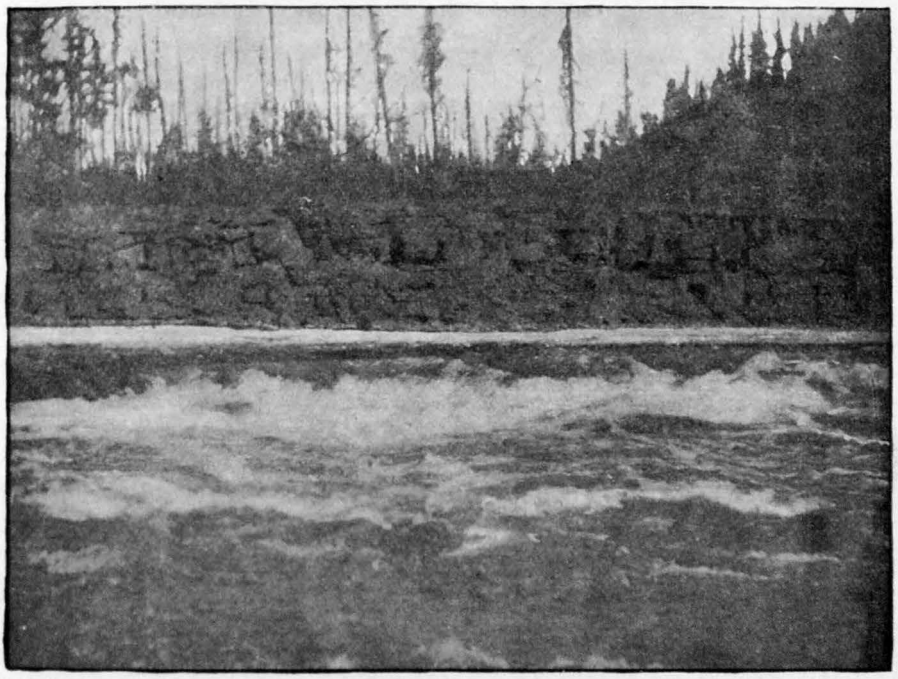


FIG. 15.—Basalt, White Horse Rapids.

lava from the canyon is seen under the microscope to consist chiefly of plagioclase-feldspar and olivine. The feldspar is in narrow strips with ragged edges and borders, and the olivine in crystals which often show roughly hexagonal outline. Disseminated throughout, sometimes in cloudy masses and again in fibers or shreds, is an abundance of reddish-brown material, which, indeed, gives color to the section and probably to the rock. This, from its occasional association with olivine, is probably serpentine stained with hematite and other metallic oxides. Quartz is present in small amount. A specimen of black crystalline basalt, with only occasional very small vesicles, has

[1]Ann. Rept. Geol. Nat. Hist. Survey Canada, Vol III, Part I, p. 161B.

essentially the same characteristics as that just described, except that the crystals are larger and an ophitic structure is often well shown. It also contains considerable titanite and magnetite.

CHICKEN AND NAPOLEON CREEKS.

Occurrence.—On Chicken Creek, at the head of Fortymile Creek, basalt outcrops below the main forks, apparently overlying shales and shaly coal seams, which have been referred to the Mission Creek series. It is nearly black and finely holocrystalline in the hand specimen, and quite massive. It is said to outcrop in places over the whole country drained by the lower part of the creek and its tributaries, and on Myers Fork to form the walls of a canyon 100 feet in depth.

On Napoleon Creek, just below the main forks, is found dark-blue, nearly black basalt associated with arenaceous limestones and grits, which likewise have been referred to the Mission Creek series. In the vicinity of the basalt the limestone is marmorized and apparently somewhat dolomized.

In the upper part of Franklin Gulch large bowlders of finely crystalline basalt occur in the gravels, where they are known as "gold rock" by the miners, since their considerable specific gravity tends to make them sink to the bottom of the gravels, where the gold also accumulates.

Structure and composition.—Specimens collected from Chicken Creek, Napoleon Creek, and Franklin Gulch are all identical in appearance, structure, and composition. Under the microscope the rock appears to be rather coarse-grained holocrystalline, and consists essentially of plagioclase, augite, and olivine. The plagioclase is in fresh, lath-shaped crystals, which have the ophitic arrangement; the augite is often considerably decomposed, and in places has apparently yielded brown hematite and magnetite, and the olivine is somewhat altered along the margins and along cracks to greenish-yellow serpentine.

KOYUKUK MOUNTAIN AND BELOW.

AT KOYUKUK MOUNTAIN.

Occurrence and description.—On the Yukon, just below the junction of the Koyukuk, a perpendicular cliff rises directly from the water to a height of probably 700 or 800 feet. This is known as Koyukuk Mountain, and is composed of basalt. On its smooth and naked face two systems of columnar jointing are developed with diagrammatic perfection. One set of joints is nearly vertical, while another, nearly horizontal, runs at right angles to the first. The horizontal joints are closer together than the others, so that while the first set represents the ordinary columnar jointing of lava flows, the second is like that often found in dikes. It is evident that the horizontal joints were formed subsequent to the vertical ones, the first contraction in

the cooling lava having naturally produced cracks or joints, following the direction of least resistance, which was perpendicular to the upper and lower faces of the cooling sheet, while on further contraction the direction of least resistance became perpendicular to the joint cracks already formed, and thus horizontal joints, closely set together and running from one vertical joint to another, were developed. A rough diagrammatic sketch is given (fig. 16), but on the cliff itself the joints are shown much more plainly, uniformly, and beautifully than can be shown in the diagram, and for each joint in the diagram there are a hundred in the cliff itself. The rock forming this cliff is often dark-blue or gray, massive, and finely holocrystalline. In other places it is porphyritic or amygdaloidal. Included in it are large fragments of altered sediments, such as conglomerates and sandstones, which have been hardened and reddened by the baking to which they have been subjected. The lava weathers along joint planes in places with great rapidity, producing compact clays of various colors. In one seam noted the central part, adjacent to the joint, was a delicate blue-gray in color, and was quite pulverulent. On both sides of this were greater thicknesses of yellow, orange, and finally light-red clay, changing to dark-red, these bright-colored clays being less thoroughly decomposed. The process seems to be an oxidation and leaching, producing the brilliant-colored clays, and ultimately, by thorough leaching, the nearly white ones. Dr. W. F. Hillebrand, of the Survey, examined some of the red clay, and found the coloring material to be limonite. These clays are used as paints by the Indians and are considerably prized, being carried long distances for the purpose of trading to other Indians. The entirely decomposed and leached blue-gray clay, mixed with water, was used as a paint or whitewash for the interior of a cabin at Nulato, where our party stopped. This cabin belonged to a white trader.

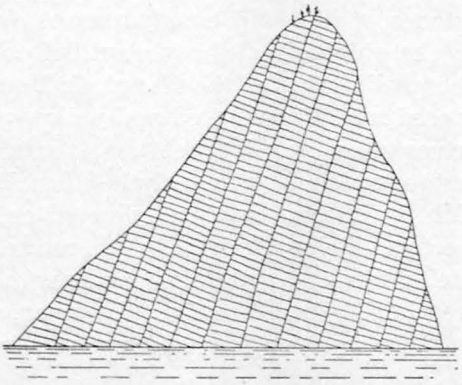


FIG. 16—Diagram showing jointing of basalt on Koyukuk Mountain, on the Yukon.

Structure and composition.—The only specimen of the Koyukuk Mountain lava which has been examined microscopically is, unfortunately, decomposed. Megascopically it is dark-green and amygdaloidal, the amygdules being partly quartz and calcite. Under the microscope a large vesicle, whose walls are lined with serpentine, is filled with barite in interlocking plates. Many small ovoidal vesicles are lined with serpentine and filled with chlorite. There are comparatively large phenocrysts, which are now pseudomorphed by calcite

and serpentine, but were probably originally olivine. The structure of the groundmass is as if originally composed of holocrystalline plagioclase and augite. The augite is abundant and not greatly decomposed, but the plagioclase crystals have been replaced by pseudomorphs of some other mineral, which is apparently, in part at least, isotropic. The rock is evidently a true olivine basalt considerably altered and decomposed.

BETWEEN KOYUKUK MOUNTAIN AND ANDREAFSKI.

The sedimentary beds which are included in the Koyukuk Mountain basalt are exposed a short distance below the mountain in a comparatively undisturbed condition. They consist chiefly of black shales and brown-weathering sandstones, and are referred by Dr. Dall to the marine Miocene. They have already been described under the head of Nulato sandstones. Everywhere between the Koyukuk Mountain and the delta of the Yukon are Tertiary sandstones, shales, and conglomerates, frequently mingled with basaltic rocks which often show beautiful columnar structure. At Anvik is basalt like that of the Koyukuk Mountain, and here also the decomposed zones furnish red and yellow paints to the natives. Along the river below Anvik much basalt was noted associated with conglomerate, which may possibly be a local river formation. At Holy Cross Mission specimens of conglomerates, sandstone, and basalt were collected. Below Andreafski there are no solid rocks, but only the flat delta deposits, and this continues to be the case until St. Michael is reached. From the river, however, a line of hills, probably basaltic, may be seen running continuously from Andreafski to St. Michael.

ST. MICHAEL ISLAND.

Occurrence and general description.—St. Michael Island is about 75 miles northeast of the Aphoon, or northernmost mouth of the Yukon. On it is situated the chief trading post of the Alaskan Commercial Company and the North American Trading and Transportation Company, and it is therefore the point at which ocean steamers are unloaded and river steamers loaded with supplies for the country up the Yukon. Near it is another island of about the same size, called Stewart Island. St. Michael Island itself is about 8 or 9 miles in width, although to the southwest a long tongue stretches out, making the total length in this direction 15 or 16 miles. The whole of St. Michael and neighboring islands and of the adjoining mainland appears to be purely volcanic. Near the trading post the chief lava flow which is now visible is about at the level of the sea at high tide. Where washed clean by the water it is wrinkled or ropy, showing it to be the true upper surface of a lava flow. These wrinklings are curved, indicating the direction of flow, but the direction thus shown varies from place to place, as if from eddying currents. Above this

lava comes a bed of waterlaid material, chiefly extremely scoriaceous lava, nearly pumice, but also partly and in some cases largely clay. Volcanic bombs are common, having a hard shell full of large pores, and a central portion which is so vesicular as to be nearly empty if comparatively fresh; this portion, however, is often decomposed to a soft, red or gray, gritty clay, recalling the decomposed basalt at Koyukuk Mountain and below, which is used by the Indians for paint. There are also occasional bowlders of sandstone and shale, mostly angular, and often a foot or more in diameter; they are generally greatly decomposed, but show no evidence of baking. This waterlaid material has a height of from 10 to 20 feet, and above it comes a solid sheet of extremely scoriaceous lava 5 to 8 feet thick; the top is

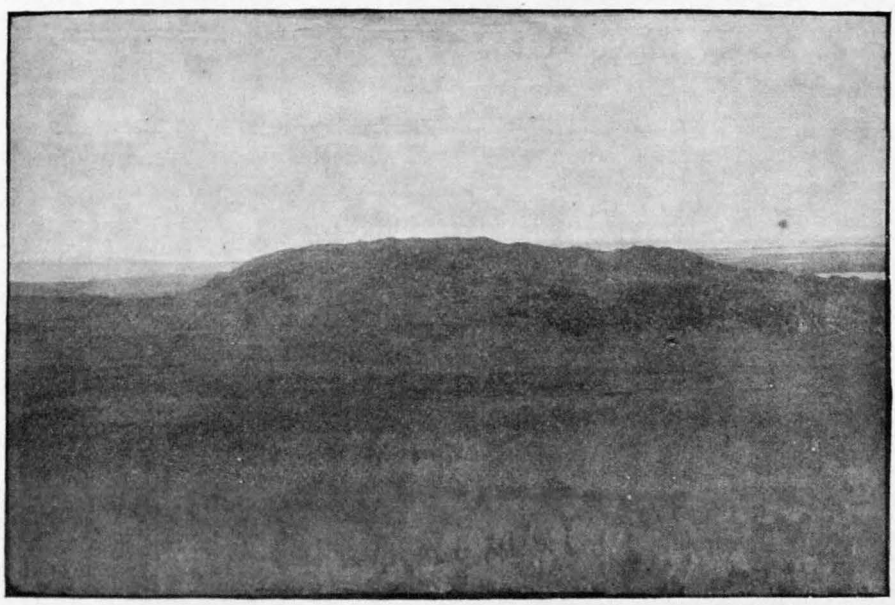


FIG. 17.—Extinct crater on St. Michael Island.

nearly pumice. Above this lava comes again a clayey waterlaid deposit, made up partly of fragments of lava, and this layer, which where observed is 4 or 5 feet thick, constitutes near the post the top of the island, which is about 20 feet above high tide. In both the beds of waterlaid material are sticks and some bones, which all appear fresh.

Craters.—At different points on the island are four or five eminences, which are only a few hundred feet above the general level, but are noticeable from a great distance by their contrast to the nearly perfect flatness of the rest. The most conspicuous one is a sharp cone which stands not far from the straits between St. Michael and Stewart Island. This is put down on the Coast Survey Chart No. 9375 as Stephens Mountain, and is known to the natives as Chinéeklk. The summit

of this is only about 400 feet above the sea, but it rises so abruptly from the flat at its base that it appears from a little distance like a mountain of considerable size. Another eminence in the interior of the island is shown on the same Coast Survey chart as St. Michael Mountain. Both these eminences and two others which were visited are long-extinct volcanoes. (Fig. 17.) On the top of each is a circular basin surrounded by a steep rock wall and filled with an irregular level mass of frost-riven bowlders. The lava of these bowlders is extremely vesicular, nearly pumice; it is black when fresh and red on oxidation, and its surface is often ropy and slaggy. The crater basin is best shown on the top of St. Michael Mountain. Stephens Mountain, or Chinéeklk, is a large crater broken down irregularly, so that one of the edges presents a sharp ridge, which appears like a cone at a little distance.

The plain from which these eminences rise is from 20 to 50 feet above the sea, and it is mostly made up, as shown by numerous sections along the shore, of stratified ash, with layers of finer clayey material. Beneath the ash, on a level with the sea, is in many places visible a bed of bowlder clay which strongly suggests ice action. The evidence shows that the lava streams cooled beneath the surface of the sea, and it is strongly probable that the volcanoes were submarine. The minor topography of the island can hardly be explained except by the action of marine currents, and even the craters bear the marks of marine erosion. The eminences now shown are only the tips of volcanoes, the rest having been covered up by waterlaid ash.

Structure and composition of lava.—A specimen of fresh lava from the lowest flow on the north side of the island is dark-gray in color, with greenish bands, and is finely porous. Under the microscope, there are seen many phenocrysts of fresh olivine, generally with good crystalline form. These are inclosed in a holocrystalline mass of plagioclase and augite, both in very fresh condition. The plagioclase is in lath-shaped crystals, and the augite in imperfect crystals or irregular grains. The plagioclase laths often have a parallel arrangement, showing the effects of flow, or again are without definite orientation. The pores are irregular in shape, and there is no glass nor any secondary minerals. Magnetite in small crystals is abundant, often inclosed in the olivine phenocrysts.

PORCUPINE RIVER.

Mr. R. G. McConnell[1] notes two distinct flows of basalt on the Porcupine. The first is about 10 miles above the mouth of the Rapid River, and is a thick sheet overlying shales, quartzites, dolomite, and limestones. This basalt shows no evident columnar structure, though there are evidences of different flows. In texture the rock grades

[1] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1888-89, pp. 130-133D.

from moderately coarse and granular to fine-grained, and in places it becomes vesicular and amygdaloidal. The specimens collected were composed principally of augite and olivine, with some magnetite and titaniferous iron, and were almost destitute of plagioclase.

Near the end of the Ramparts basalt is again found overlying shales, slates, and limestones.

WHITE RIVER.

Dr. C. W. Hayes [1] notes that during his journey along the White River black vesicular lava, probably of Tertiary age, was seen at a number of localities between the Yukon and the St. Elias Mountains, and this lava appears to form broad mesas north of the upper part of the White River.

PELLY RIVER.

Dr. G. M. Dawson [2] notes that at the mouth of Hoole River on the Pelly are bluffs of dark-brown basalt, often amygdaloidal or vesicular, and containing chalcedony, calcite, and zeolite, but scarcely at all columnar. Farther southeast the same geologist has noted basalts in the Stikine Valley, and between Telegraph Creek and the Tahltan River these basalts fill old river channels and overlie auriferous gravels. Still farther southeast, near the southern portion of British Columbia, are other basalt flows, forming a more or less connected chain reaching to the basalts of Washington, Oregon, and California.

RÉSUMÉ OF COMPOSITION AND STRUCTURE OF BASALT.

In every case where microscopic examination has been made of the basalt (and this has been done with specimens from various localities from Miles Canyon to St. Michael, a distance in a straight line of a thousand miles) the appearance, structure, and composition are remarkably uniform. In every case the rock is an olivine-basalt, composed essentially of plagioclase, augite, and olivine. The structure is generally finely holocrystalline, sometimes becoming moderately coarse and granular, and sometimes again very fine-grained, so that it is not always easy to differentiate the constituent minerals with the microscope. This last is especially the case where the rock is amygdaloidal or vesicular, as it is apt to be near the surface of flows. When the lava is in this latter condition it is especially liable to oxidation, and the formation of serpentine, limonite, and other decomposition products obscures in some degree the original structure. In places where no microscopic examination was made nor any specimens collected, the rock seems to be identical in appearance with those which have been studied.

AGE OF BASALTS.

All the basalts which have been cited have not only the same structure and composition, but have experienced about the same

[1] Expedition through the Yukon district: Nat. Geog. Mag., Vol. IV, p. 150.
[2] Ann. Rept. Geol. Nat. Hist. Survey Canada, Vol. III, Pt. I, 1887-88, p. 122B

slight amount of decay and erosion. It is evident, therefore, that though the different flows are probably not strictly contemporaneous they were not separated from one another by a very long period of geological time. As to their age, a limit is established in one direction by the fact that at the Koyukuk Mountain, at the junction of the Koyukuk with the Yukon, the basalt has broken through sandstones and shales of Miocene age, and is therefore later than these sediments. On the other hand, at the White Horse Rapids the lava is overlain by stratified silts and gravels. A short distance farther down the river these silts and gravels overlie older clay of glacial origin, and this and other evidences already cited show that they were formed after the retreat of the glacier; in this case, therefore, the basalt is undoubtedly pre-Glacial. With these two limits in mind, we may consider the basalt as a whole to be probably in large part Pliocene. Dr. Dawson,[1] however, on account of the blending of the British Columbia basalts with lake deposits which have been referred to the Miocene, believes that at least the first eruptions took place in this period, although the volcanic agencies may have continued active into the Pliocene. In California and Oregon, according to Professor Le Conte,[2] the great lava flows probably commenced to be outpoured at the beginning of the Pliocene epoch, as shown by the fact that these lavas lie upon eroded strata of Miocene age.

Modifying the direct evidence obtained in regard to the age of the Alaskan basalt by the suggestions derived from neighboring regions, we may say that these flows may have begun in Alaska in late Miocene and may have reached into the earlier part of the Pleistocene, since the eruptions at different localities were not necessarily contemporaneous, and that the period of greatest activity was post-Miocene. In all the cases cited the flows seem to have been relatively small and local, and often, as at the mouth of the Pelly and at St. Michael, the lava seems to have been poured from craters. This period of volcanic activity seems to be distinct from the more recent eruptions which have taken place along the Alaskan Peninsula and the Aleutian Islands and farther inland along this same axis in the regions drained by the Copper River. These more recent outbreaks seem to be largely andesitic. The volcanic ash already noted is the only evidence of comparatively recent volcanic activity in the region of the Upper Yukon, and according to Dr. Hayes this ash was probably produced by an eruption in the northern part of the St. Elias Mountains, near the source of the Klutlan glacier.[3] This last-named region may be considered as the northeastern end of a zone of recent volcanic activity which runs from this region through the Alaskan Peninsula.

[1] Op. cit., p. 37B; see also Trans. Royal Soc. Canada, 1890, Vol. VIII, sec. 4, p. 15.
[2] Am. Jour. Sci., 3d series, Vol. XXXII, p. 177.
[3] Expedition through the Yukon district: Nat. Geog. Mag., Vol. IV, p. 148, pl. 20.

CHAPTER IV.

MOVEMENTS IN THE EARTH'S CRUST.

It is intended to summarize under the heading given above all important movements in the rocks, including not only folding and faulting, but also interstitial movements, producing schistosity and the like; migrations of molten rocks, producing dikes and lava sheets; and the migrations of materials on the surface through atmospheric agencies, which produce by erosion and deposition hills and valleys on the land and new rocks in the sea. Among these processes, however, regional movements, producing the uplift or depression of great areas, and the folding or faulting of the superficial rocks, are primarily important, since it is largely upon these that the minor adjustments depend: and they will therefore be chiefly considered.

SUMMARY OF GEOLOGICAL RECORDS IN THE ROCKS.

The features of general importance in the history of the rock formations along the gold belt in Alaska are, so far as imperfectly known, as follows:

The fundamental rock of the region is a schistose granite, and lying upon this is a thick series of schistose and often impure quartzite, whose situation and petrographical characters indicate a probable derivation from the granite. The schists are also graphitic in places, suggesting the presence of organic life at this period. Lying upon these quartzite-schists, which have been called the Birch Creek series, come thick beds of crystalline marble interbedded with quartzite-schists having much the same characters as before, but grading into more highly crystalline hornblende- and mica-schists, which form finally a large part of the rocks. These hornblende- and mica-schists are often graphitic, and are evidently derived from impure sediments. Above this series of marbles, schistose quartzites, and hornblende- and mica-schists, which has been called the Fortymile series, comes a great thickness of basic volcanic rocks, alternating with tuffs and impure sediments. This has been called the Rampart series. While the Birch Creek and Fortymile series are highly schistose, the Rampart series is, on the whole, massive, although generally jointed and locally becoming schistose along definite zones. On the whole, however, there is a marked contrast in degree of metamorphism between this and the preceding formations. In the Fortymile and Birch Creek series are some dioritic and granitic dikes which have been

greatly sheared along with the inclosing rocks; and there are quartz veins which are generally parallel to the schistosity, and which also have suffered great shearing. Besides the greatly sheared dikes, there are others which show less and less metamorphism, and finally some which have been entirely unaffected by any dynamic disturbance. The massive dikes, when they occur in close proximity to the more or less schistose ones, invariably show themselves to be the youngest of the series. These same youngest dikes, or dikes of the same peculiar types, are also found cutting the rocks of the Rampart series.

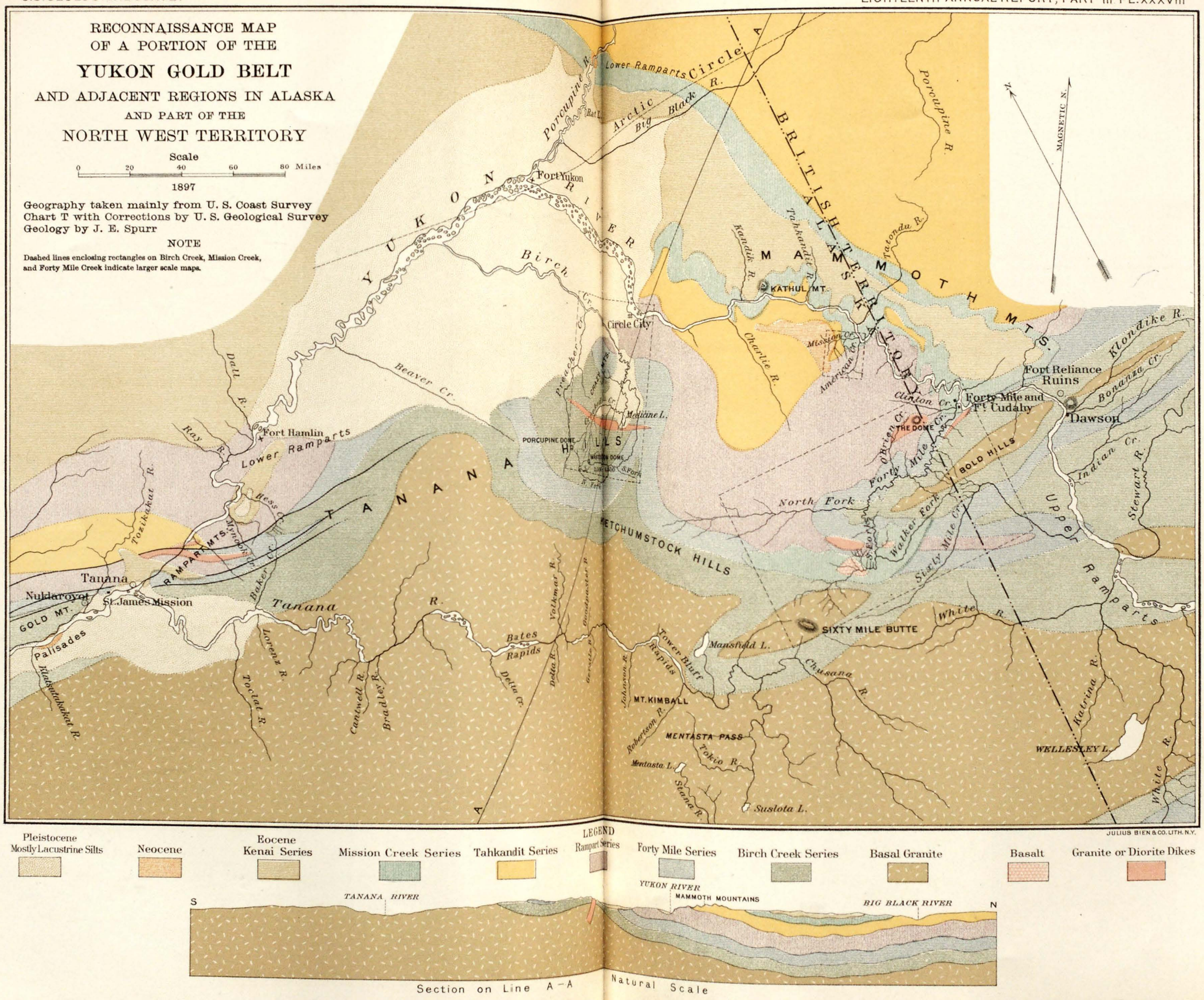
Above the volcanic rocks and impure sediments of the Rampart series come limestones, shales, and occasional conglomerates, which, from want of knowledge sufficient for their differentiation, have been grouped together as the Tahkandit series. This series contains in different parts fossils, which indicate that it is in part Carboniferous and in part Devonian; but these are not necessarily the limits of the age of the rocks included under this classification. The Tahkandit series shows in a marked degree less decomposition and metamorphism than the Rampart series, and there is a probable unconformity existing between the two.

Above the Tahkandit series comes the Mission Creek series, which is, in part at least, Cretaceous, and is made up of black calcareous or feldspathic shales, impure thin-bedded limestone, gray sandstone, and conglomerate. Seams of impure coal and obscure plant remains are often found, but occasional fossils show the series to have been largely a marine formation. At the base is a conglomerate, which rests unconformably on the Rampart series and Fortymile series, and contains pebbles derived from these rocks.

Above the Mission Creek series comes a great thickness of massive conglomerates, with coarse grits and some sandy, argillaceous limestone and impure shales. These rocks contain abundant plant remains and occasional fresh-water fauna, on the evidence supplied by which they are referred to the Eocene. There are no marine fossils or other evidence of marine conditions. The conglomerates contain pebbles of the Rampart series, Fortymile series, Birch Creek series, and of various other sedimentary and igneous rocks. This great thickness of fresh-water beds has been called the Kenai series.

The Tahkandit series, Mission Creek series, and the Kenai series all show about the same amount of dynamic disturbance, there being apparently no very great unconformity separating them from one another, and all having been folded together. Sometimes these folds are gentle, sometimes broad and open, and sometimes closely compressed and vertical. Owing to this folding there is local jointing, but all the rocks have been practically unaffected by regional shearing.

The beds overlying the Kenai series are few and scattered. On the upper part of Mission Creek are partially consolidated, nearly hori-


RECONNAISSANCE MAP
OF A PORTION OF THE
YUKON GOLD BELT
AND ADJACENT REGIONS IN ALASKA
AND PART OF THE
NORTH WEST TERRITORY
Scale
0 20 40 60 80 Miles
1897
Geography taken mainly from U. S. Coast Survey Chart T with Corrections by U. S. Geological Survey
Geology by J. E. Spurr
NOTE
Dashed lines enclosing rectangles on Birch Creek, Mission Creek, and Forty Mile Creek indicate larger scale maps.
MAGNETIC N.
N.
YUKON RIVER
Fort Yukon
Porcupine R.
Lower Ramparts
Arctic
Big Black R.
Circle
BRITISH TERRITORY
ALASKA
MAMMOTH MTS.
Tatonda R.
Tahkandit R.
Kandik R.
KATHUL MT.
Birch
Circle City
Preacher Cr.
Beaver Cr.
Charlie R.
Mission Cr.
American Cr.
Klondike R.
Bonanza Cr.
Fort Reliance Ruins
Forty Mile and Ft. Cudahy
Dawson
Clinton Cr.
O'Brien Cr.
THE DOME
Forty Mile Cr.
BOLD HILLS
Indian Cr.
Stewart R.
Upper Ramparts
Dall R.
Ray R.
Fort Hamlin
Lower Ramparts
Hess Cr.
Tozikakat R.
Myrtle Cr.
Baker Cr.
RAMPARTS MTS.
TANANA HILLS
Medicine L.
PORCUPINE DOME
WISTON DOME
S. Fork
N. Fork
North Fork
Walker Fork
Sixty Mile Cr.
FETCHUMSTOCK HILLS
Tanana
Nuklaroyot
St. James Mission
GOLD MT.
Palisades
Klatsutakkat R.
Tanana
Lorenz R.
Toclat R.
Cantwell R.
Bradley R.
Bates Rapids
Delta Cr.
Delta R.
Volkmar R.
Gladiator R.
Johnson R.
Robertson R.
Tower Bluff
Rapids
Mansfield L.
SIXTY MILE BUTTE
White R.
Chusana R.
MT. KIMBALL
MENTASTA PASS
Tokio R.
Mentasta L.
Stana R.
Suslota L.
Katrina R.
WELLESLEY L.
White R.
A
A
JULIUS BIEN & CO. LITH. N.Y.
LEGEND
Pleistocene Mostly Lacustrine Silts
Neocene
Eocene Kenai Series
Mission Creek Series
Tahkandit Series
Rampart Series
Forty Mile Series
Birch Creek Series
Basal Granite
Basalt
Granite or Diorite Dikes
S
TANANA RIVER
YUKON RIVER
MAMMOTH MOUNTAINS
BIG BLACK RIVER
N
Section on Line A-A
Natural Scale

zontal conglomerates and grits carrying plant remains, which appear to correspond with beds on the Porcupine and Mackenzie. All these sediments are probably local accumulations in lakes of limited extent. Those on the Mackenzie, which were examined by Mr. McConnell, have been referred by Sir William Dawson, on the evidence of the flora which they contain, to the Laramie (Fort Union group, or Eocene, of United States geologists and of this report); but there is still room for the suspicion that they may properly be assigned to the Miocene. These beds are separated by a profound unconformity from the underlying Kenai series, being only gently tilted, while those of the Kenai are sharply folded. At the Lower Ramparts are cross-bedded sandstones with fossil leaves, cones, and fragments of wood. These beds are probably Pliocene. Finally come the Pleistocene and recent silts and gravels, which are scattered all over the country as a result of deposition in the great lakes and rivers.

GEOLOGICAL MAP.

It was thought best to put upon a map (see Pl. XXXVIII) the information collected concerning the geology of that portion of the gold belt in Alaska which was examined in the summer of 1896. Some hesitation was felt in doing this on account of the extremely meager amount of data available. On the other hand, certain broad geological facts which were clearly proved by our investigations could not be appreciated from written descriptions alone.

In order to make clear the amount of data from which different portions of the map were constructed, an uncolored base map is presented. (See Pl. XXXIX.) On this map the routes which have been traveled by observers who have made notes concerning the geology are indicated by colored lines. The red coloring shows the traverse made by the United States Geological Survey party in the summer of 1896. For a great part of the distance traversed only extremely hurried and imperfect reconnaissance could be made, while in certain other parts, such as the Fortymile and Birch Creek mining districts, more careful though still hurried work was done. The brown line shows the route of a hurried reconnaissance by Mr. R. G. McConnell, of the Canadian Geological Survey. The yellow line is the route traversed by Mr. W. Ogilvie, of the Canadian Geological Survey, and concerning this route Mr. Ogilvie has made a few very brief notes. The blue line is the route traveled by Dr. Hayes, who accompanied Lieutenant Schwatka on his trip along the White and Copper rivers. The green line is the route followed by Lieutenant Allen on the Tanana and Koyukuk rivers, concerning which he has made one or two rather vague geological notes. The orange line represents a route concerning which some information was obtained by prospectors, the information given by whom, however, is of doubtful value, since their discrimination of rocks is not always accurate.

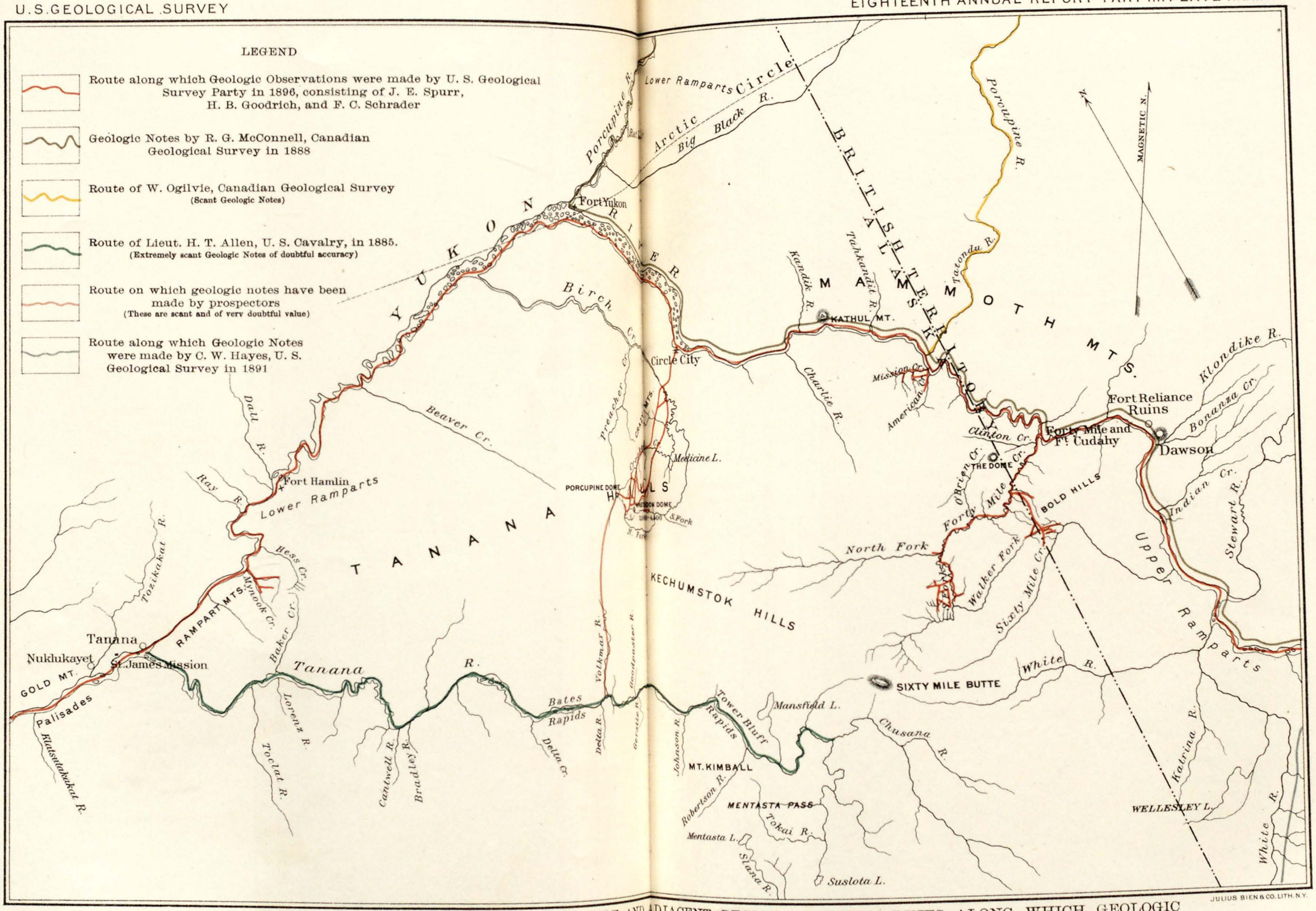
The information indicated above is all that is actually available concerning the geology of the region mapped, and on this basis the map has been constructed. Along the routes delineated the observations are always rough and sometimes unreliable, and in the intervening country the geology, as indicated on the map, is purely a matter of inference. It is not expected, therefore, that the map is any more than the rudest approximation to the truth; yet it is believed that it will serve a purpose until more careful work is done, and, indeed, may serve as the basis for such work.

In the cross section accompanying the map everything is generalized. The representation of the relative thicknesses of the different formations has not been attempted, since these are not definitely known, and unconformities are not shown. Only the general structure and the succession of the different series as roughly divided, and as explained in the text, is given.

The summit of the Yukon geanticline is shown on the left side of the section, and this changes into a shallow geosyncline on the right side. Just northeast of the Yukon the continuation of the Mammoth Mountains forms a scarp of younger rocks facing the axis of the anticline. The country shown in the left of the section and in the corresponding area on the map is represented as being entirely of granite, since the only notes available are those of Lieutenant Allen, who describes granite along the Tanana. It is the belief of the writer, however, that this structure as represented is probably incorrect, and that younger rocks will eventually be found overlying the granite near the Tanana or immediately to the southwest of it, and that these younger rocks are on the southwest limb of the Yukon geanticline. There are as yet, however, no data for this belief.

DIVISION OF ROCKS ACCORDING TO DYNAMIC DISTURBANCES.

All the rock formations may be roughly divided into three chief groups, according to the degree of dynamic disturbance which they have undergone. The first group consists of the more or less schistose rocks, beginning with the fundamental granite and ending with the Rampart series; the second group consists of the unsheared but often highly folded rocks, beginning with the Tahkandit series and ending with the Kenai series; the third group consists of the nearly horizontal and only partly consolidated sediments, beginning with the Twelvemile and Porcupine River beds and ending with the recent gravels. These great groups are separated by great unconformities, and although minor unconformities undoubtedly exist within the groups themselves, yet they do not appear to be of nearly the same importance.



MAP OF A PORTION OF THE YUKON GOLD BELT AND ADJACENT REGIONS, SHOWING LINES ALONG WHICH GEOLOGIC NOTES HAVE BEEN MADE

Scale of Miles

20 10 0 20 40 60 80 100 120 140 160 180

HISTORY OF ROCKS TO END OF RAMPART SERIES.

BIRCH CREEK AND FORTYMILE SERIES.

The facts of observation which have been given in the summary, together with minor ones given in the descriptions of the rock formations, may be interpreted as follows:

The first event which we can discern is the exposure to erosive agencies of a fundamental granite. As a result of this there accumulated a thick and widespread deposit of sandstone, often impure from the admixture of other granitic material. The occurrence of graphite in these now-metamorphosed sediments suggests the presence of life during their deposition. Above these sandstones were laid down thick beds of limestone alternating with sandstones and more impure sediments, often highly carbonaceous. The thickest beds of limestone were deposited immediately above the sandstones, while in the upper part of the series impure detrital rocks became more abundant. All these sediments seem to lie upon one another, so far as yet observed, conformably; and the accumulation of so great a thickness of conformable strata may be taken to represent a long period of nearly uniform conditions. The transition of the Birch Creek quartzites to the Fortymile marbles may represent general depression and frequent immunity from land sediments, and the increasing amount of impure sediments at the top of the Fortymile series may indicate reelevation.

This long period of quiet, with only uniform and widespread crustal movements, was brought to a close by a series of great disturbances, which lasted for a long while. The earliest manifestation of these disturbances appears to have been the intrusion of molten rock from below, forming dikes cutting the sedimentaries. At about the same time movements in the crust brought the rocks under great strain, which was relieved by the slipping of grain upon grain, and of one layer on another along bedding planes and other lines of weakness, and finally by the production of great folds. It is probable that at this time began the closely compressed series of folds along an east-west axis which are shown on the map (Pl. XXXIX) as affecting these older rocks, especially along Fortymile Creek, and farther east. The internal structure of the rocks was changed, not only by the movement of grain upon grain, but often by the crushing of minerals or their elongation along the line of least resistance. As a consequence of pressure and accompanying metamorphic influences new minerals were formed; limestone became marble or dolomite; carbonaceous rock became graphitic; and from impure sediments crystals of mica, hornblende, garnet, epidote, and rarer minerals were developed. The formation of the schists from sediments has already been well described, and the events need not be repeated. The pressure appears

to have been so general and gradual that no uniform regional planes of shearing was induced; but the movements followed whatever planes were locally the weakest, and these appear to have been generally the bedding planes. The evidence of this is chiefly found in the Fortymile district, where the schistosity is everywhere regular and parallel to the true bedding, the latter being shown by the alternation of marble with schists, though it is shown also in the Birch Creek district, where the schistosity, so far as observed, seems to be a good index of structure and of the relations of the different schistose series to one another. It thus happens that the schists on Fortymile Creek and to the east along the Yukon have a general east-west strike—corresponding to the east-west folding shown by the succession of formations—but a varying dip. On Birch Creek, however, the folding is more gentle, as seen on the map.

Very early in the period of disturbance narrow quartz veins were formed in all the rocks wherever the dynamic stresses produced open cracks or zones of weakness, which naturally became water channels. Where no previous special system of planes of weakness existed, the channels thus produced by dynamic stress were relatively few, as is the case in the massive marble of the Fortymile series. In the more definitely layered sedimentary rocks, however, such as the quartzites of the Birch Creek series, and especially the impure schists of the Fortymile series, the pressure-producing movement along the weak bedding planes made them still more available as water channels. Therefore, in the basal granite and in the massive marbles, the quartz veins are relatively few, but they are abundant in the more definitely layered rocks. As may be inferred from what has been said, they are usually conformable to the schistosity of the rocks in which they occur, but occasionally they are found cutting across the layers. These veins are generally narrow and nonpersistent, and are often merely elongated lenses, as if forming in cracks left by the spreading apart of layers under stress.

It has already been mentioned that these schists are cut by a series of dikes of different ages, of which the successively younger show less and less shearing. This is an evidence that the development of schistosity was very gradual, and much other evidence confirms this conclusion. By the continuance of the shearing process, features which were developed as the consequence of the first movement were altered or occasionally obliterated. The earliest dikes become schistose and the quartz veins became stretched or pulled into shreds; and metamorphic minerals, such as garnet, were crushed and elongated along new slipping planes.

RAMPART SERIES.

Near the end of the long period of disturbance were eruptions of basaltic lava over a great area; sheets of vast thickness and extent were poured out. Much of this lava must have been poured out in

the sea, for the sheets were apparently immediately covered up by tuffs and other sediments. These effusions occurred repeatedly for a long time, and in the intervals between them sediments accumulated, sometimes composed entirely of volcanic material, but gradually growing purer, forming impure sandstones, shales, and limestones. In these periods, also, some life existed, as is shown by fish teeth discovered microscopically in one of the specimens of altered glauconitic limestones. Owing to the great thickness of some of the lava sheets, the texture of the rock is generally comparatively coarse, so that the coarse varieties have been described as diabase and the whole series has been characterized as basaltic diabase; these igneous rocks and associated sedimentaries have been grouped together under the head of the Rampart series.

The Rampart series is only locally schistose, and forms a strong contrast to the underlying highly metamorphic Fortymile series. It appears, therefore, that the strains producing shearing were mostly spent before the initiation of volcanic activity, or they may have been relieved by it; but the production of the jointing and local shearing may be ascribed to the last effects of this regional strain. No great unconformity has been observed between the Fortymile series and the Rampart series; and although it is probable from the manner of their formation that some degree of unconformity exists, yet it seems that the movement which produced the east-west folds in the older rocks did not culminate until after the end of the formation of the Rampart series, since on Fortymile Creek and elsewhere the latter seems to have been affected by this system of folding.

HISTORY FROM RAMPART SERIES TO END OF KENAI SERIES.

After the formation of the Rampart series came the deposition of thick beds of limestones, shales, and occasional conglomerates, which have been called the Tahkandit series. This includes rocks laid down in Devonian and in Carboniferous time, and may include rocks older or younger than these periods. In the probable Devonian strata below Mynook Creek some plant remains were found in the shales associated with limestones, indicating occasional proximity to land. On the Yukon between Mission Creek and Circle City, Carboniferous fossils occur in limestone interbedded with conglomerate whose pebbles are mostly of chert of various bright colors, and especially of a deep green, like the cherts which have formed in the rocks of the Rampart series. These conglomerates suggest land in the immediate vicinity, and it is therefore probable that at this time the Rampart series formed in places a land mass. The Tahkandit series appears to be separated from the Rampart series by a great unconformity, for although no actual contact was observed, yet there was seen no great degree of unconformity between the Tahkandit and the overlying Mission Creek series, the two being folded together and in about the

same degree; while the Mission Creek series in various places was seen to rest upon the Rampart series in marked unconformity. There was probably, however, a slight unconformity between the Tahkandit and the Mission Creek series, as has already been stated. On the whole, however, the Tahkandit, the Mission Creek and the Kenai series were laid down one upon the other, under comparatively uniform conditions and with no great disturbances; so it seems that the long period of disturbances which began with the shearing, folding, and intrusion of dikes in the Fortymile series and older rocks ended with the effusion of the volcanic rocks of the Rampart series.

The rocks of the Tahkandit series are marine sediments, with occasional plant remains and conglomerates suggesting littoral or fresh-water conditions. The overlying Mission Creek rocks are impure sediments, with many layers of impure coal and abundant plant remains; yet this series contains marine fossils, so that we may conclude that the rocks were laid down in the vicinity of the land, sometimes in the sea and sometimes in fresh water; and from the usual very fine grain of the material in the rocks, erosion and deposition probably went on with only a very moderate degree of rapidity. On the other hand, the Kenai series which overlies the Mission Creek series, shows by its abundant plant remains and occasional fresh-water fauna and the entire absence of marine organisms that the rocks were formed entirely in fresh water. This series is of great thickness, and the plant remains found at the bottom are apparently the same as those found at the top, and all indicate an Eocene age. It is evident, therefore, that these rocks accumulated at a period of very rapid erosion and deposition, and this conclusion is confirmed by the nature of the rocks themselves, which are chiefly massive conglomerates and coarse grits. These conglomerates contain pebbles derived from the Fortymile, the Birch Creek, and the Rampart series, as well as granite and other igneous and sedimentary rocks.

Contrasting the evidence offered by the Tahkandit series with that of the Mission Creek series, we may assume a general elevation between the deposition of the former and of the latter, so that fresh-water beds and evidences of land proximity become much more abundant. At the end of the deposition of the Mission Creek series there must have been a marked elevation and the formation of a high land mass which was violently attacked by erosion and rapidly degraded. The material thus removed was laid down in bodies of fresh water, forming an immense thickness of sediments in a comparatively short time. From the composition of these sediments, it appears that the Rampart series formed an important part of the land mass, while all the rocks older than this series must also have been exposed, and probably rocks belonging to younger formations.

THE POST-KENAI REVOLUTION.

At the end of Kenai time there were movements of great importance in the crust of the earth, the most remarkable result of which was a series of flexures of vast dimensions, which have very long northwest and southeast axes. Of these folds the best known has been named the Yukon geanticline. Along the axis of this fold the fundamental granite extends from the Tanana along the Yukon and Pelly as far as the Dease River, a distance of nearly 800 miles in a straight line. Overlying this granite to the northeast and to the southwest come quartzite-schists and marbles belonging to the Birch Creek and Fortymile series, and lying upon these again, at a more remote distance from the granitic axis, are still younger rocks. Our knowledge of the succession of strata on the southwest side of the fold depends mainly on the notes made by Dr. Hayes in his traverse along the White and Copper rivers.[1] On the northeast side of the fold, however, the succession has been more carefully observed, and has been described in the preceding pages. The succession of formations on both sides of the granitic belt is that typical of an anticlinal ridge. It is probable that this geanticline diminishes rapidly near the point where it cuts the Yukon at the Lower Ramparts, and finally dies out.

As a general rule, the dip of the rocks on both sides of the geanticline is away from the granitic axis. This is especially well shown in the formations which are younger than the Rampart series, since these have been little or not at all affected by the east-west-trending folds which are exhibited by the Rampart and older rocks. The younger rocks, therefore, show in their structure simply and clearly the effects of the post-Kenai revolution. On the right side of the Yukon, between Fortymile Post and Circle City, these younger series are exposed in sharp mountains in which the trend of the strata corresponds with that of the range, and the dip appears to be uniformly to the northeast, sometimes at a comparatively gentle angle, sometimes nearly vertical.

Besides the Yukon geanticline there are probably other great folds having the same general trend. The existence of a geosyncline lying immediately northeast of the Yukon geanticline and having the same general trend is indicated on the map of the gold belt, but this representation of structure rests on very slight information.

NEOCENE MOVEMENTS.

In the period succeeding the post-Kenai revolution the greater part of Alaska seems to have been land. Along the Lower Yukon, in the vicinity of Nulato, are marine limestones and impure sandstones. These are ripple-marked and cross-bedded, and contain plant remains,

[1] See pp. 223, 249.

and are therefore probably a littoral formation. In the region farther northeast there is an absence of marine sediments, but there are occasional fresh-water beds, indicating a land surface with numerous lakes, which may be referred to the same period as the marine sandstones at Nulato. During this period the land surface was eroded and the axis of the Yukon geanticline was worn down, exposing the old rocks in a broad belt with the gradual recession of the younger formations. The surface of older rocks became in process of time smoothed down and leveled, and the slopes became gentle, so that the rivers meandered through broad, shallow valleys. The imperfect plateau thus produced has been called the Interior Plateau, and stretches over the greater part of Alaska and British Columbia. From an elevated point of view, it appears like a gently undulating plain, from which rise hills and mountains of no great height. In this plain have been cut the present deep river valleys, as a consequence of the Neocene elevation, which will be referred to later on.

MAMMOTH MOUNTAINS.

From Fortymile Creek to the Kandik River there is, on the right side of the Yukon, a range of tall sierras rising from 3,000 to 5,000 feet above the river, which flows close to their base; on the left side of the river is the usual broad, nearly level plateau at an elevation of several hundred feet. From the top of this plateau there is a general level observable between the tops of the peaks on the right side of the river, yet these peaks are so sharp as to present a great contrast with the gentle topography of the plateau country. The range has a general northwest trend, corresponding with that of the river; it was first noticed near Fortymile Creek, and from there continuously to the Kandik. Below the Kandik the Yukon turns to the east and the range, still continuing its northwest trend, diverges from the river and is lost sight of. From the abundance of the remains of the fossil elephant or mammoth in this region it is proposed to call this range the Mammoth Mountains. Fig. 18 is a view of the highest peak noted in this range, which has already been named Kathul Mountain, and is situated a short distance above the Kandik.

From the river these mountains appear as a ridge of nearly uniform maximum height, but carved into low, serrated peaks of bare rock, usually dark red in color, with large bands of light gray, which are more resistant to weathering, and so form pinnacles. The gray belts maintain a uniform position for miles along the side of the ridge, and therefore the rocks have a strike conforming to the trend of the mountains, namely, northwest and southeast. Below Fortymile post a short distance the dip appears to be uniformly to the northeast at an angle of 20° or more.

Near the international boundary these mountains were climbed by Prof. I. C. Russell,[1] and were found to be about 3,000 feet above the

[1] Notes on the Surface Geology of Alaska: Bull. Geol. Soc. America, Vol. I, p. 136.

river. At the place visited the crest of the range consisted of compact, earthy limestone in nearly vertical strata, striking conformably with the trend of the mountains.

The Tatonduc is one of the streams which flows through the Mammoth Mountains, entering the Yukon on the right side. Mr. W. Ogilvie[1] reports that the rocks along this river are dark shales overlain by fine-grained conglomerates and underlain by grayish Paleozoic limestones.

From this information it appears that the Mammoth range is composed of the younger rocks, and, as seen on the map, the mountains lying close to the Yukon are formed of that portion of the younger rocks which lies immediately adjacent to the area where the older

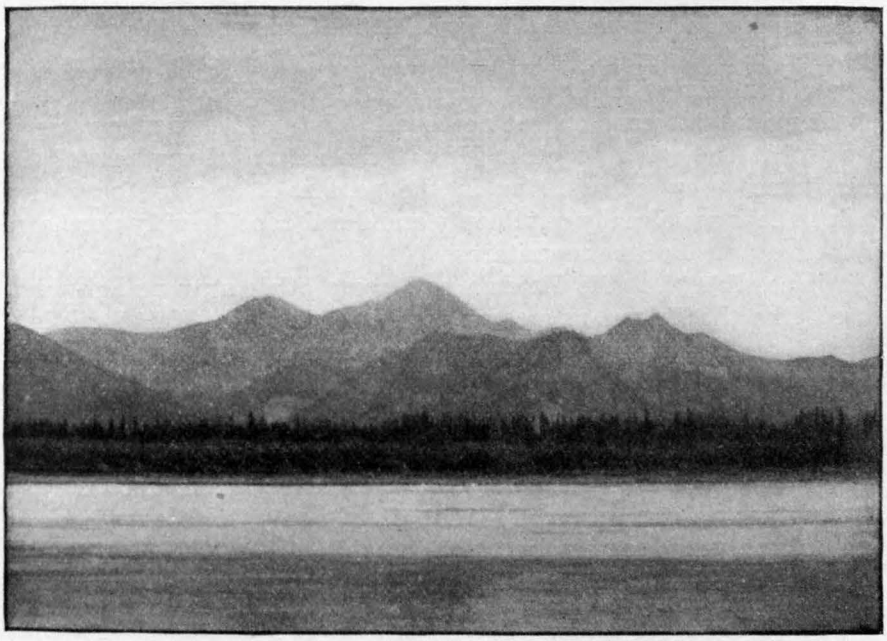


FIG. 18.—Kathul Mountain, Mammoth Range.

series are chiefly exposed. In other words, these mountains appear to be an erosion scarp of the younger rocks facing the older series which lie nearer the axis of the Yukon geanticline.

DRAINAGE SYSTEM.

The Yukon River flows along the foot of the Mammoth Mountains, which probably constitute, as already said, a scarp of erosion. The parallelism of the river to the axis of folding and its position at the foot of the mountain scarp suggest that it may be primarily due to the folding. If this is the case it is probable that the original line of drainage was parallel to the present one, but was begun farther south-

[1] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1888-89, Vol. IV, p. 138D.

west, nearer the axis of the geanticline, soon after the formation of the fold, and that with time it moved to the northeast, following the scarp made by the recession of the younger rocks. In this connection the difference between the size of the tributary streams on the northeast and on the southwest side of the Yukon along this belt must be noted. Those on the southwest side are of considerable size, reaching as much as 100 miles in a straight line back from the Yukon, while on the northeast they are, so far as imperfectly known, much shorter and smaller, as shown on the existing maps. Concerning the length of the Tatonduc, which is one of the largest of the streams coming in from the northeast along this belt, we have information from the survey of Mr. Ogilvie. This stream heads only about 50 miles in a straight line away from the Yukon, and, as seen on the map, the divide between the Yukon and the Porcupine lies remarkably close to the former river. This inequality between the size and length of the rivers on the two sides of the Yukon shows the existence of the mountain scarp on the northeast; and yet it must be remembered that they give no clear idea of the actual abruptness of the scarp, since they are assisting in the process of wearing back, and their valleys are already cut deeply and head considerably northeast of the front wall of the mountains.

It is possible that the Tanana and some other streams also originated, like the Yukon, as a consequence of this post-Kenai folding; yet so little is known as to the geology of these regions that only a suggestion can be made.

NEOCENE ELEVATION.

The records of ancient geological times are so much obscured and altered that we can ordinarily trace clearly only those events which were of the very greatest importance, while the minor ones remain unknown or can at best be only conjectured. As modern geological time is approached, however, the records become more numerous and their meaning is more evident. Thus, of the events in the enormous length of time which elapsed between the first sediments on the basal granite and the beginning of the Tertiary we have been able to offer only the roughest sketch. Of Tertiary time, however, much more detail can be presented, and the geological record increases in perfection up to the present day, when we may see the processes of change going on before our eyes.

One of the means by which we are enabled to trace earth movements in more recent geological times is physiographic development. We have already seen how the comparatively level interior plateau with its ancient broad, shallow valleys, and mountains greatly reduced by erosion, points to the stability of the land for a long period subsequent to the Kenai revolution, during which period atmospheric forces were at work. In the same manner the deep, canyon-like valleys in which

the present streams flow point to a decided and long-continued elevation of the land at the end of this period of stability. The cutting of these deep valleys along the lines of the old sluggish drainage took place, over the whole of Alaska, so far as known, and can be explained only by supposing a general elevation which lowered the outlets of the rivers, and so brought about rapid deepening of the drainage channels; and since these younger valleys are often several hundred feet deep, the new condition of affairs must have lasted for a long time.

Period of elevation.—We may believe that this elevation took place in late Miocene or early Pliocene times, for the marine Miocene sandstones in the vicinity of Nulato and lake beds such as the Twelvemile beds at the head of Mission Creek have been tilted and locally folded, while younger deposits are slightly or not at all disturbed. Moreover, the Twelvemile beds stand at an elevation and in a position with regard to the present drainage which shows a long period of erosion since lacustrine conditions were possible, and the marine sandstones are deeply cut into by the Lower Yukon, so that a large part of the erosion of the river valley has taken place since their deposition and elevation into a part of the land mass. On the other hand, these valleys existed in practically their present condition previous to the Glacial period, for the evidence is abundant that the lobes of the cordilleran glacier occupied the valleys of the Upper Yukon and other streams when they were in practically the same condition as now, and on the retreat of the glacier lakes were formed, which now occupy portions of the old valleys which have been dammed or slightly depressed.

Volcanic activity.—At about the same general period came eruptions of basalt from many scattered sources. These flows were limited in size, and were usually from volcanic vents. It has already been suggested from independent evidence that these eruptions took place mostly in Pliocene time, which was also the period of the active downcutting of the present valleys. Some of the flows appear to have dammed up the valleys, as at the junction of the Pelly and the Lewes and at Miles Canyon, between Lake Lebarge and Lake Marsh, yet at the junction of the Pelly the valley of the Lewes has been excavated 300 or 400 feet below the basalt plateau since the effusion of the lava. The course of the Lower Yukon between the Koyukuk and the sea may be due to the obliteration of the ancient valley by a lava flow; but at the Koyukuk Mountain the basalt has, subsequent to its effusion, been carved by the erosion of the river into a perpendicular bluff of 700 or 800 feet. In these instances the eruptions seem to have occurred during the excavation of the valleys, and we may believe that volcanic activity began at approximately the same time as the general elevation.

Minor folding.—Along the Yukon between Fortymile Creek and Circle City, where the river follows the base of the Mammoth Moun-

tains, the younger rocks, such as the Tahkandit, the Mission Creek, and the Kenai series, have sometimes a nearly uniform attitude for a considerable distance, but are again thrown into folds, often sharply compressed and vertical. There is some slight faulting accompanying this folding, but on the whole the absence of actual breaks in the strata is remarkable. In some cases these folds are so recent that they appear on the surface and determine the present topography. An instance of this is shown in fig. 19, which is a photograph of probably Carboniferous rocks on the right side of the Yukon, near the Tahkandit River. A broad band of white crystalline limestone makes the structure obvious even from a distance and shows that the beds are bent

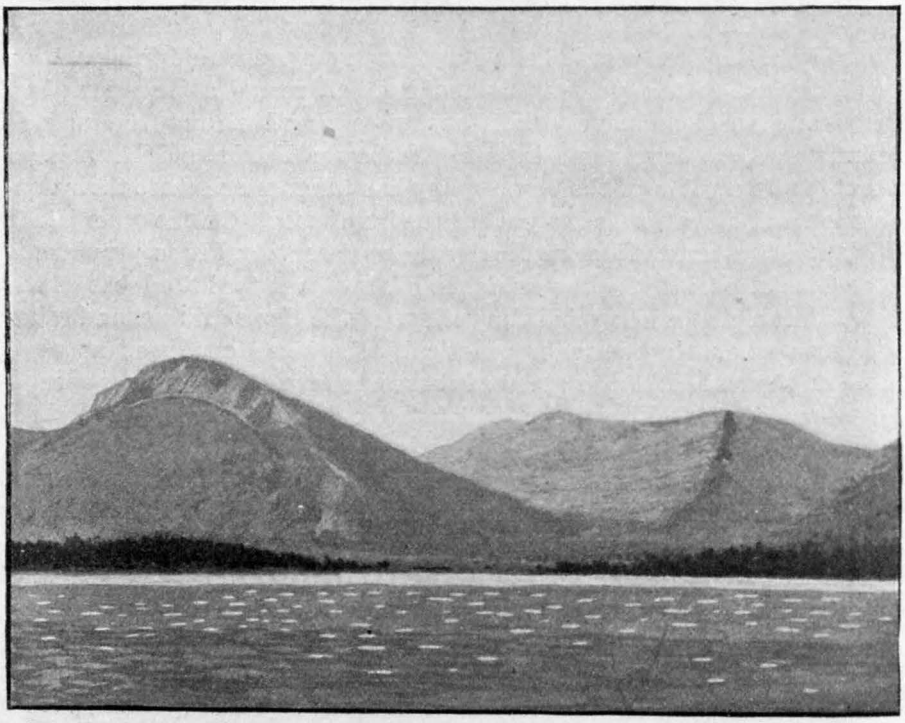
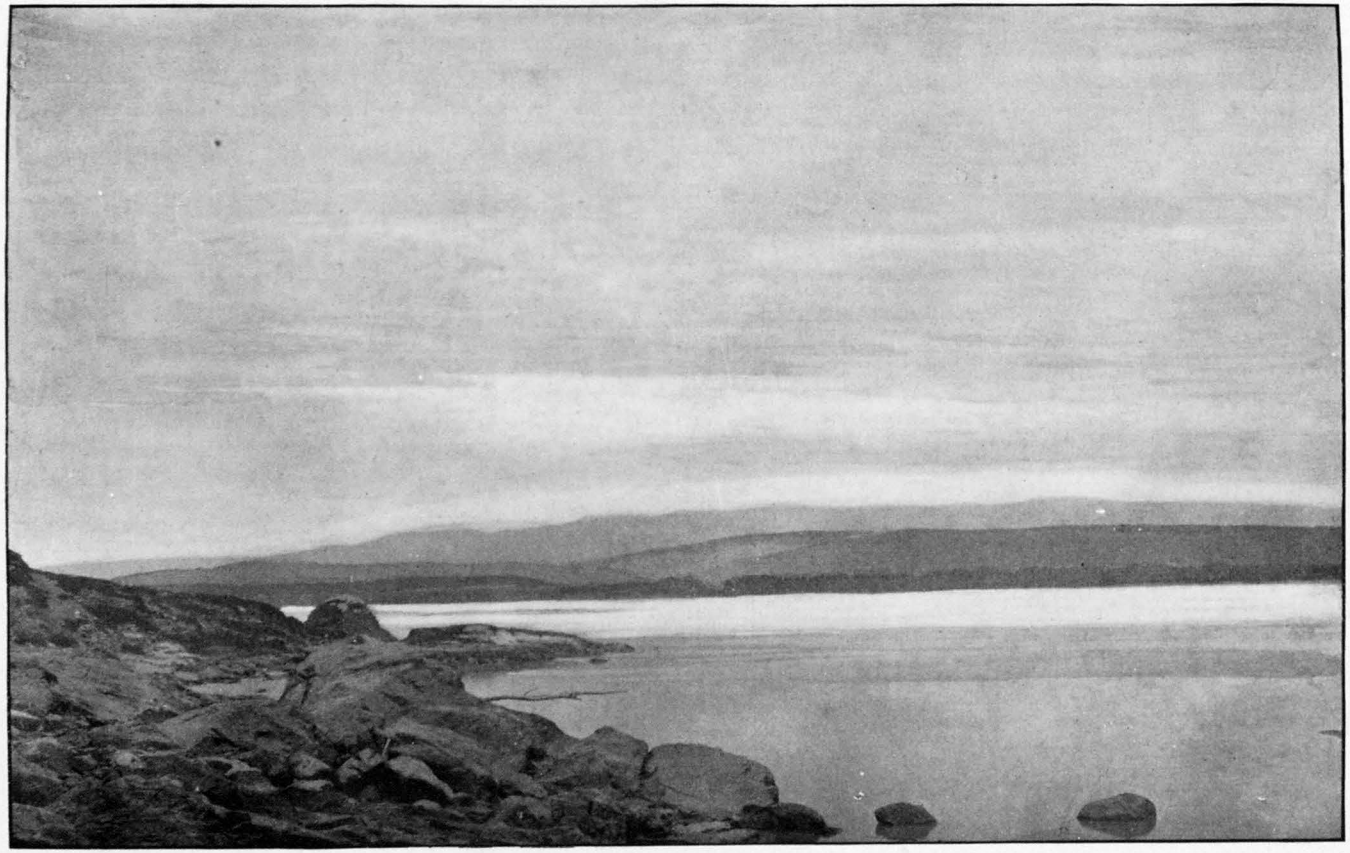


FIG. 19.—Anticlinal hill and synclinal valley on Yukon River near mouth of Tahkandit River.

into an anticline and syncline. The anticline forms a hill and the syncline a valley, the limits of these topographic features corresponding closely to those of the folds. Mr. R. G. McConnell[1] notes a similar occurrence on the Porcupine, below Driftwood River. Here there was observed a sudden anticline which showed hard quartzites and sandstones overlying compact, bluish, sometimes shaly, limestone. This anticlinal swell projects above the surface as a hill, and the curve of the strata is still unbroken by denudation, although the fractured condition of the beds shows that they were bent near the surface and not under any great pressure.

[1] Ann Rept. Geol. Nat. Hist. Survey Canada, Vol. IV, 1888-89, p. 126D.



TERRACES ALONG THE YUKON IN THE VICINITY OF THE RAY RIVER.

It is evident that folds like these must have taken place in comparatively recent time, and long after the existence of the Mammoth Mountains, which have been so deeply carved into peaks by erosion. The fact that the folds described along the Yukon are situated at the foot of the Mammoth range suggests that they may be due to the weight of these mountains, which has crumpled the lower beds where they have been stripped by the erosion of the river, and so are capable of being easily bent; and a similar explanation may perhaps hold good for other occurrences. The vast alterations in the attitude of strata of so great thickness and weight and the inequalities of balance produced by the profound erosion of Tertiary time can not fail to bring about in places minor movements which tend to restore, however slightly, the equilibrium.

PLEISTOCENE MOVEMENTS.

SUBMERGENCE.

At various points in Alaska terraces or rock-cut benches are found up to great heights and in such positions that they can be explained only by the supposition that they are marine shore-lines. These are often obscured by erosion, and yet are generally so well marked that it is clear they were formed at no very ancient period.

Terraces in the vicinity of the Lower Yukon.—In the Lower Ramparts below Fort Hamlin, the hills on both sides of the river are distinctly terraced. Besides minor benches, there is a broad, well-marked terrace about 150 feet above the river, while at 400 to 600 feet is a level-topped plateau (see Pl. XXXVI, p. 202). The top of this plateau is covered with rolled gravels derived from various sources, often indicating by their nature considerable transportation. The slopes are somewhat furrowed by gullies, but erosion is evidently very recent, and the gullies have worn back but little. These terraces are seen not only in narrow valleys, but where the river flows, as it does at times, in a more open country; and in these cases the relations of the terraces to the river are such that it seems improbable that they were due to stream erosion. Even above the clearly cut benches the country has a generally level and terraced appearance up to the sky line. Pl. XL is a photograph taken along the Yukon in the vicinity of the Ray River, and shows the terracing rather indistinctly.

After passing the mouth of the Tanana a more complete view of the Rampart Mountains is obtained, and it is seen that only the highest parts of the range have bold, sharp outlines, the greater part being distinctly, though often rudely, terraced up to a great height.

As seen from the delta of the Yukon, the line of probably basaltic hills, which is continuous from the river across to St. Michael Island, seems to form in general a low plateau with well-marked terraces or benches. Above this plateau rise irregular hills, which may be

volcanic vents. Prof. I. C. Russell[1] also calls attention to "certain obscure indications of terraces or sea cliffs at an elevation of 1,500 or 2,000 feet on a number of the mountains near the Yukon below Nulato." It is not certain whether the scarps noted by Professor Russell are the same as those above described.

Terraces on islands in the sea.—During a stay of a few days at the harbor of Iliuliuk, in the island of Unalaska, the mountains rising precipitously above the post were ascended. These mountains are composed almost entirely of igneous rocks, sometimes massive, but generally porphyritic, which belong chiefly to the diorite-andesite family. All these rocks are altered and have not the appearance of very recent origin. We must pass over further description of the rock geology, and confine ourselves to the topography, which has direct bearing on the question under discussion.

The island at this point has a very irregular coast line, being invaded by sharp, narrow fiords. In the interior the topography is rough and varied to a remarkable degree, the peaks being so sharp and the drainage system so imperfectly developed that the scenery possesses a peculiar wildness which is rarely seen even in mountainous districts. The trip from the harbor was made southward along the shore of Captains Bay past the foot of the mountain set down on the Coast Survey Chart 9007 as Pyramid Mountain Peak. Thence, turning to the left, we ascended the mountains and attained the ridge continuous with but to the east of Pyramid Mountain Peak. To the south of this ridge and to the north are rude gaps in the hills in which streams flow to the ocean. To the south was the gap in which we had ascended, while that to the north collects the waters which finally flow into the ocean at the post of Iliuliuk.

From this elevated position and during the ascent of one gap in the hills and the descent of the other, certain features of topography which were not easily visible from the shore were strongly brought out. It was then seen that the entire island up to an estimated height of 1,500 feet above the sea is distinctly terraced. These terraces appear to be nearly horizontal, and conform to all the irregularities of the topography, being, indeed, as well marked in the rude valleys as on the projecting ridges. They can be discerned nearly everywhere, but are best seen along the side of the valley which leads into the fiord at Iliuliuk. Here half a dozen or so strongly marked benches are cut deep into the bed rock, and many well-marked minor ones. As the average grade of the valley is very steep, the horizontal benches run into the valley bottom in rapid succession. Therefore it happens that the streams examined flow one after another over these benches; and on the top of each the stream wanders in elaborate meanders, diverging and splitting as in a delta, and then, at the end of each flat, it tumbles over an abrupt rock cliff, often 100, 200, or even 300 feet high. So

[1] Bull. Geol. Soc. America, Vol. I, p. 139.

steep are these cliffs that it is often difficult to climb over them, and the stream forms a waterfall or rapid succession of waterfalls to the bottom, when it again begins to meander through a swampy flat. Sometimes the stream has worn back a slight canyon in the face of the cliff, so that the fall is not so abrupt, but in other cases the amount of wearing-back is very slight, and there is an almost continuous waterfall from one bench to another. The island is extremely well watered, the snow on the mountains lasting throughout the year, and the rainfall being abundant. The hills are covered to a height of about 2,000 feet with thick moss, which holds moisture like a sponge and continuously feeds the innumerable rills which start everywhere from the mountain tops. All these little rills likewise descend from one terrace to another, so that falls are very numerous, while on the flat surfaces the waters form intricate meanders, marshes, or pretty ponds.

These rock benches can be nothing but sea cliffs, and the small amount of erosion which the streams have accomplished show a comparatively recent elevation of 1,500 feet or so. The elevation must have been intermittent, since the sea remained long enough at each level to carve a cliff, and then receded so rapidly that it accomplished little erosion. The deeply cut benches are about half a dozen in number, showing the same number of successive uplifts, which averaged 200 or 300 feet each.

In this connection it may be noted that on the right side of Captains Bay a waterfall is seen descending the perpendicular face of the cliff into the sea, and this fall is said to be 120 feet high. On the shore near the village of Iliuliuk many shells were found in nooks of the rock at elevations which would seem to be several feet above the reach of the highest waves. These were quite fresh and unbroken and occurred in large quantities, as if the animals lived in the places where the shells were found. These and other evidences, which will be mentioned later, point to the conclusion that the island is even now being uplifted.

The terraced form of the mountains surrounding Captains Bay, which has just been described, is clearly shown by hachure lines on Coast Survey Chart No. 9007 of Unalaska Bay. On the small island of Amaknak, which lies in Unalaska Bay near the post of Iliuliuk, Professor Russell[1] notes that the lower slopes have a rounded and flowing outline, which is limited in the upper portion of the mountain by an irregular scarp, above which the mountain slopes are steeper and more angular. Professor Russell suggests that the scarp may be the upper limit of former glaciation, or that it may be an ancient sea cliff.

At the island of Unga no opportunity was had for climbing the mountains, but from the shore the island seemed to show rude terraces up to a considerable height, probably at least 1,000 feet above the

[1] Op. cit., p. 139.

sea, and there is also excellent evidence of very recent elevation, which will be given later.

Unalaska and Unga were the only two islands of mountainous character which were very closely approached, yet the mountainous shore between these two islands seemed to show nearly everywhere the same topographic peculiarities.

The phenomena which have been described from the islands of Bering Sea are only those which show a very great submergence in comparatively recent time. At all these localities, and at a number of others, there is abundant evidence of elevation in extremely recent, and probably in present time, and these evidences will be considered later.

Terraces on the Upper Yukon and neighboring regions of British Columbia.—It has already been noted that the deep, well-marked valley of the Upper Yukon is distinctly terraced up to a very great height. Professor Russell[1] determined a terrace near the international boundary on the Yukon to be 734 feet above the river. Mr. R. G. McConnell[2] notes that on the Yukon a short distance below the mouth of the Pelly rolled gravels, evidently derived from broken-down terraces, were found in some abundance up to a height of 800 feet. All along the Yukon Valley terraces are abundant, the lower ones being of gravel, while those at a very high elevation are less perfect in form and have the appearance of being rock cut. On Lake Lindeman, as already noted, is a well-marked gravel terrace at a height of about 50 feet above the present water level, while above this gravel terrace is a broad, well-marked bench which appears to be cut in the solid rock.

Dr. G. M. Dawson[3] has noted well-marked terraces at many points in the drainage of the Upper Yukon and in the neighboring region of British Columbia. He finds that the highest have an average elevation of about 5,290 feet, while they have been found between 5,000 and 4,000 feet in a number of widely separated localities, though the principal development is below 3,800 or 3,500 feet. He remarks:

> Below a height of about 3,000 feet the whole Interior Plateau region may be described as terraced, and although along the various river valleys many terraces occur which have evidently been produced by the streams themselves while cutting down through the drift deposits which at an earlier stage had filled these valleys, these need not be considered here, the point to which it is wished to draw attention being the existence of terraces requiring for their explanation a general flooding of the country. Such terraces are found to be not confined to the immediate valleys of the rivers, but to occur in different situations along the higher slopes, and to fringe at similar elevations the various irregularities of the plateaus.

Terraces on the Porcupine.—Mr. R. G. McConnell[4] has noted on the mountains between the Mackenzie and the Porcupine drainage,

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[1] Op. cit., p. 144.
[2] Ann. Rept. Geol. Nat. Hist. Survey Canada, Vol. IV, 1888-89, p. 28D.
[3] Trans. Royal Soc. Canada, Vol. VIII, sec. 4, pp. 36-41.
[4] Ann. Rept. Geol. Nat. Hist. Survey Canada, Vol. IV, 1888-89, p. 27D.

terraces at an elevation of 1,500 feet and more above the sea, while along the upper part of the Porcupine Ramparts coarse gravels were noted in various points up to elevations of 400 or 500 feet above the surface of the river.

Submergence indicated by terraces.—These phenomena can be explained only by the supposition that in comparatively recent times the sea stood at a much greater elevation than at present. Over the greater part of eastern Alaska and adjacent parts of British Columbia the difference in elevation between the ancient shore-line and the present was probably at least 3,000 feet, while the terraces on the Lower Yukon and of the islands in the sea, such as Unalaska, show an elevation of 1,500 or 2,000 feet at least. Since the deep valleys of the region had all been excavated previous to the depression, these valleys must have been converted into fiords, and so benches of marine origin would naturally have been formed on their sides. It is probable, therefore, that many of the high terraces of the Yukon Valley and other deep-river valleys may be due to marine action, and that the gravels which encumber them may at times have the same origin. In support of this it is to be noted that these gravels occur not only on the terraces along the river valley, but, so far as yet meagerly noted, at many other points over the whole country. They are found in the bottom of the ancient valleys which existed before the Neocene uplift, and also on the divides between these valleys. In the Lower Ramparts of the Yukon they cover a broad, level plateau 600 or 700 feet above the river, and on the Upper Yukon they have been noted as much as 800 feet above the river. Dr. G. M. Dawson[1] notes that the summit of an isolated mountain on the watershed between the Liard and the Yukon river systems, at a height of 4,300 feet above the sea, was found to be strewn with rolled stones of diverse origin, such as to show that water must have stood at one time about 1,000 feet above this part of the Pacific-Arctic watershed.

Period of depression.—Although often mutilated by recent erosion, the high terraces which have been described conform in general with the present topography, following all the great irregularities, such as the mountains and the larger valleys. The deep valleys, as before noted, were probably eroded chiefly in Pliocene time, since they cut strata which have been referred to the Miocene, while they are older than the period at which the cordilleran glacier existed. The subsidence of the land, therefore, which enabled the sea to carve terraces on the faces of these valleys, must have taken place in late Pliocene or early Pleistocene time. This is in accordance with the conclusions of Dr. G. M. Dawson,[2] which were derived from a study of the glacial phenomena in the drainage basin of the Upper Yukon and in the adjacent parts of British Columbia. Dr. Dawson supposes that cer-

[1] Trans. Royal Soc. Canada, Vol. VIII, sec. 4, p. 38.
[2] Op. cit., p. 42.

tain glacial deposits which show evidence of water action, and which now occur throughout the glaciated region at somewhat uniform levels between 2,500 and 3,000 feet above the sea, were deposited in the sea which at that time washed the retreating front of the glacier.

Absence of glaciation and rock decay.—Throughout nearly the whole of Alaska there are no signs of regional glaciation. The northern limit of the country over which the cordilleran glacier moved is clearly defined, and has been recognized by every geologist who has traveled through this country. The line marking this limit may be drawn from the Lewes, at a point below the Big Salmon River, to the White River, in the vicinity of the Donjek, and from here to the divide between the Copper and the Tanana rivers (see Pl. XXXVII). In this unglaciated region, however, there is very little residual clay, the rocks being comparatively fresh and hard wherever exposed.

Both the absence of glaciation and of decayed rock seems to result necessarily from the conditions of submergence, which have been deduced as probably existing at a comparatively recent time, contemporaneous in a general way with the maximum glaciation. The fact of submergence explains the absence of ice action, and the same erosive agencies which have carved terraces or marine shore-lines must necessarily have swept away accumulations of decayed rock. The process of rock decay is very slow as compared with the processes of disintegration and erosion in favorable places; and the amount of such decay which has taken place in the rocks all over the glaciated portion of North America since the retreat of the ice is very slight. Professor Russell[1] explains the absence of decayed rock in Alaska as a result of climatic conditions. But in view of the considerations stated, it seems that the conditions in Alaska will not furnish any evidence on the question of rock decay as a climatic function, since the thickness of rotten rock swept away by marine action may have been considerable.

RECENT ELEVATION.

That the land could not have remained long submerged to the extent just described is shown by the comparative paucity of the records which this submergence has left. Certainly the depression was not long enough to permit the accumulation of sediments of any great thickness along the shores of the sea, for the only deposits that can be referred to marine action at this epoch are the rolled gravels, which occur everywhere and at great heights. The land, therefore, after having been rather rapidly depressed, was again as rapidly elevated to the position in which it is to-day.

The extent of the recent elevation is determined by the same measurements as those which have been used to show the previous depression, namely, the heights of the marine terraces above the present sea level. In one case the scarps carved at equal levels on a land

[1] Notes on the surface geology of Alaska: Bull. Geol. Soc. America, Vol. I, p. 134.

surface, composed of varied hills, mountains, and valleys, show that after the formation of this land surface, due to a long period of erosion, the region was sunk beneath the sea; while in the other instance the height at which these terraces now stand above the present sea level testifies to the extent of the subsequent elevation. Indeed, in the latter case the criterion used is fairly accurate, but in the former not necessarily so, since we can not safely assume that the elevation of the land previous to the depression was the same as it is to-day, and therefore the present height of the marine terraces above the sea is of itself no very accurate criterion of the amount of depression. As a means of more closely ascertaining the extent of this depression, the deep river valleys, which were eroded in the immediately preceding period, may be taken into account, since they may serve to determine approximately the position of the ancient shore line.

EVIDENCES OF RECENT ELEVATION IN THE INTERIOR.

Besides the terraces, in the interior of Alaska there are to be found other evidences of comparatively recent elevation in the deposits in river valleys such as that of the Yukon. On this river and its tributaries are thick deposits of silt, which were evidently laid down in quiet waters. These silts have already been described from many places, and the area of their greatest extent is probably the Yukon Flats, where they cover an area of about 15,000 square miles. All these silt deposits have been cut through by the present rivers, which have almost always a rapid current, unfavorable to the deposition of fine material. Above Lake Lebarge, on the Yukon, the silt bluffs are as much as 150 feet high, and at the Palisades, on the Lower Yukon, are about the same height, while at Mynook Creek they are 300 feet or more above the river. At these two last-named localities there are found in the silts numerous fresh-water shells, all belonging to living species. Along portions of the rivers, where the silts do not occur, there are, up to considerable heights, almost continuous gravel terraces through which the streams have cut. It seems probable that the gravels are derived from detritus with which the deep valleys were partially filled at the time of the submergence; while the peculiarities of the broad, deep silt deposits indicate that they were formed in numerous large, shallow lakes subsequent to the emergence of the land from the sea, but before it had attained its present elevation. These lakes were drained in consequence of further uplifting, accompanied by slight tilting, which accelerated the drainage, so that lakes and sluggish streams became transformed into rapid rivers. The record of this sudden change is found, among other places, in the thin layer of river gravels which lie on top of the high silt bluffs on the Lewes and other streams. These gravels, contrasted with the underlying silts, show a sudden increase in the velocity of the water, while the thinness of the gravels shows that the stream, in consequence of

its increased velocity, rapidly cut down until it reached its present channel. On the revival of the activity of these streams most of the lakes were drained, and the deposits which had accumulated in them are now cut through by the rivers, forming bluffs which vary in height according to the extent to which these sediments had choked up the channels of previous drainage. At the same time the gravels which had accumulated at various points in the old valleys were cut through, forming the lowest of the present gravel terraces. The rapidity of the present streams and their muddiness shows they are still engaged in active cutting.

EVIDENCES OF RECENT ELEVATION ALONG THE COAST.

St. Michael.—St. Michael Island rises ordinarily from 20 to 50 feet above the sea, except in four or five places where there appear eminences, which on examination are found to be ancient volcanic craters. The material of these eminences is olivine-basalt, and small flows of the same material are exposed in places along the shore, but the main part of the island is composed of waterlaid volcanic ash, resting in places upon a bed of clay containing ill-assorted pebbles of various sizes, which strongly suggests ice action. In the waterlaid ash are bowlders of rocks foreign to the island, which are large and subangular in shape and lie in such a manner as to indicate that they have been dropped from some ice cake. In the ash are found sticks and bones which appear quite fresh.

A short distance from the post at St. Michael is a small islet known as Whale Island, which is separated from St. Michael by a shallow strait much obstructed by large rock fragments, as may be seen on Coast Survey chart No. 9375 and in Pl. XLI. Through this strait the tidal currents are noticeably strong and continually undercut the bluffs. On the St. Michael side of the strait that part of the bluff which reaches out toward Whale Island and seems to be a direct continuation of the reef which lies between the islands, is composed of blocks of pumice, solid lava, conglomerate, shale, and sandstone, embedded in a matrix consisting chiefly of volcanic ash. Although the bowlders are very large and subangular, yet the finer material shows a rough stratiform arrangement, as if laid down in water. Taking into consideration the variety of material, which indicates considerable transportation and shows that the formation can not be a cliff talus, it seems probable that this deposit must be the result of ice action, since it has all the characters of a typical moraine. The sandstone and shale bowlders, however, and usually the pumice-like lava, are so softened and decomposed that the moraine could not have been formed within the last few years, and, as already stated, there are indications of its having been formed under water. This deposit is only found on the point of the island next to the strait; a short distance from the strait it is found to lie laterally against solid lava

STRAIT BETWEEN ST. MICHAEL ISLAND AND WHALE ISLAND.

beds with layers of waterlaid volcanic ash containing very little material to which a glacial origin can be ascribed. This localization points to the existence of a marine current similar to that of to-day at a time when the island was below the present level, and this current must at times have carried ice in large amount, which, grinding along the shores, produced the moraine which has been described. (See Pl. XLII, p. 274.)

The topography of the island is, as a rule, very slightly differentiated, and shows all the marks of ocean currents—broad channels with the low banks which cross narrow parts of the island, and which were once evidently straits; basins made by some eddy in the marine currents, and other marks of a shallow sea bottom. Along the shores of the island, moreover, are raised beaches at various heights above the water, and on the most recent of these there is evidence that an elevation is now going on, since lines of gravels have been thrown up which are apparently beyond the reach of the highest waves. According to a trader at St. Michael, the old men among the native Eskimo say that the island is now rising and is higher than when they were young, and it is well known among the natives that piles of driftwood may be found at points where there is now no water, the sea having receded for considerable distances over nearly level flats.

Unalaska.—The higher terraces on the island of Unalaska have already been described, and the lowest ones, which are now close to the sea and are so recent as to be perfect, will now be noted.

Above the beach at the port of Iliuliuk there is a well-marked scarp which was evidently recently a beach line, and yet below the foot of this scarp for a number of feet the level surface is heavily covered with grass and appears never to be reached by the highest waters. Above this scarp comes another level, grass-covered surface, which stretches back to a third scarp, which, however, is less regular in outline. Above this still other terraces may be distinctly seen on the hillsides up to a great height, though often obscured by recent erosion. The lowest terrace, however, which has been mentioned as being close to the beach, conforms very nearly in outline to the present beach, except that it is the arc of a smaller circle. On the broad flat top of the first perfect terrace all the houses of the port of Iliuliuk are built. (See Pl. XLIII, p. 276.)

Unga.—On Unga Island, especially around Squaw Harbor, the recent terraces are very strongly marked, the lowest, which is only about 6 feet above the present limit of high waters, following all the curves of the present shore line. The highest terraces are not so continuous, but are well marked at intervals.

Other localities.—The following evidences of recent elevation of land in Bering Sea have been noted by Dr. G. M. Dawson:[1] On St.

[1] Geological notes on some of the coasts and islands of Bering Sea and vicinity: Bull. Geol. Soc. America, Vol. V.

Paul Island[1] bones of walrus and whale are found in considerable abundance embedded in sandy deposits about 10 feet above the highest level of modern storm wash. On St. Lawrence Island,[1] at about 200 feet above the sea, is a level plateau, which may be an ancient plane of marine denudation, and which has a fairly distinct terrace at an elevation of about 50 feet above the sea. At the island of Attu, the westernmost in the Aleutian chain, are also evidences of recent elevation. Dr. Dawson[2] says:

> About Chichagof Harbor there are some well-marked old sea cliffs rising behind gravelly flats 20 or 30 feet in height, and such as to indicate an elevation of the land by that amount since their formation. On the slopes of the ridge on the west side of the harbor several faintly impressed horizontal lines also appear, the highest being about 300 feet above the sea. They seem to represent incipient terraces, and if so, must indicate a somewhat rapid elevation of the land, such as to prevent any long-continued marine action at any particular level.

At Cape Vancouver[3] a fairly distinct terrace was observed at a height of 80 to 100 feet above the sea. On the Asiatic side of the sea, on the peninsula of Kamchatka,[4] a plane of marine denudation was noted at about 700 to 800 feet above the sea. There is also evidence of more recent elevation in that the valleys which have been cut down through this upper plateau terminate at about 50 or 100 feet above the present sea level.

Dr. W. H. Dall[5] notes that at Point Barrow a shaft sunk to a depth of 37½ feet passed through successive layers of mud, sand, and fine gravel, with fragments of driftwood and marine shells. The formation was clearly a beach alluvium, and so recent that a pair of Eskimo wooden snow goggles with a sinew string still attached to them was found at a depth of 27½ feet.

CONCLUSIONS AS TO RECENT ELEVATION.

The instances cited show that most of Alaska is at present rising, and that this elevation has gone on for a long time. Indeed the transition of the very recent sand beaches and low sea cliffs to successively higher and higher ones, which become more and more defaced by erosion, indicates that the present movement is only a continuation of the uplift, that in comparatively recent times has amounted to several thousand feet.

Comparing the amount of this uplift with the amount of previous depression, we may note that deep valleys which were eroded subsequent to the Neocene uplift now exist as fiords on the shores of the Gulf of Alaska, while the shores of Bering Sea, on the contrary, are low and flat and the water is very shallow, the deep valleys which are

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[1] Geological notes on some of the coasts and islands of Bering Sea and vicinity: Bull. Geol. Soc. America, Vol. V, p. 139.

[2] Op. cit., p. 123.

[3] Op. cit., p. 135.

[4] Op. cit., p. 128.

[5] Bull. No. 84, U. S. Geol. Survey, p. 264.

FACE OF MORAINAL KNOB ADJOINING STRAIT SHOWN IN PL. XLI.

found in the interior usually not reaching to the sea. It may be inferred from this that the shores of Bering Sea are now more elevated than they were during the post-Miocene period of erosion, and that the shores of the Gulf of Alaska are more depressed. The difference in the character of the coast line is very marked, as shown on the Coast Survey Chart of Alaska; even between the northwest and southeast sides of Alaska Peninsula there is a great difference. This is susceptible of explanation, by supposing irregularities in the post-Miocene elevation or in the more recent uplift. That the recent elevation, at least, has been somewhat irregular is shown by physiographic evidence. In certain parts of the Territory, northeast and southwest rivers like the Lower Yukon cut always their northwest banks, while in the same regions streams like the Yukon between Circle City and the Porcupine, and Birch and Beaver creeks, which flow through level flats of silt and gravel and are therefore uninfluenced in their choice of direction by rock structure, flow straight and parallel to one another across the Yukon Flats in a northwesterly direction.

These peculiarities of drainage point to a general northwesterly tilt in this region. It is also possible, considering the evidences of recent elevation on the shores of Bering Sea, that the extreme northwestern part of Alaska has been uplifted slightly more than the southeastern part, so that the surface here has a slight tilt southeastward. Indeed, it is probable that there may be a series of broad, gentle warpings over the whole region. The axes of these warpings may be taken as approximately parallel to the Alaska Peninsula, whose two sides show such difference in the general character of the coast line. Some such warpings as these may account for the course of the Lower Yukon. Below its great bend the Yukon appears to flow in no well-marked, deep-cut valley, but rather through an irregular country, where it straggles through flats or plunges through narrow gorges of no great height. This character is in strong contrast with the Upper Yukon above the Flats, where the valley is very deep, well marked, and persistent. Along the Lower Yukon, moreover, the location of the valleys, with respect to the present drainage, suggests that the river system may have been materially altered in comparatively recent time. This was especially noted in the lower Ramparts. It may be, therefore, that the Yukon originally flowed straight northwest into the Arctic Ocean, and that, in consequence of a general southeast tilt of the region northwest of its present lower course, it abandoned its ancient channel and found a way southwest to the sea along the axis of tilting through the smaller valleys of its own tributaries and those of other streams.

RECENT WARPINGS AS SHOWN BY DRAINAGE PECULIARITIES.

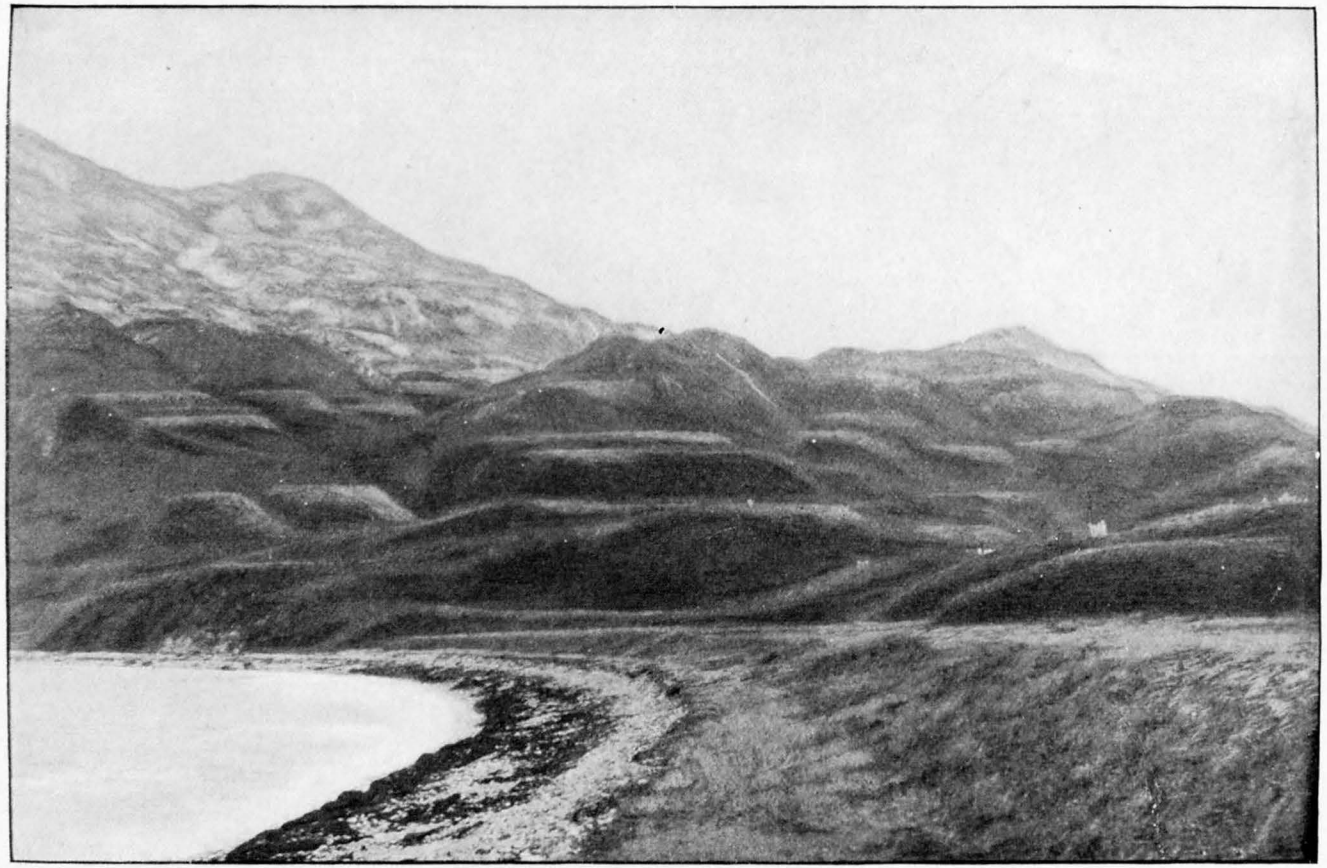
By Harold B. Goodrich.

ALASKAN DRAINAGE AS ILLUSTRATED BY FORTYMILE CREEK.

General aspect of country.—Above Fortymile Creek the valley of the Yukon is generally narrow, and confined between steep, often perpendicular, walls. These resemble the artificial walls of a fortress, and the early explorers called them "Ramparts," a term which has come into general use, so that we have the Upper and Lower Ramparts of the Yukon, and also the Ramparts of the Porcupine. At an elevation of 500 feet the steep slopes merge into a tableland, above which again rise mountains to a height of 2,500 to 3,000 feet above the river. This is the general characteristic topography of the gold region of interior Alaska, a mountain upland and a lower plateau, into which the smaller as well as the larger streams have cut sharp valleys.

Activity of Fortymile Creek.—On Fortymile Creek the observations were fuller than on any other stream, and since its drainage basin shows certain peculiarties particularly well, it may be taken as an example of Alaskan drainage. At the mouth of Fortymile Creek a flood-plain 2 to 3 miles wide has been formed by the combined erosion and deposition of this river and the Yukon. In this plain, about 3 miles southwest of Fortymile post, stands an isolated remnant of the upland in the shape of a prominent cone, arising 500 feet above the general level, from which Lieutenant Schwatka, in 1883, called the stream flowing along its base the Cone Hill River. Above Cone Hill the valley of Fortymile becomes a canyon, often with perpendicular cliffs, though the general angle of slope is perhaps 50°. The branches of the main stream flow in V-shaped gorges, with a moderately high gradient, and find outlet through gate-like barriers formed by ridges parallel to the strike of the rocks. When these branches flow at right angles to the strike their channels are narrow, their gradients steep, and their tributary rivulets flow parallel to the strike. When the general trend of the stream is diagonally across the strike of the schist, the water alternately flows parallel with the strike and cuts across it at right angles. Symmetrical ridges are formed at the points of confluence of the main creek and its tributaries by the intersection of the slopes of the V-shaped valleys (see fig. 20). The fall is considerable—on the main creek nearly 40 feet to the mile. The current is therefore strong—from 8 to 10 miles per hour—and this, together with the shape of the valleys and their ruggedness, is evidence that the drainage is in its youth and that the bed is now being deepened.

The ancient valley.—There is, however, an abnormality in the otherwise youthful-appearing Fortymile Creek, for, considering the swift-



BEACH AT ILIULIUK, UNALASKA ISLAND, SHOWING MARINE TERRACES.

ness of its current and the narrowness of its channel, we should expect its canyon course to be straight; on the contrary, it meanders and forms oxbows like a stream flowing through an open valley, the apparent reason being that the present valley follows a line of drainage previously determined; that, in other words, the meandering habit is inherited from a time when the stream flowed with less grade. The oxbows, which are generally confined between canyon walls, although erosion in some cases has almost destroyed the canyon type, are locally called "kinks." Bottom lands occur on Fortymile at various points, but these are slightly exaggerated on the map (Pls. XLVI, XLVII, p. 318), for at only one place do they exceed half a mile in

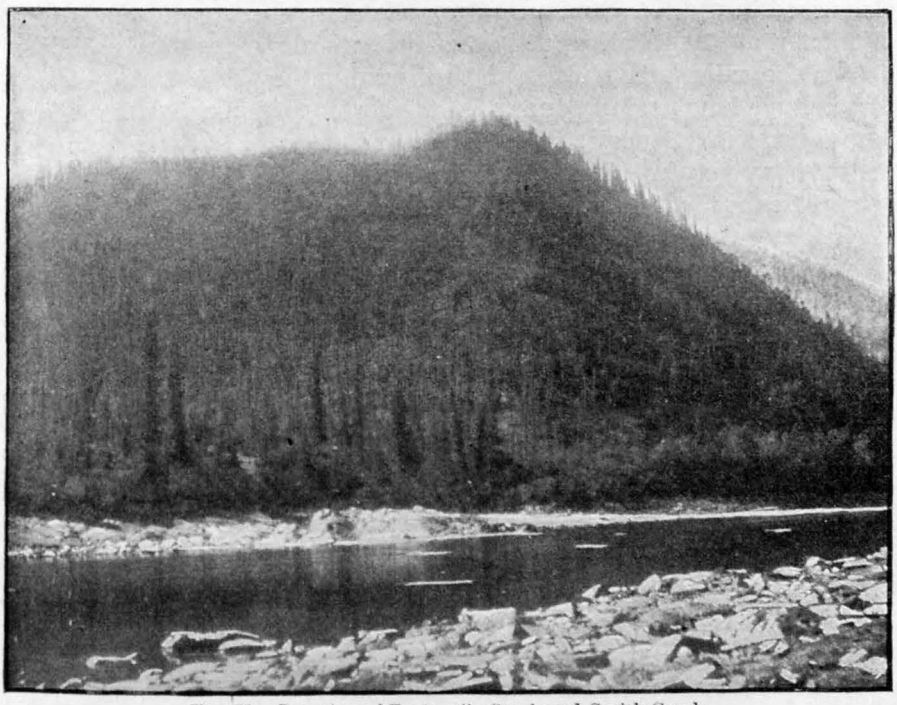


FIG. 20.—Junction of Fortymile Creek and Smith Creek.

width. They do not form a continuous flood-plain of any extent, such as is found on a stream of low carrying power; but are usually caused by the overlapping of bars on the curves of the creek, or, in some cases, by deposition in quiet ponded areas above natural dams.

The trail to the gold diggings of Fortymile district leaves the main creek at the mouth of Moose Creek, and at a distance of 2 miles climbs Moose Creek Hill by a very abrupt ascent of 650 feet in a little over half a mile to an elevation approximately 1,900 feet above the sea. Here, from the point of the hill, a rather confined view seems to show all the neighboring hills at the same elevation; that is to say, the country appears to have once been baseleveled. Toward the

south the ground rises gently, and at a point 2 miles farther a wider range of vision is obtained. With the smoothing out of the topography which a distant view affords, it is seen that the country at this elevation is not a truly level plateau, but has rather the aspect of a broad, shallow valley, extending to the west as far as the eye can reach. The breadth of this depression is approximately 8 miles, but it narrows and grows shallower toward the head of the present stream, and into it Fortymile and its tributaries have etched canyons, while above the level rise low mountains, whose rounded outlines form a great contrast to the highly accentuated minor topography.

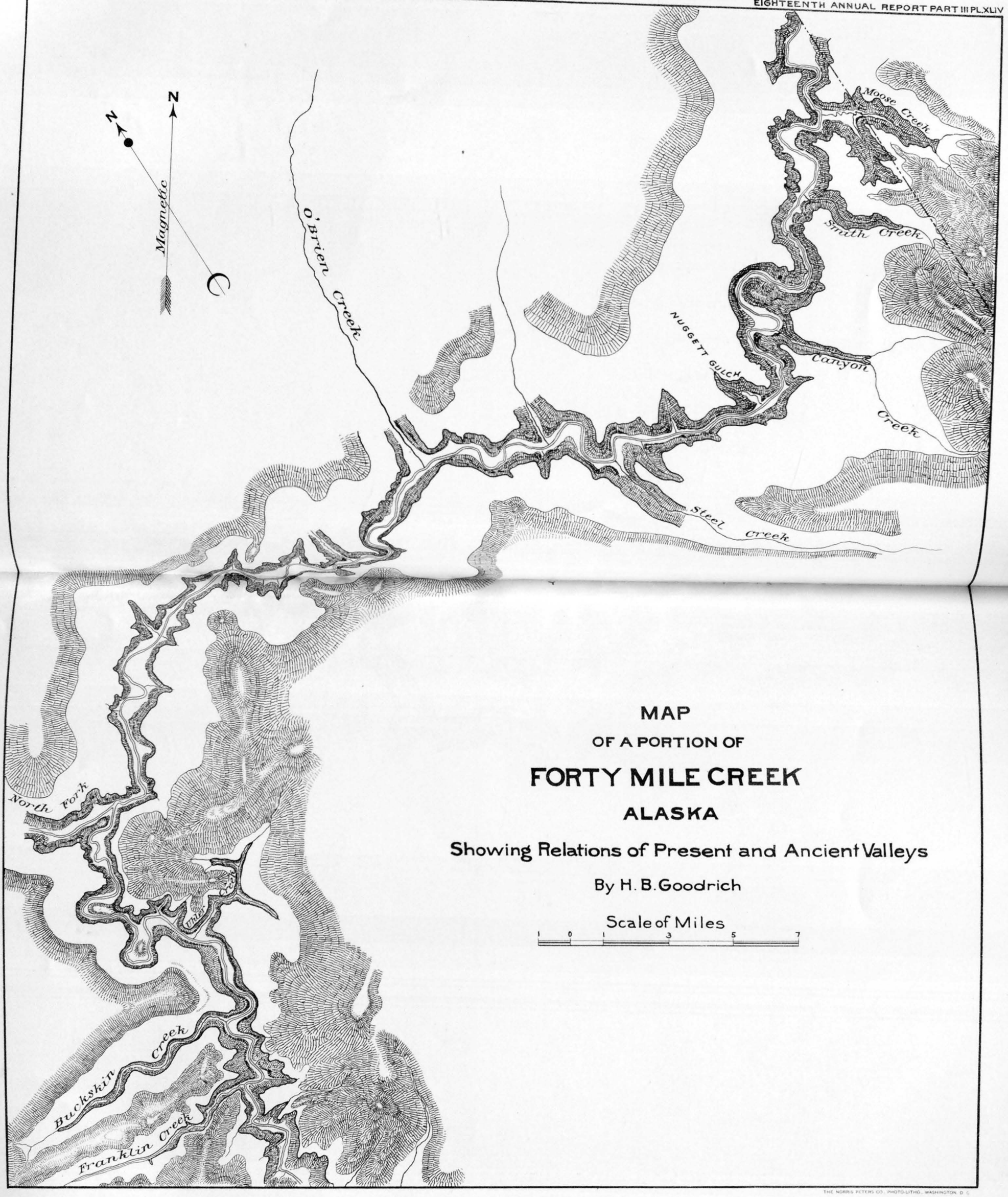
At many other points the older valley was observed, notably from the end of a ridge just above Franklin Gulch. At this point it has decreased in width to 2 miles. From its elevation here, as compared with that at the locality just described, its slope must be nearly 35 feet to the mile. How much of this gradient is that of the original stream and how much is due to later warping it is impossible to say, but at present the grades of the older and younger streams differ; so that the two may be conceived of as planes which approach each other toward the heads of the valleys. The canyon walls, therefore, decrease in height as one ascends the stream, being barely 350 feet high at Franklin Gulch, and disappearing entirely in the vicinity of Chicken Creek, near the head of the South Fork. The accompanying physiographic map (Pl. XLIV) shows the limits of the older and younger valleys, although the line of demarcation must not be regarded as absolutely accurate.

The facts noted upon Fortymile Creek are to be observed on many other streams. The upper plateau is everywhere noticeable, and upon examination it could doubtless be divided into many broad valleys extending back into the mountains with the same ramifications as the present drainage.

The present valley due to uplift.—We have, then, two incomplete cycles, the older represented by the valleys in which the streams pursued meandering courses. Although their channels had not been degraded to base-level, there must still have been some fall, and the topography, while less pronounced than the present, was not yet featureless when elevation took place. The streams acquired new activity by the lowering of their outlets and began the cutting of the present gorges. But the uplift was not revolutionary, as is seen by the fact that the streams now pursue the same general courses which they held previously, the main drainage lines at least not being altered.

RIVERS AS MEASURES OF WARPING.

For reasons already given it is probable that the cutting of these canyon valleys was accomplished mainly in Pliocene time, and that subsequent to the cutting there was a brief submergence, followed by an elevation which is probably still in progress. As a result of this



MAP
OF A PORTION OF
FORTY MILE CREEK
ALASKA

Showing Relations of Present and Ancient Valleys

By H. B. Goodrich

Scale of Miles

1 0 1 3 5 7

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

last elevation the down-cutting of the Pliocene valleys, which was interrupted by the submergence, has been renewed. That these oscillations were everywhere the same in relation to the sea level is improbable, for, in every movement of an epeirogenic nature there are irregularities, the results of which are seen in tilts, warpings, and minor folds; and these differ from ordinary plications in being upon such a broad scale that they are not generally visible to the observer, except by comparison of data extending over considerable areas. Certain criteria can be used for determining the existence, amount, and direction of such disturbances, but obviously these criteria must be different in different parts of the field.

On the coast the relation of the uplifted surface to the present sea level gives an opportunity for direct comparison; in portions of the Territory remote from the ocean no such opportunity is afforded. Here the details must be found by a careful examination of the topography and by a comparison of the previous cycle with that of the present, for the drainage upon a given surface is affected by a tilting or warping of that surface. Therefore the peculiarities of the present drainage give some hints as to the irregularities of the movement now actually in progress.

In those streams which are rapidly deepening their channels the effect will not be so apparent as in those which wander in open valleys near base-level; but even the former may show evidences of tilt in the valley topography. For instance, a competent stream upon a tilted surface will perform greater work upon the lower side of the tilt than upon the upper, and the result will be evident in different ways. Streams flowing in the direction of the tilt are accelerated; those flowing opposite to it are retarded, and the result is the development of an unsymmetrical drainage system. Furthermore, streams which flow at right angles to the tilt will tend to migrate to the lower side of the valley, while those flowing along it persist in their original course, so that the system will be not only unsymmetrical, but the trunk and minor streams will have a rectangular interarrangement. Those branches which flow down the tilt will have an advantage, other conditions being the same, over those flowing against it, so that if unhindered the former will divert the latter in adjacent systems. Cases of recent or imminent stream capture are therefore of great value in tracing irregularities in a recent uplift. The results of irregularities of uplift, then, are to be discovered both in the alignment of drainage and the latest topographic products of erosion.

The Yukon.—The alignment of the Yukon itself is significant. The character of its valley up to the point where it enters the Yukon Flats has been described above. Here it enters the old lake country and, unhindered by banks of any considerable height, shows a tendency, as also does its main tributary, Birch Creek, to swerve to the right and to outlet, as the older maps had it, into the Arctic Ocean.

There may, indeed, have been a very early course in this direction which further exploration along the northern boundary of the Flats might discover, but if such a one existed it must have antedated the interior lake, for the outlet of the lake period was, as now, by way of the Lower Ramparts. This, being the lowest point, determined the direction in which the river flowed after the revival of stream activity and the drainage of the ancient lake. Through the 250 miles of the Yukon Flats the work being done upon the right or northern bank is greatly in excess of that on the southern. As an illustration of this it is said that no boatman has ever floated down the lower Yukon along the left bank, for, trusting to the current, the boat is invariably drawn toward the northern bank. When the valley is inclosed between ramparts the tendency toward the north is not so noticeable, but it has been observed by Dall and others that the right bank is being more vigorously attacked all along the river's course.

Fortymile Creek.—The main features of Fortymile, including the older and more recent valleys, have already been described. For parts of its course the older valley seems to be dependent upon the geological structure, as, for instance, from the North Fork to the mouth, where, in general, the direction coincides with the strike of the rocks. In other portions the valley runs across the rock structure, as between Walker Fork and North Fork. The present stream also, its course being directly inherited from the former, flows in the same basin at a lower level, showing no preference for either side of the valley, but meandering between the mountains, first upon one side, then upon the other.

Several large streams enter from the north, the most important being O'Brien Creek, which divides a few miles above its mouth into two branches, flowing parallel with the main Fortymile, one rising to the west, the other having its source under a high granite peak known as "The Dome," at the east. There is a suggestion in this peculiarity of a diversion of the east and west heads of O'Brien Creek toward the south. There are also examples of probable diversion in other localities, in all of which, however, it must have occurred previous to the latest uplift. From the south side of Fortymile the tributaries are much fewer and smaller than from the other, Canyon and Steel creeks being the largest; the contrast, however, is probably due as much to the small drainage area between the main creek and Walker Fork as to any other cause.

About 50 miles from its mouth, Fortymile divides into two main branches. Of the North Fork little is known, except that it has its source near the headwaters of Birch Creek and flows in a general direction eastward. The South Fork, on the other hand, has been well prospected from the basin-like area at its head to its junction with the North Fork, so that its features are much better understood. Several small tributaries flow into the main creek between Walker

Fork and the North Fork, of which the most important, because they are the only ones upon which placer mining has proceeded beyond the stage of prospecting, are Franklin Gulch and Napoleon Creek. Both of these creeks show asymmetry in their valleys; and in both are steep sides at the south and a more gentle rise toward the north. Franklin Gulch is a strike valley, and the migration of the stream having been down the dip of the rocks, the south side is a strike ridge with overhanging cliffs and ledges—a great contrast to the smooth, easy slopes of the north side. The upper and lower parts of the valleys are widely different. Through the lower part Franklin Gulch has cut a canyon, but nearer the head the valley becomes broader, at an elevation corresponding with that of the old valley upon Fortymile in this vicinity, of which it formed a part. There is in this portion, too, a tendency of the creek to flow on the south side of its valley. In Napoleon Creek and many other tributaries of Fortymile the same tendency was observed, as also upon a few of the creeks of the Sixtymile drainage, of which Miller and Glacier creeks, in British territory, may be quoted as examples. On the latter two there is a very evident asymmetry of the valley, the steepest side being the south. On Davis and Poker creeks, which head in the Bald Hills nearly against Miller and Glacier and unite to form Walker Fork of Fortymile, the tendency, if it exists, is not noticeable.

Mission Creek.—Mission Creek enters the Yukon at a sharp elbow bend of the latter about 50 miles below Fortymile and on the same side of the river. There is a wide stretch of bottom here on the south side of Mission Creek mouth, but above this rise hills the tops of which are at an elevation of 500 feet above the water, apparently indicating by the evenness of their crest line an ancient valley which extends back for several miles into the high mountains. This is part of the same nearly level upland remarked all through the Upper Ramparts, which probably represents the old Yukon Valley.

The Mission Creek system is decidedly unsymmetrical, both in topography and alignment. For the last part of its course Mission Creek flows through a country which rises to the south very gently toward the high hills in the distance, the ground on this side being a swampy, moss-covered, sloping plain, drained by four large creeks, American, Wolf, the head of Mission, and another still farther to the west. On the north, steep cliffs and slopes of over 30° rise from the stream bed to a height of sometimes 800 feet, forming a veritable wall which is broken in the distance traveled only by one small creek and a few gullies. In other words, erosion is, in the main creek, proceeding more rapidly upon the north, so that the stream is crowded toward that side of the valley; and the drainage is rectangular and one-sided. Meanders are frequently seen upon the large tributaries, Wolf and American creeks, as well as upon the main creek. They are, however, more pronounced upon the latter, and yet, through all its wandering, Mission Creek holds its course close to the north bank.

Mynook and Hunter creeks.—The Mynook system of drainage, in the Lower Ramparts region of the Yukon, shows in its alignment the same peculiarities observed in Mission Creek. While the main creek flows west of north, its large branches—Hunter, Little Mynook, and Ruby Creek—enter at right angles to it; that is to say, there is a tendency to flow along two lines, the one east and west, the other north and south. Sometimes, as in the case of Hunter Creek, a branch flows for a part of its course along one of these lines and for another part at right angles to it; and as far as could be learned the adjacent Hess Creek system also has this habit, flowing eastward for the first few miles of its course and then bending squarely to the northwest and flowing for 15 miles in that direction until it meets Troublesome River, another westward flowing stream.

The country through which Mynook Creek flows is a plateau, into which the recent cutting has progressed some 600 or 700 feet vertically. This plateau is formed of rocks which differ in character and have varying, oftentimes very steep dips; it is, therefore, a plain of erosion. The cutting has been sharp, producing rugged valley walls; but at the bottom of the valleys there is a gravel deposit 15 to 20 feet thick. This deposit extends as a bench or terrace the whole length of Hunter Creek as far as traveled, and is seen also on the lower part of Mynook Creek, rising gradually in section up the creek; into it the creek has cut a trench or small gorge sometimes 25 feet deep. The gravel terrace marks an older valley, which, if restored, would be a little over one-quarter of a mile wide. In the latest cutting the stream has not kept to the middle of this valley, but unvaryingly holds its course to the north bank.

A further striking peculiarity is, as upon Mission Creek, the absence of minor drainage from the north. In the whole distance traveled on Hunter Creek the north bank presents an unbroken wall except at one point, where an insignificant watercourse extends back into the hills scarcely 2 miles. This is rather a gully than a creek, and represents the very latest product of erosion. The main creek meanders, and in its swings it frequently cuts for short distances into the gravels of the middle valley; but it is being straightened by frequent cut-offs in the oxbows, and here again is a remarkable fact, for the cut-offs are formed only on the north side of the valley; in no single case are they made at the south. The universality of this throughout the drainage system is indication that there is generally an acceleration in the portion of the curves flowing northward and a corresponding retardation of those flowing toward the south. The course of the creek is evidently being straightened by the cutting off, but with the one-sidedness of the straightening action there follows a migration of the whole creek toward the north. (See fig. 21.)

Birch Creek.—The topography of the region through which Birch Creek flows is diverse. The lower hundred miles is a country of

no relief, flat to the eye—a moss-covered, timbered plain, in which swamps and lakes are of common occurrence. This is known as the Yukon Flats, in which the Yukon and its tributary, Birch Creek, flow parallel in direction and are separated by only a few miles of swamp. Rising to a height of 500 feet above the streams, and forming an escarpment 3 or 4 miles southwest of Circle City, is the same elevated plateau noted in the other districts, a northward spur of which is crossed by the trail to the gold diggings. After a journey of 15 miles from Circle City along the timbered top of the plateau the traveler comes by a sudden descent to Birch Creek.

At this point, where Twelvemile Câche (a road house for miners) has been established, the creek runs through a gap, whose bounding sides, less than 2 miles apart, rise in steep walls 400 feet high. To the south of the gap the valley again spreads out into an apparently

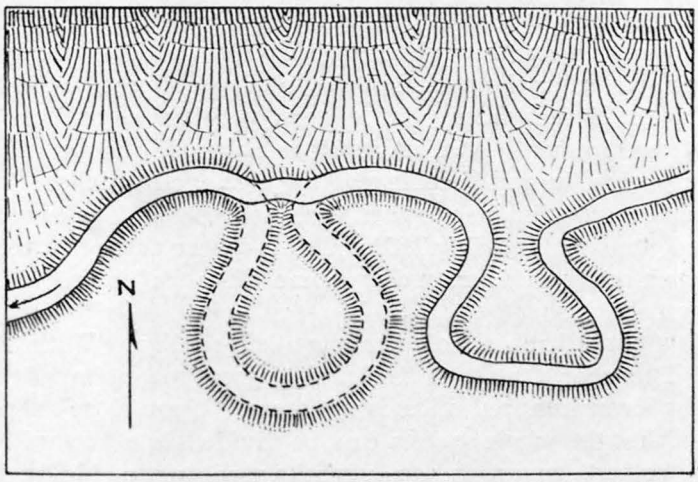


FIG. 21.—North-side cut-off and deserted meander on Hunter Creek.

level stretch over 400 square miles in area. In these Birch Creek flats the creek meanders in the most intricate manner; oxbows are frequent, and there are several examples of former wanderings in the occurrence of crescent-shaped lagoons which at no very ancient date formed parts of the meandering stream course, but have since been cut off and remain as lakelets. These are especially numerous in the vicinity of Twelvemile Câche. There is still another kind of lakes, generally larger than the lagoons, whose outline is more nearly circular and whose large area shows that they can not be accounted for in the same way. Of these Medicine Lake is an example, and it seems either that they have been caused by a very recent damming of their outlets or that they are remnants of larger expanses of water which formerly occupied the area.

Evidence has already been given to show that the Yukon Flats country was at one time occupied by a lake. It seems also, from the

nature of the deposits found in the Birch Creek flats, which are just such as would be laid down in quiet water, that there was here also a lake over 400 square miles in area, and that in these smaller bodies of water we have the last stages of the drainage and laying bare of the bottom. By the draining of the lake vertical corrasion was begun, but the topographic results of this recent erosion differ in different parts of the field and fall naturally into three divisions. In the lower, that represented by the outlet at Twelvemile Câche, vertical corrasion began immediately with the uplift, a gorge was excavated, and the valley became sharp V-shaped. But in the middle portion it was not until a great part of the water in the lake area had been drained away that vertical corrasion began. In fact, it may be said that it is at present only beginning to be an important factor in the erosion. The streams which entered the lake from the upper division had their activity increased almost immediately, and began the higher gorge-cutting that is seen at the mouth of Boulder Creek and above. Here the streams cut through gravel deposits, which were laid down during or soon after the period of the lake's existence, these being in places 20 to 25 feet thick, but generally thinning out toward the heads of the streams. A short distance above, the mountains begin, the valleys close in and become narrow V-shaped gulches; but even here and for some distance toward their source the former valley can be traced, an example being Miller Creek, where there is a terrace, as has been already said, extending some distance before it becomes indistinguishable.

In alignment Birch Creek drainage is peculiar. With its main branch, Preacher Creek, it incloses a great pear-shaped area, of which the lower hundred miles is the stem. Upon close examination it is seen that the whole system can be divided into two well-defined classes, the first comprising such creeks as Bonanza, Miller, Hog'em, Boulder, Mastodon, and the middle part of Birch, all of which, disregarding their minor meanders, flow in a general direction northward and across the strike of the rocks. In the second class are the head of Birch Creek, North Fork of Birch, North and South forks of Harrison, and also the main Eagle Creek; these flow in general east and west, parallel to the strike of the rocks, and at right angles to the former class.

Of these two sets, the streams flowing northward are performing much greater erosive work than the others at right angles to them. The cliffs at their head are being rapidly broken down by the action of frost and ice, and the material thus supplied is easily transported by the streams, so that the divide is being pushed southward. As we should expect also in a migrating divide of this kind where the two streams are unbalanced, there is a very evident tendency to a diversion of the east and west streams into a northward course; for example, Mastodon is on the point of capturing the headwaters of Harrison

Creek; again, further to the east, Hog'em Creek is lowering the divide between itself and the North Fork of Harrison, and will in time, if uninterrupted, succeed in leading off its waters by a nearer route to Crooked Creek.

In the opposition of the two sets there is throughout a rectangular arrangement which is in part inherited, as in Mastodon, Harrison, and other creeks; but it is also evident upon streams which are the latest product of drainage development since the great lakes disappeared. Examples are Crooked Creek, which flows south of east as far as Medicine Lake, whence it turns squarely to the north, and the minor branches, Quartz and Albert creeks, which, rising in the Crazy Mountains, enter Birch Creek at right angles. In these younger streams, owing perhaps to the shallowness of the valleys which they have cut, no selective tendency of the stream channel is observed. However, in other valleys of the Crooked Creek drainage a decided tendency toward the northern bank was seen. In Porcupine Creek valley, for 3 miles from its mouth, the stream remains closely under steep bluffs at the north side, leaving a broadly sloping valley at the south. In the same way, in the last 3 miles of Miller Creek, a terrace of 15 to 25 feet is observed, sloping gradually to the ridge at the southwest, while upon the left bank the slope to the creek is abrupt, with frequent bluffs. On these two creeks and on Mastodon, where the tendency is not so well shown, the asymmetry is caused by a migration of the creek entirely independent of the geologic structure. Many creeks flowing along the strike of the rocks south of the main divide of the Bald Mountains have unsymmetrical valleys also, but the one-sidedness in these has been caused by migration down the dip of the underlying formation, and the steeper side is, except on Eagle Creek, upon the south.

CAUSES OF ASYMMETRY OF STREAMS.

We have, then, through the interior of Alaska, a revived drainage showing certain peculiarities induced in the present cycle which are not confined to one creek or system, but are to be found in each and every one of the systems. These are a certain definite alignment and an unsymmetrical topography, and their extensive occurrence seems to demand for explanation some cause operative alike over great areas. We have already stated one general cause of peculiarities in drainage, and by applying those principles to the specific cases, also by a critical examination of other possible causes, we may decide to what extent differential uplift is responsible, and whether in some cases it may not be entirely subservient to other causes.

Theory of differential insolation.—Mynook and Mission creeks afford perhaps the best examples of unsymmetrical valleys, with their steep northern walls, as described above. Here by the alternation of freezing and melting temperatures, the rocks are broken down and the

material is furnished to the stream for transportation. If there is any great difference between the amount of heat received by either bank, the one so favored will be broken down more rapidly. Then, if the stream is already overloaded, the greater supply from the highly insolated bank will result in the crowding of the stream away from that side of the valley. If, however, the stream is a competent one, the material supplied will be borne away, the bank of greater insolation will remain steep, and the stream will flow close to it. The side of the valley receiving the most heat from the sun will be the north, so that the condition upon the two creeks named is that called for by the theory; yet it is probable that other causes have been still more active. That differential insolation is often subordinate to other factors in producing asymmetry is proved by the fact that many actively cutting streams, of which Franklin Gulch and Napoleon Creek, on Fortymile, and Harrison and Eagle, on Birch Creek, are examples, have their steepest sides facing the north, just the opposite to what the theory demands.

Theory of terrestrial rotation.—Another possible cause is that of terrestrial rotation. In 1859 Ferrel formulated the law that all horizontally moving bodies in the northern hemisphere are, by the rotation of the earth upon its axis, deflected to the right. At first applied to the winds, it has been extended to other moving bodies, such as streams of water, and made to account for irregularities in the work of rivers, where they seem to be pressed against their right banks. Its practicability of application has been discussed frequently, notably by G. K. Gilbert.[1] The latter came to the conclusion that terrestrial rotation is often a sufficient cause for stream asymmetry, and in a particular case—the Mississippi—he calculated that the selective tendency was 9 per cent greater toward the right than toward the left bank; but he also proved that only under peculiarly favorable conditions could the cause be efficient. "A stream which rapidly corrades the bottom of its channel does not notably corrade its bank, and in such case the effect of rotation should not be discoverable." The conditions of rapid vertical corrasion here described apply to a majority of the streams of Alaska, that part of the Yukon lying in the Flats being almost the only water course in which vertical corrasion is subordinate to lateral; consequently we should expect terrestrial rotation not to be everywhere of primary importance. If it were the principal cause, we would also expect similar results in regions similarly situated, but it will be remembered that, while the environments of Mission and Mynook creeks are alike and their valleys unsymmetrical, in the one case, Mission Creek, the greater erosion has been upon the northern or left bank in opposition to the deflective force produced by rotation. Also no general asymmetry was observed in the north and south flowing streams, although by Ferrel's law all streams in the same latitude should suffer equal deflection toward the right bank.

[1] Am. Jour. Sci., 3d series. Vol. XXVII, 1884, p. 427.

The effect of geologic structure.—Since streams are unstable bodies they are affected and their alignment is modified and often altered by the geological structure of the rocks into which they are corrading their beds. Some of these modifications are local, such as, for example, the dams frequently found upon Fortymile Creek, where a particularly resistant layer crosses the bed of the stream; others, due to the attitude of the rocks, are more extensive in their character. In case the rocks are horizontal, and there are no other disturbing influences, the gorge of a young stream will be cut vertically, but with a dip the down-cutting resolves itself into two components—the one vertical, and the other along lines of weakness offered to erosion by planes of schistosity or stratification. The bed of the creek, therefore, does not proceed directly downward, but migrates in the direction of the dip, and the bank is cut more vigorously on that side, producing a one-sided valley. The amount of asymmetry depends upon the angle of the dip. With horizontality it is 0; at an angle of 45° the deforming tendency is greatest, gradually decreasing until, when the rocks are vertical, it is again 0. Buckskin, Franklin Gulch, and Napoleon creeks are examples of streams which flow in strike valleys, and in all of these the dip is rather steep toward the south. The valley in each case is unsymmetrical, with the steepest side at the south, and this would seem to have been caused by a migration down the dip, although, as will be seen later, other influences may also enter. In Mission and Hunter creeks the facts are different. In each the bedrock has been folded so that, as often as not, the creeks cross the strike and dip; the asymmetry of the valleys, therefore, is perfectly independent of the dip, the steeper bank being always upon the north through all the varying dips and strikes.

The rocks of Hunter and Mission creeks have not only been folded but are also faulted upon a small scale, which suggests the idea that major faults taking east and west courses are responsible for the course of the creeks, and that the south-facing wall above described is a fault escarpment. However, there is no evidence to sustain this supposition.

The effect of tilting.—It is seen, then, that the general causes of terrestrial rotation, insolation, and geological structure, while applicable in special cases, are insufficient to explain all the observed phenomena of one-sidedness. We are obliged, therefore, to seek some other explanation, and the only remaining one is that of an unequal uplift, as suggested at the beginning. By it all phenomena not explained under the other ones may be accounted for.

In the Mission and Mynook systems of drainage, particularly, there is a retardation of the southward-flowing waters and an acceleration of those flowing north, which is seen not only in the branches, causing inequalities of drainage development, but in all the meanders. This, it seems, could have been produced only by a tilt of the surface subjected to erosion, in this case toward the north.

The greater activity of the northward-flowing streams of the Birch Creek district as compared with those situated to the south of the main divide, the unsymmetrical valleys at the mouths of Porcupine, Miller, and Mastodon creeks, as also the rectangular arrangement of the drainage in the Birch Creek flats, indicate a tilt toward the north in this particular area. The rearrangement of the drainage in a tilted district is, in a way, an index of the direction and axis of tilt. For example, in the cases just cited the trunk streams are straightening their courses in a general east-west direction, showing that the axis of the tilt is also east and west, while the acceleration of streams shows the slope of the tilted surface to be toward the north. The streams flowing into Birch Creek to the south of the mountains have been cited above as showing the influence which geological structure exerts upon the drainage. Late warping is disregarded here or is absent, for we have seen that upon Mynook and Mission creeks a tilt opposed to the dip of the rocks, although probably amounting only to a fraction of a foot in the mile, was still more important than the latter in causing asymmetry.

We should expect then, if there were a tilt in opposition to the dip of the rocks upon Eagle Creek, that it would govern the alignment; on the contrary, however, the dip governs. On Harrison Creek the steeper side is at the south; at Eagle Creek it is at the northwest, and migration down the dip is observed, especially well marked, just above the mouth of the latter. These two creeks, although near together, yet migrate in opposite directions, following in this change a local variation in the attitude of the rocks. Here, then, there can be no tilt toward the north; further, there can be none to the south, else Eagle Creek would have been crowded to the south side of its valley. Harrison and Eagle creeks are therefore located in a region of no tilt, probably along an axis away from which the surface has not only been tilted toward the north but also toward the south, in the direction of the Tanana, forming a broad anticline. On the Fortymile Creek drainage, Franklin Gulch and Napoleon Creek have unsymmetrical valleys in which in each case the stream has migrated to the south side. These have also been given as examples of the governing influence of structure. It is probable that no tilt has occurred in opposition to the structure, and there are reasons to believe that the peculiar one-sided valleys are produced by the two causes acting jointly in the same direction. Just above Franklin Gulch, on the main creek, the canyon walls fall back and the valley spreads out into a flood plain a mile and a half wide and extending some two or three miles up the creek. Above this the canyon is again resumed. The cause of the bottom land at this point is evidently a ponding of the water by a dam; but no local dam is now to be seen. This is the result we should have in the event of a tilt of the surface toward the south, the tilting opposed to the gradient of the stream not being

great enough to reverse the drainage, but sufficient to cause a ponding of the water above the point where the axis crosses the creek. Unsymmetrical valleys with the steeper side at the south were also observed upon Glacier and Miller creeks, where they are independent of the geological structure and were probably produced by unequal uplift.

SUMMARY.

By an examination of the Yukon River and Fortymile, Mission, Birch, and Mynook creeks it appears that during the elevation of the present uncompleted geographic cycle broad folds were produced. In almost all of the gold-producing gulches the phenomena are those of a monoclinal tilt toward the north, but at certain other points, as upon the South Fork of Fortymile, the tilt appears to be toward the south, the structure being anticlinal and, according to the arrangement of the drainage, along northeasterly axes. While the location of the axes can not be accurately determined, one of these probably very nearly coincides with the crest of the Crooked Creek-Birch Creek divide and has a direction N. 70° E., the headwaters of Birch Creek proper being located in the region of no tilt.

In the Fortymile area an anticlinal axis passes in the vicinity of Franklin Gulch, crosses north of the head of Walker Fork and into British territory to the north of the gold-producing creeks, Miller and Glacier. This axis of recent anticlinal warping very nearly coincides with the ancient anticlinal axis.

CHAPTER V.

VALUABLE METALS IN SOLID ROCKS.

Throughout the district which has been described and mapped there are in numerous places valuable metals, especially gold. With respect to their occurrence these metals may be divided into two chief classes—first, those which are found in the solid rock, having there been concentrated by chemical agencies, and, second, those which occur in rocks made up of detritus derived from the older solid rocks, from which detritus the heavy metals, such as gold, have been mechanically separated. The first class may be called bed-rock deposits, and the second, placer deposits. Placer deposits are usually found in loosely consolidated river gravels. In Alaska the gravels hitherto worked have been formed in comparatively recent times, but in other regions, such as British Columbia, California, and Australia, they are often of Tertiary age and slightly consolidated; and in some places it may happen that still more ancient gravels, whether formed in rivers or on beaches, have been entirely consolidated so as to form a hard conglomerate, while they still contain the gold originally obtained by mechanical concentration. All these older deposits, however, come under the head of placers.

In Alaska the precious metals in the older solid rocks, or the bed-rock deposits, occur, so far as noted, in two chief ways—first, in quartz veins; second, in mineralized shear zones. It may be noted in passing that in Alaska, and to a less extent in other mining countries, the term "quartz mining" is erroneously used by the miners to include all bed-rock mining as opposed to placer mining. This, however, is neither in accord with the facts nor with the common usage of miners in better-developed countries, since quartz is a definite mineral, and the term "quartz mining" refers simply to the working of veins of quartz which carry gold.

QUARTZ VEINS.

Occurrence.—Veins of quartz are found in great abundance all through the schistose rocks of the Fortymile and the Birch Creek series. They are also found occasionally, but not very frequently, in the fundamental granite, and are common but not very numerous in the rocks of the Rampart series. In formations which are of younger age than the Rampart series, quartz veins have locally developed as

a consequence of some special conditions of alteration; but as widespread and characteristic phenomena they may be said to be confined to the Rampart and older rocks, and to be by far most conspicuously developed in the Fortymile and the Birch Creek rocks.

Divisions in point of age.—Most of the quartz veins in the Fortymile and Birch Creek rocks are narrow and nonpersistent. Most of them are parallel with the schistosity, but some cut across it, and these usually show that they have taken part in the movements of the inclosing rocks. Those which are parallel with the schistosity are often shred apart by motion along the shearing planes, or have been folded and contorted (see fig. 22); others cut across the schistosity for a little distance and then terminate abruptly, as if faulted by movement along the schistosity planes. It is evident that the rocks were originally intersected by many veins, some of which ran parallel to the stratification and others across it. These veins were probably once more continuous than now, but they have been so broken, faulted, sheared, and separated that they are now usually

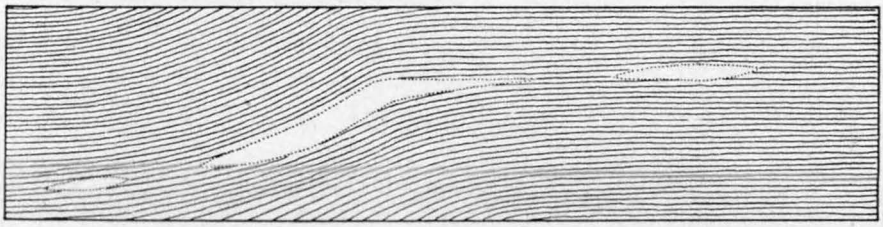


FIG. 22.—Sketch of contorted and shredded quartz veins in Fortymile schist.

nonpersistent. Veins of this class are found sparingly in the underlying granite and not at all in the overlying Rampart series.

Besides these sheared veins are often others which cut across the schistosity, jointing, and other structures resulting through disturbance without any break, showing that they are later than all movements in the rock, and therefore distinctly younger than the veins just described. On Fortymile Creek these veins cut across the cleavage and the older quartz veins and branch so that from a little distance they have the appearance of dikes. (See fig. 23, p. 292.) They often contain a little feldspar, and sometimes, by increase in amount of this mineral, pass into a variety of fine pegmatite; this in turn seems to be transitional into a coarse aplite, which is very abundant.

In the Birch Creek district, also, persistent, wide quartz veins are found, although in smaller number than the schistose veins, and in this district also they often contain feldspar, and are associated with aplite.

In the rocks of the Rampart series there are frequently quartz veins formed along shear zones. These rocks were formed practically subsequent to all regional schistosity, but they have been jointed through-

out, and the local intensity of jointing has frequently produced zones of slight movement or shearing, and along these zones quartz veins have formed in the open cracks. These veins are never sheared, and are therefore subsequent to all important movement in the rocks.

Metallic contents of older veins.—In the older schistose veins pyrite is very common; galena is frequent, and gold often occurs. In the Fortymile district, 1 mile above the mouth of Davis Creek, is a vein called Lowry's ledge, which is 10 to 12 inches thick, and lies almost horizontal in the bed of the creek. This vein contains free gold. In a ravine or pup of Miller Creek, in the same district, a quartz ledge has been found which shows free gold; and on the same creek is a wide, irregular quartz vein called Lloyd's ledge, which contains

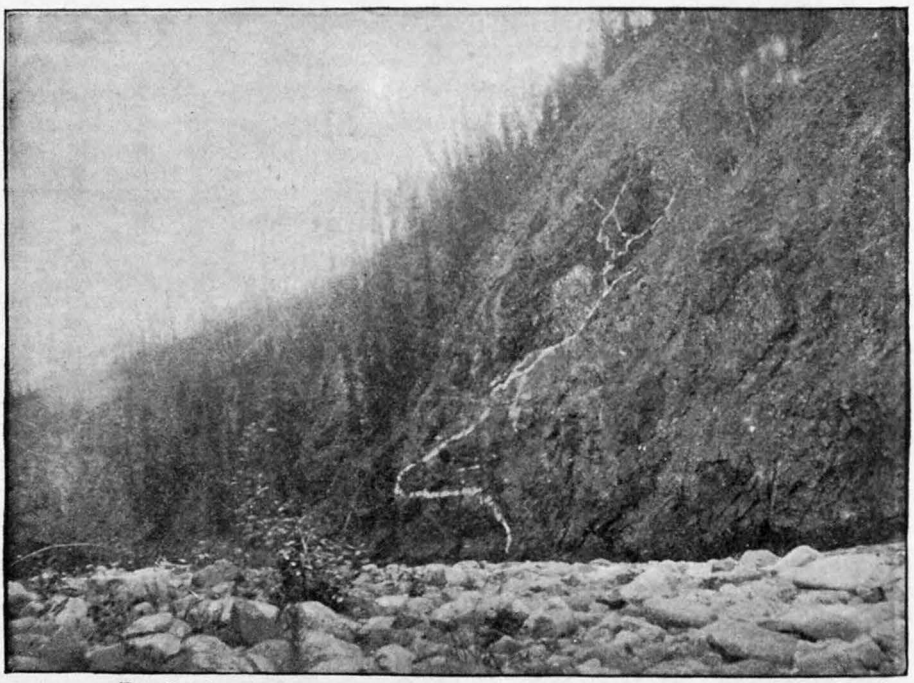


FIG. 23.—Quartz-feldspar vein in schist, South Fork of Fortymile Creek.

galena in irregular blotches. A small specimen of this galena assayed by the Survey yielded no gold and 1.6 ounces silver. At the head of Glacier Creek free gold is said to have been found in a quartz vein which has been located by Mr. Vorse. In Franklin Gulch is a wide quartz vein near which coarse gold occurs in such position as to indicate its derivation from the vein, although no free gold was actually seen in the outcrop. On the Yukon River, near the mouth of Stewart, gold-bearing quartz veins are reported.

In the Lower Ramparts there are the same quartz veins as on the upper river. A piece of quartz brought in by Indians from between the Hess and the Troublesome rivers was yellow and cavernous in

appearance, but gave in the specimen obtained by the Survey party only a trace of gold. This, however, was by no means a fair sample. On the headwaters of the Hess River a well-known prospector, Oliver C. Miller, has driven a tunnel 25 feet into a quartz ledge which is said to be auriferous. On the right-hand side of the Yukon, 35 miles below Tanana post, a tunnel has been driven 110 feet on a quartz vein in the Birch Creek schists. The vein, like so many others, has been so pinched and faulted by movements in the rocks that it can hardly be followed any great distance, and therefore its mining will always be very uncertain. A random sample of this vein obtained by the Survey party gave on assay 0.05 ounce gold and 0.3 ounce silver to the ton.[1]

Metallic contents of younger veins.—The younger quartz veins, which have been unaffected by movements in the rock, also contain metals. Fifteen miles southwest of Circle City, on the trail which passes the Eightmile cache, there is a quartz vein carrying much free gold. A specimen in our posession from this vein is of the hard, white quartz which is not generally supposed to contain gold, but this specimen is in places very full of little threads and stringers of the precious metal; it also contains a little pyrite and hematite. This vein is said to be 10 feet wide, and has been staked by a miner named McLeod. On Hog'em or Deadwood Creek in the same district there was found under the gravels on Eaton's claim a wide vein very rich in galena. A random sample of this obtained by us assayed 44 ounces in silver and no gold. On Greenhorn Gulch a fragment of quartz picked up in the gravels was full of cavities which were apparently left by the decomposition of metallic sulphides. This fragment showed minute specks of free gold, and on assay yielded 24 ounces of silver to the ton, thus suggesting that it is a highly weathered specimen of the same variety of ore which was found on Hog'em Creek. At the head of Eagle and Gold Dust gulches persistent and wide quartz veins are said to exist, the one at the head of Gold Dust Gulch being in places as much as 150 feet wide, and consisting of cavernous, rusty quartz. The same veins are found at the head of Harrison Creek. On Harrison Creek a block of quartz rich in gold was found in the gravels on claim 91 on the North Fork, about three-quarters of a mile above its junction with the South Fork. The block found is roughly square, with sharp corners, and is about 5 inches long. On one of the large faces is a thin coating of crystalline quartz, less than a quarter of an inch thick. Imbedded in this quartz are abundant beads of gold, the largest one of which measured three-sixteenths of an inch in diameter; from which size the fragments become smaller until finally they are invisible to the naked eye, although a magnifying glass shows them to be present in considerable quantities, disseminated through the quartz. The quartz vein which carries this gold penetrates the schists nearly

[1] All assays by the Survey were made by Prof. C. E. Munroe.

at right angles, thus showing that it is distinctly younger in age than the numerous nonpersistent veins which are older than the development of the chief schistosity.

On American Creek, near the head, gold-bearing quartz veins have been found. On Little Mynook Creek the movement along the shear zones has occasionally resulted in open fissures which have become filled with white, crystalline quartz veins. These often show comb structure, and sometimes have a vacant space left in the center of the vein, the walls of which are lined with crystals. One vein seen was about 6 feet wide. This ledge has been staked by a miner named Sinclair, and samples of it yield on panning a small quantity of fine gold. Similar veins occur on Hunter Creek, but are not known to be auriferous.

Microscopic occurrence of gold.—In only one thin section was gold found under the microscope; this was from the quartz vein which has been mentioned as occurring northwest of Eightmile cache in the Birch Creek district. In this specimen some of the quartz appears dark and dirty from the abundance of inclusions. This dark quartz has been brecciated and perfectly cemented again by a quartz which contains few inclusions, and so appears clean. Through both varieties of quartz run cracks, and at the intersection of two of these is an irregular bunch of yellow gold, associated with another opaque mineral, which may be hematite. The slight elongation of the gold along the cracks in two directions suggests that these have induced its deposition and that of the associated iron mineral. The cracks are stained by limonite, showing that they are still capable of acting as channels for solutions.

MINERALIZED SHEAR ZONES.

The veins of pure white crystalline quartz which have been described often show by their comb structure, or even by the leaving of residual cavities, that they are fillings of preexisting open fissures, and it is probable that this is usually the case. In other instances, however, silica and metallic sulphides have been introduced into the rock in a quite different way. Where rocks have been profoundly sheared, so that while no open fissure is presented the whole crushed rock offers a ready channel for percolating waters, both the sheared rock and the more massive portion immediately adjoining are usually found further altered by chemical means. This is especially the case where the rocks are on the whole massive and are only locally sheared, so that there arise definite shear zones, along which the water circulation is necessarily concentrated. For this reason the shear zones are most conspicuously altered in the Rampart series rocks, since in the older formations the shearing is more general, and in the younger ones it has not been nearly so great. The chemical effects along these shear zones are noticeable in the field chiefly by

an induration which arises from the deposition of silica, and by a staining resulting from the oxidation of the metallic sulphides which have been formed. It sometimes happens that along these shear zones white quartz veins form, evidently where actual fissures have existed, for they always contrast strongly with the dark, impure jasperoid or chert which arises from the silicification of the country rock.

OCCURRENCES.

Above Fortymile Creek, in the schistose rocks opposite the mouth of the Klondike River, a tunnel has been driven into a wide body of ore. This tunnel was not visited, but it is claimed that the ore has been assayed and runs $54 to the ton—$18 in silver and $36 in gold. Mr. McConnell[1] notes that between Fortymile Creek and Fort Reliance copper pyrites in small quantities occurs at several points, not in the veins but as impregnations of the schist itself.

On Fortymile Creek, 2 or 3 miles above the mouth, are shales, sand stones, and limestones which have been locally sheared and impregnated with sulphides, although on the outcrops most of the sulphides have been leached out, making the rocks rusty and crumbly. On Cone Hill, directly opposite the mouth of Clinton Creek, the rock is a limestone, somewhat altered. Through this altered rock runs a zone 200 or 300 feet wide, which is conspicuous at a distance on account of a dark-red stain. The rock is found on fresh breaks to be stained green, and to be made up largely of fine crystalline dolomite, with considerable quartz. This zone cuts vertically through the less altered rock in a northwest-southeast direction, and appears to be continuous and unfaulted, following a set of vertical joints. Under the microscope the altered rock is seen to be still essentially a fine-grained, crystalline dolomite, sometimes containing much tremolite; there is also a little quartz in very fine particles, as if secondary and in process of replacing the carbonate. Small masses of a dark-brown metallic mineral, surrounded by a slight stain of green, are scattered through the rock. Chemical examination by Dr. W. F. Hillebrand shows that the matrix is a dolomite carrying considerable iron and nickel carbonates; also some mineral of antimony and arsenic in small quantities and soluble in hydrochloric acid. The green portions are insoluble in acid, and therefore probably a silicate or quartz, and the stain is some compound of chromium, undoubtedly derived from the oxidation of chromite, which is the metallic mineral accompanying the green stain.

A sample of this altered rock was assayed by the Survey and showed no gold or silver. It is claimed, however, that other samples have shown the ore to be a low-grade gold ore, capable of being worked under favorable conditions. According to Mr. Ogilvie,[1] of the Cana-

[1] Ann. Rept. Geol. Nat. Hist. Survey Canada, Vol. IV, 1888-89, p. 30D.

dian Survey, a small lode of argentiferous galena crosses Fortymile Creek a couple of miles above its mouth. A specimen of this, analyzed by Mr. Hoffmann, of the Canadian Survey, yielded over 38 ounces of silver to the ton. Traces of gold and silver were found in a specimen of altered sandstone from above Cone Hill, on Fortymile Creek, in an assay made for the writer by Mr. R. H. Officer, of Salt Lake City.

On American Creek were observed numerous shear zones, along which the rock was silicified and contained, besides calcite, copper and iron pyrite. In the gravels in the bottom of the creek is found magnetite in good-sized, waterworn pebbles or in small, perfect crystals, and also much barite. From the association with fragments from the adjacent rocks it is probable that these minerals are likewise derived from shear-zone deposits; and it is quite likely that the gold itself, which occurs in coarse fragments in the gravels, may have the same origin; therefore, bed-rock deposits of considerable richness may be found on American Creek and vicinity.

All through the Lower Ramparts of the Yukon the rocks of the Rampart series are much jointed and are locally sheared. These shear zones are sometimes impregnated with sulphides, and often narrow quartz veins have formed conformable with the shearing. The veins are sometimes slightly cavernous and rusty, showing the decomposition of preexisting sulphides. About 25 miles below Fort Hamlin a sample was taken from a sheared zone in a dark aphanitic rock. Along this zone the rock was decomposed and yellow. This sample, assayed by Mr. R. H. Officer, of Salt Lake City, gave 0.08 ounce gold and a trace of silver. Under the microscope the rock is seen to be a tuff, consisting of a fine-grained groundmass in which are scattered rounded or angular fragments of quartz and feldspar. The groundmass is finely microcrystalline, often spherulitic. The general alteration of the rock is shown in the production of kaolin, chlorite, epidote, and carbonates disseminated throughout. The effects of pressure are shown by a strong set of irregular but generally parallel fractures. Along these are occasional veinlets of cryptocrystalline silica, dark-brown ocherous limonite or blood-red translucent hematite, a milky-white, semiopaque mineral which is probably siderite, and a yellow-green mineral of considerable single refraction which was not determined.

In the Rampart rocks on Mynook Creek the same phenomena were noted. The alteration of the rocks is shown by silicification and the deposition of sulphides. This alteration has taken place along shear zones, and also in some cases along the stratification. Sometimes it is irregular, following now one set of joints and now another, and now the stratification planes. The process seems to be essentially one of replacement along zones of easy penetration, and the mineralized portions of the rock do not seem to have any constant direction. The

joint planes themselves do not seem to have any markedly predominant trend, and there is little evidence of any important movement along any of them. The appearance is as if a massive rock had been subjected to severe strain, but had been firmly held against slipping; thus the most jointed and broken portions of the rock are of irregular shape. In places, however, there has been slipping and the production of genuine shear zones. On Miller Gulch, half a mile above Little Mynook Creek, are many of these zones, impregnated with sulphides; and near the mouth of the gulch, on the main Mynook Creek, is a body of altered rock about 17 feet wide in all, which follows now the joint planes and now the stratification. This outcrop is yellow with iron, but often has a green stain, which was determined by Dr. W. F. Hillebrand to be a mixture of calcite and copper silicate. Under the microscope the wall rocks of this impregnated body are seen to be a hard, aphanitic, green slate, while the vein itself is a calcareous sandstone containing occasional broken bits of mica. In the interstices between the quartz grains is abundant pyrite, chiefly copper pyrite. The interstices between the quartz grains appear originally to have been filled with calcite, in which the pyrite has been deposited. Small clumps of siderite occur, and the green copper stain surrounds the pyrite and from here has spread throughout the rock. This locality has been claimed by O. C. Miller. A sample assayed for the Survey by Prof. C. E. Munroe gave gold 0.00, silver 0.00; one assayed by Mr. R. H. Officer, for the writer, gave a trace of gold, and silver 0.2 ounce to the ton. It is claimed, however, that previous samples have shown considerable quantities of the precious metals, one assay being said to have shown $296 to the ton. A sample from one of the deposits in Miller Gulch, mentioned above, showed no trace of gold or silver in an assay by Professor Munroe, while one by Mr. Officer showed gold 0.01 ounce to the ton and a trace of silver.

On Hunter Creek are similar impregnations of sulphides, which are chiefly pyrite, marcasite, chalcopyrite, and sometimes pyrrhotite. At one point a tunnel has been driven on a black, carbonaceous shale which is interbedded with diabasic tuff. This shale is in portions silicified and contains much pyrite. Under the microscope it is found to be originally calcareous, but the calcite has been largely replaced by pyrite, with some chalcedonic silica. This rock is claimed to have shown sufficient values on assaying to make it a low-grade ore, but the assay by the Survey showed 0.00 gold and 0.05 ounce silver to the ton; however, this was, unfortunately, of a specimen and not of a carefully selected assay sample.

GENESIS OF AURIFEROUS QUARTZ VEINS.

It has already been noted that there are in the gold-bearing rocks of the Yukon district two chief sets of quartz veins, one of which was formed previous to the schistosity and one subsequent thereto.

Besides these two chief sets, there are frequent veins scattered here and there through the younger rocks. This is what should be expected, since silica is everywhere being taken into solution by ordinary alkaline waters and precipitated from them, so that new deposits are continually formed in favorable places. But these youngest veins are scattered and belong to no definite system; and, so far as known, they are of no economic importance. The veins of the two chief sets in the schistose rocks, however, are extremely numerous and important, and both sets appear, as described, to be auriferous. The older set has been so sheared that its relations are greatly obscured; therefore the younger set, which has been left undisturbed, offers the best facilities for study as to nature and origin.

These younger veins have a close and evident connection with acid dikes. In both the Fortymile and the Birch Creek districts the veins, by addition of feldspar, grade into aplite. Between the aplite and the quartz there is a pegmatitic stage, but the pegmatite is fine in texture and is not very abundant. From the coarse feldspar-quartz rock, or aplite, there is a gradation into finer-grained, more typical aplite, which occurs in large quantities. One variety of this has a groundmass of granular quartz, which contains phenocrysts of feldspar much larger than the quartz grains, but still small, and often not abundant. There is, in short, a gradual transition from quartz veins to typical aplite, and it follows from this that the conditions and manner of formation of quartz veins and aplite were not entirely different, but passed into each other by very slight modifications. There is, therefore, no sharp line between so-called dikes and so-called veins.

TRANSITIONS BETWEEN VEINS AND IGNEOUS ROCKS.

There has always been a tendency to regard xenogenous or intrusive masses of minerals formed in cracks or fissures in older rocks as naturally divisible into two well-defined classes: one formed by a cooling from a molten condition and one by a deposition from solution in waters, and these classes have been called dikes and veins. The conception of this sharp distinction has arisen because, on the one hand, many dikes offer indubitable evidence that they have been formed chiefly by cooling from a molten condition, while, on the other hand, many veins, by their layering, comb structure, etc., show clearly that they have been deposited from waters. Moreover, the material of which many dikes are made up is identical, or nearly so, with that of many lavas which are poured out on the surface; and the process of the formation of these lavas is quite open to observation. On the other hand, the deposition of veins and vein material from circulating waters is a process which may be everywhere observed, both at the surface and, to better advantage, in underground excavations.

With this preconceived idea of the utter difference in manner of deposition of the two classes of deposits, it has happened naturally

that rocks presenting a perfect transition between the two have long been a source of considerable perplexity and contention. These transition rocks are chiefly known as pegmatites, and have been referred by some to the division of dikes and by some to that of veins, since some observers perceived clearly characteristics pointing to an igneous origin and showing relation to granites and other crystalline rocks, while others were more particularly impressed with features indicating an aqueous origin and a close alliance to ordinary veins. This class of transition rocks is now, after much study, better understood, and the opposing evidences have been reconciled by the latest and best essays on the subject, which have been written by Crosby and Fuller,[1] Brögger,[2] and Williams.[3] It is, in the main, agreed by these writers, as well as others who have preceded them, that the formation of the coarsely crystalline aggregates of quartz, feldspar, and other minerals, known chiefly as pegmatite, have been formed under conditions intermediate between those governing the formation of acid igneous rocks, like granites, and those governing the deposition of simple quartz veins. Transitions of pegmatite to quartz veins, showing absolute and uniform gradation from one to the other, have been noted by Crosby and Fuller,[4] Williams,[5] and Van Hise,[6] and transitions or evident close and constant relations between pegmatites and granites have been noted by Crosby, Brögger, Van Hise, and Williams.

The conditions under which pegmatites have formed have been named aqueo-igneous, to signify their intermediate position between the conditions under which ordinary crystalline rocks have formed and those governing the deposition of ordinary veins. Although this terminology may be useful at present, it appears probable that a more complete conception of the conditions under which intrusive rocks have formed will show it to be artificial; and that, just as it has been found impossible to divide all these intrusive bodies into two well-marked divisions of aqueous and igneous, or veins and dikes, so it will be found impossible to divide them into three sharp classes, aqueous, igneous, and aqueo-igneous, or veins, dikes, and pegmatites. It is sufficiently proved that so-called igneous rocks have consolidated in the presence and partly through the agency of water, while many so-called aqueous rocks or veins have been formed only because the solutions which deposited them were in a highly heated condition, and so possessed especial properties. That there is no sharp line of demarcation between dikes and veins has been

[1] Origin of pegmatite, by W. O. Crosby and M. L. Fuller: Am. Geologist, Vol. XIX, No. 3, p. 147.

[2] Die Mineralien der Syenitpegmatitgänge der südnorwegischen Augit- und Nephelinsyenite, by W. C. Brögger: Zeitschr. für Kryst, Vol. XVI, 1890, pp. 215-235.

[3] Origin of Maryland pegmatites, by G. H. Williams: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 675.

[4] Op. cit., pp. 156, 173.

[5] Op. cit., p. 679.

[6] Sixteenth Ann. Rept. U. S. Geol. Survey, Part I, 1896, p. 688.

pointed out by Crosby,[1] while Van Hise[2] has remarked upon the improbability of any definite division between the aqueous and igneous processes at moderately remote depths, where the increase of pressure and temperature must give such great absorbent power to liquids; and both these writers believe that in the various stages of gradation between the preponderating agency of heat and the preponderating agency of water all the phases of pegmatization may be explained, and that thus all pegmatite is due to a moderately uniform cause. Williams, indeed, has divided the Maryland pegmatite into two classes, one being of aqueous and one of igneous origin; yet these have often identical characters and occur close together, and it is difficult to understand how such bodies can have been produced by processes differing so widely as to deserve separate names. Concerning the origin of those veins which he considers igneous, however, Williams's views are, in the main, in accord with the other opinions already given and with those held by the present writer. In regard to the relations between pegmatites and granites, these views are so clearly and forcibly stated that they may be quoted.[3]

The writer's conception of the relation between these intrusive pegmatites and the granite with which they are associated does not materially differ from the conceptions of De Beaumont, Lehmann, and Brögger. As Lehmann and many others have distinctly pointed out, a gradually solidifying magma tends through the processes of crystallization to become more and more acid and at the same time more and more liquid. The water and other mineralizing agents which all acid magmas contain become gradually excreted and concentrated in the residual portion, since they can not enter directly into the composition of the normal granite. * * * The writer therefore interprets those pegmatites which by their mode of occurrence and association strongly indicate an igneous character as the products of the residual, and therefore most acid, portion of a granite magma highly charged with water and other mineralizing agents. Such a siliceous material, in a state intermediate between fusion and solution, has been injected into fissures and there crystallized into very coarse-grained aggregates, not necessarily through any great slowness of this process, but rather in virtue of the aid to crystallization afforded by the abundance of mineralizers present.

THE ORIGIN OF DIFFERENCES IN IGNEOUS ROCKS.

The transition in the Fortymile and Birch Creek districts of aplites through intermediate pegmatitic rocks to quartz veins is a case strictly analogous to the cases which have been cited and which have given rise to the views referred to, although in this case the pegmatitic rocks are fine grained and relatively rare. On Fortymile Creek, however, the transition from quartz veins to aplite is not more complete or remarkable than the transition from aplite to acid granite, from acid granite to basic granite and diorite, and from these to successively more basic rocks, until finally rocks consisting essentially of the ferromagnesian and the metallic minerals result. All the different

[1] Op. cit., p. 179. [2] Op. cit., p. 687. [3] Op. cit., p. 684.

varieties occur in the same area as dikes which have been intruded successively and which cut one another. In view of this remarkable transition and of the consanguinity between the different varieties, which has been pointed out more fully in the detailed consideration of these dikes, the hypothesis suggests itself immediately that all the rocks have in some way a common origin, and that the different phases have separated out under gradually changing conditions.

In the light of the most modern petrography it has come to be recognized that there are no sharp lines of division between the different igneous rocks, for one variety passes into another so gradually that the limits must be drawn arbitrarily, and in some cases the best classification which can be made seems artificial and almost undesirable. This gradation, however, does not in itself go to prove any hypothesis as to the origin of the rocks. The possible hypotheses as to origin may be divided into three classes; those which explain the different phases as formed by segregation from a more uniform magma; those which explain them by the mixture of unlike magmas, and those which assume that there has been no important change, and that the rocks were essentially in the same condition as now at the time of the earth's formation. These three classes of hypotheses may be conveniently called the hypothesis of segregation or differentiation; the hypothesis of synthesis, and the hypothesis of original heterogeneity. Considering each one of these hypotheses, however, it is evident that there must in any case be transitions from one rock type to another, since hard and fast lines are unnatural. For instance, taking the extreme views, the same transitional rocks can be obtained by mixture in different proportions of an originally acid and an originally basic magma, as by segregation in different degrees of perfection of an originally intermediate magma into more acid and more basic parts. The true cause or causes of the origin of differences of igneous rocks must be sought for by more detailed observations, which may be brought together to prove some definite law or laws. The discovery of these laws depends chiefly upon the accumulation and comparison of facts; and in this work it must be held in mind that there is not necessarily a single universal law, that it would be quite unlike the complexity of nature if this were so, and that it may well be that a certain law governs in some cases and utterly different ones in others.

THE PROCESS OF DIFFERENTIATION OR SEGREGATION.

All of the three possible general hypotheses which have been named as applicable to the origin of rock differences have been maintained by different writers. Lately, however, the theory of differentiation or segregation has been most advocated, and there is a tendency to explain all igneous rocks as segregations from a common magma. The principle of the segregation of materials in a fluid condition is well known in the laboratory and is beyond dispute. Materials

intimately mingled in a solution may separate into distinct and perfect crystals—a process which requires a considerable movement of the molecules; and the crystals of mineral veins, and even of igneous rocks, must be formed in this way. In the laboratory the process of segregation frequently acts so that the materials are separated not only into single crystals, but into bunches made up of many like crystals; and the masses of the different minerals are more or less perfectly separated. In the same way it occurs in mineral veins that certain minerals are segregated in large bunches in parts of the veins, while other minerals are collected into other parts. In igneous rocks there are often small patches where certain constituents are concentrated in such a way as to place it beyond doubt that they have segregated in the same manner as a single crystal separates out from solution; and from these small patches there is a gradation to larger rock masses, which have marked differences in structure and composition from the rest of the igneous body of which they, nevertheless, form an essential portion. It is thus found that in a large igneous mass different portions have slightly different characters, and the idea naturally follows that these large differences are due to the same general causes which have produced the segregations of minerals on a small scale; or, on a still smaller scale, the segregation of individual crystals. Following this line of thought still further, it is perceived that different igneous rocks in a given district, while showing throughout certain constant peculiarities, all gradually pass into one another; and the explanation naturally suggests itself that these differing rocks have originated by the same process of segregation from some more uniform magma. Finally, modern petrographic research and comparison have shown that, although the classes of rocks are essentially the same in all parts of the world, all the rocks of a given district, taken collectively, often present certain constant differences from those of neighboring districts; and hence the theory of segregation or differentiation of the original common magmas of these districts from an original universal magma has been conceived.[1]

THE CHEMICAL VARIATIONS OF DIKES.

In seeking proofs for these hypotheses, we should proceed from the well-established phenomena of segregation on a very small scale to cases involving successively larger and larger masses. Therefore the characteristics of dikes and other masses of intrusive origin whose boundaries can be traced offer a very attractive field for study. In these rocks it is often found that there is a marked difference, both chemical and structural, in different portions of the same body. The structural differences are shown chiefly by different degrees of crystallization; and usually these differences evidently depend directly upon the relative proximity of the wall rock, those portions which are

[1] J. P. Iddings, The origin of igneous rocks. Bull. Philos. Soc. Washington, Vol. XII, p. 185.

nearest the walls having in general a finer texture and tnose more remote being coarser. It is clear that these differences of structure, which depend so directly upon the position of the wall rock, originated subsequent to the intrusion of the dike. Concerning the chemical differences in dikes and other intrusive masses, it may likewise be said that, if in any dike or other intrusive mass of igneous rock chemical variations show direct and constant relation to proximity to the sides or center, it is strong evidence, amounting almost to proof, that this chemical variation came about subsequent to the intrusion of the rock; furthermore, provided it can be proved that these variations are independent of the chemical variations in the wall rocks, it is very strong evidence that they have arisen by a process of segregation. On the other hand, lack of such relation is no proof against the possibility of segregation.

Dr. G. H. Williams[1] has described the contact phenomena of dikes intrusive into mica schists and limestones in New York. In some of the narrowest dikes the nature of the eruptive rock (diorite) is considerably altered near the contact. One of these dikes was only one-eighth of an inch wide, so that the entire width was contained within the thin section studied. The intrusive material consisted of hornblende, biotite, apatite, and probably scapolite, and the hornblende was concentrated along the edges of the dike, often standing perpendicular to its walls. In this case the wall rock was limestone. Prof. A. C. Lawson[2] describes certain dikes in the Rainy Lake region which show in a marked degree variations not only structural but also mineralogical and chemical, and these variations appear very constantly in different dikes to have the same relation to the wall rocks. For example, in a dike 150 feet wide there is a gradation in texture from an aphanitic rock at the contact to a coarse gabbro or diorite in the center. In the same dike there is a mineralogical variation from a quartzless rock at the dike wall to a quartose one in the center, and also a gradual change from augite to hornblende as the middle of the dike is approached, together with other well-marked differences. Chemical analyses show that the rock in the middle of the dike contains about 10 per cent more silica than that at the sides, a difference which is sufficient to separate the parts into two distinct rock species. Prof. J. P. Iddings[3] observed in a certain dike that the ferromagnesian elements had been partially concentrated along the sides, and refers to Lagorio as having made the same observations.

Sir Archibald Geikie[4] has briefly described certain intrusive sheets of diabase in the basin of the Firth of Forth. Near the contact with sandstones or shales these diabases have an abundance of olivine,

[1] Am. Jour. Sci., Oct., 1888, 3d series, Vol. XXXVI, p. 259.

[2] Petrographical differentiation of certain dikes of the Rainy Lake region: Am. Geologist, March, 1891, Vol. VII, p. 153.

[3] The origin of igneous rocks: Bull. Philos. Soc., Washington, Vol. XII, p. 159.

[4] Text-Book of Geology, 3d edition, 1893, p. 609.

which diminishes in proportion as the distance from the contact is increased, until in the center of the sheets it disappears. The interior parts are also found to be more acid than the exterior. Since in this case the wall rock is often sandstone, it does not seem probable that it can have had any influence in making the borders of the sheets more basic, since if assimilation of the wall rock had produced any chemical difference in the igneous mass it would naturally tend to have the opposite effect and make the borders more basic than the center. Kemp and Hollick,[1] in describing the contact of a mass of intrusive granite with limestone, have remarked that the granite becomes more basic as the contacts are approached, the proportion of pyroxene becoming much greater.

On the other hand, Mr. Hague[2] has described a dike of granite porphyry in limestone in the Eureka district of Nevada. In this dike the walls are generally more acid than the center and carry less ferromagnesian minerals. The difference in amount of silica, however, is slight, the extremes falling probably within 4 per cent of each other. Fouqué[3] has also described certain dikes the walls of which are more siliceous than the central part.

From the foregoing observations it appears that there is often a systematic variation in the chemical composition of dikes, which has a constant relation to the proximity to the wall rocks, and that, as a rule, where there is such variation the outside of dikes is more basic than the center, although sometimes the reverse is the case. Moreover, in many cases this variation can not be ascribed to assimilation of the wall rock, and must be explained by some process of chemical segregation; and from the relation just pointed out it seems probable that the causes of these segregations are differences in temperature, since, as a rule, those portions of the dike nearest the wall rocks would become cooled most quickly, although in certain conceivable cases the reverse would happen.

ORDER OF SUCCESSION OF LAVAS.

Where lavas have been erupted at different periods from a single volcanic center, petrographers have thought to have discovered definite laws of succession, showing that in the reservoirs beneath the vent the molten rock was undergoing a progressive change in chemical composition, and this change has been ascribed to segregation or differentiation. The usual law of succession, as interpreted by Iddings,[4] is that the series begins with a rock of average composition and passes through less siliceous and more siliceous ones to rocks extremely high in silica and others extremely low in silica; that is,

[1] The granite at Mounts Adam and Eve, Warwick, Orange County, New York, and its contact phenomena: Annals New York Acad. Sci., Vol. VII, p. 647.

[2] Mon. U. S. Geol. Survey, Vol. XX, Geology of the Eureka District, p. 228.

[3] Santorin et ses éruptions, Paris, 1879, p. 304.

[4] Op. cit., p. 145.

the series commences with a mean and ends with extremes. From studies in the eruptive rocks of Norway, Brögger[1] also thought to have determined a definite law of succession, by which the rocks progressed from the most basic to the most acid varieties; and Geikie,[2] from a study of the igneous rocks in Scotland and neighboring regions, has come to the same general conclusions as to the succession. Although the phenomena described and the laws deduced by these and other observers differ in detail, yet they all seem to point to a definite order of succession in lavas poured out at different times in the same volcanic region; and if this is established, it points either to chemical segregation or to a systematic original difference; and of these two alternatives the former offers by far the fewer difficulties.

Concerning the differences in the nature of succession which have been observed at different volcanic centers, it may be remarked that, even with a fixed definite law of segregation, the order of eruption would be different in different cases, being dependent upon a great number of disturbing and altering influences, many of which readily suggest themselves. Indeed, it would be unnatural if any uniform order should obtain everywhere; but by broad and careful study the general law should be found which would in a large number of cases prevail over all others, and would be perfectly illustrated when complicating influences were absent, while in other cases it would become changed until often the succession of lavas in a given district would be quite without a recognizable plan. The laws already deduced by Iddings, Brögger, Geikie, and others differ in detail, but essentially agree in this, that any rock magma under favorable conditions tends to separate into a more basic and a more acid portion; and in view of the considerations which have been pointed out, this may be accepted as an hypothesis which, although not yet absolutely proved, is strongly supported by facts. The acceptance of this conclusion as to the efficacy of segregation to produce different rock types does not compel belief that all rock types have thus originated, or that the types which have thus been formed have sprung from uniform magmas.

NATURE OF THE SEGREGATION PROCESSES.

Concerning the processes by which the separation or segregation of the more basic from the more acid rock constituents takes place very little can be said. Brögger, Vogt, and Iddings[3] appeal to forms of molecular flow the application of which is uncertain. The law regarding this is known as Soret's principle, and is that molecular concentration may be caused by differences in temperature. Brögger[4] also suggests that at the same time a partial crystallization might set in, and produce segregations of the more basic minerals.

[1] Iddings, op. cit., p. 122.
[2] Iddings, op. cit., p. 146.
[3] Op. cit., p. 159.
[4] Iddings, op. cit., p. 123.

The efficiency of molecular flow has been proved in the laboratory, and is accepted as the means by which the growth of crystals takes place in solutions and also in rocks. Mr. G. F. Becker,[1] however, argues that this process is so slow that the separation of any considerable body of rock into more acid and more basic portions would occupy an enormous period, utterly disproportionate to all our ideas. Mr. Becker also recognizes as a possible method of segregation the separation of a homogeneous fluid into distinct immiscible fluids by decrease in temperature or increase of pressure. Under the same conditions the precipitation of solids from liquids takes place. These immiscible fluids or the precipitated solid and the residual fluid would naturally separate themselves according to specific gravity; but this process is also considered to be incapable of producing any great amount of segregation, on account of the probable viscosity of the material and the apparently limited range of temperature available. It is also pointed out that convection currents are unavoidable for a very long period, since they would result from any slight local changes of temperature, and therefore, even if time were sufficient for segregation, these currents would prevent it by a continual mixing.

It seems to the writer, however, that, although convection currents in reservoirs of molten rock must be nearly always present, as pointed out by Mr. Becker, yet these currents do not necessarily in every case operate to mix, but may often have the opposite effect and be extremely important in producing segregation. For example, if local decrease of temperature or increase of pressure should produce a separation of an original homogeneous fluid into two immiscible fluids of different specific gravity, or into a solid and a fluid, weak currents might act to separate the two parts mechanically and more or less completely, according to their relative specific gravity. By such currents the lighter parts would be carried farther than the heavier, and a concentration would be effected, dependent upon the continuity of the currrents and on the perfection of the original chemical separation. Thus usually near the cooling walls of a body of igneous rock those portions which solidify first, that is, the more basic constituents, will be precipitated, and the currents will continually carry away the residual lighter material and bring new supplies of undifferentiated fluid. In this way the edges of a rock mass should be, as a rule, more basic than the center, which is the conclusion at which we have arrived from the record of facts given above. More violent currents, however, would carry both lighter and heavier materials along together, and might cause a complete mingling. In this way fluids which had separated into different portions might be again united. The different processes may be compared to the action of water on rock detritus at the surface. A comparatively gentle stream flowing over heterogeneous rock fragments brings about the separation and

[1] Some queries on rock differentiation: Am. Jour. Sci., 4th series, Vol. III, 1897, pp. 21-40.

assortment of the fragments according to size and specific gravity, forming at one point a bed of coarse gravel, and at another a layer of fine sand, and also bringing about concentrations of the heavier constituents from the lighter, while a torrent carries along all these materials and mingles them in confusion, tearing up deposits already separated and mixing them together in their original disorder.

THE PROCESSES OF SYNTHESIS OR MIXING.

While, therefore, differentiation or segregation takes place on a small scale, and, as broad geological facts indicate, probably on a large scale, on the other hand, synthesis or mixing is also known to occur in a small way, and undoubtedly must sometimes affect large masses. Mr. Becker[1] suggests that molten magmas must be mingled to some extent by violent movements and migrations, such as those which take place in the processes attendant upon a volcanic eruption.

CONTACT METAMORPHISM.

The simplest case of synthesis in the production of rock types is perhaps the alteration of wall rocks by intrusive masses, which is sometimes due to chemical and sometimes to mechanical causes. In nearly every case such wall rocks are found to be modified structurally and chemically, and to contain new constituents derived from the igneous rock. All of the numerous cases of contact metamorphism illustrate this process of synthesis. Of these, perhaps the simplest and commonest is silicification, although in many more extreme cases simple sedimentary rocks are altered into schists, or even into massive crystalline rocks whose characters are indistinguishable from those of similar rocks of igneous origin. Out of these numerous cases of contact metamorphism a few examples, taken almost at random, will be sufficient.

Modifications of wall rocks.—At the contact of the Albany granite with the schists, G. W. Hawes[2] shows that the schists have become dehydrated and silicified. G. H. Williams[3] notes that near the contact of massive diorite with micas-chist there is an undoubted metamorphism of the latter, consisting of an addition of alumina and iron and a corresponding decrease in the proportion of silica and alkalies. This change is shown by the disappearance of the quartz and muscovite and the development of biotite, sillimanite, staurolite, cyanite, and garnet. A more complete alteration of wall rocks is that noted by Miss M. T. Gardiner[4] as having been induced by the Cairnsmore-in-Fleet granite on Silurian grits and shales. In the shales lenticles of quartz appear half a mile from the granite, while near the granite there is a separation of quartz, mica, and plagioclase into separate

[1] Op. cit., p. 38.
[2] Am. Jour. Sci., 3d series, Vol. XXI, 1881, p. 28.
[3] Am. Jour. Sci., Oct., 1888, 3d ser., Vol. XXXVI, pp. 254–269.
[4] Contact alteration near New Galloway: Quart. Jour. Geol. Soc. London, Vol. XLVI, p. 569.

patches. Within 3 yards of the granite the shales become transformed into a light-gray, granular rock made up mostly of quartz and much white and brown mica; in this light-gray rock are black patches. Both granites and sedimentaries are veined by aplite, with white mica, garnets, and tourmaline, the last arranged graphically. In the grits the alteration is greater. Two hundred yards from the granite the rock contains brilliant white mica flakes with brown mica and some tourmaline, and the quartz is in large part recrystallized. At 100 yards the rock is coarser and resembles a gneiss; there is much white mica, nests of black mica, and intervening patches of quartz with garnets and sillimanite. At the junction with the granite the rock loses all sign of clastic origin.

Modifications of intrusive rocks.—On the other hand, igneous rocks themselves are sometimes modified by the assimilation of materials from the wall rocks. G. H. Williams[1] notes that the most interesting point in regard to the gabbros of the Cortlandt district is that they always, so far as observation was made, occur immediately beside limestone; and therefore they seem to represent a local modification of the more abundant norite—a modification produced by an increase of lime, which has changed the orthorhombic magnesian hypersthene to a monoclinic pyroxene.

ATMOSPHERIC MIXING.

In this connection it may be well to consider the formation of sedimentaries. In places rocks of many varieties are brought together and intimately mixed by the mechanical action of atmospheric forces, while in other places a most careful sorting may take place; for example, granitic material may be separated into its more acid and more basic parts, producing at one point sandstones and at another shales.

All these sedimentaries, as is well known, are often metamorphosed into completely crystalline schists; indeed, in the opinion of many able geologists, even massive crystalline rocks may be formed directly from them.[2] Prof. W. S. Bayley[3] has described typical quartz-keratophyres on Pigeon Point, Lake Superior, which are probably the result of the fusion of slates and quartzites by intrusive gabbro. Such rocks as these certainly can not be accounted for by chemical segregation, and we are ignorant in how great degree massive crystalline rocks are thus metamorphosed from sedimentaries whose materials have been selected by atmospheric forces.

THE PHENOMENA OF SEGREGATION.

The probability of chemical differentiation or segregation of molten material being admitted in certain cases, however, it would seem that

[1] Gabbros and diorites of Cortlandt series: Am. Jour. Sci., June, 1888, 3d series, Vol. XXXV, p. 440.

[2] Dana, Text-Book of Geology, 4th edition, p. 325.

[3] The eruptive and sedimentary rocks on Pigeon Point, Minnesota, and their contact phenomena: Bull. U. S. Geol. Survey No. 109, 1893.

in the Fortymile dikes we have evidence pointing to such an origin. These dikes consist of rock types which all change gradually into one another, and which have been introduced at successive periods. So far as determined, the earliest intrusions were rocks of intermediate composition, while the last were extremely basic and extremely acid, the acid intrusions being the very latest. All these rocks, varying from the most acid aplite to the most basic hornblendite or pyroxenite, are, however, essentially composed of the same minerals in different proportions, and these minerals are those of granite or granodiorite. The observed succession of these intrusions agrees with Iddings's law; while if the schistose dikes were overlooked, as they might be in too hurried observation, the order would seem to correspond more with that established in Norway and Great Britain by Brögger and Geikie, since on Fortymile Creek the more acid of the unsheared dikes always cut the more basic, and are therefore younger. The essential result of this is evidence that an original granitic magma seems to have separated into more acid and more basic portions.

CONTEMPORANEOUS INCREASE OF SILICA AND WATER.

In the crystallization of igneous rocks there is a definite order in the formation of the different minerals. According to Iddings,[1] ordinarily the oldest minerals are the iron ores, with zircon and apatite, which are followed in turn by one or more of the ferromagnesian silicates and the feldspars, with a feldspar and quartz as the last mineral to crystallize. In different rocks the order varies slightly, but as a rule the more basic mineral crystallizes out first. The order of succession is shown by the rock structure, since the first-formed minerals have perfect crystalline form and are often inclosed by the later minerals, which are without definite crystallographic boundaries, but fill interstices left by those already formed. Therefore, in a magma which is in the process of consolidation the more basic elements crystallize out first, and the residual liquid portion becomes more and more acid with the progressive solidification of the basic constituents. If, moreover, the partial solidification is attended by segregation, as seems highly probable, the original magma becomes separated into a solidified basic portion and a fluid acid portion. That basic rocks crystallize at higher temperatures than acid ones is shown by their contact phenomena. Cases of the alteration of the country rock of a dike or other intrusive body by actual heat, producing baking, melting, coking, and calcination, are chiefly confined to basic rocks; the change is shown to a less extent by intermediate rocks, and never by acid ones, such as granite.[2]

All rocks contain water, partly in chemical combination and partly as inclusions, as shown by microscopic study and by chemical analysis. The molten materials, however, contain much more water than

[1] On the crystallization of igneous rocks: Bull. Philos. Soc. Washington, Vol. XI, p. 84.
[2] Geikie, Text-Book of Geology, 3d edition, pp. 597, 600.

the resulting rock; most of this water is expelled at the moment of solidification, together with certain gases and a great variety of other materials held in solution.[1] In the surface lava this escaping water forms the clouds of steam, highly charged with gases and minerals, which arise from fissures, vents, and fumaroles; but when rocks solidify below the surface the expelled waters are forced into the inclosing rock and find their way along whatever channels offer passage.[2] These underground waters, being under great pressure and intensely heated, are capable of holding great quantities of matter in solution, which material is derived from the magma from which they are expelled. Therefore great chemical alteration is brought about in the rocks into which these waters find their way, and it is to them that most of the effects of contact metamorphism are due. The alteration of wall rocks by heat alone is, as stated, confined to the basic intrusives, and even then does not extend beyond a zone varying in width from a few inches to a few feet.[3]

CONTACT PHENOMENA OF ACID ROCKS.

On the other hand, contact metamorphism evidently due to permeating solutions is very common and widespread. It is often the case that rock in contact with intrusive bodies is altered in broad zones, which in extreme cases are several miles in width. The alteration is shown by the rearrangement and recrystallization of materials already in the rock, and by the introduction of new elements and the abstraction of old ones, so that the mineralogical and chemical nature of the rock is often entirely changed—limestones become altered to chert, and sandstones and shales may be transformed into perfectly crystalline schists. That this metamorphism is accomplished by solutions is shown in many ways. Where the intrusive mass cuts rocks of different porosity, such as grits and shales, it has been noted that the more porous grits are altered to far greater distances from the igneous rock than are the comparatively impermeable shales, showing that the former have been more easily traversed by waters flowing away from the contact. The arrangement and succession of minerals also often indicate clearly water action.

Among the new minerals which are formed in these schists many are common which are relatively rare in crystalline rocks of simple igneous origin. These minerals, such as tourmaline and cassiterite, point to the action of gases containing fluorine and boron, which have escaped from the solidifying intrusive rock at the same time as the waters.[4]

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[1] Daubrée, Géologie expérimentale, Paris, 1879, p. 152.

[2] Economic geology of the Mercur Mining District, Utah: Sixteenth Ann. Rept. U. S. Geol. Survey, Part II, 1895, p. 397.

[3] Geikie, Text-Book of Geology, 3d edition, p. 597.

[4] Rosenbusch, Microscopical Physiography of the Rock-making Minerals, Iddings's translation, 2d edition, New York, 1889, p. 184.

This form of contact metamorphism, due to permeating waters containing gases and minerals in solution, is chiefly confined to the acid rocks, being especially remarkable around intrusive masses of granite. It seems undoubtedly true, therefore, that the molten material from which granite solidifies contains more water than the basic magmas.

CRYSTALLIZATION OF GRANITE.

This conclusion is corroborated by the presence in granite of certain minerals, such as gadolinite, orthite, and allanite, which alter their physical characters at such a slight degree of dry heat that it is evident they can not have been formed by cooling from fusion, while it has been proved that they could have formed in the presence of water. It is only by supposing that water is present in these acid magmas, moreover, that the order of crystallization in granite and other rocks can be explained, for this order is by no means dependent upon relative fusibility.[1]

CRYSTALLIZATION OF PEGMATITE.

In the process of differentiation or segregation, therefore, we may believe that by the progressive separation and consolidation of the more basic constituents the residual portion becomes progressively more acid and more aqueous. The evidence of this in the case of granite has just been described. Passing from granites to the next rock in the scale of acidity, pegmatite (which, as described, frequently forms a perfect transition between granite and quartz veins) bears striking evidence of the presence of abundant water. These pegmatites are often found in narrow dikelets which are persistent for long distances, and even in isolated lenses in the schists of contact zones, these lenses[2] having no communication with the granitic body which has produced the metamorphism, although they occur in the vicinity of that body. In these cases, especially in the latter case, the material from which the pegmatites were formed must have been greatly attenuated in order to traverse the schists in the absence of well-defined fissures and finally to deposit the pegmatite in favorable openings. Attenuation of the fluid which has produced pegmatite is also shown by the extreme freedom of circulation which must have prevailed to permit crystallization on so large a scale as we find it, for beryls a yard in diameter and spodumenes and feldspars over 30 feet in length have in extreme cases been produced.[3] Many of the peculiar minerals characteristic of the zones of contact metamorphism in the vicinity of granite are also found abundantly in pegmatites, such as tourmaline, less frequently cassiterite, and many other rare minerals.

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[1] Geikie, Text-Book of Geology, 3d edition, p. 308.
[2] G. H. Williams, Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 679.
[3] Crosby and Fuller, Am. Geologist, March, 1897, p. 154.

ORIGIN OF CERTAIN QUARTZ VEINS.

Finally, the pegmatitic rocks, by the disappearance of feldspar and mica, grade into pure quartz veins which show by their structure (since they penetrate to the most minute crevices and exhibit frequent banding and comb structure) that they have been deposited from solutions so attenuated that they may best be described as waters highly heated and heavily charged with mineral matter in solution.

Therefore a complete series of rocks like that which we have on Fortymile Creek, ranging from ultrabasic rocks, consisting essentially of metallic and ferromagnesian minerals, to pure quartz veins, may be conceived to have formed by a process of differentiation or segregation, the crystallization of the basic portions leaving the residue successively more siliceous and more aqueous, until at the final stage this residue is little more than hot siliceous water, which contains, besides silica, small quantities of many other rock elements which have not been taken up by the rock-forming minerals.

SOURCE OF GOLD IN QUARTZ VEINS.

GOLD IN IGNEOUS ROCKS.

This being considered the origin of quartz veins (such as those of the Fortymile district) which have evident connection with granitic or other igneous bodies, we may next inquire into the source of the gold which they contain. That gold and other minerals found in the veins are present very commonly, though in small quantities, in igneous rocks, especially in dark-colored silicates, such as biotite, hornblende, and olivine, has been shown by the chemical research of Sandberger.[1] Mr. S. F. Emmons[2] has directed a series of careful tests of selected igneous rocks from different localities in Custer County, Colorado, with a view to determining their metallic contents. Five out of the nine rocks tested contained appreciable amounts of silver, and in one of these both silver and lead were found in combination with other bases in the bisilicates. These rocks were trachyte, diorite, rhyolite, and different varieties of granite from different localities.

Prof. G. P. Merrill[3] has described an occurrence of free gold in granite, which he judges to be original. The gold occurs associated with the mica or wholly embedded in the crystals of quartz or feldspar. Professor Merrill also notes that W. Möricke has described free gold, which he regarded as an original constituent, in a quartz-trachyte from Chile.[4]

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[1] Untersuchungen über Erzgänge, 1882.

[2] Seventeenth Ann. Rept. U. S. Geol. Survey, Part II, 1896, p. 209.

[3] Am. Jour. Sci., April, 1896, 4th series, Vol. I, p. 309.

[4] W. Möricke, Tschermaks mineral. Mittheil., III, 1891.

MINERALOGICAL RELATIONS OF PEGMATITES AND QUARTZ VEINS TO IGNEOUS ROCKS IN GENERAL.

In pegmatites are found an unusual number of rare and well-crystallized minerals, besides the commoner species.[1] A study of these minerals shows that the fluid from which pegmatite has consolidated contained most of the elements that enter into the composition of rocks. This fluid, however, as before stated, must have been greatly attenuated, and to this attenuation the segregation of widely different minerals in different parts of the pegmatic body may be ascribed, for it has permitted abundant circulation, and thereby promoted the concentration of materials originally disseminated in minute quantities throughout.

Passing from pegmatites to quartz veins, we find that although the other minerals become greatly subordinate in quantity to quartz, yet of those which do occur there is an extraordinary variety. Henry Louis[2] has compiled a list of no fewer than 77 mineral species, many of them rare, occurring in auriferous quartz veins. Mr. G. F. Becker[3] has made out a list of 62 minerals which occur in the auriferous quartz veins of the southern Appalachians. These species include tourmaline, cassiterite, fluorite, and other minerals which are rare, and which are also characteristic of pegmatite and of the contact zones around acid intrusive rocks. It is found also that muscovite, biotite, and orthoclase occur occasionally as part of the gangue of gold-quartz veins, and this seems to establish a further link between auriferous quartz and pegmatite.

Comparing all the minerals found in pegmatite with those in quartz veins, it appears that nearly all the elements present in the fluid from which pegmatite is formed are also present in that producing quartz veins. Among these elements are nearly all the metals—for example, silver, copper, lead, tin, bismuth, iron, manganese, arsenic, molybdenite, zinc, tellurium, vanadium, tungsten, etc. As ordinary metallic constituents of quartz veins, Louis[4] enumerates iron pyrites, galena, copper pyrites, titaniferous iron ore, arsenical pyrites, zinc-blende, stibnite, and magnetite. Mr. G. F. Becker,[5] in speaking of the gold ores of the southern Appalachians, makes the following statement:

> The gold ores of the South are quartzose deposits with very subordinate admixtures of carbonates in which pyrite is always present, while chalcopyrite is common, and galena, mispickel, and zinc-blende are by no means rare. The long list of the other minerals found in the veins is unimportant, excepting in so far as it assists in elucidating the genesis of the ores. I am unable to see that the accompanying minerals, with the one exception of pyrite, serve in any way as an indication of the value or extent of the ore bodies.

[1] G. H. Williams, Fifteenth Ann. Rept. U. S. Geol. Survey, p. 675. Crosby and Fuller, Am. Geologist, Vol. XIX, No. 3, p. 150.

[2] Mineralogical Mag., Nov., 1893, p. 241.

[3] Sixteenth Ann. Rept. U. S. Geol. Survey, Part III, 1895, p. 274.

[4] Op. cit., p. 246.

[5] Op. cit., p. 280.

In the Alaskan veins no opportunities for careful observation of gangue materials on a large scale were offered, but some of the most important minerals, such as galena, pyrite, chalcopyrite, magnetite, barite, calcite, etc., were noted as occurring; and it seems probable they are like quartz veins in other parts of the world.

MANNER OF CONCENTRATION OF GOLD.

In quartz veins as a whole, therefore, we appear to have, besides silica, most other elements in small quantities, including gold. It has already been suggested that the Alaskan veins, which are so intimately connected with acid intrusive rocks, have been deposited from the residual fluid left by the crystallization of these rocks. We may therefore conceive that the water expelled from the crystallizing granite or aplite contained chiefly silica, and also gold and many other elements, in solution. All these elements were probably very uniformly and minutely disseminated in the residual fluid, as they are in the igneous rocks. Water discharged from cooling rocks is highly heated, and in these granites and aplites, which have solidified at a considerable depth below the surface, the expelled waters must also have been under great pressure, so that the solvent power was vastly increased, although the circulation was not greatly impeded thereby.

This residual fluid is probably of a chemical character especially well suited for holding gold in solution; yet it is not necessary to suppose that the metal is present in quantity relatively much greater than in igneous rocks. It is to be remembered that, were the gold disseminated in igneous rocks concentrated, we should have in places rich deposits. In the process of solidification of these rocks, however, the materials are probably much less fluid than those from which quartz veins are formed. Therefore circulation is slight, the crystals formed are small, the rock is comparatively uniform, and the gold and other metals, not having opportunity to segregate, are generally disseminated throughout. As the magma becomes more fluid, however, circulation becomes greater, crystals grow to greater size, and the metallic elements are permitted to segregate. It is well known that quartz veins are pockety—that is, are in places rich in gold and in other places barren, and that in the same district some veins carry gold while others do not carry appreciable quantities.

MANNER OF SOLUTION AND PRECIPITATION OF GOLD.

Gold is soluble in many of the commoner salts;[1] and it has been pointed out by various writers that silica and gold may often pass into these solutions and be deposited from them under the same conditions.[2] In the precipitation of the gold it is probable that pyrite

[1] Frémy, Encyclopédie chimique, Tome III, 16e cahier, p. 43.

[2] Mr. G. F. Becker, Sixteenth Ann. Rept. U. S. Geol. Survey, Part III, 1895, p. 288. Dr. T. E. Egleston, Trans. Am. Ins. Min. Eng., Vol. IX, p. 643 et seq.

and other sulphides already formed are important factors. Of all the metallic minerals with which gold is associated in quartz veins, iron pyrite is most abundant, and its presence seems to be in a limited way indicative of the richness of the vein. Microscopic examinations of this pyrite generally show metallic gold, which has been deposited sometimes upon the pyrites, sometimes simultaneously with it; and in the laboratory it has been shown that pyrite is one of the best precipitants of gold from solution. Often, however, the pyrite of quartz veins is not associated with gold, and, on the other hand, gold frequently occurs isolated in the quartz and is pure, except for containing small proportions of silver and other metals. In this latter case the gold must have been precipitated by other means, probably often simply by change of temperature or pressure.

OBSERVED CONNECTION OF GOLD-QUARTZ VEINS WITH INTRUSIVE ROCKS.

The connection of auriferous quartz veins with intrusive igneous rocks, especially diorite and granite, has long been known. In Australia the gold-quartz veins, in certain localities at least, occur at the contact of diorite and schists, and in the Urals the presence of gold depends upon the occurrence of eruptive rocks and tectonic disturbances.[1] Prof. J. D. Whitney[2] notes that in California, while the granite itself is not metalliferous, its appearance seems to be closely associated with the metamorphism of the adjacent sedimentary rocks, while this latter condition is, as a general rule, the concomitant of the occurrence of minerals or metalliferous veins. On the Pelly River in British Columbia, on a part of the Yukon gold belt, Dr. G. M. Dawson[3] found evidence to show that the development of quartz veins had occurred contemporaneously with the upheaval of the granites, and probably by some action superinduced by the granite masses themselves while still in a formative condition. All the observations made in the Yukon gold district by the United States Geological Survey party under the charge of the present writer point to the same conclusion, and these observations have already been fully detailed.

SUMMARY.

A theory of the genesis of auriferous quartz veins may therefore be summarized as follows:

A molten magma may become segregated or differentiated into distinct portions by the successive precipitation of basic and the excretion of acid portions. With increasing amount of silica in the residue there is also an increasing proportion of water over other materials, this water being in all cases in a high state of union with the other

[1] K. von Kraatz, Am. Geologist, Vol. XVIII, No. 2, p. 107.
[2] Auriferous Gravels of the Sierra Nevada, p. 353.
[3] Ann. Rept. Geol. Nat. Hist. Survey Canada, Vol. III, part 1, p. 35B.

materials so long as these materials are unsolidified; this state of union may be either chemical or physical. In the final residue the fluid becomes so aqueous and so siliceous that it passes with no sharp division line into highly heated, siliceous waters, which contain also small amounts of most of the other rock-forming elements, and among them gold. Gold occurs in the igneous rocks, but is uniformly disseminated, since it has no opportunity to segregate on account of the relatively slight fluidity of these rocks during the process of solidification. In the final highly siliceous and highly aqueous residue, however, the fluid becomes so attenuated that circulation becomes very free, and concentration of the rarer elements is permitted; so the gold is segregated, often into pockets of considerable size; and in a like manner other materials are concentrated, generally independent of the concentration of the gold. It is also probable that the residual solution is, owing to physical or chemical conditions, or both, especially adapted to the retention of gold, and therefore is relatively richer in this metal than ordinary metalliferous solutions, and possibly more so than the molten magmas out of which the igneous rocks solidified.

This theory is not intended to apply to the occurrence of gold in any other form than in the typical gold-quartz veins.

MAP OF FORTY MILE CREEK, ALASKA.

From track survey by U. S. Geological Survey party in charge of J. E. Spurr. The portion of Forty Mile Creek below the International boundary is from a survey by J. E. McGrath of the U. S. Coast Survey. The location of International boundary from a survey by W. Ogilvie, Canadian Geological Survey.

Scale

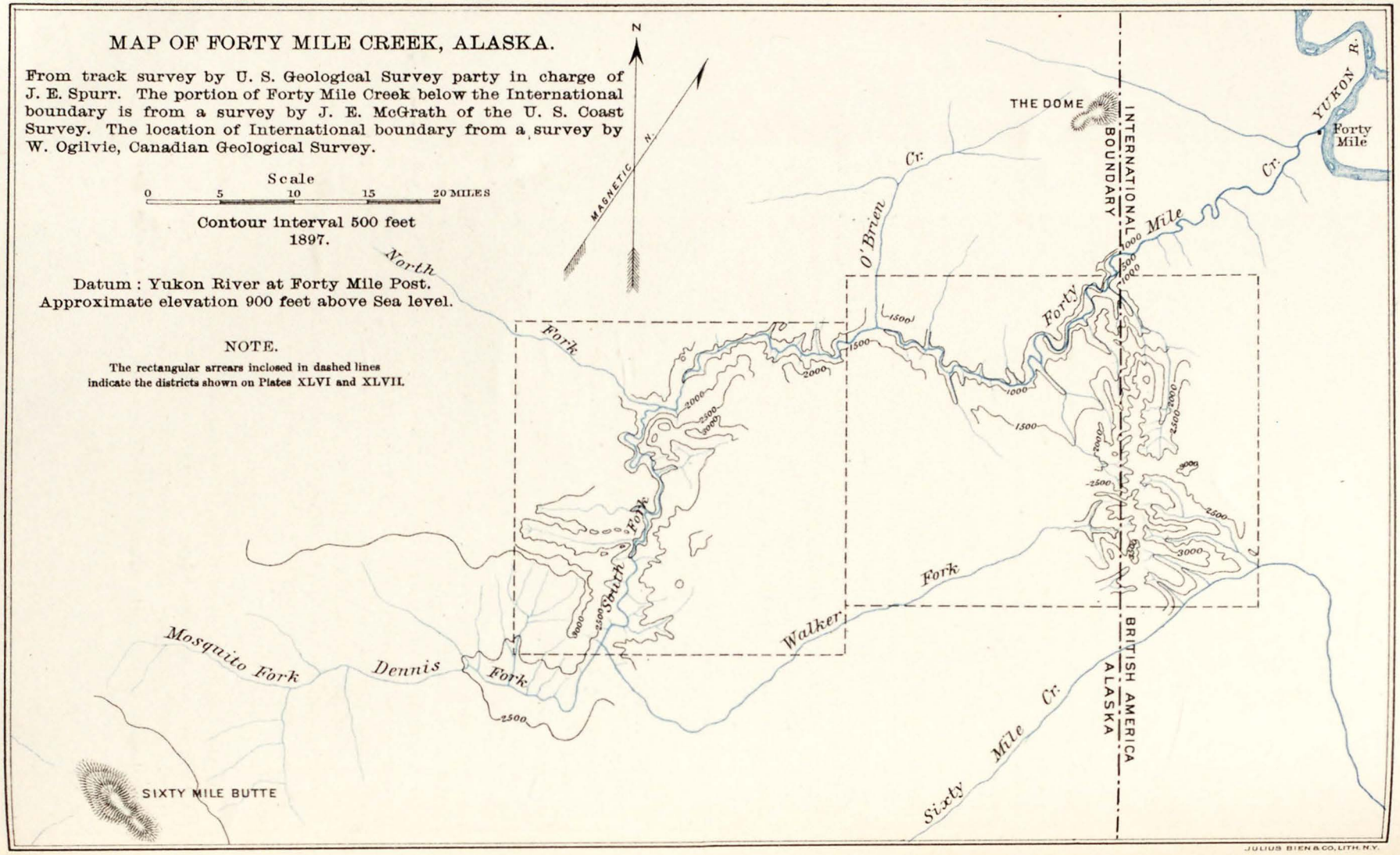
0 5 10 15 20 MILES

Contour interval 500 feet
1897.

Datum: Yukon River at Forty Mile Post.
Approximate elevation 900 feet above Sea level.

NOTE.

The rectangular arrears inclosed in dashed lines indicate the districts shown on Plates XLVI and XLVII.



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CHAPTER VI.

PLACER DEPOSITS.

Throughout nearly the whole of Alaska gold is found disseminated in the detritus which has been derived from the abrasion of the solid rocks. Often it is in such small amount that it can not be profitably extracted, but sometimes it is concentrated by water action in such degree as to invite mining. Thus far the profitable deposits have all been found in or near the beds of the present streams. These recent gravels may be divided into two chief classes. In the larger streams accumulations of gravel are made in places of slackening current, such as the inner or concave sides of curves. These accumulations are called bars, and often contain much gold. The other occurrence is in the small gulches which feed the larger streams. In the bottom of these gulches the gravels are frequently very rich in gold, and as these are easily worked, they constitute at the present time the most important class of placer deposits.

GULCH DIGGINGS.

FORTYMILE DISTRICT.

The Fortymile placer mining district includes some gulches which run into Fortymile Creek, and some which run into Sixtymile Creek. Through this district the international boundary runs, dividing it so that the gulches which flow into Sixtymile Creek, such as Miller and Glacier, are in British territory, while the greater part of the district is American. Pl. XLV is a map of Fortymile Creek and vicinity so far as is known. This map is from sketches made by the Geological Survey party under the direction of the writer, with the exception of that portion of Fortymile Creek which lies between the international boundary and the Yukon, which is taken from a survey by the United States Coast Survey. The topography, so far as was observed, is indicated on this map by contours at intervals of 500 feet. The position of this district in relation to the rest of the Yukon gold belt is indicated on the general map of the gold belt, where the area occupied by the Fortymile map is shown by broken lines.

DISCOVERY.

In the fall of 1886 gold was discovered on the bars of Fortymile Creek by a prospector named Franklin, and this was quickly followed by the finding of gold in the different gulches. A fuller account of the discovery and subsequent history is given in a previous chapter.

BED-ROCK GEOLOGY.

The bed-rock geology of the Fortymile district is described in the chapter on the geological column, and will be here only briefly summarized

The general structure is that of an east-west-trending anticline, the axis of which is in general parallel to the main trend of Fortymile Creek, and at one place runs along the divide between the Sixtymile and Fortymile waters. Along this axis is exposed a basal schistose granite, and on the flanks of the fold are quartzite-schists belonging to the Birch Creek series; and above these, marble, quartzite-schists, and more highly metamorphosed hornblende- and mica-schists, which are called the Fortymile series. In these rocks are dikes of all kinds, sometimes in great abundance, especially on the South Fork of Fortymile Creek. On the upper part of the South Fork, in the vicinity of Chicken and Napoleon creeks, are green tuffs and slates belonging to the Rampart series. All these rocks are unconformably overlain on Chicken and Napoleon creeks by the conglomerate, sandstone, and coaly shales of the Mission Creek series. Finally, on the same two creeks there occur large patches of Tertiary basalt. The most marked break in this series is that separating the Mission Creek conglomerate from the underlying Rampart and Fortymile rocks.

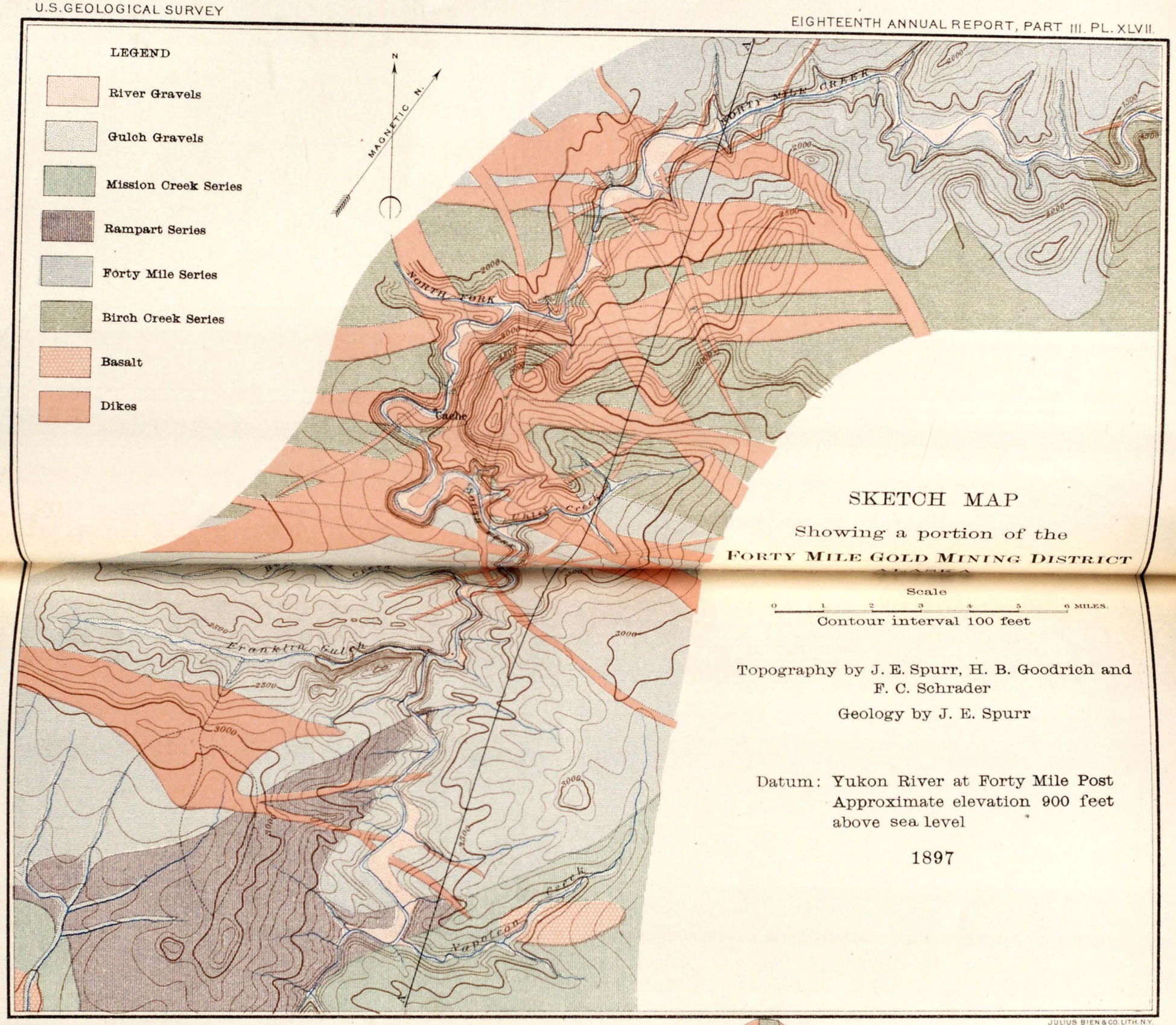
Both the Fortymile and the Birch Creek series are filled with quartz veins, many of which are auriferous. These veins furnish gold to the stream gravels.

GEOLOGICAL MAPS.

A very rough geological map embodying the results obtained in the Fortymile district has been prepared, and has been divided into two sheets (Pls. XLVI, XLVII, the former in pocket). The areas represented on these sheets are indicated by broken lines on the general map of the Fortymile district.

Sheet 1 represents the geology in the region of Miller, Glacier, Poker, and Davis creeks, the Fortymile-Sixtymile divide, and a portion of the main Fortymile Creek. On this map the gulch gravels and the river gravels are distinguished by separate colors. The gulch gravels are continuous, for they are directly made up of talus from the steep slopes, which the small supply of water in the gulches is insufficient to remove. They are everywhere present. In the main creek, however, are large supplies of water, in many places sufficient to keep the channel free from accumulations, and only in regions of slack current do gravel accumulations, or bars, form. Therefore on the map the river gravels are rightly represented as being intermittent.

In this map the granitic axis of the Fortymile anticline is shown, flanked on both sides by the Birch Creek schists, which are succeeded to the north and to the south by the rocks of the Fortymile series. In the northwestern part of the map frequent dikes are seen cutting the schists. These dikes are of a great variety of rock, as already



SKETCH MAP

Showing a portion of the

FORTY MILE GOLD MINING DISTRICT

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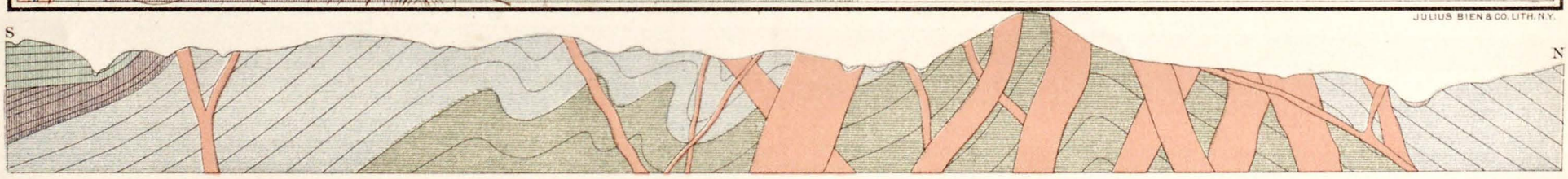


SECTION ON LINE A-A. VERTICAL SCALE 4 TIMES EXAGGERATED.

fully described, but the different types change into one another so gradually that it has been thought best not to attempt any classification. The different ages of the dikes, however, and the manner in which they cut one another, are indicated by their outlines.

Sheet 2 represents an area lying just west of that shown on sheet 1, and comprises Fortymile Creek above O'Brien Creek, the South Fork of Fortymile, and Franklin and Napoleon creeks, with the head of Chicken Creek. On this sheet the gulch and river gravels are indicated as on sheet 1. In this region the westerly pitch of the Fortymile anticline has apparently carried the granite exposed farther east along the axis of this fold beneath the surface, its place being taken by the Birch Creek schists; and to the north and to the south of the Birch Creek schists lie the rocks of the Fortymile series. The axis of the fold at this point, however, is occupied by a great profusion of dikes, some of immense size, and these have so altered and distorted the rocks which they cut that their structure, and even their nature, is not always certain. Like the dikes shown on sheet 1, these are of all varieties, from extremely acid to extremely basic; yet here, also, no classification has been attempted, save that given in the chapter on igneous rocks, and they have been mapped under one color, the difference in age being shown by their outlines. On Chicken Creek, and on Fortymile Creek above Franklin Gulch, the Fortymile rocks are overlain by the green shales and tuffs of the Rampart series, and both the Rampart and the Fortymile rocks are overlain unconformably on Napoleon and Chicken creeks by the conglomerates, sandstones, and coaly shales of the Mission Creek series. Finally patches of Tertiary basalt are found on Napoleon and Chicken creeks and are represented on the map.

Accompanying these two geological maps are rough cross sections constructed on an exaggerated vertical scale, and intended to convey an idea of the general structure, although no pretensions to accuracy of detail are made. In the cross-section accompanying sheet 1 the Fortymile anticline is shown, and occasional dikes, cutting the schistose rocks. In the section accompanying sheet 2 the same anticline is seen, but the rocks along its axis are much distorted by the great abundance of igneous intrusions. At the left of the section the Rampart series and the unconformably overlying Mission Creek series are represented.

DESCRIPTION OF GULCHES.

The different gulches in the Fortymile district which have produced placer gold in notable amount will now be described in detail. Of these descriptions the reports on Miller and Chicken creeks are by J. E. Spurr; those on Poker, Davis, and Franklin creeks by H. B. Goodrich; and those on Glacier and Napoleon creeks by F. C. Schrader.

MILLER CREEK.

Miller Creek has probably been the most productive of the gulches in the Fortymile district, and lies in the immediate vicinity of other gulches which have been notably productive, such as Glacier, Poker, and Davis creeks. The waters of Miller and Glacier creeks flow into Sixtymile Creek, while those of Poker and Davis creeks are part of the headwaters of Fortymile Creek. The drainage areas of Sixtymile and Fortymile creeks are separated by a ridge of moderate height, whose top is comparatively flat and forms part of the general plateau in which the streams have excavated their deep valleys in late geological time.

Miller Creek was first prospected immediately after the first discovery of gold in this region, which was about 1887, on Franklin Gulch. A few years ago it was the busiest spot on the Upper Yukon, but at present the richest diggings have been largely worked out, and the new discoveries in the Birch Creek district and elsewhere have drawn off most of the mining population. In the winter of 1895–96 there were about 500 miners in this vicinity, mostly on Miller Creek, but in the spring more than half of that number left for the diggings on Birch Creek, so that the entire number of men working in the district at the time it was visited (in July, 1896) was only about 200. It is on Miller Creek, however, that the richest strike yet made in the Yukon diggings was made by John Müller, who cleared from one claim of ordinary size (500 feet along the bed of the gulch) a sum which is variously estimated at $30,000 to $50,000 as the result of the work of two winters and one summer. During this time he employed on an average about 8 men, at times as many as 18, paying them $10 a day in summer and somewhat less in winter. In this as in other cases it took some time to get the claim ready for working before any gold was actually produced, so that it was actually worked four years in all, with the profit above stated. This profit is, however, exceptional, and although several other men have left Miller Creek with "stakes" of $3,000 or $4,000, yet many more have made only "wages"—that is, $10 a day—and some do not make that.

Shape of valley.—The length of Miller Creek from its junction with Sixty Mile Creek is about 6½ miles, and its course is nearly straight. The gradient of its bed is considerable, as is the case with all other streams in this region, and this gradient increases slightly toward the head of the creek. At the extreme head the slope becomes very steep, the angle nearly corresponding with that of the sides of the valley farther down.

In general the valley is V-shaped, but at the head it widens and shows a tendency to assume a more curved, or U-shaped, outline in cross-section, thus suggesting a glacial amphitheater or cirque. It is indeed probably to ice action that this broadening and flattening is due. In the winter ice and snow accumulate and have a tendency

to move from the dividing ridge down the steep slopes which the rapidly cutting stream has left; so that during the spring months, when the ice is softening and melting, the head of the valley is occupied by a veritable though small and transient glacier. The rounding of the head of the valley and its gradual alteration into the form of a cirque is due in part to the moving of the ice, but perhaps more largely to the erosion of the glacial waters, which are distributed over the whole width of the valley instead of being concentrated in its bottom, as are the streams that have no dependence upon ice. As the ice melts great furrows and ditches are formed on the glacier, and the water flowing from these and falling over the ice front forms waterfalls which churn up the gravel and carry it down the valley, so that the bed rock is often laid bare; and as the front of the ice recedes this vigorous erosion is brought to bear upon successively higher parts of the valley. This action is of economic importance, since it prevents accumulations of auriferous gravels within areas in which it operates—a fact which has been proved by prospecting.

The heads of the other gulches in this vicinity show the same tendency to develop an amphitheatrical form. Glacier Creek in particular has a cirque which is much more symmetrical than that of Miller Creek. The explanation is that on Glacier Creek the glacier is larger and more persistent on account of many springs which furnish an abundant flow of water from underground sources and help materially in the accumulation of ice.

The steep sides of the Miller Creek Valley are indented by furrows or gullies, usually small. These are called by the miners "pups." This term appears to have originated in Miller Creek, and since it has spread all over the gold districts, as a consequence of the scattering of the Miller Creek miners, it may be of interest to note its derivation as given by an old miner. Some years ago a miner by the name of Müller, who gave his name to the creek, came into the possession of some pups, which he reared for the purpose of freighting; for in this country the dog is what the reindeer, the horse, and the camel are in other regions, constituting almost the sole means of transporting articles from place to place. Müller kept his pups a short distance up the ravine, a little way from his camp. Miners seeking for some term to designate this ravine used to call it "the place where Müller keeps his pups;" but this long circumlocution became naturally shortened in course of time, so that the phrase was simply "Müller's pups;" and eventually the plural was omitted, and the ravine became "Müller's pup." The term seemed to fill a gap in the nomenclature of the miners, and from Miller Creek it was carried for many hundred miles in all directions. It has a perfectly definite application, being restricted to the short, usually dry ravines of very steep gradient which furrow the hills and run into larger and well-marked valleys.

Gravels.—What has been said in regard to the character of the

Miller Creek Valley will enable one to understand better the nature and distribution of the stream gravels in which gold is found. Near the head of the valley there is a very thin covering of detrital material, and in many places the bed rock is laid bare, or is hidden from the observer only by the thick growth of moss which tends to cover everything throughout this country. At about 2½ miles from the head there are 3 or 4 feet of gravels, and farther down the thickness increases, until at the junction with Sixtymile Creek it is about 18 feet. These gravels are made up of flat fragments of schist and bowlders, exactly like the rock outcropping on the steep sides of the valley. These fragments show some slight water action, in that they all lie flat and are stratified, but are very little worn. The feebleness of the current which has arranged the deposit is shown by the fact that mixed with the larger fragments is considerable fine detritus, which the stream has not been strong enough to separate. In the thicker gravels the material is very nearly the same from top to bottom, except that at the top the materials show a tendency to become finer, and on the very surface there is often a foot or two of fine soil, with fewer fragments of schist. Through the upper 3 or 4 feet of the gravels, as seen in cuts made in the process of mining, there are often layers of rotten moss and wood alternating with the gravel, indicating temporary periods of vegetation.

The gold found is always at the bottom of the gravels, whatever the thickness may be. Gravel which contains gold in workable quantity is technically called "pay dirt." It is usually not more than 3 or 4 feet thick, and from this runs down to a few inches or less. The bed rock itself, at the junction with the gravel, usually contains gold, and sometimes pays for working for as much as 2 or 3 feet down. Often this uppermost zone of schist is richer than the gravels.

The frequent divergence between the channel of pay dirt in the gravels and the channel of present drainage is sometimes due to the natural wanderings of the stream from side to side, and partly to forced changes of position, such, for example, as may be effected by landslides. Near the uppermost limit of pay gravels a landslide has pushed the creek to the north, producing a slight bend. In the present creek bottom there are only 3 or 4 feet of gravels, while the landslide material when stripped away reveals 7 or 8 feet of older gravels, which are also auriferous.

Owing to the fact that the valley is V-shaped and that the gradient is sufficient to prevent any considerable silting-up of the upper portion, the gravels are extremely limited as to width as well as to thickness, the average width being probably not more than 50 feet. The richest gravel, however, occupies certain narrower zones, one of the richest spots which has been found showing a pay streak only 3½ feet wide, although it is 6 feet in thickness. This pay streak is a channel of gravels rich in gold and bounded on both sides and on top by

more barren material. It sometimes lies directly under the present bed of the stream and sometimes to one side of it.

For about 2½ miles at the very head of the creek gold has not been found in sufficiently large accumulations to pay for working under present conditions. This fact is explained by the greater amount of erosion in this portion of the valley, and this is due partly to the steep slope, which increases the carrying power of drainage waters, but chiefly to the effects of the local glacier, which has before been referred to. According to the observations of miners, the front of the Miller Creek glacier coincides very nearly with the upper limit of pay gravel, showing that the more violent action of the waters derived from the melting ice prevents the concentration of the gold particles. Just below the maximum extension of the temporary glacier the gravels are thin and the gold is very coarse and present only in comparatively small amounts, so that it yields, as a rule, slight profit. Farther down the creek the gold becomes finer, but also more abundant, and the richest part of the gravels thus far discovered, which is on Miller's claim, above referred to, is situated a mile or so below the limit of pay dirt and contains gold in grains of medium size. Still farther down the creek the gold becomes on the whole finer, a sample of it presenting a very striking contrast with that taken from the head of the creek. Throughout the whole length of the diggings, however, there is occasionally coarse gold mingled with the finer material. Pieces ranging in value from $5 to $15 are common. The richest nugget taken from the creek was found about half a mile below the limit of pay dirt and weighed 5 ounces. It contained a small proportion of quartz.

It is interesting to note that, besides the gold found in the bed of the main stream, a number of the small ravines or pups also contain gold. This gold is coarse, owing to the steep slope on which it lies, but enough has been found to encourage mining, sometimes with fair results.

Source of gold.—Throughout the schists which constitute the bed rock are many veins of quartz-carrying pyrite. Large blocks of this quartz are common in the gravels, and occasional pieces show free gold. The large pieces of rusty quartz, on crushing and panning, often yield many fine "colors" of gold, while the pyrite which is separated from these veins and also from the schists (in which it occurs sporadically disseminated) yields gold after roasting. Free gold was also found in a quartz vein in place, situated in one of the ravines or pups near the head of the creek. These things show that gold occurs disseminated throughout the schist and the quartz veins, and is apparently associated with pyrite and other sulphides; and since the gravel consists entirely of detritus immediately derived from these rocks, the source of the placer gold is quite certain. The galena, which is found in fragments of all sizes in the gravels, is also derived from deposits in the schist. Such a deposit occurs about

4,000 feet above the uppermost claim being worked in 1896; here the galena occurs in irregular blotches in quartz veins. Other deposits are found in the vicinity.

GLACIER CREEK.

The first gold discovered on Glacier Creek seems to have been in 1892. In that year, however, but little work was done beyond prospecting and staking claims. The history of the gulch shows no record of "booms," but the yield has been fair from the start. In July, 1896, there were said to be about 150 men at work. This was but three-fourths of the number engaged during the more busy part of the spring season, when the supply of water was ample for sluicing.

Shape of valley.—The valley of Glacier Creek is V-shaped, notably in the upper part, with sides normally steep, especially on the south. In the lower part it is less trenchant, changing in form from a V gradually to a U as it opens out toward Gold Creek.

The gentler slope on the north side, as compared with that on the south, seems to be due to the more direct exposure to the rays of the sun during the long days of sunshine in the summer months; so that this side is subjected to a greater degree of thawing and regelation, and consequently weathering and erosion take place more rapidly than on the south side, where the rocks remain for the most part solidly frozen throughout the greater part of the summer. It is also possible that a tilt or uplift of the region on the north may have operated to shift these streams southward, and thus cause them to intrench themselves in the south side of their valleys.

It is also at once noticeable that the south side of Glacier Creek Valley is more conspicuously furrowed by side gulches, or, in miners' language, "pups," than is the north side. These pups, about a half dozen in number, vary from half a mile to 2 or more miles in length, and are often sharply trenchant or V-shaped, showing a great concentration of downcutting by the little stream which drains them. Their gradient is, of course, much steeper than that of the valley or main gulch, but,like the main valley, each pup usually heads in a roughly amphitheatrical form of its own. Normally, the pups are occupied by very small streams; in springtime, however, when melting is rapid, the claims at their mouths are said to be much harder to work, by reason of the superabundance of water which they discharge.

The head of Glacier Creek Valley is quite steep and is of the amphitheater or cirque type. The form seems to be due to local glaciers or masses of snow and ice which accumulate in the heads of the gulches during the long cold winters and usually melt during summer. Where the conditions of precipitation and attitude of the head of the gulch in relation to the sun's rays are favorable, the accumulations may become perennial, as seems to be the case at the head of Squaw Gulch, near where the Davis Creek and the Miller Creek trails separate. From the more than ordinarily high divide here, the head of the

gulch descends very abruptly to the northwest, and contained as late as the middle of July (1896) a considerable deposit of snow and ice, apparently more than would be removed by melting during the remainder of the summer.

Glacier Creek derives its name from these local and more or less transient glaciers, which form every winter, and, continuing to creep down until late in the winter or spring, materially interfere in some localities with the miners' work. In the upper part of the gulch remnants of some of these glaciers doubtless linger throughout the summer or become perennial; for considerably below the upper limits of where prospecting has been carried on, as late as the middle of July the creek banks at frequent intervals for stretches of 100 or more yards were lined by overhanging cliffs of solid blue ice 6 or 8 feet in thickness.

All the gold taken out of Glacier Creek has been obtained by placer mining; consequently from near the mouth of the creek to within a mile or so of its head the valley has been staked off, making some sixty claims in all. A claim on Glacier Creek is 500 feet in length, measured parallel with the valley, and extends laterally from rim rock to rim rock, or as far in this direction as the gravel deposits may occur. In the upper or V-shaped part of the valley this lateral extent of the gravels is usually very limited, often to 20 yards or less, while in the lower part, as in the vicinity of the Discovery claim, it attains a width of from 25 to 100 or more yards. The thickness of the gravels is only 8 feet or less in the upper part of the valley, but increases gradually downstream, until a thickness of 20 or more feet is reached.

Bed-rock.—The bed-rock in Glacier Creek is quartz-mica-schist, or hornblende schist, often graphitic. This rock contains much free quartz in more or less continuous veins, lenses, and large lenticular and irregular masses. Near the head of the gulch, on the upper slope of the divide between Glacier and Miller creeks, so abundant is the quartz that in places it forms almost the whole rock. Much of it, however, is in the form of residual bowlders, which have probably resulted from long periods of weathering down of the country rock which formerly inclosed them.

The only place in the gulch where gold-bearing quartz has been discovered in place is on claim No. 3, below Discovery, toward the lower part of the gulch. Here a quartz vein 18 inches in thickness is claimed by the owners to assay $5 per ton.

Toward the head of the gulch, where the rock outcrops near the creek, the strike of the schistosity is N. 54° E. and the dip 25° SE., but farther down the dip seems to be northward. In the lower part of the gulch the strike of schistosity is N. 11° W. and the dip is 12° N. On the ridge north of Glacier Creek the strike is N. 12° E. and the dip 8° SE.

Gravels.—The fragments in the gravels are made up entirely of

schists and quartz derived from the adjacent bed-rock. In the upper part of the gulch they are more angular than in the lower part, and the deposit sometimes resembles talus; farther down the valley sand and clay appear and form a conspicuous part of the deposits toward the mouth. The following vertical section, roughly estimated on claim 20, above the Discovery claim, is a fair average of the gravels for the middle and upper part of the present diggings:

Section (from top downward) on claim 20, above the Discovery claim.

	Feet.
1. Alluvial soil and moss, sometimes mucky	1½
2. Pebbles of quartz-schist as large as the hand, with bowlders of quartz often 6 inches in diameter, and a few small bowlders of porphyritic dike rock; these are mixed with some sand	6½
3. Alluvial soil or peaty muck, clearly a surface formation (generally, though not always, persistent)	2
4. Gold-bearing fine gravel, known as "Chickenfeed" by the miners, resting on bed-rock	10
	20

The coarse gravel (No. 2) is often interstratified with thin layers of imperfectly stratified soil and sand. These interstratified layers are horizontal, but show some slight crumpling, as if they had been deposited on ice, at the subsequent melting of which they settled down to their present attitude; or they may have otherwise suffered disturbance by ice movement while yet near the surface.

Some of the quartz bowlders in these upper gravels are traversed by small veins of galena; also upon and in a fragment of schist was found disseminated malachite. In the lower layers or "pay gravels" (No. 4) are found fragments of botryoidal iron ore. In the gold from these gravels occur nuggets up to several ounces in weight, often with crystalline quartz still adhering, showing clearly the original association of the two.

POKER CREEK.

Poker Creek or Gulch rises in the Bald Hills, which form the divide between Fortymile and Sixtymile creeks, at a point 40 miles southwest of the Yukon. Its source is opposite the head of Glacier Creek, 18 miles from Fortymile Creek, in the drainage basin of which it belongs. According to a proclamation issued by Captain Constantine, of the Canadian mounted police, at Fort Cudahy, the one hundred and forty-first meridian, which constitutes the international boundary line, crosses Poker Creek 1 mile below the divide, giving to British territory 1 mile of its headwaters. The line was surveyed by Mr. W. M. Ogilvie, of the Geological Survey of Canada, from its point of intersection with the Yukon southward nearly to Sixtymile Creek, and its course is marked by a cutting 20 feet wide through the timber straight across country. In 1891 a United States Coast Survey

party determined the location of its intersection with the Yukon and with Fortymile Creek, but as yet there has been no cooperation to determine other points on the line. A great number of the miners are unreasonably inclined to dispute the accuracy of the survey, and many think even that Miller and Glacier creeks are in Alaska, but, so far as we are able to judge, there is no reason for this belief. However, the location of the boundary has no importance on Poker Creek, for all the paying claims are well within the Alaska limits.

Last spring (1896) the first work was done on the gulch, and in the middle of July only three claims were working. These are all at or near the mouth of the creek. The low stage of water was a hindrance to sluicing, there being hardly enough water to cover the riffles in the sluice boxes. But as the creek had been opened so recently, time that would have been absolutely lost in a later stage of development was put in to good advantage in stripping the barren gravel and in other dead work.

Shape of valley.—The head of Poker Creek is an amphitheater with small torrential branches and steep gullies. From the main divide the descent is at first very sudden, being by barometer 600 feet in a little over half a mile. For 3 miles below this the fall is gradual, being scarcely over 150 feet to the point where Poker Creek enters Walker Fork. The valley is rather wide, with side slopes averaging 20° near the boundary, and becoming less steep farther down. At the mouth, by the combined erosion of the Davis, Poker, and Walker Fork, bottom lands half a mile wide have been formed and the ridges have been reduced to smooth, rolling outlines. These gently curved ridges are termed "hogbacks."

The cause of the steep grade and amphitheatrical form at the headwaters is, as upon Glacier Creek, due to the fact that for a part of the year the valley is occupied by small glaciers. At the time of visit, in July, areas of snow and ice from a hundred square yards to an acre in extent still existed at the heads of many of the smaller branches. To a limited extent, therefore, the snow is perennial, for about the latter part of August or the first of September the first snowfall occurs. Some melting goes on until the last of September, but after that time the accumulation exceeds the melting until the month of May. Precipitation is not great in this part of the country, seldom over 4 feet of snow remaining on the level throughout the winter. The conditions are favorable to the formation of an ice field, or névé, during the eight months of winter. There is almost no motion, however, until the melting in the middle of May; then tongues of ice are sent down the slopes, the ice eats back at the head, the superglacial, and in a less degree the subglacial, streams tend to widen the valley, and the cirque form is intensified. The greatest effect of this glacial action is shown at the head of the valley, for that is the region where the ice remains the longest. By the middle of

June the snow has practically all disappeared from the lower valley, leaving only small patches on the heights and at the heads of ravines.

On the sides of this cirque considerable talus accumulates. Frost is very active in breaking down the cliffs, since there is scarcely a week during the whole year when the temperature does not fall below freezing point at least once; the diurnal range of temperature is also very great, sometimes as much as 60 degrees in summer. Wherever there is the slightest hold for vegetation a thick carpet of moss covers everything and serves to protect the surface against the mechanical action of rain water. There is, however, a flow of the vegetation down the slopes, the effects of which are observed upon many of the steeper moss-covered hillsides all along the Fortymile-Sixtymile divide, and are especially noticeable at the heads of Gold, Glacier, and Poker creeks. The appearance presented at a distance is that of escalops. These are formed by little ridges of moss which lie on the slope, convex end downward, resembling in miniature the terminal moraines of a glacier. The ridges are due to a slipping of the thick moss and decayed vegetable material upon the frozen subsoil or rock. The movement, like that of the glaciers, takes place only part of the year. In the winter, when both the moss and the underlying soil are frozen solid, there can be little or no motion, but with the first melting a downward slipping begins. As the melting progresses more and more of the "muck" moves; but there is a limit, generally not more than 18 inches below the surface, where the ground is frozen the year round and there is no motion. Sometimes there is a sudden acceleration, and a slight landslide is the result. Obviously, owing to the differences in angle of different parts of the same slope, the down-creeping will be differential, and the result is seen in the waves or escalops, the rounded points of which travel faster than the sides.

Bed-rock.—Generally after the first steep descent the valley is covered with moss. Here and there, where the stream has undercut a bank, where a landslide has occurred, or in the bed of the creek itself, outcrops are found. The rock is the same for the whole length of the valley—a bluish-black quartz-schist, often graphitic, containing many quartz veins which are usually parallel with the schistosity. From the divide to within 1½ miles of the mouth these rocks dip gently to the south, generally not over 5°, and strike a little north of east, parallel, for the most part, with the direction of the valley. Just above its junction with Walker Fork a low anticline comes in, striking N. 60° E., and there is a reverse dip of 10° to 15° to the northwest.

Gravels.—Almost all of the gold is extracted from the bottom portion of the gravel resting on the bed-rock. This "pay dirt," which is composed of subangular, waterworn pebbles of quartz and schist, varies greatly in thickness and width. Near the mouth it is 3 feet thick, and from here toward the head it thins out, until at the highest claim, 2 miles from the divide, it is not over 1 foot thick. Above the

pay dirt comes a layer of barren gravel 4 to 6 feet thick. This is generally composed of rounded or flattened fragments of vein quartz and quartzitic schist, coarser than the pay gravels and showing less the effects of assortment by water.

There is a popular impression among the miners that the very often thick gravels in this and other gulches are composed of materials transported great distances, and that the agent of transportation was a glacier, rather vaguely thought by them to have overrun the whole country. There is nothing, however, to justify the idea of a continental glacier, or even a valley glacier of greater permanence than the transient ones before described. The pebbles and bowlders composing the gravels have a distinctly local origin from the immediate drainage basin of Poker Creek. In part the deposits are stratified, and when they are not so there is every other reason to believe that they were laid down in the valley of a stream. A certain arrangement observed in the upper gravel at McClarty's claim, three-quarters of a mile from the mouth, showed that the deposit, now 8 or 10 feet above the stream bed, was formed in running water. At this point bowlders of stretched quartzite and vein quartz, some of them a foot in the longest diameter and 3 to 6 inches thick, are arranged with their longest axes parallel and inclined downstream, just as in the present stream bed. The angle of inclination is about 45° from the vertical, showing that deposition was made in swiftly running water. Not much difference was noted between the upper and lower gravels. If any, there was more sand in the pay dirt than in the barren gravel, showing, perhaps, a slower current during the first deposition; but, as a whole, the deposits are coarse throughout and very similar to those now being laid down in the bars of the creek. The gravels have been cut into by the present stream, suggesting that the relation of Poker Creek to its base-level has changed. Either there has been an elevation at its head or the level of the main drainage of the country has changed. In either case the creek has acquired new activity and is corrading the older deposits. In this revival the old stream valley does not always correspond with the new, for while in the lower part the pay streak has been found near the north side of the creek, prospects farther up have shown it on the opposite side. However, owing to the comparative narrowness of the valley, the locating of the pay streak is nearly always easy.

Occurrence of gold.—Gold occurs in greatest quantities within 2 miles of the mouth of the creek. On the upper part of the creek it is absent, or is found in very small quantities. It is bright yellow, in subangular to angular grains, which are seldom over 0.68 ounce in weight. The shape of the grains is suggestive of a near origin.

No free gold in quartz veins is known on Poker Creek, although a few small nuggets, in which the gold has adhering to it pieces of quartz which have not been worn off during transportation, have been found.

DAVIS CREEK.

On Davis Creek claims are staked 500 feet in length, and are occupied up to within a mile and a half of the divide. Above this point prospects have shown little pay. All of the claims are on the Alaskan side of the boundary. With the rest of the Fortymile district, this creek suffered from the long-continued drought, and at the time of our visit was producing nothing because of the scarcity of the water supply. Ten men were doing dead work on the claims, and were prepared to shovel into the boxes with the first rain.

Shape of valley.—Davis Creek rises three-quarters of a mile north of Poker Creek, and with the latter forms the head of Walker Fork of Fortymile Creek. The head is amphitheatrical, although not so characteristically so as Poker Creek or as Squaw Gulch. At the very head the descent is steep, being 300 feet in one-quarter of a mile, and then becomes rapidly less. Several small ravines come in from the north. The creek flows through a narrow valley toward the west. Three miles from its source it bends to the southwest, the grade becomes less steep, the valley broader, and the slope of the sides gentler.

The valleys of Poker and Davis creeks are markedly different. In the former the steep grade is at the head and the remainder of the creek flows more slowly through a comparatively broad valley; but Davis Creek partakes more of the nature of a torrent for the first part of its course. This, together with the insignificance of the cirque type of head, seems to show that there has not been any very great amount of glacial action. For some reason, perhaps the absence of springs, there has not been as much accumulation of snow and ice as in its companion valley, and ordinary water corrasion has been more important in the degradation.

Bed-rock.—For the first 3 miles Davis Creek flows parallel and near to the axis of an anticline and on the southern limb. The dip is very gentle, almost never over 10°, to the south, and the strike is east and west. For the last 2 miles the stream crosses the structure. Reversed dips are met, and an unsymmetrical syncline, steeper on the north than on the south, is crossed. This is followed to the south by the Poker Creek anticline, noted above. On the whole, however, these are minor plications in the southern limb of a great anticline striking east and west.

The bed-rocks here are the same as upon Poker Creek and the Sixtymile divide—schists derived from quartzites, in which quartz veins of varying width and extent occur parallel to the schistosity. Secondary mica is frequently developed, sometimes giving the appearance of igneous rocks, but upon close examination the metamorphic character is seen. Often there are graphitic layers corresponding to original shaly portions. These graphitic schists were particularly noted on the Discovery claim, one-half mile above the mouth of the creek.

Gravels.—The gravel has the same characteristics as that of Poker Creek; its thickness, however, is usually not so great. Near the mouth the section is as follows:

Section near the mouth of Davis Creek.

	Feet.
Muck (vegetable matter and soil)	1½
Coarse gravel (bowlders often 8 inches in diameter)	4
Finer gravel, pebbles, and little sand; coarser at bottom	4
Bed-rock, black siliceous schist.	

The lower 4 feet is the "pay dirt," and it varies both in thickness and width. At the Discovery claim the thickness is 4 feet and the width is said to be 10 feet. Farther upstream there is a decrease, and at the last claim it is only 2 feet thick, with a width at most of 5 feet. The total thickness of the gravel also decreases in the upstream direction and is hardly over 6 feet in the uppermost workings.

The bed-rock under the gravel is locally decomposed and disintegrated to a depth of 6 or 8 inches, and in this layer of rotten rock coarse, well-worn gold has often been found. The decomposition must have come about subsequent to the deposition of the gravels, for a stream strong enough to carry large bowlders would have swept away any preexisting mass of decayed rock.

Source of gold.—The gold found on Davis Creek is coarse; the grains are sometimes rounded, sometimes flattened. Its origin may, therefore, not be far distant, the rounding having been due to the pounding of rocks carried over and beyond the gold, rather than to attrition effected during actual transportation of the particles themselves. In some cases fragments of quartz veins are found in which gold occurs in disseminated plates and stringers. Quartz veins occur here, as on Poker Creek, everywhere in the schist. On Lowry's claim, 1 mile from the mouth, one of these veins examined lies horizontal and is 10 or 12 inches thick. So far as opened up it extends laterally, parallel to the schistosity, for 25 feet. Macroscopically the quartz is crossed by cracks, which are often occupied by limonite or hematite. These are probably derived from the oxidation of iron and copper pyrites, which are seen in minute specks. Free gold has been found here, and one specimen in which was a flake of gold one thirty-second of an inch in diameter was given us by Mr. Lowry.

CHICKEN CREEK.

The headwaters of Chicken Creek are divided from Franklin Gulch by only a narrow ridge, but the general direction of drainage in the former is at right angles to that of the latter, so that the two streams enter Fortymile Creek about 25 miles from each other. Ascending the ridge south of Franklin Gulch, one has the whole basin of Chicken Creek and a wide expanse of country farther to the south spread out before the eye, and it is at once noticeable that the topography of this

country is remarkably different from that on the north side of the ridge, and indeed from most of the Fortymile district. The country to the south is broad and gently sloping, and is slightly and evenly indented by streams which rise in a low ridge with conspicuous clumps of hills here and there. These hills probably form the divide between the Tanana and the Yukon waters, and are known as the Ketchumstock Hills, from a tribe of Indians dwelling in their vicinity. Dennison Fork rises in a conspicuous plateau, well marked off from the sloping plain, and from this plateau rises a double or triple cone which suggests a volcano, while the plateau itself suggests a lava flow. This mountain, however, is said to be of granite by prospectors, who have given it the name of Sixtymile Butte.

Chicken Creek itself partakes of the peculiar topography just described, for, as shown on the map, its various branches drain a comparatively wide belt, and they have cut comparatively slight valleys.

Bed-rocks.—At the head of Chicken Creek outcrops the large granite dike which forms the crest of the ridge between Chicken Creek and Franklin Gulch, while the ridge which lies to the east of the creek and forms the divide between it and Fortymile Creek is composed of green slates and tuffs, which are cut by dikes of various kinds. In the bottom of the creek basin several outcrops and prospect holes show gray or black shale, and sometimes impure coal. This rock is evidently the same as that found on Napoleon Creek. At other places olivine-basalt forms the surface, and this rock is said to outcrop at intervals over the whole creek basin, and on Myers Fork to form the walls of a canyon 100 feet in depth.

Gravels.—In the gravels the most prominent rocks are green tuffs and slates, besides basalt, shale, and some coal; there is much chalcedony, and veins of quartz showing comb structure; also some granite and quartzite-schist, and plentiful fragments of marble.

Chicken Creek has hitherto produced very little, the development being still in the prospecting stage. The original discoverer, Bob Matheson, has prospected here for several years, but in general the diggings attracted little attention until this spring (1896), when nearly all the Franklin Gulch men located claims and made preparations for winter prospecting. On a number of branches, and also on the main creek, the prospects have been very good. The creek is so named from the size of the gold, which is about that of chicken feed (corn). In appearance the gold is yellow and often coarse, resembling that of Franklin Gulch. From the few prospect holes which have been sunk it appears that the gravels are comparatively deep, being from 5 to 20 feet in thickness, so that the most prospecting will be done in winter by burning.

FRANKLIN GULCH.

Gold in Franklin Gulch was discovered in 1886, and here were the first gulch diggings which were worked in United States territory.

The gulch is distant 95 miles by river from the Yukon, and flows into the South Fork of Fortymile Creek 10 miles above the North Fork. It is 8 miles long, and flows in a general easterly direction.

Bed-rocks.—The rocks through which the gulch is cut are chiefly mica- and hornblende-schists, with interbedded marble; these are cut by occasional dikes.

Nature of valley.—The valley is bounded by rocky ridges, often on both sides, but more generally on the south. Near the mouth the canyon-structure is especially pronounced, the cliffs rising at times over 100 feet from the water. In some places the cliffs are broken down by the entrance of side gullies, and the valley broadens locally behind rock gates, through which the creek breaks with an increase of grade.

In cross-section the valley is unsymmetrical, the steeper side being on the south and the creek flowing under that steep bank. The lower valley shows every character of very recent cutting, and the stream in Franklin Gulch is still actively deepening its channel. For the last 3 miles it is torrential, the grade being over 80 feet to the mile. On ascending the valley one observes a change; the grade decreases to little over 30 feet per mile, the valley broadens out, and the stream no longer flows through rock walls, but has a channel in gravel. This broader valley, with its deeper deposit of gravel 10 to 12 feet thick, is a part of the high-level valley seen on Fortymile Creek, in which erosion has not progressed to such an extent as in the lower valley.

Gravels.—The gravel in this upper portion therefore belongs to an earlier period than that which is worked below. Owing to the greater width of the valley and the consequent difficulty of locating the pay streak, but little work has been done in the upper valley. A few claims have been located and the pay streak has been found, but generally the amount of gold shown has not paid for the trouble of prospecting, and such claims have been abandoned. Mr. Feddis's claim—4 miles from the mouth—is the only one situated on the older gravels, and this is not considered among the most valuable claims of the gulch. Above this point the covering of gravel apparently thickens to 15 feet. In this prospect holes have been driven, and some gold has been taken out by the process of burning. One-half mile above Feddis's claim, on the right-hand side of the creek, the pay streak was reached under 12 feet of gravel and a prospect of 15 cents to the pan obtained. Still farther above, on the opposite side, a small prospect was also obtained, and 6 miles from the mouth a cabin was built in the early days, but it has not been occupied for the last three years, nor has the ground in that vicinity been worked. So active mining operations stop at 4 miles from the mouth.

The gravel is generally from 8 to 10 feet thick on the lower creek, and is composed throughout of granite, marble, quartzite, vein

quartz, and mica-schist, the fragments varying in size from bowlders 1 foot in their longest diameter to small pebbles and sand. These fragments are subangular to angular, very seldom showing effects of great transportation, and are ill-assorted in regard to size. There is no evidence of stratification except in the upper valley, where in some stream-cuts there is a slight indication of banding of finer and coarser material.

Almost all of the rocks composing the gravel are derived from the drainage area of the creek. The granite is from a great dike which crosses the extreme head of the valley and runs along between Franklin Gulch and Chicken Creek. Olivine-basalt also occurs as pebbles or rounded bowlders, the largest of which are about 10 inches in diameter. It is called by the miners "gold rock," and is looked upon as an indication of gold, for, they say, wherever the "gold rock" occurs in the gravel, there they are sure to find gold in quantities. The basalt may occur in place in the upper valley, hidden from view by the covering of moss, but its outcrops have not been found. On Chicken Creek, just across the mountain from Franklin Gulch, the same rock has been found in place. The rock is composed mainly of minerals of high specific gravity (olivine 3.33, augite 3 +, hornblende 2.9), and is of much greater specific gravity (over 3) than any of the quartz-schists or marbles which make up the rest of the gravel; on this account it is more closely associated with the gold.

The pay streak is generally thin, scarcely ever over 2 feet thick, and in many cases the gravel itself is entirely barren. In many of the claims the gold is taken out from irregularities in the bed-rock surface, very little being derived from the gravel. Such is the case on Pearson's claim, 1 mile above the mouth, where the overlying barren gravel is 10 feet thick. Much coarse gold has also been taken out in the bed of the stream, having been washed out of the gravels and deposited under a natural riffle.

On Feddis's claim there is in the bed of the creek a quartz vein which varies in a short distance from 2 inches to 2 feet in thickness. This vein is in mica-schist and is parallel to the schistosity, striking across the creek and dipping upstream. Much coarse gold has been taken out of the riffle just below this vein, and some crystallized silver. The miner was ignorant of the value of the latter, and had often thrown away pieces found in his sluice, but one specimen which he had preserved was not at all worn and had evidently not been carried far. A few inches above the quartz vein mentioned gold has also been found in lesser quantities. The close connection of the gold and native silver with the quartz vein suggests that the vein itself has yielded these metals, although no free gold was seen in the present outcropping.

The gold is coarse and angular, and often has particles of quartz adhering to it, showing its origin. Small nuggets are common, and

there is very little fine or flour gold. From Franklin Gulch have been taken out the two largest nuggets discovered in the Yukon district. The first was found by Conrad Dahl, in 1894, 2½ miles above the mouth in the gravel. It was flat-oval shaped, its longest diameter 4½ inches, and from seven-eighths inch to 1 inch thick. Its weight was 30 ounces, and it was worth about $500 when taken out of the ground. The next largest nugget was taken out from the mouth of a small gully on the south side of the valley. This was worth $239 at the rate of $17 per ounce.

NAPOLEON CREEK.

Napoleon Creek flows into the South Fork of Fortymile Creek on the right side, about 5 miles above Franklin Gulch and 2 miles below Walker Fork. It drains a considerable part of the region between Walker Fork on the southeast and the South Fork of Fortymile Creek on the west.

Shape of valley.—The forks of Napoleon Creek flow in sharply V-shaped or trenchant gulches, but from their confluence down to the mouth the valley is more U-shaped. Here it is cut down to some 500 or 600 feet below the general level of the surrounding country. At the mouth the valley flat, or surface of the gravels, has a width of only about 90 yards, and is bounded on both sides by a bluff of conglomerate; farther up, however, the valley broadens and soon attains a width of 200 or more yards.

Bed-rock.—At the mouth of the creek the bed-rock is conglomerate, often coarse; but about 300 yards above the mouth it grows finer and is interbedded with occasional layers of coarse sandstone or grit. At about 380 yards the conglomerate is conformably overlain by fine grit and gray sandstone, with thin layers of coal-slate containing indistinct plant remains. Sandstone and dark clay-slate now become the dominant rocks, conglomerate occurring only occasionally in thin beds.

A little more than three-quarters of a mile above the mouth the sedimentaries are succeeded by a speckled olive-green diabase, which is continuously exposed in the creek bed for a distance of more than a quarter of a mile, and, judging from the topography, probably extends on up to within half a mile of the forks, where conglomerate, with some arenaceous limestone, again appears. A little more than a quarter of a mile below the forks on the north side the arenaceous limestone again appears. It is here somewhat marmorized and apparently dolomized, probably owing to contact metamorphism, for close by basalt crops out in a small cliff.

In the lower part of the valley the sedimentaries strike N. 25° E. and dip eastward at an angle of 65°, but farther up the creek the strike veers a little to the north and is almost at right angles to the trend of the valley. The principal set of joint planes, which are quite prominent, strike N. 16° W. and dip westward at an angle of 80°.

A second set, which seems to be the best developed near the forks, trends at about right angles to the first.

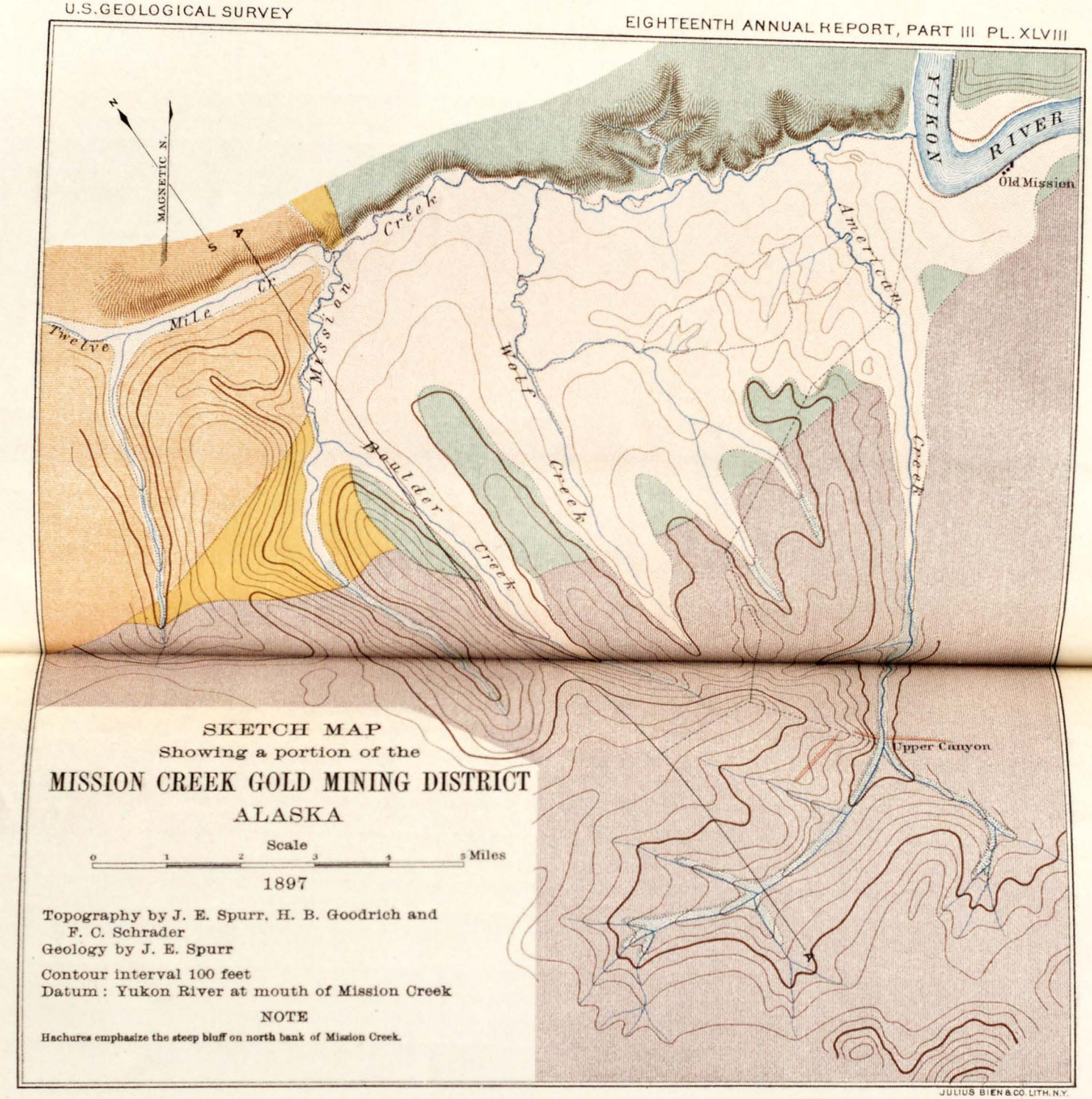
Near the mouth of the valley the conglomerate, as noted, is coarse, its constituent fragments ranging in size from mere grains to bowlders a foot in diameter, although the average diameter of the pebbles is about 2 inches. The cement is siliceous and gritty, but the rock contains no secondary free quartz in the form of veins or lenses. The pebbles are rounded or subangular, rarely flat; they consist chiefly of quartz-porphyry, aplite, and other igneous rocks; black and green slate; green and gray quartzite, and vein quartz.

Gravels.—Omitting a somewhat more than ordinary accumulation just below the forks, the average thickness of the gravel, muck, and moss covering the bed-rock in the upper part of the valley is about 8 feet. In the lower part the thickness is about 12 feet, being much greater along the north side than on the south side, so that the surface slope of the deposit to the south is very noticeable, amounting to 4 or 5 degrees. This seems to be due to the more rapid erosion of the north side, by reason of the greater insolation and consequent greater thawing and regelation. This action produces small landslides and continual soil-creep. The effect of this talus movement is to crowd the creek against the south bank, which in places it undercuts, forming a precipitous face.

A vertical section of the detrital deposits, as shown on Aylward's claim, near the mouth of the creek, consists of about 8 feet of moss, muck, and alluvium overlying 3 or 4 feet of gravel, which in turn rests on conglomerate, and farther up the creek, on other sedimentaries and diabase. The gravels show little assortment, though the material ranges from coarse sand to bowlders. The fragments are sometimes subangular, sometimes well rounded and waterworn. Of the different varieties of rock represented in the gravel, the following were noted: Quartzite-schists, micaceous or sometimes hornblendic; vein quartz; hornblende-granite; basic igneous rocks (pyroxenite?); aplite; clay-slate, often coaly; diabase; grits derived chiefly from diabasic material; and fragments of conglomerate like the underlying bed-rock.

Nearly all the gold occurs under the gravels, after whose removal it is found lodged in irregular fissures, cracks, and cavities in the conglomerate.

No gold in any amount has thus far been found on Napoleon Creek above the first two claims, beginning at the mouth of the creek, though the gravels have been well prospected up as far as the forks. These two claims are owned and worked by Mr. Aylward, who, as early as 1893, found gold here in paying quantity. The two claims together have an extent of 2,320 feet from the mouth upstream, and are said to have yielded thus far about $11,000; $1,000 is reported to be about the aggregate amount taken out by all other miners who have pros-



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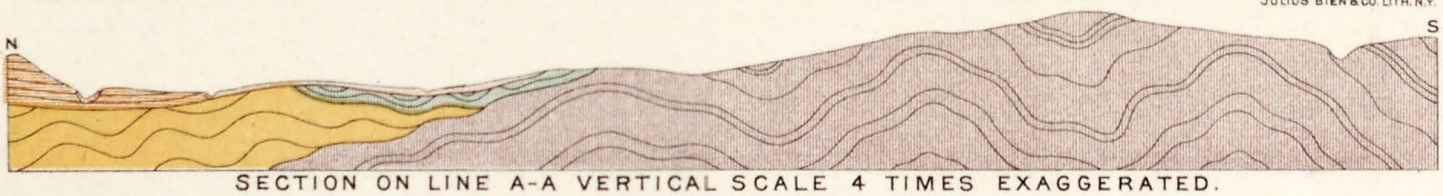


SECTION ON LINE A-A VERTICAL SCALE 4 TIMES EXAGGERATED.

LEGEND

River Gravels | Gulch Gravels | Neocene | Mission Creek Series | Tahkandit Series | Rampart Series | Dikes

pected on the creek, making a total production of $12,000 for the creek. The gold is bright yellow in color and is said to be of fine quality.

MISSION CREEK DISTRICT.

Mission Creek is a tributary of the Yukon River on the left, into which it flows at a point about 50 miles below Fortymile Creek and about 8 miles west of the international boundary.

The trend of the creek is a little south of east, but the branches flow north. The drainage is most remarkably one-sided, all of the tributaries of any note, excepting Twelvemile Creek, being derived from the south side, and flowing into Mission Creek at about right angles. The largest of these tributaries, in order of ascent from the mouth, are American, Wolf, Twelvemile, and Boulder creeks.

In 1895, or earlier, gold was known to exist in the Mission Creek district, but none was actually produced until late in the summer of 1896, when a few claims began to be systematically worked.

GEOLOGICAL MAP.

On the map of Mission Creek (Pl. XLVIII) the chief geological features, so far as known, are roughly delineated. A noteworthy feature is the broad extent of the river gravels, which extend from the main Mission Creek Valley several miles to the south. The area occupied by these gravels is well marked topographically from the more prominent ridges and valleys which lie still farther south; and it is clear that the channel of the main stream was once at the extreme southern side of this area, and that it has worked gradually to the north, leaving a well-smoothed country covered with gravels as evidence of its passage.

Most of the older rocks exposed in the area shown on this map are the impure shales and tuffs of the Rampart series. These are cut in the upper part of American Creek by a few dikes. On the upper part of Mission Creek are found purer quartzites with some limestone. These have been provisionally referred, although without satisfactory evidence, to the Tahkandit series, and are represented as overlying the Rampart series. Along the main Mission Creek, from its mouth up to near the junction of Twelvemile Creek, there are continuously exposed the conglomerates, shales, and limestones of the Mission Creek series. This series rests in apparent unconformity both on the Rampart series and on the Tahkandit series. Above Twelvemile Creek are still younger beds, composed of only partly consolidated conglomerates and sandstones. These rocks are not folded and are only slightly tilted, and seem to rest unconformably on all the older formations, including the Mission Creek series.

The cross-section which accompanies the map is intended to illustrate the principles which have been suggested. The Rampart rocks are shown to be folded and to be overlain unconformably by the

Tahkandit rocks, while these in turn are overlain unconformably by the Mission Creek rocks. These three series have been folded together, and upon their upturned edges the Twelvemile beds have been laid down.

The following report on Mission Creek is by F. C. Schrader, and that on American Creek by J. E. Spurr.

DESCRIPTION OF GULCHES.

MISSION CREEK.

Near its mouth Mission Creek is a very rapid stream of clear water about 2 feet deep and 20 feet wide. Judging from the gravel bars built up in the lower part of the valley, it must be a real river at high water. It can be ascended with a canoe or small boat some 10 or 12 miles. Supplies have been taken up by the miners on rafts as far as the mouth of Boulder Creek, though this was probably when the stream was above low-water mark.

Nature of valley.—Owing to the dip of the rocks and the one-sidedness of the drainage, the closed valley or gulch type of topography is not met with till quite near the head of the creek. The lower part of the valley is open to the south, the slope from the distant hills down to the creek being very gentle. The north side, however, presents a nearly continuous bluff or steep slope, along the base of which the creek has intrenched itself. This peculiar form of valley continues in a nearly direct line from Mission Creek along Twelvemile Creek as far as observations were made.

Bed-rocks.—The bed-rocks on Mission Creek between the Yukon and Twelvemile Creek belong to the Mission Creek series, and are exposed along the steep north side of the valley. They consist essentially of black, green, reddish, or brownish limestone, sometimes arenaceous; black lignitic coaly slates, and some brown grit. They are rarely faulted, but are highly folded, and often sheared and crushed. The slaty portion of the series is usually black, though sometimes green, and is traversed by delicate calcite veining. The coal is usually pyritiferous, and sometimes contains a good deal of sulphur. It is common to find pyrite in small quantities throughout the series, and at times the rock contains seams of hematite or earthy limonite. A 6-foot layer of this iron ore was observed by Mr. Goodrich in the black schist and limestone 3 miles above the mouth of the creek.

The rocks of this series strike a little north of east and dip in general gently north. They are well exposed a little below Twelvemile Creek; but about 600 yards above the mouth of this creek there outcrops siliceous schistose limestone, striking a little north of west and dipping 65° N. There seems to be an uncomformity between this series and the Mission Creek rocks, and judging from the topography, the line of contact lies in a ravine just north of the mouth of Twelvemile Creek.

A little more than half a mile south of the mouth of Twelvemile Creek, along the left or west bank of Mission Creek, occurs a third and much younger formation, occupying the portion of the valley between Twelvemile and Mission creeks. The rocks of this formation are all only partially consolidated, and range from fine sandstone through marl and grit to coarse conglomerate, in which some bowlders are 2 or more feet in diameter. There are also interstratified seams of brown lignitic material. The conglomerate is made up of several varieties of pebbles, among which those of granitoid character, white quartz, and limestone are conspicuous. The white quartz is more conspicuous in the fine than in the coarse conglomerate. These beds are certainly unconformable with the underlying rocks already described.

Older gravels.—On the right bank of Mission Creek, at several points between Twelvemile and Wolf creeks, outcrops of the black coaly slate of the Mission Creek series, rising to a level of 8 or 9 feet above the present bed of the creek, are capped by a thickness of about 10 feet of river gravel. The material of the gravel ranges from very small pebbles up to small bowlders, and the deposit seems evidently to have been laid down when the creek flowed at a higher level than now. Whether these older gravels are auriferous was not learned. Judging, however, from the amount of quartz-schist which they contain, seemingly derived from the Birch Creek or Fortymile series, they probably carry at least some gold.

Younger gravels.—The younger gravels, now disposed in irregular bars and riparian deposits from 1 to 5 or 6 feet in thickness along the present bed of the creek, are made up in varying proportions of materials derived from all the above-noted bed-rocks observed within the valley, as well as from the older gravels. There are also some pebbles of igneous rocks, which were not found in place and which probably occur farther up in the heads of the gulches toward the divides. These gravel deposits are thicker and finer in the lower part of the valley, while in the middle and upper part they are rather coarse, and in the gulches consist largely of bowlders.

All along Mission Creek and its branches the gravels have been found by prospecting to carry gold. At the time of visit (August, 1896) some work was being done on Twelvemile Creek and some on Boulder Creek, but the only diggings known to yield gold in paying quantity were on American Creek, about 12 miles above its mouth.

AMERICAN CREEK.

Bed-rocks.—American Creek is a branch of Mission Creek and flows into the latter stream a short distance above its mouth. About 3 miles above the point of junction gray shales, which carry seams of coal and which belong to the Mission Creek series, change to uniform gray-blue sandy limestone or impure fine-grained quartzite, which becomes nearly black or greenish, and often, on account of

weathering, brown. At the Upper Canyon on American Creek there occur, besides the quartzite, large masses of rock consisting chiefly of serpentine and chlorite, in which are fragments of residual olivine. This rock is probably of tuffaceous origin, and both it and the associated impure quartzites and limestones have been described under the head of the Rampart series.

All these rocks are generally much jointed, and often they acquire locally a schistose structure, although without any remarkable development of new minerals. Along the shear zones there is a great deal of silicification, so that the rock is altered to a jasperoid, and along the crevices quartz veins parallel to the shearing planes have been formed. These shear zones are also often rusty from iron oxide derived from the decomposition of pyrites; and often both copper and iron pyrites may be found disseminated through the schistose rock or in the quartz veins themselves.

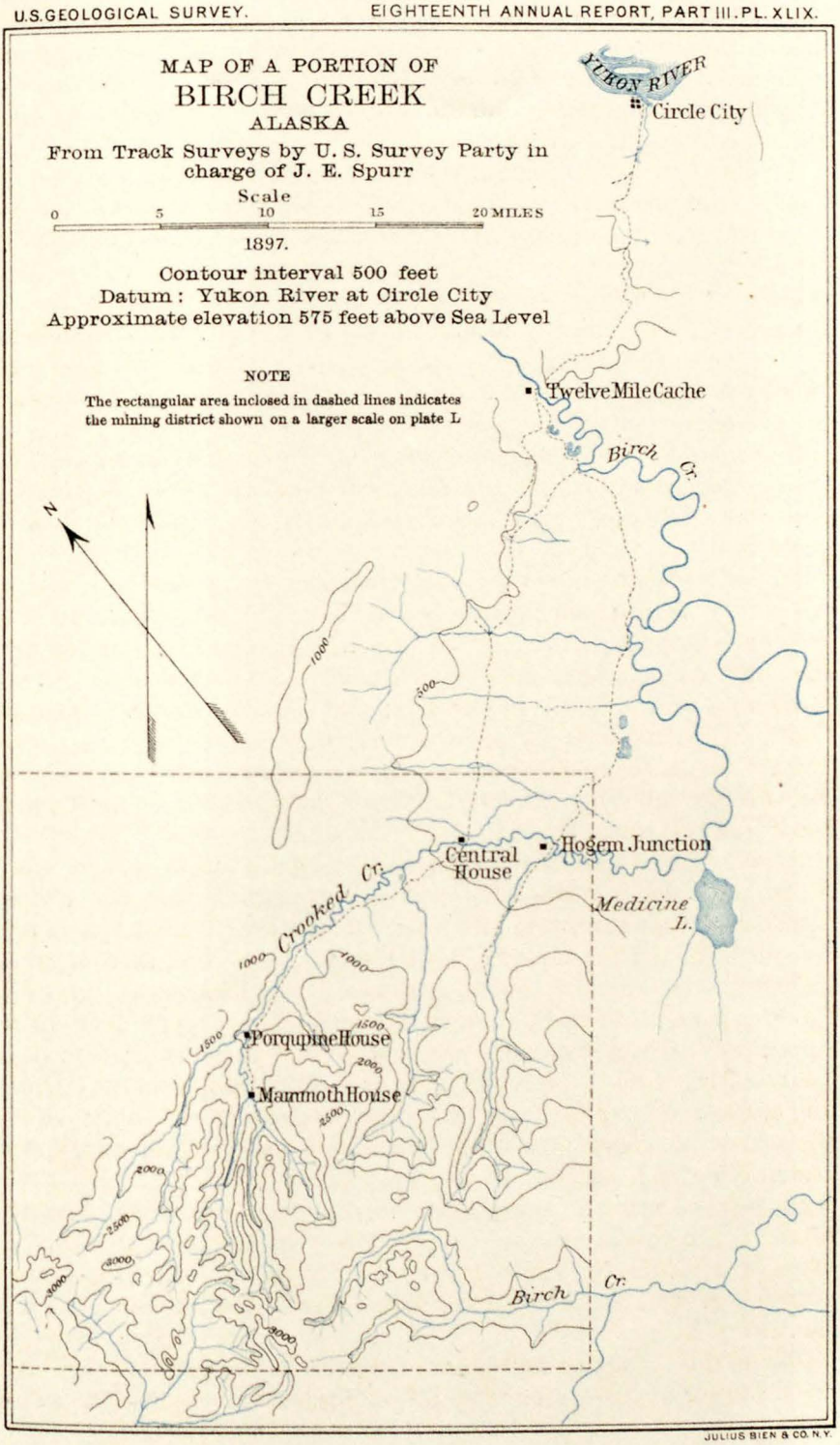
Two narrow dikes were noted near the Upper Canyon on American Creek, one of aplite and the other of mica-lamprophyre; both cut across the schistosity, and are evidently younger than the shearing process.

Gravels.—In the upper part of American Creek the valley is narrow and V-shaped, the bottom often being not more than 10 or 15 feet wide. In the bottom of the gulch are fragments derived from the cliffs above, nearly angular or slightly rounded in shape. These fragments are almost exclusively of the impure quartzites and serpentinous tuffs which have been described, and also of the quartz veins which these rocks contain. This deposit was, where observed, 3 or 4 feet thick, and was nearly barren, all the gold being found on top of the bed-rock beneath.

At the time of examination only one claim had been opened on this creek, although considerable active prospecting was being done. This claim was that of Messrs. Stiles, Roberts, and Bushnell in what is called the Upper Canyon, on account of the contraction of the valley at this point. Here the gold was found beneath the gravel on top of a zone of schistose impure quartzite 3 or 4 feet wide. In the upper part of this loose decomposed rock fragments of gold occur abundantly, often of large size. In shape they are generally irregular, sometimes rounded, and lie in the crevices of the schist, so that the coarser pieces are picked out by hand. Some of these have quartz clinging to them.

In the separation of the gravels in the sluice boxes many pebbles of magnetite and barite are found. These are well rounded, but are often of considerable size. There seems to be little doubt that these minerals as well as the gold are derived from the schistose zones in the bed-rock.

At the time of the examination of this creek the first clean-up (i. e., the draining of the water from the sluices and the collection of the



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separated gold) had just been made, and the results were $27 per day to each man working, or, as is commonly said in the mining districts, "to the shovel."

Mammoth remains.—On American Creek mammoth remains are found on top of the gravels in the gulches. A fragment of a small tusk was seen here.

BIRCH CREEK DISTRICT.

The Birch Creek district lies entirely in American territory. Its source of supply is Circle City, which is situated on the Yukon about 170 miles below Fortymile Post. The actual mining district is situated some distance to the south of Circle City, at the headwaters of Birch Creek, the diggings being reached overland by trail from the Yukon. The district includes a number of gulches, all of which flow into Birch Creek, and extends over an area of 100 or 150 square miles. The accompanying map (Pl. XLIX) shows the general course of the streams so far as is known, and the general topography is indicated by contours. The area occupied by this map is shown by broken lines on the larger map of the gold belt.

DISCOVERY.

In the summer of 1893 two half-breeds found gold on the bars of Birch Creek. This discovery was followed by a rush of unemployed miners from the Fortymile district, and a camp was established at Circle City. The next spring gold was discovered in the gulches.

GENERAL GEOLOGY.

In the district where active mining is carried on the chief bed-rock is the quartzite-schist of the Birch Creek series. These schists have a semicircular strike, changing from east-west in the central part of the district to northeast in the eastern part, and to northwest in the western part. The dip is constantly to the south at an angle varying from 5° to 30°, averaging perhaps about 10°. This strike and dip seem to indicate that the rocks in this district form part of a broad anticlinal dome.

The schists contain many veins which have been sheared with the inclosing rock. There are also frequent schistose dikes, mostly granitic or dioritic. A great dike of granite, 2 or 3 miles wide in places, runs across the district in an east-west direction, appearing on Hog'em and Boulder creeks. It is clearly intrusive and has not been sheared. In some places are small aplite dikes, and often quartz veins are found which are large and persistent and sometimes contain feldspar.

All the gulches flow at first in deep valleys, but suddenly emerge into a nearly flat country, in which they have cut mere furrows. In the vicinity of the hills this level region is composed entirely of subangular fragments of rock, forming detrital accumulations of unknown

depth, since no outcrops are seen. It has been concluded elsewhere that this detritus is torrential material, brought down by the streams and deposited along the shores of a lake which formerly existed in this region.

GEOLOGICAL MAP.

A rough geological map (Pl. L, in pocket) has been made of the mining district, and the area covered by it is shown by dotted lines on the general map of the Birch Creek district (Pl. XLIX). On this map the coarse lake deposits are shown in the northeast corner, and it is to be noted how the streams meander in their passage through this region. The gulch gravels, indicated by separate coloring, show the areas at present being worked for gold; the rest of the region is covered chiefly by the Birch Creek schists, cut by occasional dikes. The large granite dike mentioned above is seen cutting across Hog'em and Boulder creeks.

DESCRIPTIONS OF GULCHES.

Of the following descriptions, those of Hog'em, or Deadwood, Greenhorn, Independence, and Mammoth creeks are by J. E. Spurr; those of Harrison and Eagle by F. C. Schrader, and those of Mastodon, Miller, and Porcupine by H. B. Goodrich.

HOG'EM OR DEADWOOD GULCH.

Hog'em Gulch received its name from the fact that the discoverer tried to hold a large part of the richest diggings, taking up separate claims for the whole of his numerous family, and, it is said by some, for fictitious personages. When other miners came into the gulch and a meeting was held, among other things the question of naming the diggings came up, and one miner suggested that "Hog'em" would be appropriate. This suggestion was not officially adopted, and the name Deadwood was given the gulch as being more dignified, but the original nickname has persisted and among most of the miners is used almost exclusively.

Valley.—Hog'em or Deadwood Creek flows into Crooked Creek and has a total length of about 20 miles. For about 6 miles from its mouth it flows through a broad, gently sloping, slightly undulating plain, which forms a large part of the valley of Crooked Creek and joins the broad, swampy flats through which Birch Creek flows. Above this it has cut a well-marked valley in the low mountains which rise above the flats. At first this valley is broad and shallow, as compared with the V-shaped gorges which streams have cut in the Fortymile district and elsewhere, but farther up it narrows and near its head assumes the general form of a shallow V-shaped trough. At the extreme head the different gullies or pups which unite to form the main gulch have comparatively distinct and deep valleys, the amphitheater or cirque not being so strongly developed as in neighboring gulches.

POLISHED SPECIMENS OF QUARTZ.

The one to the left, from Deadwood Creek, Greenhorn Trail; the one to the right, from Fortymile Creek, below Steel Creek.

Throughout its whole course the stream hugs closely the eastern side of its valley, which it has apparently continually undercut, so that this side rises very steeply, while the other slopes more gently and has a well-marked shelf or terrace, which indicates the valley level at an earlier stage. About halfway up the gulch, on the east side, the granite bed-rock has been eroded so as to leave two high pinnacles, which stand one on each side of a tributary gully. These pinnacles form a conspicuous and striking feature in the topography, and go by the name of the Deadwood Buttes; and their existence is of itself sufficient evidence to controvert the idea that this district has ever undergone any extensive glaciation.

Lake accumulations.—The gently sloping, undulating plain through which the lower part of Hog'em Creek flows is made up of subangular or slighly worn fragments, consisting mostly of schists and gneisses, with some granite and vein quartz; and the material shows some slight arrangement in horizontal layers, as if from the effects of water action. The nature of this material shows that it has been brought down from the neighboring mountains, and since there is evidence of no extensive glaciation the agents of transportation must have been the small streams which flow in the gulches. The equable arrangement and distribution of this stream gravel or torrential detritus in the broad valley of Crooked Creek points to the existence of a larger body of water, which must have covered the whole of this broad valley at the time of the accumulation of the gravels.

The same coarse material which fills up the Crooked Creek Valley to an unknown depth extends up the narrower and well-defined valley of Hog'em Creek about 3 miles above its mouth, so that for this distance the valley has a broad and comparatively level bottom and there are no outcrops of bed-rock. Above this point are shallow stream gravels, with frequent outcrops. These gravels are a comparatively thin and narrow deposit, resting in the bottom of the V-shaped gorge through which the stream flows.

Bed-rocks.—The first outcrops above the limit of waterlaid torrential material are of quartzitic schist carrying quartz veins. Above this is a belt of granite 2 or 3 miles wide. This granite is massive, and shows no shearing or other alteration, and so far as observed contains no quartz veins. Above the granite the rock consists of quartzitic and micaceous schists, which are apparently in large part metamorphosed sediments. In one place a darker, schistose, basic rock, which was apparently intrusive into the quartzitic and micaceous schists, was observed.

Gravels.—The gravels which overlie the granite area are composed partly of schists and gneisses and partly of granite. They also contain abundant fragments of quartz veins. The gold which is found here is usually fine, and although present in considerable amount, the gravels are not considered so rich as those farther up the gulch.

Hence the granite is looked upon with disfavor by the miners, though the richest diggings are said to overlie the contact of granite and schist. At this contact the gold is coarse, as it is in the diggings farther up. The most profitable gravels are found within a distance of 4 or 5 miles from the granite belt up the gulch, but in the upper part of this distance there are often places in which the gold is scarce, although in neighboring claims it may be present in considerable quantity. When the gold is thus unequally distributed the gravels are known as "spotted." For a distance of 3 or 4 miles at the very head of the gulch the gravels are not worked.

Throughout this gulch the barren gravels which lie on top of the pay gravels are comparatively thin, being from 3 to 7 feet thick on the average, so that all claims which show good prospects can be worked in the summer time, and there is little winter drifting. On some of these claims, in the summer of 1896, the daily products were often as much as 2 or 3 ounces of gold to each man working, or, as is locally said, 2 or 3 ounces to the shovel—that is, the quantity of gravel which can be shoveled by one man into the sluice boxes in one working day of ten hours contained on the average 2 or 3 ounces of gold.

Where the gravels overlie the granite there is much of this rock associated with the other fragments, but above the contact of granite and schist there are only schist and fragments of vein material. This shows that the gravel is derived from very local sources, and that its route of travel is constantly down the gulch. Among the fragments of veins are many which are rusty from the decomposition of sulphides, and some still show pyrite, and occasionally galena. Others are remarkable for containing feldspar mixed with the quartz gangue, and these veins contain pyrite in the same way as those consisting entirely of quartz.

In the richest diggings the gold is generally coarse and greenish yellow in color, and the shape of the grains is generally broad and flat, which prevents their traveling very rapidly. Pieces containing gold to the value of $5 or $10 are common, and the largest nugget yet found is said to be worth $82. It is probable that here, as in other gulches, the gold is chiefly associated with the pyrite which occurs plentifully in the quartz veins and disseminated through certain zones of the schist. These quartz veins and sheared zones impregnated with sulphides seem to be especially abundant in the schist near the contact with granite, and this locality is considered by the miners the richest in the gulch. The comparative barrenness of the gravels overlying the granite, and the fact that this rock contains, so far as observed, no quartz veins or thickly disseminated sulphides, also point strongly to this origin. At Hill's Road House a specimen from Hog'em Gulch was seen which was about four-fifths quartz, the rest being gold which formed little reticulated veins, so that when broken out it had a leaf-like or plant-like form. This form is roughly like that of

all the coarse gold found in this gulch, as well as in most others of this region.

Galena is found in small bowlders in the gravels and in smaller grains in the concentrated dust with the gold. On Eaton's claim, which is one of the most productive on the gulch, a large vein of galena, which had partially altered to lead carbonate, was found in the bed-rock beneath the gravels. This vein is said to be continuous, and an assay of a small sample made in the laboratory of the Survey showed 44 ounces of silver. Small fragments of native lead have also been found in the gravels.

GREENHORN GULCH.

Greenhorn Gulch is separated from Hog'em by a low mountain spur. It is very short, and soon unites with others to form Boulder Gulch. At the time of visit only one claim, that of Mark Loper, was working, although the gravels have been shown to be comparatively rich in places. The chief difficulty experienced here was the lack of water, which was often insufficient to feed the sluices and separate the gold from the gravels.

On this gulch the character of the rock is precisely similar to that of the rock on Hog'em Gulch. The granite belt crosses Bowlder Creek below the junction of Greenhorn. The gravels on Greenhorn are thin, and the diggings could easily be worked if there were a sufficient supply of water. The largest nugget found on the gulch so far contains $54 worth of gold. In the gravels pieces of vein quartz have been found which show free gold finely disseminated.

INDEPENDENCE CREEK.

Independence Creek is only a few miles long from its head to its junction with Mastodon Creek. Below this point the united streams go by the name of Mammoth Creek, and several miles farther down Mammoth unites with Porcupine to form Crooked Creek.

Valley.—In form the valley of Independence Creek shows some distinct variations from the valleys of Boulder and Hog'em, farther east. From the head of Independence the slope up the divide is very steep, and the numerous small feeders which flow down this slope have carved valleys much less conspicuous than the corresponding feeders of the creeks just mentioned. In this way the head of Independence Creek, as compared with that of Hog'em Creek, shows a marked tendency to assume the form of a cirque. In cross-section Independence Creek Valley also shows some slight variations from the type represented by the valley of Hog'em Creek, for although it is, like the above-mentioned valley, roughly V-shaped in general outline, the bottom of the V is more rounded. This widening of the valley, and the steepening and broadening of its head, have been shown in cases already described to be chiefly due to the effects of ice and snow in

spring and early summer; and the erosion of these snow and ice accumulations, which may be conveniently termed "annual glaciers," to distinguish them from the larger accumulations which are sufficient in size to withstand the annual melting, may be considered as chiefly dependent upon the action of glacial waters, although the disruptive action arising from alternate freezing and thawing must not be overlooked; and even the scoring action of masses moving downward over a steep hillside during the melting season may be of no inconsiderable importance.

When we come to consider the cause of the comparatively slight difference between Hog'em and Independence creeks, we note that they run nearly parallel and are at no great distance apart, but that Independence heads in a considerably higher portion of the divide. When these creeks were examined, in the month of August, there were considerable masses of ice on the steep slopes at the head of Independence Creek, but none at the head of Hog'em. This residual ice was present not only on Independence, but at the head of all the creeks which rise in this higher portion of the ridge surrounding Mastodon Dome.

At several points in the valley of Independence Creek, particularly on the west side, there are distinct terraces at considerable elevations above the present stream bed. These terraces evidently mark an ancient level of the valley.

Gravels.—The gravels are identical in nature with those in other gold-bearing gulches, being made up of little-worn, slightly assorted, angular or subangular fragments of schist and of vein quartz, intermingled with finer material derived from the decomposition and abrasion of these rocks. At the time of visit the gulch was not worked for several miles below the head, the chief claim working being only a short distance above the junction with Mastodon Creek. At this point the actual width of stream gravels is probably 150 feet, and the pay streak, which is parallel with the present channel but on the opposite side of the valley, is about 15 feet wide. Cuts showed 10 feet of top gravel over 1 foot of pay dirt lying on a bed of schist. This gravel was paying fairly well, although here, as in other gulches, the lack of water was a great drawback.

MAMMOTH CREEK.

Below the mouth of Independence Creek the bed of Mammoth Creek widens very rapidly. A short distance below this point a pay streak has been worked on the left side of the valley, some 200 feet or more from the present channel of the stream and on the other side of the valley. Farther down the width of the gravels grows so great that locating the pay streak becomes very difficult and little mining has been done. The nearly flat bottom gravels become wider and wider, merging into the broad plain through which Crooked Creek flows,

and this into the still broader flats of Birch Creek. The material which forms the bottom of all these wide valleys is essentially the same, being subangular fragments of schist, quartz, and granite, often quite large and generally showing very little arrangement. It is probable that portions of this material are sufficiently auriferous to repay working under favorable conditions, and on account of the immense extent of these bottoms this source of supply may one day become very important. At the present time, however, mining is carried on only in the numerous feeder gulches.

MASTODON CREEK.

Mastodon Creek is the pioneer in the Birch Creek district, as Franklin Gulch is on Fortymile. It was discovered in 1894, and since that time has been worked with great profit. It is even now a large producer and shows no sign of exhaustion. The gulch is 60 miles distant from Circle City, and is reached by a trail which crosses the swampy valley of Birch and Crooked creeks in a southwest direction.

The mountains in general have nearly level tops, sloping along the dip gently toward the south. Even the highest points are generally covered with moss, and the gaps or hollows are boggy and filled with little ponds. But above this table divide are occasional peaks which have received, from their rounded and prominent summits, the name "dome." There are two principal peaks of this character at the headwaters of Birch and Mastodon creeks, which are named respectively Mastodon Dome and Porcupine Dome. The former has an elevation of 4,420 feet above the sea, as determined by aneroid barometer, while the latter rises some 200 feet higher. Under Mastodon Dome head the waters of Gold Dust and Eagle, flowing directly into Birch to the west; also the North Fork of Harrison, which takes a longer course and, with the South Fork, enters Birch Creek 20 miles to the southeast. Mastodon Creek also has its source here in three heads, and, flowing east of north for 12 miles, drains into Mammoth Creek.

The topography of the Bald Mountains depends to a great extent upon the geologic structure. As remarked above, the slope of the mesas is determined by the dip of the rocks. In addition there are lines of weakness afforded by joint planes which intersect the schistosity at high angles. Along these lines frost action breaks down the rocks, and the divide is rendered unsymmetrical. On the side opposite to the dip cliffs are produced, so that, viewed along the strike, the domes present a sharp, steep slope toward the north and a rather gradual incline toward the south.

All along the divide, indeed, the slopes to the Crooked Creek drainage system are much steeper than toward Birch Creek proper. The three feeders of the main Mastodon Creek head in amphitheatrical

basins, and are supplied by many small streams which flow from areas of snow, small patches of which still remained in the middle of August. These streams plunge in small cataracts over perpendicular cliffs and talus slopes with a fall of 800 feet in the first mile. At this point the valley assumes a U-shape in cross-section. Three miles from the summit another branch enters from the south, its valley being comparatively broad at the mouth but narrowing suddenly in an upstream direction. The mouth of this branch marks the farthest extension of mining operations. From this point onward only the waters from small gullies increase the volume, and the creek flows with considerable grade in a broadening valley from which the hills rise with slopes of about 20°. The "hogbacks," or dividing spurs, are untimbered except near the mouth; their tops are generally smooth, but are interrupted by ledges.

Bed-rocks.—The rocks are mainly micaceous quartzite-schists, sometimes graphitic. There are two sets of jointing, one especially well-marked, forming an angle of 80° with the planes of schistosity and striking north-south; the other, less well marked, intersects the schistose planes at the same angle, but also forms with the north-south set an angle of 70°. By these joint planes the rock is split up into rough rhombohedral blocks. The strike of the rocks for the whole length of Mastodon Creek is across the valley, and the dip upstream.

Besides the ordinary quartzite-schists there are igneous intrusions of two periods. At two points on the creek is a gray schistose rock containing "eyes" of feldspar and quartz. This seems to be an altered crystalline rock of the granite or diorite family, which has cut into the associated rocks at some time previous to the development of the schistosity. There is also a very acid rock, composed of quartz and feldspar, which has not shared in the schistosity. No outcrops of this rock were observed in the creek itself, but in the divide it was often seen in small vein-like dikes seldom over 6 inches in width, which send out small apophyses into the country rock.

Quartz veins are numerous throughout the whole valley. Most of them are parallel to the schistosity, and evidently, in part at least, antecedent to the shearing force, while others cut the schistosity and the conformable veins, and so are of younger age.

Gravels.—The gold is very evenly distributed from the mouth to within 3 miles of the head. The greater amount is found on the bed-rock, but the gravel for an average of 3 to 4 feet above is pay dirt. In some places the pay streak is as thick as 6 feet, and at one claim (32 above Discovery) gold has been found in paying quantities all through the lower 10 feet of gravel. An average of the pay on claims 22, 23, and 24 above Discovery was for the whole pay streak 5 cents per pan; for the portion a few inches above bed-rock, $1 to the pan.

The gravel is generally deep, from 10 to 15 feet. In the last claim opened it is fully 15 feet, but from there the deposit thins suddenly

until, at a distance of 2 miles from the dome, it is almost entirely absent. This thickness makes shoveling into the boxes especially hard work, and on some claims the shoveling is done by stages. One set of men stands at the bottom of the cut and shovels the gravel up to a platform, from which another set takes it and shovels directly into the boxes. This requires nearly double the number of men that are employed in shallow diggings, but the results have paid.

The material in the barren and pay gravel here has the same character as that in other parts of this district. The bowlders are ill assorted, of local origin, and show little evidence of transportation. A mile and a half above the mouth the 3 feet of pay dirt is overlain by 4 feet of sand. This layer of sand is slightly stratified, contains sticks, and shows evidence of having been deposited in quiet water. It was probably deposited behind some temporary dam. Several local differences of deposition have been noted in other places, but this is perhaps the best marked.

On almost all of the other creeks the gravels are generally frozen at a short distance beneath the surface, but Mastodon forms an exception to the rule. In drifting and prospecting at several points it was found that the lower gravels were not frozen even in winter.

MILLER CREEK.

Miller Creek, Birch Creek district, was discovered and named by O. C. Miller, the same man who named Miller Creek of the Fortymile district. In the spring of 1894 this prospector did some work here, but afterwards struck out for new fields.

Topography.—The creek is 60 miles from Circle City, and enters Mammoth Creek a mile and a half below the mouth of Mastodon. Its source is under a mesa of the Bald Hills, 300 feet lower than the head of Mastodon. Near it heads the Miller Fork of Eagle Creek, which drains southeast and forms a part of the drainage basin of Birch Creek proper, while Miller Creek flows northward for 9 miles into the Crooked Creek basin, in a course parallel to that of Mastodon, and separated from it only by a ridge which is steep on the southeast side, but has a more gradual slope into the valley of Miller Creek. The dip of the rocks all along this dividing spur is slight and toward the southwest. Its summit is almost flat, but is broken by north-facing cliffs into a series of southward-sloping steps or benches. At the very end of the ridge the action of the side gullies, combined with the erosion of the three streams, Miller, Mastodon, and Mammoth, has gone so far that a symmetrical cone of erosion has resulted.

The valley slopes of Miller Creek near its mouth and for 3 miles above are different on either side. On the northwest they are comparatively steep, with angles of about 30°, and sometimes, more emphatically nearer the mouth, the creek undercuts its banks, forming bluffs of bare rock 20 or 25 feet high. Upon the southeast side,

on the other hand, there is a slight terrace and a gentle rise for from one-quarter to one-eighth of a mile to a point where the hill rises steeply. The terrace is formed in gravels, which have since been cut by the creek near its mouth, forming a gorge 15 feet deep. Along the lower portion of the stream the valley is narrow and V-shaped in cross-section, but gradually, in ascending, the sides become of more even slope from the tops of the ridges to the creek bed. The gravel also thins out gradually, until, at a point 2 miles from the divide, it is almost entirely absent. Four miles from the mouth a branch enters from the southwest, whose source is in a flat, boggy gap in the Bonanza Divide. This branch has a very steep grade and flows through a V-shaped valley for 2 miles, and pay was found on it only within a very short distance of the main creek. At the head of the various branches of Miller Creek is the amphitheatrical form already described upon other creeks, and it is here, as elsewhere, due to transient glaciers, the remnants of which were still visible in the middle of August on the southernmost branch of Miller, although from all the others snow had disappeared. The rocks are the same as upon Mastodon—quartzite-schists, massive and fissile, into which have been intruded dark granite antecedent and aplites subsequent to the schistosity. The strike is generally northwest and the dip to the southwest.

Gravels.—The gravel, where worked for gold, is generally thick, averaging from 12 to 15 feet, although on the highest claims it sometimes decreases to 8 feet. The gold is generally found through the lower 4 feet, although much is also found directly upon the bed-rock. In places the bed-rock is much decomposed and the gold is found embedded in it. The pay streak is very "spotty" that is, the gold is very unevenly distributed.

No claims have been worked very near the mouth, the reason probably being that much better ground on Mastodon and the more recently discovered creeks has drawn off the claim owners. The Discovery claim is located 3½ miles from the mouth. Here the pay streak was 4 feet thick, under 8 feet of barren gravel, and yielded 30 cents to the pan. At the time of our visit 3 men were shoveling into the boxes on this claim, and above Discovery 25 men were working up to within 2½ miles of the divide. The area now being worked is comprised in the middle 4 miles of the valley, above which is the torrential portion of the stream, from which the gold-bearing gravels have been washed away.

The gold here is much like that found on Mastodon, occurring in small grains. There is very little fine gold and no large nuggets. The shape is that of flat scales, little worn or rounded, showing an origin evidently not far distant.

PORCUPINE CREEK.

Porcupine Creek is the true head of Crooked Creek. One branch rises at Porcupine Dome, whence it flows north of east through a broad valley, with an average fall of 100 feet per mile for 15 miles.

It is then joined by Mammoth Creek, and is thereafter known as Crooked Creek. Six miles above the junction comes in Bonanza Creek, which is 8 miles long and flows parallel with Miller Creek, from which it is 3 miles distant, being separated by a flat, ledgy ridge. The valleys of Porcupine Creek and its branch, Bonanza, are wide, especially near the heads, and the creeks are meandering. The spurs leading from the main divide are generally smooth and gentle, except for the last eighth or sixteenth of a mile from the creek, when their angle is increased, sometimes to 30°. The heads of the creeks themselves are steep, and there are frequent cliffs, but the true cirque is absent. The mesa is perhaps better marked upon the divide along these headwaters than anywhere else in the Bald Mountains. The dip of the rocks is slight here, and great table tops, one of them nearly circular and a mile in diameter, are seen. To the southwest, along the dip, they slope very gradually into the valley of Birch Creek, while on the other side the descent is very steep. Four of these tables, with flat gaps 100 to 200 feet eroded between, are crossed in going from Miller Creek to Porcupine Dome, all reaching to a nearly uniform altitude of about 4,000 feet.

Two years ago a few men prospected both Porcupine and Bonanza, but obtained unsatisfactory results, 5 cents to the pan being about the largest prospect. On account of the width of the valley it was very difficult to locate the pay streak, and the thickness of the gravel, from 12 to 15 feet, was also a hindrance to working gravels which did not promise exceptionally well. So it was soon abandoned and has not been investigated until last summer, when one man visited it and was at work at the time of our visit. At the mouth of Bonanza Creek the section was as follows:

Section at the mouth of Bonanza Creek.

	Feet.
Vegetable mold and moss	2
Sand, semistratified, containing a few pebbles from 1 to 3 inches in diameter	2
Gravel, containing heavy subangular bowlders of quartzite-schist	10

HARRISON CREEK.

Harrison Creek is one of the largest streams of the Birch Creek district. It is most easily reached by trail—up Deadwood Gulch and thence southwest over the divide. The upper part of the creek divides into two forks, of which the North Fork is the longer, heading up under Mastodon Dome, and at about 7 miles below the forks the main stream flows into or unites with Birch Creek. At the junction of these two streams is Pitkas Bar, where, in 1893, gold in the Birch Creek district was first discovered.

The first gold discovered on Harrison Creek was near the head of North Fork, about a mile below Mastodon Dome, in 1895 (?). The

creek is, therefore, one of the newest of the Birch Creek placer diggings. Before the middle of August, 1896, however, the whole of the North Fork was staked off in claims extending continuously from near the foot of the small lingering "glacier" which flanks the Dome down to near Ptarmagan Gulch, more than a mile below the forks. Placer digging on the creek as a whole, however, is in its first stages. At the time of our visit the total number of men at work was 21.

Bed-rocks.—So far as observed on Harrison Creek, the country rock everywhere is of quartz-schist, with talcose, micaceous, actinolitic, carbonaceous, and graphitic phases. From the roundness of the grains under the microscope, there seems to be no doubt concerning its sedimentary origin. The rock is well exposed on the right bank just below the forks and at intervals along North Fork to the Dome. Its general strike on Harrison Creek is northwest and southeast, with dip of about 30° to the southwest, but near the Dome, and on it, the strike is east of north.

Shape of valley.—The valley of Harrison Creek, and more particularly that of the North Fork, is on the whole trenchant, but not so sharply as many of the other gulches, such as Deadwood or Hog 'em. Consequently, the gravel deposits often widen out in the bottom of the valley and the stream sometimes flows in several channels, which inclose gravel bars or small islands. The pups, however, are usually quite trenchant and of steep gradient, and nearly always head in amphitheaters, on whose slopes are often remnants of glaciers or lingering masses of snow and ice, which by their melting feed the streams. Above the great bend in North Fork the south side of the valley is steep, while the north slope is more gentle. This feature has already been noted in the east and west trending gulches of Forty Mile district, where the difference of slope was attributed to insolation and tilting. In this case, however, the attitude of the schistosity is favorable to the development of a steep face on the south, and is probably an important factor. In looking eastward it is seen that the steep right side of the upper portion of the valley does not continue along the stream where this turns nearly at right angles and runs toward the south, but is in direct alignment with an escarpment or ridge formed by the upturned edges of schist, which climbs the divide between Harrison and Deadwood gulches.

Gravels.—The gravel, so far as observed, consists of material derived solely from the quartz-schist series, and the fragments are generally coarse or subangular. This is especially true of the middle and upper parts of the North Fork. The width of the gravel varies from less than 100 to over 300 yards, the maximum occurring usually at the mouths of the pups. Sometimes also, at the mouths of the pups, usually on the lower side, e. g., in the great bend of North Fork, sheets of solid blue ice, covering the gravels for some extent, linger throughout the summer and prevent or interfere with mining operations. The

deposits of gravel beneath this ice are said to be thin, but generally to yield good pay.

The vertical section of the gravels varies in different localities. Four or 5 feet of gravel, overlying several feet of clay, which in turn rests on bed-rock, is probably a fair average. Below the great bend of North Fork no excavation has yet extended deep enough to expose a complete section. About three-quarters of a mile above the forks, however, 5 feet of gravel had been passed through, and the miners expected to pass through 5 or 6 feet more before reaching bed-rock. About a mile above the bend, where the fall of the creek is rapid, the section consists of only 3 feet of gravel, resting on rotten bed-rock. This rock is a decomposed micaceous quartz-schist, traversed by quartz veins. Good colors of gold were seen quite near the surface of the gravel, as well as lower down; and the yield on claim 53 is reported to be better than was expected in these thin gravels, one nugget found being worth $25. From a little above this point up to near the head of the Fork, a distance of about 2 miles, all sections show the gravel to be underlain by several feet of yellowish-brown clay. The clay is tough and tenacious, and its stickiness is said to be quite a hindrance in the separation of the gold, which here occurs almost entirely in it. It shows some tendency to stratification and often there is some quartz gravel. The fact that it somewhat resembles in places fine bowlder-clay, and its occurrence at one point 30 feet above the level of the stream, suggest the possibility of its being of local glacial origin, though at present there are no glaciers in this section of the valley to which it could be attributed.

If of sedimentary origin, this portion of the valley must have been temporarily occupied by a body of standing water in which the clay was laid down. The most plausible view for the confinement of the water is that of a landslide dam thrown across the gulch at some narrow point below, though no remains of such dam were observed. After the lakelet was drained of its water the gold-bearing gravels were deposited above, and the gold worked its way from the gravels down into the clay.

A third view is that of residuary soil. This seems plausible enough for the clay found on the slopes above the creek, but no such residuary deposits have been observed elsewhere in the Birch Creek district, and it is difficult to see how, in a gulch of its own cutting, a stream should be able, for a stretch of 2 or more miles, to deposit its gravels on residuary soil. As other claims on the gulch are opened up, further excavations will doubtless throw more light on the origin of the clay.

Source of placer gold.—As in the gravels of the Fortymile district, so in those of Harrison Creek some of the placer gold is found in direct contact with quartz and quartz-schist, showing the country rock of the region to be the source whence the gold has been derived. The

best example of gold-bearing quartz found in the gravels is a rhomboidal block of quartz-schist, about 4½ by 5 by 2 inches, found on claim 91, on North Fork, about three-quarters of a mile above the forks. On one of the larger surfaces of this block is a quartz vein, which is richly spotted with flakes and specks of gold, ranging from three-sixteenths of an inch in diameter to mere specks, which finally become invisible to the naked eye.

EAGLE CREEK.

Eagle Creek in its upper part divides into Mastodon and Miller forks. The valleys of the forks, especially in their upper parts, are sharply V-shaped, their sides are furrowed by gullies, and they often head in a cirque. Miller Fork is fed from masses of perennial snow and ice which flank the northward slope of its head just opposite Mastodon Creek. The Eagle Creek Valley is usually precipitous on the north side and gently sloping on the south, and the stream holds to the north side of the valley.

Gold was first discovered on Eagle Creek in 1895, about a mile and a half below the forks, and by August, 1896, the entire creek from the mouth of Eagle to near the heads of Mastodon and Miller forks was staked and some mining actually begun. The supplies for Eagle are brought in via Mastodon Creek, and therefore have to be freighted over the main divide. In consequence of this an extra charge of 8 or 10 cents a pound is made on the freightage, which, with the remoteness of the diggings, has resulted in the payment of higher wages on Eagle Creek, the rates here being $12 per day, while in most of the other gulches they are $10.

The points at which claims have been best opened up are on Mastodon Fork, on claim No. 2, just above the forks, and on claim No. 7, about a mile below the forks. At the former locality some of the ground is reported to have yielded $61 to the shovel. The normal vertical section of the placers as shown here consists of 5 to 8 feet of gravel, coarse and fine, overlying 3 to 4 feet of clay, which is in other places seen to be distinctly stratified, and therefore of sedimentary origin. The clay in turn rests on bed-rock. The coarser gold occurs chiefly near the top of the clay, some nuggets being found on its very top, between the clay and the gravel; and with descent into the clay the gold grows finer and is thoroughly embedded in it. At the other locality, on claim No. 7 and those adjacent, about a mile below the forks, there is very little clay, and the gold is said to be found on and in the rotten bed-rock beneath from 5 to 8 feet of gravel. This gold is generally coarse, nuggets weighing an ounce or more being common; and some of it contains quartz.

On the main Eagle Creek the width of the flat or gravel deposit ranges from a little less than 200 to 500 yards. The maximum width is found a little below Discovery, where it somewhat exceeds 500

yards. The deposit also has considerable breadth at the forks, but soon begins to narrow above that point.

Wherever observed, the gravels were of quartz-schist and vein quartz like the bed-rocks, which are frequently exposed.

MYNOOK CREEK DISTRICT.

Mynook Creek enters the Yukon from the southeast, in the Lower Ramparts, 50 miles below Fort Hamlin. This creek is called on the Coast Survey chart the Klanarchargut River, but is universally known in Alaska by the name given above. Although this region is a long distance from the Birch Creek district, yet it lies in the northwest-southeast-trending gold belt, which includes all the districts that have been described.

Four miles above its mouth Mynook Creek divides into two branches—Mynook proper and Hunter Creek. A short distance above this point Little Mynook Creek enters. The gravels along the main creek are undoubtedly auriferous, but on account of the width of the valley over whose bottom they are distributed the pay streak is difficult to locate. It thus happens here, as on Fortymile Creek and Birch Creek, that little mining is done along the main stream, and nearly all in the V-shaped gulches of small tributaries. In these the bottom is so narrow that the pay streak, if present, can ordinarily be easily located. At the time of examination two gulches leading into Mynook Creek were being worked by the miners and were producing some gold; these are Little Mynook Creek and Hunter Creek. The description of the former is by J. E. Spurr; that of the latter is by H. B. Goodrich.

DISCOVERY.

Mynook Creek was probably prospected as early as 1882, but little was known of it until late in the spring of 1893, when a Russian half-breed, named John Mynook, prospected this and neighboring streams and found coarse gold. It was not until 1896, however, that mining was actually begun.

GENERAL GEOLOGY.

Near the mouth of Mynook Creek are conglomerates, sandstones, and shales of the Kenai series, partly firmly and partly loosely consolidated, and containing plant remains. Above these rocks, at an elevation of several hundred feet above the river, are thick silts containing fossils of living species. Above the silts, covering the whole plateau, are gravels of varied origin, which roll down the steep hillsides into the valleys. On most of Mynook Creek proper and of the tributaries which have been examined the chief bed rocks are the diabases, tuffs, and shales of the Rampart series. It is probable that on the upper waters of the creek rocks of the Birch Creek or Fortymile, or both, occur, but these portions were not seen.

DESCRIPTIONS OF GULCHES.

LITTLE MYNOOK CREEK.

Valley.—At its junction with the main stream Little Mynook Creek contains gravels in its bottom for a width of 100 feet or more, but a short distance up the gulch the gravels narrow to 30 or 40 feet or less. Above this level bottom on one side is generally a steep rock wall, while on the other a gentler talus slope for 100 feet or more, and then a steep wall corresponding with that on the other side. In general shape this and the neighboring gulches are like those of Fortymile Creek and other streams in the gold district, having steep, high, and often precipitous walls inclosing a V-shaped valley which heads abruptly with a steep wall up to the divides. In the smaller gulches the streams flow in veritable notches with no flood-plain whatever, while in the larger ones the valley is naturally somewhat wider at the bottom. The heads of these gulches on Mynook Creek show, so far as noted, no tendency toward the amphitheater form which was observed at the head of gulches in Fortymile and Birch Creek districts, and which appeared to arise from the action of annual glaciers. The difference is probably due to the fact that these streams which flow into Mynook Creek head in a comparatively low plateau which is little favorable for the preservation of the accumulations of ice, while the before-mentioned gulches head in higher mountains.

Bed-rocks.—The rocks on Little Mynook are those which are typical of the Rampart series, consisting chiefly of clay-slates and impure felspathic sandstones, with much olivine-diabase, apparently interbedded with the sedimentary rocks. A peculiar type, especially noticed on Mynook Creek above the mouth of Little Mynook Creek, is a grayish-green aphanitic slate, often light-green and changing in zones to dark-red. Some of this rock is massive and some thin-bedded.

All the rocks are considerably jointed throughout, and in certain parts these joints become set so close together as to constitute a shear zone. These shear zones, and, to a less degree, the joints and the bedding planes, afford an easy access to mineralizing waters, whose work is shown by the formation of pyrite and copper pyrite, and by the alteration of the neighboring rock to jasperoid by deposition of silica. These zones of mineralization are very common through the lower part of Little Mynook Creek and on the main Mynook Creek above the mouth of Little Mynook Creek. There are also occasionally veins of white, crystalline quartz, often with comb structure.

Gravels.—In the bottom of Little Mynook Creek there lies at the surface a deposit of muck and vegetable material, very black and full of roots. In one claim this material is 8 feet thick, but ordinarily it is only a foot or two. Below this comes loose, detrital material, consisting mostly of angular fragments which have slid down from the

hillside above, many of them being very large, often a foot or so in diameter. These fragments are unassorted, the fine dirt and the large bowlders occurring together. Mixed with these angular fragments, which are all derived from the rocks of the Rampart series that outcrop on the bluffs above, is a variable amount of well-worn and rounded smaller pebbles representing a variety of rocks, among which the gray micaceous quartzite-schists of the Birch Creek formation are conspicuous. These rolled gravels are most abundant in the bed of the present stream, above the angular deposit.

At a point about a mile above the mouth of Little Mynook Creek the total thickness of the detrital deposit is about 6 feet. The bed-rock below it is so much disintegrated that it breaks into very small fragments, and so can be torn up as easily with a pick as compact gravel. This rotten bed-rock is about 1 foot deep and contains all the gold, none being found in the overlying gravels. Beneath the decomposed material the fresher rock is a dark-green olivine-diabase, containing a large amount of pyrite and hematite.

It is evident that here, as in other gold-bearing gulches, the richest pay streaks occur in places where the bed-rock has acquired such peculiar structure as a consequence of shearing, jointing, or disintegration that the gold particles are mechanically collected and concentrated in the same fashion as in the sluice boxes of the miners, where the concentration is effected by means of riffles. It also is highly probable that the gold is, partly at least, derived from these sheared and altered zones, which are often so richly impregnated with sulphides. The fact that the diabases and slates of the Rampart series form much the larger part of the overlying gravels points to these rocks as the source of the gold, while the presence of the well-rounded, less abundant pebbles of the Birch Creek and other formations suggests the possibility of the derivation of part of the gold from these.

Gravels formed of well-rounded pebbles of various rocks, similar to those just described, are said to be found all over the broad plateau through which Mynook Creek has cut, and at various points along the Mynook Creek trail these have rolled down from the hilltops above.

The thickness of gravel in Little Mynook Creek is ordinarily between 10 and 20 feet, and this thickness continues to the head of the gulch without a great decrease. On this account the gulch is commonly regarded as "winter diggings," as it is not generally practicable to remove the gravel from the overlying bed-rock in the summer by shoveling. At the time of the examination only one claim was being worked on Little Mynook Creek, that belonging to Mr. Langford. The gold taken from this claim was moderately coarse and of good color; native copper and silver were also found with the gold, but in very small quantities.

HUNTER CREEK.

Hunter Creek is about 30 miles long. For the first 15 miles, after leaving the high Tanana range, it pursues a northward course around the head of Little Mynook Creek; then it turns at right angles to its former course and flows north of west.

Shape of valley.—The valley is cut into a nearly level plain, which is 450 to 500 feet above the present stream. The two sides are dissimilar. On the south the first descent from the ridge-top is sharp and in places precipitous for a vertical distance of 300 feet; then the slope becomes gentle and there is a broad bench which ends abruptly at the creek in a bluff of 25 to 30 feet. The upper part of this bench is composed of gravel, which averages 15 feet in thickness. The creek flows along the north side of the valley the whole distance traversed, and on this side the bank generally rises in sharp, perpendicular rock cliffs directly from the stream. When, however, the channel bends toward the south, away from the north side of the valley, the banks are often of gravel, sometimes as much as 15 feet in thickness.

Bed-rocks.—The bed-rock of Hunter Creek near the mouth is a coarse, loosely consolidated conglomerate, containing pebbles of the older formations. This rock is the same as that seen along the Yukon at the mouth of Mynook Creek. A short distance up Hunter Creek the conglomerate is succeeded by shales, tuffs, and diabase of the Rampart series. These rocks are much jointed, and along shear-zones are silicified and impregnated with sulphides. They also contain occasional veins of quartz and calcite.

Gravels.—The best-paying parts of the claim now being worked have generally been found at the southernmost parts of the meanders; that is, where the present stream approaches more nearly its old channel. This is not, however, to be regarded as a strict rule, for good prospects have been found at different localities upon the north side. The greatest thickness of the gravel is 15 feet. Its pebbles are not generally large, and it bears the same evidences of having been laid down in comparatively swift-running water as the gravels of the other districts; and the same slight stratification and illy assorted character obtain. The pebbles, however, unlike those of the smaller gulches visited in the Fortymile and Birch Creek district, are of different varieties of rocks. There is, of course, débris from the hills immediately adjoining the lower part of the creek, such as pebbles of diabasic tuffs, shale, and limestone, and these are generally large and subangular; but there are also well-rounded smaller pebbles and bowlders of the typical Birch Creek formation, quartzite-schists, and schistose granites, with vein quartz.

The Birch Creek series does not outcrop in the distance traversed on Hunter Creek; and the fact that the material derived from this formation has suffered greater abrasion than the other bowlders is, in

a measure, an index of further transportation. According to prospectors, the bed-rock for many miles up the south branch of Hunter Creek is the same as that just described on the lower creek, but the formation changes near the head, where the mountains are composed of schistose rocks. Prospecting has already extended to the headwaters, and a certain amount of gold has been found the whole distance. The gold for each creek has certain characteristics of its own as to shape, color, and size which distinguish it from that of another creek so well that an experienced miner can tell at once the particular gulch from which a given grain has been recovered. The general character of the Hunter Creek gold is that of bright-yellow, small, bean-shaped grains and nuggets, and these occur more frequently than unworn grains.

Work upon Hunter Creek began last spring, and in the summer only one claim—that of the discoverer—was yielding gold. This claim is located 1¼ miles above the confluence with Mynook Creek proper. Below this claims are staked according to miner's law—500 feet long, covering the intervening area. Above the Discovery claim, also, claims are staked continuously for 2 miles, and some at intervals still farther up. None of these, however, were beyond the first stage of prospecting.

OTHER GULCH DIGGINGS.

KLONDIKE DISTRICT.

On the Klondike and Indian rivers the gulches have yielded coarse gold in a small way for some time, but only a few men were employed there until the latter part of August, 1896, when the discovery of especially rich gravels on the gulches of the Klondike led to a rush and the transference of most of the population of Fortymile to the new district. No examination of this district was made by the United States Geological Survey party, but, according to reports, it is likely to be a rich producer. The rocks appear to belong to the schistose Birch Creek and Fortymile series, and contain abundant quartz veins, in some specimens of which free gold has been found.

UPPER YUKON.

On the Selwyn River, which enters the Yukon below Fort Selkirk, coarse gold occurs, and a number of men were engaged in prospecting here in the summer of 1896. This river, in its lower part at least, flows through the ancient schistose rocks, which here, as elsewhere, carry abundant quartz veins.

On the east side of Lake Lebarge, just below the head, is a small creek which is reported to carry coarse gold, and on the Lewes, just above Miles Canyon, is Cummins Creek, where the gravels have yielded $3 to $5 per day, while on lakes Lindeman and Bennett several streams have been worked for gold, yielding $1.50 to $4 per day.

SHEVLIN CREEK.

In the lower Ramparts of the Yukon, besides Mynook Creek, which has been described, Shevlin Creek and a number of others carry coarse gold.

THE KOYUKUK.

According to prospectors, the Koyukuk yields gold along its whole length, and is said to have produced about $30,000. In places coarse gold is found, which, according to the testimony of several observant miners, is derived from conglomerates which are made up largely of quartz pebbles. These conglomerates are associated with sandstones, grits, and shales, and usually have a steep dip. They generally form the bed-rock along that part of the Koyukuk which has been prospected, and, judging from the note of Lieutenant Allen, they are to be referred to the Kenai series.

BAR DIGGINGS.

MANNER OF FORMATION.

Owing to the considerable grade of the gulches in the auriferous area and to the consequent swiftness of the streams which flow through them, it is only the coarser particles of gold which escape being carried away. The finer particles, unless they are sheltered in some especially favorable position, find their way from the gulches into the larger streams. The limit as to the size of the grain which is thus transported is variable, depending upon a variety of conditions, such as the strength of the current, its direction, and the nature of the bottom over which the water flows. Variations in these conditions are constantly happening in the same place. Thus heavy rains or the melting of snows produce a largely augmented amount of water, and under these conditions grains of larger size will be transported than in times of drought. It is a general rule, however, that the very coarse materials remain behind, not being easily transported, and the comparatively fine particles escape and are carried to an indefinite distance—a distance which may be very roughly considered as in inverse ratio to the size of the particle.

In the larger streams, when the current which transports gold along with other detrital material suffers a decrease of velocity, and hence of carrying power, some material may be dropped to the bottom, while the water flows on more slowly and comparatively clear. It thus happens that in long rivers which flow through auriferous rocks or whose feeders flow through auriferous rocks there are at intervals deposits of fine gold in gravelly accumulations. Such accumulations of detrital material are known among the miners as bars, and when sufficiently rich in gold to repay working these are called "bar diggings." Bars are formed wherever the curves of the channel are

such that the current flows off at a tangent to the shore, thus producing slack water and often backwater or eddy in the immediate vicinity of the bank. Thus the most common loci for bars are points immediately below where a pronounced curve changes suddenly for another.

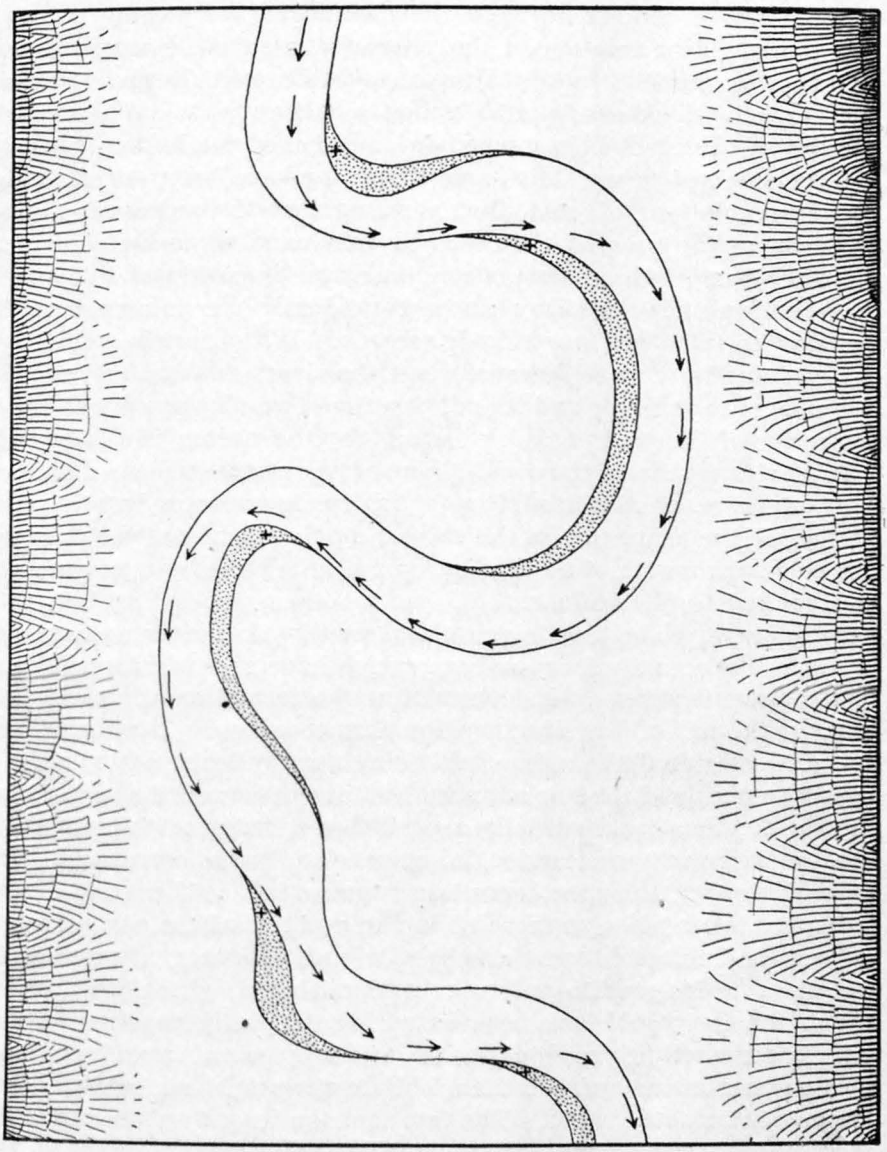

FIG. 24.—Diagram of ideal river, showing accumulation of bars

Slight concave irregularities in an otherwise straight channel also produce the conditions necessary for these deposits, since such concavities will not ordinarily influence the course of a moderately swift current. Therefore experienced miners and prospectors have little difficulty in locating the portions of the river gravels which are most

probably richest in gold after observing the action of the current. The accompanying diagram (fig. 24) shows an ideal river with the spots where the auriferous particles are most likely to be concentrated indicated by crosses.

Most of these accumulations of gold are extremely recent, as is shown by their coincidence with the channel of the present stream and their evident relation to the present currents. Moreover, the gold-bearing gravel is nearly always confined to the actual surface and varies in thickness from 20 inches to half an inch. When these bars have been practically worked out, and have been left untouched for a number of years, it is found that they have been enriched by new accumulations of gold, thus showing that the process is going on, even at the present time. Such bars can be worked only in the drier part of the season, when the water is so low as to expose them; and in some cases they can be worked only once in a number of years, when there is a specially dry season. In the spring and early summer and in the wet seasons, when the rivers are full and rapid, these bars are covered, and it is at this time that the process of concentration of the gold particles brought by the stream is carried on.

It is evident that in the flood-plains of the streams there must be many such accumulations of gold, which have been left dry by changes in the channel. In the richest diggings, such as the Cassiar bar below the mouth of the Teslin, buried bars have been prospected and worked to a certain extent, but in other places they are not usually very productive, since they are by no means so easy to locate as the actually forming bars, which have so evident a relation to the present stream. In contrasting the formation of gulch diggings with that of bar diggings the former may be considered as essentially residual, the coarse gold being usually derived from neighboring sources and the fine material having been washed away, while the bar diggings are essentially deposital, consisting of the material thus washed away and carried in suspension by the current until a favorable opportunity for deposition is presented. After such deposition has taken place an increase in the rapidity of the current may extract the finer gold from these bar diggings and carry it on until it can find suitable conditions for again depositing it. Such a bar, from which the finer gold has been extracted, is partly residual in its nature, although primarily deposital, and may contain gold considerably coarser on the average than that from a neighboring bar where the current is not so rapid. The fact that the velocity of the water is incessantly changing in any given locality makes clear the complexity of the concentration of the gold particles in these bars and also explains the continual changes. In this way a given particle travels continually, resting here and there for greater or less periods, and finally lodging in a comparatively permanent abode. The very fine particles which constitute the so-called "flour gold" are so small and

light that they are carried for a great distance, and some are found along the entire course of the streams and of other streams into which these flow; and it even seems highly probably that the more minute particles reach the sea, where they may be taken into solution by the saline waters. It is a well-known fact that sea water invariably contains a certain amount of gold and that such waters have the requisite power of solution.

As an example of the distances which fine gold may be carried in considerable quantity, it may be mentioned that at the lower end of the Yukon Flats a pan of gravel, taken from a place where the current suggested the probability of accumulation of heavy material, was washed and showed about a hundred "colors," or very fine flakes of flour gold. This locality was a short distance above Fort Hamlin, and above it for hundreds of miles the river flows through a very flat deposit, consisting of silts and fine gravels of unknown depth, in which no outcrop was seen. The silt and gravel banks, being of soft material, are rapidly worn away and taken into suspension by the waters of the Yukon, and this material is deposited as rapidly as it is taken up. The detritus in which this gold is found, therefore, must be taken into suspension and deposited many times; and yet the small particles of gold persist and under favorable conditions accumulate in considerable quantity.

RELATION OF BARS TO GULCH DIGGINGS.

In Alaska, as in other countries where placer mining has been carried on, the bars of the larger streams are generally worked first, for these, for the reasons above stated, are usually more or less profitable wherever the source of gold may be; so in the Yukon district the bars of the Lewes, Teslin, Stewart, and other large rivers were first worked. From this the gradual evolution in mining leads to the working of the richer bars on the smaller rivers. Thus the discovery and development of the bars on Fortymile Creek followed the workings on the larger rivers, and preceded all gulch digging. On Birch Creek, also, the first gold was discovered in the bars. From these richer bars the gold is ordinarily gradually traced to its source, and workings along the gulches prove so much more profitable than the bar mining that the latter is soon abandoned. In the summer of 1896 the few men working with cradles and sluices on the bars of Fortymile Creek comprised nearly all those engaged in bar mining in the Yukon district.

OCCURRENCES OF GOLD IN BARS.

Fine gold is found widely distributed in Alaska. All the smaller streams whose branches have been described as affording gulch diggings also contain gold in their bars. Besides these, the larger rivers into which they flow contain everywhere fine particles of the precious

metal, and often these particles accumulate in sufficient quantity to repay working. Thus gold has been found along the whole length of the Lewes, the Teslin, the Big Salmon, the Pelly, the Stewart, and the Koyukuk. Below the junction of the Pelly and the Lewes the Yukon yields gold continuously for nearly its whole course. Even the silts of the Yukon Flats yield gold in places, as already noted.

On White River Dr. Hayes reports a very small quantity of fine gold, although there were no encouraging prospects and very little vein quartz was found. On the Kuskokwim gold is reported by prospectors, and also on the Fish River, which flows into Norton Sound. On the Kowak S. B. McLenegan[1] reports nearly everywhere colors of gold.

ANCIENT AND FOSSIL PLACERS.

ELEVATED AURIFEROUS GRAVELS.

Besides the auriferous gravels in the beds of the present streams, elevated gravels of greater age are widespread. They occur abundantly on terraces at various heights above the present streams, and are even found on the ridges or divides. Often they are strewn over the whole surface of broad elevated plateaus. From the extensive distribution of these gravels and from the positions in which they are often found, it is clear that they can not be ascribed entirely to river action; and this, joined with the evidence of recent submergence, supports the idea that they are largely marine, or have been redistributed by marine action, although those which make up the lower terraces along the river are probably due directly to river action, being portions of older beds which have been left as terraces by the down-cutting of the stream.

In many places these gravels are found to be auriferous, as is to be expected, since they are made up largely of the gold-bearing rocks of the Birch Creek and Fortymile series, from which, under favorable circumstances, the precious metal must be concentrated. From these elevated auriferous gravels, as has been suggested, some of the gold found in the younger deposits in the beds of the present streams may be derived; and, since these gravels are very widespread, they may account in part for the occurrence of gold in small quantities in nearly all Alaskan streams. Up to the present time these elevated auriferous gravels have not been exploited for gold in any considerable way, but it is possible that in the future, under favorable conditions, it may become profitable to work them.

[1] Cruise of the U. S. revenue steamer *Corwin*, 1884, p. 107.

FOSSIL PLACERS.

NAPOLEON CREEK.

On Napoleon Creek, in the Fortymile district, the rocks of the Rampart and Fortymile series are overlain unconformably near the mouth of the creek by a series of conglomerates, sandstones, and shales, which have been referred to the Mission Creek series. The lowest bed of this younger series is a coarse basal conglomerate, made up of fragments ranging in size up to a foot in diameter. These fragments are of quartzite, vein-quartz, gray and green slate, aplite, porphyry, and other rocks derived from the Birch Creek, Fortymile, and Rampart series. The conglomerate dips steeply up the valley of Napoleon Creek, so that a short distance farther up it is overlain by sandstones, grits, shales, and limestones. In and immediately below the belt occupied by the basal conglomerate the present gravels in the bed of the creek are rich in placer gold; but above this comparatively narrow zone they are entirely barren, and below it they are very poor. It is probable, therefore, that the gold is derived from the basal conglomerate; and from the fact that this conglomerate is composed of fragments of the older auriferous rocks it seems probable that the gold from these rocks has been concentrated mechanically. In other words, we have here an ancient gravel bed in which gold, derived from the erosion of auriferous rocks, was concentrated. This gravel has been consolidated into a hard conglomerate and has been buried for an immense period of time beneath a great thickness of later deposits. It may therefore be called a fossil placer, the term "placer" being understood to include both river and beach deposits; indeed, in this case it seems probable that the material may have been a beach deposit.

THE KOYUKUK.

According to prospectors, gold occurs all along the Koyukuk. The chief producing locality is said to have been about 300 miles above the mouth, where the rocks are conglomerates, sandstones, grits, and shales, dipping steeply; this is also in accord with the brief note made by Lieutenant Allen; and from these descriptions it appears probable that this conglomeratic series is part of the Kenai series. The gold is said to be derived from the conglomerates, which contain pebbles of different rocks, especially of rolled quartz. If this is the case, we have probably here also fossil placers or ancient auriferous gravels, whose formation dates back to the Eocene or Kenai period, and which have subsequently been buried, and only exposed again in consequence of great folding and profound erosion.

CONCLUSION.

From the evidence furnished by conglomerates everywhere throughout this region, we know that the gold-bearing rocks, such as those of

the Fortymile and Birch Creek series, were exposed to atmospheric erosion since the beginning of the deposition of the Mission Creek series, and probably before; and this erosion must have gone on at intervals ever since. During all this period the processes of concentration went on in rivers, on beaches, and in other places, precisely as at the present day, so that portions rich in gold, or placers, must continually have been forming. At times of extremely rapid erosion and deposition, moreover, such as that under which the Kenai conglomeratic series was deposited, coarse gravels suitable for the accumulation of gold were rapidly laid down. It is reasonable to suppose, therefore, that these auriferous conglomerates or fossil placers will in future be found to have a wide distribution and may become of considerable importance from a commercial standpoint.

METALS OTHER THAN GOLD IN PLACERS.

All the gold produced in Alaska is alloyed with a certain small amount of silver. Besides this, pure native silver is frequently found, along with gold, in the materials concentrated in the placer workings, generally in small rounded or irregular nuggets, although occasionally, as at one place in Franklin Gulch, well crystallized. Native lead occurs in small nuggets on Hog'em or Deadwood Creek, and nuggets of gold which come from this gulch sometimes contain native lead in small bits. Native copper, in small rounded nuggets, has been found on Little Mynook and Hunter creeks.

Platinum has frequently been found in the Yukon district, chiefly in the diggings in the upper part of the Yukon drainage system. On Twelvemile bar, which is 12 miles below the Big Salmon River, on the Yukon, the yield in platinum is said to have been 2 or 3 ounces to each 10 or 12 ounces of gold; the metal, however, was not saved, since the miners were ignorant of its value.

ORIGIN OF PLACER GOLD OF YUKON DISTRICT.

The tiny flakes or colors of gold which are found so widely distributed in the sands and gravels of streams are capable of being carried enormous distances without being destroyed, and are many times deposited and again taken into suspension by changes of current. Thus it happens that fine or flour gold in small quantities may be found along the entire course of most of the rivers in Alaska. On account of this indestructibility and facility of transportation, fine gold affords no adequate index of the source from which it is derived. As the gold becomes more abundant and coarse, however, it is clear that the source is being neared. Thus on Fortymile Creek and on Birch Creek the bars on the main streams were richer than the bars on the Yukon, into which these streams flow. In this way prospectors find continually richer accumulations, until, finally, in certain

gulches whose waters run into the river on which the bars have been previously worked, gold is found which is fairly coarse and in considerable quantity. In these gulches nuggets are found, and fragments of quartz and gold mixed. It is evident that these places are nearest the true source of the gold, and that from here have been derived the finer and rarer particles which occur in the bars of the larger streams, and also the still finer and rarer particles in the rivers into which these streams empty. Therefore, in inquiring as to the source of placer gold we may pass over the widespread fine or flour gold in the great rivers and also the bar diggings in the tributary streams, and confine our study to the gulch diggings.

DERIVATION OF GOLD FROM CERTAIN ROCK FORMATIONS.

DISTRIBUTION OF RICH GULCHES WITH REFERENCE TO GEOLOGICAL STRUCTURE.

The Birch Creek and the Fortymile districts are, up to this time, the richest placer diggings in the Yukon region, although the new diggings on the Klondike and Indian rivers promise well. These all lie in the rocks of Birch Creek and the Fortymile series. Of the smaller gulch-mining districts, American Creek and Mynook Creek are the only ones which have been productive heretofore, and these run through the rocks of the Rampart series. All the districts lie in a definite zone or belt, which has a northwest and southeast trend and corresponds with the zone occupied by the exposures of the oldest rocks along the eroded Yukon geanticline. Along this zone we may say that the richest diggings have been found in areas occupied by the Birch Creek series, and also some rich gulches in the Fortymile rocks, and that gold in paying quantities has been found at times in gulches lying in the rocks of the Rampart series, while gulches which cut other formations have almost invariably proved barren. If, besides the gulch diggings, we take into consideration the richest bar diggings along the Yukon, Stewart, Big Salmon, and other rivers, we see that the alignment of the rich gold district in a northwest and a southeast direction, corresponding with the belt of the older schistose rocks, is still more striking.

The suggestions offered as to the occurrence of gold, which are derived from the correspondence above noted, are corroborated by detailed study in the gulches themselves.

GULCHES IN BIRCH CREEK ROCKS.

Miller, Glacier, Poker, and Davis creeks in the Fortymile district, the entire Birch Creek district, and also probably most of the Indian and Klondike gulches, all have characters so nearly identical that they may be described together. All these flow entirely through the quartzite-schists of the Birch Creek series. These schists everywhere contain numerous quartz veins, and are cut by occasional dikes, chiefly

of granite or diorite, which are sometimes of large size. In all the gulches the gravels are entirely made up of fragments of rock identical with that found in place on the neighboring hillsides. These gravels vary in thickness up to about 25 feet, generally, although not always, increasing with the distance from the head of the gulch; in them the schist is in quite large, flat fragments, often with ragged outline, and the quartz is in bowlders of varying size. The schist fragments all lie flat; but that water action has been slight is shown by the fact that mixed with the large fragments is sand, and even fine soil, which the current has not been powerful enough to separate. The schist, moreover, is so brittle that if it were carried far it could not long remain in the large, flat fragments in which it is found. The material, therefore, is essentially a talus derived from the steep walls of the gulch valley, and this talus has been slightly rearranged by water, but not sufficiently to bring about any great changes. As a general rule the material and arrangement of the gravels from top to bottom are the same. In some of the gulches, however, there are slight differences, which are generally found to be local. Thus, on Glacier, Poker, and Davis creeks, in the Fortymile district, the gravels have a tendency to be finer at the bottom than at the top; and on Harrison and Eagle creeks, in the Birch Creek district, there is a deposit of clay beneath the gravels. In other parts of Eagle Creek, however, the clay is lacking, and on parts of Mastodon Creek, in the same district, the gravels are finer at the top; while on Porcupine Creek a bed of sand was found to be the uppermost layer. These variations, therefore, seem to point to no widespread variations in the conditions under which the thin gravels accumulated, and the occasional differences are probably due to local and temporary causes.

The bed-rock underlying the gravels is always the quartzite-schist of the Birch Creek series, containing veins of quartz. This schist is disintegrated, decomposed, and reddened from oxidation for a short distance below the surface, this distance ranging from a few inches to 2 or 3 feet. As is ordinarily the case, the decomposition is attended by a shrinking of the rock, due to the loss of certain components by the leaching of the surface waters; and in consequence the rock becomes finely cracked, jointed, and porous for some distance down. Although as a rule the gravels rest directly upon this more or less altered schist, yet on Harrison and Eagle creeks, as noted, is a layer of clay several feet in thickness between the gravels and the schist. This clay is sometimes dirty and pebbly, sometimes clean and well stratified. It is, however, only a local deposit, since it is not found in neighboring gulches, and, indeed, not in the whole of Eagle Gulch, for on parts of this gulch the gravels rest upon the clay, and in others directly upon the schist.

In regard to the distribution of gold in these deposits, it is a general rule, to which there are few, if any, real exceptions, that the gold

is found in greatest amount at the extreme bottom of the gravels or at the surface of the underlying material. Often the gravels themselves are entirely barren, but usually they are gold-bearing for some distance above the bottom, the amount of gold becoming less toward the top, until it grows so slight that the gravels are not worth washing. The portion which contains gold in sufficient quantity to repay working under the present conditions is called pay dirt. It must be borne in mind, however, that the present conditions of working are very expensive, and that certain gravels which are considered worthless at the present time would undoubtedly, with cheaper methods, prove profitable. Under the present conditions the average thickness of pay gravels is perhaps not more than 2 feet, though rarely as much as 10 feet, while the overlying gravels average 8 or 10 feet and have a maximum thickness of about 25 feet. Below a depth of 25 feet practically no workings have been undertaken, although in certain parts of the country there are much deeper gravels which may in future be explored and worked.

Gold is found not only in the gravels above the surface of the schist, but also in the schist itself, in some cases for 2 or 3 feet down, and in others for only an inch or less. The amount of gold generally grows less as the distance from the surface of the schist increases, and as a general rule it is only that portion of the rock which has been broken up by disintegration and decomposition which is gold-bearing at all, the fresh rock beneath being barren. The depth to which gold is found in the bed-rock therefore depends upon the depth to which disintegration has penetrated.

On Harrison and Eagle creeks, where the gravels are underlain by clay, gold occurs chiefly at the very top of the clay. Here the nuggets are generally found, and the coarsest gold. Above the top of the clay the gravels are gold-bearing for a varying distance up; and below the top the clay itself contains a great deal of gold, which, however, grows finer and less in quantity as the distance from the top increases. The same occurrence of gold is reported in places on Mastodon Creek. In these places the bed-rock below the clay is practically barren.

It follows from what has been said concerning the locus of the concentration of gold that the particles of this metal are derived from the gravels, in the bottom of which they are concentrated by reason of their greater specific gravity. The fact that in places the whole thickness of gravels is sufficiently auriferous to repay working shows that the gold can not have accumulated in any special period in the deposition of the gravels; while other localities, in which the pay gravels become thinner and thinner and are always at the very bottom of the deposit, show various stages in the concentration, until in many cases most of the gold is found at the extreme bottom of the gravels, resting on the underlying material. The fact that the pay streak when thin is usually so rich as to make it as well worth working as the thicker

but poorer gravels, also points to this concentrating action. Since nearly everywhere the bed-rocks which underlie the gravels also carry gold, sometimes in greater quantity than the gravels themselves, some have been led to the belief that the gold was originally present in the rock; but that this is not true is shown by the fact that when the bed rock is overlain by clay, as on Harrison Creek, the gold has been concentrated in the sticky and impermeable blanket and the bed-rock is barren. Moreover, in cases where the bed rock carries gold, the occurrence of metal is confined to those parts which have been rendered much jointed and porous by surface disintegration, and the schist a short distance below the surface is barren. It is thus evident that the decomposed schist has acted mechanically to catch the particles of gold which have worked down from the overlying gravels and which have found a permanent safe lodgment in the cracks and joints of the rock, and that the schist in this operation has played the same part as the clay above noted, or as would any other material sufficiently penetrable to arrest the gold but not so much so as to permit its working down through it any great distance.

Having established the fact that gold is derived from gravels, it remains to be shown that it comes from the rocks which make up the bulk of the gravels—that is, schist and quartz—and that it is not from material introduced into the gravels at the same time with these rocks. In many of the gulches quartz veins which carry free gold have been found in place on the hillsides, and in nearly all the gulches blocks of vein quartz are found in the gravels, which, from their appearance, can hardly have been transported far, and which are also found to be gold-bearing. In the pay gravels, moreover, among the smaller fragments and nuggets, are found gold and quartz in the same fragments and in all relative proportions; so that a series might be brought together beginning with fragments of quartz containing seams and flakes of gold and ending with nuggets carrying grains or seams of quartz. Nearly all the large lumps of gold contain considerable quartz, and even the very small pieces often show under the microscope fragments of quartz clinging to them.

When the pay gravels are washed by water in the sluice boxes or other contrivances the heaviest minerals are separated from the lightest, which are carried away by the water. In the concentrate left behind there is a variety of minerals besides gold, and these minerals show evident derivation from and dependence upon the rocks which constitute the large fragments in the gravel. Thus, in the gulches under consideration, the heavier minerals are almost entirely those found abundantly in the Birch Creek schist—chiefly hornblende, magnetite, and limonite. When garnets are found in the schist these are also present in the concentrates, and in about the same relative abundance. Frequently galena is found, and in nearly every gulch where this is the case, as, for example, on Miller, Glacier, and Hog'em creeks, veins of galena have been found in the bed-rock.

GULCHES IN FORTYMILE ROCKS.

A number of gulches which have yielded gold in paying quantities flow entirely through the rocks of the Fortymile series. Among these Franklin Gulch in the Fortymile district has probably been the richest, and may serve as an example for all. This is nearly a strike gulch, flowing along the upturned edges of mica- and hornblende-schists interbedded with marble. These schists are cut by frequent dikes. At the extreme head of the gulch, close to the divide, is a great dike or intrusive mass of granite or granodiorite. The gravels in the creek bottom are composed of the same materials as the walls of the valley, and contain besides these materials frequent fragments, often rounded and of large size, of olivine-basalt, a rock which has not been found in place here, although it occurs abundantly just to the south, in the country drained by Chicken Creek. Gold has been found the whole length of the creek as far as prospected, and occurs in the very bottom of the gravels or in the irregularities of the underlying bed-rock. The thickness of pay gravels varies up to about 2 feet, and above this, as in other gulches described, lie barren gravels, which, however, do not differ in general appearance from those which contain gold. Every indication shows that here, as elsewhere, gold is derived from the gravels which now lie in the bottom of the gulch.

GULCHES IN RAMPART ROCKS.

On Little Mynook and Hunter creeks the bed-rocks are of diabase, tuffs, impure shales, and quartzites, and in the bottom of the gulches these rocks are overlain by from 10 to 20 feet of gravel. In part the gravels are large, angular fragments of rock like that forming the walls of the gulches. This material shows little wearing by water action and little assortment, being essentially a slightly arranged talus. Besides this, however, there is a great deal of waterworn material, consisting of well-rounded pebbles of rocks which do not occur, so far as known, in the drainage basin of the gulches. Among these fragments are conspicuous the rounded pebbles of Birch Creek schist, of schistose granite, and other rocks. The rounded fragments are mingled with the angular material of local origin throughout the whole thickness of the gravels. Beneath the detrital accumulation the bed rock is softened and decomposed for about a foot below the surface, and in this altered rock nearly all the gold is found. Below this the fresh rock is barren, while above it the lower part of the gravels sometimes contains sufficient gold to repay working. It is evident in this case, as before, that the gold has been derived from the material which now constitutes the gravels, but here the material has a twofold origin. The rocks through which the valley cuts are traversed by numerous shear zones, along which sulphides containing at least traces of gold and silver have been deposited; and there are also frequent quartz veins, some of them of large size, which are

claimed to carry gold. Since these rocks make up the most of gravel, it is probable that the gold found concentrated in the bed-rock below is partly, at least, derived from them. On the other hand, the rounded gravels of more remote origin are of Birch Creek rocks and other schists which are known to be gold-bearing; it is therefore probable that these also have contributed somewhat.

On the upper part of American Creek where gold occurs the rocks were, so far as examined, massive serpentine- and chlorite-tuffs, impure fine-grained quartzite, and sandy limestones. At the only claim which was being worked the gravels in the bottom of the gulch were exceedingly narrow, often not more than 10 or 15 feet wide. The detrital accumulation at this place is only about 3 or 4 feet thick, and is entirely made up of angular fragments of the rocks which overhang the stream precipitously, and of the quartz veins which these rocks often contain. This fragmental deposit is nearly barren, all the gold being found on top of the bed-rock beneath. Here the gravels have apparently yielded the gold, which has been collected along schistose zones of the underlying rock, and these gravels seem to have a purely local source. Associated with the gold, in the very bottom of the gravels, are frequent rounded or subangular pebbles of magnetite and barite, which seem to be derived from the veins which follow the shear zones in the neighboring rocks.

SOURCE OF THE DETRITAL ACCUMULATIONS IN GULCHES.

It has been shown that the gold found in the gulches is derived by concentration from the gravels, which are made up of rocks in which gold occurs disseminated; and that these gold-bearing rocks are chiefly those of the Birch Creek and Fortymile series, and to a less extent those of the Rampart series. It may be advantageous, however, to consider briefly the methods by which the fragments have been brought to their present position, since a knowledge of this is essential for finding those parts of the solid rock that are richest in gold.

The origin of the most of the detritus in the gulches is clearly shown by its nature. The accumulations in the richest districts consist almost entirely of flat and often ragged fragments of schist, with large, irregular bowlders of quartz and considerable fine soil, all piled together with little assortment. The materials are generally the same from top to bottom. As a rule, the fragments consist almost entirely of rocks identical with those in the walls of the gulch, and often show changes in different parts of the gravels corresponding to changes in the wall rocks. Apart from this evident relation, it is clear that these large, flat fragments of fragile schist can not have been carried far from their original source; and the same is true of the large bowlders of quartz and associated rocks. Any great amount of water action, moreover, such as would be necessary for transportation, would have

rounded and assorted the fragments. Therefore the material is essentially a talus which has been slightly arranged though not greatly modified.

Moreover, those portions of the gravels which are most highly auriferous sometimes bear a relation to certain parts of the associated bed rock. For example, on Franklin Gulch coarse gold is found abundantly just below a wide quartz vein in the bed of the gulch, while above the vein the gold is finer and scarcer. On Hog'em Creek, in the gravels which overlie the broad granite dike, the gold is fine and comparatively scarce, but coarse gold is found in the schist immediately above the granite contact and from there continuously upstream. It is possible, however, that in this case the greater concentration of the gold on top of the schist as compared with that on the granite may be due partly to mechanical action, the ridges of schist operating as natural riffles. On Napoleon Creek gold occurs in notable amount only where the bed-rock is a certain coarse conglomerate, derived chiefly from the old gold-bearing rocks, while the gravels which lie in the rest of the creek are practically barren.

Cross sections of the gulches have nearly always a general V-shape. The smallest streams run in veritable notches, while the larger ones widen their flood-plain so that the bottom of the V becomes broadened and flattened. From the steep walls of the gulches fragments loosened by frost are continually sliding down by force of gravity or are urged down by freshets or heavy snows. Very frequently a considerable accumulation of these fragments comes down suddenly in the form of landslides. At the bottom of the gulch the detritus is smoothed and slightly arranged by the waters.

It is sometimes supposed by miners that the gravels may be due to a general glacial action, which has brought the auriferous material from some unknown distant source. It is, however, quite clear that glacial action has been practically absent in the history of the country. Not only was there no general ice sheet covering hill and valley, but even local glaciers, filling the valleys while leaving the ridges free, were absent. That this is true is shown by the total lack of all glacial phenomena and by the presence of pinnacles of rock which have been left by differential erosion and which would invariably have been broken down by a glacier. Examples of this are the Deadwood Buttes on Deadwood or Hog'em Gulch, which are tall pinnacles of granite standing on the side of the valley not far from the bottom. In the formation of the present valleys, however, the action of ice and snow has had considerable effect. In the more elevated gulches considerable snow accumulates in the winter, and in spring soon becomes ice, which moves slowly down over the steep sides and head of the valley. This action is especially marked in valleys which head in high hills, and in these valleys the accumulations of ice and snow persist at the head of the gulches after they have disappeared from

the main part, being fed from the hills. The consolidation of these snows by alternate freezing and thawing produces a mass of ice which, though temporary, has all the characteristics of a true glacier; and by the disruptive action of this ice and the effects of the waters derived from its melting, the head of the valley is broadly and vigorously eroded, so that it becomes wider and flatter than the rest. In this way, in gulches which have an abundant supply of snow, the head is converted into a typical cirque or amphitheater, such as those in which glacial material usually accumulates. The perfection of this form is seen everywhere to be in direct dependence upon the amount of snow; and where it is most perfect, considerable patches of ice often last throughout the summer, while in other cases the ice is entirely melted. The same erosive action sometimes tends to widen the valley by more rapid wearing away of the side slopes. Where this vigorous erosion takes place the heads of the valleys are free from detrital accumulations, while farther down the gravels are continually supplied with new material; and this material, mingling with the talus derived directly from the sides, is carried downward, especially during spring freshets, so that the accumulations are thinnest at the head and thickest at the mouth of the valley.

In many cases, however, there are found, mixed with the large angular or subangular fragments which are so evidently derived from the rocks of the vicinity, small well-rounded pebbles, whose form indicates considerable transportation; and on some creeks, as, for example, on Hunter and Little Mynook, the pebbles are of rocks which are not found, so far as known, in the drainage area. These well-worn gravels occur not only in the gulches but also in the uplands; thus they cover the whole of the plateau through which Hunter and Little Mynook creeks cut. The source of these gravels has already been discussed, and it has been suggested that part, at least, have a marine origin, or have been arranged in their present fashion by marine action. Since they are composed in large part of materials from the gold-bearing Birch Creek and Fortymile rocks, and since on high terraces above the present rivers and on upland benches they have been found to be auriferous, it is probable that from them some of the gold in the gulches where they occur is derived. Owing to supply of this material from sources outside the drainage basin, the gravels on some of the gulches, such as Little Mynook, Hunter, and Franklin, are as deep at the head as at the mouth, or may be even deeper, since the gulch gravels with increasing elevation may reach up and blend with the thicker accumulations of the upland.

MANNER OF CONCENTRATION OF GOLD.

PROCESSES OF MECHANICAL CONCENTRATION.

By previous descriptions it is seen that the gold originally disseminated in the gravels works downward in obedience to the force of gravity, thus effecting a concentration variously perfect in different places, and that in this process the passage of the gold particles is mechanical. This concentration would hardly be possible unless the gravels were frequently slightly moved or disturbed, so as to permit movement among the particles. It is undoubtedly true that a large part of the drainage water percolates through the gravels, which are coarse and porous, and the passage of this water may bring about enough movement to permit a continual separation according to specific gravity. The alternate freezing and thawing of the gravels which takes place in this region in the warmer part of the year, when the gravels are thawed by day and frozen by night, must also produce, by alternate expansion and contraction, much movement which would facilitate the downward passage of the gold particles. When conditions are so favorable that most of the gold thus works its way to the bottom of the gravels, its retention and concentration depends considerably upon the character of the bed-rock. If this is a schist, and especially if it is disintegrated, the gold becomes lodged and can not be carried farther. Also, if the bed-rock is full of cracks and irregularities, such as a much-jointed rock or a coarse conglomerate like that of Napoleon Creek, the gold is lodged in the same manner as in the schist. If, on the other hand, the bed rock is comparatively smooth and hard, the gold may be carried on along it to a more favorable place for retention. Thus, at the Upper Canyon on American Creek, the gold is practically all found in the uppermost part of a narrow zone of schistose, impure quartzite, while above and below this zone are massive serpentine rocks, presenting a smooth, hard surface, and these portions of the creek bottom were almost entirely barren, since the rock offered no irregularities to arrest the gold particles.

The effect of schists and other rocks of unequal hardness in the concentration of gold may be compared to that of the artificial riffles in the sluice box and other contrivances used by miners. These riffles are slats introduced in the box or trough, and are generally placed parallel with the current, although often at different angles. In the water plunging over these slats vortexes are produced, by which the gold particles are carried into still water in the shelter of the slats and there lodged until the current is turned off. In a stream the same currents and vortexes are produced by projecting ledges of rock, and rough waters or rapids result, which are by the miners also called riffles. These projecting ledges do not exist in homogeneous, massive

rocks, while in schistose rocks they are everywhere well marked. Hence in the Fortymile and Birch Creek districts even the ridges dividing the gulches have been so eroded that their summits present a series of steps, giving a saw-toothed appearance. (See fig. 25.) In this case the steps or teeth are large, the distance vertically from the crest to the trough of the steps being 50 feet or more. In the stream valleys there is the same structure, only the teeth are smaller and more numerous; thus on Fortymile Creek at low water there is a continual succession of riffles or rapids. In the smaller streams gold which is carried by the current may be dropped on encountering these vortexes, and may find its way into sheltered places or cracks of the schist, from which it can not be dislodged. This concentration has actually been observed in the present streams, and considerable gold is sometimes taken from such natural riffles.

In the case of artificial riffles in sluice boxes the slats may operate to catch the gold equally well when lying at different angles to the direction of the current. In the same way the strike of the schistosity of the bed-rock with reference to direction of the overlying stream seems not to be of great importance in determining the concentration

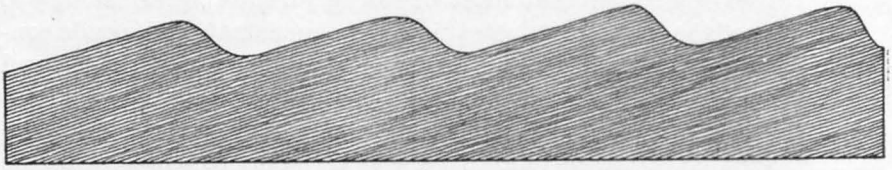

FIG. 25.—Diagram showing saw-like form produced by erosion in originally level-topped schist ridges.

of gold. Thus, when we consider the rich gulches which have been examined, we find that Glacier and Miller, in the Fortymile district, flow with the dip at right angles to the schistosity; that Mastodon, Miller, and Bonanza, in the Birch Creek district, run across the dip at right angles to the schistosity, while Poker, Franklin, and the highest part of Harrison are parallel, and Hog'em Creek oblique to it.

Gold which is now being accumulated in the bed of the present stream may be covered by gravels by a slight swing in the current. In this case this portion of the valley will be richer than neighboring portions. In other parts of the gravels in which the gold was originally uniformly disseminated, the metal will be best concentrated where the water has percolated most, for this underground water must have definite channels, although not so narrow and well defined as those of surface waters. It thus happens that certain parts of the gravels and of the underlying bed-rock are more profitable than others, and these are often called "pay streaks." On Miller Creek, in the Fortymile, a pay streak is reported which was 3 feet wide and 6 feet deep. Usually, however, it is much wider than deep, and often the gravels in the whole bottom of the gulch pay for working. Since the

underground water, which seems to be largely instrumental in bringing about the concentration of gold, must be most abundant in the bottom of the bed-rock valley beneath the gravels, it is here that the richest pay streak should be expected. Therefore, when the stream is evidently migrating laterally and is continually cutting into the limits of its old valley on one side and leaving behind it an old flood-plain on the other, the pay gravels will be mostly found in the flood-plain. In other cases, where the stream is more symmetrical in regard to its valley, the pay streak often underlies the present channel or is found on either side of it alternately.

POSSIBLE CHEMICAL INFLUENCE IN CONCENTRATION.

It is now known that gold, formerly considered insoluble except in the most powerful acids, is in reality attacked by many common salts, especially those of the alkalies.[1] Many of these salts are found almost universally in surface waters, having been derived from the soil with which these waters come in contact. Sonstadt[2] has shown that gold is present in sea water in a proportion of about 1 grain to the ton. It has, moreover, been found by experiment that gold contained in alkaline solutions may be precipitated by certain agents which are everywhere abundant in nature. From such solutions of gold a precipitation may be caused by the introduction of a piece of the solid metal; and other metallic minerals, such as iron, copper, and arsenical pyrites, galena, blende, molybdenite, and other minerals also form favorable nuclei.[3] This precipitation takes place especially well in the presence of organic matter, but also in its absence;[4] and it has been shown that organic matter alone is sufficient.[5]

That these facts which have been observed in the laboratory are important in considering the ordinary processes of nature is proved by many well-authenticated observations. In drifts through auriferous gravels pyrite often forms, and this pyrite almost invariably contains metallic gold.[6] In pieces of wood found in the Australian gravels pyrite has been deposited, sometimes entirely replacing the organic structure, and this pyrite contains gold throughout.[7] According to Mr. T. Egleston,[8] some of the copper ores of Texas, which contain both gold and silver, occur in the form of trees. It has been noted in the Transvaal[9] and in Australia[10] that gold-bearing rocks

[1] Frémy: Encyclopédie chimique, Tome III; 16e cahier, p. 43.

[2] Am. Chemist, Vol. III, p. 208.

[3] H. A. Thompson: Gold Fields and Mineral Districts of Victoria, Melbourne, 1869, p. 357.

[4] Henry Louis: Mineral. Mag., Nov., 1893, p. 247. K. von Kraatz: Am. Geologist, Aug., 1896, p. 102.

[5] Gold Fields and Mineral Districts of Victoria, p. 357. T. Egleston: Trans. Am. Inst. Min. Eng., Vol. IX, p. 640.

[6] Gold Fields and Mineral Districts of Victoria, p. 240.

[7] Op. cit., pp. 250, 261.

[8] Trans. Am. Inst. Min. Engs., Vol. IX, p. 645.

[9] Am. Geologist, Aug., 1896, p. 108.

[10] T. A. Rickard, Certain dissimilar occurrences of gold-bearing quartz: Proc. Colorado Sci. Soc., Sept., 1893, p. 9.

become especially rich in those layers or beds which contain much organic matter. In placer countries plates of gold are sometimes found in the grass roots, being probably precipitated there by the organic material.[1]

It is impossible to doubt, therefore, that solution and redeposition of gold take place continually in nature under the influence of ordinary drainage waters; and in auriferous gravels, which are porous and thus open to the circulation of water, processes of this nature must go on continually. Indeed, proofs of this are not wanting. Among the most convincing of these is a specimen shown the writer by Mr. H. W. Turner, of the Geological Survey. This specimen consisted of placer gold and black sand from the auriferous gravels of Providence Hill, Plumas County, California, the black sand consisting mainly of magnetite, with some hematite and possibly some ilmenite. Most of these minerals have a nearly perfect crystalline form, although the edges are slightly worn. Under the microscope several small octahedra of magnetite are seen to be partially coated with a thin crust of gold, which was evidently deposited very recently, since it has been laid down upon the broken edges of the crystals. This case is evidently analogous to the laboratory experiments which have been mentioned where gold has been precipitated from solution by metallic minerals.

But although this solution and deposition of gold by surface waters undoubtedly takes place in auriferous gravels, yet it must be remembered that the solvents act with great slowness, and would require an immense period of time to accomplish the transference of any great amount of gold as compared with the time required for such transference by the active processes of mechanical abrasion and concentration. The actual value of chemical influence, of course, will vary in different countries, being dependent upon the nature of the percolating waters, the presence of materials capable of bringing about a precipitation of gold held in solution by such waters, and the length of time during which these processes have had opportunity to go on. It is, however, probable that, as a rule, mechanical effects have been vastly more important.[2]

It has been asserted by some writers that the large nuggets sometimes found in gravels can not be derived from veins. In California, according to J. D. Whitney,[3] the largest nugget found weighed about 25 pounds, but Professor Whitney points out that large nuggets were rare in these gravels, and that large masses of gold were found in some of the quartz veins. In Australia the largest nugget found (the "Welcome" nugget) weighed over 184 pounds. From a quartz vein in New South Wales a block of gold encased in quartz

[1] Trans. Am. Inst. Min. Eng., Vol. IX, p. 642.

[2] F. Pošepný, Genesis of ore deposits: Trans. Am. Inst. Min. Eng., 1893, p. 139.

[3] Auriferous Gravels of the Sierra Nevada, p. 359.

was taken from the surface cropping of a vein which weighed 75 pounds, out of which 60 pounds were pure gold; from another quartz vein a mass of gold weighing over 40 pounds was taken, and with it other smaller pieces, weighing in the aggregate over 33 pounds more. In the Ural Mountains a famous nugget was found at Miask, which was free from quartz and weighed over 87 pounds.[1] It will thus be seen that masses of gold in quartz veins have approached very nearly the size of the largest nuggets, and that in Australia such masses have been found weighing several times as much as the largest nuggets in the Californian gravels. It is evident, therefore, that it is not necessary to appeal to chemical action in the gravels to account for the formation of nuggets. In the Alaskan gravels a study of the nature of the gold shows that chemical processes have had very little to do with its concentration. The metal occurs in irregular, flat scales, like those which are found filling the cracks in the quartz veins, and a mammillary form, suggesting deposition from solution, has not been noted. The flat forms are best seen in the smallest grains, the larger masses having been generally somewhat rounded by contact with harder bodies. Moreover, the gold, from the smallest to the largest fragments, is often mixed with vein quartz, in all proportions, in such a manner as to leave no doubt as to the detrital origin of both. No large nuggets have been found in the Alaskan gravels, the largest being the one found on Franklin Gulch, which weighed 30 ounces. These nuggets have usually a higher percentage of quartz intermixed than does the finer gold.

[1] Gold Fields and Mineral Districts of Victoria, p. 355.

CHAPTER VII.

COAL IN THE NEIGHBORHOOD OF THE GOLD BELT.

OCCURRENCES.

The thick beds of the Kenai series are characterized everywhere by abundant plant remains and by more or less coaly layers, and there frequently occur seams of pure coal. The underlying Mission Creek series is also highly carbonaceous in some parts, and also includes beds of coal, but, so far as observed, these beds were impure and slaty.

On Lewes River, a few miles above Rink Rapids, there is on the right-hand side a bluff where several seams of coal are exposed. The lowest is about 3 feet thick, of which probably about 18 or 20 inches is clear coal. This coal is rather slaty and lignitic, and probably contains much ash. The seam is underlain by a grit or feldspathic sandstone carrying plant remains. Under the microscope the fragments of this rock are seen to consist partly of quartz and plagioclase, but chiefly of a microfelsitic material which carries many small needles of plagioclase, and is evidently the groundmass of some andesitic lava. The cement is generally a cryptocrystalline paste, although in parts it consists largely of calcite. Above the coal seam come 6 feet of clay, with sandstone and grit layers, and over this lie about 10 inches of coal like that mentioned above, but probably more argillaceous. Next come 4 feet of lava, having fine amygdules at the bottom which grow progressively coarser toward the top; it is therefore a surface flow. The rock is light-brown, with light feldspar phenocrysts, and under the microscope seems to be probably an andesite. The phenocrysts are a clear and glassy plagioclase, altering along cracks to calcite. The groundmass is holocrystalline, with a flow-structure, and consists almost wholly of small, lath-shaped plagioclase crystals. Over this lava come about 18 inches of coal as before, and then clay, sandstone, grit, shale, etc. A tunnel has been run on the principal coal seam for a short distance.[1]

Coal Creek runs into the Yukon from the east side about 8 or 10 miles north of Fortymile Creek. The writer has been informed by Mr. W. Ogilvie, of the Canadian Survey, that about 12 miles or more up this creek there are two 4-foot seams of coal, separated by a bed of clay containing leaf impressions; the country rock is sandstone.

[1] G. M. Dawson: Ann. Rept. Geol. Nat. Hist. Survey Canada, Vol. III, pt. 1, p. 148B.

Specimens of this coal which were seen had a brilliant luster, smooth conchoidal fracture, and were of noticeably light weight. They contained tiny specks of pyrite and grains of amber or amber-like resin. This coal is said to burn with about 5 per cent of ash.

On the small creek a few miles below Coal Creek, on the same side of the Yukon, coal of the same quality occurs.

On American Creek, and on Napoleon Creek near the head of Fortymile Creek, impure coal seams were found in the Mission Creek series, but no good coal.

All the localities which have been mentioned above are in Canadian territory, yet are in a region so situated geographically that its development and that of the region on the American side of the international boundary must always go hand in hand.

American Creek, as the name indicates, is in Alaskan territory. Here the Mission Creek series contains many seams of impure coal, and large fragments of pure, glossy coal with conchoidal fracture were picked up in the stream bed. This coal burns quite readily. As a rule, however, the coal found in the seams of the bed-rock contains pyrite and much sulphur.

On the Big Black River coal is reported by prospectors.

On the right-hand side of the Yukon, just below the mouth of Whymper River—or Hess Creek—there are exposed frequent seams of rather impure, lignitic coal which occurs in the shales of the Kenai series. These shales alternate with conglomerates, grits, and impure limestones. On this bluff three distinct seams have been opened by Oliver Miller, a noted Alaskan prospector. One of these seams is 2 feet thick, with two or three clay partings; another, in which a tunnel 40 feet in length has been driven, shows 3 or 4 feet of mixed coal and coaly shale, and then a seam of clear coal 18 inches thick. This coal is generally brittle, and contains amber like that of Coal Creek and vicinity. Next it is a bed of yellow and red clay, and then comes again carbonaceous shale, passing into green sandstone and conglomerates. All these beds are nearly vertical, and are even slightly overturned, the folding being well shown in the steep bluff.

Dr. Dall[1] mentions a small coal seam below Nulato, which, however, had been squeezed out above and below by folding, so that only a mere pocket remained. He also mentions coal at various points along the coast, chiefly in the Kenai series.[2]

CHARACTER OF COALS.

Below are given two partial analyses of coals by Dr. H. N. Stokes. The first is from the small creek which empties into the Yukon below Coal Creek, and the second from Miller's coal mine, nearly opposite the mouth of Hess Creek. The first is a picked specimen, and the last an average sample of a seam 18 inches thick.

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[1] Bull. U. S. Geol. Survey No. 84, Correlation Papers, Neocene, p. 247.
[2] Op. cit., p. 237.

Analyses of coals from the Yukon region.

	1.	2.
	Per cent.	*Per cent.*
Moisture	6.24	7.29
Volatile hydrocarbons	43.94	37.38
Fixed carbon	47.74	36.91
Ash	2.08	18.42
	100	100

From these analyses it will be seen that the per cent of volatile hydrocarbons in both cases is nearly equal to that of the fixed carbon. The coal, moreover, contains probably even more moisture than is shown in the analyses, for when taken from the seam it is hard and lustrous, but after exposure to the air its luster becomes dimmed and it shows a tendency to crack and fall into small fragments. These samples, therefore, which are typical of all those examined and described, may be called hard lignitic coals.

ECONOMIC VALUES.

Coal has been found in many localities in the Kenai series and also to a less extent in the Mission Creek series. With further exploration of the country, it probably will be found to be comparatively abundant. As shown by the analyses, however, these coals are of very low grade, and do not possess high heating power. Dr. Dall[1] notes that the coal of Kachemak Bay, which is evidently of the same quality as that from the localities described, has been used for steaming purposes and also for burning in an open grate, and has been pronounced satisfactory. The coal from Coal Creek, near Fortymile Creek, was tried in a blacksmith's forge and was said to burn well.

Wherever these coal seams were examined in the interior, however, the rocks in which they occur are invariably steeply inclined, and are often highly folded and even contorted. This condition renders the veins difficult and expensive to follow, and, taken in conjunction with the low grade, makes it appear probable that, although the coal may in some cases be found convenient for domestic use, it will not pay for exportation.

It is possible, however, that in some of the older rocks coal of better quality may be found. Dr. Dall[2] notes that at Cape Beaufort coal of a very different quality from the lignites of the southern part of Alaska was found, in probably Carboniferous strata. Fossils collected on the Yukon in the neighborhood of the gold belt show that Carboniferous rocks are present in this region, but, so far as observed, they here contain no coal.

[1] Bull. U. S. Geol. Survey No. 84, Correlation Papers, Neocene, p. 237.
[2] Op. cit., p. 249.

CHAPTER VIII.

SUMMARY AND PRACTICAL APPLICATIONS.

SUMMARY OF REPORT.

The notes which have been made upon the geology of the Yukon gold belt indicate that the geological column in this region begins with a fundamental granite, which is overlain by thick quartzites; and that this quartzite series is overlain by interbedded sedimentary rocks which were originally sandstones, limestones, and shales. All these rocks have been subjected to regional pressure, and all have been rendered schistose together. The effects of the shearing, however, are much more marked in the sedimentary rocks than in the more massive granite. At about the same time as the development of schistosity, probably near the beginning of this process, dikes were intruded into the sedimentary rocks and quartz veins were formed. The series of igneous injections thus begun continued for a long period of geological time, and did not cease until after the end of the movements in the rocks which gave rise to the schistose structure. The first dikes, which were afterwards rendered schistose by subsequent regional movements, were granitic or dioritic, while later dikes, as a rule, were more basic and more acid, and the final injections, so far as observed, were of extremely acid dikes associated with quartz veins. Previous to the intrusion of these very latest dikes, but at a period when the development of schistosity was nearly at an end, there occurred vast outpourings of basaltic and diabasic lava over large areas, and these igneous rocks, with tuffs and impure sandstones largely derived from them, constitute a very thick series. This volcanic activity seems to have been very nearly the end of the period of disturbance which had been manifested by the shearing, folding, and injections of igneous material. Subsequent to the outpouring of the lavas, however, dikes were still intruded, as is proved by the occurrence of these bodies cutting the effusive rocks. But these dikes seem to belong chiefly to the extreme types which characterize the close of the series of intrusions.

The quartz veins which occur in the district seem to be closely connected with the dikes, and were probably formed at successive periods, corresponding with the repeated injections of igneous material. Therefore the oldest veins have been sheared together with the oldest dikes and the inclosing rocks, and have been faulted and

stretched so that they are characteristically narrow and nonpersistent and difficult to follow. The latest veins, however, which accompanied the latest granitic and aplitic intrusions, are, like these dikes, unsheared and practically unfaulted, and therefore may be in places wide and persistent. All these veins seem to carry gold in varying amounts, and they probably are the chief source of the gold now being taken from placer diggings.

Following the period of great lava eruptions, limestones and other sediments were laid down, succeeded by more shaly and conglomeratic beds. These sediments are largely marine, but have occasional leaf beds, indicating fresh-water conditions, and scattered fossils show a range probably from Devonian to Cretaceous. Above these sediments was laid down a very thick series of fresh-water beds, which are largely conglomerates, containing abundant plant remains and seams of lignitic coal. This series, on the evidence of its flora, has been referred to the Eocene. Subsequent to the formation of this conglomeratic series, violent movements took place in the earth's crust. Great folds were formed, among them that which has been named the "Yukon geanticline," which has a northwest and southeast trend. The beds were upturned, and the development of the Alaska of the present day began. By erosion of the Yukon geanticline the different formations were exposed in northwest and southeast trending zones. This is especially the case in the lower schistose gold-bearing formations. Parallel with the axis of the geanticline the chief drainage was established, and along this line of drainage, which has migrated somewhat down the general dip to the northeast, the Yukon River now flows. By the erosion of this and other streams, the present hills, mountains, and valleys began to be carved out. Since the period of this revolution the interior of Alaska has probably never been long beneath the waters of the ocean, and therefore the only subsequent deposits are scattered and are of fresh-water origin; although nearer the shore marine deposits are found, showing that during Miocene time the land area was smaller than at present.

In later geological times, however, the land has been subjected to repeated oscillations, which have involved great changes of elevation but have been without any great amount of attendant folding. Thus, after atmospheric agencies subsequent to the post-Kenai revolution had fashioned the topography after the same general pattern as that at present existing, an elevation caused an acceleration of the streams, and deep canyon-like valleys were cut. These are still prominent features in the topography. During this period also, which was probably mainly in the Pliocene, eruptions of olivine-basalt took place from separate vents at various localities.

Subsequent to the erosion of the canyon-like valleys the whole land mass sunk beneath the sea, as shown by terraces which represent probable shore-lines. The scattered gravels found on mountains and

in valleys all over the country seem to be one of the effects of marine action at this period; other than this, however, no marine deposits have been found, and the submergence must have been brief. It is probable that the maximum submergence may have been more or less closely contemporaneous with the maximum extension of the great cordilleran glacier, and this may explain the absence of glaciation and also of decayed rock over so large a portion of Alaska. The cordilleran glacier soon retreated, however, and the land also began to rise. On the retreat of the sea, the country being still low, the valleys of the old streams were in part occupied by numerous lakes, the water accumulating in consequence of the sluggish drainage, or basins were formed by local depression or irregularities of elevation. In these lakes mud or silt rapidly accumulated. With increasing elevation some of the lakes became drained and others were reduced in extent. The streams became more rapid, and the valleys began to be excavated again. This is the condition of things at present, and it is probable that the elevation is still going on in a general way.

Auriferous quartz veins were formed in the older rocks at different intervals, and their formation was accompanied, in a general way, by the development of schistosity, so that the veins may be divided into an older sheared and a younger unsheared set. These veins are found chiefly in the highly schistose sedimentaries which have been called the Birch Creek and the Fortymile series. They are occasionally found in the fundamental granite, and the younger set is sometimes found in the igneous and pyroclastic rocks of the Rampart series. In many places it has been noticed that the younger set of quartz veins, which, on account of their unaltered condition, can be more easily studied than the older set, grade into acid dike rocks, such as aplite. From this and other considerations, a theory of the formation of the auriferous veins has been formulated, namely, that they represent the final stage of a gradual process of rock consolidation, the rocks representing the other stages being found in the same districts. The gold is supposed to be a nearly universal constituent of rocks, and to have been a part of the general magma; and its abundance in some quartz veins is supposed to be due chiefly to the free circulation attending deposition, and perhaps partly to some special adaptability which gold may possess for solution in the siliceous and alkaline fluids which are conceived to be the final residue of rock consolidation.

In many places the rocks have been sheared, especially along certain definite portions, and thus shear zones are produced. In some of the formations, notably the Rampart series, there has been no regional schistosity, and therefore these local shear zones traverse an otherwise nearly massive rock. The zones have naturally been selected as channels by circulating waters, and along them a concentration of metallic minerals has often been effected by the deposition in crevices and interstices of materials held in solution. These

concentrations or impregnations may in some cases contain gold and silver along with other metals.

The rocks of the Rampart series have been exposed to atmospheric erosion since the time of the formation of the Mission Creek series, and probably before, as shown by conglomerates. This series, however, and the older rocks were first exposed to active erosion subsequent to the post-Kenai revolution. At this period the wearing away of the Yukon geanticline exposed the old rocks in a general broad belt, which extends in a northwest and southeast direction for at least a thousand miles. Subsequent erosion has operated only to broaden this zone, which at present constitutes the gold belt of the Yukon district of Alaska and British Columbia. Ever since the beginning of the period of active erosion the gold-bearing quartz veins and other metallic accumulations have been broken up and carried away by waters with other rock detritus, and from this heterogeneous mass the gold, being heaviest, has always had a tendency to concentrate mechanically at the bottom of any deposit. Thus at the present day it is found in the bottoms of the gulches and on the bars of rivers. The older accumulations of detritus also contain concentrated gold, and these probably furnish some supplies to the more recent accumulations.

PRACTICAL APPLICATIONS OF GEOLOGICAL PRINCIPLES.

The gold of the Yukon district is chiefly derived from quartz veins which are found most abundantly in the schists of the Fortymile and the Birch Creek series, although not infrequently in the igneous and pyroclastic rocks of the Rampart series. It is also derived, although to a far less extent, from impregnated shear zones, which occur especially in the Rampart series. Of the quartz veins one set is sheared and one unsheared. The first is difficult to follow, for the veins are broken and nonpersistent. The veins of the second set are often persistent and wide, and in some cases may be mined profitably. Impregnations along shear zones may also in some cases be sufficiently rich in metallic minerals to form ores under favorable conditions; and the rock in the region of these shear zones is often unfaulted, so that these ore bodies may be expected to be comparatively persistent.

The quartz veins are connected with dikes, chiefly light-colored crystalline rocks, such as granite and aplite. This should be kept in mind in prospecting, and auriferous veins may be looked for in the schists near the dikes. In some cases, although not so commonly, they may also occur at some distance from a dike.

These gold-bearing rocks form a definite belt, extending in a general way from the Lower Ramparts of the Yukon and below to Dease Lake and other mining districts in British Columbia, a distance in a straight line of about a thousand miles. Of this distance, 400 or 500 miles is in American territory. The width of the belt varies chiefly with the

minor folding which has accompanied the greater plications. In this belt not only the gold-bearing veins but the richest placers are found. This is naturally the case, since the gold in these placers is worn out of the solid rocks. It is especially true that the rich gulch gravels are in this belt, and also the most paying bar gravels, although fine gold in some cases may be carried somewhat outside of the belt, and may be sufficiently concentrated in favorable situations to pay for washing.

The Birch Creek, the Fortymile, and the Klondike districts are all in this belt, and are all in the schistose rocks, and in these rocks new deposits of value may be looked for. Some placer diggings of value may also be found in the rocks of the Rampart series, but as a rule higher horizons are probably barren, save in exceptional cases. Conglomerates made up of the detritus from the schistose Birch Creek and Fortymile rocks should be prospected, however, since they may prove to be fossil placers. Ancient gravels lying above the present stream channels should also be kept in mind, for they may in places contain sufficient gold to be profitably mined.

The question as to whether a certain deposit, either placer or bed-rock, contains enough gold or metals to render it profitable for working is one which can be solved by no universal rule. A deposit which under certain circumstances is extremely valuable may under others be entirely worthless. The circumstances which must be taken into consideration are: Cost of mining, ease of separating the metals from the ores, facility and cost of transportation, and numerous others. The question as to whether any deposit or any mining district in general will become profitable can be only partly solved by geology, for the rest depends upon other sciences. At the present time (1896) labor in Alaska is worth $1 an hour, or $10 a day, and this gives a fair idea of the average cost of production of placer gold, which is two or three times that in more accessible countries. In this region, therefore, a placer deposit in order to repay working must at present be three or four times as profitable as a deposit in most other places. In bed-rock mines the expenses would be proportionately much greater, since more expensive equipments, machinery, etc., must be provided for the production, and probably facilities for transportation of the ore for long distances. Under existing conditions, therefore, the probability of bed-rock mines sufficiently rich to repay working is not great. Were these conditions greatly improved, however, paying mines in the bed-rock might be found, and could be worked in spite of the severe climatic conditions. The production at present is entirely from placer deposits, which are profitable in the face of the great disadvantages, and with better conditions a vast amount of auriferous gravels now useless would become valuable.

The mineral resources must remain for an indefinite period comparatively useless, unless some means be taken for speedier and cheaper communication between the gold region and the outside world. As

the country itself produces hardly enough food to support life, all provisions are now brought from San Francisco or Seattle, the usual route being by sea to the mouth of the Yukon, and thence up the river to the mining district, a distance of over 4,000 miles. This makes supplies so expensive that unless better transportation is provided the country will probably be abandoned as soon as the richest placer workings have been exhausted.

For opening up more rapid communication, some route from the coast in the vicinity of Juneau seems most feasible. The waters of the Yukon are navigable for river steamers of light draft up to the head of Lake Lindeman, except for two or three places where short rapids exist. Two or three steamers built with due consideration as to the character of that part of the river on which they were to ply would form a complete connection between the head of Lake Lindeman and the gold region during the four or five months that the river is unfrozen. The head of Lake Lindeman is only about 25 miles from the navigable water of the sea. Another measure which would be of great value would be the building of a wagon road from the coast in the vicinity of Juneau to the junction of the Lewes and the Pelly rivers, which point is below all obstructions to navigation. This road should be built across some of the mountain passes other than the Chilkoot, which is now used, for the Chilkoot, although short, is higher than its neighbors.

CHAPTER IX.

METHODS OF MINING.

BAR DIGGINGS.

In bar diggings the material which has to be washed consists largely of coarse, round pebbles; and by whatever process the gold is extracted, these pebbles are separated first; there then remains the finer material, which is made up of the heavier constituents of the same rocks. Black sand, which consists of magnetite, hematite, and sometimes galena, is nearly always abundant, and in some diggings there is a "gray sand," consisting mainly of heavy spar; and when, as in Forty Mile Creek, the stream flows through schists, garnets derived from these form a very important part of the residue. All these, however, are still lighter than gold, and are eventually separated from it by means of their inferior specific gravity, through the agency of water applied in various ways, or finally by air applied by a bellows.

CRADLING.

The gold pan, which is worked by hand, is the simplest contrivance for separating the gold from the gravels. The next contrivance generally made use of is the cradle, which is constructed on essentially the same patterns as cradles which were used in California and Australia in the early days of placer mining. The cradle consists essentially of a long, narrow box, with an upper and a lower compartment. The floor of the upper compartment is preferably made of metal, and is riddled with holes of convenient size. Into this upper compartment the gravels are shoveled, and the whole contrivance is moved back and forth upon the rockers on which it stands, and from which it derives its name. By this shaking the gravel is sifted; the finer material passes through the holes into the lower compartment, while the coarser material, which contains little or no gold, passes out of the box as useless rubbish, or "tailing," as it is technically called. The floor of the lower compartment is, in its simplest form, an inclined plane, the surface of which is roughened or corrugated in various ways, such as by the use of cleats or wooden "riffles," corrugated metal sheeting, or other devices. A favorite method of obtaining this result among the miners of Alaska is by the use of carpeting, of coarse, spongy weave, such as ordinary tapestry. Upon this roughened surface the fine gold lodges, while the lighter material is carried out of the box by the

stream of water. In the collection of the fine gold which is thus caught amalgamation with quicksilver is usually resorted to.

In some bars there is considerable concentration of gold, and when the river is sufficiently low these accumulations are worked by the miners; but the comparatively small size of the deposits, and the fact that they are exposed only an uncertain length of time during low water, lead to the necessity of using the simplest apparatus, and so the cradle is generally utilized. In some cases the bar gravels are sluiced in the same way as the gulch gravels, the water being raised to the head of the sluice in the buckets of an undershot water wheel.

GULCH DIGGINGS.

In the gulches the conditions are entirely different, since the amount of water in the stream bed is usually small and can be easily diverted if necessary, and the gold occurs in a small channel in the narrow gravels. These gulch gravels vary in thickness from about 3 or 4 feet to 20 or 30 feet. Their upper parts, however, are invariably barren; the gold is all found concentrated at the bottom, whatever the thickness of the upper gravels may be. The gravel which contains gold in workable quantity is technically called "pay dirt." It is usually not more than 3 or 4 feet thick, and from that thickness it runs down to a few inches or less. The bed-rock itself at the junction with the gravel usually contains gold, and often repays working for 2 or 3 feet down, and sometimes the richest dust is found in this partly disintegrated schist. In the thin layer of pay dirt which rests upon the schist the gold occurs in particles disseminated through a gravel containing many large and little-worn fragments of schist and quartz.

SLUICING.

When the overlying barren gravels are not too thick they are stripped off by shoveling and the pay dirt is laid bare. Then a long, slightly inclined trough, called a sluice, which is built in sections of equal length, so as to be easily taken down and transported from one place to another, is constructed of boards. The boards for this purpose are cut by the miners from logs with the aid of the whipsaw. The different sections of this trough or sluice are called boxes, and when these sluice boxes are arranged consecutively and in position convenient to the deposit of pay dirt the water flowing in the bed of the gulch is partly diverted into them, so that a continuous stream flows through the sluice and empties at its lower end. The pay gravel is then shoveled into the boxes, mostly into the upper ones, so that the gravel will be carried as far as possible before being thrown out. The current is so regulated that the finer and lighter material and the smaller gravels are immediately carried out of the trough and deposited at its end, while the large pebbles and the heavier small particles sink to the bottom and advance more slowly. The largest

stones are removed by a miner who stands ready with a shovel to clear the boxes of such incumbrances. The heaviest of all the materials is the gold, which finds its way to the bottom of the sluice.

To prevent this from escaping a series of slats are inserted in the bottom of one or more of the boxes at the end of the sluice, and these slats, or "riffles," as they are called, afford a lodgment for the heavier particles. The riffles are usually placed parallel to the sides of the box and connected by cross-cleats, although various other patterns are employed. At stated intervals the current of water is turned off from the sluice, the slats or riffles are taken up, and the heavier material which has accumulated is carefully collected. The accumulation is very rich in gold, and also contains magnetite, hematite, limonite, galena, and pyrite, as well as many fragments of the rarer heavy minerals. This material is generally washed by hand in a gold pan, thus securing a greater concentration of the gold, but there still remains some pyrite, galena, hematite, and magnetite, which can not well be separated from the gold by washing. The magnetic iron, which is known as "black sand" by the miners, is extracted with a small hand magnet, and the other minerals are separated from the gold by blowing the aggregation with a small hand bellows. The pyrite, hematite, and galena thus blown out are roasted, ground, and panned by the more economical miners, and then yield considerable free gold.

It is important in the construction of sluices that the grade be accurately adjusted to the force of the current which flows through it and to the length of the box. If the grade of the sluice is too small, there is a constant tendency to clog, and the accumulated gold will be associated with a very large proportion of valueless dirt, while if the grade is too great much valuable material may be carried off at the end of the boxes and deposited as refuse or "tailings." As an example of this latter mistake it may be mentioned that the tailings which have been accumulated by one miner are often successfully rewashed by another.

BURNING AND DRIFTING.

The labor of removing the barren gravel which overlies the pay dirt is very great, but ordinarily this is undertaken when the thickness is not considerable. With increasing thickness a point is soon reached where the task of removing it becomes so formidable that the miner will not make the attempt unless he believes that there is rich pay dirt beneath. In this event the practice is adopted of sinking shafts through the barren material to the pay dirt and extracting this pay dirt by means of tunnels or drifts along the surface of the bed-rock. This method of working has been adopted only lately, but promises to be very important. The ordinary methods of sinking, drifting, timbering, stoping, etc., have been peculiarly modified in the Fortymile district on account of the exceptional character of

the climate, and these modifications have spread from this district over the rest of the gold diggings. Owing to the severity and length of the winters the gravels are frozen during seven or eight months of the year. The miner who desires to sink a shaft waits until the cold season arrives and then sinks through the frozen gravel, which is so firm that the shafts or drifts do not need timbering for the sake of support. In sinking or drifting, instead of employing powder and pick, as elsewhere, a small fire is built at the bottom of the shaft which is being sunk, or at the face of the drift which is being run, and thus the gravels are thawed out for some distance and can be easily shoveled up and taken to the surface. It takes a surprisingly small amount of wood to run a drift through the frozen gravel for a long distance. In this way the pay dirt is extracted and accumulates on the surface until spring, when it is shoveled into sluices and the gold is separated by washing, panning, blowing, and amalgamation, in the manner previously described. One large chamber or "stope" thus excavated in the gravels on Miller Creek, in the Fortymile district, is said to have measured 64 by 32 feet, and 19 feet in height, with only 8 feet of barren gravel between it and the surface; and yet this stood firmly until spring, when the gravels thawed and the stope caved in.

SOME COAL FIELDS OF PUGET SOUND.

BY

BAILEY WILLIS.

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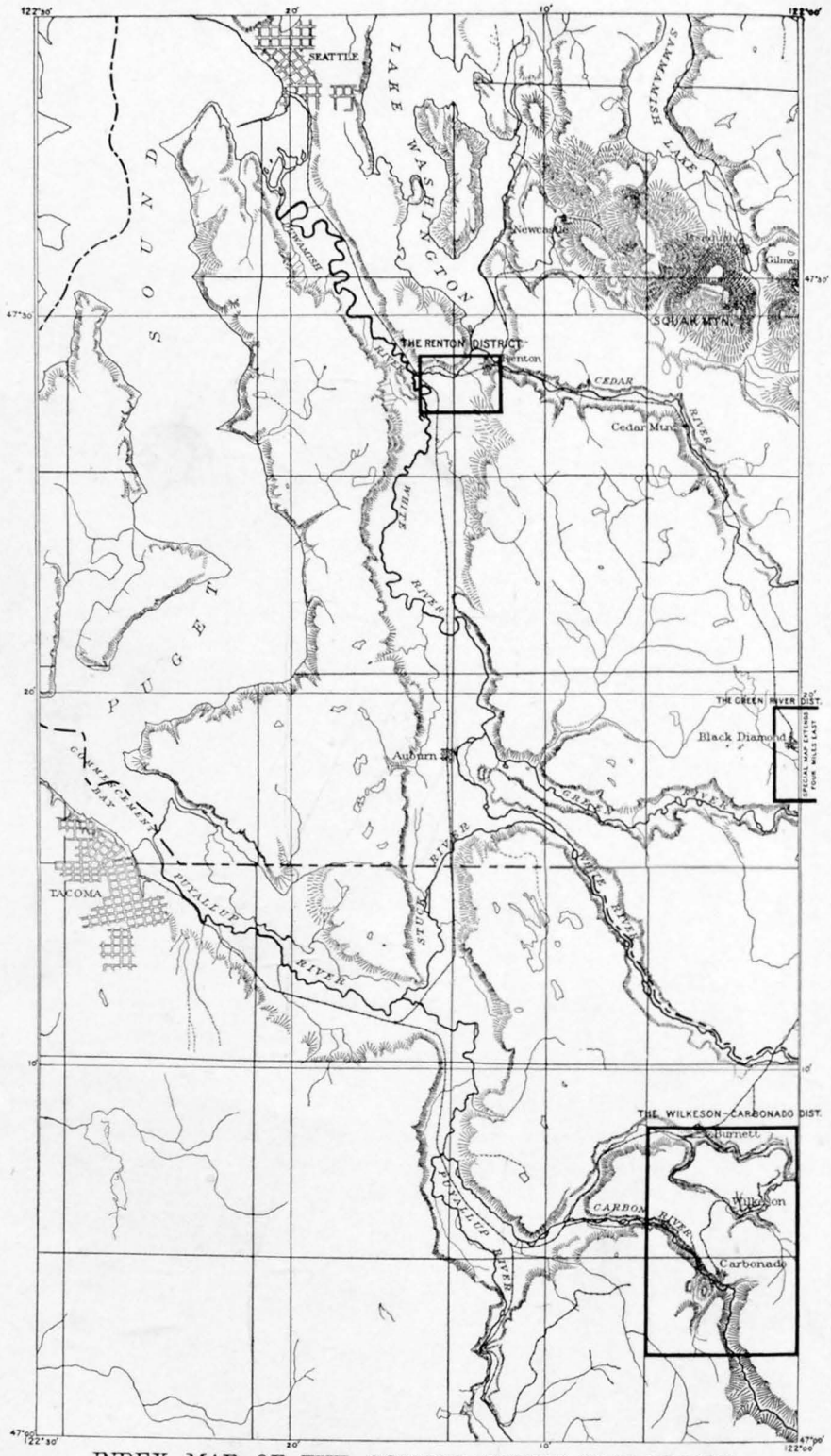


INDEX MAP OF THE SOUTHEASTERN COAL FIELDS
PUGET SOUND WASHINGTON

0 2 4 6 8 10 MILES

1897

SOME COAL FIELDS OF PUGET SOUND.

By Bailey Willis.

LOCATION.

The southern coal fields of the Puget Sound basin lie on either side of the meridian of 122°, extending 10 miles east and 10 miles west, with irregular outlines. From north to south they stretch through less than a degree of latitude, from near 47° 35′ to about 46° 45′. The fields now developed lie between the latitude of Seattle and the parallel of 47°, a north-to-south distance of 40 miles. Their relative positions are indicated on the outline map (Pl. LII).

With reference to Puget Sound, this productive district lies from 7 to 25 miles east and southeast from, and extends parallel to, the southeastern inlet, which ends in Commencement Bay. The western foothills and valleys of Mount Rainier, the huge extinct volcano, reach into the southern portion of the area of coal-bearing rocks. By railroads 12 to 35 miles in length the mines are connected with the cities of Seattle and Tacoma.

PHYSIOGRAPHY.

The water bodies of Puget Sound occupy deep and steep-sided channels in an elevated expanse of gravelly deposits, which is further divided by valleys that were formerly arms of the Sound, but which are now filled with alluvium. The escarpment of the gravelly plateaus rise from 200 to 300 feet above the waters of the Sound and the alluvial plains of its former branches. The surfaces of the plateaus present a great variety of smooth and hummocky levels, supporting occasional rounded hills a hundred feet or more in height. All the aspects of the district are characteristic of forms modeled by extensive glaciers. The individual features assumed their forms either on top of ice which has melted, or as morainic ridges in front of glaciers, or beneath ice sheets of whose lower surfaces they present the casts.

In the vicinity of the Sound these gravel deposits are deep, extending below sea level probably several hundred feet; and even at distances of 20 to 30 miles eastward along the foothills of the Cascade Range they are known to cover the older rocks locally to depths of 300 to 400 feet. They thus determine the topographic aspects of a

wide area, almost obliterating the configuration of the solid-rock surface upon which they rest.

From the bluffs about the Sound the plateaus rise toward the mountains by terraces, which are often disposed irregularly with reference to existing streams, but in a general way extend about the higher tracts between the rivers. Within these higher areas the deposit of gravel is thin or locally wanting above the older rocks. The canyons cut by the principal rivers flowing from the Cascades and Mount Rainier also expose the underlying strata, and they may be seen in occasional isolated outcrops in the gravelly expanse nearer the Sound. The topographic aspects are not markedly influenced by these outcrops, over which, as over the plateaus, extends the prevailing forest.

The gravels occur at considerable heights on the Cascades, but their general surface probably does not extend to much more than 1,000 feet above sea. From it the mountains rise up boldly, sometimes with precipitous fronts. Between these bold foothills on the east and the all-concealing gravels on the west is the zone, 10 to 20 miles wide, of terraces and transverse canyons throughout which the coal-bearing strata may be traced. It is worthy of note that the known productive coal fields all lie in the lower basin of Puget Sound, and not upon the higher western slopes of the Cascade Range.

Valleys, canyons, and hills older than the present ones lie buried beneath the gravel deposits. They are so concealed that no clear conception of their distribution can be formed, but their relatively bold character is indicated by a few facts. In the vicinity of Renton, and between that town and Seattle, sharply defined hills of hard rock rise like islands from the alluvium of the Duwamish Valley. The former canyon, now filled almost to the summits of buttes along its course, is inferred to have been deep and steep sided. At Burnett, 20 miles from tidewater and 335 feet above it, a gangway driven on a coal vein 200 feet below the outcrops passed into a channel filled with gravel and tree roots. The slope from the nearest outcrop to the point where the buried channel was struck descends at an angle of not less than 35°. At Wilkeson a similar buried channel was encountered in a water-level gangway 2,250 feet from the entrance and 250 feet below the level of the overlying gravel terrace. This preglacial topography is of much interest as a phase of the history of the Sound basin, and it is economically important as a factor which modifies the amount of coal available above any given level. It sometimes introduces difficulties in mining. The topographic surface of the gravel deposits bears no definite relation to that of the Coal Measures.

STRATIGRAPHY.

The coal-bearing rocks of the Puget Sound basin have been designated the Puget formation.[1] They are prevailingly sandstones of variable composition, texture, and color, thinly interbedded, and fre-

[1] C. A. White, Bull. U. S. Geol. Survey No. 51, 1889, pp. 49-63.

quently cross stratified. Their composition varies from that of a typical arkose, consisting of slightly washed granitic minerals, to siliceous clays. Beds of conglomerates or concentrated quartz sands have not been observed. Carbonaceous materials are generally present as fragments of plants, as vegetal ooze in greater or less proportion to the other constituents, and as distinct coal beds. Carbonate of iron is frequently an integral constituent of the rocks.

In color they are, when fresh, generally bluish-gray, shading to brownish-black. They weather to buff tints, which are usually dull. The coarser and more massive varieties form beds 20 to 100 feet thick, in which bedding planes are not distinguishable. The finer deposits are thinly laminated and carry abundant leaf impressions, which occasionally interlap with one another so as to form a mass of leaf fragments.

The weathered forms assumed by these rocks rarely present sharp profiles. The more massive beds develop rounded bosses by spheroidal disintegration due to oxidation of the iron carbonate. The thinly bedded strata break down readily, either as a clay mud, or in thin scaly fragments, or in angular bits which are externally indurated by a cement of iron oxide.

In many of the sandstones silvery white mica has developed as a secondary mineral, but they exhibit no other indication of metamorphism. The coals, on the contrary, being chemically more sensitive, have undergone metamorphism to a greater or less extent through loss of combined water and concentration of fixed carbon. They range, therefore, from lignites, whose representative analyses have the limits—

	Per cent.
Moisture	8 to 12
Volatile hydrocarbons	35 to 45
Fixed carbon	30 to 45

to bituminous lignites or steam coals, in which the moisture is reduced to 5 per cent or less and the fixed carbon ranges from 40 to 50 per cent, or to bituminous coking coals, which are fairly represented by the figures:

	Per cent.
Moisture	1 to 3
Volatile hydrocarbons	25 to 35
Fixed carbon	50 to 60

The ash of these coals is frequently as much as 10 per cent, particularly in commercial samples taken fairly to represent the marketable product. But the earthy constituents occur largely in distinct streaks in benches of purer coal, and the proportion which goes to market is determined by the cost of removing the associated bone and slate. Methods of mining and preparing the coals depend upon the characteristics of individual veins, but for each district there are also general facts which determine the handling of the product. One of

these factors is hardness. The lignites are hard. The bituminous lignites of the Green River district are softer, but still firm. The bituminous coking coals of the Wilkeson field are very soft. The two former may be hand picked; the last named require washing.

The variations from lignite to bituminous coking coal are of regional extent; that is to say, where lignites are found they may be expected to maintain a uniform composition over a relatively wide area, and bituminous varieties are equally constant in their character within the fields in which they occur. There are, however, occurrences of more condensed coals, ranging into anthracite, which are, so far as is definitely known, of local distribution only.

The cause of variations in quality among these coals may be sought in the pressure and movement which they have suffered. The lignites retain the compact structure originally assumed by the peaty deposit under the load of overlying strata. Their beds have been tilted, but internally not much disturbed. They have therefore undergone comparatively moderate chemical change. The Green River steam coals have assumed a more or less cubical structure, due to shearing under pressures which caused movement within the vein. The resulting chemical effect was to expel 5 to 8 per cent of water. Beyond the area of this mechanical influence the coal changes into lignite by transition within a single bed. The coking coals of the Wilkeson field, and those of the extreme eastern portion of the Green River field, have been rolled out between their walls and crushed. Their softness and their concentrated condition have resulted from this mechanical disturbance. The further transformation of the coal to anthracite and coke occurs in the vicinity of igneous rocks, to whose influence it is wholly due.

The stratigraphic relations of the Puget series are not determinable within the area under discussion, since the strata nowhere come in contact with older sedimentary rocks. Sixty miles northward, on the Skagit River, is a contact between similar coal-bearing strata and older metamorphic schists, described in an earlier report[1] as possibly a surface of deposition or of faulting. Examination of this locality in 1895 led to the discovery of small pebbles of the schist forming a basal conglomerate in the sandstone beds next the contact, which was therefore a surface of deposition during a transgression by the sea. Fossils found in limestone under the schists are stems of crinoids of Carboniferous or Triassic age, whereas the coal-bearing sandstones of this locality are assigned by Knowlton to the Eocene on the evidence of numerous leaf impressions.

The age of the Puget formation has been in doubt because of the obscurity of stratigraphic relations, the general absence of marine fauna, and the indeterminate character of the flora. Collections made for Newberry prior to 1884 represented various stratigraphic horizons which were not distinguished. Most of the species were new.

[1] Reports of Tenth Census, Vol. XV., p. 760.

Newberry correlated the plants with the Laramie (Cretaceous) flora, and the series has been dated late Cretaceous or early Eocene. A more definite correlation with the Tejon formation of California has been suggested by C. A. White.

The latest evidence on this still debatable question is that of collections made in 1895 and 1896 from definitely determined stratigraphic horizons on Green River, above Burnett on South Prairie Creek, and on Carbon River near Carbonado. A preliminary examination of the fossil plants enables Knowlton to report that the lower beds of the series are Eocene, whereas the upper beds may be of Miocene age. The floras from horizons several thousand feet apart in stratigraphic range are so distinct as to afford means of correlating separate strata of the Puget formation. Further collections and detailed studies must be made before we can determine how closely coal beds may be identified by their fossil plants and to what extent the fossils will aid in working out the complex, obscure relations of distinct parts of the coal fields.

In a recent article[1] an occurrence of Tejon strata at Brighton Beach, on Lake Washington, is described and compared with the attitude of strata of the Puget group at Renton. The dip at Brighton Beach is stated to be to the northeast at a high angle; that at Renton is given as 16° to the east; and the strikes in the two localities are stated to be nearly at right angles. From these data the author cited infers an unconformity between the Tejon of the Brighton Beach locality and the Puget group at Renton. As the two places are 5 miles apart the inference would not be strong, even if the structure of the strata were simply monoclinal, but, as may be seen by reference to the map of the Renton-Talbot mines (Pl. LVI), the Puget strata are so flexed as to exhibit variations of dip amounting to 90° and corresponding diversities of strike. The inference of unconformity is therefore of no value.

Most prominent among the rocks associated with the Puget group are eruptives of Tertiary or later age. They occur as dikes and flows in various forms of intruded and extruded igneous rocks. They are of such extent within the area described as to divide it into several districts, which are so separated as to make it impossible to identify their stratigraphic relations, except, perhaps, with the aid of fossils.

Thus the Puget group is related to four other groups of rocks, which may be named in the order of their age, as follows: (1) Metamorphic schists and limestones of Carboniferous or Juratrias date, upon which the Puget group was deposited unconformably, at least in the Skagit district; (2) the marine Miocene, or Tejon, with which the Puget group is stratigraphically continuous; (3) the Tertiary eruptives, which are younger than the Puget group, and date down to the Pleistocene; (4) the glacial gravel deposits of Pleistocene age.

[1] Physiographic geology of the Puget Sound basin, by James P. Kimball: Am. Geologist, Vol. XIX, April and May, 1897.

The measured sections of the Puget group exhibit total thicknesses of 5,800 feet on Green River, 5,500 feet on South Prairie Creek, and 5,480 feet in Carbon River Canyon. None of these measures is complete. In each instance the lowest stratum is of the Puget group outcropping on an anticline, and the highest is the limit of exposure where the rocks pass under later formations. These sections overlap, and there are also higher beds exposed on South Prairie Creek above the limit of the measured sections. These considerations justify the inference that the thickness of the Puget group may probably be 9,000 feet or more.

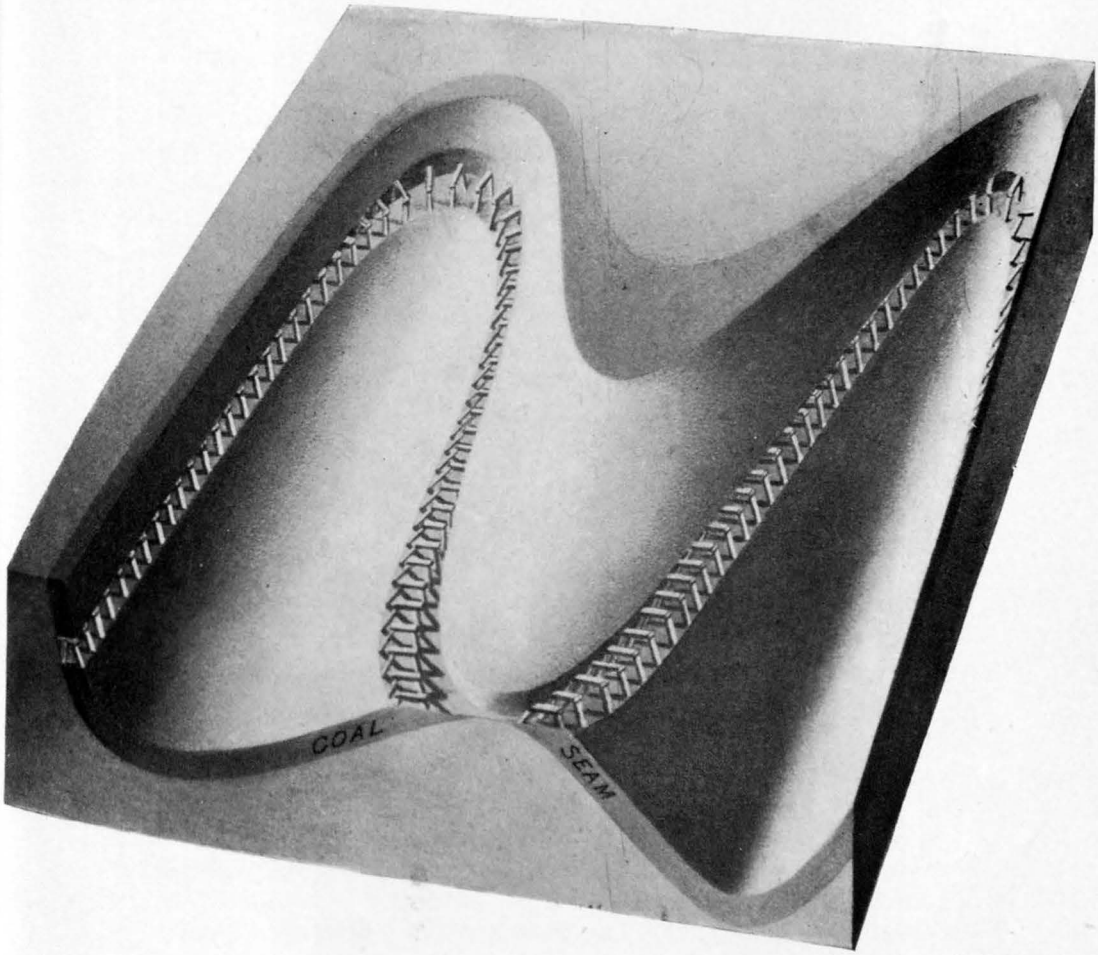
STRUCTURE.

The strata of the Puget group were deposited in marshes and beneath shallow water bodies. They accumulated, therefore, as nearly horizontal sheets of sediment. At the present time these sheets occur in tilted positions, dipping from 2 to 90 degrees from the horizontal, generally eastward or westward, but also in some localities northward or southward.

In some districts the dip is all in one direction. It is then called monoclinal, or of one slope. In one striking case, that of the Gilman district, the northward monoclinal dip is possibly due to uptilting by a mass of volcanic rock rising from below.

In other fields the dipping strata are frequently opposed in pairs. The two sides may slope each toward the other, forming a trough or syncline, or each may slope away from the other, forming an arch or anticline. The synclines are the coal basins. Their extent and form determine the localities and, to a great degree, the conditions of mining. Lying side by side, two such troughs are usually connected by an arch or anticline. If it were possible to lay bare the underground surface of any stratum involved in such troughs and arches, it would be seen to be corrugated; but, unlike corrugated sheet iron, with which it might otherwise be compared, the surface would exhibit conical or irregular troughs and arches instead of those of cylindrical shape. Where a gangway is driven on a coal bed to the axis of a basin, in driving farther it turns more or less abruptly back in the direction from which it came, in the same manner as a finger passed along the edge of a spoon turns back from the tip in a course opposite to that by which it reached the tip. At the axis of an arch a gangway makes a similar turn, but in an opposite direction. Thus the course of a gangway in a folded coal bed is a series of zigzag curves. (Pl. LIII.)

Such structures as these are in reality folds which have resulted from horizontal compression of the formerly flat strata. In a general way the axes of the principal folds trend north and south, indicating compression in a west-east direction, but there are also evidences of pressure in a north-south direction. Intimately associated with this



IDEAL SKETCH OF THE SURFACE OF A FOLDED COAL VEIN, SHOWING THE COURSE OF A GANGWAY AROUND A SYNCLINE AND AN ANTICLINE.

folded structure are overthrusts or planes of fracture along which the strata have been pushed one over others. Many of the faults traced in the mines are overthrusts.

In addition to folds and overthrusts, the structure of the Puget formation exhibits normal or extension faults. A normal fault is one in which the rocks are traversed by a plane of fracture and the separated parts have slipped one past the other in such manner that the fault plane dips toward the relatively sunken one of the two masses; or, as it is technically defined, in a normal fault the hade is to the downthrow. Movement of the masses adjoining on such a fault plane brings the wider sections of the wedge-shaped masses into line, and thus extends the space demanded by the strata.

Inasmuch as compression and extension of a given mass can not take place simultaneously, it is theoretically probable that the folds and overthrusts are the result of earth movements during one epoch, and the normal faults the result of those during another epoch.

The relations of the two sets of structures in these coal fields indicate that the strata were first folded and overthrust, and at later time suffered normal faulting. The normal faults cut across the folds in such manner as to throw the continuation of a bed from its position on one side of the fault to a position on the other side sometimes several hundred feet away horizontally. An example of this is to be seen at Carbonado, where the entire coal series is traversed by a fault plane striking about N. 50° W., and the Wingate vein north of the plane now outcrops relatively 800 feet west of its position south of the fault.

DEFINITION OF TERMS.

In the following descriptions of the different mining districts, it is necessary to employ certain terms not in common use to describe the lay of the coal. A clear understanding of the meaning of these terms is important to the reader of the following pages. As a preliminary to the definition of these terms, it is desirable briefly to state the processes through which the coal beds have passed in being moved from their original horizontal positions to the highly tilted attitudes which they now have.

A coal bed represents the accumulations of decayed vegetation in a marsh or shallow expanse of water. The plants of a bygone age, under the influence of sunlight, took from the atmosphere carbonic acid, and when their activity was over were buried beneath the growths of following seasons, and finally beneath beds of mud or sand. When so buried they passed, by the process of decay, through the condition of peat to lignite, and by slow distillation to that of bituminous coal or even anthracite.

The surface of the marsh was nearly level, and the decaying vegetation, which accumulated upon it or beneath an expanse of shallow

water, was also level. The materials of what is now a coal bed, therefore, formerly extended as a horizontal sheet of vegetal matter of greater or less extent. In any such marsh the conditions of ebb and flow of waters varied from place to place and also from time to time. Where there was just sufficient moisture for the growth of rank vegetation the mass of plant stems, leaves, roots, and mosses remained free from mud and sand; but where the currents washed the decaying vegetation into pools more or less mud and sand were deposited with it. It is the mud and sand which now form the ash of the coals, and accordingly a layer of coaly material which is pure in one locality may frequently be traced to another where it contains so much earthy material as to become what the miners call "bone," or, if it be still more earthy, slate.

The conditions which are favorable to the development of such marshes as those in which coaly material accumulated exist near the sea along low coasts. In such regions the earth's surface rises and sinks gently during ages, and slight changes of level are sufficient to transform marsh lands into shallow estuaries, or to lift the bottoms of the bays so that they become marshy again. In the tide-swept waters of a bay sand and mud accumulate, forming beds which harden into sandstone or shale. Thus, by the gentle oscillation of the earth's surface, the conditions for the formation of coal in marshes alternate with the conditions for the deposition of sand and mud, and in a series of deposits beds which become coal alternate with beds which become sandstone and shale. In the Puget region, in what is known to geologists as Eocene time, this process went on until the strata had accumulated to a thickness of more than 9,000 feet, with coal beds occurring at frequent intervals, particularly in the lower part of the series.

These strata extended horizontally, the earliest being at the bottom, the latest at the top of the pile. Toward the east the beds ended against older rocks along the shore of the land from which the sediments came, and which adjoined the coal marshes. Toward the west the coal beds passed into layers of black shale, and these probably into layers of finer shale and sandstone which formed beneath the adjacent sea.

As an illustration of the next transformation which came over the coal beds, consider the folding of an ordinary fan. When it is extended its surface is flat, like that of the coal beds in their original formation, but when partly closed the fan is thrown into narrow plaits or folds. These folds are bent upward and downward alternately, and, in consequence of the crease which determines the position of each one, they are sharp at top and bottom. This crease corresponds to the axis of the fold and determines its direction. The broad sheets of rock between which the coal beds lie were plaited into narrow folds, similar to those of a fan, but less regular. There being no crease in the rocks, the folds were curved upward or downward, forming arches

which alternate with troughs. Thus, the layer of swamp accumulation which had become a level coal bed was bent so as to raise some portions of it high upon arches and to depress adjacent portions deep in basins. The uplifted arches, as they developed, were worn away by rain and waves, while the basins received additional deposits of sediments and the coals contained in them became more deeply buried. Of the former continuous expanse of the coal bed there remain, therefore, only those portions which have been preserved by the downward bending and filling of the basins in which they are now found. Such a coal basin is not unlike the bowl of a large spoon, except that the layer does not close around, as the spoon does, toward its handle, but on the contrary widens out from the tip and passes on either side over an arch into adjacent basins (Pl. LIII). In the Puget Sound region these arches and basins extend generally north and south, and the edge of any coal bed follows a sinuous line across them from east to west. This contradicts the apparent courses of the beds, which, on account of the narrowness of the folding, trend usually northeast or northwest; but in every case, if followed a moderate distance upon such a course, the bed will be found to turn upon itself and zigzag back to the southeast or the southwest. Hence it is that a crosscut tunnel, driven east or west across the measures, would traverse the same beds repeatedly in a distance of 2 or 3 miles.

In describing these folds the following terms are used:

Strike.—Stratified rocks are divided into layers by planes of bedding, which in their original formation were practically horizontal. When the strata have been tilted a horizontal course upon such a plane of bedding gives the trend of the bed. Such a course is called the "strike" of the bed, and is measured by the compass and stated as so many degrees east or west of north. Strike is therefore defined as the azimuth of a horizontal line drawn upon a bedding plane.

Dip.—If a line be drawn upon an inclined bedding plane at right angles to the strike, it will have the steepest inclination possible upon that plane. The angle which such a line makes with the horizon is called the "dip" of the bed, and measures the rate at which it slopes beneath the surface.

Pitch.—Where the bed of rock is bent around the axis of a fold the dip of the bed corresponds with the slope of the axis. It is often desirable to distinguish between the dip on the side of a fold and this dip on the axis. Accordingly the dip of a bed on the axis is called the "pitch" of the axis. In the bowl of a spoon the pitch would be the angle with the horizontal made by a line drawn from the tip toward the handle, whereas the dip of the surface would be from either side toward the axis of the bowl.

Syncline.—A fold which has the form of a trough is called a "syncline." The dips on either side are toward each other, and the surface of any bed is concave upward.

Anticline.—A fold which has the form of an arch is called an "anti-

cline." The dips on either side are away from each other, and the surface of any bed is convex upward.

The side of an anticline is also the side of the adjacent syncline, and the occurrence of the one form of fold usually implies the existence of the other kind beside it.

In the preceding statement no reference is made to the dimensions of folds. Folds are of different magnitudes, and a large fold usually includes within itself many lesser ones, which again are themselves wrinkled by still smaller plications. In the Puget Sound region the largest folds may be several miles across, and possibly may extend 10 or 20 miles in length. Within these largest flexures lie those constituting the valuable coal basins, which are usually from one-quarter of a mile to a mile in width and from 3 to 6 miles in length. Still within these are the smaller folds, which are recognized only in the process of mining, but which constitute many of the so-called "faults" that occasion expense and difficulty in the underground working. A law which is useful as a means of understanding the relations of the

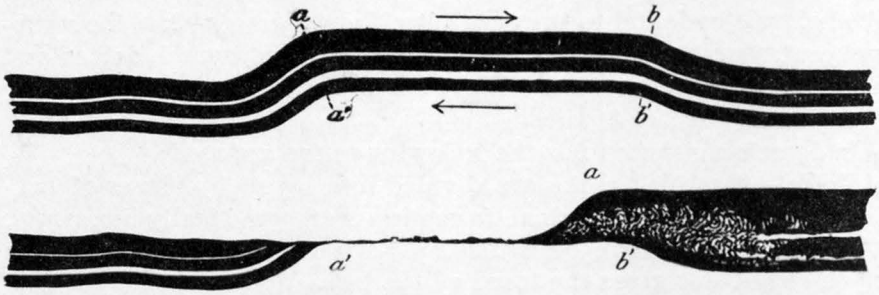


FIG. 26.—Ideal sketch to show the development of a pinch.

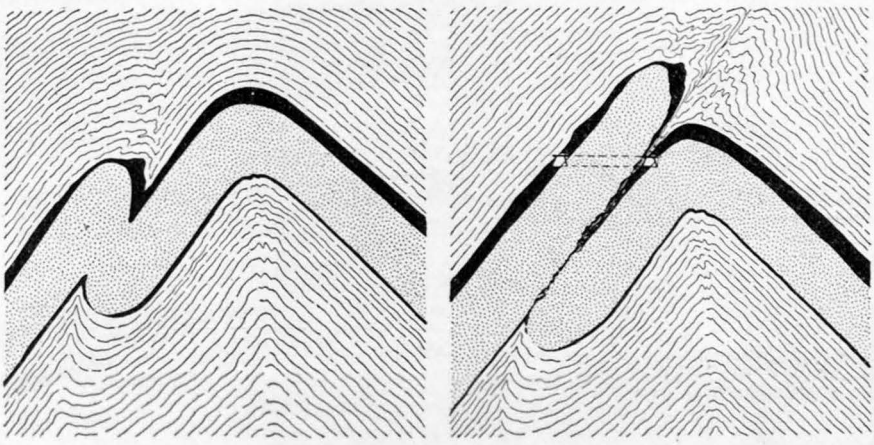
coal basins is that the least folds are similar to the larger folds. They pitch in the same direction and are likely to exhibit similar peculiarities in details of structure.

Faults.—When a sheet of material of any considerable thickness is bent, the inner or concave side of the bend is compressed, whereas the outer or convex side is extended. Between the inner compressed section and the outer extended section there is a plane which retains its original length. If several layers together be bent they will seek to adjust themselves to this compression or extension by sliding one upon another. Across the leaves of a thick pamphlet let a straight line be drawn. If now the pamphlet is bent it will be noticed that the line is distorted as each leaf moves past another in adjusting itself to the length of the curve.

In the folding of the great beds of rock which constitute the Puget coal series such movements of one bed upon another were necessarily very considerable. They were also unevenly distributed, being greatest on the planes where friction was least. The coal beds are soft, as compared with the sandstones, and more easily broken as compared

with the shales, and they therefore afforded planes of easiest movement. A coal vein between two layers of massive sandstone may be compared to a layer of tallow between two sheets of plaster of paris. The effect of this motion is to be seen in the crushed and rolled condition of much of the coal (fig. 26).

In the process of folding, massive beds like sandstone were frequently bent to a curvature which necessitated fracture. Massive beds, by virtue of their rigidity, also most effectively transmitted the pressure, which affected the other rocks as well as themselves. When they were broken, they no longer transmitted the pressure in the direction of the arc of the curve as previously, but against any obstacle in the way of their movement. Thus the thrust transmitted by a massive bed caused the crushing or breaking across of other beds



Fold before faulting. *Fold after faulting.*

FIG. 27.—Ideal section to show the mode of development of an overthrust and the duplication of a coal bed in a crosscut tunnel.

and permitted one portion of the rock series to be thrust over upon another (fig. 27).

Another form of disturbance which has occurred to these rocks is the development of planes of fracture along which one block has slidden down past another. Such planes are usually nearly vertical, and bear no relation whatever to the folds, which they may cross in any direction. In contradistinction to the breaks which are associated with compression and which develop in the process of folding, these disturbances usually require an elongation of a portion of the strata, as when the wider parts of two wedges are brought together by one sliding past another which tapers in the opposite direction (fig. 28). Occasionally such a movement results in local compression, when the thicker portion of a sinking wedge-like mass forces itself into a space too small for it. But such compression is simply local, and is not related to the general folding of the whole series.

All of the forms of disturbance of the coal veins which are due to the various movements of the strata upon one another are designated by the miners "faults." It may be well to describe them under four heads, namely: wrinkles, pinches, overthrusts, and normal faults.

Wrinkles.—Within the larger fold which constitutes a coal basin there are usually many minor folds, or wrinkles, of sufficient size to affect the direction of a gangway. Such a wrinkle may first become apparent by a change in direction of the wall of the vein. It may or may not be accompanied by a change in the thickness of the coal, which can in any case be followed in the direction of the bedding.

In one case which recently came under my observation a minor fold brought the foot wall into a vertical position across the direction of the gangway (Pl. LIV). The engineer in charge failed to note that the strike of the bed had changed to a course nearly at right angles with

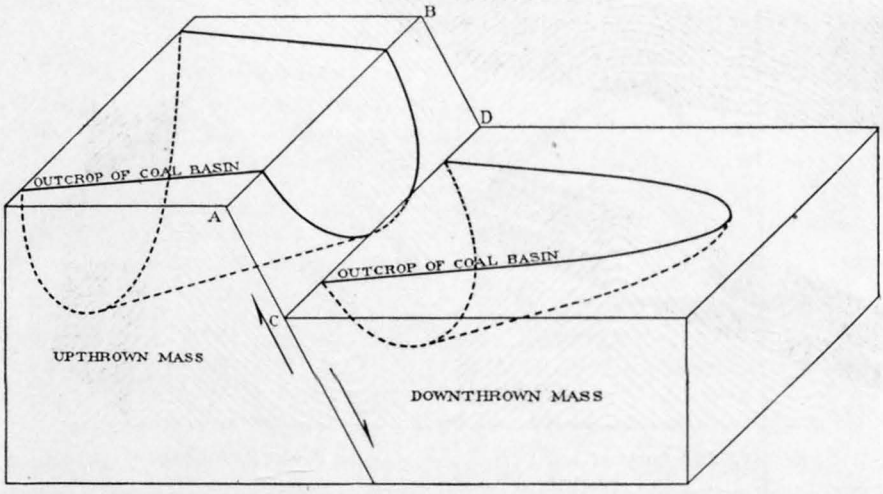
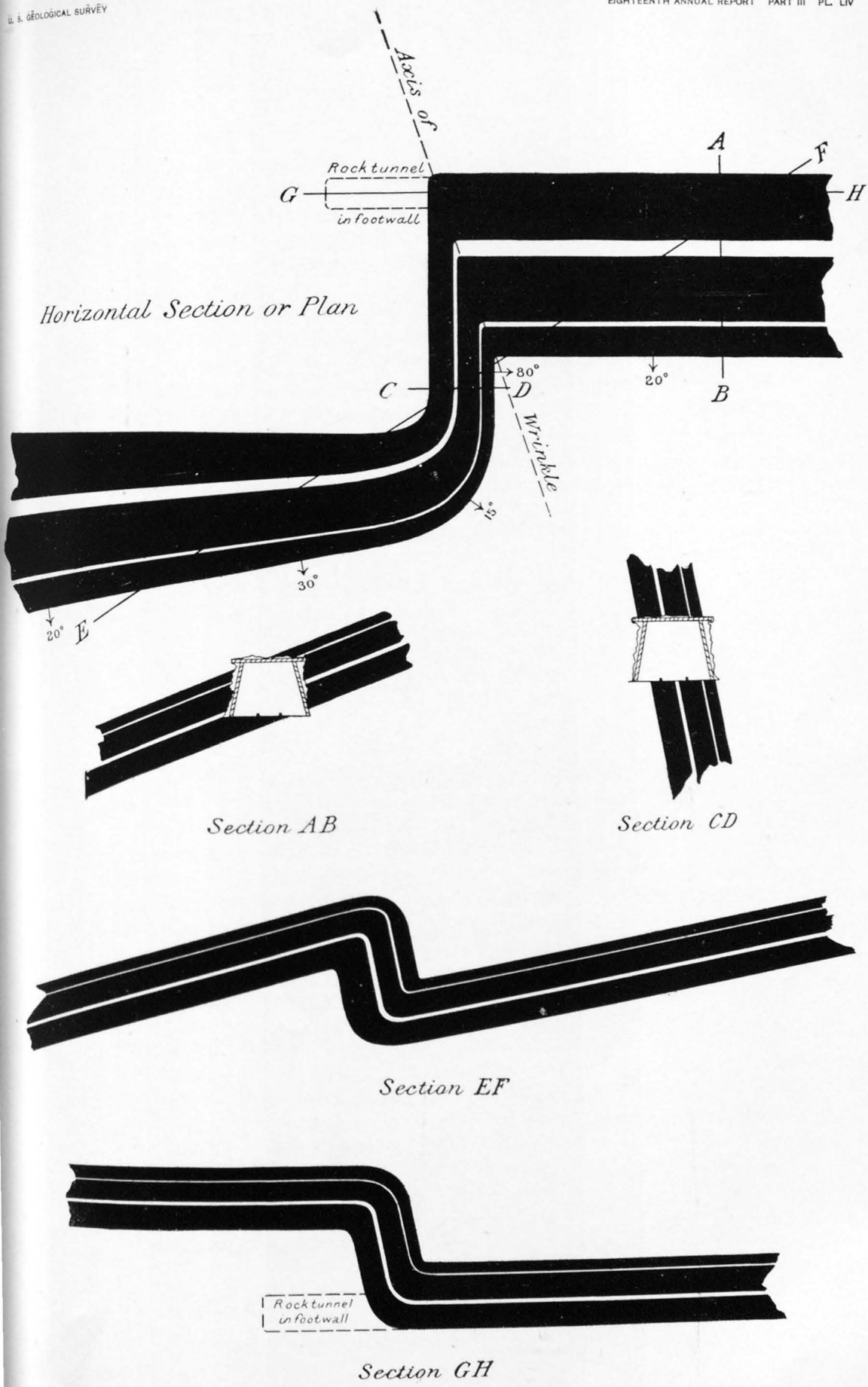


FIG. 28.—Diagram to illustrate the effect of a normal fault cutting across a coal basin.

its previous trend, and that the dip had become vertical instead of 20°, although these facts were easily observable in the side of the gangway. He accordingly drove a rock tunnel into the upturned foot wall. There was in this case no dislocation such as characterizes a true fault.

Pinches (fig. 26, p. 408).—Movement of the roof and foot wall of a coal vein past each other is a common phenomenon, and a necessary incident to the process of folding. Where the walls are flat the coal vein may retain its thickness, and exhibits the results of folding only in the crushed and rolled character of the coal. Where, however, the walls are uneven or bent so as to present corrugations, the movement of one past the other may bring two shoulders into contact in such manner as to squeeze the coal bed out from between them. This may be called a "pinch." A pinch is characterized by the continuity of the wall rocks, which are rarely broken, though usually polished and



PLAN AND SECTIONS OF A WRINKLE EXPLORED IN DRIVING A GANGWAY

scored in the direction of motion. It is a dislocation in which the faulting has pursued the plane of bedding, and a coal vein has determined the surface of easiest movement. In mining the extent of such a disturbance can not be foreseen, but the seam between the two walls will always remain to guide the direction of the tunnel. It usually happens that the coal which is forced out of the pinch is squeezed into a wider space, where the walls lie farther from each other than the ordinary thickness of the vein. Such a swelling of the vein, if the coal be crushed and rolled, may in itself be evidence of an approaching pinch, or if the pinch be discovered first, might be expected to occur in one direction or another.

Overthrusts.—In case the plane of a dislocation produced during compression crosses the beds, the mass on one side of the break is pushed over on the mass on the other side. This constitutes an overthrust (fig. 27, p. 409). Usually beds which lie deeper in the series are brought to rest upon higher beds of the series, and any one coal bed may thus be repeated in a sequence which otherwise exhibits the parallelism of the regular order. An overthrust usually originates in movement in a plane of the bedding, and frequently follows a coal bed, as the surface of easiest motion, to a point where the strata are so bent that the direction of the fault plane cuts across them. Thus, in consequence of the motion on the fault plane, the beds have been broken across and the upper mass has been pushed over upon the under. The characteristics by which an overthrust fault may be recognized are two: First, the plane of the fault dips under the overthrust mass; second, in the plane of the fault there is usually a considerable thickness of crushed coal mingled with streaks of crushed clay and blocks of sandstone, whose chaotic distribution is evidence of the amount of motion the rocks along the fault plane have undergone. In so far as such a fault may follow a coal vein the coal is rendered worthless. The upthrust portion of the vein in good condition may be found along the fault plane at a distance dependent on the amount of displacement and other factors. A case of this sort is illustrated in fig. 27 (p. 409), in the account of a fault in the Burnett mine. The vein may often be found duplicated on the other side by driving a crosscut tunnel into the hanging wall if the fault has been approached underneath, or into the foot wall if it has been reached on top of the fault plane.

Normal faults.—In the case of a normal fault the dislocation may be supposed to divide two wedge-like masses of rock, one of which was supported on the wide end of the wedge and the other on the thin edge. Then, in the movement of the masses, that which was thinner below may be supposed to have failed of support and consequently to have sunken down with reference to the other (fig. 28). The plane of a normal fault is usually nearly vertical, and the direction of its dip is always toward the sunken mass. This is expressed

in the definition: "A normal fault is one which hades to the downthrow." In mining, this law of dip of a normal fault plane may generally be applied to determine which is the downthrown side of the fault, and that fact being known the direction in which the intersected vein is to be sought is easily ascertained.

DESCRIPTIONS OF THE SEPARATE DISTRICTS.

The following descriptions of the several coal-producing districts embody the results of observations made in the summer of 1896, together with information furnished by the mining companies or copied from the official maps and records which have been generously placed at my disposal. The account is not complete even for the coal fields visited, inasmuch as some mines could not be examined and in several there was no opportunity to measure the coal veins; but the data gathered constitute a material addition to the meager information hitherto available concerning these mines.

NEWCASTLE-GILMAN DISTRICT.

LOCATION AND TOPOGRAPHY.

Fifteen miles east of Seattle, beyond Lake Washington, is the valley of Issaquah Creek, which flows northward through Squak Mountain into Sammamish Lake. Squak Mountain has a height of 1,980 feet, and at an elevation of 1,000 feet sends off a bold spur to the northward. Northwest of Squak Mountain a range of hills, rising to a height of 1,500 feet, extends for 5 miles between lakes Washington and Sammamish. Newcastle is situated on the western slope of these hills. Between them and Squak Mountain, Tibbetts Brook flows northward, parallel to Issaquah Creek and about a mile west of it, also emptying into Sammamish Lake. The town of Issaquah, formerly called Gilman, is situated on Issaquah Creek about 2 miles south of Sammamish Lake, at an elevation of 95 feet above the sea. The valley is here half a mile broad, and wide and fertile bottom lands extend to the lake. A mile south of the town the pass through Squak Mountain narrows to a wild ravine, bounded by high cliffs overgrown with timber and underbrush.

The Gilman mines are opened in the northern spur of Squak Mountain, and extend from east to west through this spur to and beyond the valley of Tibbetts Brook into the Newcastle Hills. The Newcastle mines, also extending east and west, are opened along Coal Creek on the western slopes of these hills and about 1 mile north and 5 miles west of the Gilman mines. The Gilman mines are reached from Seattle by the circuitous route of the Seattle, Lakeshore and Eastern Railroad, which passes around the northern end of Lake Washington and along the eastern shore of Sammamish Lake. The Newcastle mines are connected with Seattle by a narrow-gauge road constructed around the southern end of Lake Washington and about

the slopes of its eastern shore. There is no direct connection, except by wagon road or trail, between the two mining points.

The aspects of the topography have been suggested in the preceding statement. Squak Mountain and the Newcastle Hills are conspicuous features of the landscape from whatever distant point the district is observed. The ravines of Tibbetts Brook and Issaquah Creek are channels carved under conditions determined by the occupation of the region by former glaciers. Being cut down to a very moderate altitude above sea level, they leave the hills of the coal-bearing rocks in bold relief and give advantageous conditions for mining above water level. They also afford passes through the mountain range from the valley of Cedar River into that of Sammamish Lake, and they constitute striking instances of the peculiar relations so frequently existing in the Puget Sound region between the courses of streams and the barriers by which it might be supposed they would have been turned aside. Issaquah Creek, rising on the southern side of Squak Mountain, should more naturally empty into Lake Washington, toward which there is a continuous channel, which it formerly occupied. Its divergence and the cutting of its present ravine were determined by ice dams, whose history can not here be more fully stated.

The bold slopes and height of Squak Mountain are due to the hardness of the rock mass from which it has been carved, whereas the Newcastle Hills present more rounded forms on account of the softness of their sandstones.

The Gilman mines are opened in sec. 33, T. 24 N., R. 6 E., on the eastern side of the northern spur of Squak Mountain, at an elevation of about 175 feet above sea level. The gangways are driven westward to pass through this spur, and the veins have been in some measure identified in the gorge of Tibbetts Brook. They have not been traced farther to the west. Upon the principal vein a slope is sunk 800 feet on the dip, or down to a depth below sea of about 175 feet. In driving a gangway eastward from the bottom of this slope gravel and quicksand were encountered, showing that the old valley of Issaquah Creek was carved to at least this depth. It is now filled with drift deposits.

GEOLOGY.

No very complete section of the coal-bearing strata could be measured in this locality, as the hillsides are covered with drift and forest so as to obscure the rocks. From the mine map, however, the following intervals between coal beds were noted:

Vein No. 4 (thickness 7 feet), highest of the known series.
Interval of 300 feet, in which occurs Vein No. 3 (thickness 5 feet).
Vein No. 2 (thickness 6 feet).
Interval of 175 feet to Vein No. 1 (thickness 16 feet).
Interval of 412 feet to Vein No. 5 (thickness 8 feet).
Interval of 360 feet to Vein No. 6 (thickness not measured), the last of the known series.

Through the courtesy of the owners and superintendent, I was enabled to measure the detailed cross sections of all the veins except No. 6, and they are given in Pl. LV.

The structure of the district is that of a simple monocline, dipping northward. Squak Mountain, extending south of the mines, is a mass of igneous rock, which may have caused the northern tilting of the coal measures, or may simply have been uplifted with them. The strata strike S. 86° W., from Issaquah Creek to Tibbetts Brook, and have dips varying from 20° to 40°. They are remarkably free from faults, only one of importance having been met with in the course of mining. This fault, a simple pinch, was encountered in the water-level gangway of vein No. 4, and extended about 400 feet. The walls of the vein were continuous, and separated throughout by a recognizable coal streak, which, however, was often squeezed to a fraction of an inch. An examination of the wall rocks made it evident that they had simply slid past one another in such a manner as to bring two continuous surfaces into opposition and to force the coal out from between them. This fault does not traverse the strata, but is limited wholly to the vein in which it occurs, and gives no occasion to infer the existence of similar faults in the other veins.

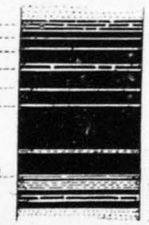
The relation of the Gilman section to that of Newcastle has not been determined. There are resemblances between the veins in the two sections, and it is possible that they present opposite sides of a coal basin. This supposition is rendered more plausible by the fact that younger strata of Miocene age are known to occur in the southeastern portion of the Newcastle Hills, where the center of the basin should be. The extent of the coal-bearing district, if it be continuous from Gilman to Newcastle, is not less than 5 square miles, and may extend over 12 square miles. The relations of the district beyond the immediate vicinity of the mines have not been studied.

RENTON-CEDAR RIVER DISTRICT.

LOCATION AND TOPOGRAPHY.

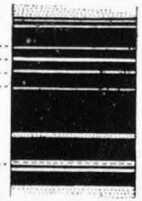
Lake Washington, a narrow water body extending from north to south for 18 miles, is an important feature of the vicinity of Seattle, which is situated on the narrow strip of land between the lake and the waters of the Sound (Pl. LII). From the southern end of Lake Washington a broad valley extends southward for 20 miles, continuing in that direction the depression of which the lake occupies the northern portion. The distinction between the lake and the valley is one of their present condition only, the lake being filled with water and the valley with alluvium of modern rivers. The surfaces of the lake and valley are uniformly level, and the banks of both present steep, terraced slopes. Through the valley White River, a stream which

VEIN No. 4 AT CROSSCUT TUNNEL.



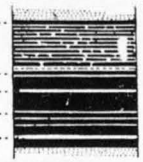
Total thickness, 7′ 8¾″.

VEIN No. 4 AT FACE.



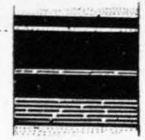
Total thickness, 6′ 10¼″.

VEIN No. 3.



Total thickness, 5′ 3″.

VEIN No. 2.

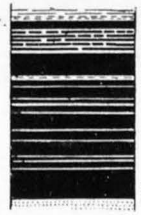


Total thickness, 4′ 5″.

VEIN No. 1.

Total thickness, 16′ 3½″.

VEIN No. 5.



Total thickness, 7′ 9½″.

SECTIONS OF COAL VEINS, GILMAN MINE.

descends from the glaciers of Mount Rainier, flows northward, and the outlet of Lake Washington at its southern end joins it after a short southward course. The two streams form the Duwamish, and find their way through a northwestern arm of the valley into the sound at Elliott Bay. Just south of the southern end of Lake Washington Cedar River enters the valley from the east through a deep and steep-sided channel. Between White River and Cedar River extends a plateau, whose terraced slopes and uneven surface appear to be composed wholly of gravel deposits. The valley level has an elevation of about 30 feet, and the plateau surface a height of 400 feet, above the sea. The intervening slopes are steep. Along the northern front, facing Cedar River, eroded surfaces of the bank expose the edges of coal-bearing strata dipping eastward, and explorations conducted many years ago discovered the continuation of these coal veins on the southwestern face farther south. Thus it is known that beneath the deposits of stratified and unstratified gravels the plateau has a core of coal-bearing strata. Six miles farther east, also on the banks of Cedar River, the rocks are again exposed, and the Cedar Mountain mine has been worked both eastward and westward from the Cedar River Valley.

At the point where Cedar River passes out into the plain of the broad valley is one of the early settlements of this region, the town of Renton, which takes its name from that of the old coal mines worked in the hillside above it. Renton lies 11 miles southeast of Seattle, and is connected with it by the Northern Pacific Railroad, the Seattle, Columbia and Puget Sound Narrow-Gauge Railroad, and electric car lines. The area of the Renton coal field, which lies in T. 23 N., R. 4 E., is probably 4 and possibly 8 square miles.

GEOLOGY.

The strata of the Renton district do not appear in exposures in such manner as to afford any considerable section of the measures. Although several veins have at different times been opened, but one is now worked, and its relation to the others was not determined. The old Renton mines were worked southward from Cedar River on a general north-south strike and a dip of 14° to 16° to the east. Another mine, known as the Renton-Talbot mine, was opened about a mile south and was worked southward. Both of these workings are now abandoned and are full of water. In a space of ground remaining between them the Renton Cooperative Coal Company opened a new slope in 1895. Sections of the principal coal veins were obtained in the new workings, and they are given in fig. 29 (p. 416).

In the accompanying diagrammatic map (Pl. LVI) the structure of this region may be seen to be as follows:

From the northwestern opening on Cedar River the course of the gangways in the old Renton, Renton Cooperative, and Renton-Talbot mines

follows the strike of the principal vein slightly to the west of south. The dip is eastward from 14° to 20°. In the Renton-Talbot mine, at the southern end, the strike of the vein, as indicated by the gangways, bends to the westward around a broad, low arch. In the old Talbot mines this western course is continued out to the edge of the alluvium in the valley. The eastern dip of the northern mines is continuous as far down as the slopes have been driven, but the southern dip of the old Talbot mines is converted into a northern dip along a sharp synclinal axis, south of which the strata rise steeply to the surface. This syncline pitches sharply southeast, and the coal basin accordingly extends in that direction. The existence of the fold was determined in the old Talbot workings, the vein being disturbed along the axis, but its character was not understood. The existence of the northern dip was recently proved by exposing the strata in the bluff south of the Talbot workings, where the solid measures were seen to

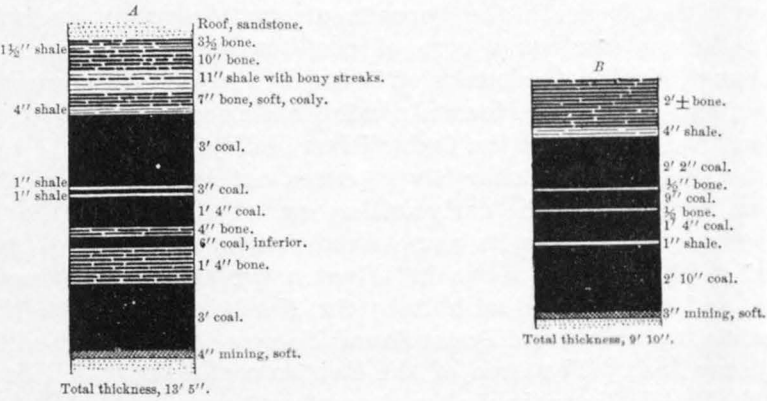


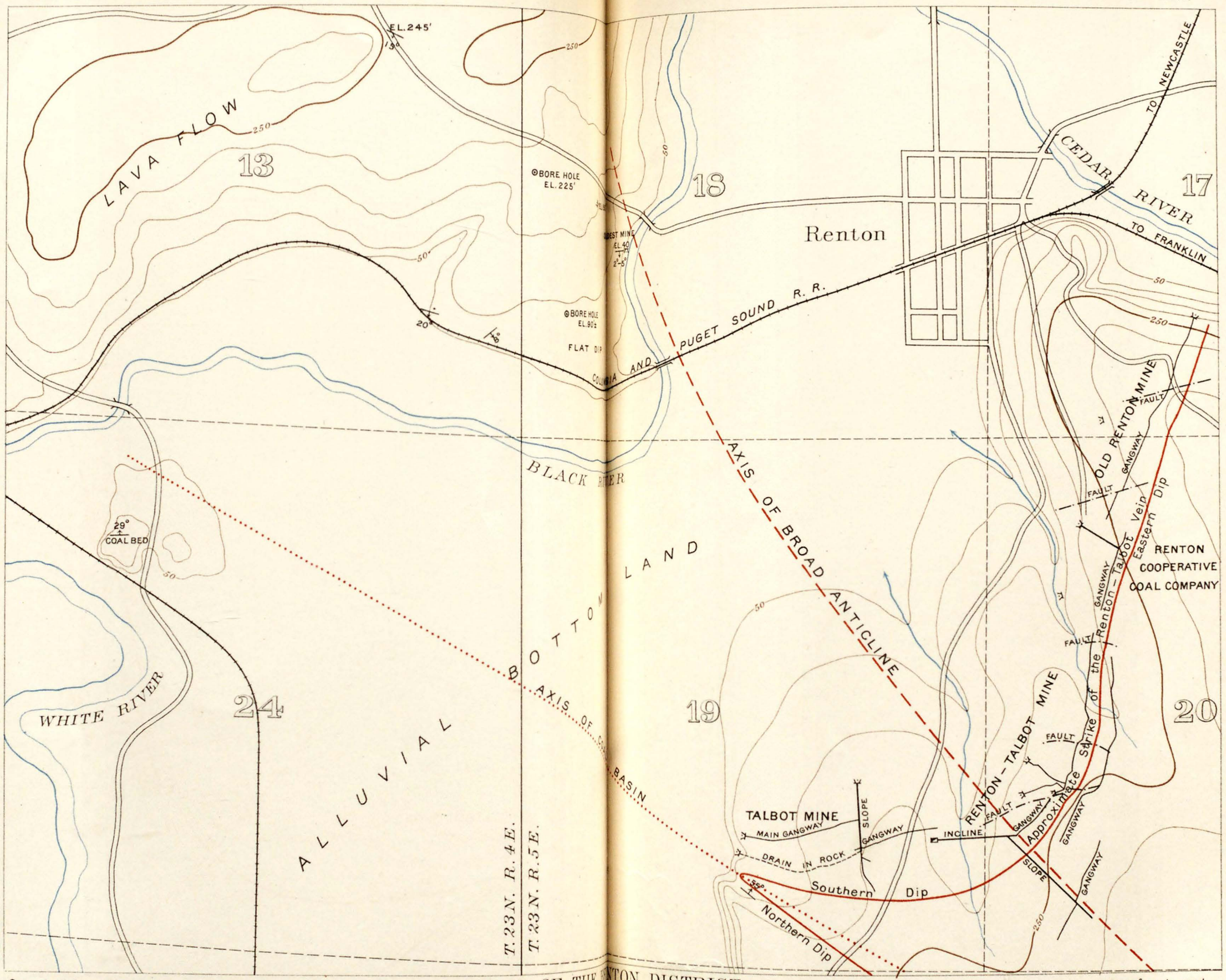
FIG. 29.—Sections of coal vein, Renton mine.

strike N. 58° W. and to dip 58° to the north. From this point southward to Panther Creek, a distance of about 5,800 feet, the edges of the strata may be seen at several points along the bluff. The strike is approximately east and west, and the dip steeply northward and sometimes vertical. On Panther Creek, a few yards below the crossing of the county road, an excavation in the bank exposed a small vein of lignite having the following section:

Section of lignite on Panther Creek.

	Inches.
Roof: shale, gray, finely sandy, homogeneous.	
Bone	1
Coal	5
Bone	½
Bony coal	8
Bone and sand	2
Bony coal	6
Total	22½

Foot wall: fine, gray sandstone.



Compiled from Mine maps furnished by C. H. Burnett and the Renton Cooperative Co.

MAP OF THE RENTON DISTRICT.

Sketch contour interval 50 feet.

Topography and Geology from notes by Bailey Willis.

Apparently this bed lies stratigraphically about 5,000 feet below the vein worked in the old Talbot mines. The great thickness of strata exposed on the constant northern dip indicates the probability of an extensive basin pitching southeast between Cedar and White rivers. This general attitude is related to that of the Green River coal field, and the coal-bearing rocks are no doubt continuous from one district to the other.

West of the town of Renton the valley is occupied by alluvium to a width of three-quarters of a mile, but northwest of Black River the hills rise somewhat gently in slopes thinly covered with till. The coal-bearing strata are exposed along Black River and upon the higher slopes in a nearly horizontal attitude, with a gentle southern dip. They obviously belong to the broad dome, from which the low arch pitches southeastward between the old Talbot and the Renton-Talbot mines. The strata to the northwest of Black River underlie the coal beds worked in the Renton mines, and have been prospected by boring to a depth of 400 feet without the discovery of workable coal beds. Early in the history of the search for coal the

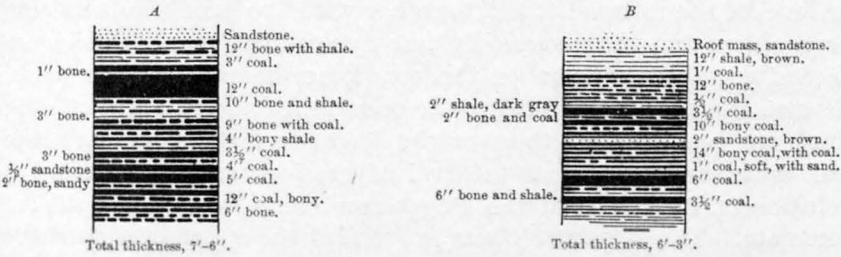


FIG. 30.—Coal veins of the Renton district.

bed shown in section in fig. 30, *A*, was opened close to the surface of Black River, and within a few years explorations 110 feet above it developed the vein shown in fig. 30, *B*. Surface explorations south of the old Talbot mines should cross the strata which are exposed north of Black River, and might well be undertaken in advance of more extensive boring operations. Toward the northwest the strata of the Puget group pass beneath lava flows, and in the valley of the Duwamish younger Miocene rocks of marine origin appear in isolated outcrops.

East of Renton, in the bluffs south of the valley of Cedar River, 4,000 feet from the forking of the railroad toward Newcastle, there is a very interesting occurrence of conglomerates and thin-bedded sandstones in peculiar relations (Pl. LVII). The exposures are in the hillside above the railroad track, where it has been partly cut away in grading the road. Low down, near the track, there is an exposure of fine clay-shale, probably belonging to the highest strata of the Puget formation, which is bedded in layers one-quarter inch to 2 inches thick, with four interbedded sandstone layers 2 inches to 1 inch thick. The strike of this outcrop is north, and the dip is 21° to the east. The thickness exposed is 52 feet. Beyond a slide about 100 feet wide a

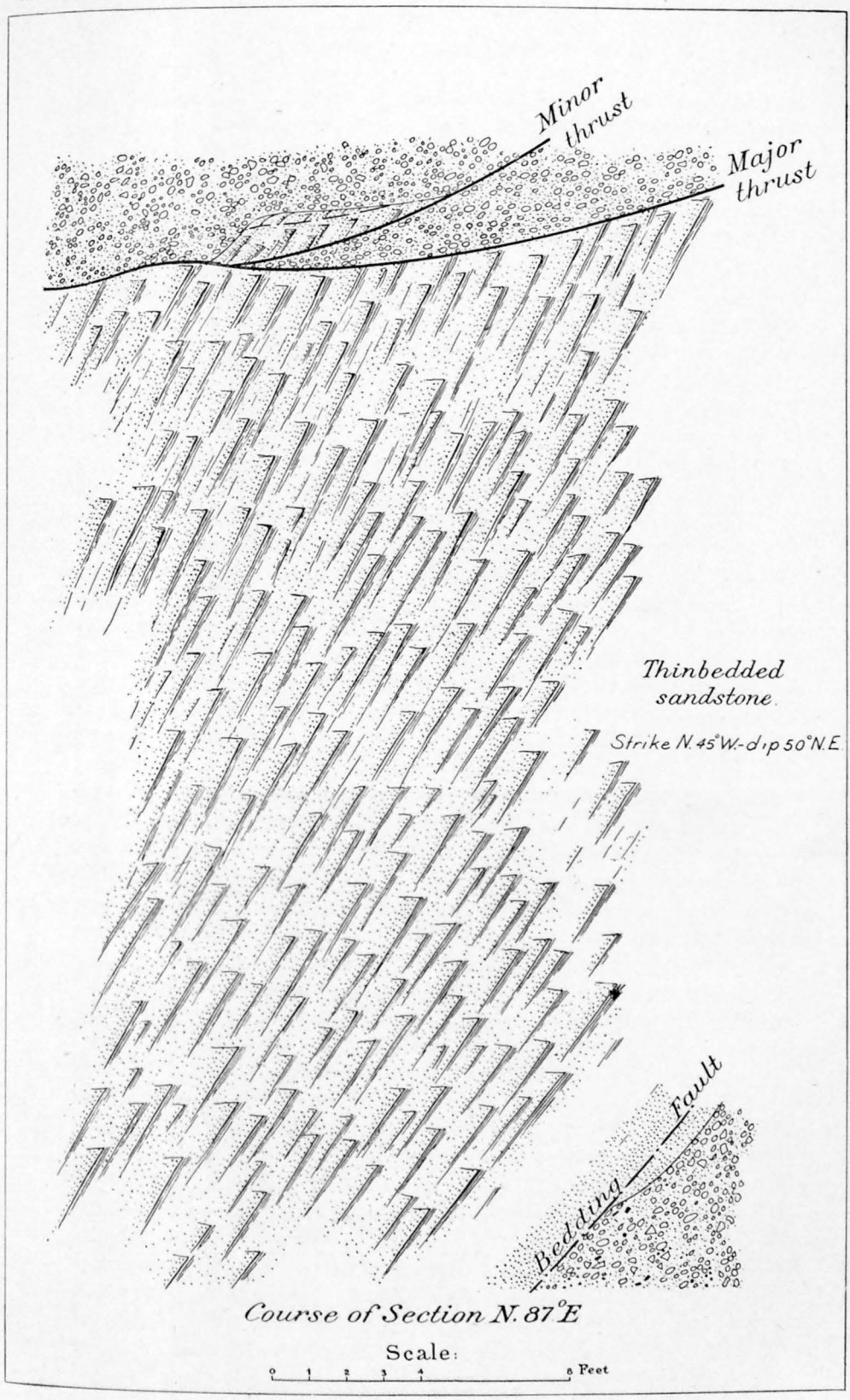
conglomerate may be seen underlying a bed of sandstone. The conglomerate consists of generally rounded pebbles up to 3 inches in diameter, associated with clay nodules of blue-gray color, which weather brown. The conglomerate contains pebbles of white granite much decomposed, of sandstone of the Puget formation, and of angular pieces of coal 2 inches long. The conglomerate is at least 8 feet in thickness (the bottom being concealed) and the overlying sandstone is about 2 feet thick. There is a slight flexure in the bedding plane between the conglomerate and the sandstone, across which the sandstone is overthrust on a small fault.

The sequence of strata upward above this sandstone bed consists of thin-bedded gray and brown sandstones, which strike N. 45° W. and dip 50° to the northeast. These beds are faulted about 30 feet above the track by an extensive overthrust, which brings the underlying conglomerate to rest directly across their edges. The association of the conglomerate with the unconformity produced by faulting tends to produce the impression of a true unconformity of dip associated with a basal conglomerate, but the small exposure of conglomerate on the level of the railroad track, together with the small fault detected there, shows that the diverse dips are due to disturbances which took place after the deposition of the conglomerate rather than before. The stratigraphic facts indicate the occurrence at this point of strata which are younger than those of the Puget formation and are separated from the latter by an interval of erosion which permitted the inclusion of fragments of the Puget sandstone and coal in the conglomerate. The structural facts prove that the epoch of disturbance resulting in the overthrusts succeeded the deposition of the conglomerate and of higher strata. The nature of the faulting is evidence that the load upon the strata at the time of the disturbance was moderate. No fossils were found in the higher strata.

GREEN RIVER DISTRICT.

LOCATION AND TOPOGRAPHY.

Midway between Seattle and Tacoma, but from 15 to 20 miles east of a line connecting those two cities, is the Green River district. Green River, descending from its canyon in the Cascade Mountains on the east, passes out into an extensive gravel plain, across which it cuts a tortuous and steep-walled canyon from 50 to 300 feet deep. In the walls of this canyon the Puget series is exposed, the strata cut through ranging in dip from near a horizontal to a vertical position. In terms of the Land Office subdivision, the exposures of the coal-bearing rocks extend through T. 21 N., Rs. 6 and 7 E., and into the adjacent townships north and south. Away from the Green River Canyon the surface is generally covered with gravel, but upon the rounded hills with which it is diversified the drift is frequently very thin, and the coal-bearing strata can be discovered by digging. This area is approximately 30 miles from both Seattle and Tacoma, and



THRUST FAULTS IN LATE EOCENE OR MIOCENE STRATA, 4,000 FEET EAST OF RENTON, CEDAR RIVER VALLEY, KING COUNTY, WASHINGTON.

its most westerly development, the Black Diamond mine, lies 11 miles due east of Auburn, a station on the Northern Pacific Railroad.

The outcrops of coal on Green River attracted attention in 1880, and led to extensive prospecting operations during the next two or three years. A single well-defined coal basin, then known as the McKay and since as the Franklin basin, was traced out near the western edge of the coal field, and two collieries were located upon the same vein—the Franklin colliery, opening on Green River, and the Black Diamond colliery, 3 miles farther northwest (Pl. LVIII). Other operations were begun to the east and southeast, but the lay of the coal in that tract has never been accurately determined, and no mines comparable in extent to the Franklin and Black Diamond have been developed. There is at the present time no adequate map of this entire coal field, and the definite information presented in the following paragraphs relates only to the Franklin and Black Diamond collieries and the intervening Light Ash mine.

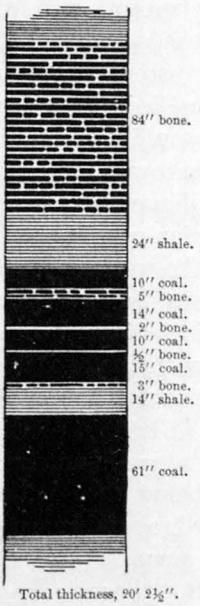


FIG. 31.—Section of the McKay or Light Ash vein (from Census Report, 1884).

GEOLOGY.

A stratigraphic column of the coal-bearing strata exposed on Green River is given on Pl. LXXXI of Vol. XV of the Tenth Census Reports. In that columnar section forty beds of carbonaceous character are enumerated, but of these only four, Nos. XIV, XV, XVIII, and XXIII, are productive coal veins lying within the district under consideration. Veins Nos. I to XII belong to lower measures, which are exposed to the north and east of the Franklin collieries. Vein No. XVIII is the McKay vein, otherwise known as the Light Ash or White Ash vein, or the Black Diamond vein. In fig. 31 is given a typical cross section reproduced from the Census Reports. This vein is the only one now extensively worked in the field, and is the one from which the principal supplies of steam coal are drawn.

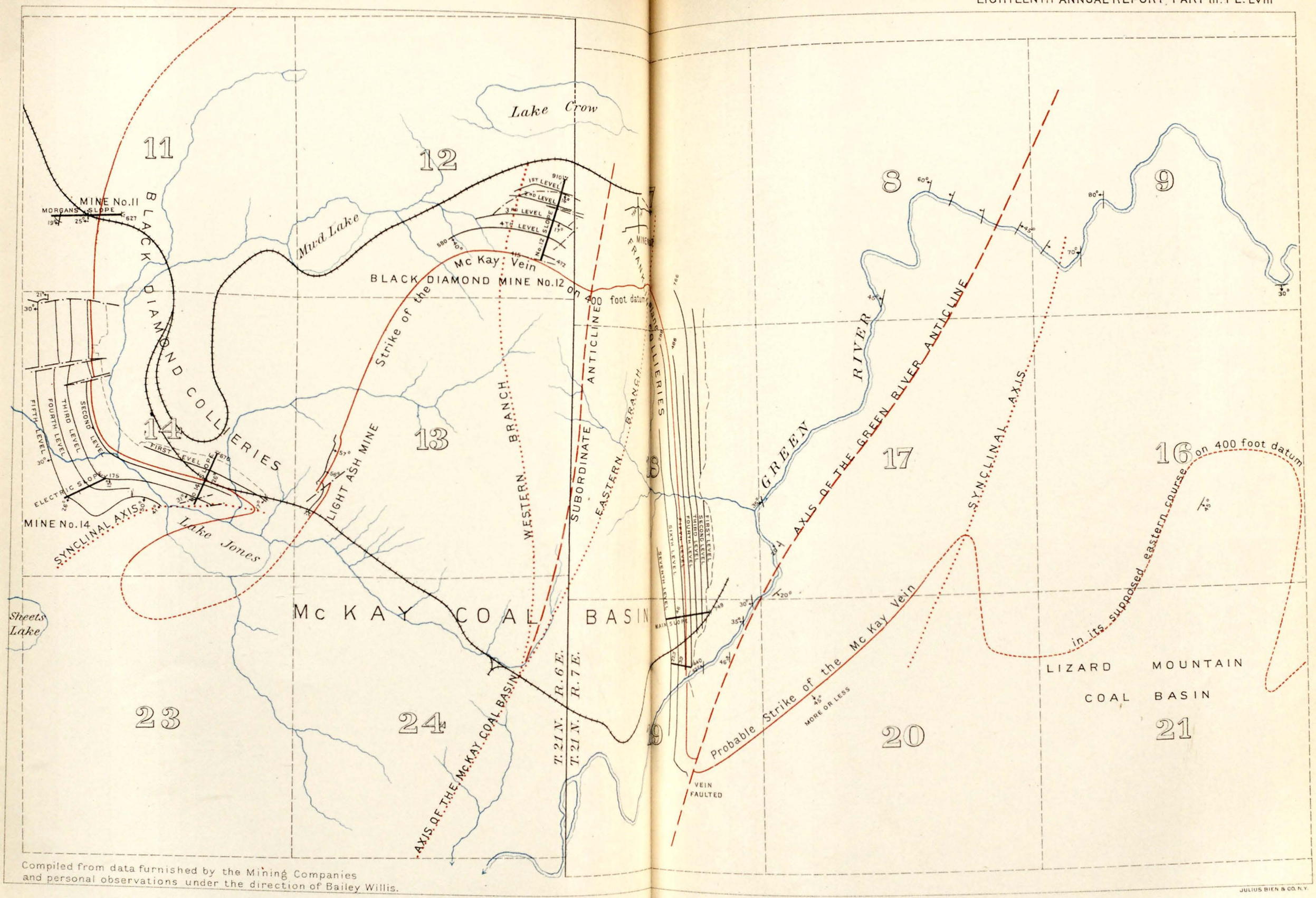
The stratigraphy of the Green River coal field bears some resemblance to that of the Wilkeson-Carbonado field. The upper portion of the series on Green River is generally barren of productive coal veins, as is that exposed on South Prairie Creek and Carbon River. Fossils obtained from the Clay mine on Green River, the highest point in this section, correspond to those obtained from the highest exposures on Carbon River. The lower portion of the Green River section, like that of the Wilkeson-Carbonado district, contains numerous beds of coal, concentrated in a moderate thickness of sandstone and shale. It is probable that future work, particularly with the fossil plants, may develop a close correlation between the strata of these two districts.

The structure of the Green River district is comparatively simple.

It consists, broadly speaking, of a sheet of strata inclined toward the southwest and fluted in broad folds. Of these folds the McKay coal basin and the Black Diamond anticline were traced out in the work prior to 1884. The general strike of the important McKay vein No. XVIII was then determined along the line through sections 18, 7, 12, 13, and 14, as may be seen by reference to the diagrammatic map, Pl. XC of the Census Report. The extensive development of the collieries has since demonstrated the general correctness of the outline then drawn. At that time, also, the axis of the Green River anticline on the east of the McKay basin was determined, but then, as now, the structure still farther to the eastward remained obscure. In Pl. LVIII the strike of the McKay vein No. XVIII is traced from its northwestern occurrence in section 11, through the workings of the several collieries and around the Green River axis, in the position which it would have on a plane 400 feet above sea. As the dip of the vein is toward the southeast, south, southwest, or west, it extends for levels above 400 feet to the north or north and east of this line. This extension may be seen in the Franklin and Black Diamond collieries, where the workings, which are to a great extent more than 400 feet above sea, lie east and north of the red line. The strike of the McKay vein is indicated with assurance of accuracy from section 11 to section 20, with the exception of a short space in section 23. Doubtful points in the position of the vein occur as follows:

First, in section 11 the precise position of the strike on the 400-foot datum is not known north of Morgan's slope. The depth of the vein below the surface has been determined by borings along the eastern edge of the section, and these indicate a northwesterly dip. The apparent course is toward the Danville mine, about 4 miles distant, but there is no doubt that the strike of the vein trends back to the westward again, although it is probable that the folds become wider toward the northwest.

Returning to the neighborhood of Black Diamond, the second place where the strike of the vein is doubtful is found in the southern part of section 14 and the northern portion of section 23. Considering the trend of workings of the Black Diamond mine in section 14 and those of the Light Ash mine in section 13, it would seem natural to infer that the strike of the vein extended from one to the other in a simple curve, without passing south of these two sections. But in the third level of the Black Diamond mine a gangway driven southeast turned sharply to the southwest, and so continued for some distance on the faulted vein under Lake Jones. It was at last abandoned on account of the crushed condition of the coal and rock. Its course, however, sufficiently determined the existence of a minor synclinal wrinkle, which must be taken account of in extending the strike of the vein on the 400-foot plane. The probable course is indicated by the red dotted line, showing that the coal may probably be found beneath section 23 at a moderate depth below the surface.



Compiled from data furnished by the Mining Companies and personal observations under the direction of Bailey Willis.

JULIUS BIEN & CO. N.Y.

DIAGRAMMATIC MAP OF THE GREEN RIVER COAL MINES.
KING CO., WASHINGTON.

Scale: 2½000

1 ¾ ½ ¼ 0 1 Miles

1897.

The third point at which the course of the vein may be considered doubtful is along the southern limb of the Green River anticline through section 20, and thence eastward. The sixth level of the Franklin colliery was driven southward under Green River to a point where the vein turned first eastward and then southward. It was there lost in a fault. The nature of this fault was not determined, although extensive explorations were made by means of rock tunnels. An examination of the section on Green River, however, between the sandstone which outcrops at the bridge on the county road and the McKay vein, demonstrates plainly the existence of the anticline, and shows that the strata beyond the fault encountered in the sixth level strike northeastward and dip to the south at an angle of 20° or more. A crosscut tunnel driven from the river at the bridge southeastward should strike the McKay vein at a distance of 1,200 to 2,000 feet, according to the amount of dip of the strata. Farther to the northeast, in the southwestern part of section 9, observations made along the river show the presence of a synclinal axis pitching southward, and to the east of this a rectangular arch, while beneath Lizard Mountain there is, according to the observed strikes, a syncline with flat bottom and steep sides. The course of the McKay vein around these folds can, in the absence of any definite observations, only be guessed at. The area of sections 16, 17, 20, and 21 is deeply covered with drift. The strike of the McKay vein may carry its outcrop farther northward through sections 17 and 16 or limit it to a more southerly position in sections 20 and 21, but there is no reasonable ground for doubt that it exists in the eastern part of the field and will eventually be worked there. Accurate maps of the eastern Green River field and a careful study of its stratigraphy and structure are much needed.

In minor details of structure the Green River field presents some interesting facts. In the Black Diamond mine, in driving the gangway northward in section 14, three normal faults have been encountered, with a downthrow to the north. Two of these, which have been traversed by the gangways, are apparently related in the amount of throw, one dying out downward, the other upward, so that the total throw of the two remains approximately the same. The third has not been crossed, as it is intended to leave the intervening mass of rock between the No. 14 mine and the No. 11 mine.

In the Light Ash mine, at 600 feet from the entrance, a normal fault was struck which throws the vein horizontally 150 feet to the northwest. The plane of the fault hades steeply to the northwest, and is scarcely distinguishable in the tunnel among the bedding planes of the strata.

In the northern part of the basin, as developed in the Black Diamond mine No. 12 and in mine No. 7 of the Franklin collieries, there are a number of small faults, some of them apparently due to the wrinkling of the walls of the coal bed, as might naturally be expected

in the sharp turn of the basin. A different fault, which is of interest, occurs across the eastern end of the upper gangway of mine No. 7, where it would appear, so far as could be determined at the time the mine was visited, that the strata had been overthrust from the south by a force of compression acting in the direction of the synclinal axis. If this interpretation be true, the continuation of the vein would be found to lie to the north of the fault plane. From the strike of the bed in sections 12 and 7 it is inferred that the broad coal basin is divided by a low but well-defined subordinate anticline into an eastern and a western branch.

In general, the structure of this field is much more simple than that of the Wilkeson-Carbonado district, and there is a direct stratigraphic relation between the moderately developed folding and the moderately concentrated condition of the coals. Toward the east, where the structure is more complex and the development of the folds is the result of greater compression, the coals of the Green River field are more highly bituminous. Toward the northwest, where the degree of compression and movement was less, the coals become lignites.

WILKESON-CARBONADO DISTRICT.

LOCATION AND TOPOGRAPHY.

The Wilkeson-Carbonado district (Pl. LII) lies southeast of Puget Sound, about midway between the city of Tacoma, from which the mines are 20 to 23 miles distant, and the volcanic mass of Mount Rainier. It is traversed by the eastern tributaries of the Puyallup River, the strata being exposed particularly on South Prairie Creek, Gale Creek, and Carbon River. It may be said to lie upon the extreme northwestern foothills of Mount Rainier, about 25 miles from the summit of the peak, and its western limits are determined by the gravel plateaus of the Puget Sound drift. According to subdivisions of the United States Land Survey, it stretches from T. 19 N., R. 6 E., southward, with some interruptions of exposure, to the Nisqually Valley, in T. 15 N., R. 6 E. The most northern mines are opened on South Prairie Creek at Burnett. The Wilkeson mines begin 2 miles south of the Burnett mines, while the Carbonado mines lie 2 miles to the southwest from the Wilkeson. All of these mines, therefore, are developed in the extreme northern portion of the field. The more southern districts, although prospected in the years 1883 and 1884, have remained undeveloped on account of inaccessibility. The general slope of the foothills across which this coal field extends is toward the west and northwest, and the descent is terraced by accumulations of drift with characteristic development of moraines and potholes. The drift has been traced up to an elevation of 1,700 feet, and is known to range in depth from 50 to 300 feet. The ravines of South Prairie Creek and Gale Creek expose occasional bluffs of the coal-bearing

sandstones, but their banks are usually composed of gravel and sand. Carbon River, which traverses the field for a distance of 8 miles, flows through a rugged canyon 400 feet in depth. A portion of this canyon just above Carbonado is cut in volcanic rocks and is almost inaccessible. In the vicinity of Carbonado itself a fine section of the coal measures is exposed, and they form the banks of the stream for a distance of 2 miles below the mines. The river then enters the drift deposits, sections of which appear in bluffs 300 feet high. The surface covering of drift and the dense growth of forest make this field exceedingly difficult of exploration, and a very large proportion of our knowledge of it is obtained from the mine maps. As a means of following the description of the mines, the reader is referred to the topographic and geologic maps contained in the pocket of this volume, Pls. LIX and LX.

The Burnett mines are opened from South Prairie Creek southward in sections 16 and 21, extending in the farthest gangways into section 22. The principal mine consists of a slope sunk on the vein to a depth of 625 feet vertically below its mouth, or 90 feet below sea level, and of three levels driven southward, the farthest to a distance of a mile and a half. Near the middle of section 21 a crosscut tunnel was driven westward, and a second workable vein was discovered 310 feet below the first. This vein was also opened in a water-level gangway, but its outcrop could not be discovered on South Prairie Creek. The dip of these two veins is about 50° toward the east. In the southwestern portion of section 16 two other openings have been made on veins on the western dip, which are believed to correspond precisely to the two veins opened on the eastern dip. Of these western openings but one has been driven to any distance, namely 1,500 feet, but as the vein was soon found to be seriously faulted the mine has not been prosecuted.

The Wilkeson mines are opened on four veins which outcrop on the southern side of Gale Creek, in the western part of section 27. At the point where the creek makes a sharp bend from a northerly to a westerly course its channel is cut upon the axis of an anticlinal fold, and the beds to the east of the stream dip about 50° to the east, while those to the west dip about 85° to the west. On the eastern dip the lowest of the known workable veins, the Kelly, has been worked to a short distance, but the mine is now abandoned. On the western dip all four veins have at different times been worked, and present operations have pushed the gangways south through section 34 and beyond an extensive fault into section 3.

The Carbonado mines are opened in sections 4 and 5 and extend northward into section 32 and southward through sections 8 and 9. The complexity of the geologic structure is such that numerous croppings of the veins are exposed in the canyon walls, and in the early history of the mines the operations were conducted in a hap-

hazard fashion to develop whatever was in sight. Most of these older workings are now inaccessible, and no information concerning them beyond the record of their position on the mine maps is to be obtained. The principal mines now operated are those south of the river and mines No. 6 and No. 3, which form the northwestern developments.

In addition to the developments made by the three great mining companies, there are numerous minor prospects opened along Gale Creek, and much information concerning the extent of the coal measures and the distribution of the coal veins was obtained by explorations conducted through the Northern Transcontinental Survey from 1881 to 1884. A portion of the material obtained by that survey has been preserved, but the original notes are not now accessible. The recent prospects, so far as they were noted in the summer of 1896, are platted on the accompanying maps, Pls. LIX and LX, in pocket.

That portion of the field concerning which there is least information, but which is likely to become important in the course of mining operations of the immediate future, lies between the Wilkeson and Carbonado mines, in sections 33 and 34 and the western part of section 28.

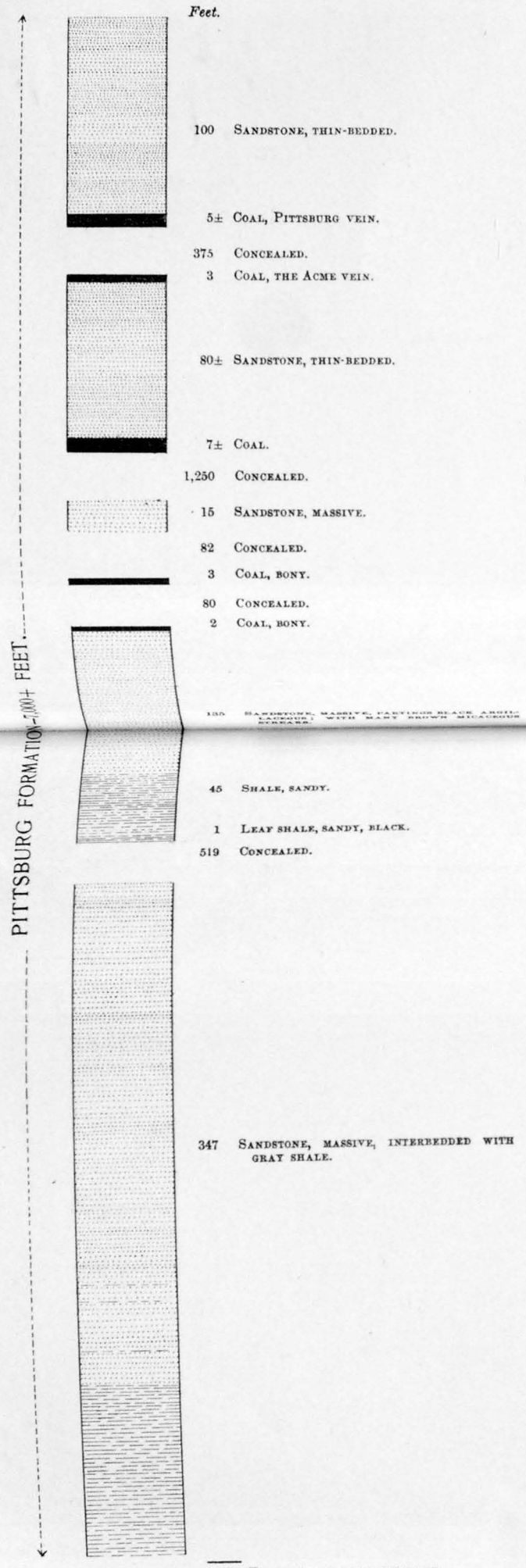
GEOLOGY.

The geology of the Wilkeson-Carbonado district presents some of the most difficult and consequently most interesting problems arising in connection with the Puget Sound formation. In each group of mines a section of the coal-bearing strata is exposed, and from each a distinct stratigraphic column can be compiled. As there are no continuous outcrops from one mine to another, and as the strata present a monotonous sequence without distinctive horizons, it is necessary to correlate the coal beds across the gaps between the Burnett and Wilkeson mines and the Wilkeson and Carbonado mines according to the best inferences to be drawn from all the facts of stratigraphy and structure. Before proceeding to do so the following sections are submitted:

On South Prairie Creek, above Burnett, there is partially exposed a section of sandstones and shales generally barren of workable coal veins, but containing five beds of inferior coal near the top of the section at Pittsburg, aggregating 4,770 feet. In this section the Burnett vein is the lowest bed observed, but beneath this vein itself lies the productive coal series. The section does not reach the top of the Puget group, the strata having been traced to the eastward, with a uniform dip, to their disappearance beneath a lava flow, giving probably an additional thickness of 3,500 feet. Thus it appears that on South Prairie Creek there is exposed a total section of at least 8,000 feet, dipping eastward above the Burnett vein. In this series, 84 feet above the Burnett vein, there are several beds of massive sandstone interbedded with shale to a thickness of 940 feet, which are

THE PITTSBURG-BURNETT SECTION.

Top of measured section. Exposures to the eastward show probably 3,500 feet above this uppermost stratum, and this is added to the following column:



Feet.

100 SANDSTONE, THIN-BEDDED.

5± COAL, PITTSBURG VEIN.

375 CONCEALED.

3 COAL, THE ACME VEIN.

80± SANDSTONE, THIN-BEDDED.

7± COAL.

1,250 CONCEALED.

15 SANDSTONE, MASSIVE.

82 CONCEALED.

3 COAL, BONY.

80 CONCEALED.

2 COAL, BONY.

135 SANDSTONE, MASSIVE, PARTINGS BLACK ARGILLACEOUS, WITH MANY BROWN MICACEOUS STREAKS.

45 SHALE, SANDY.

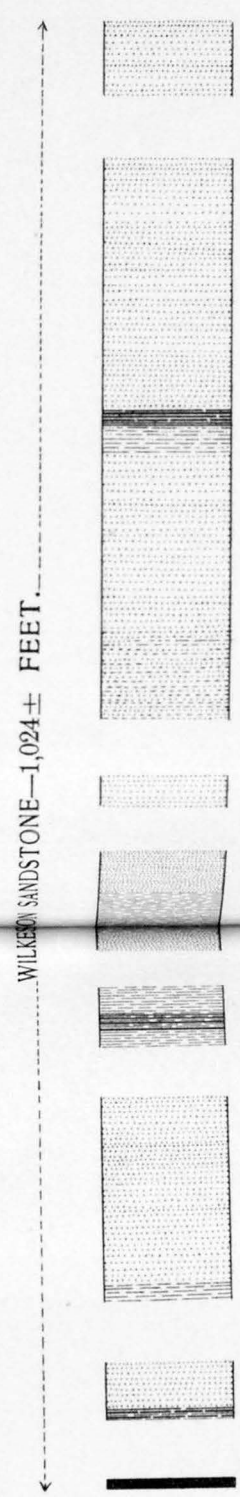
1 LEAF SHALE, SANDY, BLACK.

519 CONCEALED.

347 SANDSTONE, MASSIVE, INTERBEDDED WITH GRAY SHALE.

6,549 THICKNESS CARRIED FORWARD.

SECTION—Continued.



Feet.

6,549 THICKNESS BROUGHT FORWARD.

693 CONCEALED.

30 SANDSTONE, MASSIVE.

20 CONCEALED.

100 SANDSTONE, LAYERS 3 INCHES TO 4 FEET THICK.

6 BONE AND COAL.

10 SHALE, GRAY, SANDY.

70 SANDSTONE, MASSIVE.

36 SANDSTONE, GRAY, SHALY.

122 CONCEALED.

15 SANDSTONE.

122 CONCEALED.

30 SANDSTONE, THIN-BEDDED.

[illegible] SHALE, BROWN AND BLACK.

16 SANDSTONE, THIN-BEDDED.

4 CONCEALED.

15 SHALE.

10 SHALE AND BONE.

8 SHALE.

13 CONCEALED.

21 SANDSTONE.

58 SANDSTONE.

7 SHALE.

165 CONCEALED.

18 SANDSTONE.

4 BONE.

80 CONCEALED.

4± COAL, THE BURNETT VEIN No. 1.

8,271 FEET THICKNESS.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

COLUMNAR SECTION OF THE PITTSBURG FORMATION AND WILKESON SANDSTONES AS EXPOSED ON SOUTH PRAIRIE CREEK EAST OF BURNETT, PIERCE CO., WASHINGTON.

quarried along South Prairie Creek and are recognized in their proper relation to the Burnett vein just east of Wilkeson, where the upper beds of sandstone form three bold bluffs with slight hollows between them. These sandstones constitute an important key rock, and have been designated on the accompanying geologic map the Wilkeson sandstones. That portion of the South Prairie Creek section which lies above the Wilkeson sandstones will hereafter be referred to as the Pittsburg formation. The section, including the Wilkeson sandstones, so far as measured east of Burnett, is given in Pl. LXI.

In the canyon of Carbon River northwest of Carbonado, in sections 31 and 32, a partial section of the Puget group, much like the section on South Prairie Creek above Burnett, overlies the productive coal measures. The general dip of this section is westward, and the highest bed is accordingly seen at the western end. It consists of a small pinnacle of carbonaceous shale and sandstone, which is exposed in a railroad cut through a mass of volcanic tuff or mud flow. The exposed mass of shale is about 45 feet high, and is completely surrounded by the darker gray and black homogeneous tuff, which contains many waterworn river bowlders. Above the face of tuff and shale extend glacial gravels. It is obvious that at some date during the Glacial epoch a former river canyon afforded a course for the mud flow from a volcanic vent to the southeastward, and that the bluff of shale and sandstone which projected from the side of the channel was buried in the volcanic mud, which swept with it bowlders from the stream bed. The shale in this small exposure contains numerous leaf impressions, which appear upon comparison with specimens obtained from Green River to correspond with those obtained from the Clay mine, the highest exposure in that section. From this point to the slope on the Wingate vein, mine No. 6 north, Carbonado, a section was measured which yielded a total thickness of 3,845 feet of strata. This section in general resembles that measured on South Prairie Creek, including the Wilkeson sandstones. Workable coal veins are few in number, although it is possible that careful prospecting may yet discover good beds in either one or both of the sections. The similarity between the two is such as to justify a general correlation. The division stated on the section, into the Wilkeson sandstones and the Pittsburg formation, is, however, somewhat arbitrary, since no precise identification of strata is possible.

The section exposed on Carbon River is continuous southwestward beyond the slope on mine No. 6 north into the productive coal measures. Although the strata are greatly disturbed, the mining operations afford measurements of the thicknesses between the coal beds, and observations along the canyon make it possible to fill in most of the intervals with the appropriate descriptions of the rocks. The resulting section below the Wingate vein aggregates 1,125 feet. The complete section from the highest point beneath the mud flow

on the west to vein No. 7, the lowest vein in the series worked at Carbonado, has a total thickness of 4,970 feet. This section is given in detail in Pls. LXII, LXIII, and LXIV.

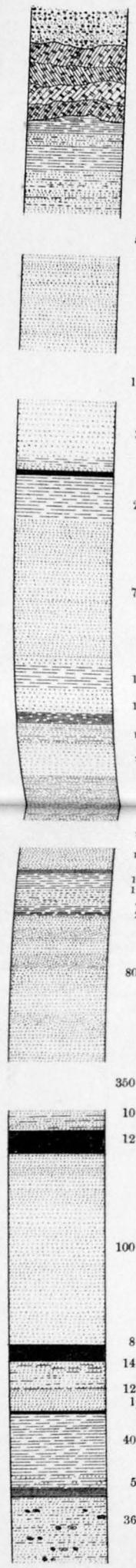
The exposures at Wilkeson do not afford any such continuous section as those obtained on South Prairie Creek and Carbon River. Northeast of Wilkeson, along the line of the railroad and on to South Prairie Creek, are sandstone bluffs with occasional croppings of coal and bone, which evidently represent the strata of the Pittsburg formation. They are in the line of strike, and only a mile distant from the section on South Prairie Creek. The bluffs of the Wilkeson sandstone, which, as already stated, are quarried on South Prairie Creek just above the Burnett vein, are also prominent in the vicinity of Wilkeson, on both the eastern and the western dips, and have been quarried for building stone at several places. For a section of the workable coal veins, however, it is necessary to accept that which may be seen in the crosscut tunnel in the southern part of section 34. Here, in the course of mining, a series of beds have been cut, the lowest a dirty vein, the highest the workable vein of mine No. 3. A careful measurement of the strata in this crosscut gives the section shown in Pl. LXV.

The independent measurements of strata having thus been presented, we may seek to compare the sections and to correlate the different coal beds according to the best hypothesis available with our limited knowledge. Correlations of coal beds are frequently made simply upon the occurrence of similar thicknesses of coal or similarity of cross section where there are several benches of coal; but it is shown by experience that coal veins are subject to great variations in quality and character, and probably this is especially true of the beds of this field. The several sections of the Wingate vein sufficiently indicate the changes to which it is liable. A simple comparison of the sections for a correlation of the coal beds and the intervals between them shows immediately that the strata are subject to much variation. Not only the coal beds, but the intervals themselves, both in thickness and character, fail to give any definite clue to their relations. It is necessary, therefore, to select the most characteristic sequence of rocks as a starting point, and to base the more specific correlation of coal beds upon that assumption.

The conspicuous fact of general significance is that the Puget series as exposed in this field may be divided into three members, namely: (1) the comparatively barren uppermost member of 7,000 feet or more, consisting of shales and sandstones, the Pittsburg formation; (2) at the base of this, and indeed forming a part of it, the Wilkeson sandstones, 1,000 feet, which are separated from the South Prairie formation only because of their importance as a recognizable horizon and not because of essentially distinctive characteristics; and (3) the productive series, which may be called the Carbonado formation,

Top of section where the strata of the Puget Group disappear under more recent tuff and gravel.

PITTSBURG FORMATION.



Feet.

20± Drift.

40± Tuff.

6 Shale, black.
7 Sandstone, shaly.
12 Shale, gray.
20 Sandstone, shaly.

570 Concealed.

50 Sandstone, massive, gray

186 Concealed.

30+ Sandstone, massive.

6 Shale, dark gray, passing into shaly sandstone.
2¼ Coal, bony.

24 Shale, weathering gray, hackly.

70 Sandstone, gray, thin-bedded.

6 Sandstone, massive, weathering brown.
12 Shale, gray, hackly.

16 Sandstone, massive, gray.
7 Shale, dark, carbonaceous, hackly
15 Sandstone, with thin shale beds.

20 Sandstone, massive, gray.

50 Sandstone, gray, in layers 6 inches to 30 inches thick, with interbedded dark gray shale 2 inches to 6 inches thick.

25 Concealed.

16 Sandstone, massive, weathering brown.
2½ Coal, bony, and black shale.
10 Shale, gray.
11 Sandstone, shaly.
4 Shale, gray.
2 Bone.

80 Sandstone, massive, gray, coarse, some beds cross-stratified; in two principal benches.

350 Concealed.

10± Sandstone and sandy shale.

12 Coal.

100 Sandstone, massive.

8 Coal.

14 Sandstone, shaly.

12 Sandstone, massive.
1½ Coal.

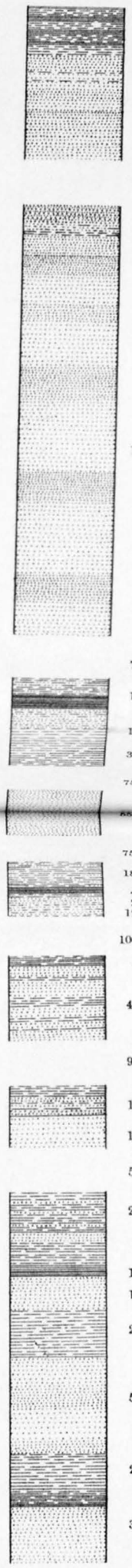
40± Shale, dark gray, sandy below, hackly.

5 Shale, dark, bony.

36 Sandstone, shaly, concretionary.

1,908¼ Thickness carried forward.

PITTSBURG FORMATION—Continued.



Feet.

1,908¼ Thickness brought forward.

20 Bone and black shale.

5 Shale, gray, hackly.

30 Sandstone, thin-bedded, shaly.

25 Sandstone, massive.

174 Concealed.

26 Sandstone, thin-bedded, with shale in middle.

195 Sandstone, massive.

70 Concealed.

10 Shale, sandy.
8 Coal, bony.
12 Sandstone, shaly.
30 Shale, gray, hackly.

75 Concealed.

55 Sandstone, massive.

75 Concealed.

18 Shale, sandy.

4 Coal, bony.
2 Shale, sandy.
12 Sandstone, shaly.

100 Concealed.

5 Shale, dark above, gray below.

40 Sandstone, with shale beds.

90 Concealed.

5 Shale, gray.
10 Sandstone and shale, interbedded.

16 Sandstone.

57 Concealed.

20 Shale, gray, hackly, with thin sandstone beds.

4 Sandstone.

18 Shale, dark gray, hackly, coaly at the base.
17 Sandstone, massive, gray.

25 Shale, dark, fossil shells, "Clam Bed."

50 Sandstone, massive.

20 Shale, gray, hard.

3 Shale, yellow, soft.
6 Black shale and bone.

30 Sandstone, massive.

3,270¼ Thickness carried forward.

WILKESON FORMATION.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

COLUMNAR SECTION OF THE PITTSBURG FORMATION AND PART OF THE WILKESON SANDSTONES MEASURED IN CARBON RIVER CANYON NORTHWEST OF CARBONADO, CONTINUED ON PL. LXIII.

SECTIONS OF THE MILLER VEIN.

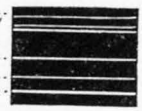
VEIN No. 3, NORTH.

(In the northern end of mine No. 3, North.)

Total thickness, 4′ 11¾″.

VEIN No. 3, SOUTH.

(1,600 feet south of Carbon River in mine No. 2, South.)



Total thickness, 4′ ¼″.

SECTIONS OF THE WINGATE VEIN.

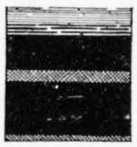
FIRST SECTION.

(Near north end of mine No. 6, North.)

Total thickness, 6′ 0″.

SECOND SECTION.

(300 feet south of first section.)



Total thickness, 5′ 7″.

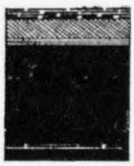
THIRD SECTION.

(500 feet south of second section.)

Total thickness, 5′ 7½″.

FOURTH SECTION.

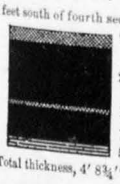
(10,400 feet south of third section.)



Total thickness, 6′ 5½″.

FIFTH SECTION.

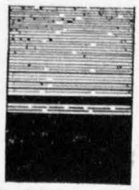
(1,150 feet south of fourth section.)



Total thickness, 4′ 8¾″.

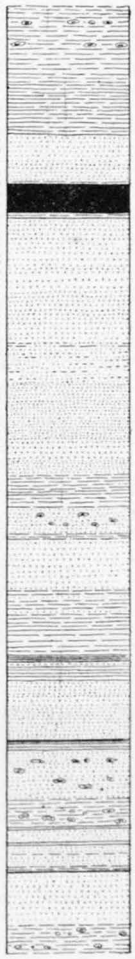
SIXTH SECTION.

(800 feet south of fifth section.)



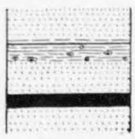
Total thickness, 7′ 4″.

3,270′ 6″ brought forward.
21′ concealed.
12′ sandstone, massive.
15′ shale and sandstone interbedded.
30′ shale, gray and dark, hackly.
10′ concealed.



30′ shale, concretionary, ferruginous.
21′ shale, black and gray.
18′ sandstone, gray, micaceous, and carbonaceous; slabby, becoming massive.
11′6″ coal and bone, the "Miller" vein.
50′ sandstone, massive, homogeneous.
16′ sandstone, shaly, largely covered.
22′ sandstone, thin-bedded.
8′ sandstone, massive.
6′ sandstone, thin-bedded.
8′ shale, weathering brown, crushed.
5′ shale, dark gray.
11′ sandstone, nodular.
2′ shale, dark gray.
20′ sandstone, massive.
16′ shale, gray, with sandstone.
10′ shale, brown, hackly.
3′ 6″ bone and clay.
6′ slate, black.
5′ sandstone.
18′ sandstone, thin-bedded, buff and dark gray, argillaceous and arkose.
1′ bony coal.
3′ black slate.
19′ sandstone, nodular.
11′ shale, gray, nodular.
1′ black slate.
5′ sandstone.
1′ 6″ black slate
8′ sandstone, with gray shale.
2′ gray shale and 6″ bone.
20′ sandstone, massive.
11′ shale, buff, nodular.
64′ concealed.

WILKESON FORMATION—Continued.



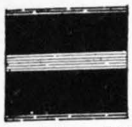
12′ sandstone, massive.
1′ shale, nodular, and 6″ coal.
7′ shale, nodular.
12′ sandstone, thin-bedded.
5′ 6″ coal, No. 6.
10′ sandstone, massive.
28′ concealed.

26′ sandstone, massive, ripple marked. Beds 2 to 4 feet thick, with dark shale layers.
44′ shale, nodular, hackly, with gypsum, white efflorescence.
17′ sandstone, massive.
9′ shale, dark gray and red, nodular.
5′ shale, black and gray, fissile.
1′ 3″ coal and black slate.
5′ sandstone, massive, ferruginous.
3,975′ 6″ carried forward.

CARBONADO FORMATION.

COLUMNAR SECTION OF THE WILKESON AND CARBONADO FORMATIONS MEASURED IN CARBON RIVER CANYON, NEAR CARBONADO, WITH DETAILED SECTIONS OF THE COAL VEINS.

VEIN No. 5, NORTH.

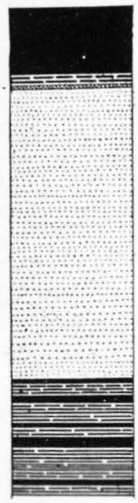


1½″ bony.
1′ 8½″ coal.
9″ slate, black.
1′ 10″ coal.
5″ bone.
Total thickness, 4′ 10″.

VEIN No. 4, SOUTH.

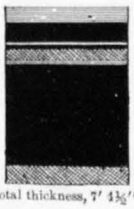
1′ coal.
11″ slate, gray.
1′ 6″ coal.
1½″ bone.
10″ coal.
1″ bone.
1′ 9″ coal.
5″ bone.
Total thickness, 6′ 8″.

VEINS No. 3 AND No. 5.



2′ 10″ coal.
2″ mining.
5″ bone.
12′ sandstone parting, 900′ south of river; 7,800′ south of river it is 2′ thick.
5′ bony coal with coal.
Total thickness, 20′ 5″.

VEIN No. 7.
(200 feet south of river.)



7″ slate, black, crumbly.
½″ slate
11″ coal.
6″ mining
2″ coal.
2″ slate, black.
4′ 3″ coal.
9″ mining.
Total thickness, 7′ 4½″.

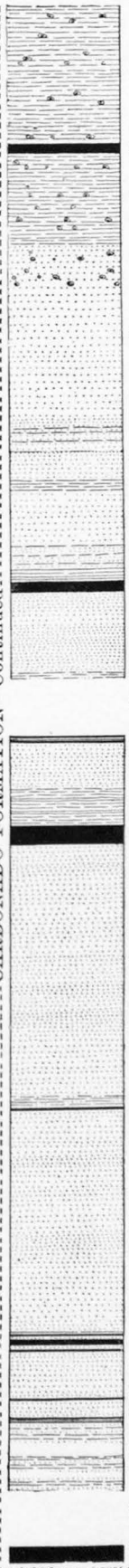
VEIN No. 8.

6″ slate, black
3″ bone
1″ soft coal.
1″ coal.
1′ 6″ shale, with streaks of bone.
10″ coal.
Foot wall, dark sandy shale.
Total thickness, 3′ 3″.

VEIN No. 10.
(In tunnel.)

Roof, gray shale.
9″ shale, black.
1″ mining.
½″ mining
8″ coal.
2″ mining
7″ coal.
1′ bony coal, with coal seams.
3″ bone.
2′ 2″ coal.
6″ mining, with coal.
Foot wall, shale.
Total thickness, 6′ 2½″.

CARBONADO FORMATION—Continued.



3,975′ 6″ brought forward.
99′ concealed.
60′ shale, dark gray and brown, nodular.
4′ coal, No. 2 or No. 5.
40′ shale, dark gray, nodular.
92′ sandstone, nodular, gray, with massive beds in middle and interbedded shale below.
12′ sandstone, thin-bedded.
4′ shale, gray, sandy, fissile.
25′ sandstone, massive.
10′ sandstone, interbedded with thin gray shale.
5′ black slate.
5′ coal, No. 4 south.
35′ sandstone, thin-bedded.
3′ shale, sandy.
30′ concealed.
3′ coal, bony.
20′ sandstone, slabby.
16′ shale, gray, hackly, with black slate.
9′ coal, bony.
110′ sandstone.
5′ shale, sandy.
1′ coal.
90′ sandstone.
8′ coal and sandstone interbedded, No. 5.
20′ sandstone.
1′ coal.
8′ sandstone.
2′ coal and slate.
30′ shale and sandstone, partly concealed.
224′ concealed.
7′ 4″ coal, No. 7 south.
Total thickness, 4,953′ 5″.

COLUMNAR SECTION OF THE CARBONADO FORMATION MEASURED IN CARBON RIVER CANYON, NEAR CARBONADO, WITH DETAILED SECTIONS OF THE COAL VEINS.

and which includes all the coal veins below the Wilkeson sandstone down to the lowest bed developed in the field. The correlation of the details of the productive series depends upon the recognition of the outcrops of the Wilkeson sandstone in different parts of the field.

The typical occurrence of the Wilkeson sandstone may be observed upon the eastern dip, either in the quarries along South Prairie Creek immediately east of Burnett or in the bluffs a quarter of a mile east of Wilkeson on the north side of the valley. The sandstones reappear on the south side of the valley, somewhat to the east of their proper course, and their strike at this point indicates that they extend southward through section 27 into section 35. The course of the levels of the Burnett mine and the discovery of the Burnett vein immediately beneath this sandstone on the north side of the valley at Wilkeson sufficiently identify the strata, although the exposures are not so ample at either place as to yield complete sections for detailed comparison. The Wilkeson formation does not appear prominently on South Prairie Creek west of Burnett on the western dip, but along Gale Creek west of Wilkeson, near the middle of section 28, it forms conspicuous and important outcrops. In the point of the hill on the north side of the valley are Mitchell's quarries, from which building stone has been obtained, and the massive sandstone strata are traceable to lower Wilkeson and the north line of section 28, where they form the hillside above Hill's mine and occur in bluffs which strike northward into section 21. They also appear in the face of the terrace near the center of section 21. These strata are on the western dip of the Wilkeson anticline. Near the middle of section 28, on the western side of the railroad, similar massive beds of sandstone outcrop with an eastern dip. They are traceable southward from near the branching of the railroad toward Carbonado almost to the wagon road from Wilkeson to Carbonado.

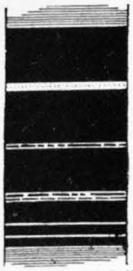
In the outcrops east of Wilkeson, in Mitchell's quarries, and in the last-mentioned outcrops on the west of the railroad, this formation presents a threefold sequence of massive beds, with characteristic absence of bedding planes in the sandstones and with interbedded layers of dark-gray, sometimes carbonaceous shale. There is no reasonable doubt that the occurrences represent one and the same horizon outcropping three times—first on the eastern dip east of Wilkeson, next at Mitchell's quarries on the western dip, and again beyond the railroad on the eastern dip. A recognition of the relations of these strata in the center of section 28 determines the existence of a coal basin whose axis extends along the valley in a nearly north-south direction. This axis is marked upon the accompanying structural map. Identification of the Wilkeson sandstone on the eastern and western dips of the Wilkeson anticline leads to the identification of Hill's vein with the Burnett vein as developed in mine No. 2, and Driver's prospects are thus placed between the Hill or Burnett and

the upper veins of the Wilkeson mines. It is possible that vein No. 3 of the Wilkeson mines is represented by the easternmost of these prospects, that on the Gopher vein.

The next step in the correlation is to extend it to the veins worked at Carbonado. This can not be done with certainty, but there is a reasonable degree of probability in the following suggested relation: The Wilkeson sandstones in the eastern part of section 28 have a low dip and a strike which swings to the west. Immediately adjacent to the branch railroad to Carbonado there is a coal bed known as Joe John's prospect, which dips but 10° to the north and strikes northwest. This coal lies in the Wilkeson sandstone. In the southwest quarter of section 28, immediately northwest of the road from Wilkeson to Carbonado, is a prominent hill which attains an elevation of 1,200 feet above the sea. The surrounding region is completely covered with irregularly heaped gravels and smooth sand plains of glacial origin, but this hill consists of sandstone, which is exposed in upturned tree roots, and which, in an opening made in the northwest corner of section 33, was found to dip westward with a strike of N. 15° E. The relations of this strike and dip to those of the Wilkeson sandstone and to Joe John's prospect indicate the existence of an anticlinal axis pitching northward, with a western limb which extends into section 32. In the southeast quarter of section 32, in mine No. 6 north, the gangway driven on the Wingate vein ends at a faulted syncline. The sequence of strata from the Wingate vein upward includes a series of massive sandstone beds, and in this series is a large, dirty coal bed known as the Miller vein. This section closely compares with that of the Burnett or Hill vein in its relation to the Wilkeson sandstone with the overlying coal opened in Joe John's prospect. The strike of the Wilkeson sandstone in the northeast corner of section 33 is directly toward the basin discovered in mine No. 6. It is highly probable that the coincidence of facts of stratigraphy and structure correctly indicates the identity of the Wingate vein with the Hill-Burnett vein, of the Miller vein with Joe John's prospect, and of the massive sandstones associated with the Miller vein with the Wilkeson sandstones. The further correlation of coal beds of the productive measures is based upon this identification.

Were the sections of the coal measures from the Wingate or Burnett vein No. 1 downward completely exposed at Carbonado and at Wilkeson, a correlation of the distinct veins could probably be made with assurance of accuracy. The section at Carbonado is probably complete in its statement of workable coal veins, but it may be incomplete in the omission of beds of black slate or bone, which, though unimportant for mining, may represent workable coal beds of the Wilkeson section. The Wilkeson section is complete from its lowest coal bed up to the vein worked in No. 3 mine. From the No. 3 vein up to the Burnett No. 1 is a gap, which can be bridged only by inter-

VEIN No. 3.



Slate.
2′ 3″ coal.
4″ sandstone.
2′ 2½″ coal.
2½″ bone.
1′ 10″ coal.
4″ bone.
11″ coal.
⅛″ bone.
½″ bone.
5″ coal.
5″ coal.
Slate.

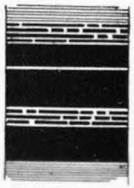
Total thickness, 9′ 0″.

VEIN No. 2.

Slate.
1′ 3½″ coal, with 1″ bone partings.
2″ bone.
1′ 7″ coal.
1″ bone.
1″ bone.
3″ coal.
1′ 1″ coal.
1″ bone.
1″ bone.
7″ coal.
2′ 9½″ coal.
3″ bone.
Slate.

Total thickness, 8′ 4″.

VEIN No. 1.



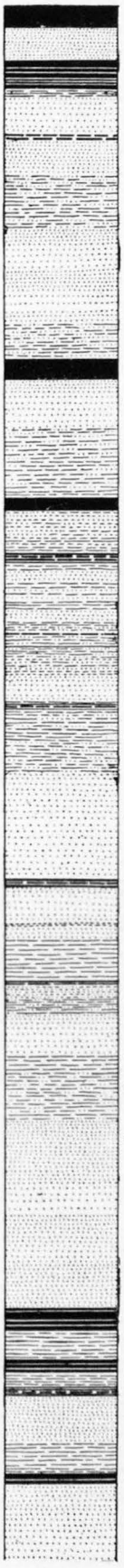
Slate.
10″ bone.
1′ coal.
1″ bone.
1′ 7″ coal.
9″ bone.
1′ 7″ coal.
Slate.

Total thickness, 5′ 10″.

VEIN No. 7, OR KELLY.

Sandstone.
4′ 2″ slate.
3″ coal.
1′ 9″ slate.
11″ coal.
1′ 6″ bone.
13′ 1″ coal.
Slate.

Total thickness, 21′ 8″.



10′ coal, No. 3.
15′ sandstone, fine, thin-bedded, in layers 2 to 3 inches thick.
12′ coal, the Bogus vein.
3′ shale, dark gray, with bony streaks.
17′ sandstone, massive.
1′ 6″ coal, bony.
16′ sandstone, very fine, thin-bedded, with homogeneous layers.
23′ shale, sandy, dark gray, homogeneous, no distinct bedding; fracture conchoidal.
42′ sandstone, thin-bedded, with leaf fragments; micaceous, with occasional massive, homogeneous beds, 1± foot thick.
15′ shale, sandy, dark gray, massively bedded.
9′ coal, No. 2.
21′ sandstone, coarse, massive, thin-bedded at the top.
31′ shale, dark gray, sandy.
6′ coal, No. 1.
13′ sandstone, argillaceous.
5′ shale, dark gray.
5′ coal and bone
1′ shale, with leaves.
27′ sandstone, fine, argillaceous, interbedded with shale in thin layers.
2′ gray, homogeneous shale.
2′ bone in sandstone, fine, argillaceous.
11′ shale, fine, sandy; conchoidal fracture.
7′ sandstone, thin-bedded, shaly, layers 1 to 2 feet thick.
12′ sandstone, massive.
3′ coal, bone, and shale.
27′ shale, fine, dark gray, sandy.
48′ sandstone, massive, soft, and friable.
4′ bony coal.
16′ sandstone, gray, heavy bedded.
1′ clay, soft, gray, sandy.
6′ sandstone, fine, thin-bedded.
18′ shale, soft, gray.
1′ bone and coal.
6′ sandstone, gray, argillaceous.
7′ shale, soft, gray, sandy.
19′ sandstone, massive grayish brown, in beds 2 to 4 feet thick.
7′ shale, fine, gray, homogeneous.
21′ shale, sandy, leaf-bearing.
28′ sandstone, thin-bedded, micaceous, with carbonaceous streaks.
15′ sandstone, massive, gray.
40′ sandstone, thin-bedded, micaceous, with leaf impressions and carbonaceous fragments.
10′ coal, No. 7, or Kelly.
13′ shale, with coal streaks.
6′ soft coal, No. 6.
6′ shale.
4′ 6″ shale, bone, and coal.
21′ sandstone, thin-bedded.
13′ shale, gray, with leaf impressions.
4′ 6″ coal, No. 5.
34′ sandstone, massive gray, in beds 2 to 5 feet thick.
686′ 6″, thickness.

SECTIONS OF PART OF THE CARBONADO FORMATION MEASURED IN THE WESTERN CROSSCUT TUNNEL, WILKESON MINE, WILKESON, PIERCE COUNTY, WASHINGTON.

polating the beds opened in Driver's prospects in their proper relations. These relations are not definitely known. A study of the maps and sections indicates that the outcrop which is called the Gopher vein is on the strike of the Wilkeson No. 3 vein and bears some resemblance to the upper part of it. It is accordingly assumed that the Gopher vein represents the Wilkeson No. 3 vein. Above the Gopher vein is an interval of 500 feet or more which has not been prospected, extending to the Bobby vein, which is correlated with the Burnett No. 4. Above the Bobby vein there is an interval of 230 feet to the Hill vein, which is considered to represent the Burnett vein No. 1 and the Wingate.

Proceeding upon these assumptions, the following comparative columns are made out:

Hypothetical correlation of the Carbonado and Wilkeson sections.

		Feet.		Feet.
Wingate vein		4	Burnett No. 1 or Hill vein	4
Interval		304	Interval	230
Vein No. 2 and No. 5 north		5	Burnett No. 4 or Bobby vein	5
Interval	176			
Vein No. 4 south	7			
Interval	107			
Vein of bony coal	9	525	Interval not prospected	500±
Interval	105			
Coal	1			
Interval	120			
No. 3 south		3½	Gopher vein or Wilkeson No. 3	2½
Interval		12	Interval	15
No. 5 south		5	Bogus vein	12
Interval		20	Interval	20
Coal		2	Coal	2
Interval		244	Interval	96
No. 7 south		7⅛	Wilkeson No. 2	9
		1,131⅚		895½

This correlation depends upon approximate coincidences of thickness, which are by no means complete and which may be misleading. The lowest interval in either column disagrees with that in the other and raises a doubt as to the completeness of the Carbonado section or the accuracy of the correlation below the Burnett No. 4 or Bobby vein.

It is possible that the section from the Wilkeson No. 3 and the Gopher vein, or up to the Bobby vein, is not complete. It may be traversed by an overthrust parallel to or forming part of the great overthrust traced in the Wilkeson mine, and, if so, the beds below the Wilkeson vein No. 3 may easily underlie the entire section exposed at Carbonado. In any case the inference stated in the report on the Wilkeson coal fields, Volume XV of the Tenth Census Reports, that the Carbonado veins underlie the Wilkeson veins, is shown to be incorrect.

The total thickness of measures determined in the Wilkeson field is, for the South Prairie formation, 7,000 feet; for the Wilkeson sandstones, 1,000 feet; and for the Carbonado formation, containing the

productive coal veins, 1,100 feet to 2,000 feet, according to the correlation. Thus the total thickness is between 9,000 and 10,000 feet, a greater amount than has been determined in any other part of the region.

Proceeding to the discussion of the structure of the Wilkeson-Carbonado district, it is desirable to call attention to Pl. LX (in pocket) and to explain the manner of constructing that map. The topographic features of the district are determined by the drift deposits, which extend to such a depth that any attempt to trace the outcrops of the coal measures from point to point upon the topographic surface is futile. It is accordingly necessary, in order correctly to represent the structure of the field, that all the observations be reduced to a plane at some definite level. In Pl. LX such a reduction has been made to a datum plane assumed at 500 feet above sea. The known facts of the positions of the mines and of the observed dips and strikes on the various strata are indicated on that map in their proper geographic relations, and the streams are drawn as a means of reference. From the observed dips and the known elevations of the points of observation the position of each coal bed where intersected by the 500-foot datum plane has been determined. The intersection of any coal vein with this datum plane is the strike of the vein at that level, and is the course which a gangway would follow on the vein. This course is a sinuous one, trending back southward at an anticlinal axis or northward at a synclinal axis, the pitch of the folds being northward. The courses of some of the principal veins, as determined on the 500-foot datum plane, are mapped in red lines. The map therefore constitutes a skeleton horizontal section or outline plan of the coal beds as they would appear if the region were planed down uniformly to a level of 500 feet above sea.

The structure of the Wilkeson-Carbonado district is that of a large anticlinal fold or arch within which the lower strata are bent into a number of minor folds. The principal arch is indicated by the outcrops of the South Prairie formation and Wilkeson sandstones. These two formations, aggregating 8,000 feet in thickness, exhibit almost constant dips and strikes. East of Burnett and Wilkeson they dip to the northeast at angles varying from 50° to 80°. This is the eastern limb of the great arch. West of Burnett and Carbonado the same strata dip northwestward at angles of 30° to 70°, except that northwest of Wilkeson they are involved in a broad and gentle arch of one of the folds of the second magnitude. The westward-dipping strata constitute the western limb of the great anticline. A section across this anticline at Burnett, between the outcrops of the lowest beds of the Wilkeson sandstone, measures 2,800 feet. The arch rises to the southward and widens out correspondingly. At Wilkeson the width between the outcrops of the Wilkeson sandstone is about 3,700 feet. This arch continues as a prominent structural feature for at least 10 miles.

Immediately south of Wilkeson the great arch widens to the westward through the appearance of a number of secondary folds, and attains a width on the line of the section AB through Carbonado and the Wilkeson mines of 13,000 feet. The details of structure in this wide portion of the great arch are of the utmost importance to mining operations.

The facts from which the details of the secondary folds may be inferred are observed in the Wilkeson mines, in the outcrops of the sandstones in section 28 about the lower town of Wilkeson, and in the northern mines of Carbonado.

It is necessary first to determine so far as possible the actual structure of the Wilkeson mine. In driving southward through section 34 on the three veins, Nos. 1, 2, and 3, each of the gangways encountered a fault, at which the vein apparently terminated. The nature of this fault was not determined. From the end of mine No. 3 a short rock tunnel was driven into the hanging wall, and a dirty vein was encountered which was followed about 300 feet. It was also much disturbed, and a rock tunnel was again driven into the hanging wall. At a distance of about 80 feet above the dirty vein this crosscut encountered the vein marked No. 5 and known to underlie the Kelly vein. As the Kelly vein is 564 feet below the No. 3 vein, its appearance here in the strike of No. 3 indicates a throw of the measures to the west.

Various hypotheses have been suggested to account for this throw by a normal fault. The more probable course of such a fault would be in a northwest-southeast direction, determined by the fact that the eastern gangways extend farther southward than the western. The downthrow would be to the north. Such a fault is purely hypothetical. The following facts suggest a different structure: In the southern extension of the mines the gangway which is designated mine No. 7 has been driven around the point of a southward-pitching anticline, and after passing eastward across a flat dip, turns northward and ends at a point where the vein is badly crushed, and presents dips varying from 85° E. to 80° W. A study of the end of the gangway, together with other observations of the structure in the crosscut tunnels lying to the northwest, shows that the crushing of the rocks in this line is such as accompanies an overthrust fault. A line drawn from the end of the gangway on mine No. 7 to the point where the fault was first encountered in mine No. 3 holds that relation to the great Wilkeson anticline that would be sustained by an overthrust on the western limb. The southward-pitching anticline and flat dip afford the minor details of structure favorable to the development of an overthrust. As is shown in the section accompanying the geologic map, Pl. LX, an overthrust of the western limb upon itself readily accounts for the duplication of the veins to the west. The positive demonstration of the existence of such an over-

thrust may yet be obtained in the gangways on mines Nos. 1, 2, and 3 in driving northward from the long western crosscut tunnel. If the hypothesis of the overthrust be correct, these veins will be found to extend in good form nearly if not quite through section 34, parallel to the positions in which they have already been mined. This would practically double the amount of available coal in the western part of that section.

The northwestward continuation of the overthrust is traced in accordance with the following facts: On the northern side of Gale Creek, at the foot of the bluff about 1,000 feet west of the entrance to mine No. 3, is a bold outcrop of sandstone, which upon close examination exhibits evidence of having been greatly crushed. The massive rock is twisted and bent as if by great pressure and friction. It has clearly been involved in a fault. In the northern part of section 28, northeast of the lower crossing of Gale Creek and the county road, the massive beds of the Wilkeson sandstone are dislocated and overthrust, so that they have a false eastern dip of 65°, the true dip of the measures in this locality being westward. Such an overturn is of frequent occurrence in connection with overthrust faulting. These overturned sandstone beds, the bluff of crushed sandstone north of Gale Creek, the fault first encountered in mine No. 3, and the fault met at the end of mine No. 7, all lie approximately in a line whose strike is N. 25° W. This line is platted on Pl. LX as the intersection of an overthrust by the 500-foot datum plane.

At the southern end of the Wilkeson mines the dip is as low as 24°, and the strike is changed from a little east of south to southwest. These facts indicate that the coal beds dip into a synclinal basin whose pitch is northward. There can be little doubt that this basin is the same as that marked by the outcrops of the Wilkeson sandstone, about the lower town of Wilkeson, in section 28. The axis of the basin is indicated on Pl. LX as passing through the eastern part of section 33 to a little to the east of the center of section 28. This basin is named the Western Wilkeson Basin on Pl. LX.

Continuing the discussion of the features of the Wilkeson anticline, reference should be made to the reasons for tracing the courses of the several veins indicated on Pl. LX in section 34. On the western limb the course of vein No. 3, and of other veins associated with it, including the Kelly vein, has been determined by mining. Vein No. 3 being probably identified as the Gopher vein, its trace is extended northward to intersect the anticlinal axis north of that exposure. On the eastern dip the location of the Kelly vein is platted from its known positions in the gangway of the old Kelly mine, and as determined by diamond-drill holes sunk in 1883 by the Northern Transcontinental Survey. The positions of the Wilkeson vein No. 3 and the Burnett vein No. 1, on the eastern dip, are platted from their relations to the Kelly vein.

Turning now to the western portion of the district, there is a complex structure developed in the workings of the mines at Carbonado. For the purposes of this discussion, that portion of the mines south of the normal fault may be omitted. In mine No. 6, north, on the Wingate vein, the gangway driven northward on the western dip encountered an anticlinal axis and was extended around the axis southeastward to a faulted syncline, the central Carbonado basin. This is in the southeast quarter of section 32. A study of this mine and of the section exposed on Carbon River for a quarter of a mile northwest of the incline shows that the vein worked in mine No. 5, 230 feet below the Wingate vein, is the same as the vein worked in mine No. 2. The duplication of the vein in mine No. 2 is due to a fault, which is indicated on Pl. LX, and which lies along the eastern side of a small synclinal wrinkle that points out on the anticlinal axis in both mines No. 5 and No. 6.

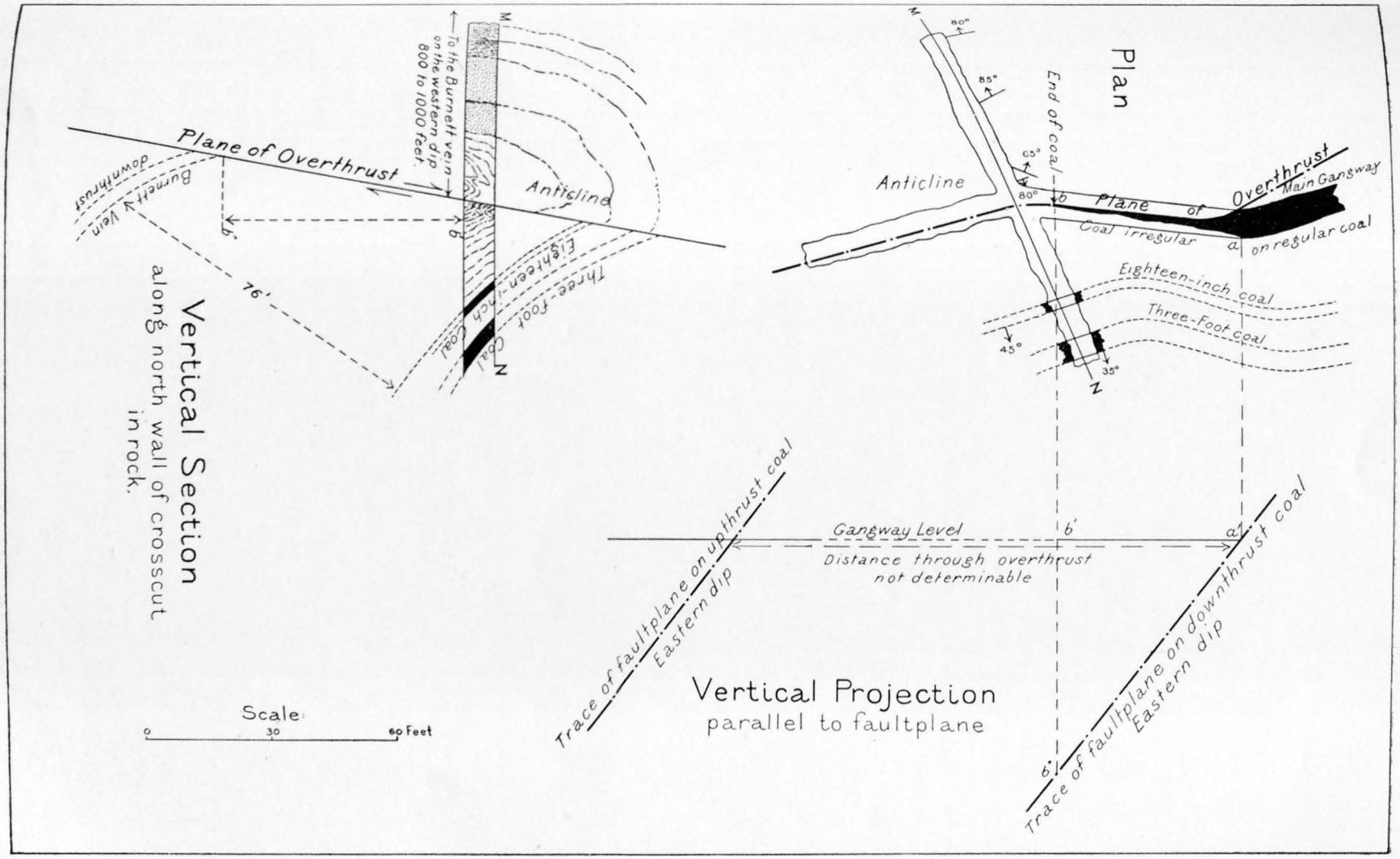
The synclinal axis of the central Carbonado basin in the southeast corner of section 32 may be traced in the windings of the old gangways to the southeast. It was crossed in the northern rock tunnel east of the incline, and eastward of it the same tunnel penetrated to the eastern limb of an anticline, which is also exposed on Carbon River above the dam. We thus have as the most easterly observation at Carbonado an eastern dip, and the dominant structure of this portion of the field is seen to be represented by two arches with the intervening central coal basin. Much of the apparent complexity is due to the fact that the strata are dislocated and overthrust, as well as folded.

Between the eastern dip of the measures at Carbonado and the western dip determined in the southern end of the Wilkeson mines, the structure is unknown. It is possible, however, to infer it with some degree of probability. Referring to the dips in section 28 and in the northwest corner of section 33, observed on the Wilkeson sandstones, it is evident that they represent a northward-pitching anticline which occupies the center of section 33. This anticline lies between the western dip of the Wilkeson mines and the most eastern dip of the Carbonado mines. It appears to limit the western Wilkeson basin on the west and to determine the existence of another basin east of Carbonado, which may be called the Eastern Carbonado Basin, and lies in the western half of section 33. These two basins and the intervening anticline are shown on Pl. LX by the red lines, which extend the strike of the Wilkeson vein No. 3 westward and of the Wingate vein eastward to the probable continuation of Hill's vein. By reference to the accompanying section AB, Pl. LX, it will be seen that the hypothetical folds in section 33 are supposed to be of such magnitude as to form a gradation from the greater Wilkeson anticline down to the smaller folds of the Carbonado mines. This is in accordance with the laws of development of such structures. But although

the facts of structure are sufficient to justify the interpolation of these hypothetical folds, a precise determination of the course of the veins is not possible. It can only be stated with positiveness that the Wingate vein follows a sinuous course approximately near that which is indicated on the map, and that the Wilkeson vein No. 3, together with all the other associated veins, follows a similar course south of the Wingate vein. The possible dislocations by normal faults or overthrusts can not be foreseen.

There are some minor details of structure of the Wilkeson-Carbonado district which are worthy of note. The reasons for assuming the existence of an overthrust on the western limb of the Wilkeson anticline, and the probable position of that overthrust, have already been stated. In the Burnett mine No. 2 the gangway has been driven about 1,500 feet in a fault which, from the descriptions given by the superintendent, Mr. Burnett, is probably a similar overthrust. Its precise character can not be observed on account of the gas in the abandoned mine. In mine No. 4 of the Burnett group, which is opened on the eastern dip, a fault was encountered in the water-level gangway, and a cross section of the faulted measures, obtained in the crosscut tunnels driven north from the main gangway, is given in Pl. LXVI. Near the center of the section, just west of the gangway, an anticline in massive sandstone is apparent, and the western dip is regular as far westward as the section extends, with the exception of a small plication in softer strata near the western end of the crosscut. The zone of faulting traverses a thin-bedded sandstone, which is exceedingly hard. These strata are compressed into short, sharp wrinkles, which are frequently broken, and which give evidence of intense pressure. To the east of the gangway the strata lie in comparatively regular attitudes, dipping 35° eastward. A crosscut tunnel is driven out to a small coal vein which is known to lie 76 feet above the Burnett No. 4. As may be seen in the figure, it is obvious that the eastern dip of the Burnett vein is cut off by the fault plane 55 feet below the level of the gangway. As this same fault intersected the vein in the gangway at no great distance to the north, it is evident that the plane of the fault intersects the plane of the vein in a trace which crosses the dip of the vein diagonally, descending southward. If continuous, this fault will strike the gangway on vein No. 4 in the lower level, in the southern part of section 21.

The extreme crushing on the fault plane indicates that the fault is of the nature of an overthrust, and this suggestion is sustained by its relation to the axis of the anticline. It is probable that the vein will be found to the west, descending on the western dip, but in the absence of any recognized stratum on the western side of the anticline no more accurate estimate as to the distance to which a crosscut must be driven can be made than by extending the strike of mine No. 2. It passes 800 to 1,000 feet west. It is possible that this fault



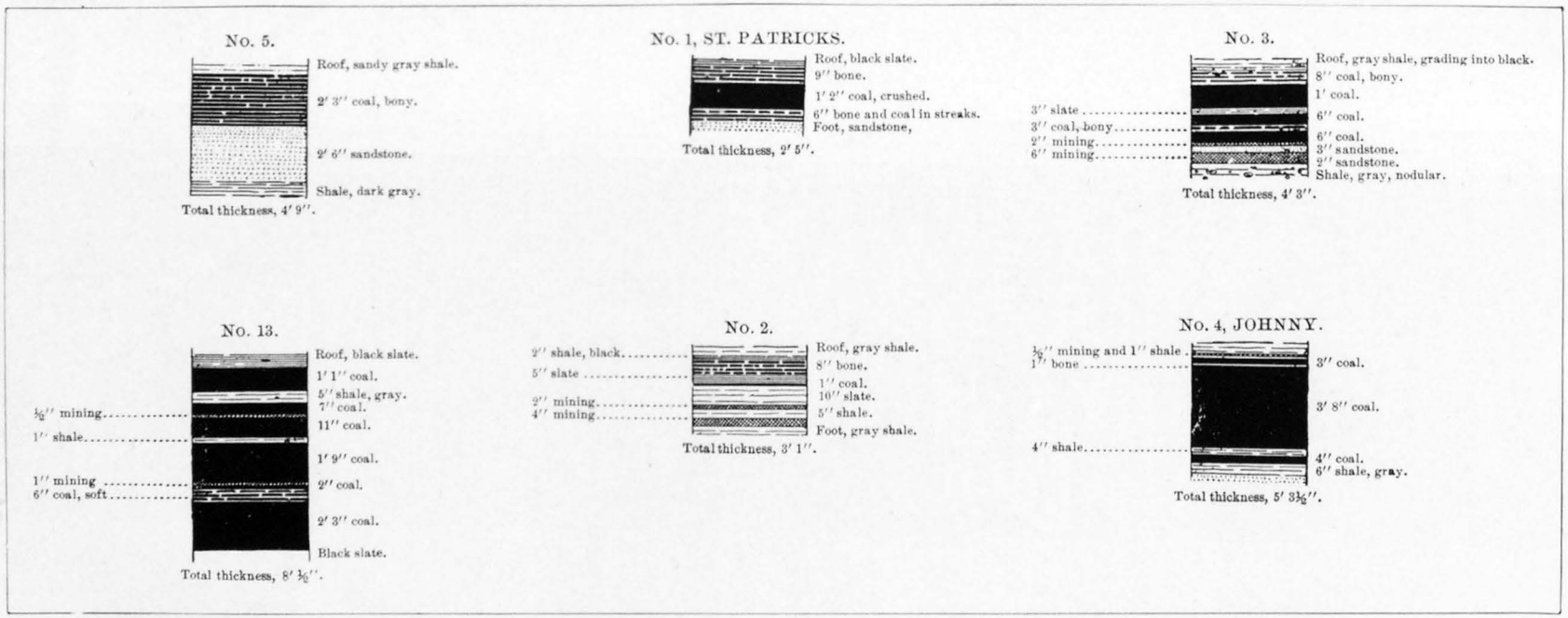
PLAN AND SECTIONS OF AN OVERTHRUST OBSERVED IN THE WATER-LEVEL GANGWAY OF MINE NO. 4, BURNETT, PIERCE COUNTY, WASHINGTON.

is the same as that on account of which the Burnett mine No. 2 was abandoned, in which case the No. 2 vein would be found in regular form.

The possibility of finding the Burnett vein on the eastern dip by driving the water-level gangway southward depends upon the amount of the upthrust. The relations are suggested in Pl. LXVI, in the vertical projection parallel to the fault plane. The position of the trace of the fault plane with the downthrust portion of the coal on the eastern dip is indicated by the line a' b''. If the amount of displacement on the fault plane be constant to the point where the gangway level driven in the fault plane would strike the upthrust coal, the trace of the fault plane with the upthrust vein on the eastern dip would be parallel to a' b''. By considering the form of the anticline exposed in the crosscut tunnel and the probable distance of 1,000 feet to the Burnett vein on the western dip, it may be inferred that the displacement on the fault plane in a vertical line would carry the upthrust edge of the vein at least 1,200 and possibly 1,600 feet above the point a'. The horizontal distance from a' south to the trace of the fault plane on the upthrust coal is then one side of a right-angle triangle whose hypothenuse is the trace of the fault plane on the upthrust and whose vertical side is 1,200 or 1,600 feet. An inspection of the diagram shows that upon this estimate the distance to the coal along the fault plane is a quarter of a mile or more. This estimate is based upon so many approximate considerations that there is a wide margin for error, but it serves to indicate the probable magnitude of the fault.

The southward extension of the coal beds developed at Wilkeson and Carbonado can not be traced continuously on the surface. West of Carbon River the volcanic rocks are known to form the hills along Voigt Creek, and they are probably continuous with those which are found on the head waters of that stream between Carbon River and the Puyallup in R. 6 E. East of Carbon River, from 1 to 3 miles south of Carbonado, a high terrace of alluvial sands covers the coal-bearing formations to an unknown depth. In sec. 10, T. 18 N., R. 6 E., this terrace abuts against the westward slope of a hill in which numerous coal veins were opened in the early exploration of the field. Still farther south, on the slope into Carbon River Canyon, a number of coal veins have been opened between the top of the hill and the terrace of river gravels which skirts its base. The cross sections of these veins are given in Pls. LXVII and LXVIII. Their underground extent has not yet been traced. A short distance to the northeast the summit of the hill is formed of eruptive rock. The strata exposed in the section along Carbon River in the southern part of T. 18 N., R. 6 E., lie at a nearly vertical dip. The river exposes a section, probably without repetition, whose lowest beds are to the east, with the higher and less productive formations coming in toward the west.

In concluding the discussion of the structure of these coal fields, it may be worth while to remark, in general, that more accurate observations of the strike and dip of the coal beds as determined in the process of mining would greatly aid in the solution of the structural problems. It is the prevailing custom to drive through the difficulties met with by the aid of guesswork, and without making record of the easily observable facts. In a short time these facts become inaccessible, as the walls of the tunnel are coated with smoke and covered with lagging or the mine is abandoned. Then the records, which would be invaluable in driving other levels or working adjacent veins, are lost. It is beyond question that inattention to or ignorance of the methods of solving problems in geologic structure has cost the mining companies in the Puget Sound fields not less than $50,000 in unnecessary burrowing during the last twelve years. Investments in these coal lands made without knowledge of the geologic structure or lay of the coal are hazardous, but capital may safely venture on the exploitation of these resources if guided by competent mining engineers.



SECTIONS OF COAL VEINS OPENED IN SEC. 26, T. 18 N., R. 6 E., WILKESON COAL FIELD.

GEOLOGY AND MINERAL RESOURCES OF THE JUDITH MOUNTAINS OF MONTANA.

BY

WALTER HARVEY WEED AND LOUIS VALENTINE PIRSSON.

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GEOLOGY AND MINERAL RESOURCES OF THE JUDITH MOUNTAINS OF MONTANA.

By W. H. WEED and L. V. PIRSSON.

PREFATORY REMARKS.

By W. H. WEED.

The region described in this paper was first visited by me in 1894 to determine whether a detailed study would be warranted. The reconnaissance made at this time revealed the unusual nature of the mountain group, whose laccolithic intrusions and tinguaite rocks aroused a keen interest in the region. During this visit the mines were examined and fossils were collected from the different geologic horizons, those from the coal seams proving new and indicating the presence of Lower Cretaceous strata. Brief notes upon the region were published in 1896.[1] The study and mapping of the mountains were planned for the summer of 1896, but assignment to the study of the Butte district made it necessary that I should spend but a short time in these mountains, and the detailed mapping was intrusted to my friend and colleague, Professor Pirsson, who has spent part of several field seasons with me in Montana work.

An attempt has been made to so state facts and legitimate deductions that they will be readily understood by the general reader and to make the work as useful to the practical miner as possible. As the economic development of the mineral resources of the Judith Mountains is promoted by a knowledge of the occurrence of the ores and coal beds and their relation to the rock structure of the region, a detailed account is given of the stratified rocks and of the folds into which they have been warped by igneous intrusions. The bedded rocks of different geologic ages are easily discriminated from one another, as the different beds and distinct geologic horizons are of widely varying appearance and composition.

[1] Mineral resources of the Judith Mountains, Montana: Eng. and Min. Jour., May 23, 1896, Vol. LXI, pp. 496–498.

CHAPTER I.

By W. H. Weed.

INTRODUCTION.

The Judith Mountains are situated near the center of the State of Montana, as shown by the index map, fig. 32, and extend from 108° 57′ to 109° 25′ west longitude, and from 47° 03′ to 47° 18′ north latitude, these limits comprising the area shown on the accompanying map, Pl. LXIX. They form one of the mountain groups of the Great Plains of the Northwest, the nearest peaks of the Rocky Mountain

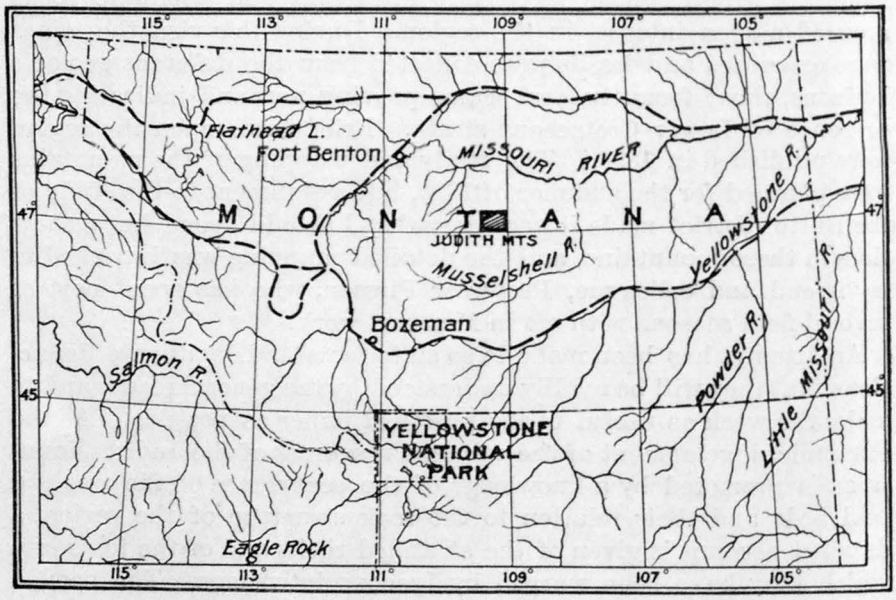


Fig. 32.—Index map to show location of Judith Mountain area.

front being 35 miles to the west. The Missouri River flows 34 miles north of the mountains, and its tributary, the Musselshell, as far south and east. Lewistown, the county-seat of Fergus County, lies at the southwestern base of the mountains, and the town of Maiden is situated in the center of the range. The region is remote from the railroad lines of the State, which are reached by a stage ride of 112 miles by the shortest route. Various stage lines run to Great

Triangulation and Topography by the Northern Transcontinental Survey.

TOPOGRAPHIC MAP OF JUDITH MOUNTAINS AND VICINITY

Scale

2 1 0 4 6 Miles

Contour interval 200 feet.

JULIUS BIEN & CO. LITH. N.Y.

Falls, Fort Benton, and Big Sandy, on the Great Northern Railway; and to Billings and Junction, on the Northern Pacific system.

The Judith Mountains rise like a great island above the plains which stretch eastward into central Dakota, and reach a height of some 2,500 feet above this level platform. They are impressive because of their solitary position and because their wooded flanks and rocky crowns are in strong contrast to the aridity and the flatness of the surrounding country. They do not constitute a range, as the term is generally used, but rather form a group of connected peaks and summits, extending in a general northeast-southwest direction for 18 miles and varying from 3 to 8 miles in width. The mountains are neither high nor rugged, the most elevated peak being but 6,386 feet above the sea, or a little less than 3,000 feet above the plains. They are therefore seen to be much lower than any of the other isolated mountains of the plains, except, perhaps, the Little Rocky Mountains, which lie to the north. South of the Judith Mountains the broad single dome of the Big Snowy Mountain rises to a height of 8,600 feet. To the west the two isolated peaks known as the Moccasin Mountains rise above the level plains, and beyond them is the broad Judith Basin. In the vicinity of the mountains wide terraces descend gradually to the general level of the plains (see Pl. LXXVI), and these higher tracts are generally well grassed and watered and fitted for cultivation, while the lower, more arid tracts are fitted only for sheep herders and cattlemen, who hold undisputed possession.

The scenery within the mountain tract is pleasing, being often picturesque, but never grand. Viewed from a distance, the range appears impressive, but within its boundaries the details of erosion are more interesting and more striking than the general forms of the mountain peaks. The surrounding plains are cut by the ramified trenches, tributary to the Missouri, and at no great distance from the mountains are dissected into the intricate Bad Lands, which, however, do not occur near the mountains. Gorges with abrupt limestone walls and sharply V-shaped valleys extending back into the mountain slopes are quite common features, but bold and sharp craggy peaks are not present. The country lies south of the glacial boundary, and no signs of local glaciation were observed. Projecting so far above the surface of the plains, the mountains act as local condensers of moisture and receive a comparatively generous supply of rain and snow. Springs are common, and the mountain area is clothed with luxuriant herbage and dense forests of pine. The climate shows the usual extremes of heat and cold common to this part of the State, but the summer is more uniform than in the Rocky Mountain tracts, so that a wider range of agricultural industries is possible within the mountain area. Few valleys are wide enough for settlement, the large valley of Warm Spring Creek being the only one suited for agriculture.

Of the early history of the region but little can be written. The explorers of the Northwest, Lewis and Clarke, followed the Missouri River, saw the Judith Mountains to the south, and named the river which has given its name to the mountains.[1]

The early history of the Judith region has been furnished me by Hon. Peter Koch, of Bozeman, Montana, who has written as follows:

The region was traversed frequently by trappers and hunters all through the early part of this century, but the first visit by white men of which I find any record is by Father De Smet, September 13, 1846.[2] He gives an interesting account of a meeting within the basin of a peace congress of various Indian tribes.

The next mention is in a report of the explorations of Lieut. John Mullan through the basin from west to east on July 22–25, 1860.[3] Before that, however, in September, 1853, it was visited by Lieutenant Mullan, who was sent out by Governor Stevens in the exploration for a Pacific railroad route to find a camp of the Flatheads, and who passed through the Judith Basin going out through the gap.[4]

In 1869 Captain Clift, Thirtieth Infantry, surveyed a wagon road from Fort Ellis to the mouth of the Musselshell River, going through the basin, and a freight train went over it at this time. All this time there were no settlements of any kind in the basin.

In the winter of 1872–73 Maj. F. D. Pease negotiated a treaty with the Crows, according to which they were to give up their reservation on the Yellowstone and accept in lieu of it the Judith Basin. This treaty was never ratified by the Senate and therefore came to nothing; but anticipating that this removal would take place, Messrs. Story and Hoffman, who were the traders to the Crows, engaged me to go down into the basin and establish a trading post. Captain Gross, an employee of the Crow Agency, went also to select a site for the new agency.

A site was selected just below the mouth of Big Casino Creek, on the south bank of Big Spring Creek, and when the ox train with the goods and supplies had arrived I built there, during November and December, 1873, the first permanent houses within the Judith Basin. While waiting in idleness for the arrival of the train, the boys put in most of their time with an old deck of cards, playing casino, and we accordingly named the creek we were camped on "Big Casino" and a little spring creek just below "Little Casino," and I was much amused years after on seeing Colonel Ludlow's map that these names had been perpetuated.

The basin was then the finest game country I ever saw, swarming with buffalo, elk, and deer. The white-tail deer were especially plentiful in the pine coulées which ran down through the foothills from the mountains, and their tameness showed that they had been very little hunted. Small bands of Crows came in to trade all through the winter, and we had considerable trouble from war parties of Sioux who came in to steal horses. One white man was killed by them.

I left there in March, 1874, when it became evident that the removal of the Crows would not take place, and T. I. Dawes took charge of the post, which I had named Fort Sherman.

That year Carroll was established on the Missouri River, and a wagon road was opened from that point to Helena, running through the basin. Meanwhile Major Reed, an old Indian trader, had purchased the trading store from Story and Hoff-

[1] See also map of Yellowstone and Missouri rivers, showing explorations of Captain Reynolds and Lieutenant Maynadier in 1859 and 1860, Washington, 1867.

[2] Oregon Missions and Travels over the Rocky Mountains in 1845–46, by Father P. J. De Smet, S. J., New York, 1847, p. 319.

[3] Report of Explorations of the Yellowstone River, by Bvt. Brig. Gen. W. F. Reynolds, Washington, 1868.

[4] Pacific Railroad Reports, Vol. XII, p. 123.

man and moved it down Big Spring Creek about a mile and a half, to the crossing of the Carroll road, where it became known as Reed's Fort, and a hard place it was.

A military post, Camp Lewis, was established in 1874, built, I believe, almost on the identical spot where I had built the trading post in 1873. Near this military post gradually sprang up a town, which is now Lewistown, the county seat of Fergus County.

In 1875 Colonel Ludlow made a military reconnaissance from Carroll through the Judith Basin to the Yellowstone Park, and in his report is found the oldest map of the basin.

At the time of this last expedition, 1875, there were no towns in the region. The site of Lewistown was then occupied by an encampment of two companies of infantry known as Camp Lewis, the camp being established as the protection to the stage station on the road from Carroll to Helena, this being the route by which supplies were then brought into the State.

Lewistown, the county seat, is the largest settlement in this part of the State. It lies outside the mountain tract, but within the limits of the map. It is seen in Pl. LXXVI in the foreground, the mountains rising in the distance.

Maiden is the larger of the two settlements of the mountain area. It is situated in the valley bottom of the headwaters of Warm Spring Creek, environed by rapidly rising slopes showing no crags or rocky steeps, but generally smooth, mantled with a heavy growth of young pine trees where northerly exposures prevail, or grassy, with scattered groups of trees, on southerly slopes. This is shown in the two views, Pls. LXXVII and LXXVIII.

Mr. George H. Eldridge visited the region in 1882, in his exploratory surveys for coal for the Northern Pacific Railroad. A section made by him of the Mesozoic rocks between the Carboniferous and coal horizon 3 miles southeast of Maiden, and also a section on the flanks of the North Moccasin Mountain, have been published.[1]

The development of the region will be greatly hastened by railroad communication, but the chances of this seem at present somewhat remote. In the summer of 1896 mining was at its lowest ebb, but the future appears promising, and the known productiveness of the mines in the past will probably be largely exceeded when some of the more promising prospects have been developed.

A resource that is as yet comparatively undeveloped is the coal that surrounds the mountains. With an increase of population it is sure to command good prices as fuel for domestic and mill use. With the advent of a railroad to the region it will become a source of great wealth. Fire clays are found associated with the coal seams, and sand suitable for glass making is found in several localities, but these last two will never become great industries in the region.

[1] Tenth Census, Vol. XV, Mining Industries, p. 741.

CHAPTER II.

By Louis V. Pirsson.

TOPOGRAPHY AND HYDROGRAPHY.

THE MOUNTAINS.

Seen from a distance across the plains which surround them on nearly all sides, the Judith Mountains show a sharply serrated crest line, and have the appearance of a mountain range of the anticlinal type dissected by denudation. A series of quite sharp and distinct peaks rise with considerable uniformity to an average height of about 2,000 feet above the level plains country. The saddles between do not appear very deeply cut, but are sufficiently so to accentuate strongly the higher points. The mountain mass seems to rise sharply from the level country, like an island from the sea, the dark pine-covered slopes standing in strong relief against the wide and treeless plains of brown grass-covered country or the gray monotony of wide stretches of sagebrush flats. The mass of the mountains as thus defined from the plains forms an irregular elongated oval in its ground plan, the longer axis, with a length of about 20 miles, extending in a northeast-southwest direction, the shorter axis having a length of about 8 miles, which measures the greatest breadth of the mountains in a northwest-southeast direction.

Although the mountain group stands quite isolated, yet on the southwestern side there is a high and distinct ridge which forms a prominent watershed and extends directly southward until it merges into the general mass of the Big Snowy Mountain. The mountains form a very compact area, the only exception being Black Butte, a separate, detached elevation about 2 miles away from the eastern end of the range. This butte was known in former times by the name of Buffalo Heart Mountain, a name now obsolete.

About 6 miles west of the Judith Mountains rises the southernmost of the two Moccasin Mountains, separated by a broad, smooth, open valley. This is the nearest mountain neighbor; it is in many respects a miniature of the Judith group and might be considered as a part of it.

The mountains are everywhere sharply bounded by easily eroded

rocks, and owe their dominant and well-defined topography to heavy and resistant rocks. In fact, the dependence of topography upon geologic structure is extremely close, and it is almost impossible to describe one without mentioning the other. Topographic details will therefore be freely given with the description of the geology.

A study of the topographic map (Pl. LXIX) shows that the western end of the range is formed of a curving, horseshoe-shaped ridge, or, in fact, a mountain with a large funnel-shaped basin which discharges to the southward. This is connected on its upper bend, by an eastwardly running ridge, with another circular and somewhat larger horseshoe ridge, whose amphitheater drains northward. At the point where the connecting ridge and the last-mentioned horseshoe come together another ridge starts southward, which eventually passes out on the very broad, flat-topped divide known as Flat Mountain. Eastward and northward of the eastern horseshoe ridge drained by Alpine Creek there is a low divide, and beyond this the country is broken, with less regularity of plan, into a group of peaks with low-cut connecting divides and deep valleys between.

The highest point in the mountains is found in Judith Peak, which rises to 6,386 feet above sea level (by triangulation), or about 2,500 above the general average of the open plains country. From this peak a main divide extends eastward, throwing out several prominent spur branches and having a winding course with an irregularly rising and falling crest line, until it ends in a high point (Lewis Peak) overlooking Ross Pass. This latter, with an elevation of about 5,000 feet, is the lowest and broadest divide or pass through the mountains, and eastward of it they again rise sharply into a single grouped mountain mass, on the north side of which is Cone Butte. Beyond this rises Black Butte, previously mentioned, the last elevation fronting on the great plains country, which sweeps in unbroken continuity eastward.

The open Cretaceous plains country that surrounds the mountains has a more or less rolling, gently contoured surface. Toward the streams it is cut by wash gulches, and presents the usual types of topography caused by the erosion of practically level, easily eroded strata. Its character is seen in several of the accompanying illustrations, and especially in Pl. LXXVI; it is that so commonly found in our western plains country and so characteristic of large portions of that region.

Toward the mountains this open country gently rises until the mountain uplift is reached; at this point there is generally an outer fringe of small, low, sparsely wooded foothills, and beyond these the slopes of the mountains themselves rise abruptly and with a very steep angle of slope directly to the upper crest line. Although steep, they are rarely precipitous, and the divides also, though generally narrow, are almost never precipitous, but may be traveled on foot or with the horse in all directions except where heavy growths of young pines prevent.

VALLEYS AND STREAMS.

From the geographic position of the Judith Mountains it is clear that all of the waters drained from its slopes fall into the Missouri River, but of the various streams Armell Creek is the only one that enters it directly, the others passing first into the Musselshell River or the Judith River. The drainage systems are simple, and extend radially outward from the main streams.

CLIMATE AND RAINFALL.

The climate is, on the whole, dry and of a somewhat semiarid nature. It shows great extremes, ranging from very hot in summer to extreme cold in winter, the total range being as much as 160° F. It is liable also to sudden changes. In the mountain tract proper, however, these extremes are considerably mitigated, and owing to the isolated position of the mountains they have a much greater rainfall than the surrounding plains country, a heavier snowfall in winter, and frequent thunder showers during the summer.

CHARACTER OF STREAMS.

In spite of the fact that there is a large amount of precipitation in the form of snow during the winter and considerable in that of rain during the summer, the streams, for the size of their catchment basins, carry surprisingly little water, or even none. The mountains, it is true, are below the level of perpetual snow and there are no snow banks lasting through the summer to act as perennial stream feeders, but a much more potent reason for the scanty supply of water is to be found in the geologic structure. As the water sinks, it reappears as springs only in the areas of shale; in those of limestone it does not often soon reappear, and streams entering the limestone areas are liable to sink from sight. The water thus passing down beneath the beds of limestone finally emerges in the channels of the most considerable streams as large and powerful springs. One of these is shown in Pl. LXXIV. The result is that within the mountain tract the streams in summer have running water in their beds only in the areas of porphyry or of Cretaceous shales; in the limestones they are dry, or on entering limestone belts rapidly become so.

The western side of the mountains is drained by Boyd and Burnett creeks, branches of Big Spring Creek, a considerable fork of the Judith River.

Boyd Creek is a running stream in its entire course from the divide east of Kelly Hill. On the south it receives accessions from a number of springs which break out in the Cretaceous hills and which ooze along downward in muddy rivulets banked with fresh grass on either side, the course of the drains being thus marked by lines of

winding, vivid green on a background of brown or russet-colored bench lands or slopes of country covered with dried grass. Such drains are favorite resorts of the herds of sheep or cattle, which trample them to a muddy ooze. This, indeed, is the character of these Cretaceous hillside runnels throughout the mountain area.

On the north side the long and winding valleys of Ruby and Pyramid gulches are dry, except in a little area of Cretaceous shaly beds toward the head of Ruby Gulch, where small springs burst forth, only to disappear in the course of a few rods as they pass into the limestones. The waters thus drained underground in the various forks of Boyd Creek on its north side come up as powerful springs in the bed of the main creek lower down.

Burnett Creek derives its waters from the amphitheater at the west end of the mountains. The deep and narrow gulches in porphyry and slate are dry in summer, and it is only just before the limestone canyon which forms the gateway from the large interior funnel-shaped basin is reached that the water breaks out in springs, giving sudden rise to an active brook which sends its waters across the plain to join Big Spring Creek.

Warm Spring Creek heads near the town of Maiden in springs which issue from the divides and slopes of Cretaceous strata filled with porphyry sheets and intrusions, east and north of the town. It passes down a deep V-shaped valley, whose character is admirably seen in Pl. LXXVII, and receives a considerable amount of water from Alpine Creek, which drains an interior funnel-shaped basin, cut by deep and narrow gulches, precisely like that at the head of Burnett Creek. The North Fork, which drains a rather flat-floored valley with sudden, precipitous slopes of porphyry and shale, flows a volume of water greater than that of the main stream, much of whose current is really underground. New Years Gulch presents a gathering of narrow canyon-like valleys which are cut in limestone, and consequently dry. There are a few springs as the Cretaceous is reached, but the main outflow is a mere seepage, and little or nothing comes into the Warm Spring in the summer season. In the main stream the volume of water rapidly diminishes from that of a fair-sized brook until, at the point where it passes out of the mountains and on to the west side of the anticline, shown on the geologic map (Pl. LXXV), through which it cuts, it runs in the summer entirely dry, sending its water over the plain only in season of flood. The large amount of water passing underground is shown about a mile west of the last point, on the edge of the map, where a large and powerful and rapidly running creek, a couple of rods or so across and several feet in depth, breaks out in a huge spring in the valley bottom. A view of this spring is given in Pl. LXXIV. The spring, from the very constant and somewhat elevated temperature of its waters, is known as Warm Spring and gives its name to the creek. Bull Creek, which is one of the

Warm Spring branches, is one of those oozy seepages in the Cretaceous hill country described above.

Armell Creek drains the north slopes of the mountains, and its various branches are shown on the map. Most of them are small, clear, running streams. The west fork, which drains the amphitheater north of Judith Peak, passes an area of upturned and lifted limestone through which the creek has cut a short canyon, and although some of the water undoubtedly sinks, the main body passes over to the Cretaceous shales beyond. The waters west of this fork and between it and Warm Spring Creek form a large branch, which joins Armell Creek some distance below the junction of its forks and is known as Deer Creek.

Box Elder Creek is a long stream, which winds through the open country to the eastward to join the Musselshell River. It receives its waters chiefly from the mountain mass south of Cone Butte, which, as may be seen upon the map, is dissected radially by a number of valleys which are deep, narrow, V-shaped, and cut in porphyry or shale. In them the streams, which, though small, are bright and running, head back in springs. The headwaters inclose this mountain mass on all sides, and hence take the drainage of Ross Pass on both slopes.

Streams on the south side of the mountains.—The various drainage areas on the south side of the mountains form the headwaters of Ford and McDonald creeks, both of which, like Box Elder, are branches of the Musselshell River. All of these headwaters are small brooks, running throughout the year when in shale or porphyry, as noted above, but disappearing in the limestone areas. This is the character of Collar Creek, which rises in the steep gulches south of Judith Peak and Red Mountain, and also of Maiden Creek, which rises in the beautiful mountain parks between Crystal and Maiden peaks, and, entering the limestone, cuts in the mountains the most considerable canyon, at the mouth of which the water sinks. Along this portion of the mountain area the streams which send their waters to the plain are apt to sink into the heavy accumulations of wash gravel which lie in their courses, and thus in general they are seen running in their channels chiefly in times of flood. The steep gulches cut back in the limestones in which Virgin, Giltedge, and Whisky creeks take their rise are dry and waterless, and only when the lower country is reached do the small seepages begin. In some of the limestone areas, indeed, the drainage appears so completely underground that there is not even an open flood channel, a dry, uninterrupted meadow extending from slope to slope. This is the case in portions of the valleys of Ruby and Pyramid gulches, mentioned above.

Valleys.—Owing to the small size of the mountains there is no large valley in them, that of Warm Spring Creek being by far the most considerable. They are generally short, deeply cut, and with rapid ascents at the heads to the divides.

FORESTS.

Owing to their position in an open, treeless country, whose stream bottoms have been mostly occupied by ranches, and surrounded as they are by a not inconsiderable, permanent population, the Judith Mountains assume each year a more important position with regard to their forest growth. They must supply to the country round about lumber, fencing, and in no small degree fuel, and the margin of profit of many mining ventures will depend largely on the nearness of an available timber supply.

There are no large and heavy forests in these mountains, but a very considerable growth of timber is everywhere to be found. The débris slopes of porphyry are almost invariably covered with a thick, matted growth of young pines (*Pinus contorta*), called "bull pine" in popular parlance. When they have attained some growth these pines form dense and tangled thickets, almost impenetrable without the use of the ax, either on foot or on horseback. Such dense thickets are especially apt to spring up after the heavier original forests have been leveled by fire or storm. On the porphyry areas they are so general that they serve as a useful means of geologic reconnaissance. The northern and western interior slopes of the basins of Burnett and Alpine creeks are heavily clothed with them.

The large timber of the mountains has been mostly cut off for building and mining purposes. Such as now remains is found in scattered groves in the foothills, especially those composed of Jurassic strata. Generally throughout the mountains, in the interior of the gulches, the northern slopes of the hills, and the outcrops of sandstone there is more or less of a forest growth of conifers. The most abundant species is *Pinus contorta*, the "lodge pole" or "bull" pine, which seldom attains a sufficient diameter to be useful for lumber, but serves well for fencing, fuel, or lagging. The Engelmann spruce and Douglas fir (*Pseudotsuga douglasii*) form the largest timber trees, but have been mostly removed from the vicinity of the mines and settlements, and timber exceeding 18 inches in diameter is found in but very few places. In the lower stream bottoms is found the cottonwood, with thickets of black alder, willows, and bushes of various kinds. In Collar Creek the white birch was noted.

While, therefore, there are no large forested areas left in this region, there is a very considerable amount of valuable timber still standing in various localities. Its value is fully recognized by the resident population, but as there is no private title to the greater part of it it is often improvidently and wastefully cut, sometimes for speculation, by those who have no permanent interest in its care or preservation.

ROADS.

Well-traveled routes run out from Lewistown in various directions, and toward the mountains in two ways. The southern route is up Boyd Creek, over a divide, and to the town of Giltedge. From here one branch of it leads up Maiden Canyon to the town of Maiden, while another goes to Fort Maginnis and on through Ross Pass down Box Elder Creek. Prominent roads run down the main streams, whose heads are shown on the map. On the north side the road from Lewistown, passing through the open country on the route to Fort Benton, turns and goes up Warm Spring Creek to Maiden. A branch passes through the foothills toward Armell Creek and reaches Box Elder Creek. In the mountain area itself wagon roads are cut in various directions. They ascend every gulch, pass over many of the divides, and connect many of the valleys. Some are good, others are mere trails suitable for horseback riding. Thus all parts of the mountains are readily accessible and may be traveled with ease.

CHAPTER III.

By W. H. Weed.

GENERAL GEOLOGY.

STATEMENT OF PROBLEM.

The Judith Mountains form an isolated, independent mountain group, separated by the lower plains country from the nearest mountain masses and from the distant front of the Rocky Mountains. It is as independent and complete in its geologic structure as in its geographic relations. The group is formed by a number of independent, coalescing, dome-shaped uplifts, involving the sedimentary series from Cambrian to Cretaceous, with laccolithic and other intrusions of igneous rocks.

Geographically and geologically the study of the region constitutes a problem complete in itself. The mountains are of comparatively recent geologic age, and there is no evidence to show that the area was an island in the Paleozoic or Mesozoic seas; but the facts indicate that the site was but a part of the plains area, at least until after the deposition of the earlier Cretaceous sediments.

The geologic history of the region must be determined from a study of the sedimentary rocks and their fossils, together with the structural forms in which the rocks are now found. The oldest rocks exposed are of Middle Cambrian age. The earlier rocks, of Archean, Algonkian, and Lower Cambrian age, if present, are yet deeply buried. The Paleozoic sediments are all of marine origin, and a comparison of the beds with those observed elsewhere in Montana shows that the strata form a part of the Rocky Mountain area of sedimentation. The formations are, however, much thinner, and agree with those observed in the Little Rocky Mountains, farther north, in showing a thinning out of the Paleozoic terranes east of the Rocky Mountain front.

The sedimentary rocks are apparently conformable from the Cambrian to the Cretaceous age. No angular unconformity of dip or irregularity of strike or evidence of unconformity by erosion has been observed. Unconformity is so uncommon in the stratified rocks of the northern Rocky Mountain region[1] that it seems well to consider,

[1] Geologic Atlas U. S., folio 1, Livingston, Montana; folio 24, Three Forks, Montana; folio 30, Yellowstone National Park, Wyoming.

in the light of the evidence of elevation and erosion afforded by the rocks themselves, why it is not observed in these easterly areas of the Rocky Mountain province.

Unconformity.—To geologists familiar with the upturned and folded beds of the Atlantic border, where angular unconformity and unconformity by erosion are phenomena frequently observed, it often appears that the evidence presented in the West is not conclusive proof of actual unconformity. In fact, however, it is rather remarkable that such marked angular unconformity has been recognized, for it is evident, upon consideration, that it is only along the actual shore line, where transgressing sedimentation has covered the eroded edges of earlier beds, that such unconformity will be recognized. This will be readily appreciated by a glance at fig. 33. The earlier strata are steeply upturned along the mountain flanks, as is actually the case at the east foot of the Rocky Mountains. This folding dies out gradually east of the mountains, until over the area of the plains the beds are level that are so steeply upturned in the mountains. Hence the new sediments rest upon the earlier beds in perfect conformity a

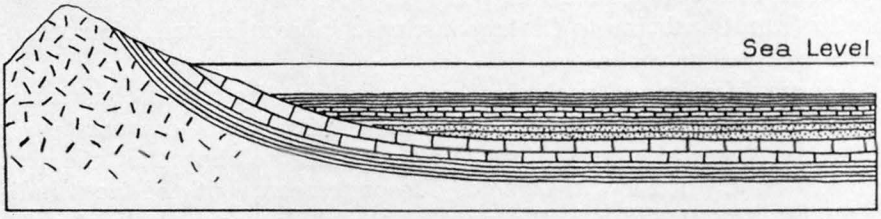


FIG. 33.—Diagram to show apparent conformity of stratified rocks.

few miles east of the mountains. For this reason we should not expect to find recognizable unconformity in the strata of the Judith region, though the beds might represent two periods separated by an interval of nondeposition and uplift far to the west.

PALEOZOIC HISTORY.

The Paleozoic exposures of the Judith Mountains afford the only available data concerning the thickness and character of the eastward extension of the Paleozoic rocks of the Rocky Mountains beneath the plains. A consideration of the sections measured in this region shows a marked decrease in thickness from that prevailing in the nearest range of the Rocky Mountains on the west or those south of the Yellowstone River. This is most noticeable in the Cambrian section, where the rocks are all of shallow-water or littoral origin. The known absence of Paleozoic rocks beneath the Cretaceous strata of Dakota, as shown by artesian-well borings, would suggest the possibility of an early land mass in that region which supplied the sediments deposited in the Cambrian and late seas.

CAMBRIAN TIME.

The Cambrian rocks are shales, cherty limestones, and limestone conglomerates, aggregating about 500 feet. As the base is not known, this does not fix the total thickness of the terrane, but the horizons are so well defined and the sequence is so definite that comparison with the Cambrian sections of other parts of the State is readily made. The rocks consist of detrital material—clay, quartz sand, and silt—worn from the land and distributed by ocean currents and waves. The material composing these Middle Cambrian rocks was not directly derived from the erosion of Archean land masses, appearing to come rather from the erosion of earlier sediments.

SILURO-DEVONIAN TIME.

The limestone conglomerates are significant, consisting of flat beach pebbles which show the erosion of a bold and abrupt coast in which earlier limestone sediments were exposed to erosion, so that the region must have undergone local uplift before this time.

The micaceous character of the shales shows that erosion was rapid and that the rock decay had not taken place on the land. The Cambrian rocks show deposition along the shores of shallow off-shore reaches, succeeded by conditions favoring the accumulation of limestones.

Throughout Silurian and Devonian times the site of the Judith Mountains continued beneath the sea. During the Silurian, oscillations of level, or a rise of the bottom due to sedimentation, caused the deposition of beds of arenaceous limestone. The rocks are colored dark by organic matter. Following this the conditions were favorable for the formation of limestones, and these rocks alone were formed until the close of Lower Carboniferous time. These limestones carry fossil remains of corals, crinoids, and other marine animals characteristic of relatively shallow water.

CARBONIFEROUS MOVEMENT.

At the close of Lower Carboniferous time an elevation of this region, as well as of the eastern part of the Rocky Mountain region, occurred. No evidences of dynamic disturbance have been noted, but the submerged region was raised above sea level and exposed to erosion. The correlated evidence from other parts of the State seems to show that the movement was differential, resulting in varying elevation throughout the raised tract. This movement is supposed to have occurred at the close of the Lower Carboniferous or the beginning of the Upper Carboniferous period, as there appears to be an absence of beds of the latter age in the Rocky Mountain region, and if beds of this age were deposited in the Judith Mountains they were certainly removed by erosion before the region was again submerged beneath the sea.

Observations made in the Little Belt range seem to prove that the close of the Lower Carboniferous epoch was marked by an elevation, and that the areas studied were lowlands during the time represented by the Upper Carboniferous. The Quadrant formation, which is the highest of the Carboniferous horizons of the Yellowstone Park and Livingston region, consists of alternating beds of sandstone or quartzite and of limestone. In the vicinity of Tiger Butte, north of the Little Belt range, the uppermost Carboniferous beds are silty shale and sandstones, containing gypsum beds, all indicating shallow waters, near-by land, and evaporating waters in tidal reaches. The thickness of the section, otherwise comparable, varies, and higher beds are found at some localities than at others, indicating erosion and partial removal of the higher beds before the next succeeding strata were laid down.

No Permian or Trias sediments occur, and the region was probably a land area during these periods. The Red Beds, so prominent in Wyoming and Colorado, appear in the Yellowstone Park section, but thin out and have not been recognized farther north. It is necessary to emphasize this fact because numerous exposures of red clays and associated sandstones of other horizons are seen about the Judith Mountains.

POST-CARBONIFEROUS MOVEMENT.

The movement by which this tract was again submerged was very uniform, as no discrepancy of dip and strike has been recognized between Carboniferous and Jurassic beds. The Ellis[1] beds were deposited during this depression. The earlier beds are limestones, succeeded by calcareous shales, with intercalated beds of arenaceous material, succeeded by a sandstone, varying to a limestone, that is a shore deposit. The fauna is well marked, essentially marine, and resembles, in species and assemblage, the fauna characteristic of the Jurassic in this province. The beds show a shallow and gradually rising sea, the movement being the beginning of a period of elevation which may be called the pre-Cretaceous movement.

PRE-CRETACEOUS MOVEMENT.

The pre-Cretaceous movement resulted in the formation of areas of low land, with broad marshes and bodies of fresh water. The sediments designated Kootanie and correlated with the formation of that name in the Canadian region are of fresh-water origin. Sandstones and red clay-shales derived from the washing away of residual clays show low land and prolonged rock decay. The beds are not persistent in character, varying from shale to sand rock horizontally as well as vertically. A coal seam formed in this period was accumulated in connecting marshy basins, and the ferns and cycad leaves

[1] Formation name of Jurassic beds in Montana.

show low land and a warm climate. A succeeding limestone carrying fresh-water shells was formed in bodies of fresh water that covered coal marshes and sandy flats alike. During this period dynamic disturbances of great moment occurred in the northern Rocky Mountains, where volcanic accumulations several thousand feet thick are found. No record of such disturbance is observed in the Judith section.

EARLY CRETACEOUS MOVEMENT.

A further movement must have occurred at the close of the Kootanie period, resulting in the elevation of the land and the cessation of deposition. That the period was a prolonged one is evidenced by the lack of sedimentation during the time that the Comanche series of Texas was being formed—a series whose representative has not yet been discovered in the Rocky Mountain region of Canada or Montana.

MIDDLE CRETACEOUS MOVEMENT.

Whatever may have been the conditions prevailing during the latter part of Lower Cretaceous time in the area of the Judith Mountains, this period was followed by a depression which marked the beginning of Upper Cretaceous time. The earlier sediments, the Dakota sandstones, record a gradually spreading beach and an ocean advancing over an area long exposed to subaerial decay and disintegration, for the clays and silty sandstones show low land and deep soil. No unconformity is recognized between these beds and those of the preceding age, but rather an essential conformity of dip and strike which, together with the similarity of the beds, make discrimination uncertain and arbitrary. Indeed, the lack of fossils from this region makes recognition of the age of the rocks somewhat questionable. The sandstones are, however, the earliest beds of the cycle of deposition which includes the succeeding Benton shales and Niobrara limestones.

COLORADO TIME.

The Benton shales, which form the earlier deposits of this period, are of marine formation and are characterized by an extensive fossil fauna at the type locality, which gives the formation its name, some 75 miles from the mountains. The presence of fish scales and other marine fossils in the Judith Mountains shows that marine conditions prevailed over this area. The beds are mainly argillaceous shales, dark-gray or black, and often bituminous. They carry calcareous and ferruginous concretions that are fossiliferous and are sometimes characterized by pyrite or an efflorescence of gypsum, and they are the source of bitter gypsiferous springs.

The Niobrara and succeeding Cretaceous sediments occur about the Judith Mountains, but not within the area mapped and discussed.

They present a record of varying sedimentation, ending with fresh-water beds of Laramie age. The evidence seems to favor the view that these beds, except the Laramie, formerly covered the site of the Judith Mountains.

POST-CRETACEOUS MOVEMENTS AND MOUNTAIN-BUILDING.

The beds about the mountains are essentially horizontal. Although, as just stated, they have been at different periods lifted above sea level and exposed to erosion, the series is essentially conformable in dip and strike from Cambrian to Lower Cretaceous, as no evidence of flexure previous to the time of the formation of the Judith Mountains has been recognized. At some later period, which was post-Laramie and pre-Miocene, the previously horizontal sedimentary beds were uplifted in a number of great blister-like anticlinal domes, the rocks being crumpled and bent, in places broken by faults, and split apart by intrusive bodies of molten rock, which rose up beneath the arches and spread out as sheets, or very rarely filled fissures as dikes in the disturbed beds. There is no record whatever of any volcanic outburst. If such extrusive rocks ever existed they have been completely removed by denudation. These igneous intrusions caused the overlying strata to arch above them, but over much of the mountain area the softer shales and sandstones have been removed, and to-day the more resistant Paleozoic rocks are exposed over much of the area. That the height of the mountains was formerly much greater can not be doubted. In the general degradation of the mountain tract this area, because of its greater altitude, has been worn down rapidly as long as the rocks were soft and readily removed; but when the harder rocks were reached the rate of degradation became less than that of the surrounding plains, and to-day the softer beds are found about the mountain flanks, occurring in the higher areas only where they have been involved in folds.

There is no record showing the history of the region during Tertiary time. Judging by analogy, it is supposed that the intrusions and uplift occurred in Eocene time. In general the topography of the mountains of Montana is relatively old. The mountain systems were blocked out and eroded into almost their present shape during Eocene time, for Miocene lakes existed in the present Rocky Mountain valleys, and their deposits are to-day almost undisturbed and, with succeeding Pliocene lake beds, are not materially eroded. That energetic degradation was in progress in the region immediately east of the Rocky Mountains is, however, certain, for the Crazy Mountains, one of the detached mountain groups of the plains, is formed of Eocene strata cut by dikes and batholiths of igneous rock of post-Miocene age,[1] and now eroded into a mountain group whose peaks are 7,000 feet above the plains at their base.

[1] Bull. U. S. Geol. Survey No. 139, 1896, pp. 78, 109.

The intrusive masses of the Judith Mountains are of the greatest interest, and their nature and structure will be fully discussed in a later chapter. In general the mountains may be said to be laccolithic; that is, they are due to a number of dome-shaped uplifts with laccolithic intrusion of igneous rock. The degradation of the region has exposed numbers of these bodies, but has not usually progressed far enough in the large ones to uncover their bases, so that their shapes and thickness can only be inferred. Nor has erosion yet developed the laccoliths that presumably underlie the domed arches which are a common feature of the mountains. It is at once seen that the structure is different from that of most mountain groups, or even that of the other island mountains of the plains, but is similar to that of the nearby Moccasins, which may be considered a part of this group, and the Sweet Grass Hills, near the Canadian border. The other mountain groups of the plains are either volcanic piles, erosion mountains, or, as in the case of the Little Rocky Mountains, one great quaquaversal dome uplift, not of laccolithic origin.

In the southern half of the mountain group the igneous intrusions appear to be laccolithic in character, and the horizon invaded by the larger bodies has been the shale beds of the Cambrian. This is not usually the case in the vicinity of Judith Peak and the mountains east of it. Here the intrusions are much more irregular and break across strata of different ages, though largely intruded in Cretaceous rocks. Though two distinct intrusions are recognizable, they probably belong to but one epoch. The results of the earlier are seen in the laccolithic masses and sheets and stocks of porphyry and the allied rocks. The later was that during which the tinguaite sheets and dikes were intruded in the porphyry and the Cretaceous shales. There is a marked scarcity of dikes of the earlier period of intrusion as compared with the laccolithic mountains of Colorado. The bodies of granular rocks found near Judith Peak may represent a somewhat different phase of the same period of igneous activity.

Following the period of uplift and intrusion of igneous rocks, ore-bearing solutions brought their burden of precious metals into the rocks. In general it is assumed that such waters follow the easiest course. For this reason the contact planes between igneous and sedimentary rocks were often followed, since differential shrinkage produced incipient fracture, which offered an easy channel, but the impervious porphyry prevented further permeation. In the larger intrusions shrinkage planes in the porphyry itself were also channels for ore-bearing waters. The Spotted Horse and Maginnis ore bodies lie in the altered limestone near the contact of the Gold Hill mass of porphyry, and the Giltedge ores are found in the limestones beneath intrusive sheets.

The denudation and dissection of the mountains, laying bare the structure and mineral deposits, is the last phase of their geologic

history, and one that is still going on. In this process the higher laccoliths have been bared, and, while others remain protected by the overlying strata, the soft Cretaceous rocks have been pared away from the intruded mass in the north, and the hard igneous rocks form the highest points of the mountains. The latest effects of erosion are shown in the beautiful gradation terraces which are found about the mountains, and which are particularly well developed in the vicinity of Lewistown.

Whatever may have been the original drainage in this area, it was probably changed and a new system developed upon the uplifting of the domes. The degradation must have been rapid, as the beds were soft, and the increased elevation subjected them to increased vigor of attack. When the Carboniferous limestones were reached in the southerly area, they yielded more slowly to attack. Elsewhere the hard and resistant porphyry was uncovered. Upon this erosive agencies worked but slowly, and erosion has since tended to emphasize the high points, while degradation of the flanks was increased by the addition of igneous débris to the stream gravels, since this harder, resistant material increased the rate of stream cutting. The rocks of the higher summits do not afford a picturesque or rugged topography, but form rounded summits, owing to the small-sized débris into which they are split by frost.

The region is situated south of the limits of the continental ice sheets, and no positive evidences of local glaciation have been observed. The topographic forms, however, are complicated, and are not those due to uninterrupted erosion of the uplift. Differential erosion produces a variety of forms, but it seems evident that the uplifts and depressions that have occurred in the plains region since Laramie time have influenced the character of the topography here, as well as out upon the plains.

PALEOZOIC STRATIFIED ROCKS.

The sedimentary rocks of the Judith Mountains cover more than two-thirds of the entire area. In the southern part of the mountains, south of the town of Maiden, the older sedimentary rocks dominate the topography and form the higher points and summit plateaus. In the northern summits the igneous rocks form Judith Peak, the highest point of the mountains, and its adjacent summits, and the topography is in strong contrast to that of the sedimentary areas. The peculiarities of topography and vegetation due to the difference in rock structure are so strong that in many cases the character of the rocks can be correctly inferred from the surface features.

The stratified beds are marine sediments and appear to be perfectly conformable. This has been found to be true of all the Paleozoic and Mesozoic sections studied by me in Montana, the great mountain-building epoch beginning at the close of the Laramie. The soft

beds of shale and sandstone which form the surrounding plains have been removed from a large part of the mountainous tract, laying bare the intrusive masses of porphyry and the heavy beds of white Carboniferous limestone which now form the mountain summits. The larger streams have cut still more deeply into the rock domes, exposing lower beds and the igneous masses which form the core of the uplifts. The stratified rocks thus exposed by the degradation of the mountain uplifts include strata belonging to all the great geologic periods from Cambrian to Cretaceous, the strata resting in apparent conformity upon one another. Sections of the stratified rocks will be given in detail, so that the thicknesses may be used in tracing out definite horizons at which ore or coal occurs. Such horizons are frequently concealed by soil, débris, or vegetation, while the overlying and underlying beds are exposed. When this is the case, the intervening thickness being known, the desired bed can be readily located.

CAMBRIAN ROCKS.

The oldest sedimentary rocks of the Judith Mountains are found about the headwaters of Burnett, New Years, and Alpine creeks, which have cut deeply into the cores of the dome-shaped uplifts, exposing the older rocks, together with intruded sheets of porphyry and greater laccolithic masses of igneous rock. The lowest strata exposed are of Cambrian age. The rocks, though greatly toughened and altered by the intruded porphyry, show that their original character was that of soft micaceous and limy shales, quite like the Cambrian shales of the eastern front of the Rocky Mountains. These soft beds afford but little resistance to the intrusion of igneous rocks, and therefore are frequently found in Montana to be altered and toughened by such intruded masses.[1]

In general, the rocks assigned to the Cambrian show a marked resemblance to those of the same age occurring in the Rocky Mountain ranges to the west and in and near the Yellowstone Park. The rocks are quite thinly bedded and are argillaceous, but contain siliceous beds near the base and thin irregular masses of limestone, whose ready weathering causes the joint planes to show a ribbed or reticulated surface in relief. These features, though hard to describe, are very characteristic of the rocks of the Cambrian of Montana, which differ widely from those of any other horizon.

As will be seen by reference to the accompanying geologic map (Pl. LXXV), Cambrian rocks are exposed on a comparatively small part of the mountains. At each place where they occur the rocks are much altered by the adjacent masses of igneous rock, and the soft shales have been changed to tough, dense, and brittle hornstone or hard and sonorous slates, and, though no slaty cleavage is developed, there is a strongly marked set of small joints, so that the original bedding is sometimes recognizable only by careful inspection of the

[1] Bull. U. S. Geol. Survey No. 139, 1896, p. 62.

color bands. This contact metamorphism is not extreme, and is greatest near the contact with the porphyry intrusion. As, however, the porphyry is not absolutely regular in its intrusion, occurring at a varying and irregular horizon and in sheets that thin out, the rocks of certain beds are not equally altered at all places.

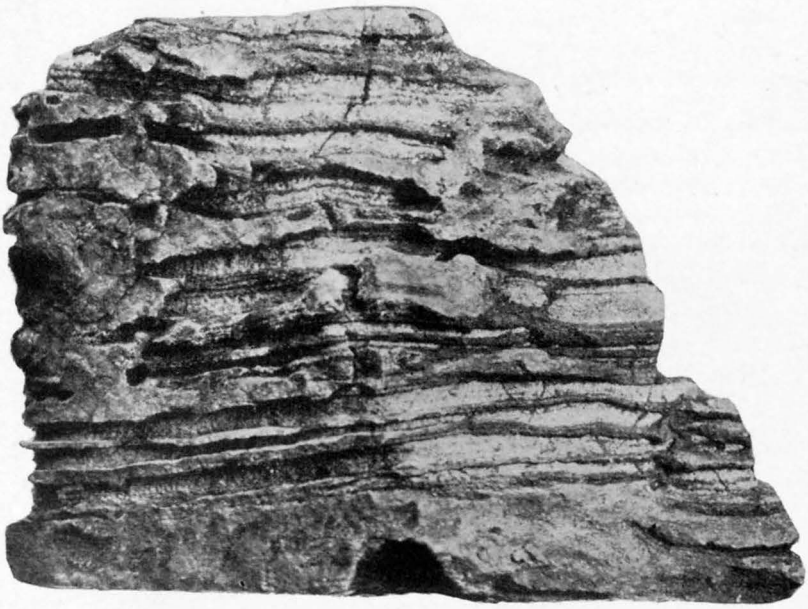
The Cambrian beds are seldom well exposed, and do not form conspicuous outcrops. The peculiar reticulated shales and equally characteristic limestone conglomerates are seen in the stream drift, but the slopes are generally smooth and débris-covered, mostly wooded or grassed, the rocks and disintegration products being frequently hidden beneath débris coming down the slope from porphyry sheets higher up. The more highly altered beds at the base of the series sometimes form low, shelf-like exposures, but they are not a striking feature of the scenery.

Several prospects have been located in the Cambrian areas, mostly on the lower contact of the porphyry sheets with the shaly strata. General observations throughout the State show, however, that valuable ore deposits seldom occur in rocks of this formation, probably because they are not readily traversed or decomposed by ore-bearing solution.

The base of the series was seen only at one point. At Black Butte a basal quartzite 100 feet thick occurs beneath the shale series and the intruded porphyry. The general occurrence of sandy beds in the lower part of the series indicates that these are not far above the lowest beds of the formation. A section of the Cambrian beds made on one of the buttress ridges, extending from near Pekay Peak to Alpine Creek, gives the following sequence and thickness:

Section of Cambrian strata in Alpine Gulch.

Bed.	Feet.
21. Limestone; thin bedded, blue-gray in color and markedly different in appearance from the beds below	40
20. Conglomerate with alternating, very thin layers of limestone and indurated shale. Conglomerates of flat beach pebbles from one-sixteenth to one-half of an inch thick and 2 to 3 inches long, cemented by a matrix that is cherty, indurated shale, rarely limy. The pebbles are limestone, and the conglomerate is usually a faint purplish gray in color. It occurs in low outcrops and forms talus of angular, chippy blocks	125
19. Limestone and shale in alternating, very thin layers. The limestone is thinly bedded and the shales are well indurated. In general, the limestone is light gray and reticulated with bands of shale, which weather with an oily green color on joint surfaces	20
18. Limestone: not occurring in definite outcrop, but forming débris of angular fragments of bright green to creamy gray; very dense. Porphyry sheet	75
17. Limestone; compact and dense, with conchoidal fracture; irregular and thinly bedded, pure and without chert or shale, light brown on fresh fracture	3
16. Shale; hard and laminated, dark greenish gray in color, with occasional concretionary masses	12



SEDIMENTARY ROCK TYPES: CAMBRIAN.

The upper figure is the banded limestone of bed 3 of the Cambrian section; the lower figure is the conglomerate of beds 3 and 7.

Bed.	Feet.
15. Limestone; finely banded, with shaly layers one-sixteenth to one-half inch thick; fine crystalline, very pale lavender color, varying to pale green on fresh fracture. Has a platy outcrop with greenish weathered surface	5
14. Shales; finely laminated; color, dark greenish gray; weathering to fine débris, and containing occasional concretionary masses of limestone	25
13. Limestone; thinly bedded, gray in color	1
12. Limestone; similar to No. 15	3
11. Conglomerate, containing pebbles of limestone up to 2 inches in diameter	1
10. Limestone; banded, showing alternating beds of varying hardness and color	1
9. Shales; generally soft and weathering into fine, scaly chips of greenish-gray color and resembling bed No. 14	8
8. Limestone; alternating bands of dove-color and dense limestone and light-brown granular limestone	2
7. Conglomerate of limestone pebbles; generally rounded, ovoid, varying from dove color to blue-gray, thickly crowded in limestone cement and ranging up to 1 inch in diameter	1
6. Shales; soft, readily weathering, finely laminated, and recognizable only from débris of scaly chips containing occasional concretionary bodies of limestone, usually oval in shape and but a few inches across. Contains rather rare shell remains	15
5. Limestone, with reticulated cherty bands, thinly bedded, and in places running into conglomerate for a few inches at a time. The cherty material weathers with a greenish surface, which is brown on the edges, the chert projecting as ribs above the surface of the limestone. The prevailing color is a dove-gray, but the débris appears green from the abundance of the cherty material	25
4. Limestone; resembling bed No. 3, often changing to a conglomerate composed of thin, flat pebbles of limestone arranged with but little order and breaking with the dove-colored limestone cementing material. These pebbles do not weather out. Some chert is present, but it is hard to distinguish it from the baked shaly material also occurring in the limestone	20
3. Limestone; usually gray, holding thin laminæ of shaly, cherty material, striping the beds conformably with the bedding. The limestone is dense, compact, and finely crystalline on fresh fracture, and changes near the top of the bed into more shaly strata	50
2. Shales; somewhat limy, much more so than the beds beneath, but showing the same thin shaly bedding; well indurated, and forming rough, craggy outcrops that stand out prominently above the smooth slopes. This bed is the rock which forms the prominent Cambrian drift seen in Big Chunk and Alpine gulches, and is characteristic of the Cambrian series, as the porphyry does not rest smoothly against the shales, but has broken along them. They are brecciated near the contact, become more limy at the top, and grade into the limestones of bed No. 3	25
1. Shales with quartz bands. These are the lowest beds of the section and are generally much altered, somewhat brecciated, and very tough from contact metamorphism. No limestone is seen in this part of the section. This series is immediately underlain by a dense porphyry, pale creamy and pink in color, which shows weathered feldspar crystals and quartzes. The dip of these beds is about 35° away from the center of the anticline	20

The Alpine Creek section shows a thickness of 477 feet of beds that are probably all Cambrian. They are composed of shales, of limestone conglomerates, limestones, and the peculiar rocks that are neither of these, yet resemble them all. These latter rocks are the most noticeable and peculiar rocks of the series, and, together with the conglomerates, form its most characteristic rock type. The rocks often resemble conglomerates, for they are an intimate mixture of limestone in flat, oval masses and hard, shaly material that is often green and cherty. Upon fresh fracture these two constituents are not especially distinguishable, but upon the weathered joint planes the harder material stands out in relief as a green network above the gray limestone inclusions, as seen in Pls. LXX and LXXI. These differences in composition appear to be due to original deposition. The greater part of the section just given consists of this kind of rock, which is there called limestone, and which is in places a true conglomerate of varicolored limestone pebbles. A graphic representation of the Cambrian section is given in fig. 34.

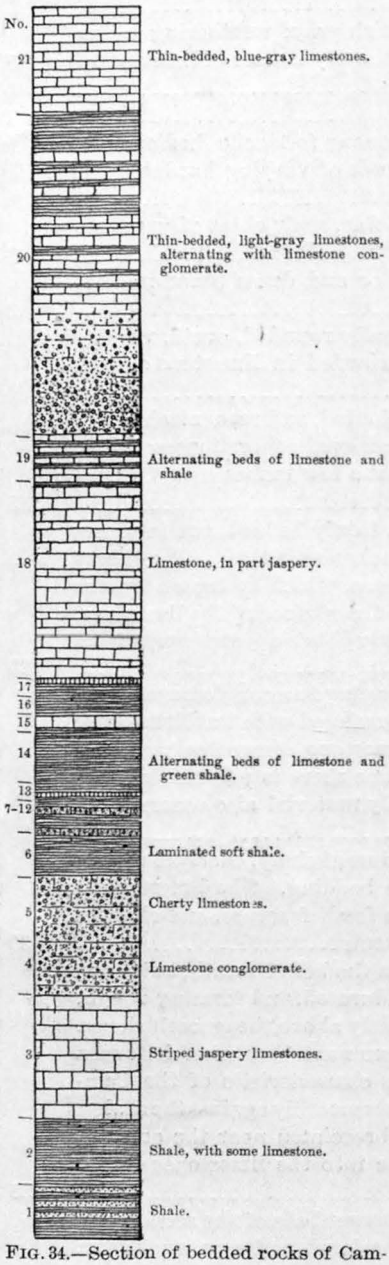
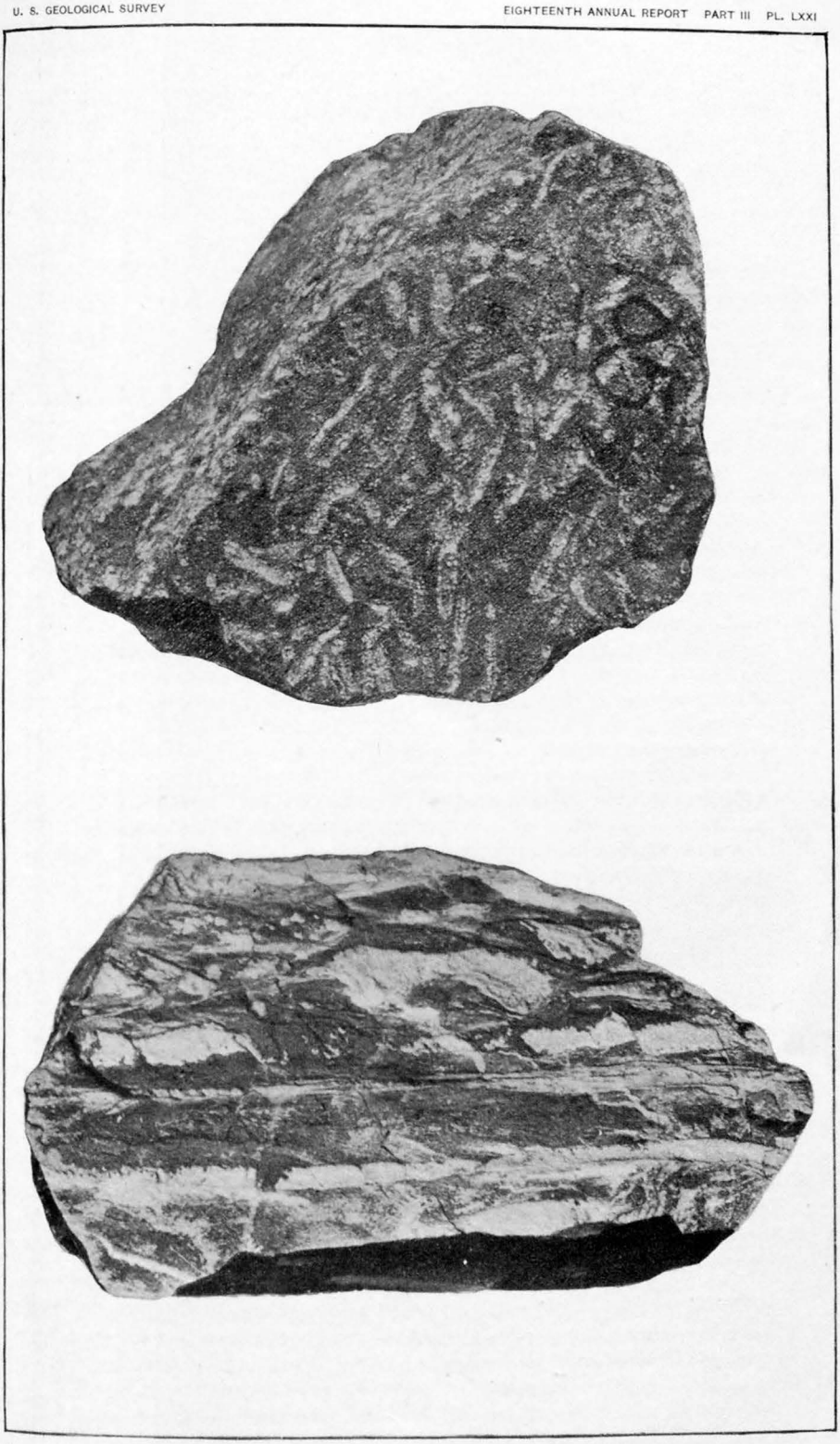


FIG. 34.—Section of bedded rocks of Cambrian age.

Careful search was made for organic remains, but only a few fragmentary fossils were found—a trilobite and a shell resembling Obolella.

SILURO-DEVONIAN ROCKS.

Above the Cambrian beds there is a series of limestone beds differing markedly in appearance from those just described, and as much from the overlying, craggy and massive, heavy-bedded, light-colored limestone of the Carboniferous. The lowest of these intermediate beds are prevailingly dark in color—chocolate-brown or bluish black—and are mostly crystalline limestones, showing a decidedly granular texture upon weathered surfaces. A characteristic feature is a dark-brown rock dashed with cream-colored markings, shown in the upper figure of Pl. LXXI. Above



SEDIMENTARY ROCK TYPES: SILURO-DEVONIAN AND CAMBRIAN LIMESTONE.

The upper figure is the granular, chocolate-colored limestone of the Siluro-Devonian series, with creamy dashes of possibly organic origin; the lower figure is the jaspery or cherty limestone of bed 5 of the Cambrian section.

these dark limestones fissile, shaly, clayey limestones occur. The latter are classed as of Devonian and the former as of Silurian age upon stratigraphic and lithologic grounds, no characteristic fossils having been found in either. The only exposures are those about the rim of the amphitheater of Alpine, New Years, and Burnett creeks, where these beds are rather inconspicuously exposed.

The dark Silurian rocks are distinctly crystalline, weathering with a peculiarly pitted surface, often the result of the weathering out of geode cavities, but in part also due to variations in texture. The dark coloring is due to organic material, and the rocks give forth a strongly fetid odor when struck with a hammer.

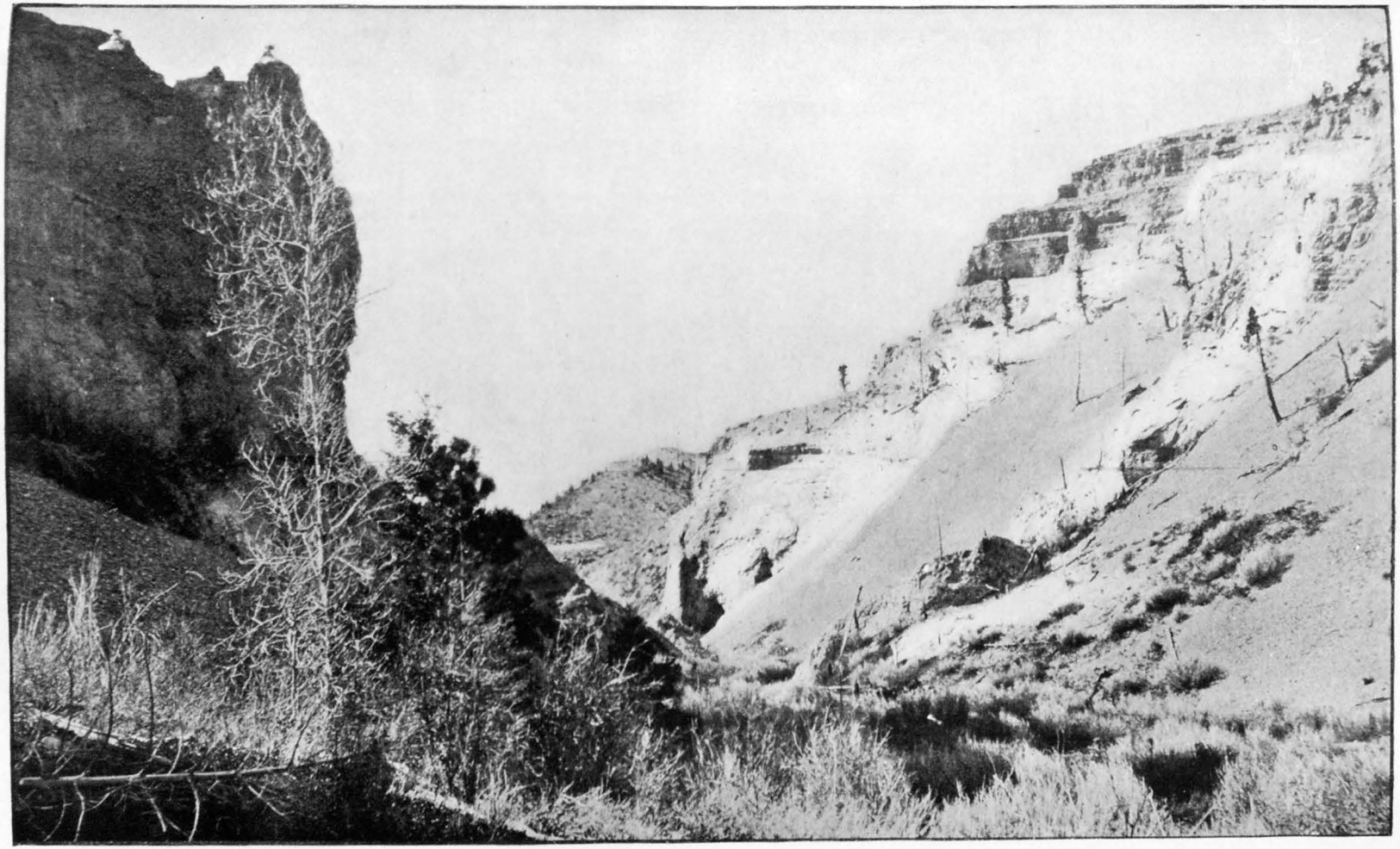
Section of Silurian and Devonian rocks west of Alpine Creek.

	Bed.		Feet.
Carboniferous, Madison formation.	28.	Limestone in alternating beds of brown-gray to blue-gray rock, rudely fissile, and breaking into irregular plates, which form angular débris. The upper 25 feet of this bed is of typical Carboniferous aspect, dark blue-gray in color, and of rudely prismatic fracture, and forms the first of the rough, craggy outcrops which characterize the Carboniferous limestones	65
	27.	Limestone; upper part showing no exposure, but abundant brownish-gray débris; the lower 5 feet is a blue-gray limestone, carrying silicified fossils. This is the lowest bed assigned to the Carboniferous	15
Devonian, Three Forks formation.	26.	Limestone; granular, gray to brownish-gray in color, showing crystalline, crinoid stems, and occasionally corals of Devonian aspect. The rock changes to a cavernous, pink limestone of inconstant nature near the top	26
	25.	Limestone; thinly bedded, breaking into débris of dove-pink or light-gray color that strongly resembles the débris of porphyry	30
	24.	Limestone; light gray, rough weathering, rudely bedded, irregularly crystalline	6
	23.	Shaly limestone, dove-gray to pink in color, and resembling Devonian horizons of Rocky Mountain front	25
	22.	Limestone; pink to cream-colored, dense, and breaking into fine, angular fragments; forms a fissile outcrop	5
	21.	Dark-blue limestone, resembling beds beneath it	6
	20.	Shaly limestone, cream to pink in color, dense, and breaking into small angular fragments	5
	19.	Limestone; light brown, rough weathering, not fissile. This is the lowest bed of what is believed to be the Devonian series	20
Silurian, Jefferson formation.	18.	Limestone; light gray, weathering with granular surface, contains chert nodules, and the outcrop shows a peculiarly pitted surface characteristic of the Silurian horizon throughout the Rocky Mountain area of Montana	12
	17.	Limestone; chocolate-colored with very finely granular surface and fracture, carrying calcite geode cavities, and occasionally brecciated with both fragments and cement of same material. The rock has a fetid odor and a peculiar, rough, weathered surface, and breaks into rounded or subangular pieces	25
	16.	Limestone; light gray, not well bedded, full of calcite strings and bunches, and rather rotten in texture	5

	Bed.	Feet.
Silurian, Jefferson formation.	15. Limestone; chocolate-colored and dark-gray beds alternating, finely granular, with fetid odor and usually Jefferson aspect	10
	14. Limestone; dark bluish gray, finely granular, and similar to beds beneath	20
	13. Limestone; light dove-colored, often blotched with pink, and generally somewhat rotten on weathered surface	7
	12. Limestone; dark blue-gray, finely granular, showing lamination lines, not splitting with bedding readily, but breaking into prismatic blocks and fragments	25
	11. Limestone; fissile, fine grained or very finely granular, dark brownish gray in color	3
	10. Limestone; light gray, rough weathering, resembling conglomerate	10
	9. Limestone; massively bedded, bluish gray, with pink mottling, and of crystalline texture	5
	8. Limestone; fissile, almost shaly in outcrop, light dove in color	5
	7. Limestone; dark bluish gray, and of saccharoidal texture	2
	6. Limestone; bluish gray, similar to bed No. 25, and including 1 foot of cream-colored limestone that is massive and carries crystal cavities	15
	5. Interval covered by dove-colored débris from upper beds	10
	4. Limestone; bluish gray, of Silurian aspect, and carrying minute crinoid stems. The rock breaks into small, angular fragments, is often mottled with a reddish stain, and weathers with a granular surface	6
Cambrian.	3. Limestone; this is not well exposed, but forms a débris of brick-red and dove-colored granular rocks, which become more shaly at the top	20
	2. Limestone; thinly bedded, dove colored, weathering with granular surface, resembling sandstone	10
	1. Conglomerates of purplish color and Cambrian aspect	

CARBONIFEROUS ROCKS.

The massive white limestones which are so prominent a feature of the mountains when seen from the plains and which form the summit cliffs and the walls of stream canyons are of Carboniferous age. The ore deposits of the Giltedge mines occur in these rocks, and the towering walls and pinnacles of the gorge of Maiden Creek, followed by the road to Spotted Horse and Maiden (see Pl. LXXII), are of the same white limestone beds. Their general distribution is shown upon the accompanying geologic map (Pl. LXXV). From the surrounding plains the limestone beds are seen curving about the mountain flanks in great overlapping plates, as shown in Pl. LXXX. These rocks, when present, define quite sharply the mountains from the surrounding level lands, for the limestones resist erosion much better than the overlying shales and sandstones, as shown in Pl. LXXVI. This feature is a common one throughout the eastern border of the Rocky Mountain region of the State, giving rise to the name "mountain limestones," often applied to these beds, and is in strong contrast to



MAIDEN CANYON; CARBONIFEROUS LIMESTONE, THINLY BEDDED.

the phenomena exhibited on the eastern border of the continent, where limestones characterize the lowlands and valleys.

The occurrence of Carboniferous limestones in the Judith Mountains was first observed by Dana and Grinnell,[1] who collected fossils from the beds in 1875, and described the occurrence of "at least 300 to 400 feet" of massive white limestones, the upper layers of which "are white, semi-crystalline, and very profuse in flinty fragments." Owing to the structure and vegetation the exact base of the formation has not been determined in the section measured, but is given in the Siluro-Devonian section previously described. The total thickness of the formation is estimated to be 800 feet. The following section, showing 731 feet of these Carboniferous limestones, was measured along the walls of Maiden Gulch, below the Spotted Horse mine settlement, and extends up to the well-defined Jurassic limestone at the top.

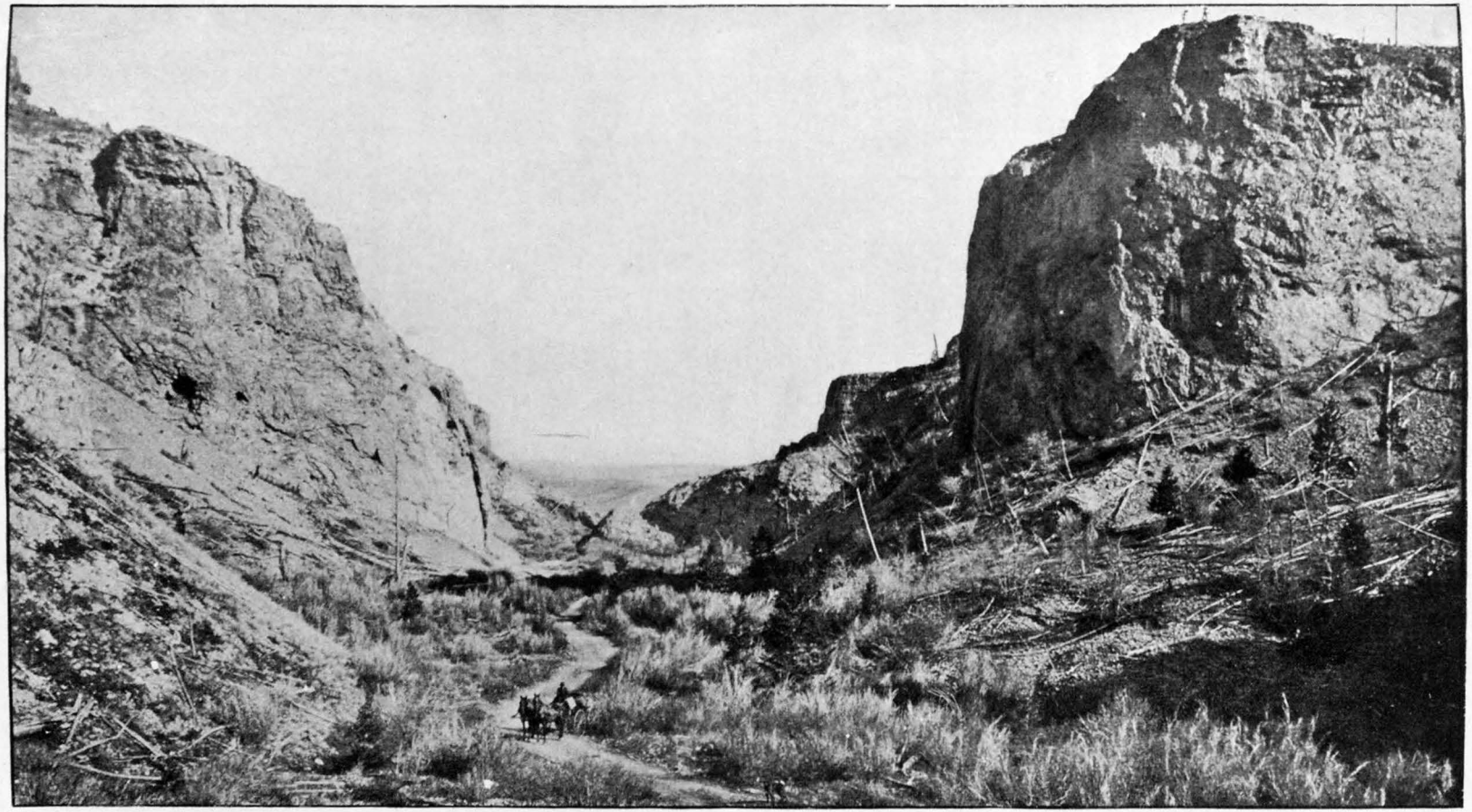
Section of Carboniferous strata exposed in walls of Maiden Gulch, below Spotted Horse.

Bed.	Feet.
21. Limestone; fissile or shaly, dense and not crystalline, dove-colored; débris fragments showing pinkish and purplish weathering; resembles Jurassic somewhat; conchoidal fracture; at 10 feet from base contains a layer of oolitic limestone	20
20. Limestone; impure argillaceous and ferruginous, possibly sandy. In places shaly, but mostly breaking into rotten, earthy material that is seldom exposed. The lower 5 feet is bright red at Giltedge. Ocherous yellow is the characteristic color. Forms sag between surface of underlying beds and a spur beyond formed by bed No. 21	40
19. Limestone; thin bedded, gray, breaking into small flat fragments	5
18. Limestone; massive, creamy gray, brecciated appearance; forms cliff that is at times overhanging, no stratification lines; contains rather rare occasional chert nodules, generally small, but at times 1 foot in diameter, banded	35
17. Limestone; fissile, weathering down and breaking into débris slope between cliffs	20
16. Limestone; forming massive ledges, gray, rudely and heavily bedded, cavernous, with intercalated layers of a brownish limestone having splintery fracture and differing from the rough-weathering surface of the main bed. Forms bold buttresses at the canyon mouth. Carries in places angular fragments of black chert	55
15. Limestone; thin-bedded, fissile, calcareous shales, in places buff to pink on weathered surface	40
14. Limestone; series of thick- and thin-bedded limestone with prismatic fracture, gray, varying somewhat in texture and tint, forming steep cliff; full of big corals and other fossils in the thin shaly layers a few inches in thickness	70
13. Limestone; thin bedded, platy, gray to buff, somewhat impure	5
12. Limestone; massive, gray, with splintery fracture breaking into prismatic blocks; carries abundant fossils of crystalline calcite. Resembles beds below, as No. 3	100

[1] Report of a Reconnaissance from Carroll, Montana Territory, on the Upper Missouri, to the Yellowstone National Park, and Return, made in the Summer of 1875, by William Ludlow. War Department, Washington, 1876, p. 99.

Bed.		Feet.
11.	Limestone; thin bedded, not crystalline, carrying argillaceous material, showing brachiopods and corals which weather out on surface	10
10.	Limestone; heavy bedded, but usually showing no stratification lines to general view; dense, carrying bands of black chert several inches thick, which are conspicuous in outcrops. This limestone is the heavy, massive limestone cliff so prominent in canyon. Cliff is nearly persistent; is much cracked and checked in places with seams filled with calcite. Forms massive buttresses in the canyon at points where side canyons come in and elsewhere; is in general a dove-gray, but weathers in places to a reddish buff (due to lichens) on large surfaces. Outcrops are often rounded. Contains numerous caves that are old water courses	70
9.	Limestone; blue-gray, thin bedded, breaking into angular débris; no good exposures; slightly crystalline	25
8.	Limestone; massive, irregularly bedded, open and cavernous structure, forming round but irregular outcrops, varying considerably in shades of gray in texture, and in purity of material, in places resembling a breccia of a dark color; fragments in buff color cement, this character being rare	45
7.	Limestone; shaly, thin bedded, weathering buff and purplish, changing horizontally to harder, less shaly limestone, showing lamination lines and varying to limestone conglomerate of flat pebbles; seldom well exposed	30
6.	Limestone; thin bedded and platy; cream-color outcrop is in strong contrast to massive beds below; finely crystalline and lacking in chert	25
5.	Limestone; dove-gray, forming second cliff and first persistent one of canyon; heavy-bedded, showing no fine stratification lines; much chert in bands and strata up to 6 inches thick; limestone showing at base round and ovoid chert inclusions of concretionary nature, well banded with concentric layers. Bed No. 4 is well exposed in cliff a rod or two down canyon, where it is seen to be continuous with No. 5, from top of that bed down to top of No. 3, and of same general character throughout. Certain layers are composed mainly of crinoid stems	20
4.	Limestone; thin bedded, but breaking with prismatic fracture; beds not well exposed, but forming slope between two lines of cliffs; fossils very abundant in certain layers, but mostly fragmentary; mainly crinoid stems. Base of second cliff from bottom	60
3.	Limestone; well-defined and thin beds, 1″ to 11″ thick. Differential weathering has developed overhanging ledges; contains considerable chert, irregularly scattered through rock, seldom forming well-defined layers or nodules. This bed forms first cliff, but it is not a persistent bluff	6
2.	Limestone; finely crystalline, dove-gray, forming massive bed, showing no stratification lines; breaking with prismatic and splintery fracture, and in marked contrast to bed immediately above; contains a few fossil remains, mostly of crystallized calcite	20
1.	Limestone; thin bedded, cream to blue gray, finely crystalline; breaks with splintery and rudely prismatic fracture. These thin-bedded rocks are not well exposed, as they break readily and are covered by grass and abundant slide of splintery fragments from the beds above	50

This section shows only limestones. At the base they are thinly bedded, somewhat darker gray than the higher strata, and weather readily, as illustrated in Pl. LXXII. The conglomerate of bed No. 3 is



MAIDEN CANYON; CARBONIFEROUS LIMESTONE, MASSIVELY BEDDED.

significant of the conditions prevailing during the deposition of the limestone of the earlier beds. The abundance of crinoids and other relatively shallow-water species of fossils is in accord with this evidence, and shows that the limestones are shallow-water deposits.

The limestones of beds Nos. 12 to 14 form a series of retreating cliffs in continuous exposure on the east side of the gulch, seen in Pl. LXXII. The rocks are evidently a part of the great series of massive-weathering Carboniferous formations, but show good bedding planes and weather with masonry-like appearance, due to slower weathering of the harder ledges, 3 to 4 feet thick, which overhang the more shaly beds. At the top of the cliff three or four of these beds weather as steps upon a timbered slope, and are in turn overlain by the heavy bed of massive white limestones that everywhere forms the "gates" or portals of the gorges leading from the mountains, as shown in Pl. LXXIII.

Bed No. 20 is the only one in the section that can be correlated with the Quadrant formation of the Yellowstone Park vicinity or the Yogo formation of the Little Belt range. These formations represent the closing period of Lower Carboniferous time in the Rocky Mountains. In the Judith, bed No. 20 is bright yellow in color, loose textured, and resembles a sandstone. It is very calcareous, shows small black stainings of moss-like form, and weathers into soft, sandy earths. It contains a large amount of insoluble material that appears to be siliceous sand.

FOSSILS.

Fossils occur at various horizons throughout the section, but none were found in the two uppermost beds. The species are all of Lower Carboniferous types. The fossils collected by Dana in 1875 from the limestone exposures west of the head of Box Elder Creek were identified by Prof. R. P. Whitfield as follows:

1. Crinoidal remains, too indistinct to be identified.
2. Terebratula or Cryptonella.
3. Spirifera (Martinia) lineata Martin.
4. Spirifera centronata Winch.
5. Orthoceras?

Spirifera centronata Winchell was the most abundant and characteristic form observed here.

Fossils were also collected from the Carboniferous rocks at the head of Boyd Creek, identified as follows:

1. Zaphrentis centralis Ev. & Shum.
2. Syringopora mult-attenuata McChes.
3. Stictopora sp.
4. Spirifera centronata Winch.

Fossils collected by myself from the summit of Crystal Peak (bed

No. 18 of section) were identified at my request by Mr. Charles Schuchert, as follows:

Chonetes loganensis H. & W.
Leptæna rhomboidalis Wahl.
Spirifer centronatus Winch.
Orthothetes.

The spirifer is not only the most abundant species in the Judith Mountains, but generally in the Carboniferous rocks of Montana.

The following report of Mr. George H. Girty upon the fossils collected from the Carboniferous horizon of the Judith Mountains shows the specific identifications and character of the fauna from the different localities:

Head of West Fork of Boyd Creek:
Pleurotomaria sp.
Murchisonia sp., near M. terebriformis Hall.
Rhombopora, several species.
Spirifer centronatus Winchell.
Seminula humilis, nobis.
Seminula madisonensis, nobis.
Seminula immatura ?, nobis.
Rhynchonella, several species.
Myalina sp., cf. M. congeneris Walcott.
South side of Crystal Peak, at 5,626 feet:
Orthothetes inflata White & Whitf.
Maiden Gulch:
Syringopora pollux, nobis.
Spirifer centronatus Winchell.

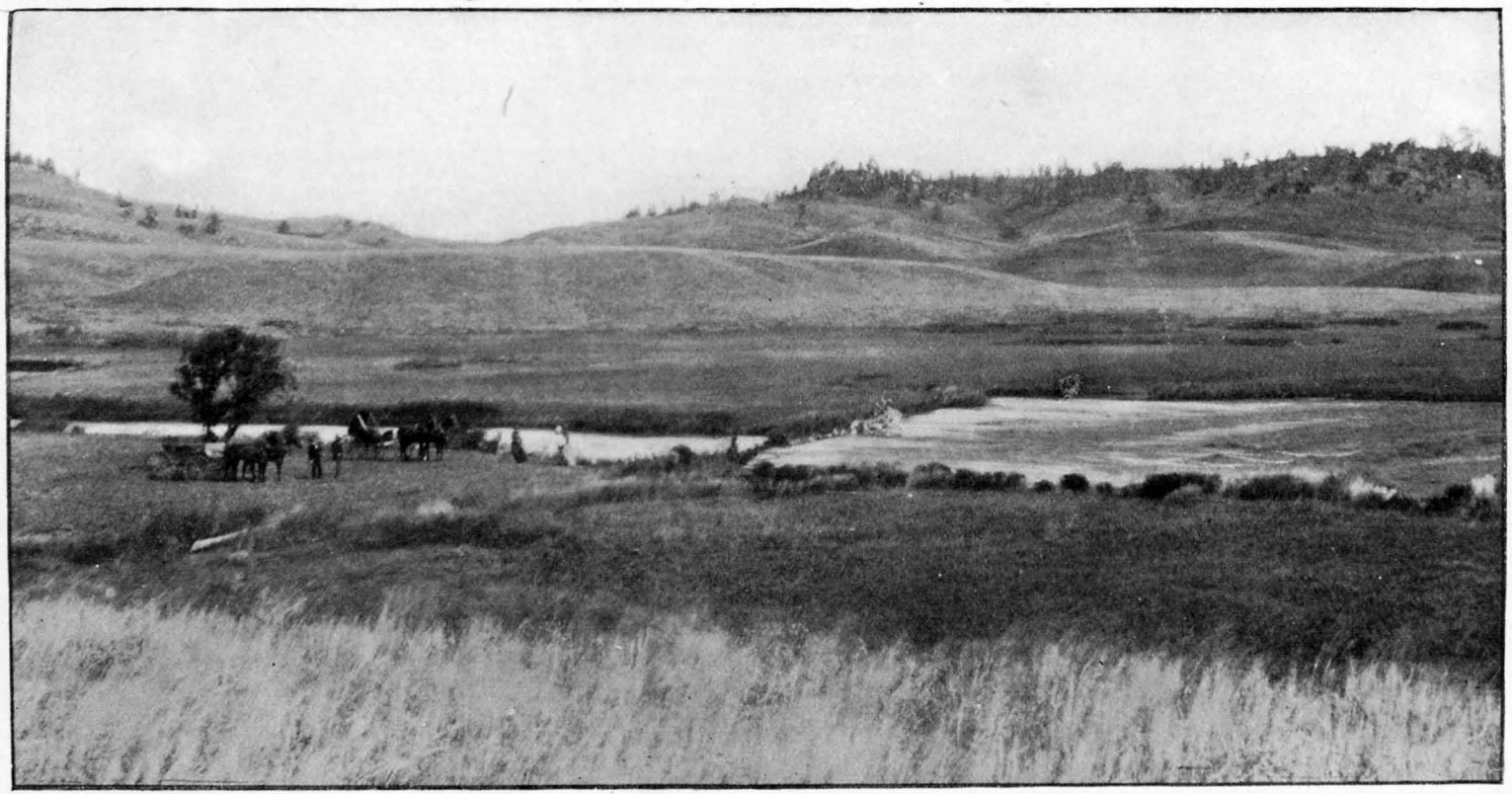
The fossils of these four localities seem to represent a single geological formation, and one showing well-marked affinities with the Madison limestone of the northern Rocky Mountain areas. The faunal resemblance is most marked where the Brachiopoda alone are considered, *Spirifer centronatus*, *S. humilis*, *S. madisonensis*, *S. immatura*, *Orthothetes inflata*, and *Syringopora pollux* being all found in the Madison limestone, where several, notably *Spirifer centronatus* and *Orthothetes inflata* are extremely abundant. Several of these are manuscript names of species described from Yellowstone National Park.

The Judith Mountain localities, however, show a quite different gastropod and pelecypod development. It is a striking fact that in the Yellowstone Park only two specimens, representing two genera of pelecypods, were collected, both of them generically different from *Myalina congeneris* (?), while the abundant, practically the only, gastropod found in the Madison limestone is *Straparollus utahensis*, which has not been found at the Judith Mountains.

The rhynchonellas cited from one locality are very small and immature forms, so that I was not able to identify them. The rhomboporas also, of which several species may be represented, were indeterminable on account of their coarsely silicified condition.

Specimens of Carboniferous limestone from the Spotted Horse mine were examined by Prof. C. E. Beecher, of Yale University, who found the following forms present:

Productus semireticulatus ?
Chonetes sp.
Derbyia sp.
A gastropod, possibly Euomphalus.



WARM SPRING, BELOW MAIDEN.

A specimen from the upper part of the Carboniferous of Maiden Gulch showed a brachiopod, probably Terebratula, possibly Dielasma.

RÉSUMÉ.

Considered as a whole, the Paleozoic rocks of the Judith Mountains present the same sequence of rock types found in the Front Range of the Rocky Mountains. The resemblance is closest to the sections in the Little Belt range in the vicinity of Yogo and Barker. This is to be expected, since they are a part of the series forming the mountain uplift that raised the Little Belt ranges, an anticline that disappears beneath the Cretaceous rocks at Judith Gap and reappears in Big Snowy Mountains, just south of the Judith Mountains. The close accordance of the sections of the Judith Mountains with those of the Rocky Mountains at such distant points as Neihart, Livingston, and the Yellowstone Park is rather remarkable, the general characters of the rocks belonging to each age being the same at these distant localities. The sections show shallow seas throughout this region at the beginning of the Middle Cambrian, succeeded by deeper waters in which limestones of varying composition were deposited until the close of the Lower Carboniferous epoch. During this long lapse of time deposition appears to have been conformable, but periods of shallowing are represented by the arenaceous limestones of the Silurian. The shales and coal of the Devonian of Three Forks have no representation here.[1] The rocks show that these oscillations were not so evident here as farther westward. The Carboniferous of the Judith region ends with massive and pure limestones. The shallow-water beds, with impoverished fauna, found on the east slope of the Little Belt, are not represented here.

The entire Paleozoic section is of much less thickness than it is farther westward. As the base of the Cambrian is not seen, a strict comparison of those terranes can not be made, but the Silurian, Devonian, and Carboniferous are not so thick as they are farther westward. This is in accordance with previous observations, which show a thickening of the Paleozoic series from the eastern flanks of the Rockies westward.

MESOZOIC ROCKS.

The strata of this age form the plains country about the mountains, and also the lower slopes and hills about the intrusive masses of the northern part of the area. In the southern part of the mountain group these rocks cover but small areas and are found in concentric exposures about the mountain flanks. The rocks are all soft and readily eroded, so that they usually form gentle slopes, in marked contrast to the bolder forms due to the more resistant rocks of other

[1] The Paleozoic section in the vicinity of Three Forks, Montana: Bull. U. S. Geol. Survey No. 110, 1893, p. 30.

ages or types. The most prominent feature of the series is a massive bed of yellowish sandstone, forming a bold hill occurring at intervals as an encircling ridge about the mountains, whose character is seen in Pl. LXXX.

The Jurassic series has no economic importance so far as known. The detailed section given in this chapter is, however, of practical value, as it is often necessary to know the character and thickness of the beds intervening between the massive white Carboniferous limestones, so generally exposed, and the coal seam that occurs in the Cretaceous. The measured sections show a total thickness of 380 feet of beds in this interval.

The Cretaceous rocks are essentially the rocks of the plains. Exposures do occur in the elevated parts of the region, notably between Maiden and Judith peaks, in Ross Pass, and about the headwaters of Armell Creek, where they have been included between intrusive bodies of igneous rock. Where the rocks occur in the well-watered mountain tract they are very generally concealed by soil and vegetation, and good exposures are uncommon. In the foothills and plains the semiarid climate favors good exposures, except where the thin veneer of drift on gradation terraces conceals the beds. The economic importance of the Cretaceous rests upon the occurrence of the coal seam and associated fire-clays, together with the usefulness of the easily dressed sandstones for building stones.

JURASSIC ROCKS.

Overlying the massive, heavily bedded limestones, which are the most prominent sedimentary rocks of the Judith Mountains, there is a series of thin-bedded strata which generally form somewhat gentle slopes at the base of the mountains. The lowest beds are of dark-gray limestone, thin bedded, and carrying fossils 10 to 15 feet above the base. There is frequently a sag or ravine between these limestones and the Carboniferous rocks, due to the weathering of the yellow, calcareous bed at the top of that series.

Above the dark limestones that form the base of the Jurassic the beds become more shaly and argillaceous, and near the top have intercalated beds of sandy material. The total thickness is 184 feet. Good exposures occur at numerous places about the mountain front. Below Maiden the lower limestones form ledges near the road, and an unpromising prospect pit is sunk in the rocks. These Jurassic beds often form mammillary hillocks 10 to 20 feet in height in the interval between the white limestone slopes and the ridges carrying the coal beds. The beds are well exposed near Giltedge, where the following section of the series was measured:

Section of Jura-Cretaceous beds exposed on ridge between Giltedge and Virgin creeks, near Giltedge.

	Bed.	Feet.
Dakota.	39. Sandstones, with interbedded, red earthy shales, forming bright-red soils	400
	38. Quartzite, resembling gray limestone; dense and knotty in texture	4
	37. Sandstone like that below, the lower 2 feet of the bed being a dense, buff-colored quartzite, the upper part of the bed being shaly	15
	36. Red soils, which are not exposed	20
	35. Sandstone; granular, gray in color, varying to buff	6
	34. No exposure, but slope covered with red soil	15
	33. Quartzite, dense, resembling limestone in weathering and appearance	5
	32. Shales, with interbedded thin layers of dark-gray sandstone	30
Kootanie.	31. Sandstone, coarse, gray, varying considerably in texture and weathering pinkish or red on the edges of the débris; a normal sandstone (100 feet horizontally)	30
	30. Gray shale	6
	29. Coal, soft, crumbly fuel; seam opened by short incline	(*a*)
	28. No exposure, but probably sandy shales	50
	27. Sandstone, coarse, gray, gritty, and with gray argillaceous lignite-colored band 8 inches in thickness in center, in which black fossil wood was found. (Sharp upraise above this ledge and limestone bench below)	12
	26. Shale, gray, argillaceous, breaking in small angular bits	5
	25. No exposure; débris of sandy shale	45
	24. Limestone, argillaceous and impure, dove-colored and much crackled. This bed weathers as a well-exposed ledge and forms bench	12
	23. Shales, sandy, and with fine, round, pebbly fragments	12
	22. Sandstone, gray and shaly	18
	21. Sandstone, saccharoidal, and like that beneath	10
	20. No exposure	5
	19. Sandstone, variable in color from gray to yellow, weathering pink	7
	18. Sandstone, grading into a dark-gray shale at top	15
	17. Sandstone, white to light gray or pink, and granular	1
	16. No exposure	5
Jurassic, Ellis formation.	15. Ellis sandstone; variable—buff, platy sand rock; pink blotched at base, with occasional shells; cross bedded, purple-brown outcrop. It is at top a limestone full of white and black quartz sand grains, and forms a dark-brown ledge	12
	14. No exposure, but débris of sandstone	60
	13. Marly shales and limestones, dove-colored, carrying fossils noted in following pages; seldom exposed; Gryphæa most abundant here	30
	12. Irregularly platy, earthy-brown gray limestone, carrying shell remains Gryphæa, Ostrea; weathering dark brown; rarely granular	6

a 17 inches.

	Bed.	Feet.
Jurassic, Ellis formation.	11. Sandy limestone like that above, but irregularly bedded and resembling sandstone; granular and saccharoidal in texture; carries shell fragments	4
	10. Rough-weathering limestone, fine grained, even bedded, and fissile; carries fossils	5
	9. Shaly beds which are seldom exposed and carry oolitic limestone. Granular or sandy limestone of drab color	15
	8. Shaly, argillaceous, impure limestones, dove-colored, weathering buff on joint faces, and of typical Jurassic aspect	5
	7. No exposure	25
	6. Limestone, blue to gray in color, hard in texture, and carrying ostreas in 3-foot to 5-foot beds, separated by thinner platy beds	12
	5. Limestone, dark gray, laminated, and shaly	10
Carboniferous.	4. Porphyry sheet of Giltedge mine	50
	3. Limestone, impure, thinly bedded, buff colored, with saffron-yellow outcrop; soft and with earthy outcrop; former bed No. 20 of Carboniferous section, Maiden Gulch	43
	2. Thinly bedded limestone, impure, platy, dove-colored, dense, weathering buff	25
	1. Massive Carboniferous limestone, outcropping at ore bin of Giltedge mines, east side of creek	

The rocks of the Ellis formation are not conspicuous, and are frequently concealed by soil and vegetation. They can, however, always be found, if searched for, above the white mountain limestones.

FOSSILS.

The formation is characterized by marine fossils of well-marked Jurassic types. The following species were identified for me by Mr. T. W. Stanton from collections made in 1894 in the vicinity of Giltedge:

Pentacrinus asteriscus M. & H.
Ostrea strigilecula White.
Gryphæa calceola var. nebrascensis M. & H.
Modiola subimbricata Meek.
Cucullæa haguei Meek.
Pleuromya subcompressa Meek.

Collections from numerous other localities yielded similar species. Although collections were made from different horizons of the series, the species proved the same throughout, so that the fossil evidence indicates that the beds form but one series. The following identifications were made by Mr. Stanton:

Giltedge mine:
Gryphæa calceola var. nebrascensis M. & H.
Modiola subimbricata Meek.
Pleuromya subcompressa Meek.
Natica sp.

The foregoing species indicate the fossiliferous zone of the Yellowstone Park Jurassic section.

Maiden; by roadside below town:
Cyprina? Numerous small casts and impressions, with a few indeterminate casts of a small gastropod. The material is too imperfect to fix the horizon.
Warm Spring anticline; middle part:
Ostrea strigilecula White.
Ostrea. A large species represented by fragments.
Top of Warm Spring anticline (Jurassic (?) limestone):
Cyprina? sp. Casts. Probably same as fossils of limestone found near road below Maiden.
Ridge west of Lookout Peak; head of Edwards Gulch:
Ostrea or Gryphæa. Indeterminate fragments.
Foothills southwest of Ross Pass:
Ostrea. Fragments of a large species, probably the Jurassic O. engelmanni.
Head of east fork of Pete Creek, on west side Ross Pass:
Gryphæa calceola var. nebrascensis M. & H.
Mytilus whitei Whitfield. Jurassic.
Upper Ruby Gulch, head of Boyd Creek:
Ostrea strigilecula White? Numerous fragments. Jurassic.
Head of Boyd Creek:
Camptonectes pertenuistriatus H. & W. Jurassic.
Ruby Gulch, head of Boyd Creek. Last bed faulted against Cretaceous:
Ostrea strigilecula White? Numerous fragments. Jurassic.
Boyd Creek (Ruby Gulch):
Ostrea strigilecula White.
Camptonectes pertenuistriatus H. & W. Jurassic.

The rocks of all of the localities represented are apparently of Jurassic age, though in several cases the paleontologic evidence is too meager for positive correlation. The fossils indicate close relationship with the Jurassic of Yellowstone Park, and the two fossiliferous horizons recognized in the Jurassic seem to be both represented in the Judith Mountains.

The beds of Jurassic age show rapid shallowing of the water in this area of deposit. The earlier beds represented are limestones, which are impure and fissile, unlike the pure and massively bedded limestone of the Carboniferous. There is a gradual change in the beds, which are essentially shore deposits; they become more and more argillaceous, with oolites and the appearance of quartz sand, until sandy beds alternate with the impure limestones, succeeded by a 12-foot stratum of cross-bedded sandstone, at times limy, containing marine Jurassic shells in a fragmentary condition—a beach deposit where the shells were broken by wave action. This bed, whose character proves the same wherever it has been recognized, is taken as the top of the Ellis formation. No unconformity between it and the overlying bed has been recognized either here or elsewhere in the Rocky

Mountain region, but the succeeding sediments are of different character and are separated and grouped with the shale and coal seam above, which carry Lower Cretaceous (Kootanie) fossils. This assumes that a thickness of 197 feet of beds, mostly sandstone, in which no fossils have been recognized, are Cretaceous. It is possible they may be equivalent to the Upper Jurassic (Morrison formation) recognized in Colorado, a formation whose equivalent has not yet been found in Montana.

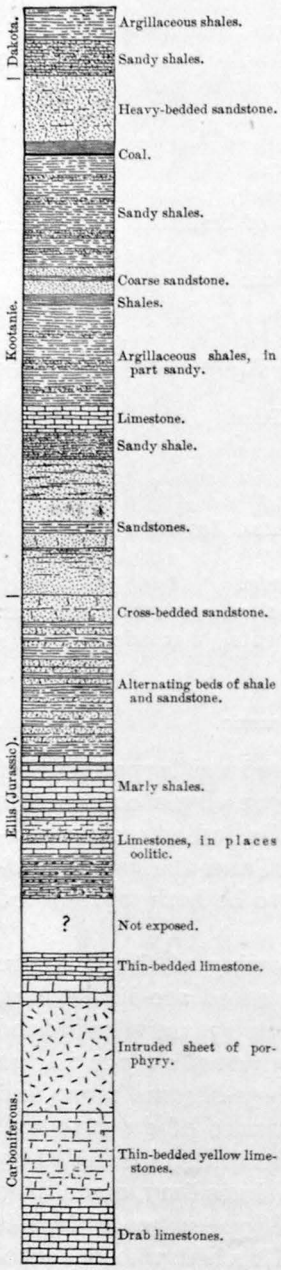


FIG. 35.—Section of Mesozoic rocks of Judith Mountains.

LOWER CRETACEOUS=KOOTANIE.

Throughout the Judith region, occurring generally at the outer base of the mountains a short distance from the foot of the slope, there is a series of light-colored sandstones with brick-red and carmine clays and a workable seam of coal. This series of beds overlies the Jurassic series and carries fossil plant remains in the shales associated with the coal seam, which are of Lower Cretaceous age. It is therefore assigned to the Kootanie horizon, a formation named from its occurrence in the region of that name in Canada. The character of the formation and the alternation of arenaceous and argillaceous beds are illustrated in the section last given, which is typical of the Judith region generally.

The delimitation of the formation is unsatisfactory. The lower limit is defined by the occurrence of Jurassic fossils; the uppermost is entirely arbitrary. No fossils are found in the interval between the coal seam and the marine Jurassic sediments—a thickness of 197 feet of strata which may perhaps represent the equivalent of the fresh-water Jurassic of Colorado.

FOSSILS.

The only fossils found in the formation occur in the clay-shales above the coal seam. Collections made from this bed at Giltedge coal mines in 1894 yielded a number of interesting species, the determinations having been made by Professor Fontaine, who regards them as Kootanie. His preliminary report upon these fossils, embodied in a letter to Prof. L. F. Ward, is as follows:

The plants collected by Mr. Weed from the new localities in Montana constitute a flora different from any known to me. A careful study of the plant remains sent gives the following results:

The plants have suffered some from drifting and maceration, but the shale in which they occur takes such sharp imprints that any parts which retain their character show it very distinctly in the imprints. Considering that the number of specimens is so small, they show a surprisingly large number of new plants of great interest, and I think that if careful collections are made from these localities much light will be gained concerning the Mesozoic flora. The forms made out are these:

1. A fine Zamites, which I think is new. It belongs to that group of Zamites in which occur Dawson's *Z. montana*, and Heer's *Z. brevipennis*, *Z. borealis*, and others that are so characteristic of the Lower Cretaceous. It might be called *Z. weedii*.

2. A smaller Zamites of the same type, which I think is certainly different from the preceding. It is a good deal like Dawson's *Z. montana*, but is, I think, distinct from it. It is exactly like the Zamites which he does not name but figures in his paper On the Mesozoic Floras of the Rocky Mountain Region of Canada, Pl. I, fig. 4.

3. A beautiful and very distinct little fern of the well-marked Acrostichites types so characteristic of the Richmond coal field group, but a new species. It is very different from any Kootanie species known to me. It is a good deal like *Pecopteris geinitzii* Dunk., as figured by Schenk on Pl. VIII, fig. 2, in his Wealden Flora. It is possibly near enough to be a variety of this.

4. These are fragments that agree well with *Angiopteridium strictinerve* of the Potomac.

5. Impressions of stems that in size, etc., agree well with *Equisetum lyelli*, but are without sheaths. Some scattered portions of sheaths not attached to stems are exactly like the sheaths of the same Equisetum, so it is pretty certain that *Equisetum lyelli* is present.

6. There is another and larger Equisetum present that is probably a new species. It is always macerated, and never shows sheaths and leaves attached to the stem preserved well enough to indicate the character of this plant. Its width seems to be $1\frac{1}{2}$-2^{cm} and it is larger than any of the Equiseta of the Lower Cretaceous known to me, except, perhaps, the plant from the Grenschichten, which was named by Schenk *Calamites phillipsii*, and by Schimper *Equisetum phillipsii*. As this also shows no leaves and very imperfect sheaths, the two can not be compared. The dimensions of this Montana Equisetum are more like those of the Equiseta of the Jurassic. There is one imprint of this plant that shows at the summit of a node a number of long apparent leaves and with a midrib, which looks exactly like the leaves of Phyllotheca. My first inspection of this and the presence of rosettes on the stems, which are more common on Phyllotheca than Equisetum, led me to think that this plant is certainly a Phyllotheca. This and the fact that many of the other forms had not been found, as it seemed, in the Lower Cretaceous, led me to think that these strata containing them may be Jurassic. A further careful inspection of all the specimens of the plant in the collection makes me think that it is a new Equisetum, and that the resemblance, in one specimen, to Phyllotheca is due to a peculiar mode of accidental uplifting of the sheaths. Better material is much to be desired. The plant may provisionally be called *Equisetum montanense*.

7. There is a poorly preserved imprint of a fine fern, with all the character of a Thinnfeldia, that is something like one of the forms of the Potomac *Thinnfeldia variabilis*, and very much like Heer's *Dicksonia longifolia* from the Jurassic of east Siberia. More and better material would probably show that it is a new species which might be called in that case *T. montanensis*.

8. There is a pretty stout twig covered with numerous thread-like leaves that is much like *Laricopsis longifolia* of the Virginia Potomac. More specimens are needed to make out its true character.

Besides these, there seemed to be a species of fern that occurs in fragments too small and too poorly preserved for its character to be made out. One specimen is a good deal like the Potomac *Thyrsopteris elliptica*.

As stated, I think that these localities ought to be collected from. There is every indication that they will yield a large number of new plants which will add much to our knowledge of the Lower Cretaceous flora. The facies of the flora seems different from that of the Kootanie and the Great Falls coal group, owing to the large proportion of new forms, but my last study convinces me that its age is Lower Cretaceous and not Jurassic.

UPPER CRETACEOUS ROCKS.

DAKOTA GROUP.

Overlying the coal seam and its associated sandstones and shales is the series of sandstone and dark-gray and red clay-shales which is assigned to the Dakota. The beds are capped by the black marine shale of the Benton. A thickness of 500 feet of strata is assigned to rocks of this age in the Judith section. The section already given shows the character and sequence of beds constituting the formation.

The two formations, Kootanie and Dakota, are both characterized by open and porous sandstones inclosed between Jurassic shales below and Benton shales above, and outcrop about the base of the mountain. These horizons are the water carriers, and, passing beneath the gently inclined strata of the plains, are water reservoirs available for artesian wells. The lower beds of the following section are classed as Dakota.

BENTON FORMATION.

The leaden-gray and black carbonaceous shales of this formation underlie the terrace lands about the mountains, and appear involved in the folds about the intrusion of the northern peaks. The strata carrying intercalated beds of sandstone are characterized by marine fossils. Where these rocks outcrop they yield readily to erosion and form bad lands, but about the mountain flanks they are protected by a veneer of drift and soil, and within the mountains they do not erode in this way. The shales are essentially argillaceous and are of no economic use whatever. The upper part of the following section in Ross Pass, begun where the creek crosses the road the second time, is referred to this group.

Section of Cretaceous in Ross Pass, south side.

Bed.	Feet.
22. Sandstones, argillaceous, similar to No. 21, passing into thin sandy shales at top, which form large bench and highest exposure seen on this side of the mountains	35
21. Ash bed of a chocolate-brown color, undoubtedly a volcanic tuff, much altered and with gypsum layers; recalls tuffs of the Highwood Mountains; shows lamination and cross bedding, so was laid down in water; contains fossil bones	1

Bed.		Feet.
20.	Sandstone, thinly bedded, fissile, fine, even grain, sugary feel; gray color and shaly character; contains fish scales	10
19.	Shale, black, outcrop broken down and forming steep slope covered with plates of sandstone bed above it	30
18.	Sandstone, mostly broken down, the débris weathering to a brick color; on fresh fracture pale yellowish gray; rather fine, even grain; outcrop broken down	10
17.	Shales, soft, black, scaly; like Nos. 9 and 14	15
16.	Shales, thinly fissile, gray; weathering into tiles one-fourth inch thick, which lie scattered about the slopes and are sometimes pale brown, sometimes bright dove-gray, somewhat sandy, weathering rust-brown on joint faces, with very perfect lamination planes of parting; often somewhat indurated, so that the tiles do not break easily, and pass into a brown, thicker, tougher variety, more like sandstone, that forms top of little bench	10
15.	Same as No. 14, without layers of iron ore	40
14.	Black shales, interspersed with layers a few inches thick of tough iron ore (hematite?) that is black and burnt-looking on surface and breaks into conchoidal chipped pebbles and small but heavy blocks, lying about on surface of soft, weathered shale. There are also occasional drab-brown sandy layers an inch or so thick	25
13.	Sandstone, fissile, in layers 3 inches thick, alternating with bands 5 inches thick, which are very fissile, weather more easily and retreat, leaving others projecting; color, gray; grain very fine and rock argillaceous; weathers on cracks and joints with a brown iron stain; contains what appears to be a very regular mud cracking; forms top of little bench	5
12.	Interval of shale; soil covered with drift from above	40
11.	Shales like No. 9, somewhat indurated at top by what is supposed to be an intruded sheet of porphyry which is thin and broken down	10
10.	Sandstone very fissile, gray, of rather sugary feel, not much indurated, somewhat cross bedded; on slope breaks into small pieces and disintegrates on top to a gray, sandy soil; weathers into extremely large, even, and thin plates	4
9.	Black shales, somewhat indurated at bottom by sheet of tinguaite shales, weathering into fine, black scales, and showing black, side-bank exposures in the drainages. Intercalated every few inches are thin layers of brown, iron-stained bands only an inch or two thick; while the shales are very fine and soft, these are tougher and more indurated and break into little chips an inch or so square, which cover the soil slopes with their brown fragments; occasionally there are flat, lenticular or rounded masses in the black shales. No fossils were seen in them. These black shales recall those of Arrow Creek and Missouri River	60
	Tinguaite, intruded sheet	15
8.	Sandstone, olive-brown, weathering dark umber-brown. Fissile, somewhat indurated and quartzite-like; forms curved smooth surfaces where weathered; shows very fine thin lamination planes and is somewhat cross-bedded, of a fine grain; forms a marked overhanging ledge and is top of second bench in valley; shows what may be worm tracks or casts; has thin fissile layers and others 5 inches thick; softer, thinner layers weather back, thicker overhang; all show the fine laminæ. This rock in large plates is strewn all over the flats below and does not crumble like No. 4 in weathering, but makes characteristic brown soil. It forms bench with wooded outcrop	35

Bed.		Feet.
7.	No exposure; gray-brown soil with thin, chippy, brown shaly fragments, largely also with chips of sandstone from ledge above	10
6.	Drab-colored sandstone, thin, platy, with rough feel and loose texture, and cross bedding	1
5.	No exposure, but a brownish-gray crumbly soil filled with small fragments of a brown, indurated shale; slope covered with plates from ledge above	50
4.	Sandstone, thinly fissile, showing cross-bedding plates about 1 inch thick; has a sugary texture, weathers buff and pink, and changes at the top to a loose-textured variety of a gray color; forms top of first bench; shows ripple marks; recalls sandstone over the coal in character	38
3.	No exposure; soil of a gray sandy character; débris from ledge above	5
2.	No exposure; soil clay, of a reddish color	25
1.	No exposure; soil of a black color; appears débris of a black shale	40

The section is necessarily imperfect from lack of good exposures and the necessity of walking down the backs of the little benches and changing to start anew. It starts necessarily at an unknown point, but certainly low down in Cretaceous and probably near top of Kootanie. The dip is there 15° to 20°.

Whenever a change was made in the section the succession was hunted up and overlaps were made as well as possible, and certain parts were repeated in several places to make sure no slips had taken place. It is believed, therefore, that the thickness given is correct, while the upper part of the section beginning with the black shales is fairly accurate. The porphyry sheet mentioned in bed No. 11 seemed, on later investigation, to be merely scattered talus; if really a sheet, its thickness is inconsiderable.

LEGEND

SEDIMENTARY ROCKS

Cretaceous

Kdc — BENTON FORMATION (black shales and sandstones) DAKOTA FORMATION (red clays and sandstones)

Kk — KOOTANIE FORMATION (shales, sandstones and coal.)

Jurassic

J — Shales, thinly bedded limestones and sandstones.

Carboniferous

C — Massive bedded limestones.

Silurian and Devonian

D — Thinly bedded limestones.

Cambrian

€ — Conglomeratic limey shales and thinly bedded limestones.

IGNEOUS ROCKS

P, SP — Acidic porphyries of the laccolithic masses and intrusives.

ĝp — Granite porphyry

S — Syenite

p — Acidic porphyries in intruded sheets.

t — Phonolite (tinguaite) and phonolitic porphyry in dikes and sheets.

Triangulation and Topography by the Northern Transcontinental Survey

GEOLOGIC AND TOPOGRAPHIC MAP OF JUDITH MOUNTAINS AND VICINITY

Geology by Walter Harvey Weed and Louis V. Pirsson

Scale $\frac{1}{125,000}$

2 1 0 6 Miles

Contour interval 50 feet

JULIUS BIEN & CO. N.Y.

CHAPTER IV.

By L. V. Pirsson.

DESCRIPTIVE GEOLOGY.

THE WESTERN PART OF THE MOUNTAINS.

INTRODUCTORY.

In this and the two succeeding chapters is presented a detailed account of the geology of the Judith Mountains. Since, with the exception of the brief reconnaissance made by Dana and Grinnell in 1875, in which they crossed the mountains at two points during a march through the region, the country is geologically a terra incognita, this description is given with considerable fullness, the intention being to embody such details as will render the report valuable for local use by laymen as well as interesting to the geologist.

THE GEOLOGIC MAP.

The geologic map shown in Pl. LXXV has been made on the topographic base, previously mentioned (Pl. LXIX). In mapping, the horizons determined by Mr. Weed have been used. The Cambrian conglomeratic shales form horizons easily recognized by their topography and outcrops; the Carboniferous is readily delimited by aid of the outcrops of the massive bed No. 18, near the top, which so commonly forms ledges and gateways throughout the mountains. The fossil bed in the Jurassic, which lies a short distance under the Ellis sandstone at the top, is to be found nearly everywhere; it is an extremely characteristic horizon, and by its aid the top of the Jurassic formation may be determined. The position of these beds, which usually furnish distinct outcrops in relation to the prominent outcrops of the heavy sandstone that is taken as the top of the Kootanie series, enables the ready discrimination of the latter in spite of the lack of other exposures; and as it is the series which is of economic importance, in that it contains the coal of the district, it is shown on the map. This heavy sandstone, which is so prominent in the foothills, has been called for convenience the coal sandstone. The lack of exposures of the Dakota and Benton groups, due to the soft, clayey nature of their shale beds, renders it impossible to map these formations and

delimit them without an expenditure of time which would not be warranted by the results to be obtained. The presence of these beds, wherever they are clearly recognizable, is mentioned in the succeeding chapters. Two months of field work have been given to the mapping and study of the district.

The topographic map (Pl. LXIX, p. 446), drawn for reproduction on a smaller scale than that on which it is now given, does not show the topographic detail which would assist in expressing geologic structure, but that the structure is fairly well expressed on the map will be shown in the following pages.

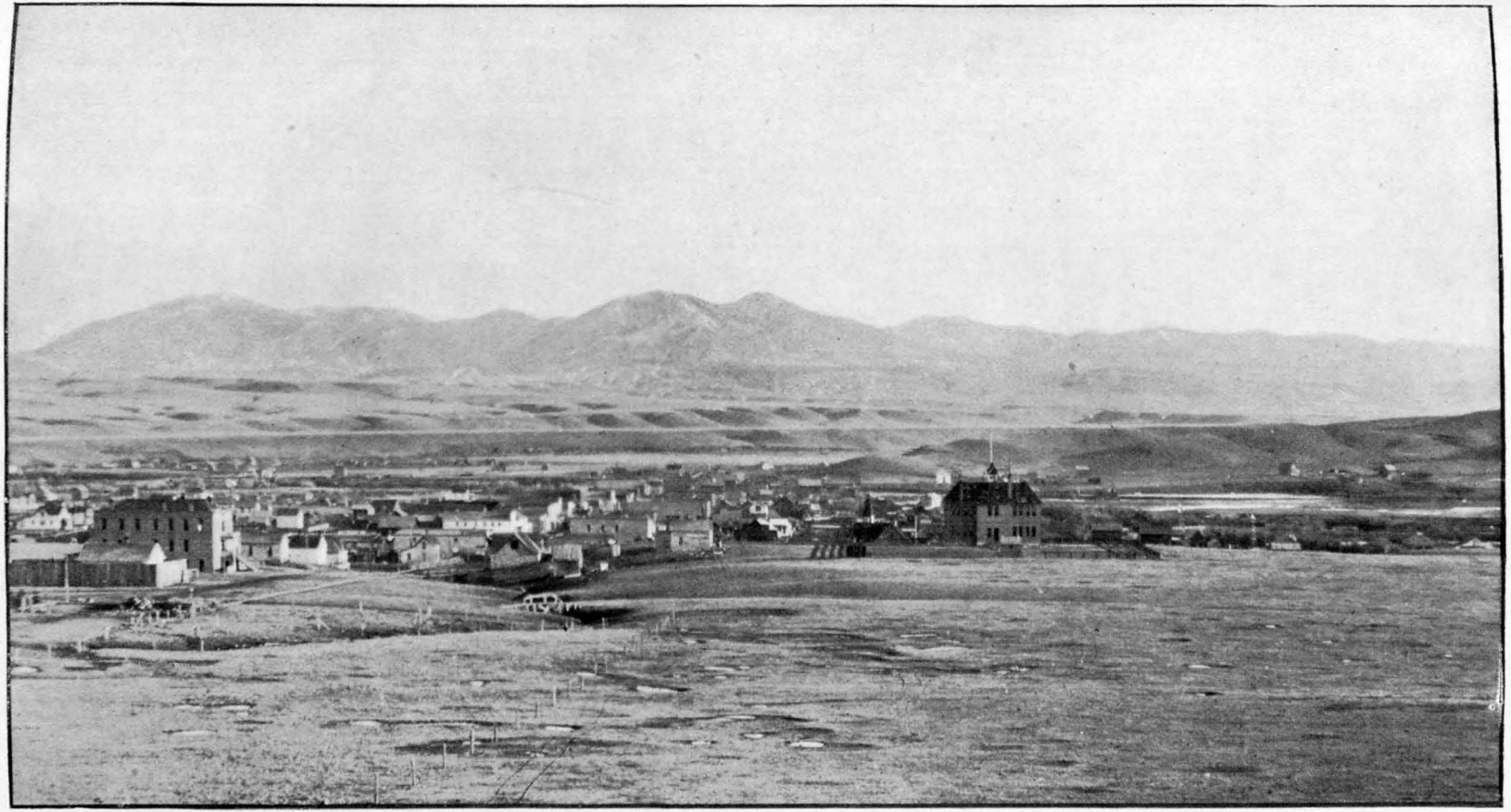
WESTERN FOOTHILLS COUNTRY.

The open country around the western end of the Judith Mountains is of smooth, gently rolling, softly contoured aspect, and rarely does one find any outcrops of the rocks. It is composed entirely of the soft strata of the lower members of the Cretaceous in this region. The hills and benches are determined by the sandstone cappings; the wide, open, shallow, and gently winding drainage channels are cut in soft shales. Long, even planation terraces leading down the stream valleys are characteristic features, and one of them is well illustrated in Pl. LXXVI. The appearance and character of the country show that it is cut in almost horizontal beds of the Cretaceous.

Lewistown, in the valley of Big Spring Creek, is situated on the Dakota-Kootanie rocks, and as one approaches the mountains more red beds are passed over, and Boyd and Burnett creeks pass through many gateways of flaggy sandstones of the Dakota group.

On the north side, in the direction of Warm Spring Creek, the same character holds; there are long inclined planes of erosion coming down with regular slope from the mountains; seen in front they are not conspicuous, but in profile they are very noticeable. The divide between Warm Spring and Burnett creeks is wide and low, cut by open, shallow coulées, winding in and out; rock exposures are rare. It is possible that the tops of some of the higher hills in this part of the region are composed of rocks of the Benton group, but exposures of these soft, black shales are so uncommon, because of their easy weathering and degradation, that none were found in the time which could be devoted to this object.

From any point in this open country to the west of the mountains one sees their bases surrounded by a chain of foothills, beyond which the slopes ascend abruptly, with imbricated outcrops of white limestone gradually rising one above the other to the crest line, the scallops being formed by steep ravines cutting through the sharply upturned beds of heavy Paleozoic rocks. The line of foothills around the outer slope is formed of the heavy, resistant sandstones of the Dakota-Kootanie and Jurassic formations, the shale bands being marked by annular valleys between them. The sandstone outcrops are each marked by fringing growths of yellow pines, and there is a remarkable uniformity



LEWISTOWN AND THE JUDITH MOUNTAINS.

of appearance in this chain of outer flanking foothills, separated from one another by stream courses which have cut narrow ravines through them, with sandstone gateways. The only variation in appearance is their length along the strike of the beds. They may be seen on the topographic map as small outer hills, or may be distinguished by the sudden lengthening of the spur contours.

BURNETT CREEK DOME AND LACCOLITH.

Following up any of the channels of the streams coming from the western end of the mountains, one finds that the dip of the beds, as shown in the sandstones passed, is away from the mountain uplift, and the dip becomes steeper until, when the Paleozoic rocks are reached, it has attained angles of from 30° to 40°. Each of these drainage channels except Burnett Creek, as soon as the heavy limestone of the Carboniferous is reached, ends in a very steeply rising ravine, incised in the limestone, which gradually grows smaller and shallower as it ascends and dies out at the crest of the ridge. The angle of ascent being less than the dip of the beds, the various strata are cut through, giving rise to the imbrication of the outcrops along the mountain side which is so characteristic a feature of this end of the range as seen from below. All of these gulches are dry, and only when the foothills are reached do the seepages begin.

Following up the course of Burnett Creek, however, one finds that when the gateways of Dakota and Kootanie sandstones are passed the channel, which carries a running brook, does not die out upward in one of the steep gulches described above, but continues with a very gradual rise through a canyon cut in the Paleozoic rocks. Leaving the Dakota and Kootanie, one passes the sag which marks the soft beds of the Jurassic and forms a couple of side drainages, and, entering the canyon, passes, while slowly ascending, the whole Paleozoic section from the Upper Carboniferous down through the Siluro-Devonian to the Cambrian. The dip of the beds downstream being very steep, as indicated above, the canyon is very short—about half a mile in length. In spite of bold crags and picturesque scenery, it does not afford good sections for geologic study, as the outcrops are much broken down and covered with talus or vegetation. Passing upward through the canyon, one enters a deep V-shaped valley, which soon forks. The valley is here cut in the greenish conglomeratic Cambrian slates, whose outcrops, considerably indurated, can be occasionally found. As soon as the valley forks both forks are found to be cut in porphyry, whose slide composes the slopes. The valley is heavily wooded with small pines, and a passable wagon trail leads up the main fork toward some mining prospects. At the juncture of the porphyry and Cambrian the stream breaks out in large springs, which form a little swampy area; above this the channels cut in porphyry-wash are dry.

If, instead of ascending the stream bottom, where the outlook is hidden by the pines, one climbs a thousand feet upward over the steep, wooded slopes to the crest of the horseshoe-shaped ridge so well shown on the topographic map, and reaches the point which forms one end of the heel of the shoe, he obtains an excellent view over this inclosed basin. It is seen to be a deeply cut, funnel-shaped basin with a diameter of about 1½ miles across from rim to rim (see fig. 36). Toward the north, at the toe of the shoe, the ridge rises in a peak to its highest point, over 6,000 feet. This represents the calk of the shoe, while on the western side the curving ridge is interrupted by several points before it declines to a last and lower point, from which it sinks abruptly to the canyon. On the east side, to the southeast of the high peak, is another twin peak, from the eastern point of which a high ridge runs eastward, which continues the mountain crest line in that direction; this point is just above the New Years mine. From the western point of the double peak a low, broad divide, heavily clothed with young pines, extends southward to the double peak which ends the ridge.

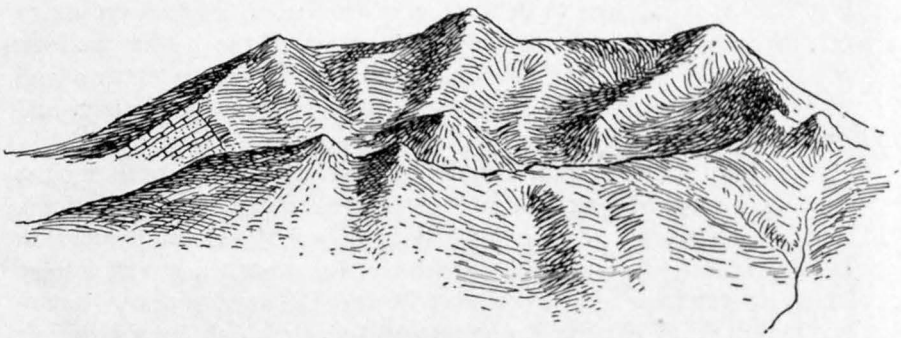


FIG. 36.—Stereographic sketch of Burnett Creek Basin.

The interior of the funnel-shaped basin is cut by ravines running sharply downward and converging toward the center. In the center there rises a hill of porphyry, which divides the drainage into two main branches. The interior of the basin is heavily covered with small pine wherever there are porphyry slopes, as are the north and west sides of the spurs; the east and south slopes, of Cambrian shales, are open. There are enough of these openings, in combination with rugged outcrops or long talus slides of porphyry, to enable the main geologic features to be readily seen. The double peak which forms the eastern heel of the shoe is composed of dark limestones of Silurian and Devonian aspect, the beds dipping sharply south. Descending northward to the broad divide, one finds the Cambrian shales, greatly indurated, standing on end, with strike along the ridge; a short distance beyond they are in contact with a rotted porphyry of a buff color. The band of Cambrian shales in a few rods changes its direction of strike more to the eastward and is cut off by the porphyry which breaks across the horizons.

This mass of porphyry now forms the divide extending some distance down both slopes to a point near which the south slopes of the west New Years Peak begin, where the Cambrian shales are again met, with strike northwest and dip at a small angle southwest. This is abnormal for the general structure, according to which the beds dip outwardly around the circle in a domed anticline, and is probably caused by the intrusion of the porphyry mass of the west New Years Peak. This Cambrian is much covered by porphyry talus, and its exact thickness can not be told. It appears to wedge out along the divide, and to the northwest to run down the hill to meet the heavy mass of Cambrian forming the inside slope of the basin. Rhyolite or quartz-bearing porphyry of the same decayed type just mentioned forms the west point of New Years Peak, the contact between it and the limestones lying in the saddle between the two points; and on either side, north and south, runs a gulch, one side of which is porphyry slide-rock, the other limestone, so that the gulches are thus strike-and-contact ones. The limestone at the contact on the saddle is considerably altered and metamorphosed by the igneous rock. It is of a light-purple to red color, a peculiarity which is assumed by certain horizons of the Devonian, or what is believed by its relation stratigraphically to the Carboniferous to be such, no fossils being present.

On the north side of this porphyry peak the igneous rock is continued across the saddle separating it from the high peak which stands on the most northern part of the ridge at the extreme head of Burnett Creek. The porphyry is continued a short way up the slope of this mountain, and then gives place to Cambrian shales of the usual greenish, conglomeratic aspect, much indurated, with strike northeast and dip sharply northwest into the hill. A short distance below, on the hill slope, other outcrops appear with the dip reversed, and there is at this point some disturbance of the structure due to the intrusion of masses of porphyry, an intruded sheet lying in the Cambrian shales below the high point southwest, on the inside slope of the basin. These shales on the north side of the saddle run down in a strike-and-contact gulch similar to the ones described above.

On the slope of the high point there appears a considerable thickness of Cambrian, about 100 or 150 feet, which is succeeded by blackish limestones supposed to be the Jefferson (Silurian) formation, followed by the chocolate-colored limestones of Devonian aspect. This continues to the top of the peak, which carries a thin, small, intruded sheet of porphyry. To save repetition it may be said that from this point to the end of the ridge, where it sinks to Burnett Creek, the strike is always in the general direction of the ridge, while the dip, which varies from 30° to 40°, is down the spurs toward the open Cretaceous country—that is, normal to the dome structure. Along this crest the dark Siluro-Devonian limestones form the common outcrop; when the crest line sinks a little they are thrown on the outside

and the Cambrian slates advance to the divide; as the latter winds, it crosses the strike of the beds obliquely. The Carboniferous beds are just on the outside, and as the spurs run down, the massive bed near the top, a persistent ledge in the measured section (see p. 471), forms a shoulder on each spur.

At the high triangulation point the Carboniferous, here full of crinoid stems and badly preserved corals, advances to the crest line. Below this point and to the southwest the dark, chocolate-colored limestone appears again, forming some very massive outcrops. The rock is here full of curious vermicular markings of a light color.

The whole interior of the basin is filled with a great mass of quartz-porphyry cut into by steep descending ravines. The portion exposed is somewhat oval in shape, about a mile long by one-half mile wide. In the center it rises into the hill which divides the two main forks of the stream. On the basin slopes it is everywhere in contact with the Cambrian shales, which are indurated but not greatly metamorphosed. As the porphyry is more resistant to weathering than are the shales, the point of contact on each descending spur is apt to be marked by a

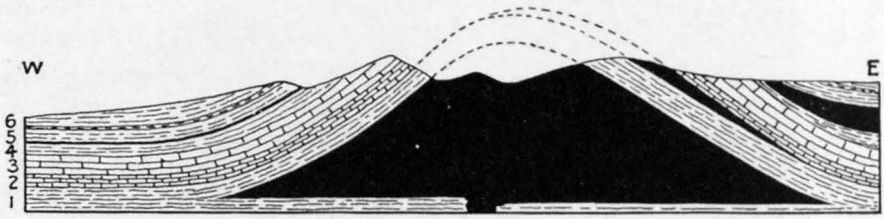


FIG. 37.—East-west section through Burnett Creek dome and laccolith. Black = porphyry; lower broken lines = Cambrian; smaller rectangles = Siluro-Devonian; larger rectangles = Carboniferous, with Jurassic and Cretaceous shale above. Figures indicate height above sea level, in thousands of feet.

rising shoulder of porphyry, often seen in considerable crags. The porphyry itself is of a brownish color, largely altered, and breaks into small angular fragments which furnish long reddish-brown talus slides.

The geologic features of this mountain mass at the head of Burnett Creek have been given in some detail because the structure of this portion of the mountains illustrates most clearly, and affords a key to, that of the remainder. From what has been given above it is plain that there is here, as is so clearly shown on the geologic map, a domed anticline, in which the doming up of the strata is due to the laccolithic intrusion of a great mass of porphyry beneath into the easily separated shaly Cambrian beds. The dome has been dissected on the top and the sedimentary cover stripped back from the apex of the laccolith, which is just beginning to emerge. This is most clearly illustrated in fig. 37, which shows an east-west cross section through the middle of the laccolith and its covering load of sediments. It shows also the upper intruded lenses of porphyry, the top portions of which, like the sediments, have been cut away by erosion. The

structure is clearly seen on the geologic map, with the central mass of porphyry and the encircling bands of sedimentary strata in proper stratigraphic order, the crest line of the ridge being formed by the resistant limestone horizons.

RUBY GULCH.

The branch valley which leads down from the eastern side of the Burnett dome to the southeast, into Boyd Creek, is known as Ruby Gulch. The name was given it from the small red garnets, coming from the metamorphosed Cambrian at the head of the creek, found in the stream by those washing for gold. In the upper part it is an open, almost treeless basin, with gently descending slopes of light-colored Carboniferous limestone, which meet in a rather flat floor cut in Jurassic and Cretaceous rocks. On the western side of the valley a spur runs out which rises in a low, oblong hill, elongated down the valley; its slopes rise quite abruptly from the stream bottoms which it divides. It consists of a mass of porphyry intruded in Jurassic beds and uncovered by denudation. The rock composing it is of the usual rotten, crumbly, buff-colored type. On the southwest side of this mass the Jurassic shale beds, as usual, are cut out into a drainage channel, but where the strike crosses the spurs they form a line of wooded hillocks on the slopes. Southwest from here the spurs descending steeply from the double peak which forms the eastern heel of the Burnett horseshoe ridge, as they approach the level of the lower country, are prolonged outward, as shown on the map. The dip of the upper Carboniferous beds suddenly flattens out, and within a quarter of a mile or so becomes nearly horizontal. The limestone forms here, in fact, a low, flat dome, cut across by two streams, branches of Boyd Creek. This dome is open and grassy, and standing in the center of it one sees the southern part encircled by the wooded hills of the Kootanie coal sandstone, the Jurassic beds forming a subordinate row of lesser hills in front of them, their crests determined by the Ellis sandstone. It is clear that the structure here is dominated by a lens or flat laccolith of porphyry, which lies under the heavy Carboniferous limestones, arching them up into a low, flat dome, the structure lines of which may be seen on the geologic map (Pl. LXXV). The two drainage channels unite before reaching the encircling Kootanie beds, and pass out through a sandstone gate. On the western edge of this dome the beds have been cut away to a lesser degree, and rise in a long hill covered with tall pines, shown on the map by the southward extension of the 5,000-foot contour. From its position it can be easily seen that it is a strike ridge, the beds dipping east. Ruby Gulch cuts along the eastern limb of this dome in the Jurassic beds, which, on the east side of the stream channel, rise in another long strike ridge following down the valley. Both ridges on either side are cut across by short, dry ravines, or wind gaps, which do not

serve for drainage purposes, and the explanation of whose presence must be sought in a certain geologic structure to be presently explained.

It will be noticed, by reference to the geologic map, that on the northeast side of Ruby Gulch there is an elongated patch of Cretaceous strata belonging to the Kootanie and Dakota groups. It is a still uneroded remnant, lying in the end and side of the synclinal half-boat at the head of the gulch. As one passes down the gulch from the head, one sees that the beds feel the influence of the Pyramid Peak intrusion and are thrown back until they stand nearly on end, so that the plane projection of the map gives almost at one point the actual thickness of the sediments from Cambrian to Dakota, provided none of the softer beds are slipped back, as often happens. The strike is northwest; the dip is 75° to 85° southwest. The beds of the Cretaceous are thrown back so strongly that they have yielded and broken, and are now standing faulted against the Jurassic formation of the other side of the valley, which dips gently eastward, away from the low dome described above. The actual line of the fault is covered; at the head of the valley it probably dies out. On the long spur running down from Pyramid Peak into Ruby Gulch, at the point where on the map this spur approaches the 5,000-foot contour line as it crosses Ruby Gulch, the Jurassic has a dip northeast of 20°. The upper bed is the conglomeratic limestone, full of gryphæas near the top of the Jurassic section; it slopes down a little hillock to meet the red beds of the Dakota. A few feet beyond is the sandstone next above the coal sandstone, which strikes northwest and dips 75° southeast. The distance from the last outcrop of Jurassic to this sandstone is about 75 feet, and the fault and amount of its throw are most clearly indicated at this point. Its hade is of course unknown, but is probably southwest. The amount of throw would be indicated at about 350 feet from the measured sections. Down the valley the same general relations are held until the hill of porphyry on the west side of Pyramid Gulch is met. This mass of igneous rock will be mentioned again later; it is sufficient to say here that it lies between the heavy beds of the upper Carboniferous and the lighter Jurassic, the latter stretched out by the bulging mass of porphyry and ending in the west slope in a series of upturned and torn sediments, most of which, so to speak, fray out in the porphyry, as shown in a general way on the map. The Kootanie beds are also thrown back by this intrusion, which carries the fault line along in the same direction as before. The red beds are still seen in some little spurs, and end finally in a grassy meadow on the drainage area of Pyramid Creek.

This area of Cretaceous is marked by an abundance of pines, especially on each band of sandstone as it crosses the spurs, and by a series of springs which break out near its base, the water from which runs but a short distance, when, entering the Jurassic across the fault

line, it disappears in the limestone beds. Ruby Gulch itself is not only dry (except for these springs), but throughout the greater part of the valley there is not even a stream channel, a dry, grassy meadow stretching unbroken from slope to slope, the drainage being entirely under ground.

If one stands at the lower (southeast) end of the fault line described and looks upward along it to the northwest, he will see that it marks the

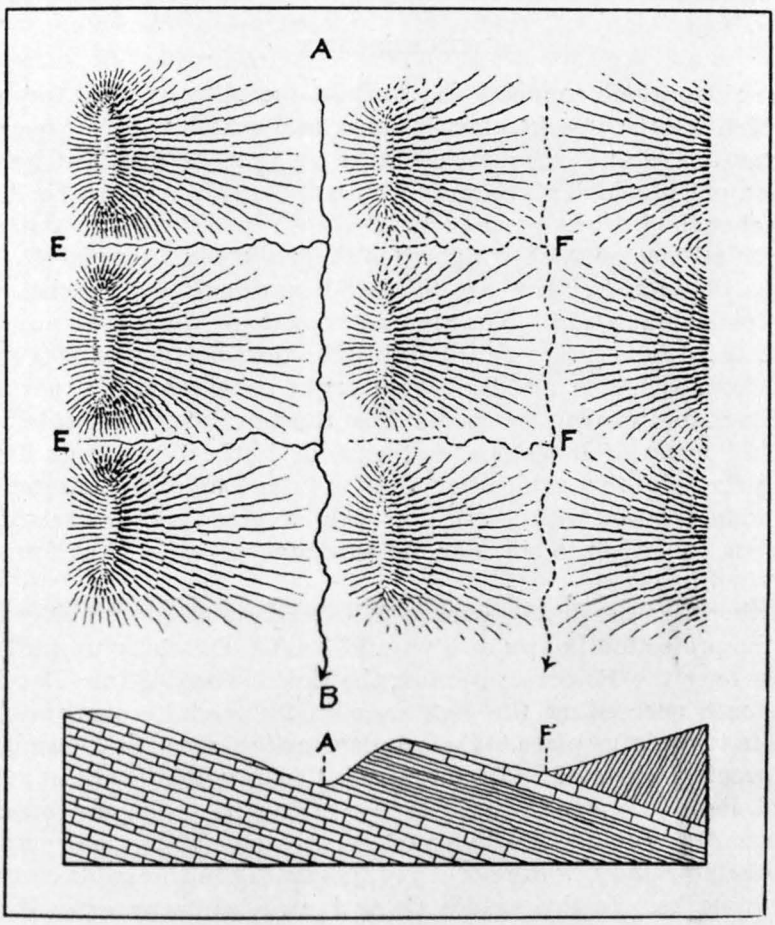


FIG. 38.—Sketch map and section of Ruby Gulch. A B, course of present Ruby Creek; F F, former course along fault line; E F, former drainages. Cross section: A, present channel; F, former channel.

direction of a shallow but distinct valley, which stretches in a general way at its upper end parallel to the present Ruby Gulch. The strike Jurassic hills between these valleys, as mentioned above, are cut across by wind gaps, as are also the Carboniferous hills on the west side of Ruby Creek. The whole relation shows clearly that the former valley drainage ran down in the direction of the fault, and that from the arch of the large dome west the drainage ran into it by several

eastward-running drains. Eventually, however, the stripping of the laccolith cover revealed the soft Jurassic beds, which at once determined the new line of drainage, leaving the former valley at a higher level, with the ancient cross drainages into it showing as wind gaps in the ridge intervening.

This is shown in the accompanying figure (fig. 38, p. 493), and in the cross section is shown the former valley line along the fault at F, and that of the newer narrow channel cut out in the soft Jurassic at A.

PYRAMID PEAK.

The ridge which connects the Burnett laccolith with the large one in which Alpine Creek takes its rise, and which will be described later as the Alpine laccolith, contains an area of intruded igneous masses, one of which gives rise to Pyramid Peak. From the line of contact of the intrusive mass of west New Years Peak with the lower Paleozoic limestones, the ridge rises sharply up in a crag of Carboniferous limestone, giving rise to New Years Peak, from which point the divide sinks again. The summit is made of Carboniferous limestone, and the beds are considerably broken; on the spurs they dip down from each side, and the ridge may be considered the apex of an anticlinal fold sharply compressed at the top. On the divide there is a hill made of limestone, and east of it the beds again flatten out, giving rise to a table about half a mile long and a quarter of a mile wide, covered with a thick growth of pines and containing in one spot one of those sinks or old drainage pipes so often found in flat-lying limestone areas.

Farther east the beds begin to tilt sharply up and the ridges rise into the projection known as Pyramid Peak. Climbing upward, one passes over the Paleozoic section, the dark-colored Siluro-Devonian limestones succeeding the lighter-colored Carboniferous ones, and these in turn giving place to the conglomeratic shales of the Cambrian, here greatly indurated. From this point to the top all is composed of rotted, light-brown to whitish porphyry (rhyolite-porphyry), breaking into small, angular bits. The next point eastward is also composed of the same chippy, white porphyry, beginning in the saddle between the two peaks. In this saddle Cambrian slates occur, extending up Pyramid Peak a short distance and dipping back into the slope. There is a thickness of fully 75 feet of them shown, and how much thicker they may be is unknown, as porphyry slide-rock covers the slope. On the east side of the last-mentioned hill the relations of the sediments are precisely the same as on the west side of Pyramid Peak—the Cambrian, then the Siluro-Devonian, succeeded by the Carboniferous, which rises to another peak terminated by a crag where drainage channels of New Years, Alpine, and Pyramid creeks head up against one another. The successive upturned arrangement of the sediments shown in the saddles on either side of this intruded por-

phyry mass exists also on the spurs leading down from the two points, the crest of the spurs yielding sections and structure similar to the main divide. On the southeast the intrusion of the porphyry has crowded back the beds until they stand very nearly on end, as previously described. This produces, with the heavy beds of limestone of the upper Carboniferous, a tremendous mass of light-colored crags, which dominate the whole of the valley of upper Ruby Gulch, and are indeed its most conspicuous feature.

The relations existing along the ridge from New Years Peak through Pyramid Peak are illustrated in the following figure:

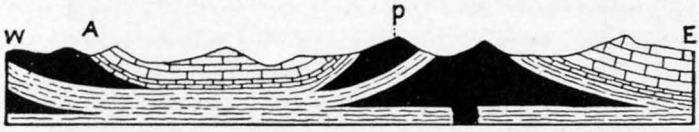


FIG. 39.—East-west section through New Years and Pyramid peaks. Porphyry in black; Cambrian in broken lines; Siluro-Devonian in small blocks; Carboniferous in large blocks. A, New Years Peak; P, Pyramid Peak.

The drainage channels from the porphyry masses have cut out the Cambrian slates on both sides, forming strike gulches, as may be seen by reference to the map. As these gulches descend everything becomes covered with porphyry slide-rock, and the relations of the strata are best seen on the exposed backs of the spurs. The Silurian limestones surrounding these intrusive masses of porphyry have been considerably altered and mineralized by deposition of quartz in places, formation of calcite nodules, etc. This has led to their being prospected, and in one place considerable work has been done, but the mine has not yet advanced beyond the prospect stage. So far as geologic conditions indicate, there is no reason why ore bodies should not be found in connection with these porphyry masses and their contacts.

PYRAMID GULCH.

This is the next tributary to Boyd Creek on the north side above Ruby Gulch. In many respects it resembles the latter. Like it, it has a dry drainage channel, the water passing underground its whole length, and even in flood time appearing on the surface only in its upper course, the lower part showing a dry, grassy meadow without stream channel. In its longest course it extends from Pyramid Peak to Boyd Creek. A number of drainage channels come into it from the east, none from the west. The dry, steep gulches leading down from the mountain converge into a short, rocky canyon with limestone walls as the sharply turned-up beds of the Paleozoic are passed. A deeply cut, narrow valley, with both walls of porphyry, succeeds, and as it then passes out into the Jurassic formation the valley opens into the general one of upper Boyd Creek, the pines of the upper course giving place to the groves of aspen and thickets of the lower country.

The mass of porphyry which is here cut through, as may be seen on the geologic map, lies intruded between the steeply upturned beds of the upper Carboniferous, which have been tilted not only by the Pyramid Peak intrusion but also by the great laccolith of Alpine Creek and the lighter, softer strata of the Jurassic. As will be shown in the course of this paper, and as may be seen by inspection of the geologic map, this horizon plane has been frequently the seat of igneous intrusions.

On the west side of Pyramid Gulch this porphyry rises into a prominent wooded hill which dominates the general lower basin inclosed by the higher Carboniferous ridges and traversed by Ruby, Boyd, and Pyramid creeks. Around the western and southern base of this hill the sharply tilted strata of the Jurassic and Cretaceous are seen pushed back by the intrusion, away from the Carboniferous. At the south base of the hill there is a little saddle, and the spur again rises into another subordinate shoulder of porphyry, which terminates it. In this saddle are found the Jurassic and Cretaceous, with dip toward the south; in the space of a few yards the sandstones of the Jurassic are found, with strike northwest and dip northeast, against the beds just mentioned, and it seems altogether probable that the faulting of the Jurassic against the Cretaceous, which has been mentioned as occurring about a mile up the valley, is continued, passing through this saddle and dying out in the meadows to the east. At least the trace of it is there lost.

Other drainage gulches coming into Pyramid Gulch from the east side have the same character mentioned above where they cut through the porphyry mass. The contacts of the porphyry have been prospected, but no large amount of work has yet been done. There is a considerable quantity of good timber in the gulches and on the spurs, but the entire lack of water in the stream channels is a great drawback to mining. Water is found by digging wells in the porphyry débris bottoms. The nearest surface water in summer is found in springs in the Cretaceous shales to the west. On the east side this mass of porphyry also ends in a gulch, but in its upper portion, where it comes in contact with the Carboniferous formations, it has thrust itself into them in intruded sheets, which are separated by long masses of limestone wedging out into the porphyry and altered by the contact. These relations are best seen on the crest of the spur, where three intrusive sheets are to be found. The porphyry of this mass is of the usual whitish-buff or light-brown, altered, chippy type.

The other little intrusion of porphyry mentioned above, which is south of the high hill, appears to be an eroded remnant of a sheet or thin lens intruded into the Jurassic beds and tilted by the rising of the large, low dome to the west, which has been already described. The porphyry is similar in character to that of the larger mass to the north, but contains occasional large phenocrysts—that is, porphyritic

crystals of feldspar. It forms a small wooded knoll, with light-colored slopes of porphyry débris.

In the gulch which limits the large mass of porphyry to the southeast, and where it is intruded among the limestone beds in sheets, is seen the northwest edge of a tilted dome in the heavy Carboniferous beds. The breadth of this low anticlinal dome or blister is not much more than a half mile. It lies tilted up at a low angle on the generally domed-up beds of the Paleozoic which slope down to the west from the high divide ridge running north from the triangulation point shown on the map, a mile north of Flat Mountain. The attitude of the beds forming the blister is precisely like that of an inverted saucer resting on the roof of a house. It is caused by a lens of porphyry intruded among the heavy Carboniferous beds, a horizon which has only in a few cases been the seat of intrusions of igneous rock. At the upper edge, near the ridge, the erosion of the beds has peeled back the cover, allowing the edge of the porphyry lens to appear, and it may be seen curving round on the map. In nature it is beautifully seen from above, the long, bare, light-colored slopes of the Carboniferous limestones contrasting strongly with the protruding edge of the porphyry, whose course may be readily traced by the dense and almost impenetrable thicket of young pole-pines growing on it. Several minor gulches which cut across this low dome dissect it excellently for a study of its structure, but they do not penetrate deep enough to reach the porphyry below. At that spot on the dome where the beds are horizontal, eroded and broken-down remnants of a sandstone of a light-gray color are found. The area is well wooded with young pines, and the relations, so far as can be told, would seem to indicate that a small area of Jurassic is still lying uneroded on the Carboniferous. Below this point on the hill the drainage has cut a small, narrow canyon into the back of the anticline, exposing a beautiful descending arch in that horizon of the massive Carboniferous which forms a persistent ledge near the top of the formation. Of course only a very small segment of the circle is shown, but the radius of the curve can not be far from 100 feet.

The spur on the outer edge of this tilted dome and next to the large porphyry mass to the west which has been already described is very nearly a strike spur. In descending it one crosses the formation at an acute angle and passes over the whole section as the crest of the spur curves to the south, passing from bare limestones to the wooded beds of the Jurassic, and finally, in the valley, nearly reaches the top of the latter formation—a little hillock that ends the spur, showing the characteristic bed full of gryphæas, which makes such a valuable reference plane in this formation.

A cross section of this almost concealed lens of porphyry is shown in the geologic cross section A–A of Pl. LXXXII.

In the valley of upper Boyd Creek, between the Ruby and Pyramid

drainage areas, there lies a rounded, wooded hill, shown on the map by a single contour. This hill is nearly the central point of a very small domed uplift, quite similar in character to the large one 2 miles or so to the west. It is believed to represent a small concealed lens of porphyry. The structure is shown at a number of points where the outcrops of the Jurassic are found dipping away from the hill at moderate angles. Just north of the hill there is a very low divide, over which a road passes from Ruby Gulch to Pyramid and upper Boyd creeks. North of this divide there are some hills and a ravine or two in which exposures of the rocks give a moderately good section, showing the upper Jurassic, and also a thin sheet of intruded quartz-bearing porphyry, which lies conformably in the strata. Beyond this the Jurassic comes against the Cretaceous, and as the two dips are opposed to each other within a short distance, it is believed that the fault already mentioned must pass through here, to die out in the meadows below.

The top of the central hill, which exposes the lowest beds in the uplift, is wooded and covered with soil and vegetation. Everywhere on it one sees fragments of a dove-colored, thin-bedded, chippy lime-

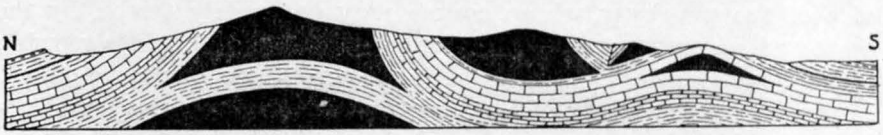


FIG. 40.—North-south section through peak east of Pyramid Peak. Black=porphyry; lower broken lines=Cambrian; smaller rectangles=Siluro-Devonian; larger rectangles=Carboniferous; upper broken lines=Jurassic and Cretaceous.

stone. No fossils were seen, and it is uncertain whether the beds are Jurassic or upper Carboniferous. A little area of Carboniferous has been shown on the geologic map.

Some of the relations which have been discussed can be better seen from the accompanying section (fig. 40), which is drawn almost north and south through the porphyry peak next east of Pyramid. The section is swung a few degrees west of south to cut the different porphyry masses.

UPPER BOYD CREEK.

Upper Boyd Creek is closely followed from its mouth to its source by the mail road from Lewistown to Giltedge, which passes over the high divide just north of Flat Mountain. From its source in the springs which rise under the shadow of Kelly Hill to its mouth as it empties into Big Spring Creek it is a running stream throughout the year, small at first, but greatly reenforced by underground waters which burst up as springs in its bed. As one follows up the mail road, he finds the red earths and sandstones of the Dakota group everywhere prominent, the dry drainage channels descending to the creek being little canyons with cornices and buttresses of these sandstones.

The valley bottom, while not wide, is fertile and well ranched. Eventually the last and lowest sandstone is reached, that above the coal, which ascends from the creek in a long, prominent ridge covered with pines, which turns westward and passes over the south limb of the domed anticline already described. Across the stream rise the high, pine-covered slopes of Kelly Hill. The valley bottom is here cultivated, and the color of its soil changes to a deep black, due to the coal and coal shales whose outcrop crosses the stream at this point. The Kelly ranch lies in the meadow just above. The coal which is under this sandstone ridge, if of good quality at this point, should be in a favorable attitude for working.

Kelly Hill.—Following the road, one sees the steep slopes of Kelly Hill rising more and more abruptly until, on its north side, they ascend sharply, with but little talus, from the valley bottom to a quite imposing crest several hundred feet above. They are composed of the light-colored limestones of the Carboniferous. The gulch is cut in the Jurassic beds, and these may be seen as wooded hillocks resting in normal position on the flanks of the bare white limestone

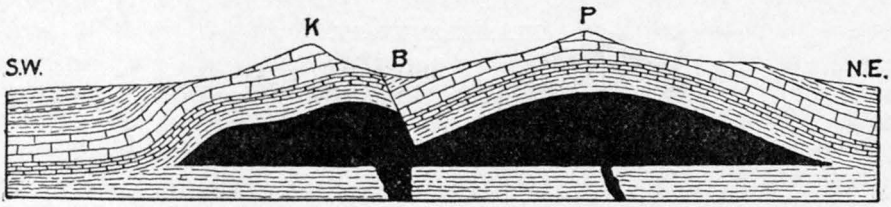


FIG. 41.—Cross section through Kelly Hill (K) and A point (P) 2 miles northeast. (Explanation as under fig. 40, opposite.) B=Boyd Creek.

spurs coming down from the high triangulation peak. It is therefore clear, to one seeing this imposing wall of limestones of the Paleozoic rising so sharply above the Jurassic, that a fault must exist here. Toward the divide it may be seen that the fault dies out in the massive Carboniferous in the end of a synclinal fold, the massive outcropping ledges showing the turning and gradual change of dip of the strata. The dry limestone gulches at the head of the valley contain a considerable quantity of excellent timber, which, however, is being rapidly cut off.

If the slope of the hill is followed around to the southwest, crossing some dry gulches full of copsewood, the Jurassic beds finally appear, and beyond them on the hillside the red earths of the Dakota. On the west slope there is a small spring-stream which passes through a gateway in the sandstone, a road from below also ascending at this point. On the slopes of this hill the beds are again found in their normal position and the fault has died out. The dip of the beds here is about 30° a little south of west, and the succession of the outcrops shows the coal sandstone with the red beds beyond it in very close proximity to the upper Carboniferous. It seems clear that the

rise of the anticlinal dome, with the bulging and compression of the sedimentary beds, has slipped back the soft shale layers of the Jurassic and Kootanie, bringing the Carboniferous and coal sandstone very near together, with but little intervening Jurassic. From here southward the beds resume their normal relations, dipping away regularly from the south arm of Flat Mountain. They are cut through by several wooded gulches, while the coal sandstone, which forms its usual wooded ridge in facing toward the mountain, gradually rises to the divide running southward beyond the limit of the district shown on the map and separating Boyd Creek from McDonald Creek drainage areas.

From phenomena studied elsewhere in the Judith Mountains, it appears most probable that Kelly Hill is due to an intrusion of porphyry in the Cambrian shales, which, along the north limb of the dome, has lifted the beds with so much force as to rupture them and to raise them until the Carboniferous is brought against the Jurassic. It seems probable, also, that the intrusion is connected with that of the triangulation-point dome, as shown in fig. 41 (p. 499).

FLAT MOUNTAIN.

This is the large flat-topped elevation which is the most southern one shown on the map. From it there runs southward a divide which is much lower and which passes into a group of hills most inappropriately known as the Little Snowies, foothills of Big Snowy Mountain. Flat Mountain is, both topographically and geologically, the southern terminus of the Judith Mountains. On top it is somewhat gently undulating, with open, park-like spaces alternating with groves of small pines and stretches of white, level-lying limestones. On the outer slopes of the mountain these limestones are very apt to break down into a low cliff, and from the open country to the east, to the south, or to the southwest, these long lines of white ledges of the upper Carboniferous are very conspicuous, and sharply define the mountain as they rise above the dark pine-covered talus below. These ledges are in the main defined by the 5,000-foot contour line, which passes around the mountain. The streams, and notably McDonald Creek, have cut back into these limestones, forming large amphitheaters, with walls of the light-colored rock. Below the outer débris slopes are those of the Jurassic, which form the upper part of the foothill country. Beyond this is the Kootanie, with the prominent wooded ridge of the coal sandstone. On the various branches of the heads of McDonald Creek these formations are deeply trenched into a series of wooded ravines, presenting a country highly accidented on a small scale. The numerous sandstone outcrops dip down the streams and often form descending ledges. Below the coal sandstone, along the streams, the red beds and sandstones, which are stratigraphically above it, are everywhere prominent and conspicuous.

All of the main channels on the southeast side of the mountain contain running water, and the country is well ranched. An excellent road, coming from Lewistown, passes over the divide and down McDonald Creek. No porphyry of any kind is found in this portion of the mountains, and it is not seen in the stream gravels. The Kootanie beds, as shown on the map, cross the divide, extending to the edge of the mapped area. South from here the limestones of the Paleozoic are again seen in a prominent hill, and on the main road along a fork of McDonald Creek, not seen on the map, the Cretaceous is faulted against the Carboniferous, the stream at one point cutting the fault line. At several points here the coal has been prospected and mined to some extent, the gentle outward dip of the bed, with its usual elevation on a ridge, placing the seam in a favorable attitude for working. Further details are given in the economic chapter, p. 614.

On the east side of Flat Mountain there is a small subsidiary anticlinal dome in the Jurassic, partly denuded of the Cretaceous. It is dissected by one of the branches of Chippewa Creek, the south fork cutting across it. It is not over a half mile in diameter, and the swinging round and the changing of dip of the heavy sandstone beds enable one to perceive it almost in one view. It is doubtless caused by a small concealed lens of porphyry, very probably at the base of the Jurassic beds, a favored horizon for intrusions.

Flat Mountain itself is evidently a large single laccolith, or a series of laccoliths forming one of the compound type, whose Paleozoic cover has not yet been broken through. Very probably, like the Burnett laccolith, it lies in the Cambrian shales, but it appears to be of a broader and less thick lenticular type. It appears probable that the Kelly Hill uplift is part of the same set of intrusions.

This portion of the mountains, though it has been prospected, does not appear so far to have yielded anything to encourage further work, a fact not surprising when one considers the close connection in this region of the ore bodies with intrusive masses of porphyry or their contacts. Flat Mountain must probably yet undergo a geologic period of erosion before its riches, if it contains any, shall be revealed.

RIDGE BETWEEN FLAT MOUNTAIN AND ALPINE CREEK.

North of Flat Mountain is the divide crossed by the Lewistown-Giltedge mail road. It climbs up through the wooded, dry, limestone ravine at the head of Boyd Creek and, crossing an open flat on the top, winds down through similar steep ravines toward the open country below. North from this divide rise the bare, treeless, white slopes of the triangulation-point peak, covered in places with a scanty growth of grass, but in other spots bare, and exhibiting in its outcropping ledges the geologic structure. On the peak the strata are horizontal, or nearly so, but from this point they dip away in all directions, and the peak represents the center and highest point of a domed

anticlinal uplift. Dry, narrow gulches in the limestones dissect it on either side to the east and west. It appears to be caused by an intruded mass of porphyry not yet revealed, and is so shown in the section A–A of Pl. LXXXII.

North of this the upper edge of the tilted lens of porphyry, heretofore described, appears upon the ridge covered with a thick growth of pine; beyond it the Carboniferous is again found. From here various gulches lead down into Whisky Creek. They are all dry, however, and in reality there is no stream, the drainage course, with its various heads, and especially that one which leads up to the edge of the great Alpine laccolith, being familiarly known as "Whisky Gulch." After the uniting of the various channels there is a short canyon leading out through a limestone gate into the open basin of Jurassic and Cretaceous beds. The main ridge passes on northward, with occasional craggy outcrops and slopes of upper Carboniferous limestones showing through the pine trees, until the intruded masses of porphyry and upturned Cambrian shales of the Alpine laccolith are reached.

The ridge has been prospected at a number of places, but none of these prospects have been carried to a point which would indicate that anything valuable had been found.

THE ALPINE LACCOLITH.

By reference to the topographic map it will be seen that Alpine Creek, one of the head branches of Warm Spring Creek, drains an interior basin surrounded by a horseshoe-shaped ridge or divide. It is true that this divide varies in elevation, and that it is broad in some places and very narrow in others, but in the main it follows the horseshoe outline quite closely. It is thus precisely like the basin at the head of Burnett Creek, which has been already described, but is somewhat larger, being about 2 miles across from crest to crest at the greatest width of the oval and nearly 3 miles long.

Viewed from any of the high points which command the outer rim, this basin presents the appearance of a very wide and shallow funnel, cut on every side by descending and converging ravines separated by long spurs with generally narrow and sharp crests, and which in a number of cases, as they descend into the bottom of the basin, form small hills which stand as points on the spur ends. This huge, shallow, ridged bowl presents a very dark and somber appearance, due to the thick growth of small pines which covers nearly every part of it. Occasionally a small patch of gray slope is covered with shale débris or a red-brown streak of porphyry talus, but in general a hue of somber green is everywhere to be seen. The trees which produce it are of varying age; sometimes in the bottoms of the ravines they are of good size, but generally they are small, closely set, and difficult to penetrate, while considerable areas of the porphyry are covered with young trees about an inch or two in diameter, which are packed

together with a closeness almost beyond belief, and a description of which would seem incredible to one who had not actually seen them. Such areas are absolutely impenetrable without the use of the ax. Fortunately for geologic purposes, the prospectors have cleared paths through them in various directions.

From what has been said, it will be seen that the Burnett Basin is quite similar to the Alpine. It is, indeed, so to speak, an epitome of it, both topographically, as already shown, and geologically, as will be described. The Alpine Basin is, however, much larger, more complicated in its geologic structure, and less easy to study on account of the denser vegetation.

From the wagon trail from the main highway which passes down Warm Spring Creek up the Alpine Creek Valley, the slopes of the high prominent hills are seen to be composed of Carboniferous limestone with white ledges and outcrops, which at the entrance to the basin narrow down to the stream. They hardly produce a canyon, but rather a deep, V-shaped valley with occasional heavy outcrops of rock along the sides, talus slides, or pine-covered slopes. Through this the stream runs—a noisy brook with a moderate volume of water even in the driest part of summer, the narrow valley bottom through which it passes everywhere cut up by placer works and diggings. The occasional rock outcrops are seen to be, first, the upper part of the massive Carboniferous, which, as usual, forms a projecting ledge with strata dipping downstream—i. e., north, at an angle of about 30° to 35°; along the stream occur outcrops of the Paleozoic series, then an intruded mass of porphyry dipping with the strata and tunneled by prospectors, and lastly the dark-greenish conglomeratic slates of the Cambrian, intruded with a sheet of porphyry, which, rising along the slope, covers the latter with its talus.

The main valley continues deep, narrow, and wooded, with an occasional prospector's cabin, and wherever rock exposures occur they are of porphyry—a rotted, or at least always greatly altered, rather dense, quartz-bearing porphyry, of a rusty, reddish-brown color, much crackled and breaking into small angular débris, the usual type of the mountains. On either side narrow gulches of the same wooded character come in, with occasional porphyry outcrops and a small thread of a stream running in the bottom. This continues to the foot of a rather prominent porphyry hill which stands in the bottom of the valley and is shown on the map. The main stream divides at this point into two forks, into each of which the usual small gulches come down. Both are of the same narrow type, with porphyry débris, and are thickly set with small timber and often encumbered with fallen logs. As these gulches ascend there are open areas on the slopes facing south, the soil made up of fine gravelly débris of porphyry or fragments of the greenish-gray Cambrian shale.

No productive mines have as yet been developed in Alpine Creek,

but considerable placer mining has been done, and in several places prospecting of the contacts has been carried on, described more fully later (p. 606).

If one follows the divide, which heads all of the converging gulches around in its horseshoe curve, taking the road which leads upward through the dry limestone ravines from Maiden to the P. K. mine as a starting point, one finds that the sedimentary beds, wherever they occur, dip away from the center of the interior basin at angles of from 30° to 40°, and the strike thus in general follows the outline of the divide. There are some exceptions to this rule, where intrusions of sheets or lenticular masses of porphyry have locally disturbed the general structure of the beds, but in general it becomes evident that the ridge is geologically similar to that of Burnett Creek, and that the whole structure is that of a domed anticline whose top has been cut off and then hollowed out, crater like, by erosion. Continuing up the road mentioned, one passes various intrusive sheets of the rotted quartz-bearing porphyry. Pekay Peak is topped by a crag which gives a magnificent view over the mountains to the east. It is composed of Carboniferous beds, shown by the character of the large corals the rock contains. On the south side of the porphyry hill is the Globe or P. K. mine, to which also an excellent road runs around on the inside slope, past the War Eagle mine, to join the main one coming up the gulch, and affording, where cut back into the hillside, sections of the Paleozoic rocks and intruded sheets of porphyry. In this portion of the uplift the Siluro-Devonian beds are either greatly thinned down by slipping in the uprise or are wanting; they are certainly not clearly to be found and recognized, as on the opposite crest across Alpine Creek. Beyond the P. K. mine—that is, south of it—greatly altered limestone occurs on the divide, and then beyond this the divide is rather broad and variable in height and is composed of masses of porphyry which are the tops of intruded sheets coming up diagonally over the spurs and gulches from Alpine Creek below.

On the outer side, to the southeast below, the massive Carboniferous has retreated down the slopes, and south of Pekay Peak amphitheaters and dry gulches have been cut in the heavy limestones leading down into what is locally called Virgin Gulch; and at the point on the divide above mentioned these gulches are cut at their heads in porphyry, a broad mass of which crosses the spurs, and in Cambrian, whose rough, craggy outcrops of indurated conglomeratic slates and thinly bedded limestones form infrequent but characteristic exposures. As is usual with such gorges, the final gorge of Virgin Creek passes out into the open country through gates of upturned upper Carboniferous limestone. Where the Cambrian occurs on the divide it is open or sparsely clothed with trees, the slope being covered with the broken, chippy débris of the greenish or purplish gray shales. The porphyry, as previously mentioned, is densely clothed with young pine·

Careful search for Cambrian fossils in these beds resulted only in the finding of a minute shell, strongly resembling an Obolella, and in one of the limestone layers fragments of a trilobite. Beyond here to the south another intruded sheet of porphyry advances to the divide and occupies its crest for a long distance.

A wagon trail has been cut through the dense pine, that leads eventually to an open hill on the divide composed of the Cambrian slates, which here show a local disturbance from the general structure, for they strike nearly south and dip 20° W. A spur puts out from the divide, which rises into a peak, called Giltedge Peak, the spur forming a divide which separates the head drainage of Giltedge Creek from the most southerly ravine draining into Virgin Creek. Outward on this spur the grass-covered Cambrian gives place to the dark limestones of the Siluro-Devonian, with a very thin intruded sheet of porphyry, which in turn gives place to the Carboniferous, the latter forming the crag that marks the top of the peak. This, like Pekay Peak, contains numerous fossils, corals, crinoids, etc., but seldom well preserved.

From the open hill of Cambrian slates, which here forms the highest and most conspicuous point on the divide, a long spur runs southeast, dividing Giltedge Creek and Whisky Creek drainages. On this spur crest the Cambrian gives place to porphyry, which is succeeded by Cambrian, and then by the remaining Paleozoic beds, with sharp dip to the southeast. The main divide from this hill sinks rapidly about 200 feet to that portion of the divide which separates the heads of Whisky and Alpine creeks. This is all of porphyry, extending a long distance into Whisky Creek, all the upper gulches at this point being cut in it. On the north side all the head gulches of Alpine Creek are cut in it, and in Alpine Basin all is porphyry, either down the spurs or the drainages. No sedimentary beds are to be found until the upper western slopes of the basin are reached.

As shown on the geologic map, here is found the boundary of an immense mass of porphyry, whose uncovered or exposed portion is of a rudely elliptic outline, which is, roughly estimated, about 2 miles long by 1 mile broad. This represents the upper portion of the main Alpine laccolith, which underlies the intruded sheets and smaller lenses. On both sides of this divide the surface of the porphyry is very irregular and cut into by sharp V-shaped gulches; the slopes are apt to be covered with gravelly débris of rotted porphyry. No prominent outcrops of porphyry are seen; it is broken down into masses of rather small, platy blocks. The rock itself is of a rusty-brown to pale-pinkish color, and is somewhat variable in different parts of the mass, passing from a rather dense porphyry to a form more granular, filled with small feldspar crystals with much less or no quartz and some black spots of a hornblende or pyroxene, and resembling closely in all essentials the porphyries or porphyrites which compose so large a number of our western laccoliths.

The contact of this porphyry mass in the head of Whisky Gulch has been explored, and there are several prospects located upon it, but they have not been sufficiently developed as yet to rank as mines.

From this portion of the divide there are steep slopes to the high points where the divide runs southward to Flat Mountain, heretofore described. Cambrian shales, with intruded masses or lenticular sheets of porphyry, are again met with, similar to those south of the Pekay mine. The spurs that lead down into Pyramid Gulch show the normal succession of the bedded rocks, dipping at sharp angles down the spurs; occasionally thin sheets of porphyry are intruded in them. A number of prospects are located at the contacts on these spurs, but no active development work is being carried on. This character of the divide, or mountain crest-line, continues to the point where Pyramid, New Years, and Alpine creeks head against one another. The spot is marked by a heavy crag of Carboniferous limestone on the divide, the rock there being filled with ill-preserved corals. Just below here, on the slope toward Pyramid Peak, there are deposits of a soft, earthy, red hematite or red oxide of iron, mixed with hard nodules, in the limestone. The material has the brilliant-red color of the brightest red ochers, and has been prospected. A little of this red ocher will color a considerable area of limestone. There is not sufficient of it to make it of any technical value.

The geology west of this locality, toward Pyramid Peak, has been already described. Northward, on the Alpine Creek divide, there is a sharp descent, over porphyry and then Cambrian, to a low saddle cut in porphyry. The heavy limestones of the Carboniferous are seen turning here on several spurs in the direction of their strike. They form the prow of a synclinal boat between the anticlinal dome of Pyramid Peak and the western side of the Alpine uplift, as shown on the map. The porphyry which forms the low saddle is part of an intruded sheet; it is of the usual brownish, rotted type. The divide from here northward rises gradually and is so exactly a repetition of the western side or crest of the Burnett horseshoe ridge that it is unnecessary to repeat the details. A high, prominent hill on it is composed of an intruded mass of porphyry. The rest of the divide is mostly over the Siluro-Devonian rocks, the section of which given in Chapter II was made here. Toward the north the ridge passes over into the Carboniferous, and from here to the point where it slopes down into Warm Spring Creek Valley it is entirely in that formation. On the western side of the basin the inside slopes are mostly of Cambrian, with intruded sheets of porphyry, as shown on the map. These upper slopes are generally open, covered with débris of porphyry, shale, or limestone from the various rocks above; as they descend they begin to be scored by the heads of the inside ravines. Throughout all this part of the region large outcrops of rocks are wanting except when the main porphyry approaches the creek, when it is

exposed in some heavy crags. In several places there are heavy slides of porphyry from ascending sheets. Very little prospecting work appears to have been done on these western slopes of the basin, and it is locally considered an unpromising area.

From what has already been said it is now clear that the Alpine Creek dome is due to the intrusion of a great laccolith of porphyry, and that it is precisely similar to the Burnett laccolith. Its history seems to have begun with the intrusion of sheets and lenticular masses or laccoliths of small size in the Cambrian; eventually one of the lower of these became larger and larger, lifting the sediments and their contained sheets and lenses. The intrusion of these latter had already lifted the strata somewhat; the intrusion of the great mass below completed the domed uplift as we now find it. As at the Burnett dome, erosion has cut away the upper portion of the cover and dissected out the crater-like bowl, but the dissection of the crest line in relation to the heavy limestones has been more irregular than at the Burnett dome. The geologic structure is shown in the section, fig. 42 (p. 509), which is taken northwest and southeast directly across the middle of the dome, and it will be seen that it is precisely similar in principle to the Burnett dome and laccolith (fig. 37, p. 490).

NEW YEARS CREEK AND VALLEY.

This valley, called locally New Years Gulch, after the New Years mine, which is located on the crest of one of the spurs leading into it on the west, lies between the mountain upraise of the Burnett anticline and that of Alpine, which has just been described. Essentially it is in geologic structure a synclinal half-boat or prow, and this structure is modified only in its upper part by the intrusive masses of Pyramid Peak, which have disturbed this symmetric arrangement in the lower series of strata. As can be seen on the map, the coal sandstone, which circles around the northwest foot of the Alpine dome, takes here an incurve, and then passes to the west around the Burnett dome. It forms here, as usual, a high, conspicuous, wooded ridge. Inside of this is the Jurassic series, which is either cut down into meadows or, where it crosses the spurs, forms a conspicuous sag or small saddle. When not in the valley bottom it is generally covered with open groves of heavy timber. Above are steep slopes of Carboniferous limestone, which rise rapidly to the crest line. The main valley inside of the coal sandstone forms a rather flat-floored open basin, from which several valleys branch out, which are dry and do not even show in places any stream channel.

On the western side another drainage channel passes through a wooded and copse-covered bottom, into which several gulches from the Carboniferous slopes empty. This is separated from the open basin mentioned by a spur which, ending in the Kootanie beds with

the coal sandstone, forms a dark, wooded hill in the valley mouth. Above it the Jurassic saddle forms a very low divide, over which a wagon trail passes. A road leads up the west branch and, ascending steeply by one of the spurs, a short distance below the top of the divide it attains the New Years mine. At this point a sheet of quartz-bearing porphyry of the usual altered type is intruded in the Carboniferous limestones. The beds dip steeply down the spurs away from the Burnett dome, and the porphyry appears to be intruded conformably in them. The sheet consists of soft, disintegrated material without outcrops, and is so covered in places by limestone débris that its thickness can not be given, but it must be considerable. The same remark might be applied to nearly all the intruded sheets of porphyry in this region. The sheet mentioned appears in the next spur west, and forms long talus slides in the intervening gulch. Below this there are at least two and probably three other sheets intruded in the limestones. The New Years mine is mentioned in the economic part of this paper (p. 607). The spurs east of this locality are of quite similar character, and also contain a sheet of intruded porphyry. The gulches between these spurs are dry, and it is not until the Cretaceous beds near the mouth of the gulch are reached that the water attains the surface, in springs, whose branches uniting form a small brook, which is New Years Creek proper. This runs down through an open country composed of the Dakota beds, and, cutting through the anticlinal upraise on Warm Spring Creek, joins that stream.

The country between Warm Spring Creek and the mountain is well adapted to ranching and stock raising, and has the usual character of the rolling, open foothills of the Cretaceous formation.

GILTEDGE CREEK.

By reference to the geologic map it will be seen that the sedimentary beds between the debouchment of Maiden Creek on its open alluvial plain (or, in other words, the mouth of its canyon) and the eastern slopes of Flat Mountain make a great infold, similar in character, in some respects, to that in New Years Gulch, which has been described above. On the map this structure is best seen in the Jurassic and Kootanie, which curve in a great arc. About the middle of the chord of this arc lies the town of Giltedge. The beds are upturned in the central part of this curve by the Alpine laccolith, and the structure is seen in the cross section shown in fig. 42. This half-bowl has three drainage systems—Virgin, Giltedge, and Whisky creeks. The former and latter have been already described.

The main drainage of Giltedge Creek comes down through a very deep, steeply cut V-shaped ravine, which extends back to the main Alpine divide. It is full of timber, and its sides and bottom are full of the débris of the Carboniferous limestones in which it is cut. The spurs on either side are also covered with clumps of pines or show

white limestone ledges. Several sheets of porphyry are intruded into these limestone beds, and their outcrops are found on the crests of each spur. This character continues till the top of the Carboniferous is reached. The massive beds then form heavy outcrops, and are seen as ledges descending transversely across the slopes of the ravine. At this point a heavy sheet of porphyry has been intruded in the lighter, thinner beds above the massive Carboniferous. It appears to be conformably interbedded, and its strike is northeast, its dip southeast, like that of the limestones. The porphyry sheet appears on the crests of both spurs; its outcrop ascends diagonally, and, as usual, is apt to be covered by a heavy growth of pines. Situated on this porphyry and at its contact with the limestone are the Giltedge, Chickadee, and other mining properties, which are described in the economic portion of this paper (p. 607). The porphyry itself is, as near as can be told, of the usual quartz-bearing type. It is very greatly altered; so much so in places that it is changed almost to a clay nearly capable of being worked with a shovel alone.

The outer ends of the Carboniferous limestone spurs descend in

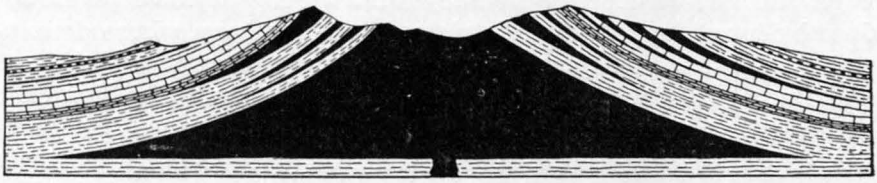


FIG. 42.—Northwest-southeast section through Giltedge Peak and Alpine laccolith. Black= intrusive porphyry; broken lines=shale; rectangles=limestone.

a sharp slope, generally wooded, to the foothills of Jurassic beds. The stream channel coming down does not cross these beds directly, but, deflected by the sandstone at the top of the Jurassic, and more especially the heavy coal sandstone above it, it follows the course of this interior moat-like valley for nearly a mile or so southward, when, eventually cutting through the coal sandstone ridge, it debouches on the open plain. This valley is of a narrow, shallow character, with an alluvial bottom, composed mainly of débris of Jurassic and Kootanie shale, with thickets of bushes. Up it the ore road from the Giltedge mill to the mine passes. The coal sandstone forms its prominent wooded ridge. On the north end of it the Giltedge mill is situated, as shown in Pl. LXXXVI. It strikes to the south here and dips perhaps 20° E. The coal for running the engine at the mill is mined here, and the seam has been opened in several places.

The mail road from Lewistown to Giltedge, descending the limestone ravines of the south fork of Whisky Creek, on reaching the open country at the Cretaceous area, turns northward along the shallow valley inside of the coal sandstone until it reaches the main Whisky Creek, when it follows the stream out through the sandstone gate

and turns northward over the red soils of the Dakota beds to Gilt-edge. This town, which is an active little mining camp, is situated on the creek that bears its name. It is on the Dakota beds, whose red soils are everywhere prominent in the roads and cuttings about the town.

In the open Cretaceous plains country, east of this portion of the mountains, the various drainages are of the seeping character described in the previous chapter, and along their course numbers of ranches are situated. The volume of water is not sufficient for extensive irrigation, but the moist bottoms along the drainage channels yield excellent crops of vegetables or cereals adapted to the climate.

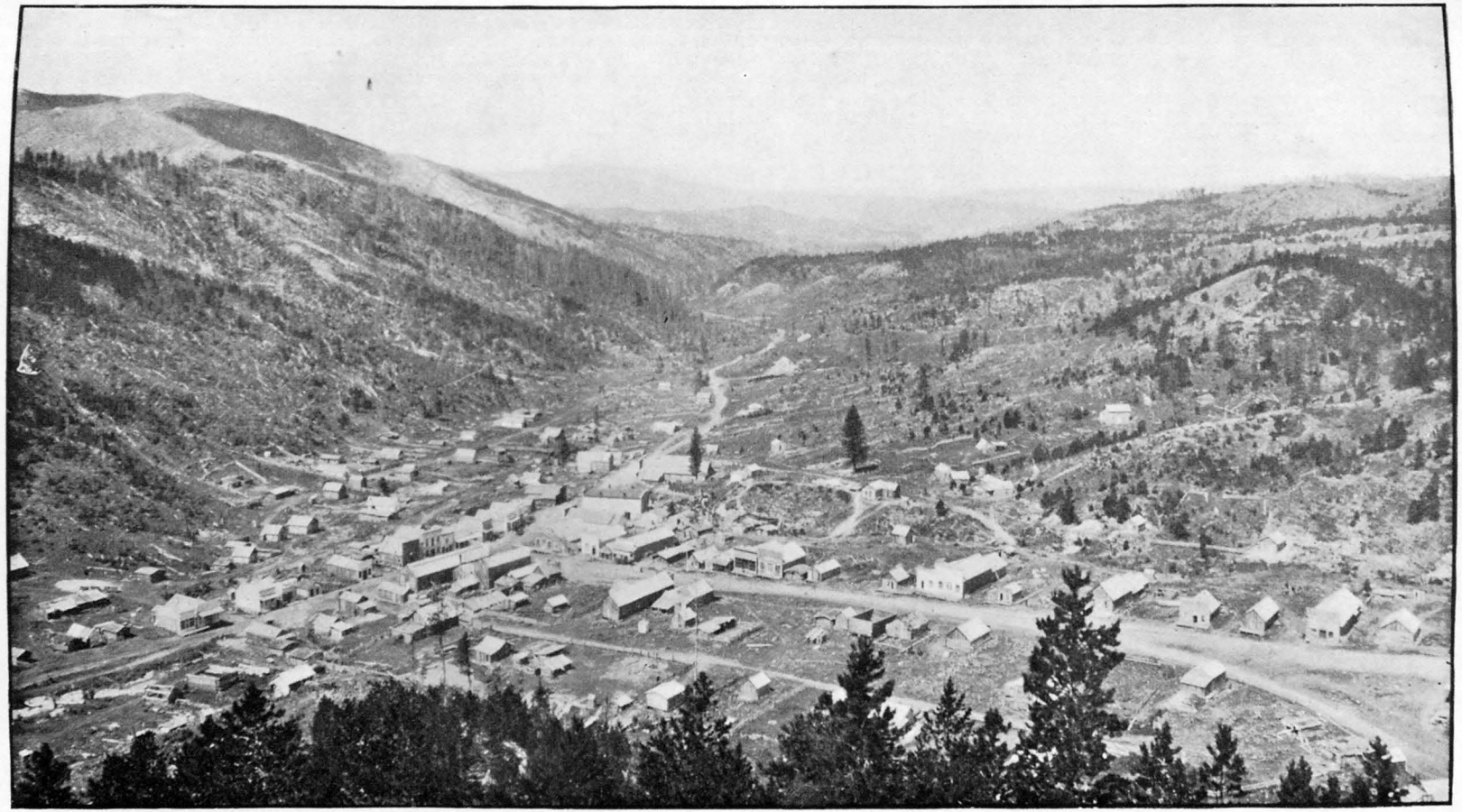
THE MIDDLE PART OF THE MOUNTAINS.

UPPER WARM SPRING CREEK AND VALLEY.

The valley of upper Warm Spring Creek is, near its head, narrow and deeply cut, and between it and Maiden Creek Canyon there is a low divide, crossed by the mail road from the town of Maiden to Gilt-edge. These two deeply cut valleys and the low divide separate the Judith Mountains into two districts, a southwestern, whose descriptive geology has been given in the preceding portion of this chapter, and a northeastern, the subject of the following one. The division is not only topographic but also geologic, since the area to the southwest is characterized by a certain simplicity of structure, its main features being determined by the three great intrusions of the Flat Mountain, Burnett, and Alpine laccoliths, while the district on the northeast is of a much more complicated character, both in its topography and in its geology, for although its structural features are due to intrusion of igneous rocks there is considerable variety both in the character of the intrusions themselves and in the nature of the igneous rocks composing them.

Briefly stated, the valley of upper Warm Spring Creek is due to the cutting out and erosion of soft shales lying between upturned strata of resistant limestones on one side and intruded masses of porphyry on the other.

The limestones, which compose the southern side of the valley, are of upper Carboniferous age. They form the northern slope of the Alpine anticlinal dome, caused by the intrusion of the large Alpine laccolith. To the east of the Alpine uplift there is another intrusion of porphyry, which has domed up the strata. This will be described later. It is here sufficient to say that between these two uplifts there has been an infold of the strata, in character similar to that of New Years Gulch, but forming the synclinal prow of a longer, shallower, and narrower boat. The symmetry of this has been greatly disturbed, however, by intrusions of porphyry, which have destroyed part of it entirely and so thickened other parts by sheets that the structure is



MAIDEN, FROM THE EAST.

not at first evident. The infold, however, has brought the Cretaceous far up the valley to the very divide at its head. On the south side of the valley erosion has cut away the less resistant strata until the massive Carboniferous has been reached, and its outcrops form ledges whose white imbricating outlines are a conspicuous feature. They are fairly well shown in Pl. LXXVII, on the left. Alpine Creek has cut through them at one point, and toward the head of the valley they are scored by a number of dry ravines leading down from Pekay Peak, and which are indicated in a general way on the map (Pl. LXIX).

At the head of the valley the dip of the limestone begins to flatten out, and the strike swings round from southeast to east and then to the northeast. At this point, which is on the divide between Warm Spring and Maiden creeks, the limestone reaches the prow of the synclinal boat, and it is at a very low point on the divide. It is here cut off abruptly by the intrusive mass of Gold Hill porphyry, the Maginnis mine being on the contact. The last outcrop of the limestone is seen resting as a large tilted block on the divide above the Maginnis mine; it is well shown on Pl. LXXXIV, all to the left of it being of porphyry. The wooded character of these steep limestone slopes is well shown on the left of Pl. LXXVII. Generally speaking, this portion of the Alpine dome—its outer Carboniferous slopes forming the south wall of Warm Spring Valley—is nearly free from intrusive sheets of porphyry, and in consequence, although considerable prospecting has been done in the limestone, no important ore deposits have been developed.

The Jurassic beds, above the Carboniferous, as is so generally the case in these mountains, have been stripped back from the uplift, on account of the soft, erodible nature of the shale horizons, and now form the valley bottom, the limestones, affording small ostreas, and of typical Montana Jurassic aspect, being found in and above the road leading down to Warm Spring from Maiden, where they form small craggy outcrops on the ends of the little spurs coming down from the north. This road and the extreme ends of the little spurs a few feet above it are shown in Pl. LXXVII, and the central portion of the town is on the Jurassic. Above this are the Kootanie and other Cretaceous formations, which also follow the Jurassic up the valley. The intrusions of porphyry they contain will be mentioned later. Both the Jurassic and the Dakota-Kootanie are carried up to the divide in a tilted and somewhat warped condition. On either side the Jurassic has been cut down, as usual, into a gulch, so that these beds, as seen on the geologic map, are left resting in the curved prow of the Carboniferous limestone boat as a tongue-shaped mass, the extreme end of which appears as a tilted pine-covered table of the heavy sandstone over the coal. The road from Maiden to Giltedge, in ascending the divide, passes up a gulch cut in these Cretaceous beds, and the road-cutting affords a section of them. Thus, in ascending, one passes

over the red earths and sandstones of the Dakota, and then the black shales, coal, and sandstone of the Kootanie, in regular sequence. The coal has been prospected here, and also in the head of the valley below; but it appears in an unfavorable condition for profitable working. The outcrops of the Jurassic beds, being exposed on both sides of the tongue, cross the divide twice, and in both places cause a low saddle in it. As usual, a sheet of porphyry has been intruded into these beds, and its outcrop follows around through the most southerly of the two depressions. The Jurassic of the extreme end of the tongue forms the usual gulch between the Carboniferous of the west slopes of Sheep Mountain and the coal-sandstone table mentioned above. This gulch forms the extreme head of Maiden Creek. The divide is seen in fig. 43.

To the north this divide rises into the rounded eminence of Gold

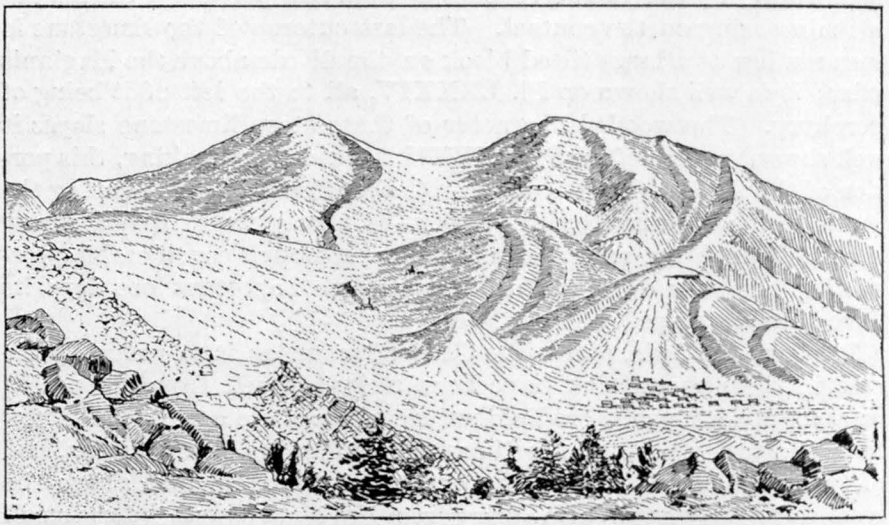
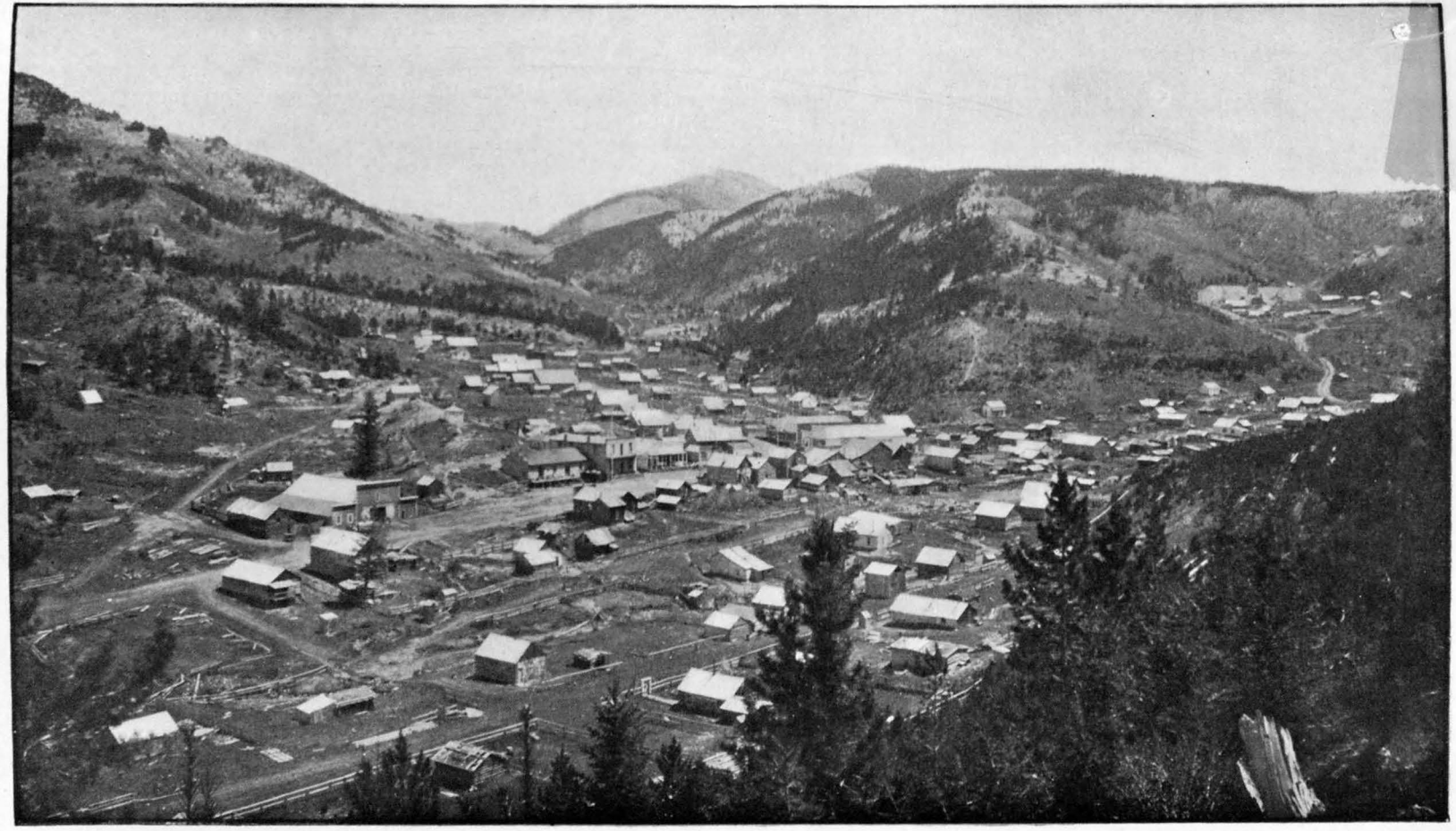


FIG. 43.—Sketch of Sheep Mountain (on left) and Pekay Peak, seen from slopes of Maiden Peak.

Hill, composed entirely of porphyry. This portion of the intrusive mass does not have the character of a sheet or laccolith, but is shown by its contacts, by the variety of formations it breaks through, and by its relation to the geologic structure, to be of the nature of an intrusive stock. Its contact with the limestones at the Maginnis mine is irregular, the plane of contact shading in toward the porphyry, as shown in fig. 54 (p. 600). Above the town of Maiden, to the northeast, a couple of gulches are cut back into this porphyry, and one of them leads by a low divide over into the beautiful park at the head of the Spotted Horse branch of Maiden Creek. Beyond this divide the porphyry continues into the high point of Maiden Peak. This porphyry is greatly altered; it weathers down into a gravelly débris in which rock outcrops are rarely seen; a few occur on the sides and at the top of Maiden Peak. The character of its smoothly modeled, pine-dotted slopes is well shown in Pl. LXXVIII.



MAIDEN, FROM THE WEST.

The north slopes of upper Warm Spring Valley present a highly accidented surface, and are cut by a series of narrow, deeply trenched V-shaped gulches, separated generally by spurs having narrow crests alternating with prominent shoulders. They are composed of the Cretaceous beds in their regular stratigraphic order, but tilted to the north and greatly thickened and swollen by intrusive sheets of quartz-bearing porphyry, as shown in the cross section C–C of Pl. LXXXII. The porphyry forms the knobs, or shoulders, while the softer shales retreat, forming saddles on the spurs. In following down the crest of the spurs from Maiden Peak to the town below, as many as twelve of these sheets have been counted, of varying thickness. It would appear as if the sheets did not remain everywhere of the same thickness, but swelled out into thicker lenticular masses in places; but this is difficult to decide positively, as the Cretaceous shales almost never show any outcrops, but weather down to a soft soil, which the porphyry slide-rock easily covers. In the side gulches the talus slides of several sheets may coalesce, so that a large intrusive mass appears to be present. The sandstones of the Dakota group are most useful in this connection; they show the relations of the sedimentary beds, and that they are dipping northeast or normally away from the Alpine dome. It is possible that several of these sheets may run into one thicker one, but, for the reasons given above, this can not be positively determined. The sheets appear to have produced very little action in the shales; the latter are, directly at the contact, somewhat indurated, but at the distance of a few feet the effect is lost. The sandstones do not appear changed at all. The intrusive mass of Maiden Peak has indurated the black Benton shales to a greater extent, but considering the size of the intrusion the effect seems small.

The highest Cretaceous beds shown in this ridge are the Benton shales, which are best seen in several exposures near the heads of the gulches and on the divide west of Maiden Peak. At the latter place a cut bank exposes a considerable thickness of them. At this point they are somewhat indurated and of a dove color. One layer contains fish scales; no other fossils have been found in them. In these shale areas in the gulches springs break out, and each gulch contains a little rivulet of cold water.

The character of these long, narrow spurs running down into the valley, with the occasional porphyry knobs on them, is well shown in Pl. LXXVII, on the right-hand side. The one of these knobs highest up in the valley is that which forms a little conical peak just above the town of Maiden (see fig. 43); it is below of porphyry, then sandstone, and lastly porphyry to the top. On the side toward Gold Hill it is separated from the latter by a very low-cut saddle composed of shale. It is seen in Pl. LXXVIII, just back of the town and a little to the right of the middle of the view; the saddle mentioned is seen on its right. Between the small conical peak and Gold Hill in the background lies a little basin, scored by gulches, back of the Maginnis mill.

The variety of porphyry composing the sheets which have been described is the usual type—a rotted, altered porphyry of pale-brownish to white or pale rusty-red color, showing occasional quartzes of the size of coarse shot embedded in it. The rusty colors are due to the decay of some former iron-bearing mineral, such as hornblende or pyroxene. The variety of the intrusion of Gold Hill is similar, but in places varies somewhat, the quartzes disappearing and large feldspars, up to one inch long, occurring as phenocrysts. They are well crystallized and weather out of the rock, so that specimens as perfect as crystallographic models, showing also Carlsbad and Manebacher twinning, may be picked up in the gravelly débris. They are most numerous on the slopes of Maiden Peak.

Phonolite-porphyry.—On the north side of Warm Spring Valley, below the town of Maiden, is a large, well-defined intrusive area of a variety of porphyry of phonolitic habit. It forms one of the spurs known as Cemetery Hill. The outcrops of the porphyry are extremely large, heavy, and massive, and where broken down the rock produces masses of huge bowlders. Everywhere it is surrounded by soft shales, and no definite relation of the igneous rock to the stratified beds could be determined; it may be a broken-down sheet or an intrusion of dike-like or stock-like form. Toward the northeast the boundaries of the mass narrow, and eventually one sees only occasional bowlder-like outcrops leading to the divide. On the divide itself (between Warm Springs and North Fork creeks) are two well-defined dikes of the same rock, which pass down the slope toward the North Fork, and one occurs west of here in the edge of the steep grass-covered slope leading down into Warm Spring Creek.

The rock found in Cemetery Hill and in the Smelter Gulch is of a greenish color, with large white feldspars abundantly scattered through it. A close inspection shows small, glittering, black prisms of pyroxene, or dark, bronzy plates of mica; these minerals are embedded in a greenish groundmass. The rock is a variety of the phonolite family, and might be called an ægirite-syenite-porphyry. The other dikes mentioned are of similar character, but much denser in grain and of dark-greenish color. They are a variety of phonolite, and might be properly termed tinguaite-porphyry. They are described in Chapter V, p. 567.

NORTH FORK OF WARM SPRING CREEK.

Standing on the north slopes of Maiden Creek and looking down into the valley of the North Fork of Warm Spring Creek, one sees an open, basin-like valley with a rather flat floor descending toward the west. On all sides this valley appears shut in by mountain walls with sharply descending slopes. Sometimes these steep mountain sides are open and covered with grass, sometimes with dense and crowded growths of young pines; often they show long, brown slides of porphyry talus.

The valley bottom alternates with open fields or groves of tall timber. Many springs run down from different sides, their courses marked by lines of trees or tangled thickets of willow and black alder. The most striking feature in its scenery is the huge mass of tall, red-brown crags which rise precipitously from its slopes toward Judith Peak, and which are known as the "Chimneys." They form one side of a stock of granite-porphyry to be described later. From nearly every point this mass of huge crags dominates the valley.

The geologic structure of the North Fork Valley is simple. It consists of a mass of soft Cretaceous beds surrounded on nearly all sides by intrusions of porphyry. Erosion has cut away the soft shales of the Cretaceous forming the valley floor, while the more resistant masses of porphyry are left standing as its steep walls.

The spur between the North Fork and the main stream consists, as noted before, of black Benton shale, which is exposed at a low point or saddle west of Maiden Peak. A rude wagon trail from Maiden to the North Fork Valley and the Lincoln ranch crosses the ridge at this point. West of this locality porphyry is again found on the divide, and it continues to the end of the spur, which is cut by two narrow, transverse dikes of phonolite-porphyry of the tinguaite variety. On the north side this porphyry mass descends in a long, steep slope of porphyry talus, thickly covered with young pine, to the creek below. The igneous rock crosses the stream, and for half a mile or so the North Fork, after leaving the open, upper valley, runs down through a small, narrow canyon cut in it. The stream is a rather small, swift-running brook, whose clear pools contain small trout. On its south and west slopes this porphyry mass descends in talus slides and has large areas of broken-down rock in place; the outcrops are so cracked and broken that it is difficult to recognize them as such. Toward the south a long tongue protrudes from the mass and reaches nearly to the highroad passing up Warm Spring Creek. So far as can be told, this mass is not intrusive in the Cretaceous beds as a laccolith or sheet, but is erupted through them as a stock or chimney, the difficulty in the determination being due to lack of exposures of the soft Cretaceous beds with which it is in contact.

South of this porphyry, at the forks of the little branch of Warm Spring Creek and but a short distance from the contact, coal has been mined. It does not appear to be of good quality or favorably suited for working at this place, but its presence is of importance in locating a definite horizon of the Cretaceous—the Kootanie.

The central part of the valley of the North Fork contains a number of porphyry knobs which appear to be exposures of sheets. No definite outcrops of the Cretaceous are seen, but the disposition of the beds, with their frequent terrace-like aspect, shows clearly by the topography that they are of Cretaceous character.

At the eastern head of the valley the upper slopes are of porphyry

débris from the intrusive masses of Maiden and Big Grassy peaks, which are separated by a low divide containing Cretaceous sandstone. On the east and north the entire upper slopes are of porphyry, cut in the great mass of which Big Grassy and Judith peaks are a part. Near the edges of this mass, and especially near the Chimneys, the Cretaceous shales are somewhat indurated by the igneous rock, but still fail to give good exposures. One feature of the Cretaceous beds in this valley is the frequency with which masses of the soft shales have slipped along the slopes, producing little cornices or shelves.

The northern branches of the stream rise in the grassy upland meadows and basins cut in the porphyry between Judith and Porphyry peaks, one of which, the most westerly, flows down past Porphyry Peak, after leaving the mountain meadows, through a steep ravine full of porphyry talus, and, passing a long spur, joins the main stream as it issues from its canyon. This long spur, which is wooded with open groves of large timber, is everywhere covered with bowlders and broken-down masses of a light-colored syenite-porphyry, sprinkled with large feldspar phenocrysts. Cretaceous beds were not actually found exposed on this spur, but the topography clearly indicates their presence. After this large branch joins it, the North Fork flows through a pleasant, open valley, passing at times through heavy copses in the bottom, or the fertile meadows of the Dougherty and other ranches, to join the main stream of Warm Spring Creek.

BALD BUTTE AND THE WARM SPRING CREEK DOME.

After the North Fork joins the main Warm Spring Creek the stream flows through a bushy, alluvial bottom, having a number of excellent ranches on either side, the waters of the creek and of the side branches that come in being used for irrigation. These small streams head back in springs rising in the Cretaceous foothills and rarely run dry.

The North Fork joins the stream at the point where the coal sandstone crosses. The latter forms a low ridge, but on the south side of the creek, just back of the Wocasek ranch, it rises into a high, dark, wooded hill of the usual type. Below this, to the southwest, the country is open, level, and ranched, belonging in part to the New Years Creek Basin, heretofore described. On the north side of Warm Spring Creek, between it and the North Fork and west of the latter, there is a long ridge of Cretaceous beds running down to the valley, which appears to be a strike ridge from the attitude of the beds, composed chiefly of the Dakota, trending southwest and dipping about 20° NW.

Northwest of this spur the country is much broken, cut into numbers of narrow gulches, usually open and grassy, but with occasional patches of pines. There are several ranches here. In this area there are a number of intruded sheets of porphyry, some of which form shoulders and points, and the topography is precisely similar in its

main features to the shale and porphyry slopes of the hillsides north of the town of Maiden, already described, and these features are due to a similar intrusion of sheets of porphyry into Dakota beds. Several excellent exposures of the sandstones in this little group of hills are to be found. They gradually rise to a high, flat-topped ridge forming an open, grassy divide between the North Fork and the heads of Deer Creek, which is crossed by a wagon trail. This ridge passes into a craggy ledge of porphyry which runs toward the northwest and finally culminates in Bald Butte.

Bald Butte is a high, conical hill composed entirely of porphyry and covered with plates of the broken rock. It is quite bare and devoid of vegetation, a fact which has evidently suggested its name. Standing thus elevated and dominating all the open country to the north and west below, it is a very conspicuous object and was evidently one of the landmarks of the old freighting road from the Missouri River to Helena, which passed along the north side of the mountains. It is mentioned under the same name in the report of the Ludlow expedition in 1875 by Dana and Grinnell (see p. 471).

The structural relations of the sedimentary beds to this mass of porphyry are very difficult to ascertain, since no exposures of them are to be seen in connection with it. The porphyry may be intruded directly through the strata without reference to bedding, or it may possibly be the remnant of a thick lenticular laccolithic mass. The former supposition seems more probable. The rock composing it is generally altered, but where found in fresh exposures it is seen to be a syenite-porphyry of a pale-buff to gray color, with numerous small, indistinct, white feldspars and many small black prisms of hornblende embedded in it.

The Dakota beds, in which the numerous sheets of porphyry mentioned above have been intruded, appear to dip away from the small anticlinal dome which has been cut through by Warm Spring Creek. In following down the main road along the stream, when opposite the porphyry hills to the northwest above, one passes over the red clays of the Dakota formation and soon close under a heavy mass of tilted sandstones. Beyond this the road forks, one branch going toward the right, over to Deer and Armell creeks, while the other keeps on down Warm Spring Creek and is the highroad to Lewistown. At this point there is an area of hilly country through which Warm Spring Creek cuts its way. This tract is due to the doming up of the strata by a laccolithic intrusion, as already mentioned, and its dissection by Warm Spring Creek affords excellent means for its study. As shown on the map, the upraise has brought the Kootanie to the surface, and within it the Jurassic and top of the Carboniferous formations. The intrusion of the porphyry has taken place in the lower shale beds of the Jurassic, but below there must be concealed another one which has brought up the Carboniferous.

The heavy sandstone mentioned above is that just over the coal; at the point indicated it dips sharply northeast and forms a high ridge. The outcrop is extremely massive, weathering the usual light-buff and pink colors, and it passes northward over a hill, where it is cut through by a little spring stream. At this point the coal seam under it has been prospected. It passes up the side of the ravine and emerges on an open, rolling country, the strike of the outcrop bending to the west. On this table-land the outcrop forms no prominent ridge, but is easily traced by its débris. The road to Armell Creek crosses it. East and north—i. e., above the sandstone—appear the red clays and sandstones of the Dakota formation. The outcrop of the coal sandstone gradually bends southward, again assuming its ridge-like character and passing down a ravine, of which it forms one side, and reaching Warm Spring Creek about 1½ or 2 miles below the point where it left that stream. Where the creek cuts across it there is an alluvial flat, and the outcrop is here for a short distance lost, but on the other side of the creek it immediately reappears, assumes its character of a high wooded ridge, and, running eastward with a slight southerly curve, forms a continuous rampart or bluff along the south side of Warm Spring Creek, until eventually it disappears in crossing the stream to the point where it was originally met. This long ridge is cut through at one place by New Years Creek, and at a point perhaps a half mile west of that stream a gulch or ravine has been cut back in it, and here the coal has been mined and considerable work done. This is mentioned later in the economic chapter (p. 616). The thickness of the sandstone bluff over the coal is about 30 feet at this point.

From what has been said it will be seen that the outcrops of the coal sandstone form a rude circle, over a mile in diameter, through which Warm Spring Creek has cut its way. Inside of this circle and stratigraphically under it are the beds of the Jurassic formation. The limestones are well exposed at the forks of the road, and their outcrops may be traced up the hill toward the coal sandstone. They exhibit the usual section, and the thinly bedded limestones contain ostreas and gryphæas. The little stream descending from Bald Butte has trenched a short, narrow ravine through these limestones, and on the west side of it they rise in a wooded hill, domed up by the intrusion of porphyry. The outcrops may be traced up the hill and out on the table-land to the north. Inside of the Jurassic and on the north side of the stream the intrusion of porphyry forms a high hill, which rises probably about 300 feet above the stream, its steep front extending almost a mile. The highroad runs directly at its base. It is cut into on this south front by one prominent and several minor gulches, and the crest line at the top is undulating. On its face, fronting the stream, there are sedimentary beds below, then shales and calcareous sandstones, with porphyry above them to the crest. In the

main gulch outcrops of altered argillaceous limestone occur, dipping gently back into the hill. At the top fossiliferous Jurassic limestones are found, and an inspection on the north side—that is, the back or upper surface of the laccolith—shows that the sedimentary cover is, geologically speaking, just on the point of being stripped off. In most places it is very thin, and in some the porphyry is exposed nearly down to the table-land below, where the upward-facing outcrop of the Jurassic beds, with a sharp dip to the north, is clearly seen, while

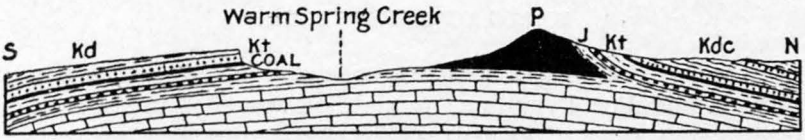


FIG. 44.—North-south section through the Warm Spring anticline. Kd, Dakota sandstone; Kt, Kootanie sandstones and coal; P, porphyry; J, Jurassic; Kdc, Dakota and Colorado groups.

a little farther west it suddenly ascends the hill again nearly to its crest, covering up the porphyry. The main mass of the sediments, however, produces a curving gulch, which descends to Warm Spring. These relations are shown in fig. 45, while a north-south section is given in fig. 44. From this it is evident that Warm Spring Creek has cut away nearly one-half of the laccolith and its cover, and this portion is now replaced by a narrow alluvial flat. Since Warm Spring

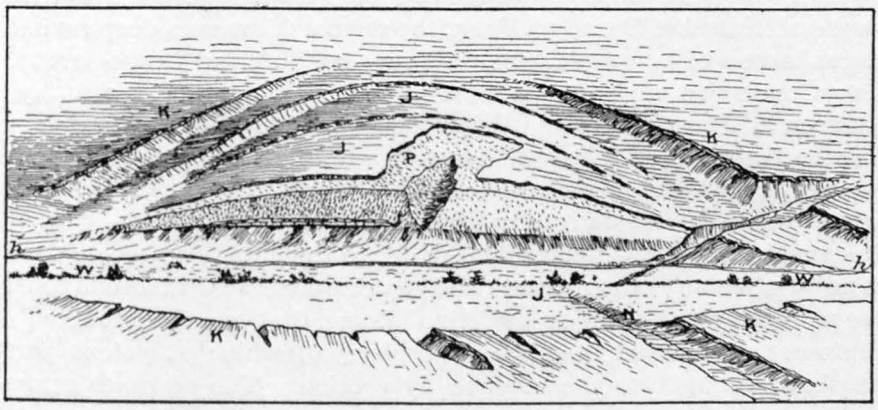


FIG. 45.—Stereographic sketch of Warm Spring anticline and laccolith. Looking north. J, Jurassic beds and outcrops; K, Cretaceous beds and outcrops; P, porphyry of laccolith, dotted; W, Warm Spring Creek; N, New Years Creek; h, road.

Creek has not been deflected by this dome and forced to go around it, we must conclude that it is an antecedent drainage.

The rock of this laccolith is a very fine, dense, quartz-bearing porphyry of the usual type, much altered, of light-buff to brownish color, and generally broken into small, chippy fragments or weathered to a gravelly débris. It does not present any bold or prominent outcrops.

There does not appear to be any extensive contact metamorphism produced by the intrusion. In the main gulch, facing Warm Spring

Creek, the lowest sediments exposed are dark, chippy shales, much indurated, and it is believed that these are the soft greenish shales of the Jurassic, which form so many stream courses or are weathered so commonly into saddles on the ridges throughout the mountains. The lowest beds exposed in the anticline are believed to be those at the top of the Carboniferous; they are the yellow, earthy, arenaceous beds which form the top of the section and are exposed at one point on the bank of Warm Spring Creek, where a ditch-cutting begins.

HEADS OF DEER CREEK.

The western heads of this stream rise in a hilly country north of Bald Butte and Porphyry Peak, which is formed of Cretaceous beds cut into by a number of small gulches that afford but few exposures of the rocks, grassy hill-slopes, wooded ravines, and meadows everywhere prevailing. As in the valley of the North Fork, heretofore described, the porphyry either comes down in a mass of slide-rock from the upper elevations to meet the grassy Cretaceous slopes, or, if the slope is not too pronounced, forms of itself a grassy upland with gravelly soil. Thus in general, while the boundaries of the porphyry are easily traced, its structural relations to the Cretaceous beds are not clearly defined.

In the branch of Deer Creek which heads directly north of Porphyry Peak, near the point where the forks come together, less than a mile northwest of Porphyry Peak, the stream trenches a deep ravine, which is seen to be cut in black shales, probably the Benton group. Gray Cretaceous sandstones are found in other gulches, and red clays are seen in the valley below. What the structure of this valley is can only be surmised, but general considerations lead to the belief that the porphyry bears no definite relation to the structure of the sediments, but is intruded directly through them.

Deer Creek dome.—Somewhat farther to the north, however, there is no question as to the attitude and structure of the Cretaceous beds; they are elevated into an anticlinal dome, that must undoubtedly represent a concealed laccolith of porphyry of which as yet no part has been brought to the surface by erosion. The distance across the surface of the dome is somewhat over a mile. It appears to be chiefly the Dakota formation which is exposed, though the Kootanie probably comes to the surface in the center, and is so shown on the map. The structure is clearly shown by the sandstones of the Dakota, which form a series of revet hills disposed in concentric circles, each hill with an abrupt face turned inward and showing a section of the strata, but having a long slope to the outer side, where the backs of the beds are seen. In other words, each hill is a monocline, dipping away from a common center. The red clays of the Dakota are prominent on the backs of the hills. The west fork of Deer Creek is deflected by this anticline

and flows around it in the moatlike or encircling valley. From the high porphyry point southeast of it the structure of the anticline is clearly revealed and a most excellent bird's-eye view of it obtained. This porphyry itself, which is a part of the great Judith Peak mass, appears to have been intruded through the strata without regard to the anticline and to have cut into its southeast limb. It is in contact with sandstones which form a sort of terrace around the porphyry at this point, and these sandstones dip inward toward the porphyry, or rather outward and normally away from the center of the anticline without regard to the porphyry, with which they come into contact. On the south the strike is northeast, changing to north as one advances northward along the front face of the porphyry. A number of small drainage channels coming down cut through the sandstones, forming small gateways and giving good exposures. One of these streams, as shown on the map, cuts directly through the center of the anticline. The present road from Warm Spring Creek to Armell Creek passes along the west and north sides of this domed anticline, and from it excellent views of the little revet hills and upturned sandstones of the Dakota formation may be obtained.

East fork of Deer Creek.—The porphyry mentioned above is a protrusion to the northward of an apophysis or tongue-like mass from the great Judith Peak mass, to be described later. At this point it rises in a hill, descending on the north side in craggy, precipitous masses to a saddle, whence it again rises a little, to the crest of a spur which descends northward into the open country, the spur being wooded and covered with porphyry débris. On the east side of this spur there is a deep ravine full of springs rising in a bottom made of step-like masses of black shales, probably of the Benton group. Above, to the south, the porphyry forms a sort of terrace, and as soon as its edge is reached the descent through the shales is rapid. This ravine joins a larger one, which seems to carry the main head of the stream and is cut back into the porphyry, forming a wooded gulch, which reaches back and upward to the mountain meadows on the porphyry northwest of Judith Peak.

On the east side of the stream limestones appear on the hillside, and a little dry cross-gulch, not shown on the map, which comes in from the northwest, gives an excellent exposure of them. They rise along the hillside until, eventually, at the point where they cease, they form a high and rather precipitous crag, which marks their extension to the south. At this point they are in contact with the porphyry and are whitened and bleached by contact metamorphism. The strike here is nearly north and south, the dip west. The wooded slopes above are all of porphyry. This mass of limestone, shown by exposures elsewhere to be of the upper Carboniferous, is, in its total area, considerably over half a mile across, and the exposed portion has the shape of a tilted spoon. Around the upper contact of lime-

stone and porphyry the strike is found to change to nearly east and west, the dip being north. Only at its southern point, mentioned above, does the limestone show any noticeable contact alteration.

Several small dry ravines have been cut into this limestone, and form head branches of the east fork of Deer Creek. One of these shows on each side of the ravine long exposures of the massive Carboniferous as a continuous ledge. Each of the ridges between these ravines invariably shows a considerable mass of porphyry intruded above the Carboniferous, and beyond this appear the beds of the Jurassic, sharply tilted back, and lastly the Cretaceous, whereupon the spur ends in the open country. It thus appears that the great block of Carboniferous which has been torn up and bent back by the porphyry intrusion is also completely surrounded by porphyry. The porphyry, in advancing on either side and intruding between the Carboniferous and Jurassic beds, has lifted the latter and thrust them away from the Carboniferous. These relations are shown in the cross section, fig. 46.

The end of this exposure of the Jurassic formation appears to round into the gulch on the west, where it dies out under the edge of the

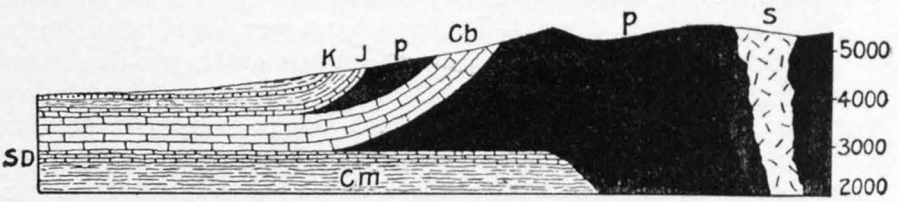


FIG. 46.—Section northwest and southeast through foothills and mountain summit 2 miles northwest of Judith Peak. K, Cretaceous; J, Jurassic; Cb, Carboniferous limestones; SD, Siluro-Devonian limestones; Cm, Cambrian rocks; P, porphyry; S, syenite. Figures represent heights above sea level.

advancing Cretaceous. On the north and east the Jurassic beds are carried across the end of each spur and there turn toward the south, where, as usual, they form a strike gulch, and do not appear until they reach the spur that separates this drainage area from that of West Armell Creek. The porphyry lies inside of this Jurassic series and forms the crest of the spur which advances back of the limestone block to a high point, shown on the map. Beyond and stratigraphically above the Jurassic the Cretaceous follows it round, but on the northeast side there is a heavy intrusion of porphyry in these Cretaceous beds, which has been eroded into two sharp conical hills, shown on the map, with lesser crags of porphyry connecting them. They are held to be the uneroded part of a tilted laccolithic mass intruded in the Cretaceous at this point. The sandstones and shales into which it has been intruded show considerable induration and hardening by contact metamorphism. The Cretaceous beds of the open country to the north are weathered down and show no outcrops, but about a mile due north of the porphyry hill last mentioned there is a considerable amount of

broken-down porphyry, in heaps and bowlders, which would appear to be the remnant of a sheet intruded in soft Cretaceous beds.

The porphyry which composes all the masses at the head of Deer Creek, while usually much altered, is by no means so thoroughly decomposed as most of the quartz-bearing porphyries which have been described as occurring in these mountains. It is of a reddish to brownish-gray color and in a fine base contains numerous large feldspar phenocrysts and smaller ones of black hornblende or pyroxene. It may be called a syenite-porphyry. It would be classified under the Big Grassy type described in Chapter V (p. 564).

WEST ARMELL CREEK.

The mass of porphyry mentioned above as forming the two little hills is stripped of its Cretaceous cover at its most easterly point until West Armell Creek cuts past it, the igneous rock reaching to the stream. Above this mass is a gulch cut in Cretaceous shales, with a fine spring in the lower end of it. Above, in this gulch, the Jurassic appears on the little spurs, as seen on the map, the porphyry still above it. It appears to take a very sharp bend here, and the gulch running down to the West Armell is cut in it.

The main stream itself, before cutting through the Cretaceous, has a well-defined canyon in Carboniferous limestones; it is the second largest and longest canyon in the mountains, that of Maiden Gulch being first. Above these limestones comes the porphyry of the Judith Peak area, in which the head forks of the stream have cut some large amphitheaters, described later in connection with this porphyry mass. A general survey through the canyon and from the hills on either side and the mountains above shows that in the main there is here another heavy block of tilted limestone, quite similar in its chief characters to that on Deer Creek, described heretofore, but of three or four times the area. Observation shows, further, that this mass has its edges bent up near the porphyry intrusion; that it then flattens somewhat in the center, owing to intruded masses of porphyry under it, and that finally, on its northern boundary, it dips down sharply under the sediments above it. How thick the mass of limestone here exposed is it is difficult to say, but the part that is most prominent is the heavy, massive series near the top of the Carboniferous, and there must be several hundred feet of these limestones exposed. On the east side of Armell Creek these beds are cut through by a number of dry gulches which come down from the porphyry of the long ridge above and pass into the main canyon through gateways of the limestone formed by imposing crags. These limestones are somewhat altered and mineralized, and in one exposure above the forks of the creek was the Cave mine. (See p. 610.) On the other side of Armell Creek—the southwest side—the limestone rises in several spurs which run back toward Judith Peak. On one of these spurs, near the contact

with the main porphyry, an intrusive sheet is injected, while on the next spur east, between the forks of the creek, there is an intrusive sheet of syenite-porphyry about 15 feet in thickness, and this is cut by a dike of phonolite-porphyry. Nearer the forks of the creek, below the occurrence mentioned, another dike of this phonolite-porphyry penetrates the limestone; by alteration, however, it has been leached of its iron contents and changed to a light-colored clay, whose nature would not be recognized if the feldspar phenocrysts and the structure, being perfectly preserved, did not reveal its identity. It has been prospected for gold, which it carries in small quantity.

In the main canyon itself a considerable mass of porphyry is exposed on the south side of the stream at and below the forks. It is covered with a heavy growth of timber, and is easily distinguished in this way from the more open limestone areas above and around it. It underlies the massive Carboniferous and is evidently the top portion of the mass which it conceals.

Ascending the stream channel from the open country, one finds the following succession of exposed beds:

Beds exposed in West Armell Canyon.

No.

13. Black shales, containing a heavy intruded sheet of porphyritic tinguaite (phonolite-porphyry), about 10 to 12 feet thick, and carrying numerous immense feldspar phenocrysts, some being 4 by 2 by 1 inches; weathers reddish, and is seen only on east side of stream. Black shales, believed to be the Benton group, baked and indurated near the contact.
12. Interval marked by prominent gulch on both sides of stream.
11. Shales, with intruded sheet of porphyritic phonolite (tinguaite), which is about 4 feet thick.
10. Interval marked by a little gulch.
9. Outcrops of a sandstone, weathering to bright-red soil.
8. Interval of about 75 feet.
7. Sandstones, perhaps 100 feet in thickness, indurated at bottom, but passing to a sugary character at top, of a light-gray color, but weathering buff.
6. Series of shaly, argillaceous, calcareous beds, considerably altered, but not so much as No. 4.
5. Dove-gray limestones, which are believed to be Jurassic, though no fossils could be found in them.
4. Shaly beds, baked to tough green and black adinoles, containing a layer of impure marble about 1 foot thick, probably Jurassic shales.
3. Porphyry sheet intruded, about 300 feet thick, rising into hills on either side of the stream.
2. Massive Carboniferous limestones, which extend a long distance and in which the canyon is chiefly cut.
1. Porphyry under the massive Carboniferous.

No positive definite section is attainable, but the above gives an idea of the succession of the beds and their character as seen. The porphyry is the usual altered type. It is noticeable that both the porphyry and the phonolite have metamorphosed the sediments above them much more than those below.

One other feature of West Armell Creek deserves notice, and that is the deposit of limonite which occurs on the west fork of the stream, near its contact with the porphyry of the main mass. The deposit is described in the last chapter (p. 614). West Armell Creek is charged with iron salts, which are deposited as a whitish to pale-brown carbonate in its bed.

Below the canyon the creek broadens out and ranches appear in it. An exposure of the modern stream deposits near the mouth of the canyon shows about 15 feet of well-bedded clays, gravels, etc., very red from iron ore. In one place they have been washed for gold with some success.

SPOTTED HORSE GULCH.

Beyond the smoothly modeled slopes of porphyry and Cretaceous shales which are seen on the left in Pl. LXXVIII is the beautiful mountain park at the head of Spotted Horse Gulch, which lies between Maiden, Big Grassy, and Crystal peaks. It shows an evenly floored basin, whose sides gradually rise in long, smooth slopes to the divides between the peaks mentioned. Toward the south the basin begins to slope down more rapidly, and between Crystal Peak and Gold Hill it assumes the character of a deep, narrow valley, which passes into a deeply cut V-shaped ravine that, turning more and more to the south, ends in Maiden Canyon.

In the upland basin, at the head, under the slopes of Big Grassy and Maiden peaks, rise many springs, which flow down in small, cold rivulets. In the early summer the long, moist slopes are richly decked with a wild luxuriance of grasses and many-colored, delicate wild flowers, or interrupted here and there by clumps and groves of dark-green pines. All is fresh and verdant. It is a natural garden whose pleasing features are in strong contrast to the wide horizons of arid plains country whose heat-hazed distances are seen from any point on the basin's rim.

A wagon trail leads into this park from the town of Maiden, and others pass into and down Collar and Spotted Horse gulches. They are not impassable, which is the best that can be said for them.

The upper portion of this basin is cut entirely in the porphyry of the Gold Hill-Maiden Peak intrusive mass. There are no exposures of this porphyry to be seen except on the south slopes of Maiden Peak. It is everywhere weathered down into a soft, reddish-brown, gravelly débris, which affords smooth slopes. On the divide between Big Grassy and Maiden peaks this uniformity of porphyry is interrupted by the occurrence of Cretaceous sandstones. Unfortunately, the outcrop is so broken down into débris that it affords little evidence of the relations of the porphyry to the sandstones. The latter continue up the slopes of Big Grassy Peak to an elevation of 150 feet above the lowest point on the divide. They are indurated almost to a quartzite,

are of a clear-gray color, and are to be told from blocks of porphyry only by close inspection. Above them is the porphyry of Big Grassy Peak, the most southern extension of the great Judith Peak mass. These sandstones, with occasional outcrops in place, are to be traced

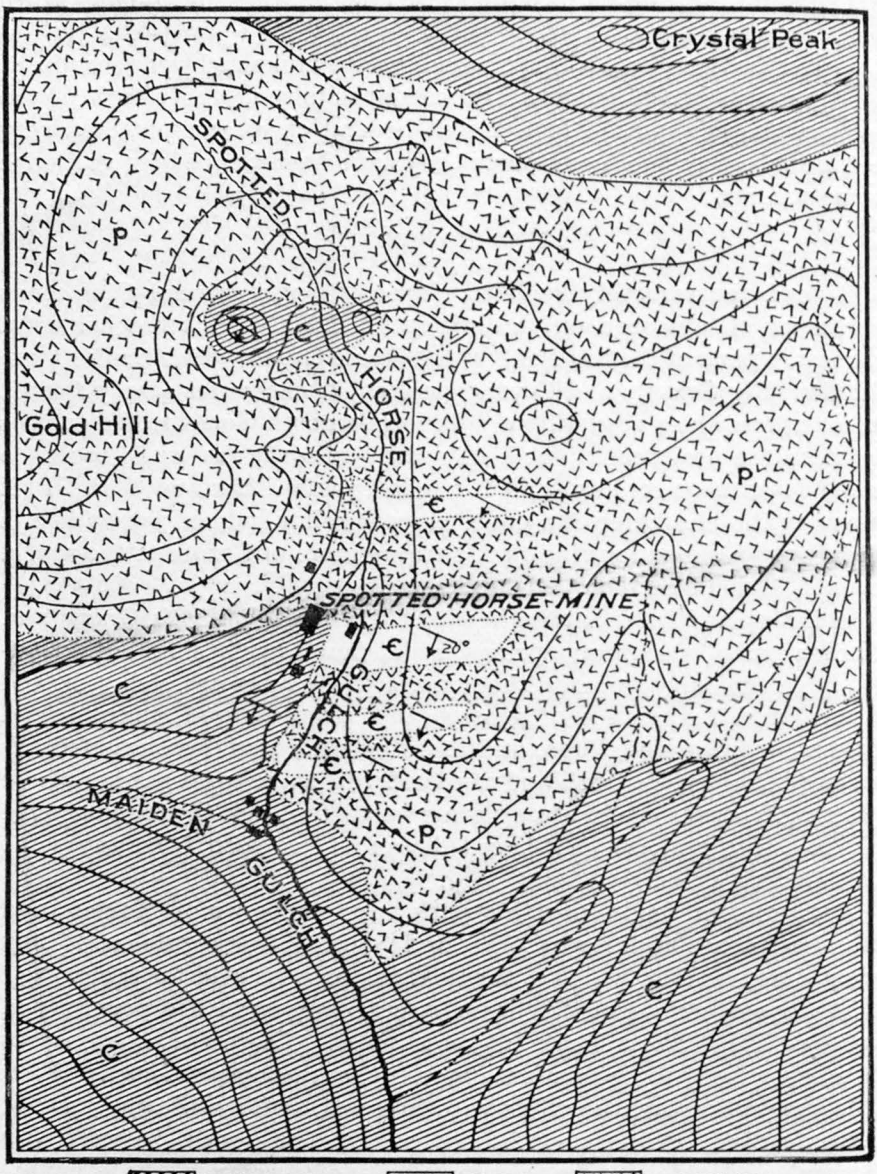


FIG. 47.—Geologic sketch map of Spotted Horse Gulch and vicinity.

in a broad band down to the divide between Crystal and Big Grassy peaks, where they pass down into Collar Gulch and become involved in the structure of the Crystal Peak uplift. Whether, on the divide between Maiden and Big Grassy peaks, these sandstones are merely lying on a continuous mass of porphyry passing from one peak to the

other, or whether they pass down under the Big Grassy porphyry, can not be certainly told, but the latter is believed to be the case.

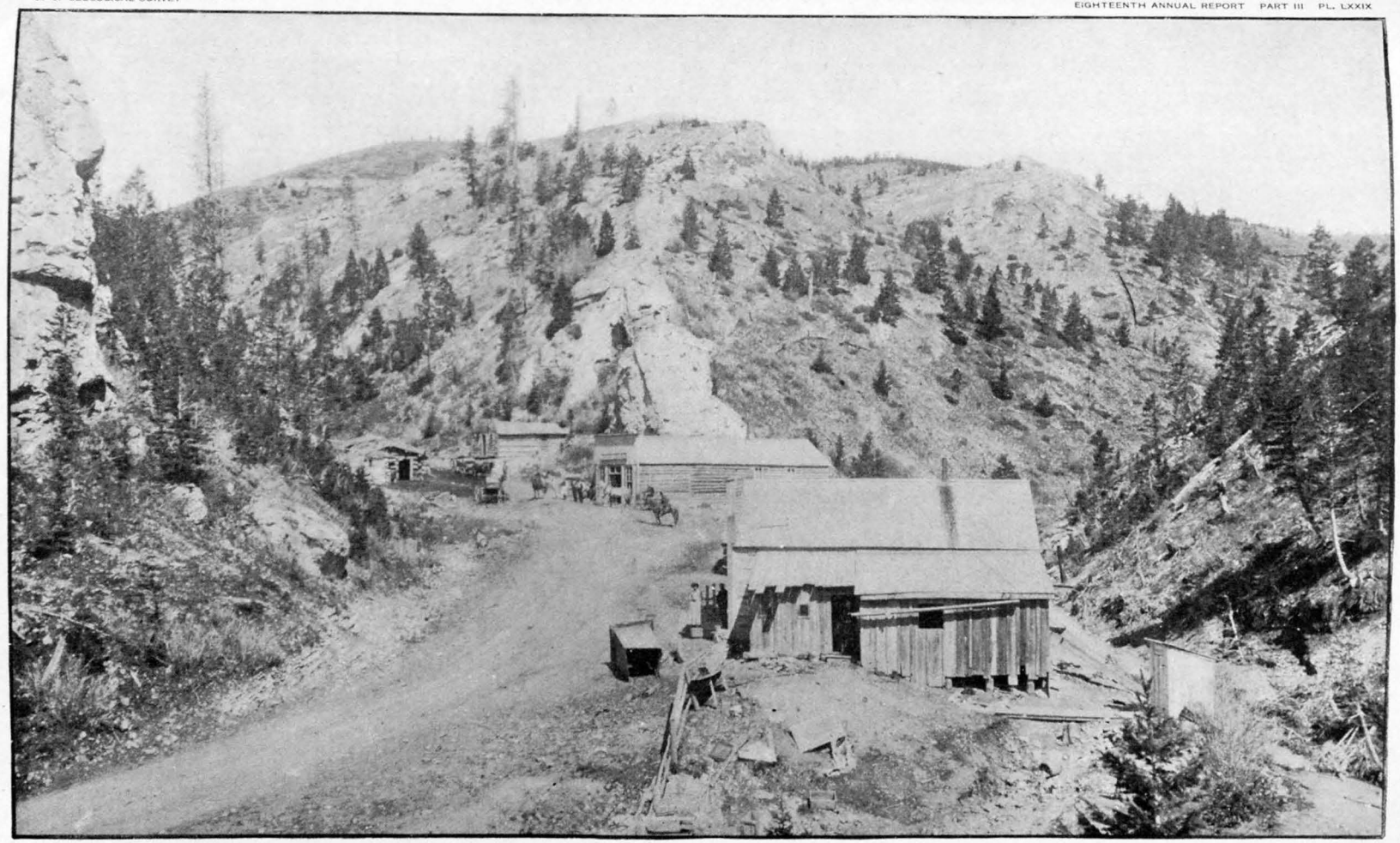
In the southern portion of the park, not far from the Gold Hill-Maiden Peak divide, there is an isolated area of Cretaceous sandstones which are much baked and metamorphosed. They are believed to be merely a remnant of the former covering of the intrusive mass and to have no considerable thickness.

The porphyry of Gold Hill is much altered, and on the crest, to which a wagon trail leads from the divide just mentioned, there are found in it zones of alteration and apparently of crushing, in which the rock is reduced to an almost pure-white material resembling kaolin. In other places, as shown in the prospect pit at the very summit, it is considerably mineralized and filled with pyrite. This is said to carry a fair assay value. At the foot of the upland basin and at the point where it begins to rapidly descend into the gulch below, there stands the most conspicuous and noticeable object in it. This is a huge crag of massive Carboniferous limestone, which dominates the valley and was early known by the first miners in this region as "Collar Butte" (see fig. 47). There is a steep ascent on the west to its crest, but on the side of the stream it descends precipitously and the limestone appears again on the other side of the valley, where it also forms a smaller crag. It is entirely surrounded by porphyry and has a very steep dip to the south. The stream cutting through it shows a considerable thickness of limestone. It is much altered by contact metamorphism and is cavernous and somewhat mineralized. Though no fossils were found, it is undoubtedly massive Carboniferous. It appears to be a huge, isolated block torn off by the porphyry from the beds which either yet lie below or have been displaced by the intrusion of igneous matter. It has been somewhat prospected, but no considerable development work has been done in it, and whether it contains any promising leads we do not know.

Fig. 47 shows the relations of the igneous and sedimentary rocks in the vicinity of the Spotted Horse mine. The upper part of Spotted Horse Gulch is found to be cut entirely in porphyry to a point a short distance above the mine, where the channel is found cutting through a thin upturned block of much altered, conglomeratic Cambrian slates, about 10 feet in thickness. These are succeeded by porphyry, followed by more of the Cambrian slates, and farther down they are found to be of considerable thickness, but are intruded by sheets (blankets) of porphyry. There appear to be four of these intruded porphyry sheets, two perhaps 50 feet thick and two thin ones—about 10 feet. On the east side of the stream the Cambrian slates rise into the crest of the spur, and good exposures of them may be found. They dip southwest toward the end of the spur at 20°, and the upturned block ends toward the east nearly at the crest line of the spur, or a little below, toward the next drainage, the slates being cut off by the porphyry. On the Spotted Horse side the hill-slopes are mingled masses

of débris from both the porphyry and the slates; on the other side of the gulch, the mine side, the slates ascend only a short distance, being covered with Carboniferous limestone. The latter, at the point where the mine is situated, is but a rather narrow wedge, being cut off by the porphyry above; but from this point the line of contact of the limestone and porphyry follows round Gold Hill nearly at a level to the divide above the Maginnis mine. The Spotted Horse mine is on the contact of the Gold Hill porphyry with the end of the limestone and just above the upstream end of the block of slates. The mine workings show that the contact between the porphyry and limestone has its plane or hade inclined inward toward the porphyry. Below the slates the line of contact between limestone and porphyry crosses the stream, and the limestones appear in the very end of the spur on the east side. Above them is a crag of porphyry on the hill, and the contact then runs along the front face of this spur end, facing into Maiden Gulch, its contact marked by porphyry crags, till at one point the porphyry comes down to the stream. From here it turns and runs northeast up the spur into the next gulch.

Where the limestone crosses the lower end of Spotted Horse Gulch fresh rock is exposed by the road cutting, where fairly well-preserved fossils of Lower Carboniferous aspect were obtained, such as a productus (probably *P. semireticulatus*), *Chonetes* sp., *Derbyia* sp., and a gastropod, possibly Euomphalus. The relations of the beds at this point, on the opposite side of the gulch and on the crest of the spur, show that, although the general dip and position of the limestone above the Cambrian slates are nearly conformable in structure, they are not conformable in stratigraphy, since apparently the whole of the Siluro-Devonian section is here wanting. The outer contacts of the porphyry mass with the limestones show that the former has been irruptive across the strata, and the probability is that the Cambrian slates represent a large block of that series which has been forcibly displaced and uplifted by the porphyry intrusion and whose normal structural relations to the surrounding strata have thus been violently ruptured. The porphyry itself, wherever it has been observed in contacts, as under Maiden Peak and in the next gulch east from the Spotted Horse, is always of this irruptive nature. In this next gulch its contact is marked at the spur end between the forks of the creek by a very massive crag exposure. The east fork cuts a deep ravine in it; turning northward it passes under Crystal Peak, where the long spur descending shows a great width of it, and from here it cuts off the beds until it meets the Cretaceous beds, previously mentioned, near the divide to Collar Creek. The mass thus outlined is of the shape of a rude triangle with sides about a mile and a half long. It is where this mass has come into contact with the Carboniferous beds that the largest mines in the district have been located—the Spotted Horse at one end of the contact and the Maginnis group at the other



SPOTTED HORSE GULCH.

end. It is believed that the area of contact between these two will become a favorable ground for exploration work in the future. Further details in regard to these mines will be found in the last chapter of this paper (p. 602). The porphyry has had a decided contact action on the limestones, bleaching them in places; but the action from hot solutions, vapors, etc., shown by the formation of purple and pink fluorite, quartz, etc., with deposition of the ores, is more marked, while a third set of changes, due to the decay from air and surface waters, has often masked many of the former.

In the Spotted Horse Gulch the Cambrian slates have been prospected, but apparently without success, as no development work has been done.

In regard to the character of the porphyry composing this large mass, details have already been given, and the rock is described in the chapter on the igneous rocks (p. 560).

CANYON OF MAIDEN CREEK.

The canyon of Maiden Creek, which, commencing at the divide above the town of Maiden, leads down into the open country on the southeast side of the mountains, is about 2½ miles along, and presents in this distance the most picturesque scenery to be found in the mountains. From the divide down to the point where the Spotted Horse Gulch opens into it the canyon is cut in Carboniferous limestones, descending the slopes from Sheep Mountain above. The bottom of the canyon is dry, whatever drainage there is passing underground, and its floor is occupied by the mail road. The grade is excellent and without break. The character of the canyon and the weathering of the Carboniferous limestones are seen in Pl. LXXIX, which is taken looking upward at the juncture of the Spotted Horse Gulch (to the right) with Maiden Canyon and the road turning the corner to the left. One of the buildings of the Spotted Horse mine is seen in the upper right-hand corner of the view.

At this point the water of the stream from the Spotted Horse Gulch comes into the canyon and flows for a considerable distance (depending on the season) before sinking in the limestone floor. The canyon itself widens and deepens. On the left are seen the crags which mark the limits of the porphyry; on the right all is Carboniferous limestone. Several gulches with dry, steep-descending sides open on the left down into the canyon.

The dip of the limestones at first near the mouth of the Spotted Horse is somewhat variable. They are warped, but approach horizontality; finally they dip downstream at more and more acute angles, until the massive bed near the top plunges downward at an angle of 40° and passes out of sight beneath the soft beds of the Jurassic and Cretaceous, which form the open country, producing an impressive gateway which ends the canyon and is shown in Pl.

LXXII. It is just above this that the most massive exposures are attained, and the pinnacles, crags, and buttresses of the light-gray rocks present a picture of quite imposing canyon walls, as illustrated in Pl. LXXI. It is here that the section of the Carboniferous given on pages 471–472 was made.

CRYSTAL PEAK ANTICLINE.

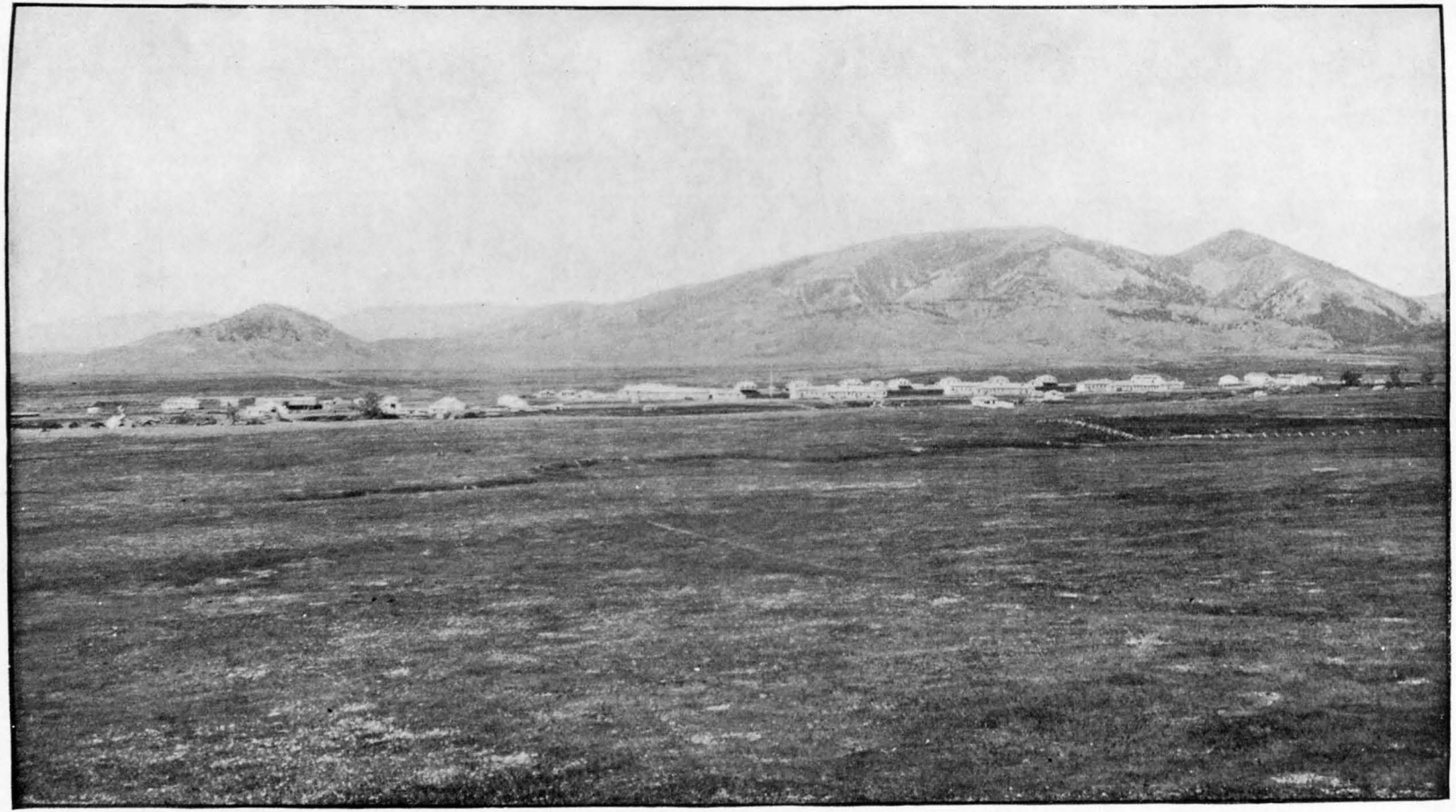
From any point in the park at the head of Spotted Horse Gulch Crystal Peak is prominent, and it is also clearly seen from the open country below, where it forms one end of a high mass of limestone. A little peak on the summit of this ridge, about a half mile south of Crystal Peak, is indicated on the map as a triangulation point. At Crystal Peak itself the limestones, which are upper Carboniferous, are nearly horizontal, with a dip of a few degrees to the south. A little below the summit, on the southwest side, is the Florence mine, located on the contact of the limestones with a porphyry dike. The outcroppings of the dike on the surface are so meager as to give little indication of its size and trend, while the mine workings which have cut it were not accessible when the locality was visited.

About 300 feet below, by aneroid, is the contact of the Gold Hill intrusive mass. On a spur to the north is the Pilgrim mine, also near the porphyry, but in limestone. A very steep road leads from the Collar Creek divide to the Florence mine, and Carboniferous fossils were found in the material thrown out in the road cutting, as mentioned on page 473.

A study of this limestone ridge, which commences at Crystal Peak and turns southward in a long spur down to the mouth of Maiden Gulch, shows that it is an anticlinal uplift of a domed character, the symmetry of the dome being destroyed along one side. Toward the northeast, east, and southeast the symmetry is well preserved, as is shown on the geologic map by the outlines of the various formations. The strike of the beds changes from that seen at the divide between Collar and Spotted Horse creeks until, at the mouth of Maiden Canyon, it has completed a half circle.

On Crystal Peak the dip is very slight, being near the top of the dome, but as one descends toward Collar Creek the dip increases to about 45°, and at this inclination the beds swing round the outer part of the circle.

On the western side the beds, as shown in Maiden Canyon, approach more nearly to the horizontal, and this side of the dome is sharply cut off by the intrusive of Gold Hill. Toward the west the anticline or dome impinges on the similar one of Alpine Creek. It is more irregular, however, in its central portion than the other domes so far described. All of the analogies show that a laccolith not yet uncovered has domed up the massive beds of the Carboniferous, just as at Flat Mountain. It would appear, however, that the intrusion of the



FORT MAGINNIS; JUDITH MOUNTAINS IN REAR.

laccolith was far less regular than in the cases so far described, and that it breaks through the cover on one side, giving rise to the irruptive Gold Hill-Maiden Peak mass. This, in all probability, was intrusive in the Cretaceous, and has been relieved of its cover only lately, speaking geologically.

Erosion has stripped the Crystal dome of its Cretaceous and Jurassic beds, and these have retreated back to the foothills and open country, where they form the usual revet hills with a steep inface. Thus the massive Carboniferous is left bare to outline the uplift, and, as usual, its white outcrops show the mountain slopes.

An excellent view of this dome from the east is seen in Pl. LXXX. The photograph is taken on the east side of the now abandoned Fort Maginnis, which is in the foreground. On the extreme right is seen the divide between Crystal and Big Grassy peaks; Crystal succeeds to the left, and then the long limestone ridge, the little point which is the highest next to Crystal being the triangulation point shown on the map. The white imbricating outcrops of the heavy limestone beds as they pass around the ridge are moderately well shown in the view. On the left is a dark, wooded hill in the open country, which is a mass of rhyolite-porphyry intruded in Cretaceous sandstones. It is the remnant of a tilted lens, the beds in which it is intruded being conformable in structure with those of the Crystal dome. The porphyry, which forms one or two massive outcrops on the inface of the hill, is a very white, much altered, greatly kaolinized rhyolite-porphyry of pretty fine, dense texture. This wooded hill is a conspicuous landmark for the open country on the southeast side of the mountains.

The retreat of the Cretaceous beds from the superior part of the dome to the open country has produced, as usual, the wooded coal-sandstone ridge which follows round and crosses Collar Creek. On either side of the mouth of Maiden Creek, and near Collar Creek, the coal has been prospected; but it is much crushed in the sharp upturn of the beds.

The heavy beds which form the roof of the arch are quite free from intrusions, the dike at the Florence mine and another down on the side toward Collar Gulch, with a small one in the first branch of Maiden Canyon, completing the list.

COLLAR CREEK AND GULCH.

Collar Creek rises in the mountain basin cut in the porphyry of Judith Peak and Red Mountain, and flows downward through a deep, narrow, wooded valley, all cut in porphyry, until, between the south end of Big Grassy and Collar peaks, it leaves the porphyry area and, reaching the soft beds of the Cretaceous and Jurassic strata exposed in the Crystal anticline, seeks the soft greenish shales and easily eroded beds of the Jurassic formation and cuts its way downward along them, producing a strike valley. At this point the very deeply

cut valley appears almost like a deep hole between Collar, Big Grassy, and Crystal peaks. A pine-covered table of the coal sandstone ascends under Big Grassy Peak to the divide; between it and Crystal Peak is a deeply cut gulch, at the head of which is the old Collar mine and alongside of which a road descends to the bottom. In cuttings in this gulch, the soft, green Jurassic shales are found exposed—a rare occurrence, as they are generally weathered down or covered with débris in the bottoms of valleys.

From this point Collar Creek has a very steep, narrow valley, locally known as Collar Gulch; on the south there rise the huge masses of heavy limestones whose imbricated outcrops rise to Crystal Peak above. Deep, rapidly descending, dry gorges are cut in them, which contain scattered clumps of heavy timber, and in which there are several mining prospects.

On the opposite side of the gulch—the north side—rise a series of benches of Cretaceous beds in which the sandstones are well shown. Intruded in these Cretaceous beds are four heavy sheets of porphyritic phonolite (tinguaite-porphyry), the lower one from 12 to 15 feet in thickness, then two thinner ones, and another heavy one which forms the crest of the spur. These sheets split into very heavy, massive blocks, and their exposures are seen as long, low cliffs along the hill slopes. They contain a great abundance of white porphyritic feldspars, lying in a green base. In ascending to the crest of the ridge from Collar Creek, one passes over successively higher formations, as the beds are tilted in conformity with the Crystal Dome anticline, and observes the sandstones and red clays of the Dakota, while the top is formed of the black Benton shales, somewhat indurated and containing large nodules of a black, fetid limestone weathering brown gray and divided by cracks into polygonal forms, the cracks filled with gypsum or fibrous barite. The beds were searched for fossils without success.

Toward the north the upper end of this spur abuts against Collar Peak, whose porphyry mass cuts off abruptly both Cretaceous beds and phonolite sheets. An apophysis or extension of this porphyry forms a prominent knob on the slope of the spur.

The top of this spur is for some distance rather level and park-like, but a small ravine soon begins to split its outer end, between Collar Creek and West Maginnis Creek, giving rise to a drainage channel which joins Maginnis Creek a little above the fort. This drainage way at its top is sparsely clothed with pine and cedar, and affords several good exposures of the Benton shales.

Toward the southeast the spur, as it dies out in the open country, turns more to the south as the beds bend in accordance with the Crystal Peak anticline. The stream here leaves its gulch, which has been cut back into the Carboniferous, and crosses the formations successively until it emerges from its canyon into the open country, as seen to the

right in Pl. LXXX. Of the phonolite sheets, only the lower one follows persistently round on the side of the dome and crosses the creek, where it is seen in the Dakota foothills. The road, following down the stream, but higher on the left bank, also crosses the beds, and the road cutting affords several good exposures.

Near the point where the stream cuts through a mass of Carboniferous limestone, forming a gateway, it seems clear from the close proximity of the Dakota formation to the Carboniferous that a considerable portion of the Jurassic beds must have been slipped back in the uprise of the dome; the exposures are not sufficient to determine which beds have slipped back, but they should undoubtedly be the soft shales. The occurrence is similar to that on the west side of Kelly Hill previously alluded to.

From what has been said, it will be seen that Collar Gulch, from the edge of the porphyry to the open country, is the exact analogue of upper Warm Spring Creek, the valley being determined as a strike one in Jurassic beds on the side of a domed anticline, and with one wall of the valley consisting of massive Carboniferous limestones, while the other is of Cretaceous beds with intruded sheets of porphyry. This is clearly shown by a comparison of sections C–C and E–E, Pls. LXXXII and LXXXIII.

MAGINNIS ANTICLINAL DOME.

About a mile south of Fort Maginnis there stands upon the open country a cluster of hills of small size but so grouped that their topography forms a significant geologic feature. An inspection of them shows that they are small monoclines, arranged in concentric lines and dipping away from a common center. In other words, they represent a domed anticline in Cretaceous beds, of precisely the same character as that on the west fork of Deer Creek previously described. The diameter of the group is about 1 mile—that is to say, the anticline shows that breadth on the surface. It is dissected by a drainage way passing through its center, and the hills cut in sandstones and red soils show that the Dakota group is mostly exposed in the uplift. It is undoubtedly due to a laccolith of porphyry not yet exposed.

JUDITH PEAK AND RED MOUNTAIN.

This is by far the largest single body of exposed igneous rock in the mountain area, measuring over 4 miles across in one direction and about 5 in its greatest length from east to west; but, as may be seen by reference to the geologic map, it is of very irregular shape. The center of it culminates in Judith Peak, the highest point in the mountains. While all the evidence goes to show that it is not a laccolith in the accepted use of that term, it is none the less an intrusive mass which has solidified under a cover of sediments, although, as the map shows, it is in contact with a variety of formations.

On the western side, between two forks of Deer Creek, the porphyry forms a high point which descends toward the north in a sharp-crested, wooded spur. This part is in contact with Cretaceous beds, and it has burst up along the southeastern side of the Deer Creek anticline without disturbing the symmetric arrangement of the beds which dip back toward it. This is well shown on the highest point of the hill, where the sandstones furnish excellent exposures. The outcrops of porphyry on the north side of the highest point are among the heaviest seen in the mountains.

On the east side of the tongue-like spur that runs north are what appear to be black Benton shales; they are largely cut down into a small gulch. East of this the porphyry recurs again and is in contact with the upturned mass of Carboniferous limestone at the heads of the east branch of Deer Creek. There can be no doubt that this mass of limestone is tilted by the porphyry and that porphyry lies under it; certainly it lies above it, separating it from the Jurassic beds. East of this the porphyry again rises into a high point and forms hill slopes facing east, where it is in contact with Jurassic beds.

At the heads of West Armell Creek the porphyry is again in contact with Carboniferous limestones, an immense block of which has been raised by the intrusion and partly filled with sheets; porphyry also underlies it, as described under the head of West Armell Creek (p. 524). Of the porphyry area which has been so far described, the slopes lead back to smooth, broad spur crests, from which, on the west side, smooth, grassy, basin-like meadows descend into the heads of Deer Creek. This is the character also of the ridge which connects Judith and Porphyry peaks, and of the ridge running to the north. These smooth, grassy basins especially characterize the areas of porphyry at the extreme head of that branch of the North Fork of Warm Spring Creek that passes Porphyry Peak. In these grassy uplands the porphyry is weathered down to a gravelly débris; no rock exposures are seen—only an occasional bowlder. Examination of the soil shows, however, that it is invariably made up of the débris of porphyry.

PORPHYRY PEAK.

Porphyry Peak, or, as it is sometimes locally called, from its dark color, "Black Mountain," is a steep, conical mass of porphyry, its sides covered with talus plates, almost without vegetation except for occasional clumps of pine. The peak is a very conspicuous object from all points of the open country below. It marks the extreme southwest extension of the great porphyry mass. It is clearly in contact here with Cretaceous beds, but what their attitude may be can not be certainly told, as there are almost no exposures. On the south base, near the stream, are sandstones which strike northeast and dip 20° NW. The branch of the North Fork which rises in the mountain meadows mentioned above, on leaving them plunges down into a

steep talus-choked ravine on the southeast side of Porphyry Peak, and, emerging into a wooded bottom, joins the main stream.

The west spur of Judith Peak, in descending to the meadow basin, rises, forming a hill between two branches of the stream flowing west. This is composed of a mass of fine-grained, chocolate-colored syenite, the character of which is mentioned in the chapter on the igneous rocks (p. 561). It lies chiefly on the west side of this hill and consists of broken bowlders; no definite contact between it and the surrounding porphyry could be made out, as there are no good exposures of either to afford proof, but it is held, from its different structure, to be intruded through the porphyry as a small stock or chimney; it may, indeed, represent a former canal through which porphyry was intruded. In contrast with the surrounding porphyry the rock is hard, fresh, and unaltered. The area shown on the map is that of the broken-down rock, as seen on the surface.

JUDITH PEAK.

Judith Peak itself is composed of quartz-bearing porphyry (rhyolite-porphyry) of the type described on page 560. The small, angular, light-colored flakes compose the crest and slopes. Pine trees grow thickly upon it, and in places they have been burned and the porphyry has been reddened or blackened by the fire.

On the north side the slopes fall away into several steeply descending, half-funnel gulches. The angle of slope of the broken porphyry is extremely steep, and the gulches have almost the aspect of amphitheaters. Farther down the blocks of the broken porphyry naturally become larger.

Almost at the summit of Judith Peak, a few hundred yards northwest, the porphyry is very greatly altered, rotten, leached, and of light color. It is cut here by a vein, about 10 feet wide, of quartz and purple fluorite, upon which is located the American Flag mining claim. The same or a similar vein appears across the gulch, on the north side, and is also located.

At the summit of Judith Peak the porphyry appears crushed and filled with narrow quartz seams, which are stated to carry low values in gold. Southward from here, although the porphyry is greatly rotted and broken down, it can be seen that there is a gradual increase in the number and size of the quartz phenocrysts until, at a point perhaps a quarter of a mile east of the "Chimneys"[1], these quartzes assume a large size, the phenocrysts being often an inch or more long. The rock is now a granite-porphyry and of the character described in the chapter on the igneous rocks (p. 558). There appears in this mass, also, the same lack of definite boundaries noted in regard to the syenite, and it seems uncertain whether it is a differentiated phase or a distinct and later intrusion.

[1] See description of the North Fork Valley, p. 515.

The quartz crystals weather out as pebbles, and very perfect specimens may be obtained.

RED MOUNTAIN.

Although one continuous mass, there is some difference between the porphyry of Judith Peak and that of Red Mountain, and this difference in character is clearly visible in the difference produced in the weathering. Instead of the hard, irregular little blocks which cover the former, the porphyry of Red Mountain is broken down into extremely small, fine débris, producing a kind of gravel in which no outcrops are seen. This gravel varies from place to place, especially in color, which grades from a strong buff to the deep red to which the mountain owes its name. The oxidation of the iron-bearing component has been so great that no specimen could be found which would show the former character of the mineral. Toward the east Red Mountain divides into two branches, one of which turns southward, while the other gives rise to a high, prominent spur, running northward and separating West Armell Creek from the eastern forks. All this part of the mountain is covered with the same hard, angular, broken down, light-colored, quartz-bearing porphyry as on Judith Peak. On the north side steep gulches covered with its débris lead down into the head of Armell Creek.

A number of dikes of phonolite-porphyry of a deep-green color, with large embedded feldspars (tinguaite-porphyry), cut the mountain in various directions. They are often broken down to a train of bowlders, but sometimes project as the heavy, massive walls seen on its eastern spurs. The porphyry is here in all directions covered with a heavy growth of small pines, which have been recently burned.

The spur that runs north from Red Mountain is itself a very large mass of igneous rock, which on the east breaks up through sharply tilted beds of the Benton formation; the slopes rise steeply and at times precipitously from the low-cut shales. In several places on the north face there are, indeed, some quite imposing amphitheaters, in which rise heads of the middle fork of Armell Creek. The rock here is fine grained but not dense, and has almost no phenocrysts; it might be termed a very fine-grained syenite. On the crest the spur, which is open and grassy, descends sharply from a high shoulder to a lower saddle, which appears to be caused by a band of sedimentary rocks—limestones—much altered and containing very thin phonolite sheets; they dip back into the hill, and on the north descend in a little ravine till they end against the upturned Cretaceous beds; they are clearly a mass of beds, probably Jurassic, which has been torn from the large blocks of sediments below and wedged off by the intrusion of porphyry. Beyond them to the west the spur rises again in a hill of porphyry, which terminates it in this direction; its north side is in contact with nearly vertical beds that appear to be of Benton age. On the south the slopes descend to West Armell Creek and

are in contact with slaty beds, probably altered Jurassic, before the limestones are attained. The porphyry composing this mass is not the quartz-bearing porphyry of the higher part of the spur, but a syenite-porphyry of the Big Grassy Peak type. In this northeast portion of the great porphyry intrusion there does not appear to be very much contact metamorphism; some is noted in a hardening of the shaly beds, but this does not extend far and is not great. On the eastern side, however, where the mass ends in the saddle above Hanson's mine, at the extreme head of East Armell Creek, there appears to be a greater amount of change in the shales, which are here baked very hard.

Ascending the east spur of Red Mountain, one finds small areas—"blow-outs," as they are called by the miners—of shales, which are baked to adinoles, still sticking to the porphyry, often but a few inches thick and a yard or two across. They represent the immediate contact of the porphyry with its sedimentary cover—the thin, hard-baked skin which has not yet in places been eroded. This same character of remnants of altered shales sticking to the porphyry is found also on the broad expanses of porphyry cut into by the heads of the west fork of Maginnis Creek. Prospect pits sunk through them are found to quickly reach into the porphyry. The occurrence of these masses of altered shales on the porphyry is of interest as being considerably lower than Judith Peak and Red Mountain; it shows that the middle portion of the upper surface of this porphyry mass was higher than the edges, and had therefore something approaching a dome shape.

On the south the intrusion is cut into by the head of Collar Creek, which flows in a deep, wooded ravine with talus-covered slopes, which gradually widens at its head into open gulches descending from Judith Peak and Red Mountain. On either side the porphyry rises in narrow-crested spurs, which terminate in the high points of Big Grassy Mountain and Collar Peak. On the south side the igneous rock breaks up across the Cretaceous beds, and in the spur between Collar and West Maginnis creeks it crosses the Cretaceous section from the Dakota to the Benton, and cuts off apparently the green phonolite-porphyries which lie as intruded sheets in them. In the upper valley of the North Fork of Warm Spring Creek the porphyry descends sharply in talus-covered slopes to the low-cut shales that form the valley floor.

Throughout the whole area of this intrusion the rock is generally broken down into débris and slide-rock plates, and solid outcrops are rather uncommon, the most prominent and massive being the cliffs at the "Chimneys," in the North Fork Valley, which are really composed of granite-porphyry, and in the precipices and crags on the south side of Collar Peak, and at the head of the middle fork of Armell Creek.

A noteworthy feature of the intrusion is that wherever the periphery of the mass is examined it is found to be a syenite-porphyry of the Big Grassy type, while the main rock of the interior, as shown at the surface, is a dense quartz-bearing porphyry of the Giltedge type. There appears, therefore, a tendency for the mass to be more basic at the outer edge, and it passes, indeed, in some places into a type which distinctly recalls in structure and appearance the phonolite-porphyry of this area.

THE EASTERN PART OF THE MOUNTAINS.

EAST ARMELL CREEK.

The open country shown on the northern part of the map, between the forks of Armell Creek, is made up of grassy, rolling hills which afford few exposures of the sedimentary beds. Toward the mountains the first and most prominent outcrop that occurs is a very heavy, massive white sandstone, rather fissile, somewhat soft and crumbly, cross bedded, and forming, when tilted at medium angles to the north away from the mountains, revet hills with occasional clumps of cedars or groups of pines whose inface shows a massive, conspicuous exposure of the white sandstone. While this bed is tilted up where West Armell Creek crosses it, farther to the eastward it is nearly horizontal and furnishes, over considerable areas, a flat floor to the valley of the East Fork of Armell Creek. It stretches around the northern flanks of the foothills in a wide loop, and is again seen in a series of revet hills around the northern flanks of Black Butte, whence, as seen in the drainage cuts, it stretches eastward over the plains country. It appears to mark the top of the Benton group, and under it and toward the mountains we find the valleys cut in black shales and scored by shallow drains whose bottoms show the green lines of the oozy seepages they commonly contain.

Stretching from West Armell Creek to the head of the middle fork at the northern foot of the great porphyry mass, a distance of some 2 miles, is a series of little hills which mark the contact of the porphyry with the Cretaceous beds. They present a singular and striking geologic and topographic feature. There are about a dozen of them, in nearly a straight line, and each terminates in a knob with a double crest having a little green wooded patch on it and a light and dark streak on the side. They recall at once a row of soldiers standing in a line. They are composed of the Benton beds, which are altered and baked by the porphyry; the beds at the west end dip very steeply away from the porphyry; toward the middle of the row the dip becomes perpendicular, and toward the eastern end the dip reverses, inclining inward toward the porphyry until it becomes a part of the anticline to be mentioned later. The strike is in the direction of the row of hills, a little north of west, and a certain sandstone

appears in the crest of each hill, giving the curious appearance of uniformity, which is thus, of course, due to the repetition of the same beds.

Near the middle of this line of foothills there projects northward into the valley of the middle fork a curious long gravel ridge; it is about a quarter of a mile long, not over 50 yards wide and about 20 to 30 feet high, and on top not over 15 feet wide, with a regular slope on either side; as it dies out it broadens and lowers somewhat. It is composed of pebbles of all descriptions, mostly porphyry blocks from a few inches to a foot in diameter, the smaller size predominating and the pieces being quite angular. In the lack of all other signs of glaciation in the mountains and the absence of anything in the valley that would indicate any former lake action, it is possible that the origin of this long, esker-like ridge is due to torrential action of some kind.

In the flat floor of sandstone of the open valley, between the middle fork and the main stream, a large dike occurs, forming a conspicuous wall which trends to the north. This is suspected to be of phonolite, but was not visited. The beds of the Benton group which form the floor of this valley are approximately horizontal, but are disturbed at the head of the middle fork by the intrusion of a laccolith below them, which has domed them up in an anticline whose outer limits form a circle about a mile in diameter. On the outer side the black shales of the Benton are the upper beds involved in the disturbance, and being somewhat hardened here on the south by the intrusion of the great porphyry mass, they resist erosion better than ordinarily and form a number of conspicuous coal-black exposures. Toward the center lower beds are exposed and the red clays of the Dakota group are seen, and the center itself is formed by a dome-like hill covered with sandstone. No porphyry is there exposed, but there can be no doubt that it lies below. A sheet of green porphyritic phonolite lying in the Benton is involved in the uplift, and on the map helps to bring out the structure.

In the valley of the East Fork of Armell Creek above this the porphyry of the main mass, whose walls dominate the valley, is in contact with the same Benton shales, which dip in toward it and away conformably from the Elk Peak anticline to the east. It thus appears that the great porphyry mass at every point on its periphery is erupted through the sediments without disturbing their previous structure, and it is therefore one of the last intrusions in the mountains.

The upper part of East Armell Creek, toward its head, is narrow and deeply cut, even canyon-like in places. It is here in part a strike valley. Heavy masses of syenite-porphyry have been intruded into the upturned beds, and the stream branches have deep gulches between them, some coming down from the Elk Peak dome, others from the divide and from the west. On the west side sheets of green phonolite

porphyry are seen in the shales. The divide itself, which is, so to speak, threefold, in that it divides the head of East Armell Creek from both the east and the west heads of Maginnis Creek, is in the black shales; they are hardened and metamorphosed in places by the porphyry intrusions and are turned to slates. It is where these slates are cut by an altered dike that the Hanson mine is located.

WEST MAGINNIS CREEK.

Maginnis Creek, which flows down through the now abandoned fort of that name, and sinks into its stream bed in summer on reaching it, is formed by two main branches, which unite less than a mile above the fort; they are separated by a large mountain forming a spur extending southward from the main divide, called Maginnis Peak.

The west fork, or West Maginnis Creek, as it may be called, rises in a large, bowl-shaped basin surrounded by Red Mountain, Collar Peak, Maginnis Peak, and the divides connecting them. As most of the upper walls, on nearly all sides, are of porphyry, sometimes in massive exposures, but generally in broken-down talus or slide rock, the basin has but little vegetation and has a very wild and rough appearance. It is scored by shallow canyons or ravines, converging toward the center, which carry the head branches of the stream. The south side of the basin is made by the spur between this creek and Collar Gulch. The spur, as previously described, consists of Cretaceous beds, the Benton shales at the top; the strike of the beds is southeast, the dip northeast, in conformity with the Crystal Peak uplift. On this side the spur is full of intruded sheets of green phonolite-porphyry, but instead of presenting the inface or crop of the exposure, since the dip is down the slope, the broken-down backs of the sheets are presented, and instead of outcrops there are long lines of débris heaps which cover nearly all the hillside, while the sediments are not seen until the creek bottom is reached. In this the stream has cut through the sediments, showing small bluffs in which they are well exposed. They are, as at the spur top, the black Benton shales, which form all of the sediments seen in the valley; they dip slightly northeast into Maginnis Peak and form a sort of terrace or bench which rises above the stream bluff till it meets the precipitous porphyry slopes of Maginnis Peak and continues along the west base of the mountain to the Hanson divide. When they reach this divide the beds dip, however, in the opposite direction, westward, away from the Elk Peak dome, but between these points the relations are not clear, from the prevalence of porphyry débris and the lack of sufficient exposures. The stream itself presents a curious feature. There are two main forks, each of which is clear and limpid, but the moment they unite the water becomes milky from a precipitate that forms, presumably a basic iron carbonate; and this precipitate is seen for a mile below before the stream becomes clear again. Just what produces this effect

can not be told without chemical investigation of the waters. It recalls the precipitates in West Armell and Edwards creeks.

The shales at the contact of the main Red Mountain porphyry mass are much altered, baked, indurated, and changed to slates, while the porphyry assumes a syenite-porphyry character with a phonolitic aspect. Sheets or dikes of phonolite are seen here; also in the shales and under Maginnis Peak their outcrops are found.

On the spur between the forks of the creek, at the contact with the hardened slates and where they are also cut by a dike, the Chicago prospect mine is located.

On its course down the valley the stream gradually cuts back into the shales toward the northeast until it reaches the igneous rock of Maginnis Peak, and the talus is found coming down to the stream.

After leaving here the stream flows through a wooded bottom with no rock exposures to its junction with the other fork in the open country. The geology of its valley is, therefore, that of the Benton beds tilted by the Crystal Peak dome, intruded with sheets of phonolite and cut off by the intrusive masses of Red Mountain and Maginnis Peak, and is seen in the geologic section E–E, Pl. LXXXIII.

MAGINNIS PEAK INTRUSIVE.

This mass of igneous rock furnishes some of the most precipitous walls and some of the heaviest exposures in the mountains, rising in cliffs and crags of naked rock where often a vertical exposure of 50 feet may be seen along the outer surface of the crags. It consists of a rock which in composition lies between a syenite and a syenite-porphyry, as described in the following chapter (p. 561). The mass appears to have broken up abruptly through the sediments and to have produced only a very local upward drag and not any far-reaching disturbance of the geologic structure of the sedimentary beds.

On the south face of the mountain, between the two forks of Maginnis Creek, there are heavy masses of the Benton shales which have been baked to tough black slates and which, resisting erosion as the unaltered ones never do, form the lower end of the spur.

On the eastern and northern sides the mountain appears to show the same features as described above, but the talus slide covers so much of the slopes that it is difficult to positively determine the structure.

EAST MAGINNIS CREEK.

This stream flows down through a deeply cut canyon-like valley with steep slopes of porphyry talus on either side. Near the mouth of this canyon the stream has cut through the Maginnis Peak syenite and its contact rim of hardened slate which forms crag-like exposures on either side. The contact is prospected by the Edwards tunnel. Above here the stream forks, and the valley widens a little and is

heavily wooded. The road which is built in the valley bottom follows up the western fork and attains the Hanson divide and mine. There are several steep, narrow gulches which come into the valley from the northeast, forming other branches of the stream. They appear to be largely cut in porphyry, from the amount of slide which covers the valley slopes.

The features of the geology at the upper part of this stream are formed by sedimentary beds, mostly Cretaceous but in part Jurassic, steeply tilted on the outer side of the Elk Peak dome and intruded with porphyry sheets and masses. The gulches are, therefore, strike gulches, in part cut in the less resistant sediments, with porphyry masses forming the spurs between, and in part cut across the beds. The sediments form almost no outcrops, while the steep slopes are so marked by porphyry slide rock that one gains the impression at first, on viewing the area from one of the peaks, that there is nothing but igneous rock present. The exposures on the crests of the ridges and the material brought out from the prospect tunnels give, however, a fairly accurate idea of the geology and structure. The Maginnis Peak mass on this side, as well as the west, as described heretofore, cuts upward through the Benton beds, which form a sort of platform around it and contain one or two intruded sheets of phonolite.

From what has been said, and by reference to the geologic section E–E of Pl. LXXXIII, it may be seen that this stock of igneous rock has broken up through the syncline lying between the Crystal Peak and Elk Peak arches.

ELK PEAK ANTICLINE AND LACCOLITH.

Although this mass forms a link in the longer axis of the mountain group, it is, in a way, a geologic unit by itself. This is because it consists of a single uplift in which erosion has brought the older Paleozoic rocks to view and outlined them by the Jurassic and Cretaceous beds. Moreover, the drainages are away from it radially, so that it stands as a topographic unit. It is drained on its sides by the head of East Armell Creek, Box Elder Creek, and the heads of Ford Creek. The general geologic structure is clearly seen on the map; the beds dip away in all directions from a common center, and are very clearly raised in an anticlinal dome, due, without doubt, to heavy laccolithic intrusions of porphyry similar to those which have formed the Alpine and Burnett laccoliths. The laccolith, in the amount of denudation it exhibits, lies between them and the Flat Mountain dome; erosion has progressed further than with the latter, and the masses and sheets overlying the main porphyry mass are being brought to light. These are intruded not only in the Carboniferous, but still more so between it and the light, easily separated beds of the Jurassic and Kootanie, assuming at times the proportions of considerable laccoliths themselves.

ELK PEAK.

Elk Peak consists of a double knob, the south one being formed of massive crags of syenite-porphyry (Big Grassy type), with large glassy orthoclases. The peak commands an excellent view of the surrounding country, and the large number of stone rings made for sheltering lookouts upon it testify to the Indians' appreciation of that fact. The porphyry is the protruding edge of a thick sheet whose outcrop curves down the hill toward the east, forming a short cliff on its lower side, whose talus covers the slopes of limestone below. Another mass of quite similar porphyry occurs to the northward; it forms the crest of the ridge for some distance and finally, like the one above, descends to the northeast into Peerless Gulch, the most western of the small head forks of the Box Elder.

The crest of the ridge is made in the main, however, of Carboniferous limestone, more or less whitened by contact metamorphism, some projecting crags near the porphyry being changed to a white marble. Along this crest there are a number of prospects, the Last Chance and the Bob Ingersoll being the most developed. In addition to being cut by the porphyries mentioned it is cut also by two parallel dikes of green phonolite, one much more porphyritic than the other, about 100 yards apart and with an east-west trend; the dikes are from 5 to 10 feet wide.

On the northwest side of the dome gulches are cut back in the limestone which lead down into the head of East Armell Creek. There is a heavy mass of porphyry intruded here which furnishes some massive exposures. It rises into a hill which forms a northward-projecting spur from the dome. The saddle between the dome and the hill on the spur is formed by the Jurassic, the Cretaceous sandstones forming the hill above. Some heavy phonolite sheets are intruded in the Cretaceous, and are seen on the spurs on both sides of the drainage, while several heavy dikes of this rock are also seen cutting down through the westward-projecting spurs of the dome.

On the west the dome connects with the Hanson divide, which affords a rough section of the sequence of the beds, the higher part of the dome being of rugged slopes of bare, light-colored Carboniferous limestones, dotted with occasional clumps of pines, which lead down to the small grassy saddle that marks, as usual, the position of the Jurassic shales on a divide. Above these limestones the crest rises again, and the Jurassic limestones, with ostreas and gryphæas, are met. A sheet of phonolite crosses the ridge, and beyond are the Cretaceous beds in normal sequence.

The head of the east fork of Maginnis Creek has already been described; it is only necessary to mention a heavy mass of porphyry which has been intruded between the Jurassic beds and the Carboniferous strata, forming a spur leading to the south and between the head branches of the creek.

The porpnyry does not follow one horizon, but breaks across a number of them, like one wall of a dike. The crest of the spur shows several points of interest. After leaving the contact of the porphyry with the Carboniferous, hard, indurated shales, resembling somewhat the Cambrian shales of the region, are seen; they are the green shales of the Jurassic metamorphosed and indurated by the porphyry intrusion. Beyond are altered limestones of Jurassic character, and then sandstones with depressions marking the position of the shale beds; and eventually these sandstones, which mark the Kootanie, are succeeded by red clays baked to a brick-like consistency, which are the Dakota; succeeding them is porphyry, which ends the spur.

On the south side of the dome a spur projects between East Maginnis Creek and the next branch of Ford Creek to the east. Between the Paleozoic beds and the high part of the spur there is the usual Jurassic saddle. The spur itself, above this, is composed of Cretaceous shales and sandstones, much altered, and intruded with a very heavy mass of porphyry, which, in the crest of the spur, is about an eighth of a mile across. It is badly altered, but of the usual syenite-porphyry aspect. Above this in the sediments, or farther south, are intruded two heavy sheets of a light-colored ægirite-syenite-porphyry (Cemetery Hill type), the most southerly of which forms some heavy crags and walls that terminate the crest of the spur to the south. These sheets are from 10 to 15 feet thick. The heavy bowlders of this rock strew the hill slopes. The large amount of porphyry intruded into the upturned sediments of this spur, chiefly sandstones and black shales toward the south end, covers its western side to Maginnis Creek with such heavy masses of porphyry slide that from below it appears to be all porphyry.

From the Jurassic saddle mentioned above a gulch runs down to the east, cut in the Jurassic shales, of which, near the head, it affords some fair exposures. The shales are altered somewhat by the porphyry intrusion. The Cretaceous is in part in the gulch, and in part it forms a long spur running to the southeast, the crest corresponding with the strike of the beds, which are steeply and sharply upturned. The cause of this is the intrusion of an enormous mass of porphyry, which lies in between the massive Carboniferous and the lighter beds above. It reaches from the south spur described above; the whole upper part of the valley is cut in it, and it extends back to the divide between Elk Peak and Lewis Peak. On the east side of the valley of this fork of Ford Creek the hills are all composed of this porphyry. By inspection of the map it will be seen that the intrusion of this mass has forced back the Jurassic and Cretaceous beds until they are widely separated from the Carboniferous. Eventually the Jurassic and Cretaceous beds are broken through and turned back, the porphyry passing to higher horizons in the Cretaceous. On the southeast side of this porphyry intrusion the Jurassic beds appear in the foot-

hills, and where they cross the spur between two little ravines good exposures of the limestones are found, with included fossils—ostreas and gryphæas. The beds are found on the sides of the hill above, with steep dip. At the most southern point, where they are pushed back, the beds are indeed vertical, or nearly so, but toward the north they eventually become much flatter in dip, as they end against the porphyry, and are exposed in two small canyons cut down through them. In some places these Jurassic beds are very greatly altered and hardened by the action of the porphyry, and this is especially noticeable where the beds end against the porphyry on the south side. They are exposed here on the crest of the ridge which separates the deeper valley of the branch of Ford Creek from the more elevated, open hill slopes which face eastward toward Ross Pass. An exposure of the shales here, where a prospect pit has been cut in them, shows them to be hard, dense, green and purple slates.

The Jurassic beds afford the usual saddle in the divide between the Elk Peak dome and Lewis Peak. On the south several long spurs of porphyry lead down into the head of the branch of Ford Creek, separating small gulches. It should be mentioned here that the porphyry composing this large mass is of a diorite-porphyry type, with few large feldspar phenocrysts, but very many small ones. In places it is extremely decomposed.

A little south of the divide the Jurassic beds, torn apart by the intrusion of the porphyry, commence again, cross through the divide as mentioned, and, trending northward with sharp easterly dip under the Lewis Peak porphyry, are cut out, as is so often the case, into a little valley. Porphyry sheets are found in them, a considerable one separating these beds from the massive Carboniferous to the west.

This little valley was visited by Dana and Grinnell, who thus mention[1] the character of the massive Carboniferous limestones exposed on its western side:

> This limestone rises in a series of sharp ridges, very distinct, and seen from a distance as a number of white lines running up the sides of the hills. It dips 50° northeast, the strike being northwest. The upper layers are white, semi-crystalline, and very profuse in flinty fragments. These are exposed by the weathering, and on the surface the rock has quite a coralline aspect. Lower layers are firmer, bluer, and also cherty, though not to the same extent as those above. A very careful search showed that fossils were very rare, though a few were found, enough to determine the age of the rock to be Carboniferous.

PEERLESS GULCH.

By reference to the map it will be noticed that the Jurassic beds form the saddle between the Carboniferous beds of the dome and the northward-projecting spur, and that as they trend eastward they are cut out into a little valley descending eastward, just as they form

[1] Report of a Reconnaissance from Carroll, Montana Territory, on the Upper Missouri, to the Yellowstone National Park, and Return, made in the Summer of 1875, by William Ludlow, War Department, Washington, 1876, p. 99.

the northward-descending valley which is mentioned on the preceding page. Between these two gulches, whose courses are at right angles to each other, is a third, whose descending course is northeast, and at the mouth of which, before the streams come together, the Jurassic beds are cut at right angles. This is known as the Peerless Gulch, from a mine prospect situated in it, and it contains several points of interest. In the main it is cut into the sharply upturned beds of the Carboniferous limestone, which dips steeply to the northeast, in conformity with the dome structure, as mentioned by Dana and Grinnell in the paragraph just quoted.

The cutting down of the gulch, however, has revealed intruded masses of porphyry, and the edge of the great sheet on the main crest above descends in a wall down the gulch, curving round as the beds are eroded. On the north side some sheets are exposed, and a very interesting feature is the intrusion of a small lens of porphyry among the upturned limestone beds; the structure is clearly seen, and the limestone is swelled in a large bubble several hundred yards across, the ordinary dip being reversed at the upper end in conformity with the intrusion. The steep cutting of the canyon wall shows the disposition of the arch admirably, and at its lower end crosses the lens so that the lower edge of the porphyry is exposed.

Porphyry intruded in the Lower Jurassic beds appears also as an exposed ridge in places, following the outer edge of the Carboniferous down into the valley below. All of these porphyries are of the usual type previously mentioned, with large orthoclase phenocrysts, and are generally considerably altered. They have metamorphosed the limestones to some extent and given rise to ore deposits, which have been prospected at a number of points.

LEWIS PEAK.

This is wholly composed of igneous rock, and on all sides except the south it presents extremely steep, talus-covered slopes. On the east they descend abruptly into Ross Pass, but on the south there is a gradual descent down the gently modeled foothill country. Geologically, Lewis Peak is a laccolith intruded in the Cretaceous beds, which is now entirely stripped of its cover by denudation. It is structurally also a part of the same mass described above as lying on the southeast side of the Elk Peak dome and forcing itself between the Carboniferous and the Jurassic beds. The igneous magma has, however, torn its way through the latter, or, in other words, they yielded to the great stretching they had undergone and the molten material passed to higher horizons, and, intruding here again on a large scale, has formed the Lewis Peak laccolith. The connection between the two masses is a quarter of a mile wide, too wide in relation to its short length to be called a dike. One can thus walk continuously on porphyry from Lewis Peak to the south side of the Elk

Peak dome. The porphyry composing Lewis Peak, however, differs somewhat from the other mass. It is of a somewhat darker color and much more dense in the groundmass. It appears, in fact, like the same magma in a much more finely crystallized condition. The hornblendes in it are also slender, acicular in form. On the west side of the peak the descent is in places quite precipitous, with columnar exposures of the porphyry. This was noted by Dana and Grinnell[1] who state that "on the western side the trachyte shows itself in a series of columns which are very regular and well formed, much more so than is common in this rock." It is, in fact, the best exposure of columnar jointing to be seen in the mountains. The geologic structure of Lewis Peak is seen in section F–F of Pl. LXXXIII.

ROSS PASS.

This forms the lowest divide in the whole mountain group along its southwest-northeast axis. It is about 5,000 feet above sea level and is less than 1,000 feet above the open-plains country on either side. The approach to it is a long, gradual ascent on either side. It is thus admirably adapted for a passage across the mountains, and is crossed by the mail route from Fort Maginnis down Box Elder Creek. The heads of Box Elder and east fork of Ford Creek rise either side of the pass, the former largely in a spring just north of the divide.

In the descriptive geology that follows under this heading are included the slopes on either side down to the plains country.

On the southwest the slopes rise with gentle modeling toward Lewis Peak, and a long ridge separates the head branches of the east fork of Ford Creek from the more western branch which drains the south side of the Elk Peak dome. Passing from the open country, which is dry, grass covered, and strewn with porphyry bowlders, and which rises gently toward the mountains, the first rock exposure is that of the heavy sandstone capping the Benton shales. This forms a series of revet hills which curve to the northwest, so that the shales form the outer southern edge of the south spur from the Elk Peak dome, and, passing westward, are in contact with the Maginnis Peak intrusion, as previously described. This heavy sandstone, although forming these noticeable hills, as soon as it strikes the alluvial flat formed by the branch of Ford Creek draining the south side of the Elk Peak dome as it issues into the open country, disappears and is not again noticeable on this side of the mountains. Toward the east it curves somewhat to the north, forming more revet hills, which are the southern foothills of the mountain mass on the east side of Ross Pass. These are cut through by the drainage channels from the south side of the mountains, and at the point where the east fork of Ford Creek cuts through there is a quite deep valley with prominent bluffs

[1] Op. cit., p. 98.

on either side, with the heavy sandstone capping showing very prominently as it starts at the high upstream end of the hill and dips slowly downstream until it reaches the stream level. This bluff, especially on the east side near the Bessey ranch, furnishes the best section of the Benton group seen in the mountains, and it was here that the section of these beds given in Chapter III (p. 482) was made.

It will be noticed on the map that the stream forks, the eastern fork coming down from a valley cut in the porphyry mass on the east of the pass, while the western branch drains the southern slopes of Lewis Peak. Both branches cut shallow drains in the Cretaceous beds; and the hill slopes, as soon as the Benton shales are left, exhibit the red soils of the Dakota group. On the east side of the east fork the indurated sandstone at the top of the Dakota forms a long, conspicuous, tree-covered ledge along the valley side, the top of which is a terrace covered with the bowlders and débris of a broken-down sheet of phonolite-porphyry (tinguaite). The western hill slopes are also strewn with the thin, brown, indurated plates of this sandstone, above which are the red clays already mentioned. Until one reaches the upturned beds of the Jurassic formation which lie on the back of the laccolith, as previously mentioned, there are no exposures which are sufficiently clear to determine whether the Kootanie beds occur here also, but from the position of the other sediments it is believed that they undoubtedly must. An interesting feature is a very small domed anticline in these southern foothills, which exposes black shales in its center. It is shown by a structure-line on the map, and is thought to bring the Kootanie beds up in the exposure.

As one approaches the pass the red clays and sandstones of the Dakota group become more and more in evidence, and at the lowest point in the divide they form the surface exposures. They are also seen down on the Box Elder side of the pass. The beds at the east and north foot of Lewis Peak are very sharply upturned, producing a series of small revet hills. Below, on Box Elder Creek, the slopes are smooth and grassy, without rock exposures.

CONE BUTTE MOUNTAINS.

On the east side of Ross Pass rises a mountain mass of porphyry, its most northern point forming a very sharp and quite symmetric conical hill, which, being a prominent landmark, has long been known under the name of Cone Butte. Of Cone Butte itself a more detailed mention will be given later. It is introduced at this point only to call attention to the fact that in the lack of any name for this general mountain mass it will be spoken of here as the Cone Butte Mountains, since, being quite deeply dissected by erosion, it gives from a distance the impression of a cluster of peaks rather than that of the single unit mass it really is.

On its western side this mass of igneous rock rests on Cretaceous beds—the top of the Dakota, as previously mentioned—which here

dip in under the porphyry at an angle of about 10°; that is, they dip east. They form a terrace, and from them the porphyry slope springs abruptly up at a steep angle. Hence, along the western front of the mass the beds are not turned up by the porphyry, but, on the contrary, it rests upon them, and the base of the laccolith is thus exposed. The porphyry composing the mass is more or less altered, and of the character of that forming Lewis Peak, as described on page 565. It is generally more or less decomposed and in places forms a reddish gravel. This is especially noticeable on the eastern side of the mass. And a knob of this porphyry between the extreme heads of Edwards and Little Box Elder creeks resembles in all essential respects—in its weathering, alteration, and colors—the porphyry débris of Red Mountain, described on page 536.

In all directions erosion has scored deep V-shaped valleys or ravines in this mass, from which the drainage is radially outward. The north sides of these valley slopes are covered with thick forests of small pine trees, while the south sides to the spur crests are open and grassy, often with broken-down rock barely concealed by the grass—a difficult and tiresome slope to ride or walk over. The spurs and hills are somewhat variable in their profile, but culminate in the highest point of the mass—the triangulation peak shown on the map just south of Cone Butte.

In all directions the porphyry is cut by dikes of greenish phonolite, with embedded white feldspar phenocrysts (tinguaite-porphyry), a detailed description of which is given in the next chapter (p. 567), the dike between Cone Butte and the peak south being selected as a type, as all the others closely resemble it. In width these dikes vary from 5 to 15 feet; in many places they form heavy, massive, conspicuous walls, cutting the smooth slopes; in others they are broken down into rock heaps and trains of bowlders whose linear extension alone gives hint of the dike structure. On the northeast slopes, in fact, these dikes are so thick and so much broken down and the débris so scattered that it is difficult to tell which mass really represents the site of the dike and which is transported material.

On the eastern and northeastern sides the porphyry is in contact with the Benton beds, and this appears to be true also on the southwest and extreme south, as previously noted in Ross Pass; but on the southeast this is not the case, and the spurs here show the porphyry in contact with thin-bedded, much-altered limestones which, although no fossils have been found in them, are believed to be of Jurassic age, both from their lithologic character and appearance and from the fact that the beds of this age have so generally suffered intrusions in this mountain area. Moreover, they are certainly not the massive Carboniferous, and this horizon is nowhere exposed in this part of the region. These limestones, with associated shales changed to slates, and sandstones altered to quartzite, are seen on a number of

spurs on the southeast side, where they come in contact with the porphyry, and are also cut by dikes around the head of Edwards Creek.

The amount of contact metamorphism the Cretaceous rocks have suffered through the intrusion of this igneous mass, though extending but a short distance from the contact, is considerable for a few rods. The shales and limy beds are changed to hard, tough, gray, green, and black slates, which have all the appearance and character of similar rocks found only in the Archean in Montana. In two areas shown on the map, patches of these altered sediments are found, still uneroded, on the back of the laccolith. These are baked and altered in the same way and show the same metamorphic character. They contain considerable altered limestone, and the most northern is, in fact, a limestone changed to a hard, white crystalline marble. There is but a small patch of it ("blow-out" of the prospectors), completely surrounded by porphyry, and but a few feet in thickness, as shown by the prospect pits penetrating it. From its evident limestone character it is assigned to the Jurassic, as is also, for similar reasons, the rock of the southern area.

On the extreme east, in the saddle between this laccolith and that of Lookout Peak, the porphyry is in contact with a sandstone underlying Benton shales. This sandstone is changed, by contact metamorphism, to an extremely dense, tough, hard, blue quartzite, resembling those of Archean areas. Considerable talus slides of it are seen on the slopes leading down into the head of Edwards Creek.

In the ravine which separates Cone Butte from the peak to the south a series of altered slates also occurs, as mentioned by Dana and Grinnell,[1] who say:

> In the ravine spoken of, 355 feet below the summit of Cone Butte, we were surprised to find a series of slates and sandstones. * * * The total width of the gap is about 70 yards, the trachyte [porphyry] rising abruptly on both sides. The section [of the beds] in the gap is as follows:

	Feet.
Coarse ferruginous sandstone, vertical	3
Fine blue shale, vertical	20
Slate, sometimes shaly, sometimes a good slate, and very sandy, in layers; color whitish and yellowish; dip, 70° south	180 to 200

> The strike of these slates is east and west. The age of these rocks is uncertain, as the only fossils found in them were some cycloidal fish-scales, with occasional impressions of fish-vertebræ and spines, which were quite numerous in some layers in the slate. It is hardly to be doubted, however, that they are Cretaceous. * * * The present position of these slates is very remarkable: they lie far above (about 600 feet) the rocks visible in the hills below, and doubtless owe their elevation to the eruption of the trachyte, having been squeezed up between the two great masses of igneous rock.

By reference to the Cretaceous section given on page 482, it will be seen that these beds are of the upper part of the Benton group.

[1] Report of a Reconnaissance, etc. (see footnote on p. 545), pp. 98-99.

Their occurrence is, as mentioned above, a matter of interest in that they afford another instance of how warped and irregular the upper surface of the laccolithic intrusion was.

CONE BUTTE.

This is described by Dana and Grinnell[1] as follows:

> The summit of Cone Butte commands an extensive view over the prairies of the north. The Little Rocky and the Bear's Paw Mountains, though far in the distance, are the most conspicuous points to be noticed. * * *
>
> Cone Butte is itself a conspicuous object from all the surrounding country, even as far north as the Little Rocky Mountains, its perfectly conical shape being very striking from any point on the Carroll[2] road. Viewed from the west the sides of the cone are broken, and not so symmetrical as shown in [the] figure. The slopes are covered with loose blocks of trachyte [porphyry] and at some points are precipitous. The angle of the cone is about 40° or 41°; indeed, it is so steep, and the loose blocks of trachyte furnish so insecure a foothold that, were it not for the trails made by the mountain-sheep ascending and descending, it would be no easy task to climb it from the west side.

In addition to this it is only necessary to note that the precipitous portions on the east side of the butte furnish good examples of columnar structure in the porphyry, the jointing being perpendicular and forming huge slabs standing on end. On the north side the talus descends to grassy slopes, where the heavy white sandstone forming the top of the Benton group is exposed.

INTRUDED SHEETS AND DIKES ON SOUTH SIDE.

On the south side of the mountain mass there are a number of small, narrow, deep ravines which cut down from the porphyry basins above, through the hardened zone of contact rocks with intruded sheets upturned against the porphyry, to the wide open Cretaceous drains below. They usually contain small rills of water rising in springs above, and furnish head branches to the east fork of Ford Creek. There are several occurrences of igneous rocks here which are of sufficient interest and importance to justify a more detailed description.

At the south end of the porphyry mass is the point shown on the map as the triangulation point. From this a heavy dike runs southward, forming a conspicuous wall 15 feet broad along the slope. This dike descends to the sedimentary beds below, and there abruptly ends as a dike, but continues eastward as an intruded sheet 10 to 20 feet thick. Another large dike also descends the hill, with southwest trend, to the intersection of dike and sheet above. The rock composing these is much altered, but is a feldspar-porphyry.

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[1] Op. cit., pp. 96-97.

[2] A former important steamboat landing on the Missouri River near the head of summer navigation. A freight road led thence to Helena and other points in western Montana, passing the Judith Mountains.

Beyond these to the east are several intruded sheets of green phonolite-porphyry (tinguaite), one of which is extremely dense and without any phenocrysts. They are intruded in the black Benton shales, which are somewhat indurated by metamorphic action, so that exposures of them are seen in the small gulches.

Still farther eastward, on the southeast side of the great laccolith, there are several dikes of green phonolite which run out from the porphyry, forming the crests of spurs and cutting the altered sediments. They expand into the strata in the form of intruded sheets as they extend outward, and eventually give rise to a sheet at least 50 feet in thickness, which terminates them. This sheet thus appears fed at several points, and the ravines between the dike spurs form short, narrow canyons through it and the upturned metamorphosed sediments above and below it, which afford excellent exposures. The sheet is really a small laccolith or lens standing tilted up at a considerable angle; it thins out rapidly both east and west. The rock is a light-colored feldspathic one, described in the succeeding chapter (p. 566); at the contact it has the green phonolite (tinguaite) facies, and it is believed to be the same magma as that composing the dikes and sheets in a more coarsely crystallized form, but chemical analysis would be required to definitely decide the point. The contact edges of the main porphyry have also a distinct phonolitic facies all through this part of the area. The whole occurrence is of great interest, as it gives a distinct clew to the origin of the abundant phonolite dikes cutting the main porphyry mass and the intruded sheets of the same rock in the sediments surrounding; this feature is fully described in the next chapter (pp. 572-574).

A feature of interest occurs in the upper part of Edwards Creek. In the ravine it forms in the mountains, before it debouches on the plain, there are quite thick deposits of limonite along the banks, perfectly similar to that described as occurring between the head forks of East Armell Creek. This deposit is of interest when it is noticed that the water in the stream drains, in part, from the gravelly, reddened, leached porphyry hill of the east side of the Cone Butte Mountain mass, as previously mentioned above, just as East Armell Creek and West Maginnis Creek drain from the similar porphyry of Red Mountain, and both contain iron deposits. The cause of this action is by no means clear, but there is certainly some connection between this altered porphyry and the iron hydroxide in the streams below.

LOOKOUT PEAK LACCOLITH.

The mountain area of the Cone Butte Mountains is prolonged to the eastward by another intruded laccolithic mass of porphyry, to which the name of Lookout Peak has been given on account of the magnificent view in eastward directions which it affords, there being, with the exception of Black Butte, no other elevation to interrupt the outlook to the horizon's rim.

Between this mass and the one to the west is a deep saddle cut in black shales of the Benton group. It is traversed by two dikes of phonolite, and a spring rises in it. The exposures of the soft shales are not such as to give any definite clew concerning the dip and strike of the strata, but from analogy and from what is known elsewhere it is believed that the beds run in under the porphyry at a moderate angle of dip. The porphyry itself is similar to that of the larger mass. It is cut by phonolite dikes, surrounded by fringing sheets of the same, and is in all respects similar to the larger mass to the west, which it accompanies like a satellite, and of which it is a miniature. At the extreme east end there is a little patch of baked and altered sediments, apparently on the porphyry, and beyond this is a mass of the light-colored feldspar-porphyry similar to that described in the previous section. It appears to be a dike, but the exposure is not altogether conclusive, and it may be a border facies of the main mass.

The steep slopes of porphyry talus descend to the revet hills of Cretaceous below, which are upturned sharply on all sides and contain several intruded sheets of phonolite.

BLACK BUTTE.

This mountain rises as an isolated mass at the east end of the group, towering above the open, gently contoured plains country that surrounds it on all sides. An interval of about 2 miles of this country separates its western foot-slopes from those of the nearest point in the mountains, Lookout Peak.

The butte has at first rather smooth, gently ascending slopes, grassy, and cut by small drainage valleys. Toward the butte these grow steeper, and at an altitude of about 600 feet above the plain talus slopes are met, and from here all is rock to the top. The sides are very steep, and are composed mainly of broken slide rock, with occasional crags and small precipices, and scored by narrow ravines, which at the south end become a number of deeply cut gulches, with heavy buttresses of naked rock on either side.

The slopes are dotted with occasional pines and bushes, but timber of good size is found only in several of the deeper ravines. At the head of the grassy slopes, below the line of talus, several springs break out around the sides of the butte. The crest is about 1,500 feet above the open country below.

This mountain is composed in part of a mass of granite-porphyry, upthrust through the heavier strata of the Paleozoic beds below into the lighter strata of the Cretaceous beds above. This mass has upturned with it a great block of these Paleozoic strata, which is tilted against its southern flank, and now, denuded of its sedimentary cover, the butte consists of a mass of granite-porphyry in its northern half, while the southern portion consists of the upturned Paleozoic beds,

which dip at very steep angles to the southward and lie against the porphyry. This is shown in fig. 48, which presents a map of the butte, and the cross section, fig. 49, gives an idea of the geologic relations and shows that it is an asymmetric laccolith.

The porphyry composing this mass is described in the following chapter (p. 559). At the contact with the sediments it changes to a felsite, very dense and compact, of a deep-red color.

Immediately in contact with the porphyry, on the south side, is a heavy, massive quartzite, about 100 feet in thickness, which is succeeded by Cambrian slates of the usual lenticular variety. They are

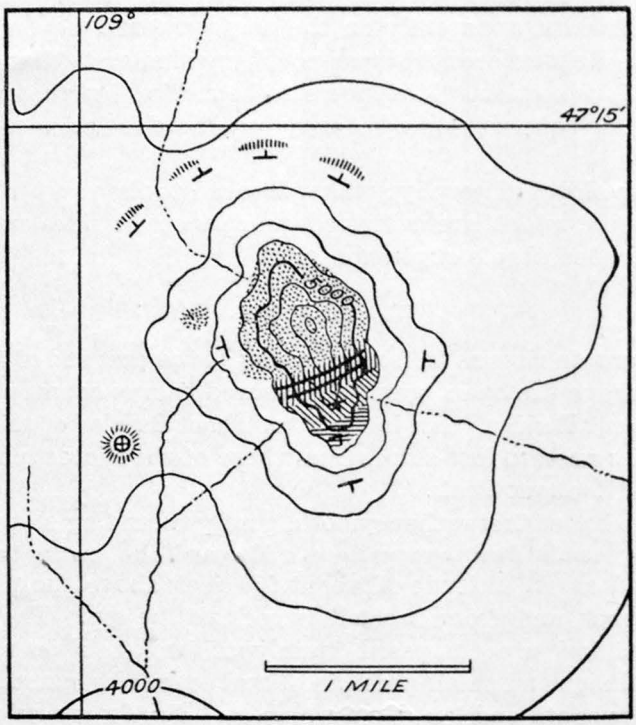

FIG. 48.—Geologic map of Black Butte. White area, Cretaceous, the sandstone reef encircling the butte shown by hachures. The stippled area is granite-porphyry. The vertical lines show Cambrian limestones with two intruded sheets of porphyry.

very greatly indurated and metamorphosed, and a couple of sheets of porphyry are intruded in them. This quartzite is of interest, as it represents the lowest horizon of this age which has been seen in the area; it occurs nowhere else.

Succeeding the Cambrian beds are strata of massive limestones, which are greatly changed by metamorphism, being whitened to marble and filled with seams and cavities full of crystallized quartz and calcite, while others are of rich purple color, due to the presence of fluorite.

The limestones in turn give place to thinner beds of shales and

limy shales, which have been changed to hard, dense, tough, green, gray, and purple slates and schists. They would be difficult to tell from the altered Cambrian were it not for the lenticular structure of the latter, while both these have all the characters of hard, schistose rocks belonging to the Archean formation. These altered beds give place in the south slopes to strata which eventually are of normal Cretaceous aspect.

The amount of contact metamorphism in this upturned block is very great, and surprisingly so when the much less altered character of the sediments around the northern part of the base is taken into account. These latter appear to be the Benton shales, which apparently formed the cover of the laccolith. The sandstone capping them forms a series of revet hills around the north end, in which the white upturned sandstone is very conspicuous. These hills are indicated on the sketch map. This sandstone recurs again in a little hill

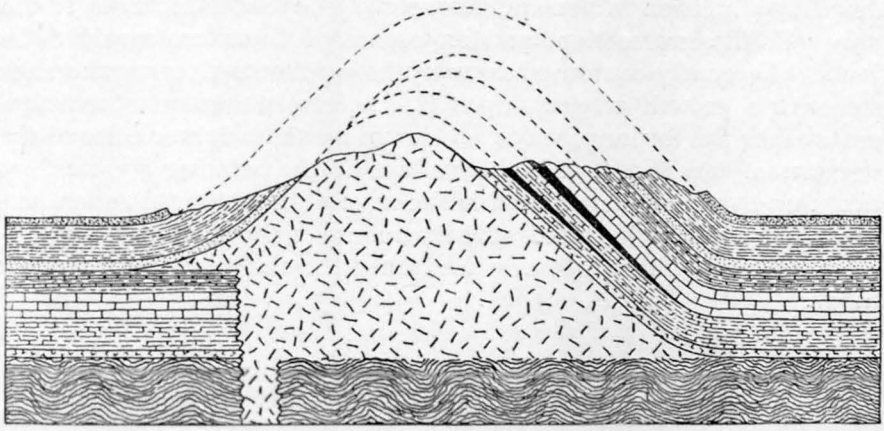

FIG. 49.—Cross section north and south through Black Butte, showing asymmetric laccolith.

southwest of the butte, where it is horizontal. Somewhat nearer to the butte on the west is a little hill in which porphyry is exposed.

The section, fig. 49, shows in a general way the manner in which the beds have been upturned, but this has not been an absolutely regular process, because in the breaking loose and thrusting back the stratigraphic relations have been disturbed in places; faults occur, and in one place the Cambrian overrides the Carboniferous, while in another place a block of brown sandstone appears under a part of the Carboniferous in nearly horizontal position, as if thrust in under it.

It is believed that the sedimentary strata are in the main, however, represented in their normal sequence, as the beds show the regular characters typical for the district, the contact metamorphism being taken into account. It is not thought that the whole thickness of the Cambrian is represented, nor that of the whole limestone section from the Silurian to the top of the Carboniferous, and probably a portion

of the Jurassic is also wanting. It spite of the excellent exposures, it is not possible, owing to the faulting and metamorphism, to make a satisfactory section, but it is believed that in the upturning of the beds some of the strata have been crowded or pinched back, as has happened elsewhere in the district under such circumstances.

The zone of altered limestone has been prospected for ores, but so far nothing has been found which would warrant development. The isolated position of the mountain and scarcity of an available water and timber supply render it an unfavorable locality for mining any but ores rich enough to stand the cost of transportation.

COUNTRY SOUTH OF THE CONE BUTTE MOUNTAINS.

This is of the general character of the open country elsewhere described in this report. Bordering the streams are long and often wide stretches of alluvial flats, while the shallow open valleys are bordered by planation tables and terraces. The beds are those of the upper Cretaceous section, and exposures of them are rarely to be found, the gently contoured country being mantled everywhere by soil with a growth of grass upon it. A certain amount of moisture seeps along the drainage ways, as shown by the brighter color of the vegetation, and these, with the valleys of the running streams, are taken up by the ranchmen, while the intervening stony flats and terraces, often thickly covered with fragments of the mountain porphyries and green phonolite, are used only for the pasturage of their herds.

CHAPTER V.

By L. V. Pirsson.

THE IGNEOUS ROCKS.

INTRODUCTION.

In some respects the igneous rocks of the Judith Mountains have already been described, where, under the descriptive geology, the general appearance of each type has been mentioned in connection with its occurrence. The aim of the present chapter is not, therefore, to present a detailed account of the various occurrences, but to give a generalized account or summary of the facts observed in the field, together with enough petrographic detail to enable one to recognize the various types occurring in the area described and to understand their petrologic significance and bearing. The field occurrences have been given in detail and will not be repeated here, while the general relation of the igneous masses to the broader problems of structural geology will be found set forth in the succeeding chapter. Thus the aim of the present chapter is chiefly petrologic, yet it is not intended at the present time to give a complete study of all of the rocks of the district, but to present data concerning the more important types sufficient to achieve the purpose mentioned above. The complete study it is hoped will be published elsewhere at a future date.

The igneous rocks of the Judith Mountains belong to only a few types, are of simple mineral composition, and are all acid rocks; that is, the amount of silica in them varies from 57 to 75 per cent. One or two types approach what may be called a medium composition, but it is a remarkable fact that in a district of such considerable size and with so many occurrences of igneous rocks there is not a single occurrence of what may be called a basic rock; they are all of light-colored feldspathic aspect, dark-colored pyroxenic rocks being absolutely wanting.

Alkaline types, rocks deficient in lime, iron, and magnesia, with high alumina and alkalies, are common in the district, and the element that varies chiefly is silica; accordingly, members of the granite, syenite, diorite, and nephelite-syenite families are found, the latter being represented by rocks of phonolitic character.

GRANITE FAMILY.

The granite family, consisting of rocks composed of alkali feldspar and quartz, with some other accessory minerals which may or may not be present, is very largely represented, but true granite, consisting of these minerals in a granular, nonporphyritic structure, does not occur. There are, indeed, in the district, one or two occurrences of granular rocks which are not porphyries, but as these are composed chiefly of alkali feldspar, they should be termed syenites, lacking, as they do, the quartz necessary for the granite. Among mining men in the West the term granite is so generally applied to all granular rocks without regard to their mineral composition that these would also undoubtedly be termed granites, but according to more strict petrologic usage they would be termed syenites. The granite family, then, is not represented by its granular member, but by the finer-grained porphyritic types, such as granite-porphyry and the still finer-grained and less porphyritic rhyolite-porphyries (commonly called quartz-porphyries).

GRANITE-PORPHYRY.

This rock constitutes a portion of the Judith Peak massif, forming there apparently a chimney or small stock intruded in the quartz-bearing porphyry, as described in the account of the Judith Peak mass on page 535. As no distinct contacts were found, it is not certain whether it is a differentiated portion of the whole mass or a separate, later intrusion.

Megascopic appearance.—In the hand specimen the rock has a light brownish-green color; it has a pale greenish-gray matrix, of a very dense, hornlike appearance, in which are embedded great quantities of a pale-gray feldspar, appearing as small square phenocrysts 1 or 2^{mm} in diameter; these are present in equal amount with the matrix. The other porphyritic component is quartz, which appears in large phenocrysts, at times one-half inch or more in diameter. The cross sections of these large quartzes show them to have (megascopically) a zonal structure. This seems remarkable with quartz, but is nevertheless clearly visible, and it would appear as if the mineral had had a renewed period of growth in which the new material differed somewhat in its physical characters from the older interior part; examined with a strong lens the difference disappears. These quartzes weather out on the rock, and many of them are extremely perfect dihexahedrons with a short prism. Crystals over 10^{mm} in length are not uncommon, and as the edges, angles, and symmetry are very perfect they make attractive mineral specimens; only the luster of the faces is wanting to distinguish them from ordinary crystals of solution, though they are not limpid, as many of the latter are. They are, in

fact, with respect to their size and perfection, the most remarkable quartz phenocrysts that have come under the eye of the writer. Such may have been mentioned in the literature, but no description of them has been seen.

No ferromagnesian mineral is megascopically visible.

Microscopic characters.—In thin section the quartz shows nothing remarkable beyond its size and the fact that certain grains penetrate, so to speak, on their outer boundary, into the groundmass and include quantities of small crystals of the minerals composing it. Sometimes they are cracked, and the cracks are filled with a pale-yellow substance which shows a spherulitic structure between crossed nicols, like many of the flow-lines of chain spherulites seen in rhyolites.

The feldspar phenocrysts which have been mentioned are composed in the main of an unstriated feldspar, which is probably orthoclase, containing quantities of small crystals, and rather large microlites of albite much twinned. These latter are often arranged in a rudely zonal structure, and the whole appearance of the phenocrysts is precisely similar to that of the feldspar phenocrysts described by the authors in the syenite-porphyry of Lookout Butte in the Little Rocky Mountains[1] and in that of Gray Butte in the Bearpaw Mountains;[2] while somewhat related occurrences have been described by Brögger.[3]

The groundmass between these feldspars, which is small in amount, is made up of microlites of albite, small irregular patches of anorthoclase, and occasional small areas of a spherulitic character, which appear like little patches of devitrified glass, together with small prisms of ægirite. These are mingled in a microgranitic structure. The ægirite has the usual optical characters, pyroxene cleavage, and crystal form, but is of a rather light tone, more the character of an ægirite-augite; nevertheless the bisectrix $\mathfrak{a}$ lies close to the crystallographic axis.

This occurrence of an ægirite-granite-porphyry is of great interest, as such rocks are extremely rare, and the present instance is quite typical.

At the "Chimneys," in the valley of the North Fork, which form the boundary of this granite-porphyry in one direction, the rock has a gneissoid look, owing to the fact that the huge quartz phenocrysts have been cracked up into a series of chips and distributed along in streaks showing the flowage action of the ascending magma as well as the intratelluric origin of the quartzes.

Granite-porphyry also occurs at Black Butte, of which it forms the chief mass. This variety is more like that of the ordinary type of such rocks, with rather small quartzes, which are not very abundant, and numerous black hornblende prisms.

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[1] Geology of the Little Rocky Mountains, Weed and Pirsson: Jour. Geol., Vol. IV, 1896, p. 422.
[2] Bearpaw Mountains, Montana, Weed and Pirsson: Am. Jour. Sci., 4th series. Vol. I, 1896, p. 291.
[3] Grorudit-Tinguait Serie, Christiania, 1894, p. 17.

RHYOLITE-PORPHYRY ("QUARTZ-PORPHYRY").

This is probably the most common rock in the Judith Mountains, forming everywhere numbers of intruded sheets, as well as masses of the laccoliths. It rarely occurs in a fresh condition, and a typical specimen from the intrusive porphyry sheet on the spur above the Giltedge mine is selected for description.

Megascopic characters.—The rock does not occur in large blocks, but is cracked into small angular fragments a few inches square. These fragments on a weathered surface are of a light brownish-buff color, often turning to a darker brown or crimson on the edges, sometimes a straw-yellow. When broken with a hammer the pieces often show that they have broken along a joint face and are dark and discolored from infiltrated iron oxides; when the break is across fresh material the rock has a pale-brown color.

The outer exposed faces of these fragments show only matrix and no phenocrysts, the place which they formerly occupied being represented by quantities of small angular pits dotting the surface of the rock and giving it a cavernous appearance.

The broken surface of fresh portions shows a dense, flinty matrix of a light-brown color, in which are embedded considerable numbers of small feldspar and quartz phenocrysts, which speckle it with lighter-colored spots; these embedded crystals are from 1^{mm} to 2^{mm} across. Small rusty spots show the presence of some former iron-bearing mineral, which is now decayed.

Microscopic characters.—Under the microscope the thin section of this rock shows a very fine groundmass made up of a mixture of quartz and alkali-feldspar granules in allotriomorphic structure. Embedded in this are occasional quartzes of the rounded, corroded type common in such rocks; they are not abundant. In addition there are occasional sections, mostly converted to clay and sericite, which are the former feldspar phenocrysts; while an occasional one of muscovite stained with iron ore indicates that biotite was probably present. The groundmass is filled with fine shreds of sericite, and the rock is everywhere stained with secondary iron; everything, in fact, shows that it has been much altered.

The rock shows all the typical characters of the intrusive rhyolite-porphyries (generally called quartz-porphyries) which occur so widely in Europe—in the "elvans" and acid "sills" of England and the "quartz-porphyry" masses in Germany and elsewhere.

The rocks of which the above may be taken as a type, as noted in the descriptive chapters, occur in a great number of localities, the laccolithic masses of the southwest part of the mountains, with the numbers of intrusive sheets above them, being the main occurrences. The intruded sheets above the town of Maiden, a considerable portion of the Gold Hill intrusion, and large areas of the Judith Peak mass may also be added.

SYENITE FAMILY.

Rocks of the syenite family, consisting chiefly of alkali feldspars, are not uncommon in this region. They include syenite and syenite-porphyries, and a number of important occurrences of what may be called syeno-diorite-porphyries, rocks transitional to the diorite family, with some types actually belonging to the latter.

SYENITE.

What appears to be a small intrusive stock of this rock occurs on Judith Peak, about a mile west of the peak proper, at the head of the north branch of the North Fork Creek. It does not have exposures which enable one to infer definitely concerning its relation to the surrounding porphyry. It has been described in Chapter IV under the account of the Judith Peak intrusion (p. 535).

Megascopic characters.—On a fresh fracture the rock appears of a dark brownish gray with a reddish tone; it appears clearly granular without porphyritic crystals; the grain is rather fine, the rock feldspathic with dark-colored ferromagnesian minerals very sparingly present. This lack of colored minerals and its compact fine grain make the rock appear very similar to many granitic aplites.

Microscopic characters.—In thin section the rock appears composed chiefly of unstriated alkali feldspar, with a good deal of striated feldspar, an oligoclase, present in somewhat larger crystals. These feldspars are rather idiomorphic but thickly crowded, and the small interspaces are filled with finer grains of the same, mingled with some of quartz; the amount of this latter mineral is small and by no means sufficient to throw the rock into the granite group.

In addition to these minerals there is a small amount of pyroxene present in the shape of occasional prisms of a clear, sea-green diopside, and this, with a little iron ore, titanite, and apatite, completes the list. The structure is granitic, the rock very fresh and unaltered.

A syenite which closely resembles this occurs at Yogo Peak, in the Little Belt Range, Montana, and has been described by the authors,[1] but the present type does not probably contain as much lime, iron, and magnesia. The amount of plagioclase present is, however, considerable, and the rock inclines toward the diorites or toward the family which Brögger[2] has classified as the monzonites; in this classification it would lie between a typical alkali syenite and a banatite.

A rock of very similar character to this syenite of Judith Peak constitutes the mass of Maginnis Peak. It is, however, distinctly finer grained, and there is a decided approach to a porphyritic development of the feldspars, which in places carries the rock into a distinct

[1] Igneous rocks of Yogo Peak, by Weed and Pirsson: Am. Jour. Sci., 3d series, Vol. L, 1895, p. 470.

[2] Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtyrol, 1895, p. 21.

porphyry. It thus stands on the border line between a syenite and a syenite-porphyry. The same is true of that portion of the Judith Peak-Red Mountain intrusive mass which lies at the head of the middle fork of Armell Creek, the high spur which sets out to the north from Red Mountain.

The rock here is almost without phenocrysts, but the grain is very fine. Separated by intervals of several inches are found sporadic feldspar phenocrysts. The rock might be described, perhaps, as syenite-porphyry with the phenocrysts wanting. The groundmass is distinctly granular to the eye and as fine as many aplitic rocks. These types are transitional to the syenite-porphyries.

SYENITE-PORPHYRIES AND DIORITE-PORPHYRIES.

GENERAL DISCUSSION.

As previously remarked, rocks of this class are very common in the district, but under this name is included not only typical syenite-porphyries but also a number of rocks in which there is a considerable amount of free quartz. This quartz does not appear, however, in the shape of phenocrysts, and is not, therefore, megascopically visible; it is entirely concealed in the groundmass, and many of the rocks, both on account of the lesser amount of quartz and the habit they possess, stand as a transition type between the granite-porphyries or rhyolite-porphyries on the one hand and the true syenite-porphyries on the other. It seems best, therefore, to call these rocks quartz-bearing syenite-porphyries. They might, indeed, be termed felsite-porphyry, but the name is rather objectionable, and with their abundance of large alkali-feldspar phenocrysts and granular-looking groundmasses they do not at all resemble those rocks which have been called felsites.

In another way these rocks are difficult of classification, in that they grade from types which are clearly syenite-porphyries, in which alkali feldspars predominate, into types in which just as clearly plagioclase or soda-lime feldspars predominate, and hence are diorite-porphyries. Probably the most common rock of them all is one which contains numbers of very large idiomorphic phenocrysts of orthoclase, often an inch or more long, and much more numerous phenocrysts of plagioclase, varying from oligoclase to andesine, whose size is about that of coarse shot, embedded in a groundmass of alkali feldspar and quartz. The light-colored surfaces of this rock are dotted by small prisms of a black, glittering hornblende. The rock of Maiden Peak illustrates this type. It is a very common type of rock in western America, and it is probably the most common one found in laccolithic intrusions—so common, indeed, that some authors have been inclined to see a special connection between the type and that mode of geologic occurrence.

Cross[1] has described a number of occurrences of this intermediate type from the laccolithic mountain groups of the central plateau region under the name of diorite-porphyrites and hornblende-porphyrites. Lindgren[2] also mentions rocks of this character from the Moccasin Mountains and other localities in Montana, and calls them porphyrites. In a previous paper[3] they were called dacites. These Montana localities, so briefly described by Lindgren as the result of his reconnaissance work, have been more fully studied by us, and in the course of our work we have found numbers of these rocks, occurring in various modes of intrusion.

Other examples might be cited, but the above are sufficient to show that the type is a common and well-recognized one, and that the rocks have been generally called porphyrites or diorite-porphyrites, and thus placed in the diorite family.

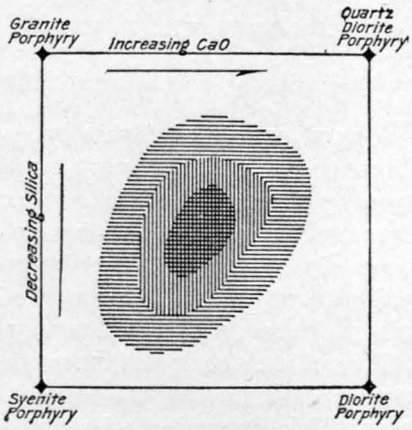

FIG. 50. — Graphic representation of rock-type relationships.

In some cases the classification adopted for these rocks has been based wholly on the dominant phenocryst, and no account has been taken of the groundmass. While often the plagioclase phenocrysts are numerically the greater, if the whole amount of alkali feldspar present in the rock, in opposition to the plagioclase present, should be summed up, the former in many cases would exceed; and it can not be correct to call such a rock a member of the diorite family, in which a lime-soda feldspar is supposed to dominate. Carried out with logical correctness, the transition would present the following types:

Granite-porphyry Grano-diorite-porphyry Dioro-granite-porphyry Quartz-diorite-porphyry
Syenite-porphyry Dioro-syenite-porphyry Syeno-diorite-porphyry Diorite-porphyry

These relations are best seen in fig. 50, in which the more heavily shaded parts indicate the more common type.

Analyses of this class of rocks frequently show that, magnesia and iron being low, the lime is compelled to enter the feldspar, and thus a comparatively small amount of lime will turn a large amount of soda into an acid oligoclase, which might otherwise have formed alkali feldspar with the potash. With more magnesia and iron present the lime might enter wholly into hornblende or pyroxene, and, the feldspar being a nonstriated one, the rock would be classed as belonging to the syenite family.

[1] Laccolitic mountain groups, etc.: Fourteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 157.
[2] A sodalite syenite, etc.: Am. Jour. Sci., 3d series, 1893, Vol. XLV, p. 286.
[3] Eruptive rocks from Montana: Proc. California Acad. Nat. Sci., Ser. II, Vol. III, p. 39.

The writer's feeling in regard to the matter is that such rocks may, for ordinary field purposes, be termed simply "porphyries," or if the character of the prevailing phenocrysts can be made out on a cleavage surface by the lens (which will rarely happen), it may then be termed diorite- or syenite-porphyry; but when the rock is subjected to petrographic study, it should not be classified by the phenocrysts alone, but by the total feldspar present, and, if necessary, chemical determinations should control the microscopic analysis.

Brögger[1] has attempted to meet the difficulty of the proper classification of transition types between the alkali and the soda-lime feldspar rocks, in the case of the granular rocks, by proposing a new class for them, the monzonites; and if, following this idea out into the porphyritic rocks, we should name them according to Brögger's proposal, they would vary from *adamellite-porphyry* to *banatite-porphyry*.

SYENITE-PORPHYRY.

A good example of this type occurs in the intrusive rock at the Florence mine. A variety exposed on the hillside above the mine opening shows a purplish chocolate-colored rock, of rather dense character, spotted with pale-yellow tabular feldspars. These feldspars are orthoclase, and the groundmass is of trachytic structure, with altered and decomposed hornblendes. Rocks of this type, more or less altered, occur in several places in this region.

The rock which forms the summit of Big Grassy Peak may be taken as a type which shows affinities toward the diorites. It is brownish-gray, thickly crowded with feldspar phenocrysts and speckled with black prisms of a ferromagnesian mineral. The microscope shows both augite and hornblende to be present. The augite is in part a green diopside, which varies into a deep-green ægirite-augite. The hornblende, which is partly resorbed, has the following optical scheme: $\mathfrak{c}$, deep green with olive tone; $\mathfrak{b}$, pale leather-brown; $\mathfrak{a}$, pale leather-brown; absorption strong. $\mathfrak{c}>\mathfrak{b}>\mathfrak{a}$.

This variety of hornblende occurs in a number of the rocks of this area. The feldspar phenocrysts are mainly orthoclase, but a very considerable quantity of andesine is present. These minerals lie in a groundmass of flakes of alkali feldspar with some quartz; a little titanite, iron ore, and apatite complete the list of minerals.

Rocks that seem to be of this type occur commonly throughout the mountains; the dikes and sheets on Elk Peak appear to belong to it, as well as portions of the Gold Hill intrusive mass on its southern edge.

The brownish color of these rocks, with the strong mottling of the prominent white feldspars, serves to distinguish them from the next type. A most interesting feature in connection with this type of Big

[1] Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtyrol, 1895, p. 21.

Grassy Peak is that the great Judith Peak-Red Mountain intrusion has on its periphery a facies consisting of this type, while the interior of the mass, as far as it is yet exposed, is the rhyolite-porphyry previously described. It thus appears to show a distinct, though slight, differentiation border.

DIORITE-PORPHYRY.

This is illustrated by the rock which forms the talus blocks and masses on the southwest side of Maiden Peak. The rock is very light colored, with numerous phenocrysts, large ones of alkali feldspar, and smaller, much more numerous ones of plagioclase, which is variable, but may be as basic as andesine, with black prisms of hornblende embedded in a fine groundmass, which the microscope shows to be made up of alkali feldspar and quartz, generally arranged in a peculiar micropoikilitic structure. The rock is apt to be altered. Many of the intrusive sheets in the mountains appear to be of this type. It seems to be that composing the masses of and around Bald Butte.

Another variety of this diorite-porphyry is that which forms the mountain mass east of Ross Peak, of which Cone Butte is the northern part. Of this rock Dana[1] says:

> The main constituent of the rock is a triclinic feldspar, as revealed by a thin section under the microscope, though occasional crystals of orthoclase of greater size may be observed. Hornblende follows next in order, the crystals being very distinct; and, further than this, magnetite plays an important rôle—this is distributed more generally than is common in similar rocks and is seen by the microscope as extremely minute grains whose metallic character is revealed only in reflected light. These particles of magnetite have suffered alteration to a considerable extent, and the feldspar is often stained red and yellow in a ring about them by the oxidized iron. It is to this alteration that the peculiar red color of the talus on the sides of the hills, as seen from a distance, is undoubtedly due.

The rock is rather dense and compact, with numerous small phenocrysts of andesine and larger, less numerous ones of orthoclase embedded in a very fine-grained groundmass of alkali feldspar with a very little quartz and stained with iron hydroxide. Phenocrysts of hornblende are present, more or less resorbed, and shreds of hornblende appear scattered through the groundmass. A little iron ore and apatite complete the list of minerals.

The rock of the mass on the west side of Ross Pass, composing Lewis Peak, is of the same character but somewhat fresher.

Other types of these diorite-porphyries and syenite-porphyries might be mentioned, but the above is sufficient to give an idea of the most important occurrences and to furnish descriptions by which all of them may be readily classified. It is believed, also, that sufficient has been said to show the transition from the syenite to the diorite family and the intermediate position of many of the types.

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[1] Report of a reconnaissance, etc. (see footnote on p. 545), p. 97.

PHONOLITE FAMILY.

In addition to the types of rocks previously described as occurring in the Judith Mountains, there are a large number of intrusive sheets and dikes of alkaline types—that is, rock in which the percentage of silica is lowered and a proportionate increase of alumina and the alkalies has forced some silicate to form, in addition to feldspar, which is richer in alumina and alkalies and poorer in silica than the latter. These rocks are also deficient in lime, magnesia, and to some extent iron, and they are thus members of that family of rocks that are nephelite-syenites when granular, phonolites when fine grained and porphyritic. They belong, moreover, most of them, to that subclass of phonolites characterized by a considerable amount of the soda-iron pyroxene, ægirite, and have in consequence, as a rule, a greenish tinge and greasy luster, this becoming more pronounced as the rocks become denser in grain, until they are tough, dense rocks of a dark grass-green color. This variety of phonolite is known as *tinguaite*, and hence these rocks are chiefly tinguaite and tinguaite-porphyry; but in a few instances the rocks are so much coarser in the grain of the groundmass (the ægirite, instead of being thickly disseminated in microscopic needles as a coloring matter, being condensed in larger prisms, so that the green color is largely lost) that the rock can no longer be called a tinguaite, but is really a very fine-grained porphyritic nephelite-syenite or, probably still better, an ægirite-syenite-porphyry, since the actual amount of nephelite in the rocks is small and the mineral is to be considered as accessory rather than as a component of equal importance with the feldspars. Thus the rocks lie between the classes of the alkali syenites and nephelite-syenites.

ÆGIRITE-SYENITE-PORPHYRY.

There appear to be three important occurrences of this type, in each case forming a thick intrusive sheet. The first is intruded in upturned Cretaceous beds on the southeast side of the Cone Butte Mountains, between the heads of Edwards Creek and the east fork of Ford Creek, and has been described in the previous chapter (pp. 549–550). The rock is of a grayish color, weathering rather brown, and has a strong tendency to split into thin plates, owing to pronounced parallelism in flow structure of the large quantity of very thin tabular feldspar phenocrysts which it contains. These are embedded in a fine-grained groundmass, which, however, is easily perceived to be granular by the eye alone and which contains numerous small black prisms of augite.

Another occurrence of this rock is found in a thick sheet intruded in upturned Cretaceous strata in the spur next east of Maginnis Peak and on the east side of the east fork of Maginnis Creek. It is referred to in the previous chapter (p. 541). The rock has a rather fine, dense

groundmass of a pale gray-green color, speckled with black prisms of augite, and in this are embedded large feldspar phenocrysts, which are thickly crowded. The rock furnishes a transition to the denser, greener tinguaites.

The third occurrence is that of the Cemetery Hill below Maiden. It is not quite certain whether this is an intruded sheet or an eruptive mass, but it is probably the latter. On a surface of fresh fracture the rock is of a gray color with a tone of green. It is distinctly granular to the eye alone, the average size of the smaller components reaching perhaps 0.5^{mm}. They consist of feldspars of a gray color, a feldspathoid of a pinkish tone, which is present in small amount, prisms of a black augite, which vary greatly in size, and a small quantity of a fibrous zeolite. In this lie embedded tabular feldspar phenocrysts, thickly crowded, which are of all sizes from 20^{mm} down. The section of this rock shows that the black augite is ægirite-augite, with an exterior mantle of ægirite and often with diopside cores; that the feldspar is entirely an alkali feldspar, showing various interesting features, and somewhat kaolinized. A considerable quantity of an isotropic mineral is also present, which shows occasionally faint optical anomalies and which may be analcite, perhaps in part sodalite. A fuller petrographic and chemical investigation of these types will undoubtedly reveal a number of interesting details.

These types lead us by a greater compactness of groundmass into the tinguaites, to be next considered.

TINGUAITE-PORPHYRY.

This type occurs in large numbers in the northeastern part of the district. It has not been found in that portion of the mountains which lies south of the dividing line of Maiden Canyon and upper Warm Spring Valley. It occurs entirely in the shape of dikes and sheets. The former cut the intrusive masses of the Judith Peak-Red Mountain massif, the Elk Peak mass, and that of the Cone Butte Mountains in all directions, while the intrusive sheets have been found almost entirely in the Benton group. When fresh these rocks are hard, tough, very dense, dark green, with quantities of light-colored, white, or glassy feldspar phenocrysts scattered through them in all directions. These feldspars are usually crowded. They are generally tabular, sometimes arranged in parallel lines, indicating flowage in the dike or sheet, and in that case parallel with the walls and sometimes scattered without direction or orientation. They vary greatly in size in the different occurrences—from very minute ones 2^{mm} or 3^{mm} long to those of huge dimensions, whose thick tables show surfaces as large as the palm of one's hand, an instance of this kind occurring at the mouth of the canyon of West Armell Creek, as described on page 524. In general they average from 0.5^{mm} to 10^{mm} across.

As this rock type is a rare one and yet is a very common and prominent one in this district, it seems well to select one occurrence and give a somewhat detailed account of it, in order to present one description which will serve as a basis of comparison for all the others. For this purpose a specimen of the dike which lies with a north-south trend in the saddle between Cone Butte and the triangulation point south is selected. This dike is mentioned by Dana and Grinnell,[1] who give the following account of it:

The descent from Cone Butte was made by way of the deep ravine which separates it from the trachytic hills to the south. The white trachyte is carried down nearly to the gap, where we passed a transverse dike, east and west in direction, of a hard green trachyte, with a cubical fracture breaking into large blocks. . . . This is probably a later dike, subsequent to the formation of the other hills. This trachyte, as well as that of Cone Butte, was found in fragments abundantly over the prairie, even to a distance of 15 miles from the mountains. It is characterized by crystals of a glassy orthoclase, which give it a porphyritic structure. Under the microscope these crystals are found to be more or less clouded, in consequence of incipient alteration; this is also shown by the indistinct color obtained in polarized light. Accompanying the large crystals of orthoclase are smaller thin-bladed crystals [of orthoclase] in great numbers. The other essential constituent is the hornblende, which is seen in simple distinct prisms; it has a deep-green color, and is strongly dichroic. No quartz was observed. The most interesting feature of the rock is the green base, which, under a low magnifying power, seems to be without structure, but, when magnified highly, is resolved into countless minute, acicular crystals jumbled together in a confused mass.

The hornblende mentioned is, of course, ægirite, which, in the condition of petrography at that time, was not distinguishable from it; so also are the needles mentioned as being in the base. This, so far as we know, is the first tinguaite which has ever been described.

The writer owes to the kindness of Prof. E. S. Dana an opportunity to examine and study the specimen mentioned above, and finds it to coincide with examples collected by himself. A previous study and analysis[2] of the rock had been made, the results of which are here given.

Megascopic characters.—In a dense, compact, green (dark grass-green without tone of gray) groundmass lie numerous feldspar phenocrysts of tabular and columnar form, but rather stout habit, from 10^{mm} in size down. Besides these there are many very much smaller black prisms of augite. The rock has a rather platy fracture.

Microscopic characters.—In thin section the large feldspars are seen to be somewhat altered; they present the varying, mottled character of anorthoclase, but there are areas which are perfectly homogeneous and with orthoclase character. It would appear as if this variable character was due to a breaking up of the compound molecule of anorthoclase into albite and orthoclase. The phenocrysts of augite are of clear green pleochroic ægirite-augite, with ægirite mantle.

[1] Report of a reconnaissance, etc. (see footnote on page 545), p. 97.

[2] The Bearpaw Mountains of Montana, by Weed and Pirsson: Am. Jour. Sci., 4th series, Vol. II, 1896, p. 192.

The groundmass in which these minerals lie is made up of small feldspars, minute areas of nephelite, others of an isotropic mineral, the whole mingled with considerable quantities of secondary zeolites and pinned through and outlined in every direction by countless slender needles of ægirite, which shrink to the most minute size perceptible with high powers. They frequently outline small sections of a round shape, now converted into zeolites. The structure may be said to be allotriomorphic as nearly as anything. The character of the rock as seen in thin section is shown in Pl. LXXXI, *A*.

Chemical analyses.—The analysis of this rock shows the composition given in Column I of the following table:

Analyses of tinguaites.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	Ia.
SiO_2	57.63	57.46	56.58	54.46	58.89	53.21	55.90	52.91	0.960
Al_2O_3	17.53	15.40	19.89	19.96	19.67	22.02	19.00	19.49	.170
Fe_2O_3	3.46	4.87	3.18	2.34	1.79	.....	2.05	4.78	.022
FeO	1.18	.87	.56	3.33	1.23	4.18	2.54	2.05	.016
MgO	.22	1.37	.13	.61	.17	.91	1.10	.29	.006
CaO	1.35	2.59	1.10	2.12	1.31	1.33	3.12	2.47	.024
Na_2O	5.80	5.48	10.72	8.68	4.41	10.37	8.49	7.13	.093
K_2O	9.16	9.44	5.43	2.76	11.00	6.41	5.41	7.88	.098
H_2O	3.22	.91	1.77	5.20	1.11	.81	(?)	1.19	.....
TiO_2	.23	.60	(?)	trace	(?)	.35	1.45	none	.....
Cl	.08	.20	(?)	(?)	(?)	(?)	(?)	.53	.002
P_2O_5	trace	.21	(?)	(?)	(?)	(?)	(?)	trace	.....
SO_3	.....	.13	.....	.....	.....	.....	.....	.52	.....
CO_2	.....	.13	.....	.....	.....	.....	trace	none	.....
Fl	.....	trace	.....	.....	.....	.....	.....	X.48	.....
MnO	trace	trace	.47	trace	.59	.42	.28	.44	.....
BaO	not det.	.60	.....	.....	.....	.....	.....	.....	.....
SrO	not det.	.16	.....	.....	.....	.....	.....	.09	.....
Li_2O	trace	trace	.....	.....	.....	.....	.....	trace	.....
	99.86	100.42	99.83	99.46	100.17	100.01	99.34	100.25	.....
O Cl	.03	.05	.....	.....	.....	.....	.....	.13	.....
	99.83	10 0.37	.....	.....	.....	.....	.....	100.12	.....

I. Tinguaite-porphyry dike, Cone Butte, Judith Mountains, Montana; L. V. Pirsson, analyst. Weed and Pirsson, Am. Jour. Sci., 4th series, Vol. II, 1896, p. 192.

II. Tinguaite-porphyry dike, Bean Creek, Bearpaw Mountains, Montana; H. N. Stokes, analyst. Weed and Pirsson, Bearpaw Mountains, Am. Jour. Sci., 4th series, Vol. II, 1896, p. 192.

III. Tinguaite dike, Hedrum, South Norway; G. Paykull, analyst. Brögger, Grorudit-Tinguait Serie, p. 113.

IV. Tinguaite dike, Njurjawpachk, Umptek, Kola; K. Kjellin, analyst. Ramsay and Hackmann, Neph. Syen. Gebiet Kola, Fennia II, No. 2, 1894, p. 158.

V. Tinguaite ("Leucit tinguait vitrophyr") Picota, Serra de Monchique, Portugal; A. Zilliacus, analyst. Kraatz-Koschlau and Hackmann, Eleo. Syen. der Serra de Monchique, Tscher. Mitth., vol. 16, 1896, p. 252.

VI. Tinguaite-porphyry dike, Foia Serra de Monchique, Portugal. Ibid.

VII. Mica-tinguaite. Ibid.

VIII. Leucite-tinguaite, Magnet Cove, Arkansas. J. F. Williams, Ig. Rocks, Arkansas, 1890, p. 287.

I*a*. Molecular ratio of oxides in I.

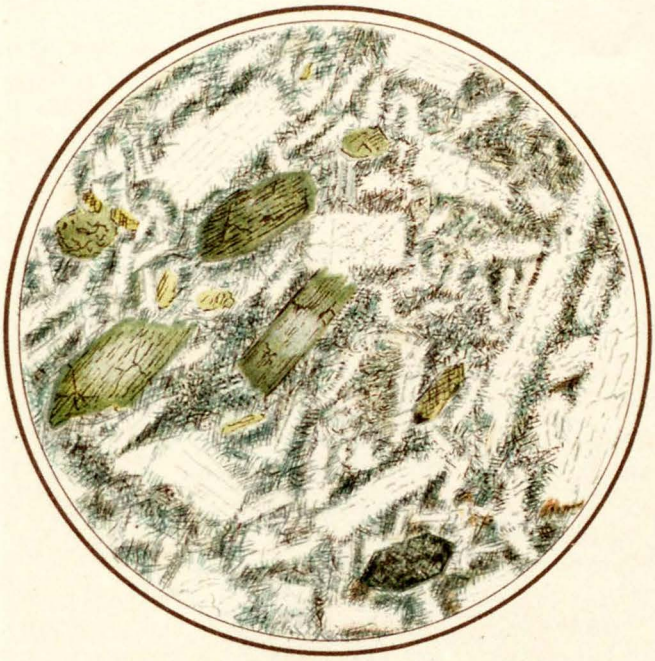
A comparison of this analysis with analyses of other tinguaites from various parts of the world shows that it possesses all of the type characters. In its relative proportion of soda to potash it agrees very closely with tinguaite from the Bearpaw Mountains, another island mountain group whose peaks on a clear day can be seen from the Judith Mountains. The peculiarity of these rocks lies in the large amount of potash they contain, which is, as our studies of the central Montana rocks show, a regional peculiarity, a feature of this "petrographical province" which is akin to the strong soda content of the alkaline rocks of southern Norway.

A study and comparison of the molecular ratios given in Column I*a* of the preceding table shows, in connection with the minerals made out by microscopic study, that the rock has the composition seen in the following table:

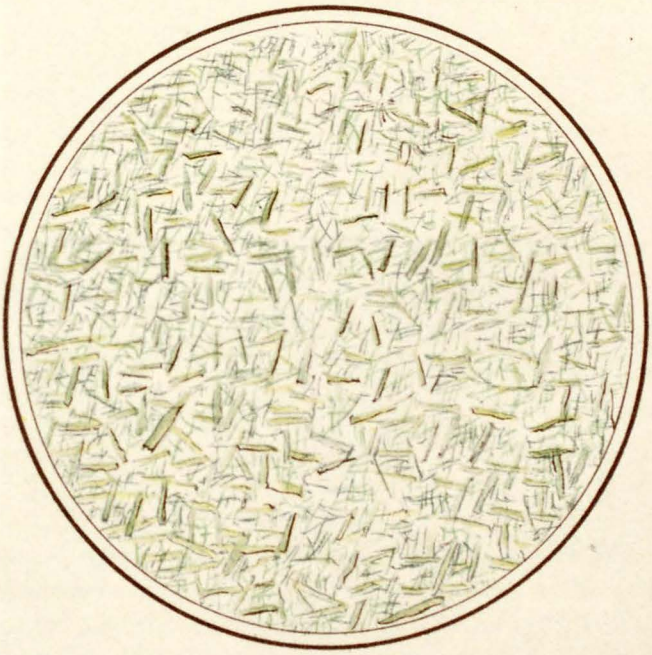
Mineral composition of tinguaite.

	Ægirite.	Diopside.	Orthoclase.	Albite.	Nephelite.	Sodalite.	Calculated.	Found by analysis.
SiO_2	2.69	2.69	35.35	12.89	3.71	0.43	57.76	57.63
Al_2O_3	.....	.....	10.11	3.69	3.18	.37	17.35	17.53
Fe_2O_3	3.46	.....	.....	.....	.....	.....	3.46	3.46
FeO	.....	1.18	.....	.....	.....	.....	1.18	1.18
MgO	.....	.22	.....	.....	.....	.....	.22	.22
CaO	.....	1.24	.....	.....	.....	.....	1.24	1.35
Na O	1.36	.....	.....	2.22	1.92	.30	5.80	5.80
K_2O	.....	.....	9.16	.....	.....	.....	9.16	9.16
Cl	.....	.....	.....	.....	.....	.08	.08	.08
Total	7.51	5.33	54.62	18.80	8.81	1.18	.....	.....

The quantity of water furnished by the analysis shows the very considerable amount of zeolitic alteration the rock has undergone. Fortunately, however, in these zeolitic formations the changes are in the majority of cases merely a shifting of the molecules among themselves with the addition of water. Matter (except water) is usually neither added to nor subtracted from the rock, and the proportions of the elements given by analysis in such cases show those of the original



A



B

THIN SECTIONS OF PHONOLITIC ROCKS (TINGUAITE) FROM THE JUDITH MOUNTAINS.

L.V.P. del.

A. Tinguaite-porphyry dike at Cone Butte, collected by E. S. Dana. Plain polarized light. Phenocrysts of ægirite-augite with ægirite rims and of anorthoclase or soda orthoclase in a ground mass of the same feldspar with nephelite and a little altered sodalite penetrated by innumerable needles of ægirite. Multiplied by 36; actual field 2 mm.

B. Dense non-porphyritic tinguaite; sheet in Benton shales, south side of Cone Butte mountain mass. Fine prisms and needles of ægirite-augite and ægirite mixed with small laths of alkali-feldspar and a little nephelite. Multiplied by 63; actual field 1.2 mm.

unaltered rock. Of course cases are common where this is not so, but such are readily seen in the change in the character of the rock itself. We may therefore disregard the water in making this calculation, and refer the oxides to those mineral molecules which are present and which we know have been the ones altered. The close agreement between the calculated and the theoretic composition is proof of the correctness of the composition assigned.

The ægirite-augite, then, has the following composition, deduced from the analysis:

Theoretic composition of ægirite-augite.

		Molecules.	
SiO_2	41.1		
Fe_2O_3	26.9	$Na\dddot{F}eSi_2O_6$	219
FeO	9.2	$Ca\ddot{F}eSi_2O_6$	164
MgO	1.7	$CaMgSi_2O_6$	55
CaO	10.5		
Na_2O	10.6		
	100.0		

Or, in other words, it consists of a mixture of exactly one molecule of diopside-like pyroxene with one of ægirite.

NONPORPHYRITIC TINGUAITE.

Description.—In addition to those tinguaites which contain large phenocrysts of feldspar there are one or two cases where these are entirely lacking and the rock becomes a typical tinguaite. The best example of this is seen in the sheet intruded in Benton shales on the south side of the Cone Butte Mountain mass, and which is mentioned in the latter part of the preceding chapter (page 552). This, like the groundmass of the rock already described, is without any porphyritic crystals; it is perfectly dense, dark green, and its character is shown in Pl. LXXXI, *B*. A somewhat similar rock is found in the bowlders in the park at the head of Spotted Horse Gulch and on the south side of Big Grassy Peak. It contains a few scattered phenocrysts, however, and brown melanite was noted in it. The same mineral occurs in other rocks of this class. In fact, every transition from tinguaites without phenocrysts to those with phenocrysts of great size, thickly crowded, may be found. While it is clear that in many cases the phenocrysts have been brought up to the place where they now are from greater depths, in other cases the evidence is against this and points to their formation in place.

Weathering.—While these rocks often assume a dark, rusty color, due, perhaps, to change of the iron from ferric silicate to hydroxide, it is noticeable in this region that they often weather and bleach, becoming at the same time gradually much lighter in color. In some cases, indeed, the dike has been thoroughly kaolinized and the iron leached out, so that it is now a light-colored clay recognizable only

by the feldspar pseudomorphs and characteristic structures it retains. Just what the process is that produces this bleaching and leaching out of the iron is not known, but it is to this that the iron ore accumulations on several of the streams—West Armell, West Maginnis, and Edwards creeks—are due, the tinguaite dikes as well as the large porphyry masses furnishing the material.

Tinguaite border facies.—In several localities on the edge of the great Judith Peak-Red Mountain intrusion, as, for instance, near the Chicago prospect mine, between the head forks of West Maginnis Creek, the porphyry appears to pass into a tinguaitic phase, with tabular feldspar phenocrysts and greenish groundmass; but unfortunately the relations are obscure from the broken-down and altered character of the exposures; and so, while the authors believe this to be the case, they do not feel that it is certainly proved. A similar case was noted by Mr. Weed in the Little Rocky Mountains and mentioned in our joint paper on that region.[1]

GENERAL PETROLOGY.

From what has been said in the foregoing pages of this chapter it can be readily seen that the Judith Mountains present types of igneous rocks which fill only one portion of the list of groups—the acid-feldspathic half. They range from syenite to granite-porphyry, but the basic types, the pyroxenic rocks, are wanting. Nevertheless, they appear to occur in most of the varied modes of intrusions, as laccoliths, dikes, sheets, and stocks, which cut across the sedimentary series. If one believes in the theory of differentiation one must think that the basic types have not been erupted toward the surface and are still concealed below. However this may be, there is still a considerable variety shown by the rocks that occur. They range from dioritic into syenitic types, and on into phonolitic types, with silica remaining about the same, the variation being effected by the change of iron, magnesia, and chiefly lime, as against alumina and alkalies. In another direction they vary in the silica and pass from syenite to granite-porphyry.

ORIGIN OF DIKES AND SHEETS.

By far the most interesting feature, in a petrologic way, of this mountain group, lies in the occurrence of the phonolite (tinguaite) dikes and sheets and their relations to the other rocks. First, it is a noteworthy fact that these rocks do not occur in the mountains south of the divisional line of Maiden Canyon and upper Warm Spring Creek Valley. They are thus confined entirely to the northern part of the mountains. Further, the dikes are confined almost entirely to the large bodies of igneous rocks, which they cut in all directions and

[1] Weed and Pirsson, Geology of the Little Rocky Mountains: Jour. Geol., Vol. IV, 1896, p. 419.

without system, so far as can be told. The intrusive sheets, on the other hand, are found only in the Cretaceous beds—in the black shales of the Benton group almost exclusively. It is also noteworthy that these sheets generally curve round conformably with the beds domed up by some laccolithic mass. If we therefore assume from this fact that these intrusive sheets antedate the intrusion of the porphyry which uplifted or broke through the sediments, we must then assume that there have been two periods of the eruption of phonolite magmas—the first into the Cretaceous beds, at that time horizontal; the second producing the dikes which cut the intruding masses of porphyry which have domed up the strata. While this seems plausible, there are several difficulties in the way of accepting it. The phonolites, whether in sheets or dikes, are exactly alike, and it is hard to believe that two periods of intrusion, separated by a long interval during which a vast amount of entirely different magma was intruded, should have produced such highly differentiated, peculiar magmas exactly alike, one of which appears wholly in the form of dikes and the other in the form of sheets. Again, on this assumption it is difficult to see why all the sheets are in Cretaceous and all the dikes cut the porphyry masses; it would seem most logical that the dikes should have cut, not the porphyry, but the sediments surrounding the porphyry masses. And, again, why should laccolithic masses be cut by dikes of an entirely different kind of igneous rock? Any theory which explains the origin of these phonolitic intrusions must also explain these points.

It seems to us that all of these facts may be explained by the assumption of a theory by which it is supposed that after the intrusion of the magmas took place, processes of differentiation of some kind produced in the still liquid masses smaller bodies of phonolitic character. This assumption seems warranted by the border facies of somewhat phonolitic type which have been noted in several places, and by the fact that such "laccolithic differentiation" has of late been shown to be a rather common process under proper conditions. The general character of the main porphyry masses warrants the assumption that differentiation taking place in them would produce bodies of alkaline magma.

By "differentiation" is here understood a *result*, the separation of an original fluid into fluids of a different chemical composition, not a *definite kind of a process*. Be the *process* what it may—diffusion, convection currents, chemical repulsion, or some other process yet to be discovered—the *result* is beyond doubt, and it is that with which we are immediately concerned.

As these main masses cooled and solidified, there must have been a large amount of contraction, and such contraction may have forced these still liquid phonolitic magmas through fissures in the main masses, producing dikes; while the settling down of the cover would

have relieved the compression of the arching sediments, especially along the outer spring of the arches, and permitted the magmas from the dikes to penetrate the light beds, forming intrusive sheets, which would have found it easier to penetrate the arching strata of the easily split shales than to cut across them as dikes. Possibly they did both. In the southwestern half of the region all of the laccoliths are below the massive beds of the Paleozoic series, and the load may have been too great to permit of this secondary upthrusting of material; while in the northern and eastern half the intrusion took place above the Paleozoic, either in the Jurassic beds or toward the base of the Cretaceous section, with but one exception, that of Elk Peak, which appears to have taken place just below the massive bed at the top of the Carboniferous. The fact, also, that this massive bed is cut by phonolite dikes seems to furnish additional confirmation to the theory. The light, easily split horizons of the Benton shales would furnish an admirable locus for the conversion of the ascending dikes into sheets.

It is probable, however, that the geographic distribution of the phonolite dikes and sheets depends much more on a variation of chemical composition of the original intruding magmas than on local physical conditions.

A case which seems to favor this explanation for the mode of occurrence of the dikes and sheets is found on the south side of the Cone Butte laccolith, where, on the crests of several spurs, phonolitic dikes run out from the main porphyry mass, cutting the sediments until the Benton beds are reached, when they diverge into intrusive sheets and end. This occurrence is shown on the map (Pl. LXXV), and has been already described (p. 552).

While this theory of differentiation and contraction to explain the origin of the dikes and sheets is open to objections, it seems to the writer that it serves better to explain and harmonize the various facts observed than any other which has suggested itself.

SIZE OF GRAIN NOT DEPENDENT ON DEPTH.

An interesting feature presented by the laccolithic masses is that the granularity of the rocks, their degree of crystallization, bears no relation to the depths at which they have been intruded. The laccoliths in the Cambrian show the same dense grain as the sheets intruded in the upper members of the Cretaceous. This is in accord with the facts adduced by Cross[1] for the laccoliths of the Colorado Plateau. On the other hand, chemical composition has been a most important factor, the more basic phonolitic magmas, though intruded in the Upper Cretaceous in small masses, being in some places quite granular rocks, while the vastly larger masses of the great laccoliths in the Cambrian, composed of very acid types, are dense felsitic por-

[1] Laccolitic mountain groups, etc.: Fourteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 230.

phyries. This is an illustration of the general rule that, other things being equal, the more basic a magma the more granular and the coarser its degree of crystallization.

SUMMARY.

The igneous rocks of the Judith Mountains are of acid-feldspathic character, and are very like those characteristic of other laccolithic areas. They comprise granite-porphyry, syenite, syenite-porphyry, and diorite-porphyry in the main masses, with dikes and sheets of the variety of phonolite-porphyry called tinguaite-porphyry. While the intrusion of the former rocks has taken place according to well-known processes, it is believed that the phonolite-porphyry was formed by some process of differentiation in the main masses and was injected into the sediments above them by what may be called secondary intrusion.

The granularity of the rocks depends on their chemical composition and not on the depth at which they have been intruded.

CHAPTER VI.

By L. V. Pirsson.

DYNAMIC AND STRUCTURAL GEOLOGY.

INTRODUCTORY.

In his now classic work upon the geology of the Henry Mountains Gilbert[1] says:

> The Henry Mountains are not a range and have no trend; they are simply a group of five individual mountains separated by low passes and arranged without discernible system. * * * The Henry Mountains are similar among themselves in constitution. They all exhibit dome-like uplifts; they all contain intrusive rocks, and their intrusive rocks are all of one lithologic type. They are, moreover, quite by themselves; the surrounding country is dissimilar in structure, and there is no gradation or mingling of character. Thus similar and thus isolated, it is natural to regard the mountains as closely related in origin, to refer their trachytes to a common source, and to look for homology in all their parts.

This general statement, written for the Henry Mountains, might just as well, with a few minor exceptions, have been written for the Judith Mountains. While they have a longer axis and may thus be said to have a trend, they are not a mountain range in the ordinarily accepted use of that word, since they owe their elevation, so far as can be ascertained, not to any general movement over the area, but entirely to disturbances produced by local intrusions of igneous rocks.

POSITION AND NUMBER OF JUDITH MOUNTAIN LACCOLITHS.

The Judith Mountains, in fact, consist entirely of a group of laccoliths of varying size, many of which are of perfectly normal, symmetric character, while others are asymmetric, and these pass into intrusions of porphyry into the strata, which are of the most irregular character and are laccolithic only in the sense that they certainly possessed a cover of sedimentary material under which the fluid mass hardened and crystallized. No evidence of any kind has been seen which would tend to support the view that the mountains owe their elevation to any general folding of the strata or that the horizons of strata lower than those lifted on the backs of the laccoliths are in any other than a horizontal and undisturbed condition.

[1] Report on the Geology of the Henry Mountains, by G. K. Gilbert, 1877, pp. 2 and 52.

The number and position of the laccoliths composing the Judith Mountains are seen in the ground plan shown in the figure below (fig. 51). In this the laccoliths are represented as circular in ground plan; some actually are circular; most are probably more or less so, while one is certainly not circular but oval in ground plan. The plan is, of course, merely an ideal one, to give an indication of the relative size and position of the laccoliths.

From this figure it can be seen that the main features of the mountain group are formed by six principal laccoliths and three intrusive masses of porphyry. The distinction, of course, between a principal

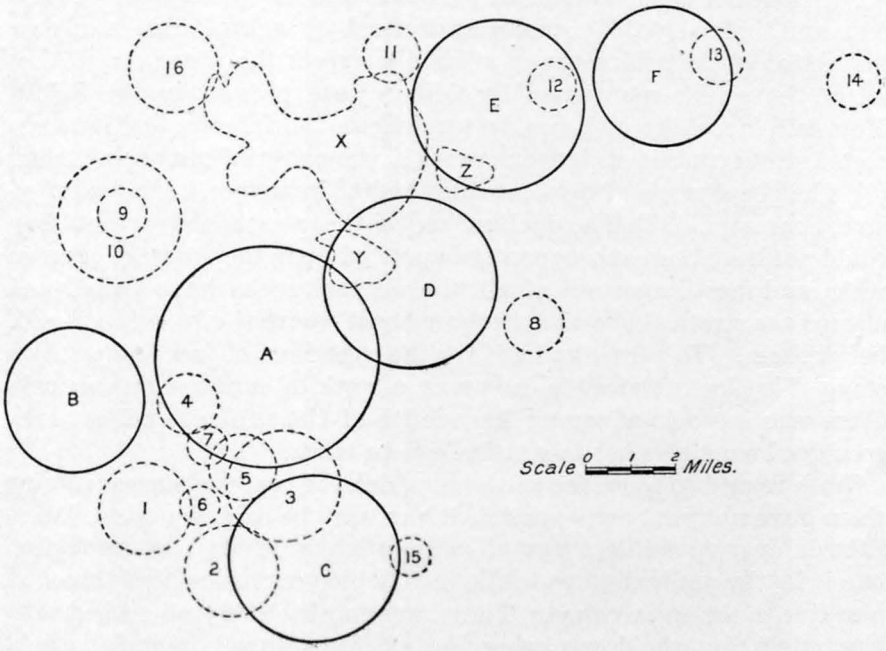


FIG. 51.—Ground plan of Judith Mountain laccoliths. A, B, C, D, E, and F, principal laccoliths, doming up Paleozoic strata, except F, the only principal laccolith in the Mesozoic. A, Alpine; B, Burnett; C, Flat Mountain; D, Crystal Peak; E, Elk Peak; F, Cone Butte Mountains; 1, 2, 3, 4, 5, subordinate laccoliths in Paleozoic horizons; 7–16, subordinate laccoliths in Mesozoic horizons. X, Y, Z, intrusions of porphyry: X, Judith Peak-Red Mountain mass; Y, Gold Hill intrusion; Z, Maginnis Peak.

and subordinate laccolith is purely arbitrary, dependent on the size. Of these six laccoliths, two (A and B) are known to be intruded in the Cambrian shales and are only partially denuded; F, the only one in the Mesozoic, is almost wholly denuded, while the others are yet concealed by their Paleozoic covers. The remaining subordinate laccoliths are partly in the Paleozoic and partly in the Mesozoic.

They also exhibit every stage of denudation, grading from those like Lewis and Lookout peaks (Nos. 12 and 13) which are almost wholly deprived of their covers, through intermediate stages like the Warm Spring laccolith (No. 9) illustrated in fig. 45, p. 519, to simple

anticlinal domes, like those of Deer Creek (No. 16) and Fort Maginnis (No. 8). In the latter case, since the porphyry is not yet exposed, the horizon at which it is intruded can, of course, only be surmised; but knowing the diameter of the dome on the surface, the lowest beds that are exposed in it, and the thickness of the various sedimentary horizons, it is easy to calculate at what depth the porphyry must lie, and by the aid of the dips to determine the shape of the upper portion of its mass.

PROOFS OF THE LACCOLITHIC CHARACTER OF THE INTRUSIONS.

Evidences of the character of the intrusions are everywhere manifest, and, indeed, to the geologist trained by actual field study an inspection of the geologic map at once suggests the structure. Also, all of the proofs mentioned by Gilbert[1] are present in the Judith Mountain laccoliths and may be summarized as follows: (1) The associated strata contain no igneous rocks in the material composing them. (2) The porphyry is always compact and of intrusive, never of extrusive, character. (3) The inclination of the strata shows that they could not have been subsequently deposited upon the domes of igneous rock; and most important of all, the igneous rocks have baked and altered the strata above and, in those cases where the base is exposed, below them. To present proofs for the existence of laccoliths at this stage of geologic history is, however, a work of supererogation; only those who have no adequate knowledge of the subject and have not seen good examples hesitate to believe in them.

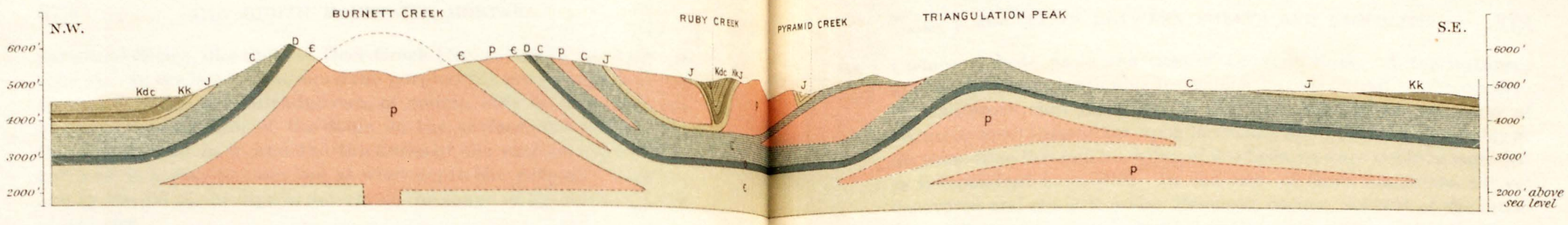
With regard to those laccoliths in which the igneous masses doming them have not yet been exposed, it can only be said that since laccoliths in every possible stage of denudation are found in the region, one is led by gradual steps to the inevitable conclusion that these are also due to the same cause. They have in absolutely all respects the characters that the domes whose laccolithic nature is revealed would have if restored to the same stage; and as no other geologic agency of any kind is seen in the district to account for them, one is led to believe, from the continuity of nature itself, just as firmly that these domes are due to laccoliths, yet concealed, as in those cases where the laccoliths have been exposed.

Similar domes of stratified beds are also described by Gilbert in the Henry Mountains, and more recently Russell[2] has ascribed to such agencies domes occurring in the Black Hills of South Dakota.

HORIZONS INVADED.

Two principal stratigraphic horizons have been the seat of igneous intrusions, the Cambrian shales and those in the Jurassic just above the Carboniferous. In some cases intrusions have occurred in the

[1] Geology of the Henry Mountains, p. 51.
[2] Jour. Geol., Vol. IV, 1896, p. 21.



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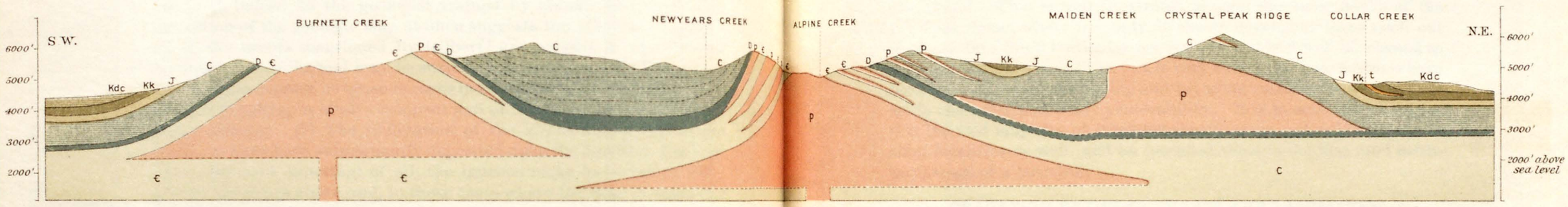

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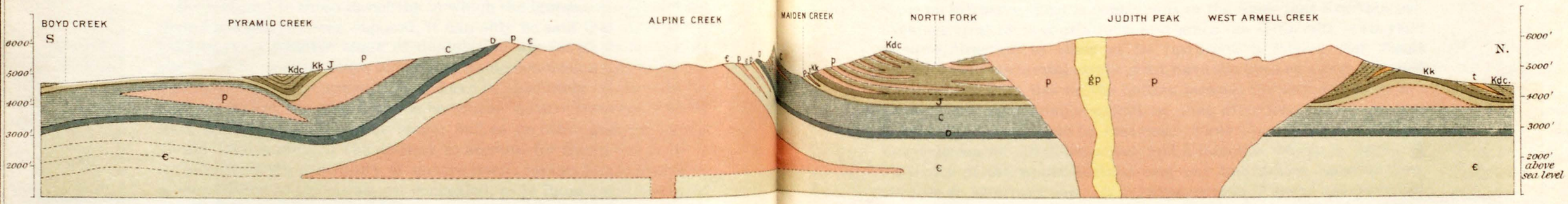

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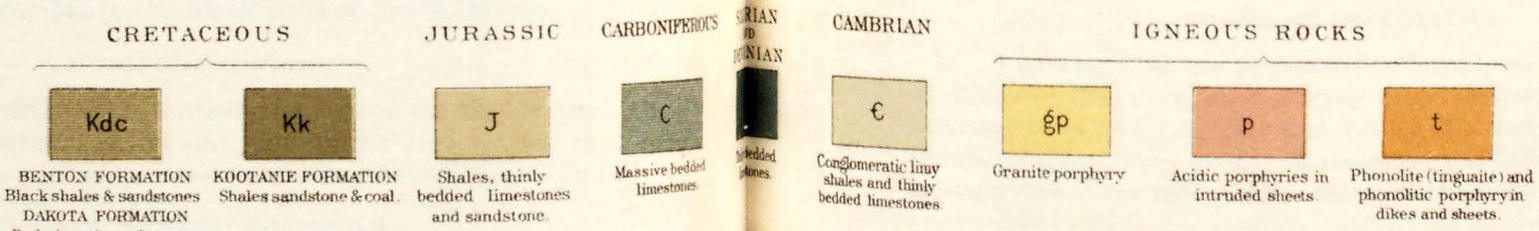


GEOLOGIC SECTIONS, JUDITH MOUNTAINS

Scale

Walter Harvey Weed Geologist in charge.
Geology by Louis V. Pirsson.

JULIUS BIEN & CO. LITH. N.Y.

Cretaceous beds, as in the case of Lookout Peak. A few instances are known where lenticular intrusions have occurred in the massive Carboniferous; but these are in the main more of the character of intrusive sheets attendant upon laccoliths and introduced probably at the same time through buckling of the beds, and are not to be regarded as independent laccoliths. In the case of those which are not yet uncovered and are still under Paleozoic covers, the seat of the intrusion must be conjectural; but by analogy it is assumed that the Cambrian has been the horizon invaded.

The base of the Mesozoic is not only a horizon in which laccoliths occur, but to a very large extent one in which intrusive sheets are also found. This is well illustrated around the outer flanks of the Elk Peak dome, where not only do sheets occur, but these swell out in places into thick lenticular masses which might well be classed as small subordinate laccoliths. It is very clear that these horizons have been selected by the ascending and invading magmas because of their fissile character and ready penetrability. It is in such shaly horizons that the vast majority of intruded sheets occur, not only here but in other localities as well, and an intruded sheet is the first (and necessary) stage of a laccolith.

GRADATION BETWEEN SHEETS AND LACCOLITHS.

In the Judith Mountains every gradation from intrusive sheets to highly arched laccoliths occurs, and these gradations are well illustrated in the accompanying figures and plates of geologic sections. Since no intrusive sheet is continuous in the sense that a certain sedimentary stratum is continuous, and since the sediments must yield in some direction to allow of its intrusion, it follows that sheets intruded into horizontal strata must have the form of a very flattened plano-convex lens, flat on the bottom because the sediments can not yield to any appreciable extent in that direction, convex on top because they must yield in that one. Thus there is no real distinction between an intruded sheet and a laccolith except in degree of convexity of the upper surface, and any line drawn between them must be an arbitrary one. In a recent article Gilbert[1] has described and figured as a laccolith an igneous intrusion whose degree of convexity is so low that in a small mass it would usually be designated a sheet.

FORMS OF LACCOLITHS.

It will be seen from the figures which have been given in a number of places in this work, representing cross sections of the laccoliths, and also from Pls. LXXXII and LXXXIII, that the laccoliths, as intimated above, vary greatly in the degree of their convexity. This is partly due to the fact that the sections often cut the laccoliths near

[1] Jour. Geol., Vol. IV, 1896, pp. 816, 824.

the outer boundaries, necessarily giving sections of low arch, and partly, as suggested above, to actual variance in the forms of the laccoliths. Judging from those facts which have been observed, and from the known thickness and disposition of the strata, the laccoliths, though they may be very convex on top, yet taper off on their edges

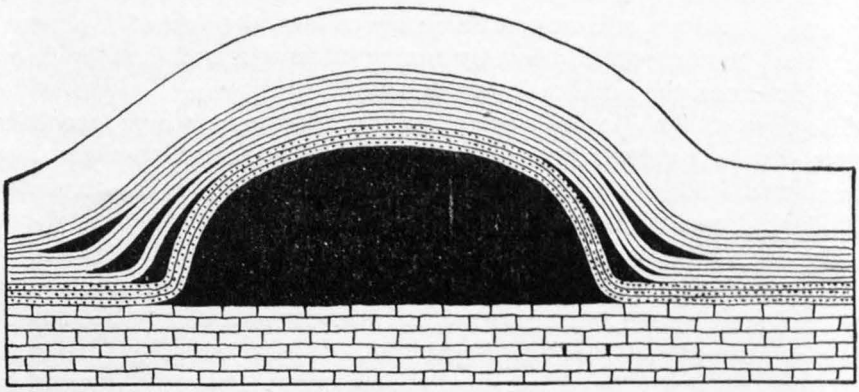


FIG. 52.—Mount Hillers type of laccolith (after Gilbert).

and do not end, abutting abruptly against the strata, as Gilbert has, for instance, figured the Hillers laccolith in the Henry Mountains.[1] This is shown in figs. 52 and 53, where both types are represented, the Hillers type being Gilbert's figure with slight modification.

In the Judith Mountains the sheets are of common occurrence in the Lower Mesozoic strata just above the Paleozoic arches, and these,

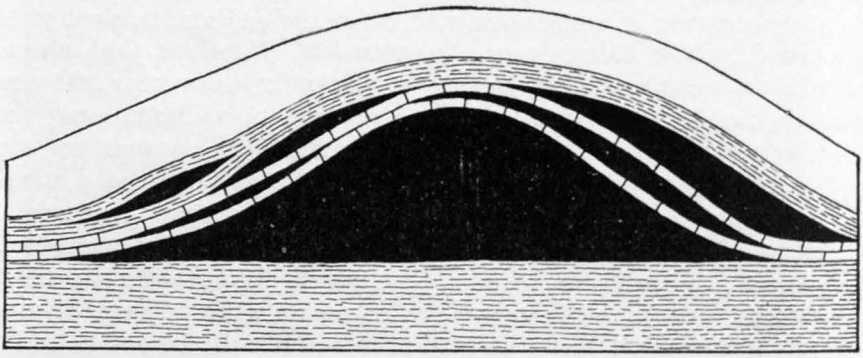


FIG. 53.—Judith Mountain type of laccolith.

as shown in fig. 53, occur in all transitions to what are really subsidiary laccoliths. Thus in fig. 53 the whole uplift is due not only to the principal laccolith but to the subsidiary ones as well, and such a structure appears to be a compound laccolith. The thickening or compounding of laccoliths in this way and the doming up of the strata are phenomena which are found not only in the Judith Mountains

[1] Geology of the Henry Mountains; plate between pp. 31 and 32.

but in other localities as well. Thus the peripheral fringe of intrusive sheets at Castle Mountain, described by the authors,[1] seems to be of a similar nature, and also some of the cases described by Cross[2] in the laccolithic mountain groups of Colorado, especially the La Plata Mountains.

ASYMMETRIC LACCOLITHS.

In some cases the laccoliths are not perfectly symmetrical, but have burst up along several stratigraphic horizons, forcing back the lower sediments into the arch raised by the lighter, upper beds. This is well illustrated by Black Butte, a cross section of which is shown in fig. 49 (p. 555). Such cases furnish transition types to the irregular intruded masses of Maginnis Peak, Judith Peak-Red Mountain, and Gold Hill. Cross[3] remarks that the regular dome shape of the theoretical laccolith can be seldom realized in nature, and describes several asymmetric forms, such as those of Mount Marcellina and the Anthracite Range. It is a question, of course, how far the term laccolith may be applied to irregular intruded masses, but it seems proper to extend it, as Cross has done, to all thick lenticular masses which have domed up the strata and have over the greater part of their area a floor of sediments. One usually thinks of the floor of the laccolith as being at least approximately horizontal, but the thick lenticular masses that lie intruded in the Mesozoic strata and tilted against the Paleozoic domes in the Judith Mountains (illustrated in fig. 53 and in other figures appearing in this paper) are also really laccoliths. In many cases it will be impossible to say whether these may not have been intruded previous to the main laccoliths and tilted by them, or whether they were a contemporaneous filling, as the strata doming up under the main intrusion allowed areas of relief of pressure radially along the spring of the arches. Mr. Weed has recently described doubly convex intrusions as laccoliths in inclined strata.[4]

Russell[5] has recently described some of the igneous intrusions in the Black Hills of South Dakota, and, associated with them, domes in the sedimentary beds, of quaquaversal type, arching up the strata like those in the Judith Mountains. Russell,[6] however, was not inclined to believe that the Black Hills intrusions are of normal laccolithic types, but held these intrusions to be due to plugs of igneous rock forced up into or through the lower horizons of sediments but doming up the higher beds. He does not give any figure to illustrate his idea, and it is not altogether clear just what form he assigns to the uneroded igneous mass; but it is inferred that an occurrence like that of Black Butte, illustrated on page 555, would represent them approximately.

[1] Geology of the Castle Mountain mining district: Bull. U. S. Geol. Survey, No. 139. 1896, p. 60.
[2] Fourteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 209.
[3] Op. cit., p. 236.
[4] Science, May, 1897, pp. 811-812.
[5] Jour. Geol., Vol. IV, 1896, p. 23.
[6] Op. cit., p. 177.

As we have no sections through these masses, or other formal data showing their relations to the sedimentary beds, it is impossible for one who has not visited the locality to pass any judgment concerning them; but one sees no reasons, from the descriptions given by several observers, why these intrusions may not be, in part at least, of normal laccolithic character. It is impossible to conceive that the tall, shaft-like mass of Mato Tepee (Bear Lodge), with a vertical columnar structure whose columns are several hundred feet long, can be a volcanic plug in a condition anywhere near approaching its original horizontal diameter. The mechanics of the jointing of igneous rocks forbids such a supposition, and we must believe that it represents only a still uneroded fragment, whose vertical walls are produced by the columnar structure of a mass which formerly was of much greater lateral extension and possibly of laccolithic form.

JOINTING IN LACCOLITHS.

In the Judith Mountains the character of the jointing of the igneous rocks appears to depend more on the nature of the rock than on its form or mass. The very acid rhyolite-porphyries or granite-porphyries usually break into extremely small blocks of angular shapes, the syenite-porphyries into blocks of a similar character but considerably larger, while the tinguaite (phonolite)-porphyry forms large, massive, cuboidal blocks or thick plates. Thus one may state that, in this area, the more acid the rock the finer jointing it possesses. There does not seem to be any system to the jointing of the acid porphyries that can be discovered, but in the more basic rocks it approaches a rude columnar structure.

This breaking up into blocks appears to be the character of laccoliths which have been described elsewhere that are also composed of very acid types. In laccoliths or thick sheets of rocks of medium basic nature, however, the character of the jointing appears to depend very much more on the form, size, and character of the intrusion.

Thus in the case of Square Butte, a laccolith in Cretaceous strata some 40 miles to the northwest of the Judith Mountains, the jointing assumes the character of a platy parting parallel to the domed surface.[1] A somewhat similar occurrence, on a much greater scale, is described by Ramsay[2] as occurring in the Umptek Mountain group, which he regards as produced by the erosion of a tremendous laccolith. On the other hand, columnar parting occurs, and this is, indeed, very characteristic for thick sheets or thin laccoliths of very basic rocks. The much jointed, highly crackled condition of these acid porphyries has permitted the circulation of waters through them while they were still heated, and this explains, in a large degree, why they are so greatly altered. It may be that the waters came already heated from below,

[1] Bull. Geol. Soc. America, Vol. VI, 1895, p. 400.
[2] Das Nephelinsyenit gebiet auf der Halbinsel Kola Fennia, II, No. 2, 1894, p. 81.

carrying ore which they deposited in part in the porphyry; or it may be that they received their heat from the porphyry and leached from them the ores they previously contained. This will be mentioned again in the economic portion of this work—the next chapter. The much crackled and frequently decomposed condition of the porphyry is a great aid in mining operations.

DEPTH OF LACCOLITHIC INTRUSION.

The total thickness of the sedimentary beds exposed in the Judith Mountains is about 3,000 feet, and this is the thickness which is now involved in the deepest laccolithic domes. This thickness certainly does not represent the total original thickness of the strata, because laccolithic masses, such as those of the Cone Butte mountain mass, are intruded in the highest beds, and a great thickness must have once rested upon them, otherwise they could not have the form and structure they now possess. The same is true of the intrusive masses of Judith and Maginnis peaks. These are also found cutting the Benton group, the highest beds seen in the mountains, and yet it is clear that over them also once rested heavy covers of sediments. The Niobrara group of the Colorado formation, the southward extension of the Belly River formation of the Canadian geologists, with both groups of the Montana, the Pierre and Fox Hills, may all have been once present, while most of them undoubtedly were. The Laramie is regarded by Mr. Weed as probably not present. These sediments unquestionably were several thousand feet in thickness, and by that much the mountains have suffered from denudation in addition to what they have lost of the sediments now represented. They must have had originally a height of upward of 10,000 feet above sea level. This would also tend to show that the intrusions must have taken place toward the end of the Cretaceous or beginning of the Tertiary.

CONTACT METAMORPHISM.

This phenomenon attending the intrusion of igneous rocks into the stratified ones varies locally very much in the Judith Mountains. There is a good deal of it present, and yet one may say in general terms that the laccoliths have not altered the beds with which they come in contact to the excessively hard, dense rocks usually seen in connection with the cores filling volcanic throats or around heavy bodies of coarse-grained granites. It is also a noteworthy fact in this area that the more irregular the intruded body of porphyry the more intensely the sediments in contact with it are apt to be altered. Thus the laccoliths of Alpine and Burnett creeks have baked and toughened the Cambrian shales considerably, causing them to assume a slaty character, but the limestones above these slates are almost unaltered; while at Black Butte, on the other hand, the whole mass of upturned sediments has suffered a very great degree of alteration, and

around the Cone Butte mountain mass the limestones and shales of the Jurassic beds are converted, on the back of the irregular laccolith, to marbles and slates of the most metamorphic character, and even the Cretaceous sandstones are changed to quartzites. It seems probable that this is due in part to the considerable thickness of Cambrian shales over the large laccoliths (over 500 feet in the Alpine), which took up the effects of metamorphism and prevented the other beds from being affected. The shaly, penetrable nature of these Cambrian beds would allow the heat and moisture to spread out among them, producing, instead of a small, intensely altered zone, a metamorphism of a more gentle character through greater thicknesses. At a distance of a few hundred feet, and usually much less, all perceptible traces of metamorphic action disappear.

ORIGIN AND CAUSE OF LACCOLITHS.

What the origin of the upward, ascensive force in the molten magmas which gives rise to laccolithic intrusions really is we have, as Professor Dana so well expressed it, "many theories, but no real knowledge." We may, therefore, dismiss this phase of the subject, well assured that whatever may be its origin there is no doubt about the force itself, and that there is plenty of it to accomplish any work which the physics involved may demand.

It appears to the author that in the treatment of the mechanism giving rise to laccoliths the fact that it is really a vast hydrostatic press, while underlying the discussion of the subject by various authorities, has not been made as prominent as it might be. Suppose a fissure extending upward through comparatively undisturbed strata and forming a dike, and that it does not reach the surface. At some horizon where the conditions are right, the beds being easily separable at that point, it enters the strata as an intrusive sheet. As soon, however, as it spreads out, the whole upward-propelling force becomes as much greater as the horizontal area of the sheet is greater than the area of the dike or source of supply. It is in fact now converted into the upward member of a hydrostatic press. One thing, however, must be taken into account at this point, and that is, that owing to its viscosity lava is not a perfect liquid, and therefore does not transmit the pressure as a theoretical liquid would. A certain portion of the force must be expended in overcoming this internal vicosity, and the amount so expended would vary with the greater or less viscosity of the lava. The loss of force in this way would, however, tend to maintain the heat of the liquid. A certain amount of the force is also expended in overcoming gravity and raising the weight of the lava itself. Whatever remains over above these two is used in lifting the sediments, and may be said to roughly measure the effectiveness of the hydrostatic press.

As the sediments lift they tend to split, and into this split the lava

tends to insinuate itself, and in proportion as it does so it becomes a part of the press and the lifting goes on. Thus a very liquid lava tends to spread itself widely for two reasons: First, because it transmits the pressure readily; and, second, because it readily enters all the cracks in the strata. It is, in other words, a wedge with a very sharp edge, which, with a stroke of given force, enters farther into the grain than one with a dull edge.

In proportion as the viscosity of the lava increases, these effects cease. As the distance from the point of application of the force increases, the retarding effect of the gradually cumulative viscosity comes into play and the onward-propelling force decreases, while the more viscous material, like a blunt wedge, splits the strata less and less easily. In this case, then, the upward effects of the force are felt much more strongly in the neighborhood of the point of application—that is, the point of supply—the sediments yield more and more, the material is locally concentrated, and a laccolith is formed.

The following factors, therefore, must be taken into account in discussing laccoliths: The upward force of the lava, which is transmitted in all directions, owing to its fluidity; the viscosity of the lava, which tends to diminish this force; gravity, which also detracts; the load of sediments; and the cohesion of the strata or their resistance to splitting. While we understand these factors in principle, we can not state all of them quantitatively, and hence quantitative discussions of laccoliths can not have any real value.

The consideration of these principles leads to several interesting applications of them.

Gilbert,[1] in his discussion of the Henry Mountain laccoliths, calls attention to the plasticity of strata when acted upon in large masses, and this has since been shown repeatedly in many ways. Therefore, if in any such intrusion it happened that the rapidity of the supply, or, in other words, the upward force, was so great that a laccolithic dome was formed, in the readjustment that would follow the final convexity of the mass would be determined according to the principles stated above. Hence a laccolith forming with comparative rapidity may afterwards readjust itself and assume a more sheet-like character. Such a process is probably of rare occurrence, but it is of interest to note that the convexity of a laccolith is not a necessary function of its depth but of the viscosity of the lava in relation to the other factors; hence laccoliths of various shapes and sizes may be found in the same horizon. We have seen this, from the present work, as occurring in the Judith Mountains.

It also seems evident that the rate of supply, or the time within which the force acts, must have a bearing in this case, and it is imaginable that the upward propulsion of the magma might be so rapid that a small laccolith could be formed where the arch of the strata

[1] Geology of the Henry Mountains, p. 97.

was such that it was within the limits of plasticity and would tend to maintain itself after the upward force ceased, even though the magma was in an extremely liquid state.

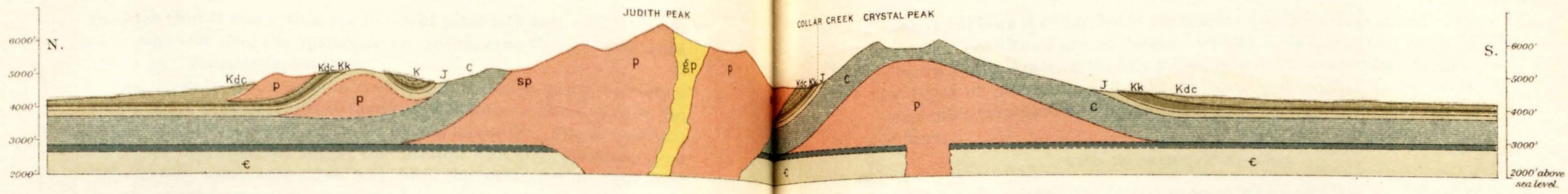
Also, there is with a given source of supply and a given viscosity a certain limit beyond which a lava can not form a sheet, but, if the supply of material continues, must form a laccolith. For at a certain radial distance from the supply the internal viscosity, assuming even that its ratio remains the same, will check the transmission of pressure and the onward-propelling, splitting force of the lava; but, the supply continuing, the strata must uparch and form a laccolith.

Another point of interest is that clearly the mechanism of the laccolith is complete without regard to the chemical composition of the lava or its specific gravity; these have no direct or controlling influence on its formation. But while they may exert no primary influence, secondarily they are of considerable moment, and in this way: Very acid magmas have no determinate point of solidification; like melted glass, they stiffen more and more gradually until rigid, and this rigidity is itself largely a function of mass. This we see in the extrusive material, and undoubtedly the same capacity for high degrees of viscosity, though not carried to the same extent, exists when such magmas are intruded. The basic lavas, on the other hand, preserve, comparatively, a high degree of liquidity down to rather low temperatures, with a quick process of solidification by rapid crystallization. This is well illustrated in blast-furnace slags, where the constant endeavor is to keep them as near as possible to an orthosilicate, such as olivine, in composition, while an increase in silica means an increase in viscosity and in the heat necessary to keep the slag fluid. Examples of a similar kind are familiar to all petrographic geologists.

The result is that the basic lavas will tend in the main to form sheets and not laccoliths, and that while, the conditions being right, laccoliths may be expected for lavas of any composition, and will undoubtedly be found composed of very basic rocks, yet, for the reason given above, it is certain that they will generally be composed of acid rocks, since these will more often possess the necessary viscosity.

From what is stated it is clear that there is no difference in principle between an intrusive sheet and a laccolith except the degree of a certain kind of form; a laccolith is a short, thick sheet, or a sheet is a thin, flat laccolith, as one is disposed to regard it. Those, therefore, who, never having seen them, confidently pronounce laccoliths to be mechanically impossible, must at the same time deny the existence of intruded sheets.

In areas of thick, easily separable strata, undisturbed by foldings or displacements due to tectonic forces, in which igneous intrusions have taken place, laccoliths, like sheets, are perfectly normal methods for the occurrence of igneous rocks, and, from a consideration of the factors involved their existence, could have been predicted from



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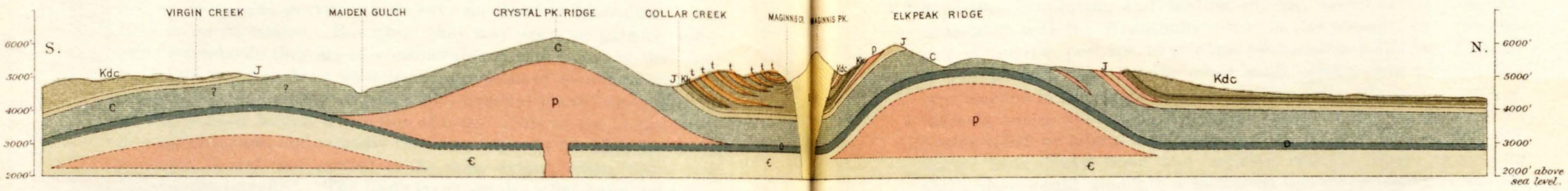

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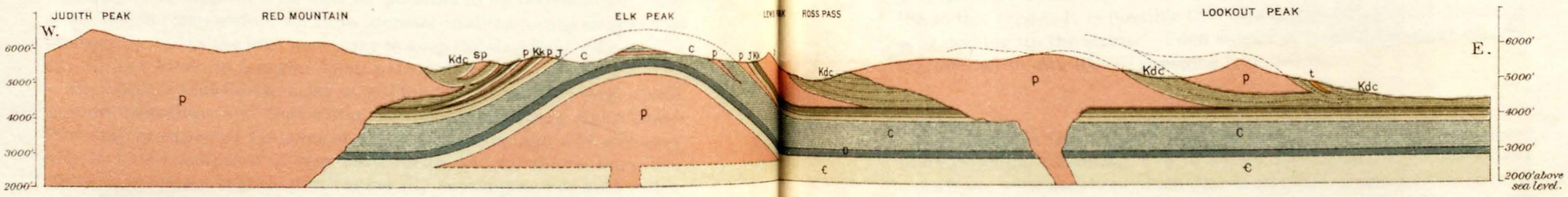

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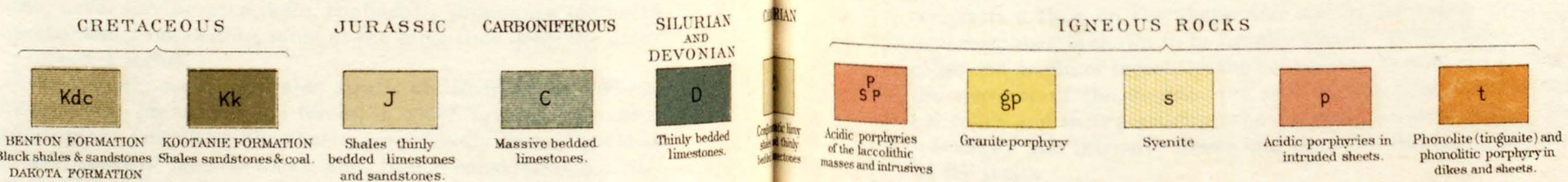


GEOLOGIC SECTIONS, JUDITH MOUNTAINS

Scale

Walter Harvey Weed Geologist in charge.
Geology by Louis V. Pirsson.

JULIUS BIEN & CO. LITH. N.Y.

mechanical laws if examples of them had never been discovered. The necessary conditions are so largely present over such great areas of western North America that they here constitute one of the commonest types of intrusion, and may be seen and studied under every imaginable condition of environment, stage of dissection, and variety of form.

THE INTRUSIVE STOCKS.

If the molten magma is forced upward with sufficient rapidity it is evident that the proper adjustment of load necessary to form a laccolith can not take place; and as the magma ascends from one horizon to another it continually spreads out laterally as the lateral resistance diminishes, rupturing and tearing up the beds and carrying this material on with it. Eventually it may in this manner reach the surface, giving rise, perhaps, to volcanic phenomena or causing effusions of igneous material. On the other hand, after a certain height has been reached in the strata, the diminishing of the lateral resistance of the beds, due to the lighter load above them, may permit the magmas to seek relief by lateral expansion, and in so doing they may lift the lighter beds above them and solidify beneath them; thus from above they would simulate a laccolith, but would differ in having no proper floor. So in the sections, Pls. LXXXII and LXXXIII, Judith Peak is represented as being of this character, as is also Maginnis Peak, while the Cone Butte mass (shown in section F–F, Pl. LXXXIII, to the right) would indicate a transition from the laccolith to this type. It is possible that this is Russell's idea of a volcanic plug doming up the strata. Such stocks or intrusions would then be represented by fan-like expansions from below.

SUMMARY.

It is shown in this chapter that the Judith Mountains are composed of six principal laccoliths, five of which are below the Paleozoic and one above, with numbers of smaller ones which grade eventually into sheets. This gradation is discussed, and it is pointed out that the distinction between the laccolith and intrusive sheet is an arbitrary one. The forms of the laccoliths are treated of, and it is shown that some are asymmetric, but still may be called laccoliths. The jointing in the sheets and laccoliths is shown to depend more on the chemical composition than on the shape and size of the mass. The contact metamorphism is shown to be usually small. In the discussion of the cause and origin of laccoliths the controlling factors are shown to be the viscosity of the magma, the rate of injection, and the load of sediments and their plasticity, when in mass, under stresses. Finally it is shown that intrusive stocks may show fan-like sections and dome up the strata.

CHAPTER VII.

By W. H. Weed and L. V. Pirsson.

MINERAL RESOURCES.

HISTORY OF DEVELOPMENT.

The Judith Mountains present peculiarly favorable conditions for a study of the relations of ore deposits to geologic structure. The problem is a complete one, as the geographic isolation of the mountain group corresponds to a geologic isolation as well. The region presents a novel kind of ore deposits, occurring in connection with laccolithic and other igneous intrusions which have disturbed previously horizontal rocks. The mountain-folding and profound dynamic movements which occurred in the Rocky Mountain region have not taken place here. The mine workings are as yet, unfortunately, not extensive enough or deep enough to afford data for an exhaustive or detailed study of these interesting ore deposits.

Very little can be written concerning the history of the mining development of the Judith Mountains. In the early settlement of the State the mountain groups of the plains were not regarded as favorable prospecting grounds by mining men. Prospectors discovered rich placer gravels in the region about the year 1880, and soon after locations were made of both gold and silver properties.

The first workings appear to have been those of the Collar mine. A 10-stamp mill and hoisting machinery were erected, but they were soon abandoned, and were afterwards removed to the Spotted Horse mine. In 1881 the Maginnis Mining Company was incorporated, and purchased the Montana and Oro Cache lode, and a year or two thereafter erected a 10-stamp mill upon the property, which was worked with more or less success for several years.

In the spring of 1886 Mr. P. W. McAdow acquired control of the Spotted Horse mine. After spending $1,000 in driving a tunnel the ore was found, and after that the ore paid all expenses of mining and furnished a profit besides, being very rich and easily handled. Mr. McAdow states [1] that not less than one million and a half dollars of gold bullion has been taken out. It is locally stated that at times the rich bodies of soft, decomposed telluride of gold were taken out with a spoon and packed in small sacks by the owner.

[1] In a MS. letter dated April 21, 1897.

The discovery of the pocket of silver-lead ore of the Cave mine led to the erection of a small smelter below the town of Maiden, but this was abandoned after a brief existence, when the ore was exhausted.

The picturesque intermontane town of Maiden soon sprang up as the outgrowth of the development and working of the Maginnis and Spotted Horse mines. At the height of its prosperity, in 1888, it had a population or about 1,200 inhabitants, and was well supplied with stores of various kinds, and a few buildings of stone were erected, with many frame and log dwellings. In the summer of 1896 the town contained fewer than 200 inhabitants.

Fort Maginnis, a former military post, has been abandoned for several years, and though maintained as a post-office, has less than a dozen residents.

The town of Giltedge is the direct outgrowth of the development of the mines from which it is named, and is largely dependent upon the mines for its existence. It has about 150 inhabitants and is situated in the level, open country south of the Giltedge mill.

Although the district is suffering from the blight which has at times overtaken the best of mining districts, the future looks promising, and enough has been seen of the ore deposits to warrant the prediction of prosperous times for the mining industries of the Judith Mountains when financial and economic conditions are more favorable.

THE ORE DEPOSITS.

CHARACTER OF THE ORES.

The Judith Mountain ores are mainly those of gold. A little argentiferous lead has been found, and the gold contains some silver alloyed with it; but silver is of minor importance in this district from an economic standpoint. The ores consist of country rock impregnated with and replaced by quartz and fluorite as the most abundant minerals. They are all from the zone of leached and oxidized rocks.

The ores greatly resemble in character those of Cripple Creek, Colorado, of Mercur, Utah, and of the Little Rocky Mountains of Montana. Like those of the localities mentioned, they do not occur in veins or in well-defined shoots, as is so commonly the case with gold ores. The occurrence of the richer bodies in the limestones near the porphyry contact is unique for gold ores. The characteristic ore of the district is a more or less decomposed and crushed limestone, containing angular masses of brilliant purple fluorite and quartz intimately mixed. Another type, that of Giltedge, has no fluorite or other prominent gangue mineral of any kind, appearing to be merely an altered, crushed, and brecciated clayey limestone. Detailed description of the types of ores from the more important mines is given with the accounts of the mines (pp. 599–613).

Of course a gold ore, as a rule, shows little of the metal to the naked eye, but, generally speaking, it has a definite character by which it is recognized when mined and by which it may be described. It may be, for instance, a mixture of quartz with pyrite or a rusty gossan resulting from the decomposition of the same, but in the present case it would be impossible to give any definite description which would cover the character of the gold ores in these occurrences. Sometimes it is a rusty limonitic limestone, sometimes a dark brownish-gray to clear-gray limestone, rather crystalline, but otherwise not appearing altered, and showing here and there patches of red-purple fluorite with dull, greenish, soft, earthy flecks, which sometimes have a bronze-like color and which are an altered gold compound, probably a telluride. These spots, on treatment with intense heat and a flux, develop into beads of gold, and a specimen of the limestone, which has a dull, faint greenish tone, but otherwise shows no hint of the precious metal, will, on heating in a forge ("blistering"), come out spangled and glittering with beads and threads of gold. This is the character of the best and richest ore which has yet been found in the district, and the bonanza shoots of the Spotted Horse were composed of it.

Again the ore may be a silicified limestone with mixtures of quartz and occasional stains of copper by weathering, or it may be a hard, black, cherty material in which are fine points, appearing like pyrite, with an occasional minute, microscopic fleck of free gold. This is the only unoxidized and unaltered material which has been seen anywhere in this class of ore deposits, and such cherty masses are generally surrounded by decomposed limestone and limonitic material.

The limestones are usually much cracked, and these cracks are frequently filled with decomposed limonite material. The ore ordinarily occurs in thin seams, stringers, shoots, and cavities, as it generally does when deposited in limestone.

In the midst of so much alteration, and from the lack of any definite wall, it appears difficult to tell ore-bearing material from that which is barren except by assay checks, but the miner experienced in the Gold Hill workings says that the ore has nearly always a "lively, firm, clinky" feeling, which practically means that those portions are the richest in ore which have the most secondary silica, are the most cherty in character, and feel rough and sharp to the touch, or grind under the heel with a crushing, clinking sound. The reason for this appears to lie in the fact that as the ore was deposited from solutions, silica of a secondary nature was also deposited with much of it at the same time, and thus the most siliceous, flinty portions are apt to be the best ore.

In some places the ore appears of a more limonitic character, as at Giltedge and in the New Years mine, and even pure limonite bands in the limestones not directly connected with any porphyry intrusion may contain gold, as at the Black Diamond claim, on the east side of the Crystal Peak dome, where the ore runs as high as $14 a ton.

Free gold occurs in all the ores thus far worked. The gold appears to be most abundant in the quartz-fluorite masses. In the richest ores it occurs in particles or small cuboidal masses, generally platy and open textured, or spongy, rarely one thirty-second of an inch thick and one-eighth of an inch across. The gold is always dark colored, being coated by a rusty or yellowish-brown film. Tellurides occur with the free gold, and the condition and form of the gold indicate its derivation from such tellurides by oxidation. The tellurides thus far observed are too finely disseminated to afford satisfactory material for testing. The color and luster are not those characteristic of calaverite. Unaltered pyrite occurs somewhat rarely with the gold ores, and under the microscope it seems to contain small particles of what is possibly a telluride.

Silver minerals occur in small quantities in the ores of some of the undeveloped prospects, and quartz stained with silver sulphides was found on the dump heap of the old Collar mine. Assays show the presence of a considerable proportion of silver in the gold ores, and it seems probable that in this case the silver was derived from a gold-silver telluride. The only considerable quantity of silver ore mined came from the Florence mine.

Lead ores occur but sparingly in the district, and most of the silver-bearing lead ore was found in limestone at the Cave mine. Galena occurs sparingly in several of the ore bodies of various prospects, but never in large enough quantity to have economic importance.

Copper minerals are extremely rare in the districts, their only occurrence in any quantity being at the Northern Pacific claim, where chalcopyrite was observed.

Fluorite is the common and characteristic mineral of the best ores yet worked. It is generally conspicuous by reason of its brilliant purple color, which has faded to pink on those ores which have been long exposed to the weather. It occurs chiefly in a finely crystalline condition, intimately mixed with quartz and forming small angular blocks in the limestone of the ore body, but is sometimes found, lining vugs, in the usual cubic crystals. Its significance will be alluded to later in describing the ores.

Quartz, though less prominent than the fluorite, is of even wider distribution, filling the interstices between the fragments of broken limestone and impregnating the contact zone generally. Siliceous material which is apparently not quartz is often found, especially at Giltedge, where it forms a jaspilite substance with conchoidal fracture and brownish color, occurring in bowlders in the soft, earthy material.

Calcite is abundant, but in most cases is of secondary origin, and must be attributed to the alteration of the ore deposit itself. In the decomposed porphyry calcite replaces the ferromagnesian minerals, and here the calcite must be assigned to the period of ore deposition, as it contains minute particles and specks of pyrite.

Superficial alteration has taken place throughout the district, all

the ores thus far mined having come from the zone of alteration. The original ore deposits have been decomposed and leached by oxidation and hydration of their original minerals, due to the access of surface waters and air. The depth of alteration is not known, as the deepest workings, those of the 400-foot level of the Spotted Horse mine, do not extend down to the unaltered ores. The gold is mostly free, but may be confidently expected to change to tellurides in depth. The alteration of the deposits has in most cases altered the iron minerals and pyrite to rusty masses of limonite, and at the same time the gold minerals have been oxidized and the gold has been set free. The feldspar of the eruptive rocks has been altered to sericite and sometimes replaced by calcite, and the porphyry in many places leached to a white siliceous or kaolin-like mass.

The value of the ores, like that of most gold ores, is quite variable, running from the rich bonanzas of the Spotted Horse mine, which went many thousand dollars to the ton, to the leaner ores of many prospects which would hardly pay for working. One may say, however, that the gold ores of the district are, in general, of low grade, not exceeding $10 to the ton.

MODE OF OCCURRENCE OF THE ORES.

The gold ores of the Judith Mountains occur in small quantities in placer gravels, but chiefly in deposits associated with the igneous rocks of the district. True fissure veins in the strict sense of the term do occur, but the more valuable deposits thus far worked are not of this nature. The geology of the region has been fully described in the foregoing pages. It has been shown that no true volcanoes existed here, but great masses of molten rock pushed up the level beds of limestone into great domes, beneath which the igneous rock cooled and solidified. At the same time molten rock was intruded between the arched beds of rock of the domes. Other bodies of igneous rock were forced violently up through the limestones and shales, but appear to have failed to reach the surface, though now exposed by denudation. Phonolite dikes were intruded in the hardened igneous rocks and the sedimentary beds alike in the northern part of the area. This is, in brief, the geology of the region now exposed by the gradual wearing down of the mountains by erosive agencies.

In connection with these igneous intrusions different types of ore deposits occur, which may be grouped as follows:

1. Ore deposits in fissures in the porphyry masses.
2. Ore deposits along contacts of phonolite dikes.
3. Ore deposits in the limestones at the contact of an irregularly intruded mass of igneous rock or beneath intruded sheets of porphyry.

The first and second classes are at present of relatively small economic importance. The dikes filling the fissures in porphyry show a

fissuring of the rocks at or before the time of their injection, but it is certain that the fissures now holding mineral deposits were formed at the same time and are of the same character as those filled by dikes. At any rate the deposits occurring at the contact with these phonolite dikes may be due to the penetration of ore-bearing waters along the shrinkage cracks.

ORE DEPOSITS IN PORPHYRY.

These have played but a very subordinate rôle in this district up to the present date. In certain places the porphyry itself, from its cracked and fissured condition, seems to have been the way for ore-bearing solutions, and along such areas there are ore deposits. In a number of places, like the interior of Alpine Gulch, the porphyry has been prospected and free gold may be easily panned from the rich material filling very thin cracks. Such deposits are usually but paper-thin and of limited extent, and it is a question whether such limited deposits in the massive porphyry would pay for working. If they were found to increase in width and extent they of course would do so, but this can be told only by development work that has nowhere as yet been undertaken.

On Judith Peak and in the porphyry in the immediate neighborhood there occur several seams of quartz filled and colored with purple fluorite. The association is such that one might expect the presence of a gold ore similar to the ores of Cripple Creek, but the veins have so far yielded only the baser metals, mostly lead and copper.

ORE DEPOSITS ALONG CONTACTS OF DIKES.

In this class of deposits feldspar-porphyry or phonolite dikes, usually those cutting the shales near the contact, have been the locus of active prospecting. At times intruded sheets occur and indeed the more complicated the mixture of sheets, dikes, and slates the more they have been prospected. Usually in these occurrences the igneous rocks are greatly leached and altered, and it is difficult to tell the character of the ore, but in a few cases they are quite unchanged, and it is then seen that the porphyry appears somewhat silicified and is more or less filled with pyrites.

It is difficult in this class of deposits to always discover with certainty which of the various rocks of the mines is ore and which is gangue; usually the dike itself is regarded as the "vein" and is mined, but sometimes the wall rock is mined also, and both appear to be regarded as ore.

No considerable mines have as yet been developed in this class of deposits. The Hanson properties, at the head of East Armell Creek, have been most thoroughly tested, and the Golden Jack, Butcher Knife (the latter in limy Cambrian shales), and Golden Eagle are prospects which are being developed. The value of these ores is never claimed as being high, from $6 to $14 a ton, the average

being about $10 a ton. There are many such claims, and there is no doubt that considerable bodies of low-grade ore of this character exist.

ORE DEPOSITS IN LIMESTONE NEAR CONTACT WITH IGNEOUS ROCKS.

This class of deposits is by far the most important and the most productive type in all of the mines which have been considerable producers of ore. The Spotted Horse, Maginnis, and Giltedge properties are of this description. The two former mines are located, as will be described, on the contact of the Gold Hill porphyry mass with the heavy Paleozoic limestones. The contact, as shown in fig. 54, p. 600, has a broken, irregular wall, with a general pitch toward the porphyry. If it were of a less irregular character the limestone would form the hanging wall, as, indeed, at times it does. In these mines the best and richest ore is not found directly at the contact, but a short distance beyond, in the shattered limestone. The Giltedge and New Years ore bodies differ from this only in occurring on the under contact of an inclined porphyry sheet intruded in the limestone.

The association of the gold and fluorite seems to be an intimate one. In a general way it may be said that the amount of gold present is found to increase with the proportion of fluorite. Thus the facts show that the highest-grade ores and richest ore bodies have been found in the Spotted Horse workings, the ores carrying the larger proportion of fluorite. The Maginnis ores carried less fluorite and less gold, when the general character of the ore is considered. The New Years, which shows fluorite masses, is a still lower grade ore, and the Giltedge properties, whose ores are of low grade, show none of the brilliantly purple fluorite noticeable in the ores of the mine previously mentioned, although colorless fluorite is sparingly seen.

SOURCE AND DEPOSITION OF THE ORES.

Owing to the fact that detailed examinations of the mine workings were not practicable, but little can be stated concerning the source of the ore other than may be deduced from surface observations. The descriptions already given have shown that the chief and thus far the only valuable ore deposits worked occur in the brecciated contact zone between intruded igneous rocks and limestones. These intrusions are either irregular and break up abruptly through the limestones, or they occur as sheets intruded between layers of them. Faults are found near the site of greatest mineralization, but it is believed that the brecciation of the limestone would of itself furnish an available channel for uprising mineral-bearing waters. Later movements undoubtedly occurred, however, as the brecciated ores show fragments of rhyolite-porphyry in limestone, and this proves brecciation after the cooling of the igneous intrusion. Differential shrinkage—that is, the shrinkage of the cooling igneous rock and the different shrinkage of

the adjacent rock walls—would also tend to form favorable conditions for uprising mineral waters.

That the ores have not been derived from the body of igneous rock immediately at hand seems evident to one familiar with the decomposition of rocks by hot waters and vapors. That the eruptive rocks at greater depths furnish the gold seems, however, certain. In the other outlying mountain groups of the State no ore deposits occur in surface volcanic rocks, but where the igneous intrusions have been denuded ore deposits are found near the contact. As ores occur only under such conditions and no others in these mountains, it seems certain that ore deposition has been dependent upon the igneous intrusions.

The close association of the gold and fluorite is significant here, as it has proved to be at Cripple Creek.[1] The presence of fluorine vapors is a frequent characteristic of volcanic emanations, and its action upon the readily attackable limestone would result in the formation of fluorite. Phonolite-porphyry (tinguaite) often contains fluorides in the fresh and unaltered rocks. Such rocks were intruded after the solidification of the laccolith and other great intrusions, and the ore deposition, with fluorite formation, seems to have taken place at about this time. It is to be noted that where the large ore deposits occur there are no rocks of this nature. As already stated, however, small deposits of low-grade ore are also found in intimate connection with such rocks throughout the northern part of the area, in the Cone Butte district.

Microscopic examinations of thin sections of the purple ore show it to be an intimate mixture of quartz and fluorite. The descriptions given by Mr. Penrose of similar ores of Cripple Creek apply quite as well to those of the Judith Mountains.[2]

While the workings showing fluorite in greatest abundance have had the richest ores—and there seems to be a general relation between the abundance of fluorite and of gold—the number of occurrences is not sufficient to base definite conclusions upon. At Cripple Creek, Colorado, the association of the richest ores and most abundant fluorite is the exception and not the rule. Here, as there, it is true that in the same mine the purple ore "sometimes contains large amounts of gold, sometimes but little, and sometimes none." The Judith ores add another to the small but important list of telluride deposits where the ore is associated with fluorite.

The evidence of aqueous action is apparent in the decomposition and alteration of the porphyry adjoining the ore deposits and in the ore gangue itself. This process has not gone far enough to efface the brecciated character of the ore, or to produce the frothy silica seen

[1] R. A. F. Penrose, Geology and mining industries of the Cripple Creek district, Colorado; Mining geology of the district: Sixteenth Ann. Rept. U. S. Geol. Survey, Part II, 1895, p. 157.

[2] Loc. cit., p. 158.

at other localities, but it is nevertheless quite marked. The summit of Red Mountain also shows the extensive alteration of the larger porphyry mass.

The mode of ore deposition is probably a replacement of limestone. The fluorite masses occur in angular, sharply defined pieces, resembling in shape and size the fragments of limestone about them. In the richest ores the fluorite replacements carry the gold, and the surrounding limestone fragments are of low grade. It is difficult to understand why one fragment of the limestone should be entirely and completely replaced by fluorite and quartz, while other fragments near by are only flecked by small grains of it or carry none at all. It is easy to understand the replacement of limestone by fluorite in the waters carrying hydrofluoric acid, but the selective action of the solutions is not explainable by any phenomena seen in the specimens, although there seems to be a possible favoritism for the portions of the limestone carrying the most organic matter. The cavities now seen in the ore appear to be wholly secondary, and the ore filling was brought about by metasomatic replacement and not by the filling of open cavities.

Ore shoots or bonanzas occur in the ore bodies of this region, as in nearly all gold districts. The name is used in the generally accepted sense, as applying to a part of the ore body in which the gold is especially concentrated, and which is surrounded by ore of lower grade. In the Judith deposits these bonanzas are surrounded by lean ore, often too poor to pay for working, or in other cases by good average ore. In the workings seen by the writer, there was no general rule governing the occurrence of these bodies, but they seem to be grouped together. The ore shoots are supposed to extend a considerable distance downward with the vein, but in the Judith mines they do not form such extensive shoots, but rather what the miners often call "bowlders" of rich ore. No data were obtained tending to any special characteristics of these bowlders, and the records of the production of the two great mines are not available; in one case they have been destroyed. It has been noticed, however, that these "ore bowlders" do not occur in the shaly or impure limestone, but are found in the purer, coarsely crystalline limestone darkened by organic matter. As has been already stated, the ore deposit is not a fissure vein, but more in the nature of stockworks or mineralized masses of broken rock fragments (breccia) which have been more or less altered and replaced by ore.

An examination of the mines, so far as it was practicable, and of the minerals seen on the dump heaps, appears to show that the following processes have been at work: First, the eruption and injection of the porphyry, attended by more or less rupture of the limestone strata, with some direct alteration from the heated masses. Second, the secondary processes attending the cooling of the deeper-seated porphyry

(pneumatolytic), in which heated waters circulated in the contact zone—waters which were of a more or less acid and solvent character from the gases given off by the cooling and crystallizing igneous magmas, especially fluorine vapors. These have acted on the limestones, and to some extent on the porphyry itself, with deposition of ore and the formation of other minerals, such as secondary silica, crystallized quartz, fluorite, pyrite, and perhaps others. Third, the alteration processes, caused by the oxidation and leaching action of surface waters charged to a greater or less degree with carbon dioxide, air, and acids formed by vegetable decay, producing decomposition of the limestone and porphyry, with deposition of limonite, formation of caverns and smaller cavities and the lining of them with calcite crystals, alteration of the ores, except where protected by being in chert, formation of clay, and similar chemical work.

As has been said, in the Judith Mountains the ores are gold ores, and although the alteration has been very complete to all depths which have yet been worked, it is pretty certain that the ores were originally tellurides.

It will be noticed that the occurrence of the ore bodies is quite similar to that of the great silver-lead deposits which have in recent years been actively developed in so many localities in the Rocky Mountain region. The ore bodies, therefore, have much of the character and all the uncertainty of occurrence that such classes of silver-lead deposits have. They occur in pockets, stringers, shoots, and chimneys, and the development work may lead to rich bonanzas or be prosecuted for great distances with little or no return. In general, however, it may be said that the work which has thus far been done tends to show that the zones of mineralization are quite extensive and probably reach greater depths than have yet been worked, and that skillful and intelligent development has usually been rewarded. Unfortunately too little of the latter has so far been shown in the district.

It has been generally noticed in the region, both in the cases mentioned and where prospecting has been combined with assay tests, that on contacts of limestone with porphyry the best results have been obtained where the contact plane is inclined or hades, with the porphyry as the hanging wall. Thus, in the case of intruded sheets of porphyry it is always the under contact that is worked or prospected, while the upper contacts have generally proved unremunerative. This might be attributed to the ore having been leached out of the porphyry by the circulating waters and having been deposited in the limestones below, while in the reverse case the waters passing through the upper limestones would not yet have been charged with ores. Although this appears at first glance a plausible theory, it is by no means a certain one. If the ascending mineralized waters came from great depths below and passed upward along an inclined con-

tact plane, the ore would be mostly deposited in the limestone and not in the porphyry, because, being of acid nature, as we have shown above, they would be neutralized by the limestone, and the ores would be deposited in it. Thus, with the limestones as the floor for the ascending currents, the neutralization and deposition of ore would be more complete than in the reverse case.

Similar contacts of porphyry with Cambrian or Mesozoic shales have so far proved unremunerative, and no important mine has been developed in them. At the present time only one prospect of this class—the Butcher Knife, in Alpine Gulch—is being developed, the results of which time alone can tell. It might be surmised that these shale beds have not proved ore carriers to so great an extent as the limestones on account of the difference in their chemical composition, which has been less favorable for action on the ascending acid currents. In a few cases ore deposits have occurred in the limestones which are not directly connected with any body of porphyry, but since all of the limestones in this district which are exposed have been uplifted by masses of porphyry from below, it is clear that solutions carrying ore might circulate through these rocks at considerable distances from the porphyry. In such cases it is always a silver oer that occurs, and examples are found in the Pilgrim claim, on Crystal Peak; in the Last Chance, in Elk Peak; in the Wocasek claim, below Maiden; and in the Cave mine, in West Armell Creek. Though some very small bodies of rich ore have been found in these deposits, nothing warranting extensive development has yet appeared.

The district is in fact essentially a "gold camp," and while silver ores, both of the sulphuret variety and also associated with lead, occur, as well as gold and silver ores together, there has so far been only one mine developed which has produced silver and paid well—the Florence, on Crystal Peak.

FUTURE OF THE DISTRICT.

The future development of the mining resources of this region must in a great measure depend upon the securing of cheap transportation and the inducements offered to outside capital. At present the remoteness of the region from the railway, which is over 100 miles distant, is a great drawback. It is thus little visited and rarely heard of, for its isolation not only hinders its accessibility to a market, producing extremely high freights, but causes it to attract little outside attention.

It is a fact to be noted that in nearly all of the prospects which have so far been tried, ore—usually gold—has been found, though not always by any means in notable or paying quantity; or one might say that in the great majority of cases where the altered porphyry and its under contact of limestone have been assayed more or less gold has been shown. It is therefore certain that gold has a very wide distribution

in the district, being found in the main masses of porphyry, in their contacts, and in the dikes and sheets. It appears therefore safe and reasonable to say that there are considerable bodies of low-grade gold ore present in this district which have not been developed.

The contact zone of the Gold Hill porphyry, between the Spotted Horse and Maginnis mines, should prove a favorable development ground. Under proper conditions several small mines, conservatively managed and intelligently conducted, may find profitable returns in this district, even though the chance of finding bonanza ore bodies like those in the Spotted Horse may never be realized.

If the future shows a considerable mining development in this region, the scarcity of water may be much felt, while that of timber will inevitably become a serious problem.

DESCRIPTIONS OF MINING PROPERTIES.

MAGINNIS MINE.

This mine was located in the earlier period of the camp, and in 1881 passed into the hands of a corporation known as the Maginnis Mining Company, which purchased the property known as the Montana and Oro Cache Quartz Lode and a year or two thereafter erected a 10-stamp mill. An investment of several hundred thousand dollars was made in the mill and power plant and in obtaining a water supply, for which a 6 by 6 inch flume several miles long was constructed. The mine was worked from 1881 to 1894 under several superintendents, but the returns to the company were unsatisfactory and the mine was closed down. From 40 to 50 men were employed in the mine and mill. The ore is considered free milling, though it is stated that not more than 65 to 70 per cent of the assay value was saved. The cyanide process, so far as is known, has never been tried on this ore, though some of the tailings have been treated in this way with indifferent success. The mine is located at the very head of Warm Spring Creek, at the upper end of the town of Maiden and just under the divide to Maiden Gulch. A view of it is given in the accompanying plate (Pl. LXXXIV). At this point the porphyry mass of Gold Hill comes in contact with the infold of strata lying between the Alpine and Crystal Peak laccolithic dome, as described elsewhere in this work, and the porphyry abuts against the Carboniferous limestone, a mass of the ledge belonging to the top of the Carboniferous series lying still uneroded on the divide and being seen from below as a prominent block-like crag against the sky line, as seen in Pl. LXXXIV. An examination of the mine workings shows that the ore is the characteristic one of the Gold Hill contact zone as found here and in the Spotted Horse mine.

The ore body of the Maginnis mine consists largely of a crushed and brecciated limestone, recemented and hardened by silica (quartz) and showing crystals and masses of quartz and calcite. Fluorite occurs

somewhat less abundantly. The ore resembles that of the Spotted Horse mine. It shows both light and dark crystalline limestone and compact brown, bluish, or gray shaly limestone. A microscopic examination of a thin section of the characteristic purple ore, the richer ore of the mine, shows it to be composed of grains of quartz intimately mixed with almost colorless fluorite, the grains being of about equal size and the fluorite predominating. Scattered areas of a yellowish substance are seen that give an aggregate polarization and appear to be the result of the decomposition of some former iron-bearing minerals. This substance contains considerable iron hydroxide, but is not definitely determinable.

A winze has been sunk below the lower level, but sufficient depth has not been attained to reach below the zone of alteration. At times the contact shows slaty beds which are really altered shaly rock. The adjoining diagram (fig. 54) shows the general character of the contact area, the darkened portion being the ore-bearing zone. In the shaly beds very little good ore is seen, the best always occurring in the pure crystalline limestone. Of the best ore, the green and purple variety described above, a rough estimate by one familiar with the mine places the total amount mined at 500 tons. It is impossible to obtain a general average of the value of the ore; some has run at $50 to the ton, some very much higher, while much of it would average perhaps $20 to the ton. The mine is situated on the contact of limestone and porphyry. It has two levels, the lower, near the mill, being about 1,000 feet long, with a large number of side tunnels, stopes, and winzes; the upper, on the hill above, is about 300 feet long, and considerable work has also been done here. These workings show that the contact does not even approach a smooth wall, but is very broken and irregular, the porphyry having torn up and penetrated the beds of limestone in wedge-like masses. In general terms the whole plane

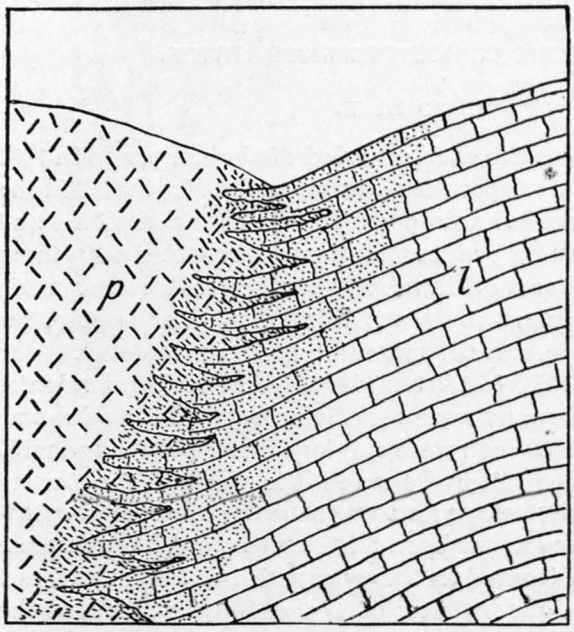
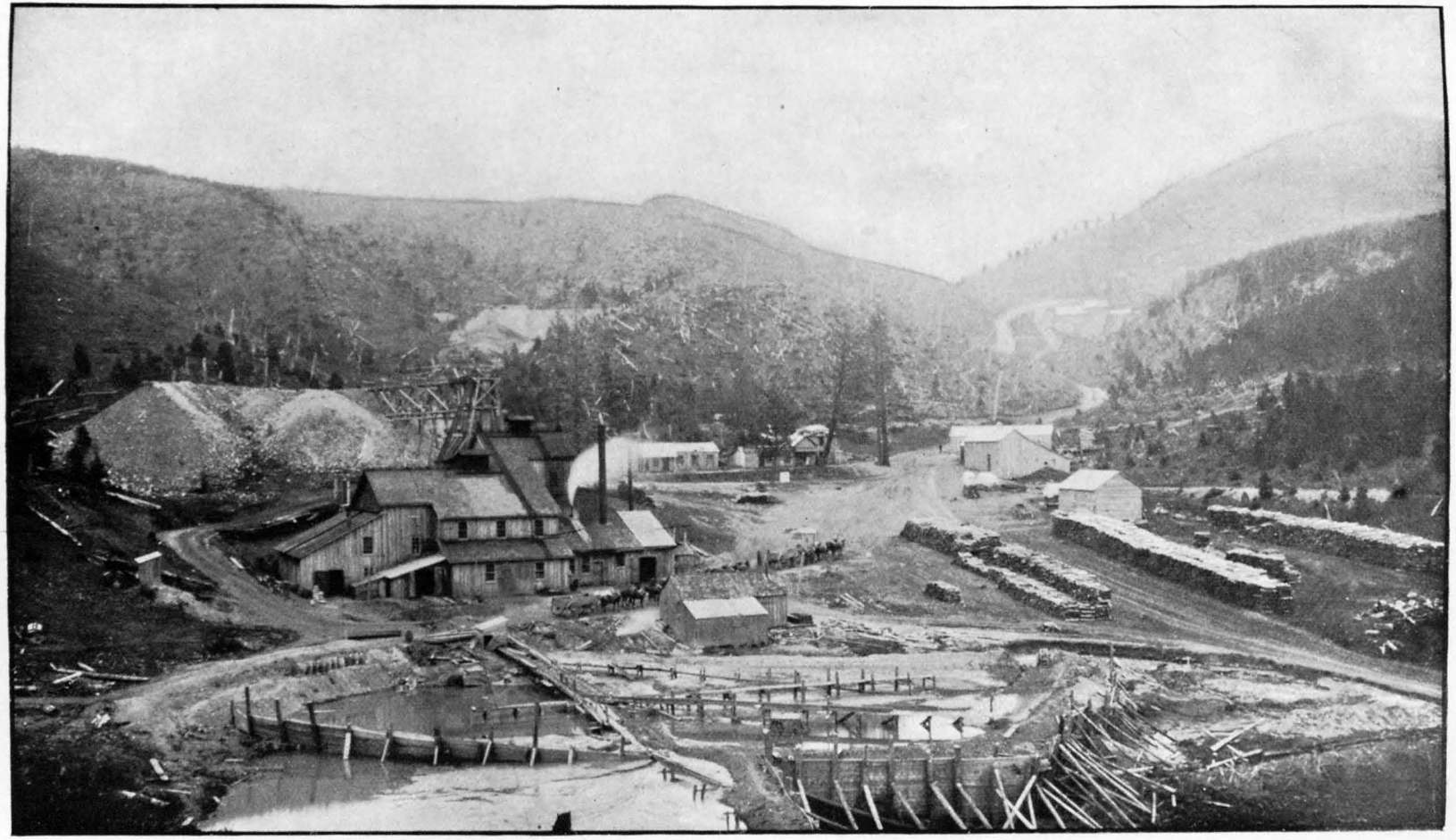


FIG. 54.—Diagrammatic section showing contact of porphry and limestone and zone of ore deposition. p=porphyry, l=limestone.



MAGINNIS MINE.

of contact hades strongly downward toward the porphyry. Thus in the various levels and stopes, while the chief working has been in a mineralized zone in the limestone, the workings frequently pass through porphyry, which appears now on one side and now on the other.

The amount of alteration suffered by the various rocks composing the contact has been very great; the limestones are generally decayed, cavernous, and filled with masses of limonite. In other places soft masses of limonite, or even of soapy, talc-like clay, are passed through. It is difficult, in the midst of so much alteration, to trace out the various changes which the limestones have suffered—first from the action of the intruded porphyry, second from the processes of mineralization, and lastly from oxidation and decay. The amount of the latter has been very considerable, and has been caused largely by the action of running water, as is shown by the caverns and old water pipes which fill the limestone. In one tunnel a natural pothole-like shaft was encountered, which showed no bottom at 150 feet of depth. Many of the caverns are coated with fine calcite crystals, and vary from vugs but a few inches in diameter to rooms of considerable size.

Above, near the divide, is the other property, called the South Shaft, 150 feet deep, with several levels. This gave a silver-lead ore, running, so it is said, some 60 ounces in silver, of which about 1,500 tons were shipped to Wickes. The buildings of this mine are seen in Pl. LXXXIV, on the road crossing the divide.

These mines, being rather high above the adjacent drainage channels, are very dry, and the old waterways found in working afford a steady draft of natural origin through them. At present, from nonusage, the mines and machinery are not in the best condition.

Pl. LXXXIV shows the Maginnis mill and tailings pond, with the dump heap of the lower level behind the mill. The mouth of the upper tunnel is seen in the background on the slopes of Gold Hill. To the right the road to the Spotted Horse mine, Giltedge, and Lewistown is seen going up the gulch and crossing the divide between Gold Hill and Sheep Mountain. The south shaft of the Maginnis mine is seen to the right of the road on the divide.

P. K. MINE.

Besides the properties already mentioned, the Maginnis Mining Company operates the Black Bull, Globe, and P. K. claims, the latter a mine situated on the mountain ridge that forms the Alpine divide at the head of Virgin Creek, and a short distance south of Pekay Peak. It is about 1,000 feet above Maiden and 2 miles distant by road. The development here consists of a tunnel 400 feet long, with a 200-foot branch, a lower shaft of 80 feet depth, and an upper shaft of 45. The ore was carried down by teams. The mine is situated on the contact of the Carboniferous limestone with one of the upper, intruded, lenticular sheets in the Alpine dome. The ore was considered a free-

milling gold ore, and its character shows that the lode is likely to yield favorable results if careful, systematic exploitation is conducted for rich ore bodies.

SPOTTED HORSE MINE.

The Spotted Horse mine has been the great gold producer of the region and is one of the noted gold mines of the State. It is situated on the slopes of Gold Hill, a mile and a half from Maiden, near the ravine cut by a branch of Maiden Creek. (See Pl. LXXXV and fig. 47.) The mine was located in 1881 by Messrs. Anderson and Jones, who sold it to Messrs. P. W. McAdow and B. Dexter. Mr. McAdow became sole owner in 1883, and worked the mine very successfully for five or six years and then bonded it to the so-called Jay Gould Mining Company, composed of Helena people, for $500,000. The mine was worked by these parties for a year or two without much success and they then relinquished the bond. Mr. McAdow again worked the mine very successfully for several years, and finally sold it, in the winter of 1893, to the Double Eagle Gold Mining Company, composed of Chicago people. They worked the mine a year and a half, were not successful, and it fell to the lien holders, by whom it was sold to the present owners.

The ore body occurs at or near the contact of massively bedded white limestones with the intrusive mass of Gold Hill porphyry. The surface outcroppings of these rocks are shown in the sketch map (fig. 47) given with the detailed description of the geology of this place. The ore occurs wholly in the limestones, for although the porphyry is mineralized, it is of too low grade to work, and is generally base. The ore body consists of a breccia, or mass of fragments of broken rock, chiefly limestone, but carrying porphyry fragments as well, near the contact. The limestones were altered by the intrusion of the porphyry mass, being rendered more crystalline, as is so commonly the case, in the contact zone about intruded bosses of igneous rock, but few contact minerals have been observed. The processes of ore deposition and late surface alteration have changed the character of much of the rock and formed the clayey and shaly masses met with in mining.

The Cambrian rocks occur on both sides of the gulch adjacent to the mine, but in the workings they are not encountered. There is reason to believe that here, as elsewhere in this region, they would prove poor ore carriers. These rocks are faulted against the massive white Carboniferous limestones.

The ore body is extremely irregular. It appears to be similar to that of the Maginnis mine; that is, it occurs apparently where the porphyry projects into the limestone in jagged masses, and the contact has been brecciated, and the diagram given with the description of the Maginnis mine also illustrates the mode of occurrence of the ore body here.

Fig. 54*a* shows the workings of the mine as surveyed in 1889, the later workings having been sketched in. This shows the extreme

irregularity of the workings and the unequal distribution of the ore. In every case where the levels have been driven into the ground immediately between the two shafts, rich ore bodies have been found, but this has been done only after drifting through barren ground. No systematic prospecting of the property has been done, although it would appear to offer extremely favorable conditions for diamond-drill work.

A cross section of the workings, so far as developed in 1889, is shown in fig. 54*b*. Later surveys have not been obtainable.

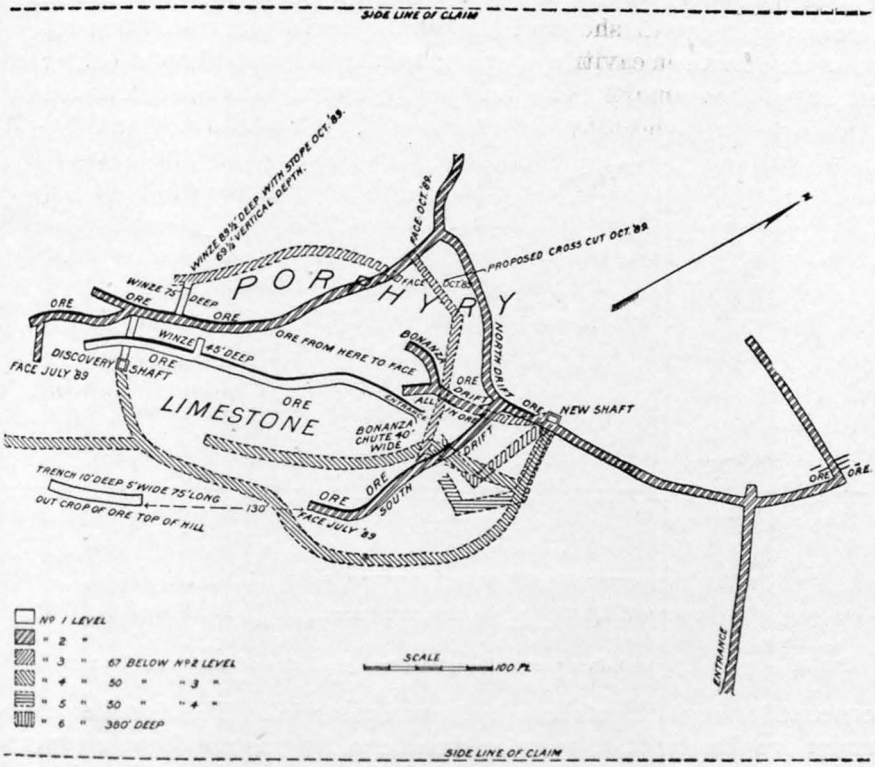


FIG. 54*a*.—Ground plan of workings of Spotted Horse mine, October, 1889, from survey by G. T. Wickes; fourth, fifth, and sixth levels of later workings sketched in.

Pl. LXXXV shows the hoist, mill, and general aspect of the surrounding slopes. On the extreme left of the view the Carboniferous limestones form a hummock on the hillside, and in this a bonanza of rich ore was found in 1893, which yielded $30,000, the body of rich ore being less than 10 by 25 feet across, and perhaps 15 feet deep. In the plate the distinction between the porphyry mass of Gold Hill, seen in the background, and the limestones of the mine, upon which the buildings all stand, is not very apparent, as no prominent outcrops occur. The distinction is more apparent near the mouth of Spotted Horse Gulch, where the limestones form the heavy outcrops seen in Pl. LXXIX, p. 528.

The Spotted Horse ores vary greatly in appearance, though the same general characters prevail throughout. The richest ores consist of coarsely crystalline, light-gray limestone, carrying fragmental masses of fluorite impregnated with gold. Other ores are of limestone of varying grain crossed by fractures or seams of earthy material, with parallel arrangement. The fluorite occurs both as angular masses replacing limestone fragments and in specks and particles in the compact limestones. The limestone is seen to be such, and not vein calcite, by its structure and by the calcite grains replacing fossils. The ores often show considerable secondary alteration and solution, forming open cavities lined with secondary calcite crystals. Bowlders occurring in the soft, clayey parts of the deposit show a center of cemented limestone, fluorite, and porphyry fragments, surrounded by

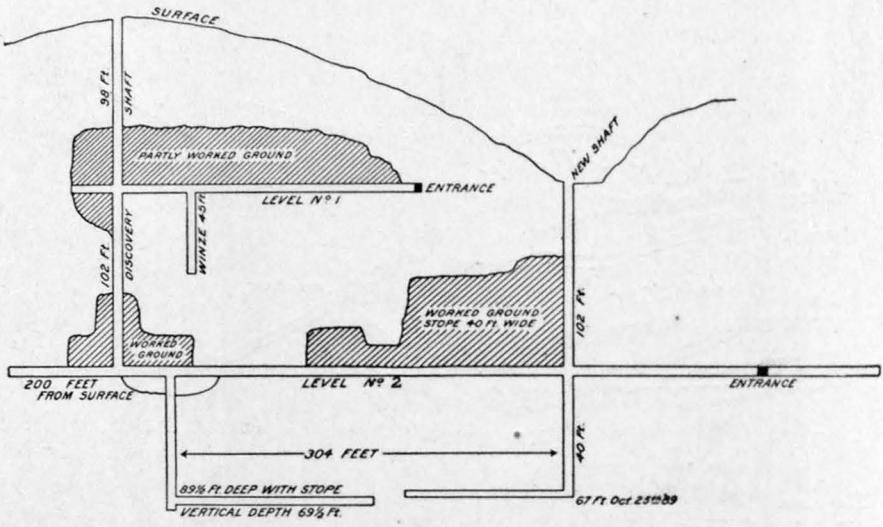


FIG. 54*b*.—Spotted Horse mine; vertical section through shaft and workings, October, 1889.

concentric rings of soft, earthy brown material. The fluorite occurring as replacement of angular limestone fragments shows a contact film of brown ferruginous oxide, which may represent impurities of the original limestone, expelled during replacement. The coloring of the fluorite seems deepest where the limestone carries most organic matter. The shaft sunk upon the adjoining claim, the Kentucky Favorite, develops mineralized porphyry, which is of too low grade to work, though containing unaltered specks of telluride. The rock shows considerable pyrite and is quite thoroughly altered. Under the microscope this low-grade ore is seen to be a rhyolite (quartz)-porphyry of the type described in the chapter on the igneous rocks, but it has been greatly altered and changed by various agencies. It consisted originally of crystals of feldspar of small size, and occasional rare ones of quartz, embedded in a very dense, compact groundmass

SPOTTED HORSE MINE.

of quartz and alkali feldspar in extremely minute, microscopic grains. In the process of alteration this character has been much changed, and the feldspars are largely converted into masses consisting of fibers and scales of sericite, a variety of muscovite. Originally also a ferromagnesian mineral, probably pyroxene, was present, and this has been leached out and replaced by masses of calcite, often retaining the shape of the original crystal; this occurs also at times in the altered feldspars. Scattered through this are many small masses and distinct crystals of pyrite which occur embedded sometimes in the calcite, sometimes in the altered feldspar, and sometimes in the groundmass. Where the surface of the pyrite has been ground off in the process of making the section there is often seen by reflected light minute dark spots, which may be due to some mineral embedded in it, but they are so small that their exact character can not be determined. The alteration of the porphyry is clearly that produced by the action of hot, solvent solutions, which have altered the original minerals and deposited the calcite and probably the pyrite.

The Spotted Horse mine is now owned by Mr. John L. Bright, of Columbus, Ohio, and Albert L. Losinger, of Maiden, Montana, the former owning a three-fourths interest. It is understood that a stock company will shortly be formed to operate the property. The mine was bonded for $30,000. The work done under the new ownership consists chiefly in the working out of the ore body exposed at the time of purchase and in the opening of the adjoining claim, the Kentucky Favorite, by means of a drift from the Spotted Horse shaft, run in a northwesterly direction. This drift starts from the second level at a depth of about 125 feet. The present owners have discovered several shoots of ore on the second and third levels, situated in close proximity to the 80-foot stope. The ore in these shoots was exceptionally high grade and consisted principally of tellurides; it was shipped to the Montana Smelting and Refining Company of Great Falls. The amount extracted did not exceed 100 tons, but the high value made it an extremely desirable ore to handle. The mill was closed down in April, awaiting a supply of coal from the neighboring mines. Previous to that the mill was running on an ore averaging $17 per ton, taken partly from the mine and partly from the surface working known as the "Open Cut," situated in the southeastern corner of the Spotted Horse claim, where the ore body has yielded some $35,000 from a space about 7 feet wide and 15 feet long. This bonanza was worked out under the former management, but considerable low-grade ore has been extracted by the present management from the vicinity of this ore shoot.

The pans of the mill have been replaced by copper plates, which were found to do quite as good work as that accomplished by the pans.

The old tailings are now being worked in a small cyanide mill with

a capacity of about 40 tons per day, an extraction of 95 per cent (an average of $11 per ton) being made, a total amount of about 2,500 tons of tailings being available for work. The mine shaft will be sunk deeper by the present owners during the coming year.

The ore is treated in a 20-stamp mill, in which the free gold is extracted. The base minerals of the ore, said to be largely sulphides with telluride of gold, were concentrated and shipped for smelting. A letter from Mr. P. W. McAdow states that under his ownership about 65 per cent of the ore was free milling and 35 per cent telluride. The vanner saved 15 per cent of the tellurides, and 20 per cent was lost in the tailings and was carried down Maiden Creek.

The mine is not a wet one, barely enough water being obtained to supply the boilers of the hoist. For milling it has been found necessary to pump water from the head of Collar Creek Canyon, a lift of 300 feet and a distance of 2 miles.

The mill and hoisting plant were in poor condition in 1896, the mine and mill both requiring a considerable investment for satisfactory working.

FLORENCE MINE.

This mine was located by John Kemper in 1881. It consists of a tunnel cut in the limestone of Crystal Peak. The mine was worked only a short time, a number of years ago. At that time about 25 tons of very rich silver ore were shipped, of which 17 tons gave $9,000. The mine has not been worked to any extent since.

The Florence mine is situated in the limestone east of the porphyry mass, and the ore body occurs along the contact of limestone and a lesser porphyry intrusion. The ore appears to be mainly dog-tooth spar (calcite), stained and colored by copper carbonates, with green pyroxene characteristic of altered metamorphosed limestones, due to the proximity of eruptive rocks.

PILGRIM MINE.

This is a small working on the side of the mountain below the Florence. It consists of a thin seam of very rich silver ore, but the lead was too narrow and the limestone too hard for profitable working.

BUTCHER KNIFE MINE.

In Alpine Gulch this is the only prospect being actively pushed at the present time. An intrusive sheet lies in the calcareous Cambrian shales, and both are cut by a feldspar porphyry dike. The ore is along the contact between the porphyry and the limy, altered shale. A shaft 60 feet deep on the hill heads to a tunnel 180 feet long, driven to meet it. Some of the ore pans free gold; no general assay has yet been made and no ore has been shipped. Three or four men are employed in the mine.

Below the mouth of Alpine Creek, J. Wocasek has shipped small amounts of rich silver ore obtained from an open pit in the limestones.

NEW YEARS MINE.

New Years Gulch is the general name applied to the amphitheater cut in the mountains by the headwater branches of New Years Creek. A number of claims have been located here on contacts between the porphyry sheets and limestones.

The New Years mine is the only one from which ore has been extracted. It is still the property of the locators, Messrs. Harmon and Norman. The ore body lies on the under contact of an intruded sheet of porphyry, like the ore body of the Giltedge mines. The ore is a brecciated limestone, fissured and seamed with calcite seams and crusted with calcite, and decomposed porphyry also occurs in the ore body. Fluorite occurs here, replacing limestone fragments, as at the Spotted Horse mine. The ore is said to average about $14 a ton. An attempt was made to work the ore in a small cyanide mill, but the machinery was inadequate for the work and did not crush the ore fine enough to permit the extraction of the gold. As a seam of good coal outcrops at the mill, cheap fuel is assured.

BOULDER MINE.

This claim is on the northwest side of Pyramid Peak and consists of a tunnel 300 feet long driven in through the limestones toward the porphyry. The black Silurian limestone, which appears mineralized, is stated to be the ore and is said by the locator and owner, Mr. W. Wilson, to run 100 ounces in silver.

THE GILTEDGE MINES.

Ownership.—The Giltedge mines consist of a group of claims, of which Giltedge is but one, located in 1884–85 by Messrs. Wilson, Anderson, and Munson. The Giltedge claim was sold to Collins & Armington, who worked the property for a short while, building a small and crude cyanide mill for treating the ores. The ore body was worked without system, but sufficiently to show the existence of a large body of ore of low grade, easily handled and cheaply treated. The owners disposed of the property in 1893 to the Ammon-Stivers Mining Company, who employed Prof. W. B. Potter, of St. Louis, as consulting engineer. Under his guidance the mill was rebuilt and the plant greatly improved. His early treatment of the ore was not so satisfactory, however, as the method at present employed, and his plans for development were never carried out. The financial embarrassment of the company led to the attachment of the property, and in the summer of 1896 the property was being worked by the lien holders to satisfy unpaid wages of the miners and for the benefit of the lien holders themselves. The ore extracted during this arrangement was very successfully treated and considerable gold was shipped.

The property is at present (May, 1897) managed by a receiver, who is making many improvements in order to increase the output to 75 tons a day.

Occurrence of ore body.—The ore body occurs at the lower contact of an intrusive sheet of porphyry with the soft limestone overlying the massive, heavy-bedded Carboniferous limestones that form the mountain slopes. The structure here has been already described, and is illustrated in fig. 42 (p. 509). The beds are tilted, dipping at an angle of 30° away from the mountains, and, as the beds curve about the dome produced by the underlying laccolith, the limestone outcrops are not persistent in course, but curve about the mountains. The porphyry sheet is comformably intruded and then eroded, for the ore body at the contact is exposed on the surface of the mountain, and its upper portion has been swept away by erosion.

The ore is in part a crushed, broken, and altered limestone—much of it soft and clayey and some of it shaly—and in part a decomposed porphyry. The ore-bearing waters have dissolved out or altered the limestone and leached and decomposed the porphyry, but the impregnation with gold extends only a short distance, rarely over a foot, into the porphyry mass, the ore occurring chiefly in the limestone. A common feature of these deposits is that the mineral impregnation extends more or less uniformly and but a little way into the porphyry, and irregularly and much more deeply into the limestone.

The mines are on each side of a gulch cut deeply into the steep limestone slopes of the mountain, the openings being at an elevation of 6,000 feet, or 700 feet above the mill. The ore body is from a few feet to 40 feet in thickness. The porphyry sheet is about 50 feet thick, but was not measured. The limestone on the slopes above the ore body is indurated and splintery from the metamorphic action of the intruded sheet, and the fossils are replaced by fibrous, crystallized calcite, and their nature is not generally recognizable, although abundant crinoid stems, with Zaphrentis and spirifers, can be made out. The limestone underneath the porphyry is cracked, checked, and fissured, the seams carrying calcite. Even this dense and apparently unaltered limestone carries gold. The main mass of the ore body appears to be a shaly, argillaceous material, the result of the alteration of the massive limestone, and is itself generally rotted to clay. Fragments of this are seen inclosed in the porphyry, and it apparently represents a horizon of fissile rock through which the porphyry sheet has been intruded. This shale ore is not always present in following the lead, although it is quite common. Some 6 inches of the porphyry wall is ore bearing, and the barren-looking limestone itself often carries $6 in gold. The general appearance of the ore mass is, however, so unpromising that close assays of the face are necessary to avoid mining waste rock. But it is generally true that whenever the limestone is checked and fissured it

carries gold. No other minerals save calcite were noticed, although on the surface exposures fluorite is abundant. The calcite forms stalactitic masses and incrustations, particularly in the old water-pipes and cavities which are occasionally encountered. In one instance a cavity was found which was gravel filled.

Underground workings.—The mine workings consist of an incline about 300 feet long, a lower tunnel, and a rock tunnel through the porphyry, together with a 60-foot winze and some meandering work which is apparently without any plan. There is a difference of over 500 feet in elevation between the mill and the mouth of the rock tunnel. This tunnel runs into the hill, the direction being N. 80° W. The walls exhibit a bleached, white, and decomposed porphyry, this rock showing sheeting or platy structure; the planes dip 25° to 30° toward the mouth of the tunnel, the seams being marked by a rusty color. The rocks at the ore bin are thin bedded and carry Carboniferous fossils. They strike N. 60° W. and dip 30° NE. The exposures along the ridge from the ore bins to the mill appear to be conformable, though the dip changes somewhat, becoming about 29° near the coal outcrop, where the strike is N. 30° W. The limestone slopes above the mine show three sheets of intruded porphyry, which are apparently conformable with the bedding of the limestones, and in the exposures seen are not over 5 feet thick. The workings are very advantageously situated for easy handling of the ore. At present there is a trestle and ore incline down to the bins from the mine incline. The situation of the mines and mill is admirably adapted to a gravity cable and ore-bucket arrangement to carry ore to the mill.

Character of ore.—The ore is low grade, and will perhaps average $10. The cost of mining is about $1, the hauling by teams to the mill is 50 cents, and the milling about $1.15 per ton. It shows no free gold, or, in fact, any visible mineral. The ore from the claims on either side of the gulch is very similar in character. The softer ore mined at the time of our visit consisted mainly of a clayey material, resulting from the thorough alteration of the original ore and containing masses of decomposed porphyry and irregular, rough-surfaced pieces of limestone up to a foot or two in diameter. These bowlders consist of crystalline and brecciated limestone, often surrounded by a concentric shell or crust of clay, resulting from the alteration of the bowlder itself. The softer clayey material also holds harder, cream-colored nucleal masses.

Treatment.—The cyanide process has been used with marked success at the Giltedge mill. In the earlier work the ore was heap-roasted and pulverized before treatment in the leaching tanks. The limy nature of the ore, resulting in much dust and in a slimy pulp through which the solutions percolated with difficulty and slowly, made this process unsatisfactory. Under the process as modified by the present owners, the ore as it comes from the mine is crushed and pulverized,

and the treatment in the leaching tanks is very satisfactory, the leached pulp showing no gold upon assay. Following the practice elsewhere, it seems possible that the cost of treatment may be materially reduced if cheap copper sulphate can be supplied from local sources. The precipitate of cuprous aurocyanide is readily treated for the extraction of the gold.

The mill includes a small rock crusher, in which the ore is broken, and the product passes through a chilian mill, the pulverized material being lifted to be transmitted by cars to the leaching tanks or tubs. The resulting solution is precipitated at a lower level in the zinc room. The mill and offices lie on the flank of the hill formed of the coal-bearing rocks, which are mined for the use of the mill. (See Pl. LXXXVI.)

CONE BUTTE DISTRICT.

The Cone Butte mining district (unorganized) embraces the claims located in the northern half of the mountains, north of the fourth standard parallel of Montana as shown by the Land Office. This district includes a large number of located claims, none of which have as yet been extensively worked. The claims all show ore, rarely of high grade, and differing from that of the producing mines in character. The deposits mostly belong to the two classes already noted—first, deposits in fissures in porphyry; second, deposits on contacts of phonolite dikes.

The following notes show the extent of development of the various properties examined and the main facts of interest, the prospects being grouped by localities to facilitate reference.

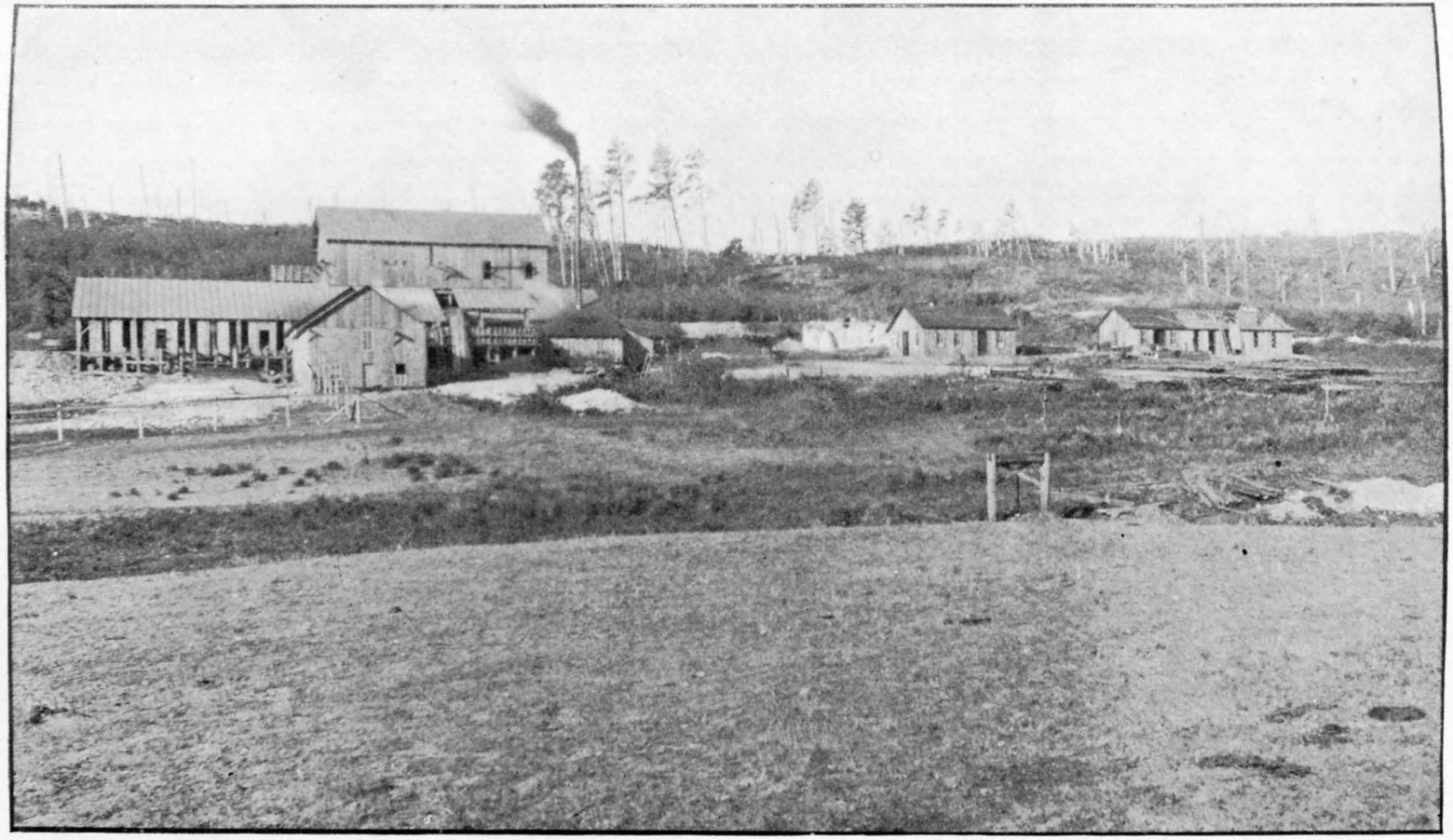
COLLAR GULCH.

The earliest developed mine in the district is located here—the Collar mine. It consists of a tunnel, stated to be about 1,000 feet long, penetrating the limestone of the Crystal Peak dome at the divide between Collar and Maiden creeks. What ore is now to be seen shows only a broken and silicified limestone, with apparently no considerable amount of ore-bearing constituent. It was worked as a silver ore. A large and expensive mill was built below in Collar Creek, which, however, was never practically used. The mine has been abandoned for many years and the machinery of the mill was largely used in the Spotted Horse mine.

The Ivanhoe is a prospect in these limestones, owned by Mr. L. Poland. The *Black Diamond* is a claim on a limonitic band in the limestones, owned by Mr. J. Dougherty and stated to carry $14 in gold. There are also several other prospects of a similar nature in limestone and not in porphyry.

WEST ARMELL CREEK.

Cave mine.—This was located early in the history of the camp by the Gies brothers. It consists of a chamber of silver-rich galena in



GILTEDGE MILL.

the limestone. The ore was hauled to a small smelter built for the purpose in Maiden, but after exhausting the pocket of ore in sight further work was abandoned.

First National.—This prospect was located by L. R. Davis on the contact of a rotted porphyry dike cutting ferruginous limestones. It affords a low-grade gold ore.

American Flag.—This prospect was formerly known as the Northern Pacific, and it belongs to Messrs. Anderson and Rhodes. Development consists of two shafts, the lower 50 feet, the upper 40; timbered. These are on a vein said to be 10 feet wide, of a dark-red to purple massive ore consisting of quartz and fluorite and showing occasional bunches of galena with rare grains of chalcopyrite. At the upper shaft the ore is much altered, and the porphyry of the vicinity is extremely altered, much leached, light colored, and rotten in character. It is stated that the ore is valued chiefly as a copper ore, that its average value is $15, and that 500 tons are on the dump. None has been shipped or worked.

Under the microscope, in thin section, this ore is seen to be composed of nearly equal parts of quartz in very fine grains and fluorite, the latter in larger masses of irregular shapes and also in fine grains penetrating the quartz. It has a deep blue-purple color, and, as usual with this mineral, the coloring pigment is very unequally distributed, being generally much deeper around the border of the masses, which have therefore a zonal, banded appearance. Besides these minerals an occasional speck of gray galena or lead ore is seen.

The development work upon this deposit of copper ores is not sufficient to warrant any further definite statement concerning its mode of occurrence or the future of the lead. The association of minerals is unusual, and, so far as we know, it is unknown elsewhere in the ore deposits of Montana.

In this connection attention should be called to the possible use of these copper ores in the cyanide treatment of the gold ores of the district. The lack of railroad communication and the present price of potassium cyanide and zinc make the cyanide process more costly than it would be if a cheap supply of copper sulphate or chloride were at hand, and this would give a local value to ores that would otherwise be of too low grade to work.

EAST ARMELL CREEK.

Voltaire.—This is the Hanson mine, at the extreme head of the creek. The "vein" consists of a decomposed phonolite dike cutting the Benton shales, which are here altered by the action of the various porphyry masses to black slates. The development consists of a tunnel on either side of the gulch, each driven in about 200 feet. The ore is a bluish, silicified porphyry, showing occasional pyrite. A small Huntington mill has been erected. The cyanide process was tried,

but not successfully, probably owing in part to lack of experience. The ore carries gold and silver in small, thin streaks which run very high in value. The maximum value of ore treated was $30 a ton, but much of the ore did not average over $6 or $7. A little of the high-grade ore occurring in small pockets in the slate was shipped away. The mine employed nine men at one time, but was not successful, and is now closed down.

HEAD OF BOX ELDER CREEK.

Bob Ingersoll.—This claim, owned by Messrs. Anderson and Rhodes, is developed by a 30-foot shaft. The ore body occurs at the contact of limestone and porphyry.

Last Chance prospect, located by J. Murphy, is said to show a silver ore. The work consists of a timbered tunnel 75 feet long and a shaft 47 feet deep. The ore consists of a porous silicified limestone with green and blue specks of copper carbonates.

These two prospects are in the heavy limestones and porphyry sheets on the Elk Peak ridge.

Peerless, in Peerless Gulch, was located by Messrs. Shields and Noble. The ore body is a small, narrow vein running through the limestone near porphyry, and is developed by a timbered shaft of 30 feet and a tunnel of 30 feet. The ore carries copper, silver, and gold. Six tons of selected ore have been shipped, which gave an average of $100 per ton.

Birmingham, owned by J. Mitchell, is also located at this last locality. Development work consists of a tunnel, 75 to 100 feet long, run in on the contact of a mass of porphyry intruded in the limestone. The ore is a silver-rich galena and some of it has been shipped away.

Homestake, a claim of J. Leonard, consists of a 75-foot tunnel driven in on the contact of an intrusive sheet in the limestone. It shows lead ore, said to carry gold and silver.

None of these claims are being developed at the present time beyond the necessary assessment work.

CONE BUTTE MOUNTAINS.

Several prospects have been opened here, generally located on altered dikes of phonolite (tinguaite) cutting the main porphyry. The only one of these that deserves special mention is the *Golden Jack*. This is situated on one of the head forks of Edwards Creek, and the so-called vein is a dike of altered phonolite-porphyry cutting the main porphyry at its contact with altered beds of what are believed to be Jurassic shales. The development work consists of two tunnels 150 and 100 feet long, respectively, the latter being driven to secure drainage and crosscut the dike, the former being apparently exploratory and without definite purpose.

The porphyry in the unoxidized material of the ore body is cracked and somewhat silicified and shows on the cracked surfaces films of pyrite and patches of fluorite. This forms the ore, which is stated to

run from $10 to $30 in gold. No average has been taken. Five men are employed in development work, but no ore had yet been shipped or treated from the prospect.

EAST FORK OF MAGINNIS CREEK.

A road has been built up this gulch which gives access to the Voltaire mine and other Hanson properties. There are a number of prospects in this gulch which are on contacts of the limestone of the Elk Peak dome with intruded masses of porphyry. Two locations have also been made on the contact of the Maginnis Peak syenite with the altered Cretaceous beds. The following claims may be briefly mentioned:

Gies mine.—On the contact of the porphyry and limestone are prospects owned by Mr. V. Gies. There is a tunnel 200 feet long, and gold ore has been mined which is said to have assayed as high as $80. About one ton of the ore has been shipped to Great Falls. Mr. T. Burke has a similar deposit, the ore from which is said to run about $20 in gold, and which has about the same amount of development. Similar prospects are claimed by Mr. C. F. Williams, and there are others of lesser note.

Other claims are located on the contact of intrusive rocks with the altered Cretaceous beds, among them the *Golden Eagle* claim of Mr. J. Murphy, which is partly in the igneous rock and partly in an altered conglomeratic material. Fissures in these, filled with films of pyrite, form the ore. No average value has been stated, but some of the ore is claimed to run very high. Work consists of a shaft and 170-foot tunnel. This claim is near the upper forks of the creek.

The other claim of this character is the *Edwards*, located below the last, and developed by a 70-foot tunnel driven into the black Benton shales, here converted into tough black slates by the action of the intruded syenite. The igneous rock crosses the creek at this point, and is seen on its east side. The ore is said to average $14 a ton.

WEST FORK OF MAGINNIS CREEK.

In the valley of this fork of the creek are several gold prospects, of the character of those previously described as occurring on porphyry dikes. The *Chicago* is one of these, occurring near the contact of the black slates with the main porphyry dike. It consists of a timbered shaft and tunnel. Similar claims are owned by C. Ridell and C. Stevens.

PLACERS.

The presence of gold in the porphyry is shown in the fact that wherever the streams have a course through porphyry areas, into which they are cutting, placer washings occur. A certain amount of placer work has been done, but the deposits are too small and the available water supply is too deficient to allow of work of any magnitude. It has been carried on mostly in Alpine Gulch, where a few men

have made small sums from it. The gold found is usually very coarse and unworn, indicating its short transport.

IRON ORES.

On West Armell Creek, near its head, and not far from the contact of the porphyry with the west head branch, there is a considerable deposit of limonite. It lies exposed, forming a point between the main creek and a little side drainage. The latter has cut a small ravine down through it, and a thickness of at least 50 feet is seen in the banks. The material is of a spongy, fibrous, filamentous character, and altered stems and branches of trees are found in it. It appears to have been laid down by hot-spring action, the iron having been probably leached from the porphyry. As its boundaries merge back into soil and slide rock, the exact size of the deposit can not be told, but there are certainly several thousand tons in sight. The streams are wearing it away, and the water of West Armell Creek appears to be heavily charged with iron salts, which, as the stream loses its carbonic acid, are deposited as whitish to pale-brown carbonate in its bed.

A similar though much smaller deposit appears on the banks of upper Edwards Creek, while west Maginnis Creek, as previously noted, also deposits iron in its bed.

The Black Diamond lead, on the south side of the Crystal Peak dome, is also a bed of limonite, of what appears to be fair quality, lying in the limestones. It varies from 18 inches to 2 feet in thickness.

COAL.

Coal has been mined to a greater or less extent at the various localities marked on the map. The Cliff and Giltedge workings are the most developed.

Cliff mine.—The coal seam is opened in the narrow stream cutting of one of the headwater branches of Chippewa Creek. The mine is owned and worked by William Cliff, the product being marketed at Lewistown, Giltedge, and the Spotted Horse mine. The seam is here 2 feet 6 inches to 2 feet 8 inches thick. The coal comprises both bright and dull varieties, the former predominating; the two occur in irregular alternating layers, giving the coal a streaked appearance.

The shale over the coal is hard and firm and forms a good roof, needing little support. It is generally quite uniform, but in one place cuts out the coal, filling an old channel. An inch of coal occurs in the roof shale a few inches above the main seam. The coal is underlain by shaly sandstones, forming a gently rolling floor which occasionally rises and pinches the seam to 6 inches less in thickness. The seam, together with the inclosing rocks, dips at an angle of 14° to the east, away from the mountains.

A seam is worked by an entry 1,000 feet long, with the usual system

of pillar and stall. The coal sells for $2.50 per ton at the mine, but when the seam is worked in benches and the lower 2 inches of blacksmith coal is separated, the latter sells for $14 per ton.

Lewistown coal mines.—There are coal mines about 4 miles south of Lewistown. From Lewistown to the coal mines the road follows the right-hand side of Big Spring Creek, along the borders of a very beautiful bottom land, well cultivated and cleared, and fringed with a thicket of haw bushes. Southward the inclosing slopes become steeper, in places forming bluff banks, in which the red clays observed on the first terrace above the town are seen to rest upon massively bedded but flaggy sandstone whose outcrop is marked by occasional pine trees. These sandstone beds form reefs separated by softer beds, and possess the peculiar yellowish, irregularly surfaced, knotty structure so well developed above the coal at Belt Creek, where similar sandstones also occur in the same red-clay series. The coal is first seen a mile or so below the forks of the valley on the south side of the creek. An abandoned opening is seen on the slope south of the stream, and another in a coulée just above the opening, being on the lower side of the coulée, while the mine now worked is half a mile up the side coulée on the west side of the creek. The mine belongs to Frank Bland, of Lewistown. The rocks strike diagonally across the creek and dip 5°, though the ledges slope down the creek at an angle of 2°. The coal sandstone is seen outcropping upon the right bank in occasional buttresses, while the overlying sandstones form continuous reefs which cross the road.

In the lower opening, which is now abandoned, the following section was made:

	Inches.
Dirty coal, under sand-rock roof	17
Light lavender-colored, clayey sandstone	24
Impure coal	16 to 18
Clay rock	
Lower seam of coal	

East of the crossing of Big Spring Creek, beyond the town, the bench land shows in a side hill, cutting the purplish-red and dark-red earths which characterize the rock series above the coal and prevail eastward to Boyd Creek.

The following section of the seam was made at the Bland workings:

	Inches.
Top coal	6
Massive slate	10 to 12
Bright coal	4
Rock parting, generally clayey, the lower 3 inches being at times a coal	6
Flinty clay parting, which is quite persistent	1
Cannel coal	8
Bright coal	4 to 5

The coal as sold is a splint, part of it a so-called "cannel" coal with

conchoidal fracture, while a part shows bright streakings, and might be classed as a semicannel.

Specimens from the different parts of the seam were collected and an analyses was made of each variety.

Table of analyses of coal from Judith Mountains.

[Analyses by J. Edward Whitfield, of Booth, Garret & Blair, for U. S. Geological Survey.]

Lewistown mines.	Moisture.	Vol. C.	Fixed C.	Ash.	Color.	Coke.
No. 1	6.66	44.78	38.67	9.89	Ash-brown	None.
No. 2	3.24	35.60	52.72	8.44	White	Worthless.
No. 3	2.44	37.01	49.41	11.14	White	Do.
No. 4	6.45	42.16	48.11	3.28	Brown	Do.

1. Coal from top seam, 6-inch band above slate.
2. Bright coal from middle layer of seam.
3. "Cannel" coal.
4. Bright coal from base of seam.

These analyses show that the coal is of excellent quality. The percentage of moisture is low, there being less than in the Lethbridge (Galt) coals, and but little more than in the Sand Coulée coals. The percentage of ash varies widely in the different layers, but the greatest is not high for a cannel, nor is it as great as that of other fields, while the average for the seam is relatively low. The fixed carbon percentage is the same as that of the best coals of the State.

Giltedge coal mines.—The coal seam near the Giltedge mill has a true southeast strike and dips 20° to the east. It rests on a bright, saffron-yellow rock, like that of Big Spring Creek, and is capped by a coarse-grained, gray sandstone. The seam is opened by an incline, which runs down a few feet and shows 2½ feet of dirty, dull coal, overlain by 4 feet of impure, argillaceous lignite shale. A persistent parting an inch in thickness was noticed 10 inches above the floor. Plant remains were collected here from the shales above the coal.

Warm Spring coal mines.—The coal is also opened in the Warm Spring anticline, where it is 14 inches to 2 feet thick, with 6 inches of bone in the center of the seam. There is a 120-foot drift, with rooms on each side. A little bright coal occurs in each bench.

Maiden Gulch.—At the mouth of Maiden Gulch on either side there are several coal prospects, but the beds are too much tilted and the coal is too much crushed to be successfully worked. Besides, the coal is shaly and full of pyrite.

New Years Gulch.—At the mouth of New Years Gulch the coal seam has also been opened in two or three places, the coal having been used here in running the engine of the New Years mill. The extent of the workings is inconsiderable, but the coal is of excellent quality; it is 29 to 31 inches thick, which is barely enough to warrant working. The bed dips at an angle of 35° to the north, away from the mountains.

THE MINING DISTRICTS OF THE IDAHO BASIN AND THE BOISE RIDGE, IDAHO,

BY

WALDEMAR LINDGREN;

WITH

A REPORT ON THE FOSSIL PLANTS OF THE PAYETTE FORMATION,

BY

FRANK HALL KNOWLTON.

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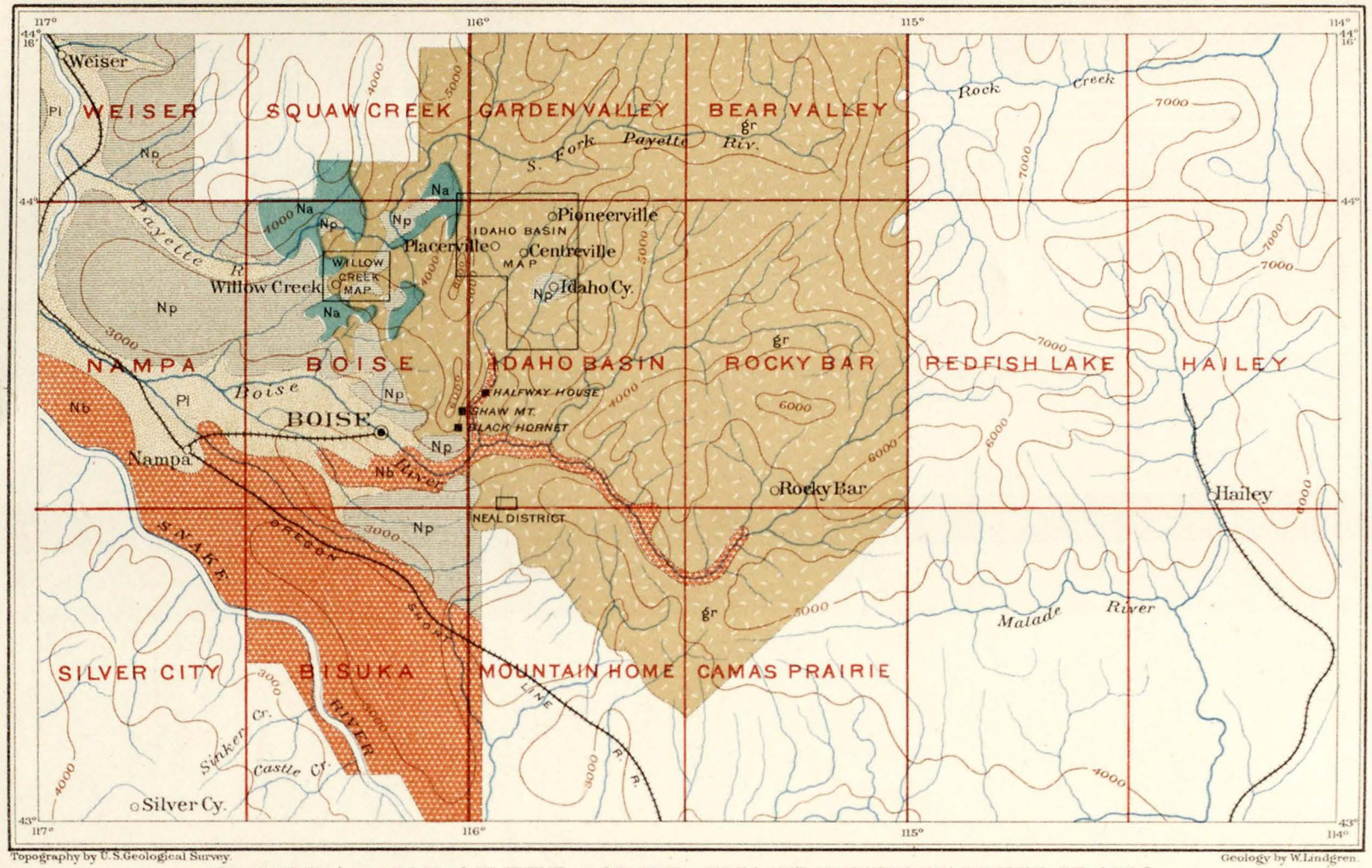


Topography by U.S. Geological Survey. Geology by W. Lindgren.

GENERAL MAP OF THE LOWER SNAKE RIVER VALLEY, IDAHO

Scale of miles

25 0 25 50 75

Contour Interval 1000 feet

LEGEND

PLEISTOCENE

Pl — SANDS & GRAVEL. River terraces.

NEOCENE

Np — PAYETTE FORMATION Sandy Lake beds. Early Neocene

Na — BASALT AND RHYOLITE of the age of the Payette Lake beds.

Nb — BASALT (Late Neocene) with Lake beds of same age

PRE-NEOCENE

gr — GRANITE

THE MINING DISTRICTS OF THE IDAHO BASIN AND THE BOISE RIDGE, IDAHO.[1]

By WALDEMAR LINDGREN.

CHAPTER I.

GENERAL TOPOGRAPHY AND GEOLOGY.

GEOGRAPHICAL POSITION.

The region shown in Pl. LXXXVII includes a portion of the lower Snake River Valley and the mountains adjacent on the northern side. The total area is about 13,500 square miles. It embraces, besides a part of the Snake River, almost the whole drainage of the Payette, Boise, and Wood rivers, and, in the northeastern corner, a part of that of the Salmon River. The irregular mountain complex within the drainage of the Boise and the Payette rivers is designated the "Boise Mountains;" along the parting between these rivers and the Salmon River drainage rise a series of sharp peaks, usually referred to as the "Sawtooth Range." The "Boise Ridge" extends from the Boise to beyond the Payette just west of longitude 116°, and attains elevations of over 7,000 feet. The Idaho Basin is an intermontane valley in the Boise Mountains south of latitude 44° and east of longitude 116°.

The map shows the positions and names of the quadrangles represented by the topographic sheets issued by the United States Geological Survey. It also shows, in a somewhat generalized way, the geology of a part of the area.

SNAKE RIVER VALLEY.

The discussion of the geology of this district necessitates a short reference to the large Snake River Valley and an abstract of previous work relating to its remarkable geological features. The Snake River Valley stretches across the whole width of southern Idaho in a broad curve opening toward the north and having a radius of 160 miles. The length of this valley from the base of the Tetons to Weiser, where the river enters into a narrow canyon, is over 400 miles, while its width

[1] The field work upon which this report is based was done during the summer and fall of 1896 by the author, assisted by Dr. E. C. E. Lord.

ranges from 50 to 125 miles, its total area being about 34,000 square miles. The grade of the river is moderate. At Blackfoot the elevation is 4,505 feet, and 350 miles lower down, at Weiser, it is 2,125 feet, giving an average grade of less than 7 feet per mile between these places. On both sides of this valley rise higher ranges, chiefly of granite in the lower valley, of granite and Paleozoic and Mesozoic rocks in the upper valley. The lower slopes of these ranges are often flanked by Tertiary lake deposits. The larger part of the valley is occupied by vast flows of basalt, frequently resting upon and covered by fluviatile and lacustrine accumulations contemporaneous with the flows. The basalt of the Snake River Valley bears evidence of being throughout of the same age approximately, though consisting of a great number of individual flows, and has generally been regarded as Pliocene. The eruptions did not originate from large volcanoes. Ashes and other fragmentary rocks are generally absent, and the basalt evidently flowed out quietly and without explosions from numerous local vents along the margin of the valley or within the valley itself. This volcanic action is usually referred to as fissure eruption, but it must not be inferred that these fissures were long or large. It appears rather as if the vents had the character of rounded local orifices, hardly extensive enough to be classed as fissures. The basalts often flowed down from the foothills of older rocks, closely following the present canyons, though the streams have since then generally succeeded in wearing through the filling in their bottoms. Thus it is, for instance, along the Boise River.

It will be shown that the Snake River Tertiaries consist of a thick series of early Neocene (Miocene) lake beds, with which are associated vast masses of eruptives distinct from the Snake River basalts proper, and another series of deposits of late Neocene age (Pliocene), consisting of the Snake River basalts and associated sedimentary rocks. These two terranes represent successive stages of the Neocene lake and are often difficult to separate.

LITERATURE.

The upper Snake River Basin has been described by Messrs. Hayden,[1] Bradley,[2] Peale,[3] and St. John,[4] in the reports of the United States Geological and Geographical Survey of the Territories. Hayden describes the basalt flow along the present line of the Utah and Northern Railroad, mentioning that there were several flows of basalt, or at least two, separated by somewhat tilted Pliocene deposits of slight depth. St. John and Peale describe the basalt flows east of this, near the headwaters of the Snake River. Peale states that a number of extinct craters exist, that there were several flows of

[1] U. S. Geol. and Geog. Surv. Terr., Rept. 1871, pp. 25-30.
[2] Ibid., Rept. 1872, p. 190.
[3] Ibid., Rept. 1877, p. 543.
[4] Ibid., Rept. 1877, p. 323.

basalt, and that the basalts are generally horizontal in position and fill the valleys and the more depressed portions of the basins. There appear to have been two periods of basaltic flows, one at the close of the Pliocene, the other at the beginning of the Pleistocene. The Pleistocene age is inferred from exposures at Marsh Valley, near Red Rock Pass, where Pleistocene beds were somewhat eroded before the basaltic flow.

According to Gilbert, however, this Pleistocene is older than the highest stage of Lake Bonneville, during which the lake found an outlet at Red Rock Pass. The river draining the lake at this time appears to have flowed over the surface of the basalt.

According to Hague,[1] the latest eruptions in the Yellowstone National Park are of basalts, which stretch far into Idaho in somber, monotonous beds. These basalts are pre-Glacial, and their eruption is referred to the Pliocene.

About 1869 Mr. Clarence King visited the lower part of the Snake River basin and collected a number of fossils from beds beneath the basalt at Castle and Sinker creeks, tributaries from the south, joining the river about due south of Boise. The fossils have been described in detail, while no description of the localities was ever published, a fact which has led to some confusion. A few notes regarding this occurrence are contained in King's Systematic Geology[2] and may be quoted:

> In the basin of Snake River . . . there were basaltic eruptions in the middle of the Pliocene period which overflowed the earlier lacustrine beds of the period, and in turn were themselves overlaid . . . by the main, later Pliocene series. . . . Sections obtained along the plains between the Owyhee Mountains and Snake River show that a considerable portion of the beds of the valley, which consist chiefly of white sands and marls carrying numerous well-defined Pliocene forms, were overlaid by large accumulations of basaltic flow, and that subsequently a second period of lacustrine deposition took place, likewise characterized by Pliocene forms, the latter representing a more advanced stage of development and more recent type than those beneath the basalt.

King further states that near Shoshone Falls the basalt rests on the eroded surface of a trachytic soft rock which he considers of pre-Miocene age.[3] From the collections of King and the later collections of Wortman, Cope has described an extensive fauna of fresh-water fishes, and proposed for the sediments in which these are contained the name *Idaho formation.*[4]

The locations given are very vague, as "Catherine Creek," "Castle Creek," or "Southern Idaho," and no description of the beds is vouchsafed. The fauna consists of 22 species, all differing from existing species so far as known. Professor Cope thinks that the

[1] Am. Jour. Sci., 4th series, June, 1896, Vol. I, p. 455.
[2] U. S. Geol. Expl. Fortieth Par., Vol. I, 1878, pp. 418, 440.
[3] Ibid., p. 593.
[4] Proc. Phila. Acad. Sci., 1883, pp. 153-166.

evidence clearly indicates a Pliocene age. From the same beds were obtained three species of crawfishes specifically distinct from all others described from the West. Mammalian remains were also collected by King from similar beds on Sinker Creek, which were determined by Leidy to be *Mastodon mirificus* and *Equus excelsus*, both of which belong to the Niobrara Pliocene fauna. A few mollusks have also been found in the same deposits on Sinker Creek. Thus Meek[1] described *Sphaerium* (?) *idahoense* Meek from Castle Creek, collected by King. Gabb[2] described two species, *Melania taylori* Gabb and *Lithasia antiqua* from a "Deposit on Snake River on the road from Boise to the Owyhee mining country;" thus probably from Walters Ferry. The same forms have been found, according to Mr. George H. Eldridge, at Glenns Ferry, 120 miles above Walkers Ferry. Dr. White describes the same two species and another, *Latia dallii*, from a point 50 miles below Salmon Falls, Snake River, which probably refers to Glenns Ferry, and states that these forms differ considerably from any known fresh-water fauna of America either fossil or living.[3] Both Meek and White are in favor of correlating these Tertiary beds with King's Truckee Miocene. To this the utterances of King are directly opposed, and it is, indeed, from stratigraphic grounds, improbable that these beds are of Miocene age. Near Glenns Ferry beds of sand and clay occur intercalated between the basalt flows, and it is probable that the fossils came from this locality and that all of them were collected in beds very closely associated with the late basaltic eruptions, from which it would follow that they should be placed in the latest Pliocene.

Prof. O. C. Marsh states (oral communication, January, 1897) that a large amount of Pliocene mammalian remains was found in a bluff about 100 feet above the Snake River, some distance below Weiser, at the old crossing of the stage road to Oregon, on the Oregon side of the river.

None of these localities were visited during the field season of 1896 on account of pressing economical and areal work in other sections; but from the area studied it was possible to read in its chief features the later geologic history of the lower part of the Snake River basin. The correlation of these results with the older work remains for the future.

TOPOGRAPHY.

The chief topographic features of the region, of which the geology is shown on Pl. LXXXVII, are as follows:

Broad flat mesas of basalt and Pliocene lake beds spread on both sides of Snake River, though chiefly on the northern side. Through these mesas the river has cut an abrupt canyon, bordered by basaltic

[1] Proc. Phila. Acad. Nat. Sci. 1870, p. 57.
[2] Paleontology of Cal., Vol. II, p. 13.
[3] Proc. U. S. Nat. Mus. 1882, Vol. V, p. 99.

cliffs, to a depth of from 200 to 700 feet. The low mesas, surmounted by several buckles or domes of basalt a few hundred feet high, rise gradually toward the edge of the mountain. Near the mouth of the Boise River the basalt mesas cease, and from here down to Weiser, where the great Snake River canyon begins, several large tributaries enter, such as the Payette and the Owyhee, and, at elevations of from 2,200 to 2,700 feet, level bottom lands and broad low terraces flank the water courses.

Between the mouth of the Boise and Weiser flat-topped hills of soft sandstones rise on both sides of the Snake River to a height of 600 to 800 feet. Similar complexes of high sandy mesas rise between the lower courses of the Boise and the Payette and north of the Payette. The mountains of older rocks surrounding the tectonic trough of the Snake River Valley rise gradually, on the north side of the river, beyond the sloping mesas of Tertiary rocks, their margin having a northwesterly direction in this vicinity. The transition between mountains and mesa is abrupt only at the Boise River, near Boise, and the abruptness is here due to the extensive erosion of the Payette sandstones by the river.

The mountain region extending up to the Sawtooth Range, dividing with a north-northwesterly trend the waters of the Boise and the southern branches of the Payette from those of the Salmon, has an average width of 55 miles and culminates in summits with an elevation of from 10,000 to 11,000 feet. This mountain complex, which is made up chiefly of granitic rocks, does not form a well-defined range, but rather a broad uplift dissected deeply and in the most intricate manner by the forks of the Boise and the Payette. The summits of the narrow ridges generally form gently sloping lines. If a surface were constructed containing all these lines it would be of undulating, curved character, sloping gently from elevations of 9,000 down to 4,000 feet. From the southwestern edge a steeper slope carries the granitic rocks below the surface of the Tertiary rocks of the Snake River Valley. The canyons of the Boise and the Payette have cut down in the uplift to a maximum depth of 3,000 feet, and are joined by deep lateral canyons, dividing the whole region into a maze of narrow arêtes. The grade of the main rivers is relatively low, from 10 feet up to 50 feet per mile, and only well up toward the head waters are grades of 100 feet per mile attained. The grades of the lateral canyons are also often relatively slight in their lower course, but extremely steep cirques rise near their head waters. The Idaho Basin quadrangle offers excellent illustrations of these relations, which are the result partly of a considerable antiquity of the drainage, partly of the crumbling character of the granite. At the main divide (Bear Valley quadrangle) the broad valleys and gentler slopes of the Salmon River drainage contrast strongly with the deeply incised canyons of the Boise and Payette. The latter streams are continually capturing territory

belonging to the former, and the divide is in process of migration northeastward. The whole region may be regarded as an uplifted sloping plateau deeply dissected by a drainage system, whose origin evidently antedates the Miocene period. Smaller individual ranges occur in a few places, as in the Boise Ridge, rising to elevations of 7,500 feet and extending due north, dividing the Idaho Basin from the waters of the Payette. This range also crosses the South Fork of the Payette and continues for some distance north of it. Within this mass of mountains several depressions or basins with gentler slopes also exist, such as the Idaho Basin, the Deadwood Basin, and Smiths Prairie, which have been created or emphasized by more recent orographic movements. Evidences of glacial topography occur only near the Sawtooth and Trinity mountains.[1] The lower area here specially described has never been covered by ice.

GEOLOGICAL HISTORY.

The vicinity of Boise River, where it debouches from the mountains, proved to be an exceptionally fortunate location for the study of the geological history of this part of the Snake River drainage, for the record left by the river of successive geological events back to a certain date is remarkably clear and easy to read.

PRE-TERTIARY.

The oldest rock exposed is the granite of the Boise Mountains. This forms an extremely large area, embracing, so far as known, the whole of the upper drainage of the Boise and Payette rivers and extending northeastward beyond the Sawtooth Mountains and eastward as far as Wood River, where it is adjoined by sedimentary rocks of probably Carboniferous age.[2] This rock is largely a typical, coarse granite of gray or yellowish-gray color, consisting of orthoclase in often large crystals, plagioclase, quartz, biotite, and sometimes muscovite. Pegmatite dikes are common in many places. Locally the granite contains hornblende, and is by gradual transition connected with intermediate rocks standing between granite and diorite, and also, though more rarely, with diorites. Narrow dikes of light-colored granite-porphyry and dark lamprophyric dike rocks, chiefly minettes, are abundant and present a great variety of structural types. A belt characterized by dikes of coarse quartz-diorite, porphyrites, and occasional occurrences of gabbro and diabase extends, with one short interruption, from the vicinity of Wilson Peak, east of the Idaho Basin, by Quartzburg, to the Willow Creek mining district. All of these dikes are probably connected with the granite eruption—that is, they were intruded shortly after the consolidation of the granite. Within the area described the granite is remarkably unaltered and massive, no

[1] George H. Eldridge, Sixteenth Ann. Rept. U. S. Geol. Survey, Part II, 1895, p. 223.
[2] George H. Eldridge, loc. cit.

bodies of schist appearing in connection with it. It weathers easily and crumbles to a coarse sand which largely covers the hillsides. Only in the higher mountains and along the bottom of the canyons are satisfactory exposures found. The age of this granite, which is clearly of igneous and intrusive origin, is an open question. Messrs. Becker[1] and Eldridge[2] assign to it provisionally an Archean age, but a thorough study of its contact with surrounding formations is necessary before its age can be determined. The granite is in many places traversed by shear planes, giving it a jointed or sheeted structure, and often these planes coincide with the direction of the fissures on which mineral veins occur. It is probable that these two features are of the same and contemporaneous origin. Nearly all of the primary mineral deposits are contained in the granite or allied porphyries. By far most of them have a direction ranging from E.-W. to ENE.-WSW., and dip to the south at angles from 40° to 85° from the horizontal. While it is probable that all of them belong to the same period of formation, there are few definite clews to their age. It is likely, however, that they are post-Carboniferous, and it is certain that they antedate the Miocene lake deposits. A Cretaceous or early Tertiary age may provisionally be assigned to them. The mode of their occurrence indicates beyond doubt an origin by deposition from mineral waters, probably ascending hot springs. A slight recurrence of the vein-forming activity occurred after the Neocene period.

Before the beginning of the Neocene the chief features of the topography were outlined—the broad uplift of the Boise Mountains and the depression of Snake River Valley. The latter is not unlikely a sunken area separated by old fault lines from the mountains to the north. At that time the basalt flows and the lake beds did not exist, but the drainage of the Boise, and probably also of the upper Payette River, was outlined in practically its present form. The granitic range presented a bold scarp facing the valley, and the canyon of the Boise River was, at its debouchure from the mountains, cut to practically the same depth which it has at present. It had not, of course, cut back so far toward the Sawtooth Range as at present, and many features of the drainage, notably in the Idaho Basin, were different from those existing now. As substantiating this it will be shown that the Miocene lake beds fill the old canyon at the gate of the mountains, 10 miles southeast of Boise, and that in front of it lie enormous masses of coarse Neocene gravel and conglomerate. Thus the time immediately preceding that from which the first records date was one, first, of uplift and subsidence, during which the rough features were blocked out, and second, one of long-continued erosion, during which the Boise Mountains were dissected and the débris from the excavated canyons deposited in the basin of the Snake River Valley, where it is

[1] Tenth Census, Precious Metals, p. 54.
[2] Loc. cit.

now deeply covered below later formations. If we should venture tentatively to go back one step further, it might be suggested that the uplifted surface of the Boise Mountains is probably the result of a far older erosion, of early Tertiary or Cretaceous age, which planed down a more ancient range to gentler outlines, or to a peneplain.

THE PAYETTE FORMATION.

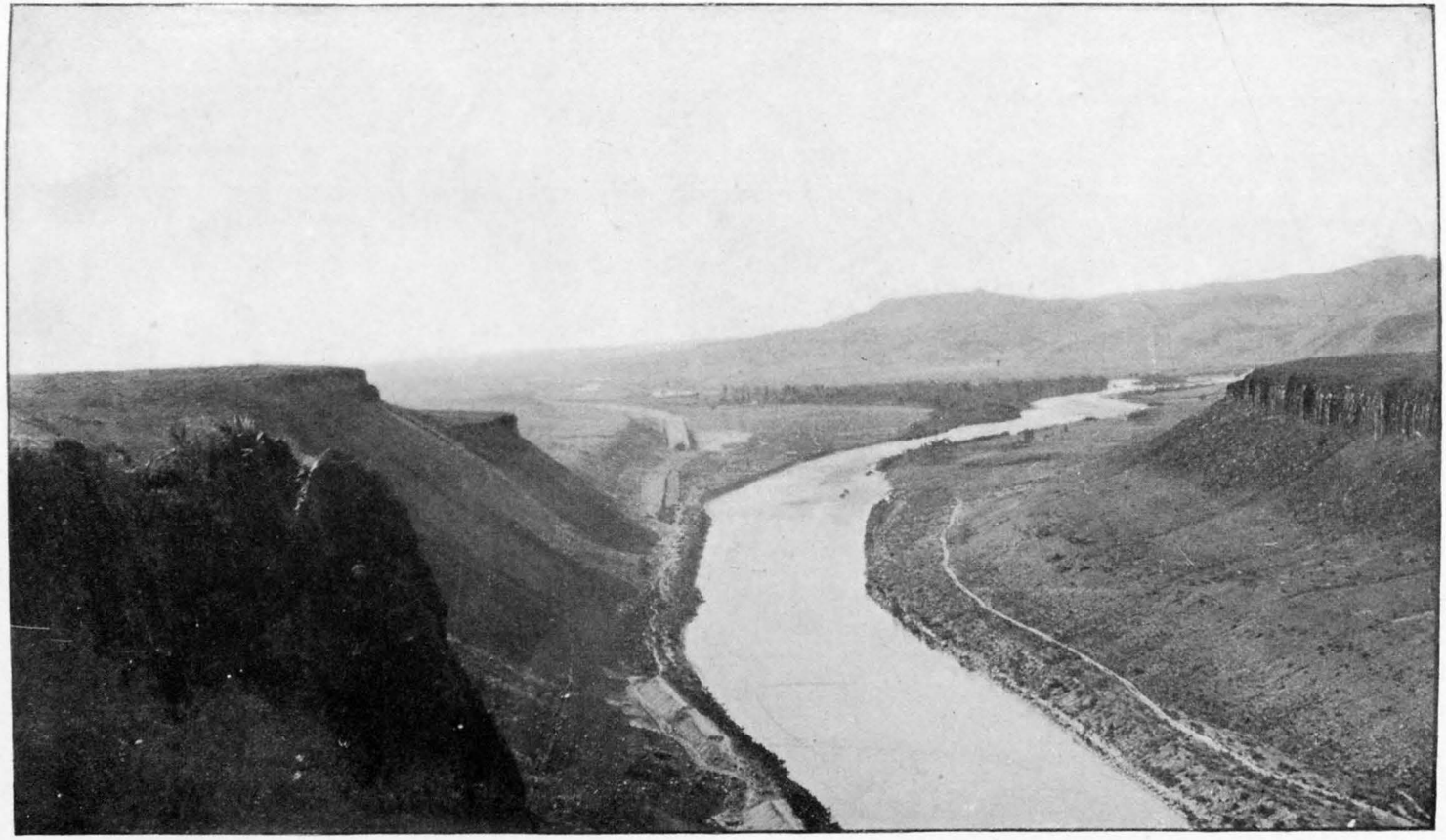
During the earlier part of the Neocene (Miocene) a large fresh-water lake occupied at least the lower part of the Snake River Valley, and its sediments are now prominent features of the region. For these lake beds the name Payette formation is proposed, and their age is determined as upper Miocene. This formation is probably not the same as Cope's Idaho formation, to which a Pliocene age was assigned and which appears to be connected with the later basalt flows.[1]

The extent of the formation is shown in Pl. LXXXVII, from which it is seen that it lies in front of the Boise Mountains and occupies the whole lower part of the ridge between the Boise and the Payette. It extends over large areas to the north of the Payette, along the flood plains of the Snake River, and is seen to occupy vast areas in Oregon between the mouth of the Owyhee River and Weiser, where the Snake River Canyon begins. On both sides of the lower Snake River the bluffs of the Payette formation attain a height of over 800 feet. In the Payette Valley south of Emmett the sharply defined bluff of Payette beds rises 600 feet above the alluvium. Smaller masses, detached by erosion or uplifts, lie in the intermontane valleys as far east as the Idaho Basin.

Along the Boise Mountains the Payette beds rest against the irregularly eroded and sharply sloping surface of the granite, and the top stratum attains a height of 4,100 feet. A total thickness of 1,000 feet is exposed near Boise, and wells bored show several hundred feet of similar strata below the surface. Over the larger part of its extent the formation lies nearly horizontal or dips only a few degrees. Near the mountains dips of 8° to 10°, generally westward, are noted, and the smaller detached masses in the intermontane valleys are still more disturbed, generally dipping westward at angles up to 50°. This is particularly marked in the long arm of sediments of the Payette formation filling the valleys of Horseshoe Bend and Jerusalem, on the Payette.

As might be expected from the character of the land mass from which the sediments were obtained, the latter consist chiefly of granitic, light-colored sands, locally cemented by hot-spring deposits to hard

[1] From the results of more extended surveys during the summer of 1897, it has become evident that the Payette and Idaho formations represent two successive stages of the lake, the often deformed shore-line of the former being found at elevations of from 4,200 to 5,000 feet, and those of the latter at a maximum elevation of 3,000 feet. To separate the deposits of the two formations is not always easy.



HEAD OF BOISE VALLEY, 8 MILES SOUTHEAST OF BOISE, LOOKING NORTHWEST, SHOWING BASALT TABLE AND PLEISTOCENE TERRACES.

sandstones (as at Table Mountain near Boise; see Pl. LXXXVIII) or clayey semiconsolidated sandstones. Heavy masses of conglomerates and gravels begin to appear at Table Mountain, and reach their greatest development opposite the mouth of Boise River, in the high ridge extending in a westerly direction. Purely clayey deposits are rarer, occurring only in convenient sheltered locations near the shore line or in places where volcanic eruptions took place. The basal part of the formation contains, at Horseshoe Bend, Jerusalem, and other localities along the Payette, small coal seams. In the clay accompanying these coal seams vegetable remains are of frequent occurrence. The following forms were identified by Professor Knowlton:

Two miles southeast of Marsh post-office, on the Payette, is a small coal prospect. The disturbed beds of the Payette formation lie here on a sharply sloping surface of granite. At this place the following forms were found, together with many new species:

Sequoia angustifolia ? Lx.
Quercus consimilis Newb.
Acer trilobatum productum ? Heer.

One mile southeast of Marsh, along the road to Willow Creek, a few hundred feet above the river, is an outcrop of yellowish-gray "chalk," or diatomaceous earth, intercalated in the Payette beds and capped by basalt. In this the following forms were found, in an excellent state of preservation:

Salix angusta Al. Br.
Quercus consimilis Newb.
Q. simplex Newby.
Platanus aspira ? Newb.

From Cartwright's ranch, on Shafer Creek, 4 miles southeast of Horseshoe Bend post-office, the following forms were identified, together with several new species. This is an excellent locality, and the leaves embedded in a dark clay shale are beautifully preserved.

Sequoia angustifolia Lx.
Salix angusta Al. Br.
Ficus ungeri Lx.

This area is separated from the main one by a small ridge of granite, but that the two formations are identical admits of no doubt. The beds are here disturbed, dipping west at 20° to 25°. The plants were obtained near the base of the series, of which about 800 feet of alternating, fairly consolidated shale and sandstone are exposed. The elevation is 3,500 feet.

Near Idaho City another detached mass of lake beds is preserved at an elevation of from 4,000 to 4,500 feet, the occurrence of which is described more in detail in Chapter III. From the middle of a series 800 feet thick the following plants were obtained:

Sequoia angustifolia Lx.
Ulmus speciosa Newberry.
Betula angustifolia Newberry.

From these data Professor Knowlton draws the conclusion that the age is Upper Miocene, contemporaneous with the flora of the auriferous gravels and the Ione formation of California, the Lamar flora of the Yellowstone National Park, and the John Day formation of Oregon. The paleobotanical evidence confirms the conclusion, confidently drawn from the field work, that all these smaller detached masses of lake beds are of practically the same age.

During the time of the maximum extension of the Payette Lake its surface stood at the present elevation of 4,200 feet. Its deposits, over 1,000 feet thick near the shore, rested against the abrupt slope of the Boise Mountains, and filled the old canyon of the Boise to the same depth. The canyon must have formed a fiord, the branches of which reached as far back as the Idaho Basin, and in which vast quantities of gravel and sand accumulated. Isolated occurrences of well-washed gravel on the summit of high ridges in the lower Moore Creek drainage, at elevations of 4,500 feet, confirm the above conclusions. The data are not at present sufficient to determine the extent of the Payette Lake, though it is probable that it was confined to the Snake River Valley, inclosed on the west by the Blue Mountains and on the east by the divide toward the Salmon River.

EARLY NEOCENE VOLCANIC ACTIVITY.

Near the base of the Payette formation sheets of rhyolite and rhyolite-tuff occur, but this eruption was of limited extent. The best exposures are found near Boise and in the Willow Creek mining district. After the rhyolitic eruptions there occurred enormous outpourings of basaltic lavas, distinctly different from and earlier than the Snake River basalts. The rocks are in part normal basalts, but have usually a somewhat andesitic habit. In large areas the outcrops generally have a reddish-brown color, distinct from the somber black of the later flows. These early Neocene eruptives are to some extent represented near Boise, but become more abundant northward. Many exposures are seen along the lower Payette from Marsh post-office to Horseshoe Bend and Jerusalem Valley, and the conspicuous sharp ridge of Squaw Butte, rising just north of the Payette above the lake beds to an elevation of 5,800 feet, is composed entirely of these older effusive rocks. Squaw Butte is well visible from the railroad near Nampa and Caldwell as a rugged, reddish-brown peak, contrasting with the white lake beds. The evidence shows that these flows were contemporaneous with the deposition of the Payette beds, and are underlain and covered by sandstones. In some places they break through the lower lake beds and metamorphose them. The vents were located chiefly along the margin of the old lake. At Jerusalem (see Pl. LXXXIX) and in Squaw Butte the whole volcanic series—in the latter place consisting of countless flows, attaining a thickness of several thousand feet—has been disturbed and uplifted, and now

dips to the west at angles ranging from 10° to 35°, the monoclinal uplifts vividly recalling those in eastern Washington described by Professor Russell.[1] There, however, the Miocene beds lie only on top of the volcanic flows of the Columbia formation, while here they lie both below and above similar igneous masses.

On both sides of the Snake River, from Caldwell to Weiser (near the upper edge of the map, Pl. LXXXVII), the beds do not contain much evidence of volcanic activity, though from Parma a few volcanic buttes are visible from the railroad, far to the west, among the lake beds in Oregon. But a few miles beyond Weiser the white bluffs of lake beds begin to assume red or orange colors, and contain streaks of intercalated tuffs. The valley contracts, and at the entrance of the canyon basaltic rocks appear, partly interstratified with the lake beds, partly underlying them. Near Huntington the deep and narrow canyon is composed entirely of basic volcanic rocks, clearly connected with the early Neocene lake beds, and assuredly different from the later basalts from the upper valley. How far down this volcanic canyon extends is not known.

POST-PAYETTE EROSION.

After attaining its highest stage, the lake was drained by the establishing of the present course of the Snake River below Weiser. The lake receded as the canyon was rapidly cut by the mighty volume of water, and erosion has steadily proceeded since the end of the Miocene or the beginning of the Pliocene. The broad valleys of the Boise, the Payette, and the lower Snake were eroded in the soft lake beds. A new course was established for the Payette River, which evidently did not debouch at its present position before the Payette epoch. The Boise River, on the contrary, maintained its old course. The accumulated gravels were scoured out from its canyon, and, before the Pliocene basaltic eruptions, its channel in the canyon was deepened nearly to its present level. There was, however, at least one temporary check in this process of draining. For a considerable interval of time the lake remained stationary, at a present elevation of from 2,800 to 3,000 feet. The deposits and basalt flows of this epoch are regarded as late Neocene (Pliocene) and belong to the Idaho formation of Cope.

POST-PAYETTE OROGRAPHIC DISTURBANCES.

Before the epoch of the Pliocene basalt flows the sediments and flows of the Payette formation were subject to some disturbances, reaching their maximum in the smaller areas in the intermontane valleys. Certain parts of the series acquired a slight westerly dip. More intense orographic movements took place at Squaw Butte and in the Horseshoe Bend and Jerusalem valleys, resulting in monoclinal

[1] Bull. U. S. Geol. Survey No. 108, 1893, p. 28.

uplifts, the detailed character of which will be discussed in the text accompanying the Boise folio of the Geologic Atlas of the United States. Important movements also took place along the Boise Ridge, which separates the Idaho Basin from the Payette River, and it is probable that it has undergone an extensive uplift. Over the larger part of the area no orographic movements have affected the beds.

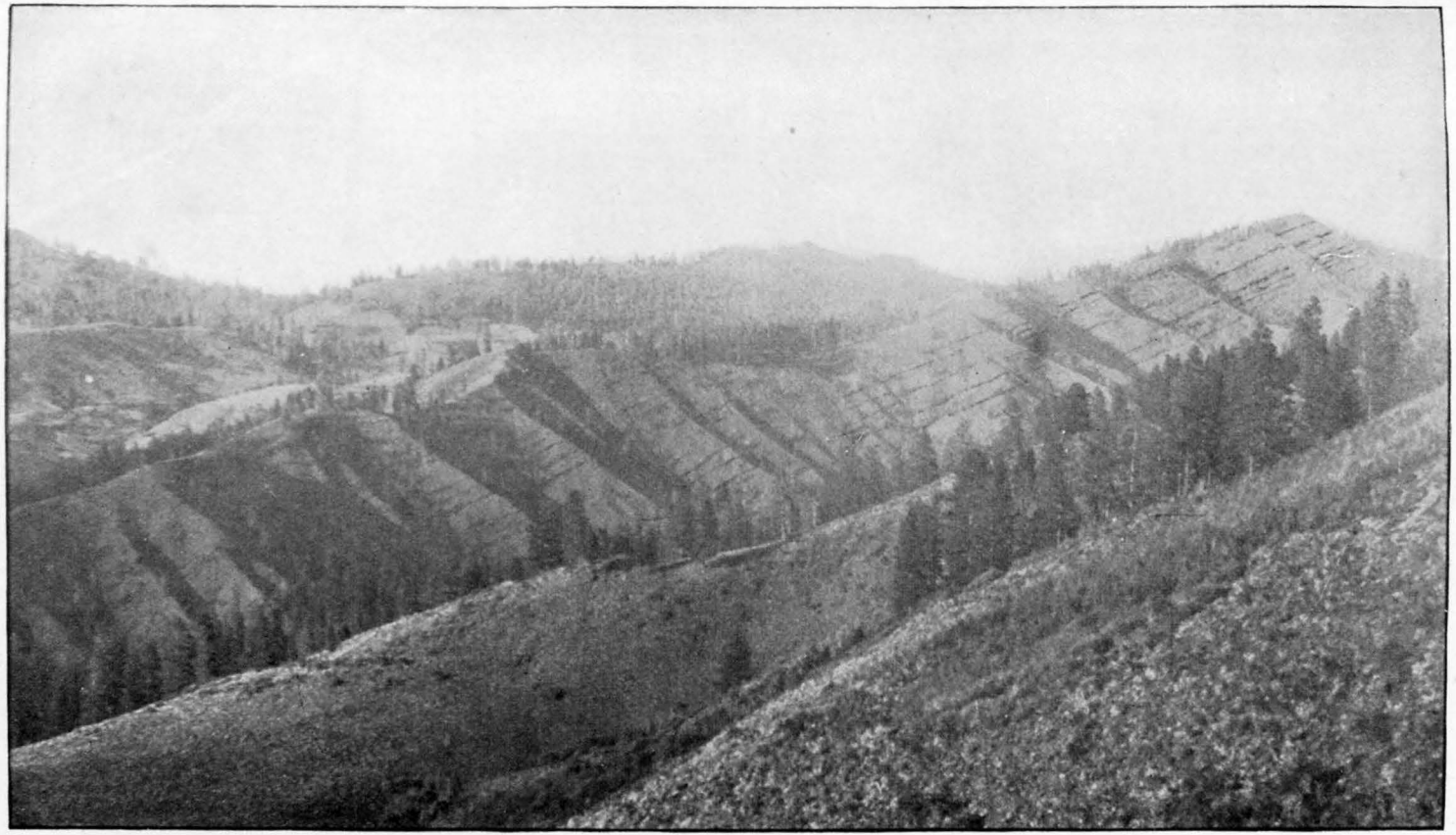
LATE NEOCENE BASALTS.

When the lake had been partly drained, vast basaltic eruptions began, and in time, intercalated with lake beds, filled the whole of the upper Snake River Valley from the base of the Tetons, near the Wyoming line, to a point near the confluence of the Boise and the Snake. Between this point and Weiser no basalts are seen. The basalt flows lie horizontal, filling the plains and the modern canyons. They are also distinguished by their fresh character, black color, and columnar structure. The aggregate thickness probably never exceeds 1,000 feet, and is ordinarily much less, individual flows being rarely over 100 feet thick.

As already indicated, the basalts were erupted from a great number of inconspicuous craters, both in the plains and in the adjoining mountains. Their fluidity was remarkable, continuous flows of 50 miles or more being noted. Where the Boise River emerges from the mountains the exposures are exceptionally good. There are three or four flows, the principal ones coming down from the South Fork of the Boise. The deepest flow of comparatively small volume is probably the oldest, and lies but a few feet above the present bed of the river. Deep river gravels accumulated on this flow, and, soon afterward, two later flows came down the Boise River and filled the canyon near the mouth to a depth of 300 feet. Beyond the mouth the basalt spreads out, and its surface rapidly sinks westward. Still another basalt flow, about 75 feet thick, came down from Moore Creek and joined the large ones at the mouth of the main river. Above the source of this basalt the damming resulted in terraces and bench gravels now lining the upper valleys of Moore Creek and Grimes Creek, described in Chapter III.

POST-BASALTIC EROSION.

If the epoch of the basaltic flows be placed at the very close of the Neocene, the events that have taken place since then must be referred to the Pleistocene. Among these are the erosion of the canyons of Snake River and its tributaries to a depth of from 200 to 700 feet and the deposition of extensive flood plains and terraces along the lower Snake, Boise, and Payette. The Boise River has, in Pleistocene times, cut through the 300 feet of basalt accumulated at the mouth of its canyon, and thus laboriously regained the same stage it occupied before the beginning of the Payette epoch. The direction of the channel has gradually changed. During the Payette epoch it had a nearly



UPPER CANYON OF BRAINARD CREEK, JERUSALEM VALLEY, BOISE RIDGE, SHOWING TILTED BASALT FLOWS RESTING ON GRANITE.

westerly trend, while subsequent events have more and more forced it in a northwesterly direction. Pl. LXXXVIII illustrates well the present condition at the mouth of the canyon—the basalt flow cut in two and the two Pleistocene flood plains in the widening valley of the river. Pliocene gravel older than the flood plains underlies the basalt. In the right background the Miocene sandstones of Table Mountain are shown, while the background at the extreme right shows the first granitic hills of the Boise Ridge.

Having thus traced the cycle of events which have taken place in this region since the beginning of the Neocene, it may be well to rapidly review the main points in the history.

RÉSUMÉ OF GEOLOGICAL EVENTS IN THE LOWER SNAKE RIVER BASIN.

Pre-Neocene	The depression of the Snake River Valley outlined by orographic movements.
Pre-Neocene or early Neocene (Miocene).	Long-continued erosion, dissecting the Boise Mountains. Boise Canyon eroded to its present depth at its mouth.
Early Neocene (Miocene), possibly extending over into late Neocene.	Large fresh-water lake occupying Snake River Valley. Deposition of the Payette formation at least 1,200 feet thick. Highest level reached, 4,200 feet above present sea level. Eruptions of rhyolite and andesitic basalts, contemporaneous with the sedimentation.
Late Neocene (Pliocene)	Orographic disturbances of the Payette formation. Partial drainage of the lake and epoch of erosion excavating the valleys of the Snake, Boise, and Payette from the Payette lake-beds. Basalt flows, filling the Snake River plains and the Boise Canyon. Deposition of lacustrine sediments between the flows. (Idaho formation.) Complete draining of lake.
Pleistocene	Erosion of the Snake River basalt canyon above the confluence with the Boise; Boise River cuts down through the basalt to its present depth. Terraces, up to 100 feet above the river, and present flood plains along the Lower Snake, Boise, and Payette rivers.

CHAPTER II.

THE ORE DEPOSITS IN GENERAL.

GENERAL FEATURES.

Throughout the Boise Ridge and the Idaho Basin the primary gold deposits present a certain similarity. They are all contained in granitic rocks or associated dikes. They are all either fissure veins or impregnations connected with fissures. Nearly all of these fissures have a direction ranging from east-west to northeast-southwest, the chief exceptions to this rule being found in the Black Hornet district. The dip is ordinarily to the south at angles of from 45° to 89°, but in the Willow Creek and Rock Creek districts similar dips to the north are found. The prevailing direction of the fissures is the same as that of an often well-developed system of joint planes commonly seen in the Boise Ridge. Finally, the ores are, on the whole, of a similar character, consisting chiefly of auriferous pyrite, arsenopyrite, zinc-blende, and galena in a gangue of quartz or, more rarely, calcite. The fresh ores from deeper levels contain a variable percentage of free gold. Rarely, however, is more than 60 per cent of the total value caught on the amalgamating plates. Gold predominates largely in the value of the ore, though seldom by weight, for in the ordinary ores the weight of the silver considerably exceeds that of the gold. The alteration of the country rock in the vicinity of the veins is throughout of the same character.

ALTERATION OF THE COUNTRY ROCK.

A marked change appears in the rock in the vicinity of the veins. The dark constituents, biotite and hornblende, are bleached or disappear, and the feldspar is altered to a soft, white, opaque material, only the quartz remaining unaltered. Besides abundant iron pyrite, arsenopyrite also appears in small, scattered, perfect crystals. The width of the altered zone may be from a foot up to 50 or 60 feet. This alteration of the country rock has been noted by Messrs. George H. Eldridge,[1] J. B. Hastings,[2] and F. D. Howe, but has ordinarily been described as kaolinization. The soft, white substance, which often has a greasy feel, is also referred to by the miners as "talc." This change in appearance and composition is without the slightest

[1] Sixteenth Ann. Rep. U. S. Geol. Survey, Part II, 1895, pp. 225, 252.
[2] Idaho Mining News, Vol. L, No. 1, p. 15.

doubt directly due to the chemical action of the solutions from which the mineral content of the vein was deposited. The process consists in a sericitization, or replacement of the ferromagnesian silicates, feldspar, partly also the quartz, by sericite, a fine-fibrous or felted variety of white mica. In composition it is a hydrous silicate of aluminium and potassium, probably identical with muscovite. In many places a carbonatization, or replacement by carbonate of lime and magnesia, goes on at the same time, and sulphides, chiefly pyrite and arsenopyrite, rarely other minerals, are usually also formed in the rock as minute and perfect crystals. It is certain that this metasomatic process is a common one in fissure veins,[1] and its chemical character is very different from kaolinization. Kaolin, in fact, is a product not ordinarily found on the mineral veins, and talc occurs still more rarely.

This altered granite, together with the ore and gangue occurring in seams or veins through it, constitutes what miners term a "ledge" and "ledge matter." This may be many feet wide, and the paying ore may, and in fact does usually, form only a small portion in width of the ledge matter. The altered country rock, though often well filled with pyrite and arsenopyrite, is ordinarily very poor, containing at most one or two dollars in gold. Exceptionally it contains enough gold to be considered an ore, but generally only when adjoining rich vein filling and large ore shoots; even then it constitutes only second-class ore, and its sulphides are much poorer than those in the vein proper. It rarely contains any free gold. As examples a few typical rocks of this kind may be described.

The altered dioritic granite from the Checkmate mine, Willow Creek (88 Boise sheet collection), is a granular, white, soft rock, consisting of quartz grains, white earthy grains replacing the feldspar, a few foils of pale-yellowish mica and abundant small and perfect crystals of pyrite, showing the combination $\infty 0 \infty$, $\infty 0 2$, and a few small prisms of arsenopyrite. A few narrow seams, 1^{mm} wide, traverse the rock and carry only blende and galena. The microscope shows quartz grains with undulous extinction, which contain in places a few shreds of sericite, but are on the whole hardly attacked by any metasomatic process. There are a few larger muscovite foils, which evidently represent the biotite of the fresh rock. The space between the quartz grains is filled by a fine-felted sericite mass, which incloses nearly all of the idiomorphic pyrite. Intergrown with and inclosed by the pyrite is a little brown zinc blende and galena in small anhedral grains; one crystal of arsenopyrite was also noted. No calcite was found. This rock occurs close to a rich ore body, but an assay of it gave only 0.1 ounce of gold and 0.5 ounce of silver per ton. The total replacement

[1] For studies of the metasomatic processes of fissure veins by the author, see Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, pp. 243-284, and Seventeenth Ann. Rept. U. S. Geol. Survey, Part II, p. 144; also Bull. Geol. Soc. Am., Vol. VI, p. 221.

of the feldspars and ferromagnesian silicates and the immunity of the quartz is noteworthy.

From the Silver Wreath tunnel, Willow Creek district, Boise County, two rocks were collected, analyses of which are given below. The first is a perfectly fresh granitic rock, the ordinary country rock of the district. The second, occurring only a few feet away, is the same granite altered by the vein-forming agencies, and a comparison between the two will show the character of the process. Both rocks are unaffected by atmospheric agencies.

Analyses of rocks from Silver Wreath tunnel.

[Analyst, George Steiger.]

	I.	II.
SiO_2	65.23	66.66
TiO_2	.66	.49
Al_2O_3	16.94	14.26
Fe_2O_3	1.60	.67
FeO	1.91	2.41
MnO	trace	trace
CaO	3.85	3.37
BaO	.19	none
MgO	1.31	.95
K_2O	3.02	4.19
Na_2O	3.57	none
H_2O below 100°	.18	.36
H_2O above 100°	.88	2.16
P_2O_5	.19	.17
SO_3	none	none
S	none	.95
CO_2	.25	3.67
	99.78	100.31
Less O		.24
		100.07

I. 79 Boise collection; fresh granitic rock.
II. 80 Boise collection; altered granitic rock.

The unaltered rock is light gray and coarse grained, the average size of the constituents being 5^{mm} to 6^{mm}. With the naked eye, white plagioclase, reddish orthoclase, biotite, titanite, and quartz may be distinguished. Under the microscope the quartz proves to be very abundant and is slightly crushed. The plagioclastic feldspars predominate and occur generally in anhedrons, more rarely in roughly prismatic forms. Symmetric extinctions show a maximum of 10°. A

little orthoclase lies between the plagioclase grains. The biotite occurs in small foils of brownish yellow color. Magnetite occurs sparingly. Titanite is much more abundant, occurring in large crystals or anhedrons, sometimes wedge-shaped. It includes small feldspar grains, but its crystals also project into larger feldspar grains. The structure of the rock is eugranitic.

An approximate calculation of the analysis of the fresh rock (I) may be made in the following manner: On the basis of a preliminary calculation and estimate there is about 15 per cent of biotite present. For this 1.20 per cent potassa was subtracted. The baryta is calculated as hyalophane, which necessitates a deduction of 0.12 per cent more of potassa. The remainder is calculated as orthoclase. The lime needed for calcite, titanite, and apatite is subtracted from the total lime. The amount of magnetite is estimated. Finally biotite and quartz remain. From the amounts of the bases in this remainder it is estimated that there is 25 per cent free quartz present.

SiO_2	6.51	
Al_2O_3	1.85	
K_2O	1.70	
$KAlSi_3O_8$		10.06
SiO_2	20.78	
Al_2O_3	5.90	
Na_2O	3.57	
$NaAlSi_3O_8$		30.25
SiO_2	6.00	
Al_2O_3	5.09	
CaO	2.79	
$CaAl_2Si_2O_8$		13.88
SiO_2	.59	
Al_2O_3	.25	
BaO	.19	
K_2O	.12	
$Ba\ Al_2Si_2O_8\ 2KAl\ Si_2O_8$		1.15
P_2O_5	.19	
CaO	.25	
Apatite		.44
TiO_2	.66	
SiO_2	.50	
CaO	.49	
Titanite		1.65
FeO	.20	
Fe_2O_3	.41	
Magnetite		.61
CaO	.32	
CO_2	.25	
Calcite		.57
Quartz		25.00

SiO_2	5.85	
Al_2O_3	3.85	
Fe_2O_3	1.19	
FeO	1.71	
MgO	1.31	
K_2O	1.20	
H_2O	.88	
Biotite		15.99
Hygroscopic water		.18
Total		99.78

The biotite would have the following composition:

SiO_2	36.59
Al_2O_3	24.08
Fe_2O_3	7.44
FeO	10.69
MgO	8.19
K_2O	7.51
H_2O	5.50
	100.00

The water is somewhat too high, no doubt due to the fact that chlorite and other decomposition products are present.

According to mineralogical composition, habit, and chemical composition, this rock corresponds closely to the granodiorite of the Sierra Nevada, the only difference being that it contains no hornblende, which in the granodiorite is as a rule abundant. It thus occupies a position between a quartz-mica-diorite and a granite. However, as it grades imperceptibly over into more normal granites, it has not been thought worth while to segregate it from that rock. The plagioclase in the Willow Creek rock is, according to the ratio between albite and anorthite, Ab_2An, or a basic oligoclase.

The second rock (80 Boise collection) is grayish white, granular, with a clearly apparent granitic habit. It consists of quartz grains of about the same size as in the fresh rock, while a greenish-gray compact mass replaces the feldspar and has a hardness of about 3. The biotite is replaced by a dull-white micaceous mineral. Small crystals of pyrite abound, and the rock is also traversed by a few small quartz veins. In a few places small grains of zinc blende are seen.

Under the microscope, large grains of quartz with undulous extinction are noted. Between them lies a fine-felted mass of sericite fibers, calcite grains, and in places a little fine-grained quartz. No feldspar remains, though occasionally the outlines of the grains may still be noted. In places larger muscovite foils appear, evidently representing the original biotite. The quartz is in many places attacked by sericitization, fibers and tufts of sericite and calcite developing in it or projecting into it from the surrounding sericite mass. Titanite, extremely abundant in the unaltered rock, is con-

verted into a milky opaque mass, composed of a great number of small crystals. The also abundant apatite is not attacked at all by any metasomatic process. The idiomorphic pyrite is chiefly contained in the altered feldspars, but also included in the quartz. When the pyrite crystals are larger the quartz in the vicinity often shows very strong undulous extinction, but some small perfect crystals also lie in the fresh, unchanged quartz, usually attached at one side to a bunch of sericite fibers. An assay of this rock gave 0.05 ounce of gold and 0.5 ounce of silver to the ton.

Analysis II shows the composition of the altered granite. The chemical change is on the whole slight. Silica shows a small increase, alumina a decrease; a very slight decrease is also noted in the iron oxides, lime, magnesia, and titanic acid, while the whole of the soda and the baryta has been carried away, and the percentage of potash has been considerably augmented. Sulphur and carbon dioxide have been introduced, and the quantity of chemically combined water has been increased.

With the aid of the data furnished by the microscopic investigation, the analysis may be calculated as follows. The lime has been calculated as carbonate, excepting that necessary for apatite and titanite, the whole of the magnesia likewise as carbonate, and as much of the ferrous oxide as the remaining carbon dioxide would permit. The remainder is sericite and quartz. The amount of free quartz has been estimated according to the quantity of oxides available for sericite.

S	.95	
Fe	.83	
Pyrite		1.78
P_2O_5	.17	
CaO	.22	
Apatite		.39
TiO_2	.49	
SiO_2	.33	
CaO	.46	
Titanite		1.28
CaO	2.69	
CO_2	2.11	
Calcium carbonate		4.80
MgO	0.95	
CO_2	1.01	
Magnesium carbonate		1.96
FeO	.90	
CO_2	.55	
Ferrous carbonate		1.45
Quartz		42.00

SiO_2	24.33	
Al_2O_3	14.26	
Fe_2O_3	.67	
FeO	.44	
K_2O	4.19	
H_2O	2.16	
Sericite		46.05
Hygroscopic water		.36
Total		100.07

The sericite would have the following composition:

SiO_2	52.82
Al_2O_3	30.96
Fe_2O_3	1.46
FeO	.96
K_2O	9.10
H_2O	4.70
	100.00

The altered wall rock from the Black Hornet mine (60, 63 Boise sheet collection) is a grayish-white, very quartzose rock impregnated with small grains and crystals of arsenopyrite. Though adjoining ore contained from $10 to $20, it was found upon assay to contain neither gold nor silver in appreciable quantities. Under the microscope No. 60 appears as a crushed granite or coarse granite-porphyry. The quartz grains are converted into coarse aggregates; the unstriated feldspar is filled with sericite fibers and grains of arsenopyrite, some of which have a little adhering chlorite. No. 63 contains unaltered idiomorphic andalusite, besides crushed large quartz grains and sericitized microperthite, and also a little soda-lime-feldspar. Scattered grains of pyrite are associated with foils of sericite.

The ore of the Black Hornet consists of massive quartz with inclosed sulphides. The preponderating quartz is granular and shows strong evidence of pressure. The ores consist of small, perfect crystals of arsenopyrite and anhedral grains of dark-brown, scarcely translucent zinc blende; inclosed in the latter are many small, distinct foils of sericite. Smaller shreds of this mineral are also scattered through the quartz.

The granite and porphyries adjoining the veins of the Idaho Basin are altered in a similar manner. Sericitization always takes place, and is often accompanied by the formation of carbonates. A specimen from a seam in the hanging wall of the Boulder mine (19 Idaho Basin sheet collection) consists of a quartz vein 2½ inches wide, of which 1 inch is pure quartz and the rest quartz with much finely divided iron pyrite. This vein is inclosed in a greenish-white, bleached granite, impregnated with a little pyrite and arsenopyrite.

An assay of the quartz vein gave 2.25 ounces of gold and 1 ounce of silver to the ton, or a total value of $47.21. An assay of the

altered granite immediately adjoining this piece gave only a trace of gold and silver. Under the microscope the altered granite is seen to contain large, partly crushed quartz grains. The feldspar, which is partly orthoclase, partly a soda-lime-feldspar, is filled with sericite foils, chiefly developing on the cleavage planes, and a few grains are almost totally replaced by this material. A few larger muscovite foils probably represent the altered biotite. No calcite is present.

The diorite-porphyrites and quartz-diorite-porphyrites of the Gold Hill and Pioneer mine at Quartzburg show a similar alteration, chiefly consisting in a conversion of the hornblende and biotite to muscovite foils, calcite, and perhaps also pyrite, while there is a great development of fine-felted sericite in the feldspar phenocrysts and in the groundmass. The abundant pyrite is in sharp cubes, usually lined with sericite foils. Aggregates of secondary quartz also develop in places.

Silicification.—Mr. S. F. Emmons, in his studies of the mineral deposits of Colorado and other parts of the Rocky Mountains, has admirably and with deserved emphasis brought out the fact that replacement is a process to which many deposits owe their origin, and that it plays an important part in almost all deposits caused by mineral-bearing waters. Carried away with the importance and interest of these results, many geologists and mining engineers have, however, extended the theory of replacement beyond its proper bounds, and speak of every vein-filling and even of veins of solid white quartz as products of replacement. Against this view a strong protest should be entered. In this connection it may be of interest to consider, briefly, the processes by which silicification may be produced.

In the case of ores consisting of carbonates there may often be some difficulty in deciding what is filling and what is replaced country rock, for carbon dioxide and alkaline carbonates are very strong solvents, attacking easily nearly every one of the rock-forming minerals and forming pseudomorphs after them. The carbonates may replace a rock completely, wholly changing both composition and structure. As an instance may be cited the coarse-grained mixture of carbonates and mariposite (fuchsite—a chromium mica) resulting from the replacement of the serpentine along the Mother lode of California.

As to quartz, the conditions are wholly different. A solution of silica is comparatively inert and does not easily attack any of the rock-forming silicates. Silicification may take place by two greatly differing processes: (1) Cementation, or filling of the interstices of porous or shattered rocks by quartz deposited from solutions; (2) metasomatic silicification, or a substitution of silica for other minerals, the silica either being produced by the alteration of the original minerals or deposited pari passu with the dissolving of the original mineral by active reagents in the waters causing the metasomatic action.

The first process is often observed in the silicification of various sedimentary, porous rocks, chiefly sandstones or tuff or porous igneous rocks, such as certain trachytes and andesites. Silicification by the cementation of shattered rock masses by silica is, of course, a common occurrence in and near quartz veins. But silicification by replacement is a less common process, and is observed chiefly in the case of easily soluble rocks, such as limestone or calcareous shales, when it results in fine-grained or cryptocrystalline aggregates of silica. In the metasomatism of bodies of massive rocks penetrated by chemically active solutions silica is formed in many ways, as by the carbonatization of silicates and sericitization of the feldspars, and if no open spaces are available much of this free silica will be deposited within the rock, usually as fine-grained aggregates more or less mixed with opal and chalcedonite. If no material were added the final result of this would not, however, be a silicification, but merely an increase in the total free quartz of the rock. But in case the rock mass is cut by fissures it appears that most of the resulting free silica is not deposited in the rock, but finds its way out in the open ducts, where, if the solution is supersaturated, it will be deposited. In fact, in the metasomatic processes in the ordinary igneous rocks adjoining gold-quartz veins, late investigations have shown that certain elements are added to the rock, while others, notably silica, are frequently subtracted, to be carried away or deposited in available open spaces.

As for the other possible process of silicification, or a dissolving of the original mineral and a deposition of silica pari passu, it occurs chiefly in easily soluble minerals, such as calcite. In case of the ordinary rock-forming silicates it is apparently not common. The resulting silica is generally in the form of fine, cryptocrystalline aggregates. Rocks silicified by either of these metasomatic processes, or by a combination of both, may occur, but, so far as the writer's experience goes, are not often encountered as wall rocks of auriferous-quartz veins. But neither of these processes can have produced the massive, white, coarse-grained quartz of gold veins belonging to the normal type. This quartz, which contains native gold and sulphides, shows, under the microscope, a peculiar, coarsely granular structure, the grains being partly bordered by crystallographic surfaces. This structure could have been developed only by free crystallization in open spaces. It is scarcely necessary to call attention, in addition, to the frequency of comb structure, etc., proving also the same kind of origin. This does not necessarily mean that all large bodies of quartz have been deposited in an open space, as large as the volume of quartz now is. Repeated openings of the fissure have doubtless often taken place.

In nature the complication of the fissure veins is often great, and it is clear, in fact, that it must be so, for the walls are often shattered,

resulting in alteration of the country rock and deposition of a net of quartz in the interstices. Ground-up mud often fills the fissure, and the result of the action of the solutions on this will be a mass of grains of altered rock, cemented as in a sandstone by quartz.

STRUCTURE OF THE VEINS.

The existence of fissure veins is primarily due to one or more fault planes, fissures or seams forming ducts for ore-bearing solutions. The latter have then produced the materials now forming the vein, which may be divided into (1) vein-filling, or minerals deposited in the open spaces along the fissure, and (2) metasomatically altered country rock. Though it is not in every case possible to strictly separate the two classes, as a rule it can be done. Many of the puzzling questions in regard to veins and vein-filling may be solved if this distinction is made and carefully applied. Products of attrition, often present in quartz veins, belong, as a rule, to the second class of materials. The vein-filling which ordinarily constitutes the ore is composed of various sulphides with a gangue of more or less quartz and calcite. Naturally it occurs chiefly along the fault planes and seams. At Willow Creek, for instance, the seams consist of nearly solid sulphides with a little quartz and calcite. These largely represent filling, but are probably, to a minor extent, formed by replacement of the country rock immediately adjoining the fault planes. At other localities, as at Black Hornet and Shaw Mountain, the ore consists of quartz-filling exclusively, with scattered grains and masses of rich sulphides and native gold.

The typical fissure vein may be regarded as a single break or fissure along which, through faulting, more or less continuous open spaces were formed and subsequently filled with ore. On both sides of this filling there is a gradually fading zone of alteration of the country rock.

In many regions the typical simple fissure vein is relatively rare. The country rock may be cut by one or several fault planes, along which only small open spaces have formed and around which there is a wide belt of altered country rock. The ore, then, mainly accumulates along these planes, largely by filling, partly, also, by metasomatism of the adjoining rocks. Again, there may be a shattered zone adjoining one or more fault planes. The rock is then traversed by a complicated system of seams, and large areas of the country rock may be altered. In this case, again, the seams generally contain the gold and the whole seamed rock mass may form a large ore body of low grade.

On Pl. XC (p. 650) a few types of the fissure veins occurring in this region are diagrammatically represented.

MINERAL DEPOSITS OF POST-NEOCENE AGE.

As has been explained before, there is every reason to believe that all of the more important ore deposits antedate the Payette formation, or that, in other words, they are pre-Miocene. But there is also some evidence of a later period of ore deposition, although of less importance, which occurred after the early Neocene eruptions, and which may be going on in depth even at the present time by means of the hot ascending spring waters found at several places in this region.

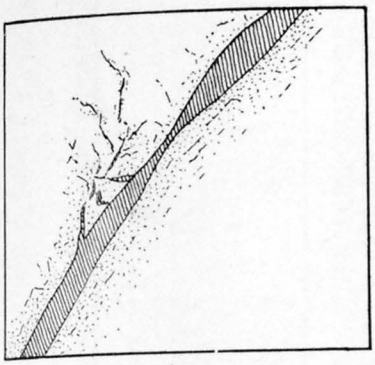
The Neocene rhyolite area occurring on the Idaho City road 3 miles from Boise is somewhat altered in places and is stated, on reliable authority, to contain $1 per ton in silver and a trace of gold. A Neocene sandstone with veins of opal, occurring near this area along the road, was assayed and found to contain 0.50 ounce of silver per ton. The knob of partly altered augite-andesite near the penitentiary at Boise was assayed and found to contain 0.05 ounce of gold and 0.50 ounce of silver per ton, a total value of $1.38.

The Neocene basalt at the mouth of the canyon of Jackass Creek, Jerusalem Valley, contains a quartz vein which is stated to assay about $4 in gold and silver.

PLATE XC.

PLATE XC.

1. Simple fissure vein with one fault plane and with quartz filling. Altered country rock on both sides. Filling only constitutes the ore.
2. Complex fissure vein with three fault planes. Rich ore as filling along narrow openings, partly also by alteration of country rock immediately adjoining fissures. Less altered country rock between and beyond the fault planes.
3. Simple fissure vein without large open spaces. Ore partly as filling, partly as altered country rock. Less altered country rock on both sides of fault plane.
4. Complex fissure vein with two fault planes, along which quartz is deposited as filling. Wide sheeted and altered zone between the two fissures.
5. Irregularly shattered zone between two fault planes. Quartz filling in seams and cracks. Extensive alteration of country rock between fault planes.
6. Single fissure in foot wall of porphyry dike. Dike traversed by stringers from hanging wall, shattered and extensively altered. Quartz filling in fissure and seams. Rich ore in quartz vein. Altered porphyry constitutes low-grade ore.



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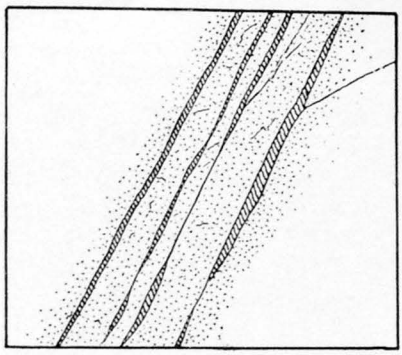

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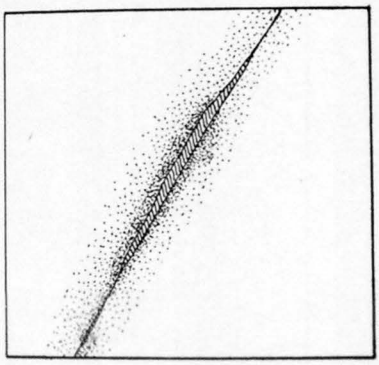

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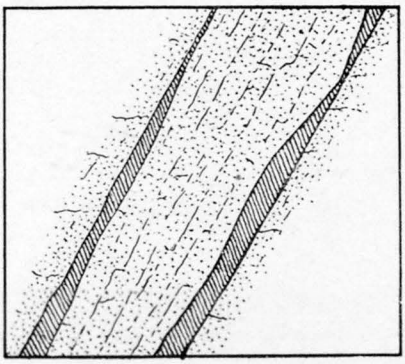

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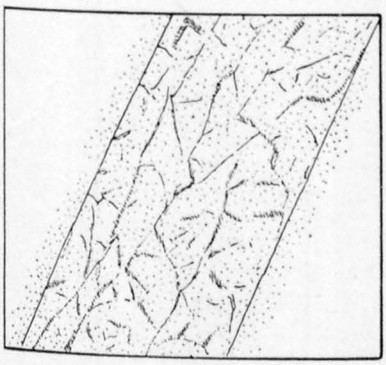

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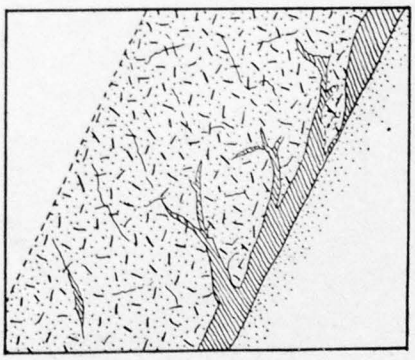

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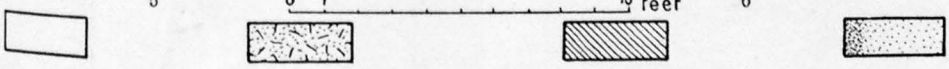


TYPES OF GOLD-BEARING FISSURE VEINS.

CHAPTER III.

THE IDAHO BASIN.

GEOGRAPHICAL POSITION.

The Idaho Basin includes the headwaters of Moore Creek, a tributary of the Boise River, and is located at a distance of 25 miles in a northwesterly direction from the city of Boise, at about latitude 43° 50′ and longitude 115° 50′. In comparision to its size this district has produced a very large amount of gold, chiefly from placer mines, but also considerable from quartz mines. The area embraced in the Idaho Basin—that is to say, the productive part of the same—does not exceed 150 square miles. Its length from north to south is 15 miles and its maximum width about 13 miles.

DISCOVERY AND HISTORY.

The placer mines of the Idaho Basin were discovered in August, 1862, by a party of prospectors from Walla Walla. During the fall of the same year the party is said to have been attacked by Indians, and its leader, Grimes, killed at Grimes Pass. The party, after ascertaining the richness of the placer deposits, returned to Walla Walla and formed a new expedition of 52 men; this party reached the basin the same year. The prospectors located first at the present site of Pioneerville. Subsequently the gold gravels of Centerville were located, and in December of the same year the rich diggings at Idaho City and on Granite Creek were found. Rapidly following these discoveries came explorations of other mineral-bearing parts of Idaho. In 1863 Rocky Bar and the rich mines of Owyhee were found. The influx of miners was extremely rapid after the report of the first discoveries had spread, and one year after the discovery several thousand placer miners were operating in the region. From 1862 to the present date placer mining has been carried on continuously, the operation being limited only by the amount of water available. Naturally, however, the output has gradually decreased since the first years following the discovery, when, as usual in placer regions, the maximum production was reached.

At an early date quartz mines began to be exploited, as it was soon seen that the placer deposits led up to the decomposed croppings of numerous quartz veins. At that time, however, quartz mining was in its infancy, and the ores could not always bear the cost of the treatment, increased in this case by the long distance over which machinery had to be transported and the high wages demanded for labor. At the present time there is a considerable quantity of gravel still left for exploitation, but these deposits will in time be exhausted, and the gold production will then have to depend on the quartz mines. In 1867 and 1868 at least ten mills are reported to have been in operation.

During the last year only a few of the quartz mines and mills were running.

At the present time the Idaho Basin contains five towns, with an aggregate of 1,200 inhabitants. Idaho City is located on Moore Creek, Centerville and Pioneerville on Grimes Creek, and Placerville and Quartzburg on the different branches of Granite Creek.

PRODUCTION.

The total gold production of the basin since its discovery has been the subject of frequent discussion, and it may be said that it is impossible to obtain undisputed data. It is often stated that the production for the first six years amounted to over $40,000,000, and that the total production exceeds $100,000,000. As will be shown, this estimate must be regarded as extravagant. The following table shows the production of the State of Idaho according to the most reliable estimates, contained in the reports of J. Ross Browne and R. W. Raymond, and the later Mint reports:

Production of gold and silver in Idaho, 1863–1876.[1]

Year.	Value.	Remarks.
1863	$7,000,000	Estimate (W. L.). Reports lacking.
1864	6,470,100	J. Ross Browne, report 1867, based on Wells-Fargo data; estimates added.
1865	6,581,400	Do.
1866	8,023,700	Do.[2]
1867	6,500,000	Mint reports.
1868	7,000,000	Do.
1869	7,000,000	Do.
1870	6,000,000	Do.
1871	5,000,000	Do.
1872	2,695,900	$2,300,000 gold, $400,000 silver.
1873	2,500,000	From Eleventh Census, Mineral Industries, p. 40.
1874	1,880,000	Do.
1875	1,750,000	From Eleventh Census, Mineral Industries, p. 40. $1,554,902 in Mint reports.
1876	1,600,000	Reports lacking. Estimate by W. L.
Total	70,001,100	

[1] During these years the defective statistics do not permit the separation of the gold and silver production, but the latter is relatively small, as shown by the figures for 1872. Few silver mines were worked up to 1876.

[2] $17,000,000 in table on p. 40 of Mineral Industries, Eleventh Census. Authority for this doubtful statement unknown.

Production of gold in Idaho, 1877-1896.

Year.	Value.	Remarks.
1877	$1,500,000	From table in Eleventh Census, Mineral Industries, p. 41.
1878	1,150,000	Do.
1879	1,200,000	Do.
1880	1,980,000	Do.
1881	1,700,000	Do.
1882	1,500,000	Do.
1883	1,400,000	Mint reports.
1884	1,250,000	Do.
1885	1,837,400	Do.
1886	1,798,000	Do.
1887	2,417,300	Mint reports; $1,900,000 according to Eleventh Census table.
1888	1,960,000	Mint reports; $2,400,000 according to Eleventh Census table.
1889	2,055,700	Mint reports.
1890	1,696,700	Do.
1891	1,685,600	Do.
1892	1,721,400	Do.
1893	1,693,600	Do.
1894	2,308,800	Do.
1895	2,594,700	Do.
1896	2,323,700	Do.
Total	35,772,900	

It appears from the tables that the total production of the State for the first six years scarcely exceeded $41,000,000, according to the Mint statistics, and that consequently the Idaho Basin can not have produced more than a fraction of this amount. Even admitting the more liberal estimates mentioned a few lines below, the total production for this period can not have exceeded $60,000,000. As to the production of the Idaho Basin itself, the data available are still more imperfect. For 1867, 1868, and 1870 there is in Raymond's reports for 1869 and and 1871 an estimation of the total production made by W. A. Atlee, agent of the Wells-Fargo Company at Boise, an authority probably better qualified to judge than anybody else. This includes not only Wells-Fargo shipments, but estimates of all kinds of shipments.

Estimation of the total production of the Idaho Basin in 1867, 1868, and 1870.

District.	1867.	1868.	1870.
Placerville	$363,237	$340,515	$184,428
Centerville	468,556	442,443	249,839
Pioneerville	494,931	552,604	250,000
Idaho City	3,001,568	2,961,213	2,000,584
Total	4,328,292	4,296,775	2,684,851

The same authority estimates a total production in Idaho of $9,000,000 in 1867, $10,000,000 in 1868, and $6,000,000 in 1870. On this Mr. R. W. Raymond comments that his estimate for the total production in Idaho for 1868 is only $7,000,000, and, admitting the excellent facilities which Mr. Atlee had for estimation, still thinks that his values are too high, and is reluctant to allow any increase in his own figures. From 1881 to the present year the statistics are in better condition, and the production of Boise County can be closely estimated. In this production the Idaho Basin furnishes by far the largest quantity of gold; it may be safely said that nine-tenths of the production of Boise County is derived from the Idaho Basin. On the basis of these data I have attempted to construct a table giving the probable production of the Idaho Basin to the present date. It is, of course, only a rough estimate, but it has some value.

During 1884, Plowman's claim, according to the Mint reports, yielded $25,000, Channel's claim at the head of Willow Creek $10,000, and the Granite Creek Company's claim east of Placerville from $15,000 to $20,000. The Chinese companies were during this period estimated to have produced $25,000 a year. In 1883, Placerville, according to the same authority, produced $25,500, Idaho City $381,500, and the Deadwood Basin, located in the northeast portion of Boise County, $8,000. It will be noticed that the greatest production is always that of the Idaho City district.

Table of probable production of the Idaho Basin, 1863–1896.

Year.	Value.	Remarks.
1863	$3,000,000	Estimated (W. L.).
1864	4,000,000	Do.
1865	5,000,000	Do.
1866	5,000,000	Do.
1867	4,300,000	Estimated by W. A. Atlee, in J. Ross Browne's report for 1869.
1868	4,300,000	Do.
1869	3,000,000	Estimated (W. L.).
1870	2,700,000	Estimated by W. A. Atlee (Raymond's report for 1871).
1871	2,000,000	Estimated (W. L.).
1872	1,000,000	Do.
1873	800,000	Do.
1874	700,000	Do.
1875	600,000	Boise County (Raymond's report for 1875).
1876	600,000	Estimated (W. L.).
1877	500,000	Do.
1878	500,000	Do.
1879	400,000	Do.
1880	300,000	Do.
1881	300,000	Boise County, Mint reports.
1882	290,000	Do.
1883	565,000	Do.
1884	400,000	Do.
1885	619,000	Do.
1886	390,900	Do.
1887	502,200	Do.
1888	283,000	Do.
1889	274,600	Do.
1890	320,400	Do.
1891	356,700	Do.
1892	376,400	Do.
1893	280,800	Do.
1894	327,800	Do.
1895	339,000	Do.
1896	326,000	Do.
Total	44,651,800	

It will be seen from this table that the total production amounts to less than $45,000,000. Allowing for the uncertainty in the data, we may safely say that the basin has not produced more than $50,000,000

in gold. Even supposing the admittedly uncertain production of the first four years to be double the amount of estimates here given, the total production would be only $62,000,000.

While it is not possible to separate the production of the quartz mines from that of the placer mines, it may be said with some confidence that the total production of the former does not exceed $4,000,000.

TOPOGRAPHY.

The Idaho Basin, the topography and geology of which are shown in Pl. XCVI, is located in the middle of that great irregular mountain mass extending between the Salmon and the Snake rivers. Defined more closely, it is situated on the ridge between the north fork of the Boise River and the south fork of the Payette. On the west rises the Boise Range, the summits of which are visible from Boise, and which attains elevations of from 7,000 to 7,500 feet. On the east rise the irregular mountain complexes of Sawtooth Range and its projecting spurs. The basin occupies the head waters of Moore Creek, a tributary joining the Boise River 10 miles above where it leaves its canyon and enters the plains of the Snake River Valley. Ten miles from its junction with the Boise River Moore Creek divides in two, the westerly branch being called Grimes Creek. Five miles above this the narrow canyon in which Moore Creek flows widens out to a broad valley, in which the creek meanders with but little fall. At Idaho City the creek branches again, and both forks head in the high mountains near Wilson Peak and Elk Creek Mountain. A long ridge with a southwesterly direction separates the Moore Creek Basin from the depression of Grimes Creek. This ridge, which for a long distance has a nearly level summit, rises to a height of 1,000 feet above Idaho City. To the south and east of Idaho City the rise is much more rapid. From the vicinity of Thorn Creek Mountain a number of very high and narrow ridges project northward, encircling the southern and eastern part by a chain of hills rising 2,000 feet above Idaho City. Six miles above Idaho City, Moore Creek enters this rugged complex of mountains, and 5 miles farther up heads in the precipitous amphitheaters of Elk Creek Mountain.

The canyon of Grimes Creek reaches to a point 10 miles above its junction with Moore Creek; then the valley broadens, exactly similarly to the valley of Moore Creek, the main branch continuing in a northeasterly direction and heading near Grimes Pass, 4 miles north of Pioneerville. This pass forms the water-parting between the Payette and Boise rivers. It is comparatively low, attaining an elevation of only 5,000 feet. Immediately east of Pioneerville and of Grimes Pass the high ridges of Wilson Peak and Summit Flat rise above the more gently undulating country of the valley of Grimes Creek. An important tributary, Granite Creek, enters 4 miles below Centerville and extends in a northwesterly direction toward Quartzburg. Granite

THE IDAHO BASIN, LOOKING EAST FROM THE JERUSALEM ROAD WEST OF QUARTZBURG.

Creek flows in a similar wide valley with gentle slopes, and passes again lead over to the Payette watershed north of Placerville and north of Quartzburg. The lowest pass is the former, which attains an elevation of only 4,700 feet. A short distance west of Granite Creek the Boise Ridge rises very abruptly in the vicinity of Quartzburg, and more gently farther south to elevations ranging up to 7,500 feet. The lowest pass leading across the Boise Ridge, with an elevation of 5,500 feet, is found 6 miles west of Centerville.

One can best appreciate the topographic features of the basin when standing high up on the slopes of the Boise Ridge or on any one of the high peaks rising toward the east. It is seen that the name is extremely appropriate, because it forms a low depression encircled on all sides by a ring of high mountains. Only toward the north, along the water-parting between Boise Ridge and Grimes Pass, is there a lower rim, leading over into the deep canyon of the Payette River. In the accompanying photograph (Pl. XCI), taken from a point at an elevation of 6,000 feet on the road leading from Quartzburg to Jerusalem Valley, the encircling rim from Thorn Creek Mountain to Wilson Peak is well shown, as are the remarkably level ridges separating the lowest depressions in the basin.

GRADES OF THE WATER COURSES.

According to the topographic maps of the United States Geological Survey the grade of the Boise River above and below the mouth of Moore Creek is very slight, being only about 10 feet per mile. Moore Creek for the first 11 miles from its mouth, to the junction with Grimes, has a grade of 40 to 50 feet per mile. The narrow canyon above the mouth of Grimes Creek has a somewhat stronger grade, approximating 66 feet per mile. From Idaho City down to where the canyon begins a grade of 50 feet per mile is obtained; above Idaho City it is for 3 miles 33 feet per mile; beyond this point the grade increases rapidly and is from 100 to 200 feet per mile.

For the first 9 miles from the junction Grimes Creek averages 40 feet per mile; then follow 4 miles of a more abrupt canyon, with a grade of 80 feet per mile. Within the basins of Centerville and Graniteville the creeks have a fall of about 30 feet per mile, which above Pioneerville and Quartzburg rapidly increases to 200 feet per mile.

TERTIARY AND PLEISTOCENE FORMATIONS.

LOWER MOORE CREEK VALLEY.

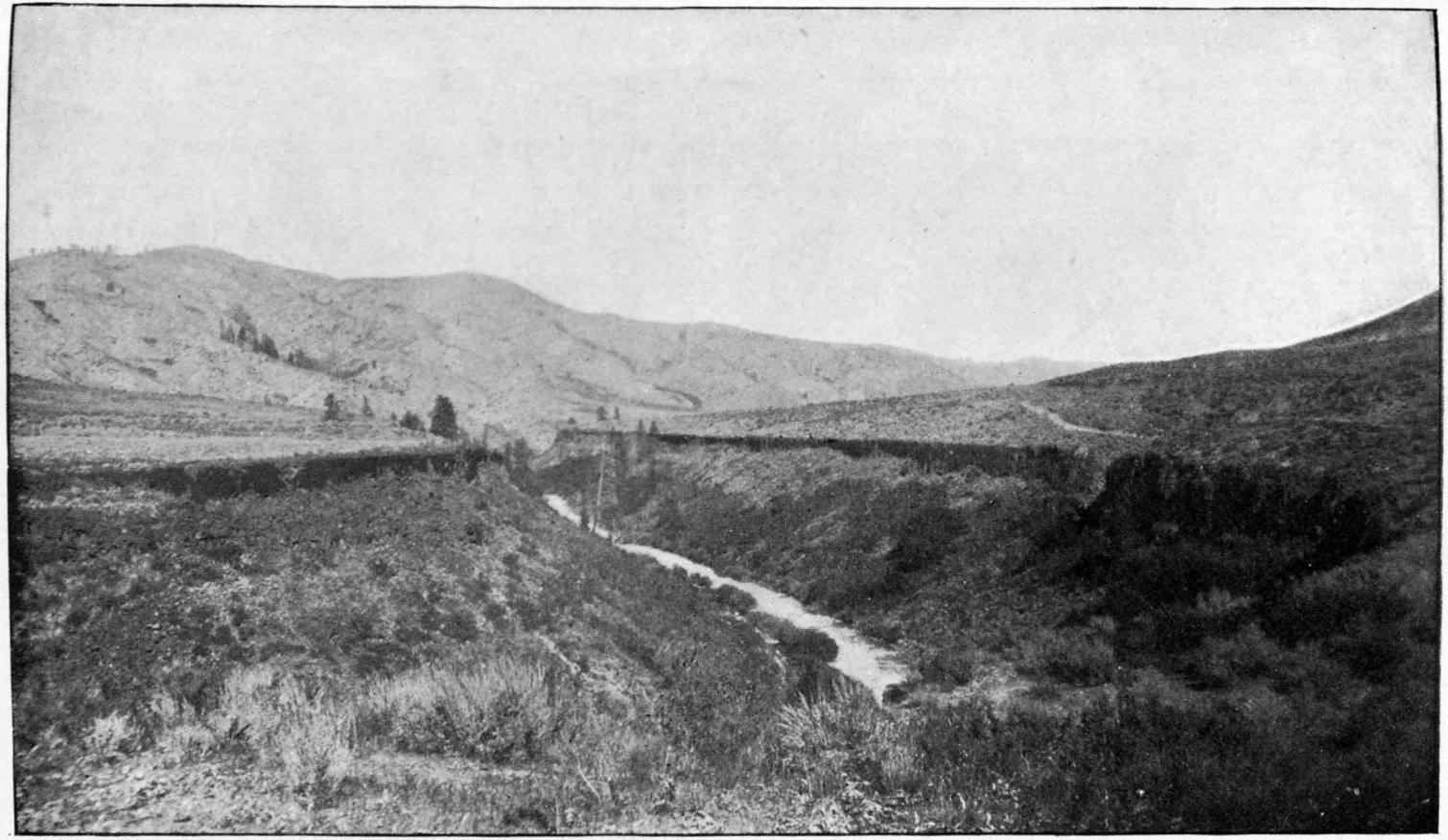
Configuration of the valley.—From Boise River up to the junction with Grimes Creek, Moore Creek flows in a somewhat broad and U-shaped valley, the slopes of which rise with increasing steepness to ridges with gentle summit lines 2,000 feet above the valley. The hills are covered with a scant vegetation and the soft crumbling

granite is easily washed down by atmospheric agencies. The width of the valley between the summits is not more than 2 miles. Above the mouth of Grimes Creek the valley contracts and the steep slopes project, the creek forming a more V shaped valley, which continues to 4½ miles above the junction. A few small alluvial flats lie in the bottom of this canyon.

The basalt flow.—The valley bottom is filled with a basalt flow rarely over one-fourth of a mile in width; its top rises to about 100 feet above the creek level. Through this flow the stream has cut down to a depth somewhat exceeding that which it had attained before the basaltic eruption. The joints in the basalt have produced perpendicular cliffs, the whole being an exact illustration of a canyon within a valley. While much of the basalt flow has been eroded, enough remains to form a nearly continuous fringe of cliffs on either or both sides of the streams, reaching from the mouth of the creek up to 1¼ miles above the junction with Grimes Creek. The level top of the flow has been covered by a sloping, sandy wash from the adjoining hills. The character of the valley, the basalt flow and its covering, is well illustrated in Pl. XCII. Above the point mentioned the basalt suddenly ceases, and no more of it, either in outcrops or in pebbles, is seen above. It also extends a few miles up on Grimes Creek, and it is probable that the vent was located at some point in the Grimes Creek Canyon, and that the flow backed up for some distance on Moore Creek. The basalt is about contemporaneous with the flows of the Snake and Boise rivers—geologically speaking recent—being referred to the late Neocene (Pliocene) period.

The present stream gravels.—The bed occupied by the stream is generally narrow, seldom exceeding 100 feet in width. The bed rock is only rarely exposed. The creek is filled with coarse gravel, largely made up of tailings brought down from the Idaho Basin by the winter freshets. The maximum depth of these tailings is 20 feet. The gravels in the present stream have been and are still extensively washed, mostly by Chinese using the ordinary appliances for river mining—dams, Chinese pumps, and derricks. The old channel covered by the recent débris has been exposed by mining at many places, being naturally richer than the tailings. The many basalt bowlders found in it are a considerable obstacle to cheap mining. On Moore Creek, about 4¼ miles above the mouth of Grimes Creek, a steam dredge was operated in 1896, with the purpose of striking the rich gravel 10 to 20 feet below the surface. The gravel is reported to have been reached, though the large bowlders interfered somewhat with the work. On the whole, the present stream gravels of lower Moore Creek can not be considered to have been extremely rich.

The gravels below the basalt.—The basalt along Moore Creek is found to rest on stream gravels accumulated in the bed before the molten flow poured down the valley. The old channel is sometimes



LOWER VALLEY OF MOORE CREEK, 3 MILES ABOVE ITS MOUTH, SHOWING BASALT FLOW CUT THROUGH BY THE CREEK.

preserved on the east side of the creek, sometimes on the west side, which makes it necessary to well establish the course of the channel before commencing extensive work. The old gravel is found at elevations of from 25 to 75 feet above the creek, and has been exposed by a number of tunnels. The gold is fairly coarse, the particles being about the size of mustard seeds, but it can not be said that these old placers have been shown to be very rich. They have not as yet been extensively worked. At a place 1 mile above Half Way House, on the east side of the creek, 6 feet of granitic gravel, covered by 3 feet of sand, is exposed below 30 feet of basalt. One-half mile farther up the old channel is well exposed by two tunnels on the western side of the creek. The old bed rock lies 25 feet above the stream, and the deposit has been developed by 175 feet of tunnels. Above the bed rock lies 8 feet of coarse gravel with a streak of sand in the middle; 70 feet of solid basalt covers this. The gravel is reported to contain about 65 cents per cubic yard. As the gravel is not extremely compact, and as the basalt forms an excellent roof, it might be possible to profitably exploit many of these small stretches of old channels by underground hydraulic operations.

High gravels.—Though the lower part of Moore Creek has not been thoroughly examined, it has been shown that gravels exist on some of the high ridges within this drainage. The study of these high gravels, which are probably of Tertiary age, is of the highest importance, as it enables us to trace more fully the geological history of the region. The largest of these high gravels was found on the summit of a high and narrow ridge between the two forks of Thorn Creek, at an elevation of 4,500 feet. This deposit, which consists of extremely well-washed gravel of granitic and quartzose character, has been worked to some extent by the hydraulic process and found to contain gold in paying quantities. The extent from east to west is only a few hundred feet. The depth of gravel is probably considerable, although difficult to estimate on account of slides on the steep slopes. Small patches of gravel are also reported to exist on the neighboring ridges. It is probable that during the highest stand of the Neocene lake which occupied the whole lower basin of the Snake River gravel deposits filled the upper parts of Moore Creek and the Boise River. The occurrence of this high gravel will be discussed again later in connection with the geological history of the Idaho Basin.

UPPER MOORE CREEK VALLEY.

Configuration of the valley.—Five miles below Idaho City the form of the valley suddenly changes. From a level bottom the slopes rise gradually, numerous creeks branch, and the whole forms a broad, basin-like depression. The general character is well shown in Pl. XCIII, looking southwest from Idaho City. Three miles above Idaho City a narrow canyon begins again. Seen from some elevation, the

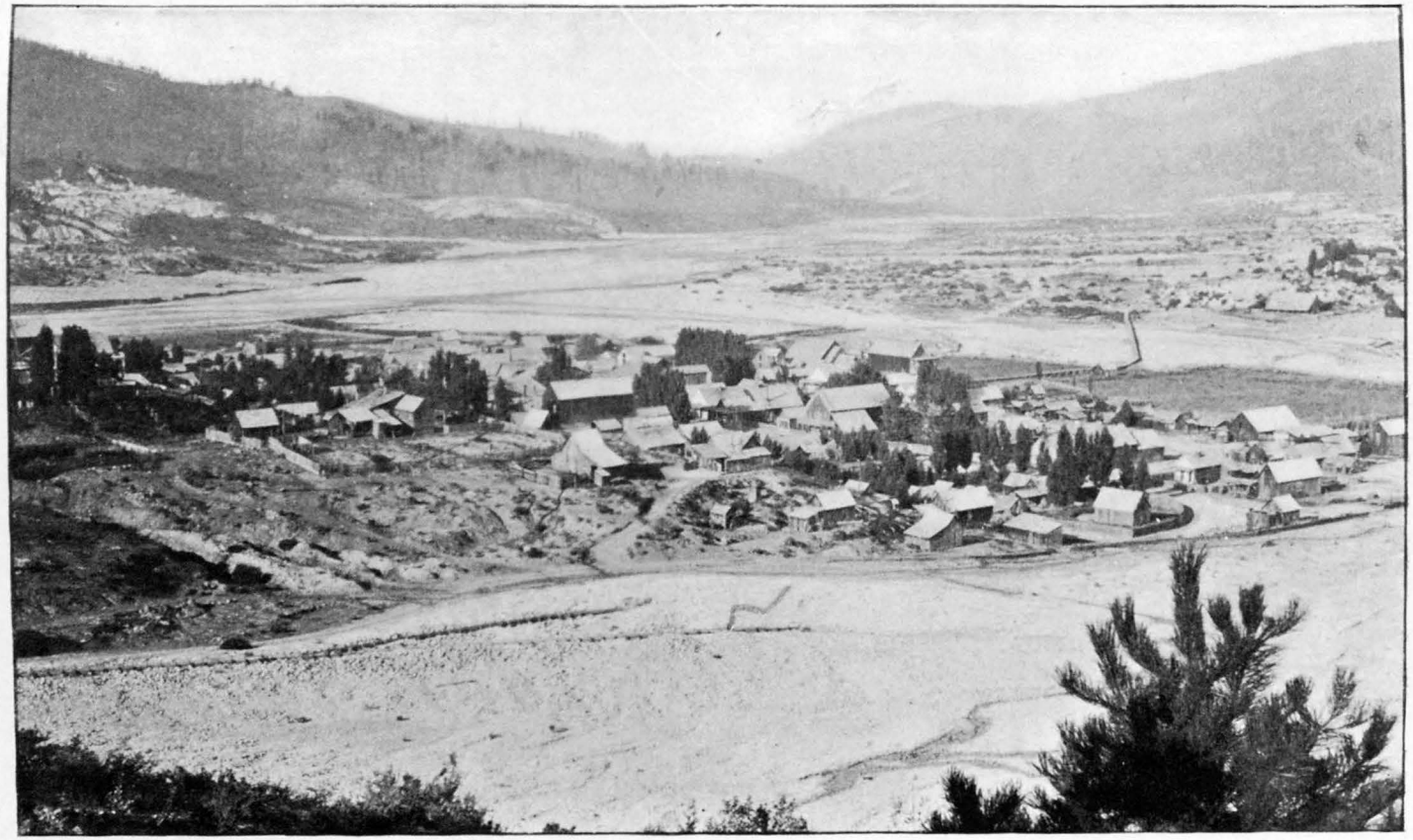
three most impressive topographic features are (1) the broad valley; (2) the level ridges between Idaho City and Centerville, between Elk Creek and Moore Creek, and between Granite and Bannock gulches, rising to an elevation of 1,000 feet above the valley; and (3) the encircling rim of high, deeply dissected peaks and ridges, attaining a height of 2,000 or 3,000 feet above the valley.

The present stream gravels.—The alluvial gravels filling the bed of the present stream form broad flats, over which the water course meanders in changing channels. The largest part of these gravels is débris from the hydraulic mining operations carried on in the bench gravels and the high gravels. The width of the tailings below Idaho City reaches 1,000 feet. In two places the channel contracts between low, projecting hills. At Idaho City the maximum width is reached; here the tailings are about 2,000 feet wide, contracting again to a narrow channel 1½ miles above the city. Two and one-half miles above the same place a comparatively narrow canyon begins, and the tailings are only up to 200 feet wide. The tailings cover the imperfectly washed original creek bed, and in many places also the first (lowest) terrace or bench. At Warm Springs they are reported to be 15 feet deep; at Idaho City as much as 40 feet. They consist chiefly of granitic and porphyritic pebbles, with much sand. By a natural process the gold in the tailings is gradually concentrated. At some time the whole creek bed will probably be washed over again to recover this gold and to reach the older bottom gravels, which are supposed to be rich in many places. Probably the only way in which this can be profitably done is by means of hydraulic elevators or dredges.

The stream gravels were most extensively worked in early days. Moore Creek was very rich up to the mouth of Gambrinus Gulch, though gravels have been washed still higher up. The gulches entering from the south, as a rule, paid only for a short distance from the main creek; their upper courses were nearly barren. On the northern side, Gambrinus and Illinois gulches were extremely rich. Bear Gulch has also been worked extensively. The bottom of Elk Creek in its upper course is generally narrow, but was rich up to Boulder mine; 2 miles below Boulder mine the creek bottom widens to 200 feet, and placer diggings were being operated in 1896. Deer Creek, heading at Summit mine, yielded very heavily, the output of the half mile near the summit being placed at $90,000. Wolf Creek has been worked, but was not so rich. Spanish Creek was also worked, and near its head lies a flat, one-eighth mile wide and one-half mile long, covered by 12 feet of angular wash, which has been extensively worked, the gold being probably derived from small seams or from a gold-quartz vein not yet discovered.

The gulches entering from the north and south below Idaho City were generally barren beyond the extent of the terraces.

Bench gravels.—Where the broad valley opens, 6 miles below Idaho



IDAHO CITY, FROM GOLD HILL, LOOKING SOUTHWEST, SHOWING TAILINGS AND BENCH GRAVELS.

City, a series of shelf-like terraces, entirely absent farther down, begin to appear. The width is only a few hundred feet, and rarely are longer stretches of them preserved, each little creek and gully usually cutting the terrace in two. For the first 4 miles most of the gravel patches lie on the northern side of the valley. At least two terraces may here be recognized, the bed rock of the lower one being 50 and of the upper about 100 feet above the creek. The depth of the gravel is seldom over 30 feet, though near the bed-rock slopes much débris has slid down over the gravel. All of these gravel patches have been very rich, and work is still in progress on some of them. The bed rock, as far up as 1 mile below Warm Springs, is granite or granite-porphyry.

Above Warm Springs the gravel terraces or benches are very pronounced and often form continuous streaks of considerable length. The best exposures are found at Turner's claim, 1 mile below Idaho City, on the road to Warm Springs. At this place the gravel terraces occupy a total width of one-half mile, and rest partly on gran-

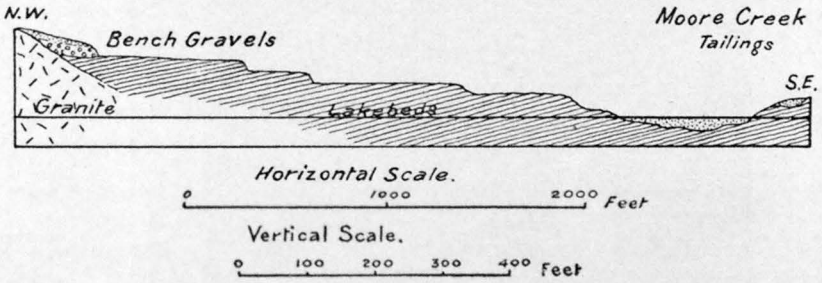


FIG. 55.—Gravel benches 1½ miles below Idaho City.

ite, partly on Tertiary lake beds, gently inclined westward. Fig. 55 shows a profile of the different terraces here exposed. The highest terrace is found at an elevation of 80 feet above the creek bed. Below this there are three others, and possibly four, at intervals of 15 and 30 feet. The lowest terrace is said to be covered by the tailings. These gravels have been very extensively washed, but a considerable amount still remains. The upper terrace, illustrated in fig. 56, is covered by 8 to 12 feet of well-washed gravel, chiefly granitic in character. This contains the largest part of the gold, and rests on the eroded surface of the soft lake beds. This pay gravel is again covered by 12 feet of fine sandy or clayey sediments with occasional carbonaceous seams. In this there is but little gold. On top rests 8 feet of angular surface gravel, washed down from the adjoining hillside. This gravel is barren. The gravel terrace extends in a northeasterly direction along Elk Creek, and is chiefly developed on the western side. The continuous bodies give way to isolated patches, and 2 miles above Idaho City Elk Creek passes into a narrow canyon. In Idaho City gravel terraces are noted surrounding a

high body of older gravel called East Hill. A part of this terrace, on which the town stands, has not yet been mined. Opposite Idaho City, and in fact all along the southern side of Moore Creek up to the mouth of Granite Creek, the gravel benches are more or less continuous. The lowest is noted 20 feet above the creek and higher ones are at 50 and 100 feet. Small benches occur on the north side of Moore Creek east of Idaho City. At least three different benches may be recognized at the elevations noted. Most of these bench gravels near Idaho City rest on lake beds of sandy or gravelly character, usually referred to by the miners as "false bed rock."

All the small patches of gravel terraces have been extensively washed and are not yet quite exhausted. The thickness of the gravel rarely exceeds 25 feet.

Above the mouth of Granite Creek, Moore Creek enters a canyon, along which there are but small indications of gravel terraces. At Plowman's sawmill the creek widens somewhat, and from here up the bottom is generally occupied by a flat 100 to 300 feet wide, the surface of which is 10 to 20 feet above the creek. Upon the sides are occasional benches at an approximate height of 50 feet above the creek. All these low terraces have been washed as high up as the mouth of Gambrinus Gulch, and from the evidence of the old washings it is clear that most of the gold came down from this gulch. Above Gambrinus Gulch the washings are less extensive, and some of the low gravel flats have never been worked, being evidently too poor. Two miles above Idaho City, as stated above, Elk Creek enters a narrow canyon, and although this widens somewhat farther up, still there are only occasional patches of gravel terraces remaining, at elevations of about 50 feet above the creek. The manner of mining the bench gravels by the hydraulic process is shown on Pl. XCIV.

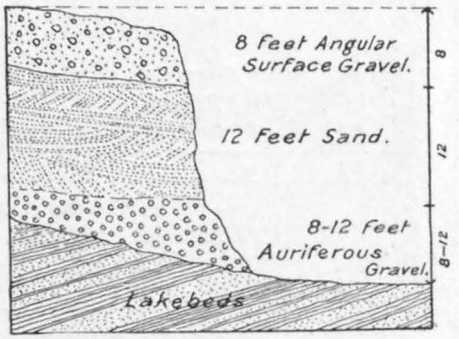
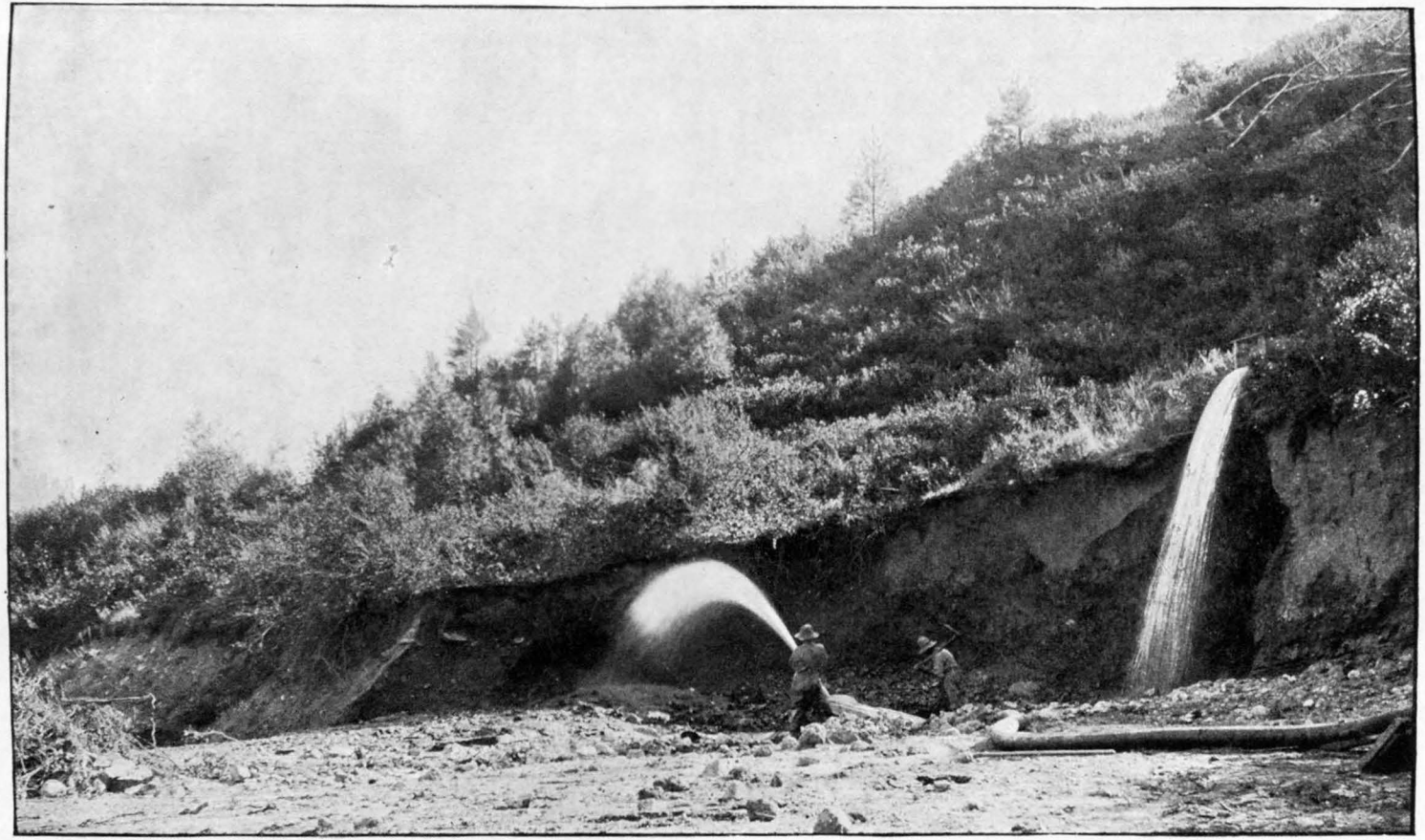


FIG. 56.—Section of highest bench, 1¼ miles below Idaho City.

High gravels.—There are several bodies of gravel in the vicinity of Idaho City which in their occurrence differ from the ordinary bench gravels, and which are generally at high elevations above the creeks. While these also are probably former terraces of the valley of Moore Creek, they are much older, and it seems desirable to treat them separately.

The slope opposite Idaho City is occupied up to 400 feet above the creek by soft lake beds cut up into sharp ridges separated by deep and narrow ravines. The gently sloping tops of these ridges are



WORKING BENCH GRAVEL BY THE HYDRAULIC PROCESS AT IDAHO CITY.

covered by auriferous gravels which have a thickness of 60 feet or less. The base of these gravels lies, at Barker's claim, 300 feet above Moore Creek. This gravel shows excellent fluviatile stratification, and appears to rest in a flat channel eroded in the lake beds. The gravel consists of well-washed granite pebbles, accompanied by some of quartz. Bowlders 2 feet in diameter occur occasionally. This gravel is quite rich, the best pay being found, as usual, on the bed rock, i. e., on the soft lake beds, but there is also gold distributed through the gravel. The gravel and gold has also, of course, slid down the steep hillside, and this material covering the slopes has been washed. During the summer of 1896 the claim of Mr. Barker, 1 mile southeast of Idaho City, was worked by the hydraulic process. The pay gravel does not extend southward beyond the lake beds. In these high gravels there occur somewhat abundant large cobbles up to 1 foot in diameter of quartz stained brownish, and which are often rich in gold, one bowlder sometimes yielding $20. The source of this quartz is not known. It certainly does not come from the high hills to the south. Fig. 57 shows the general relations of the high gravels at Idaho City.

Another important body of the high gravels is found on the hill immediately east of Idaho City. The gravel, which reaches a total depth of 100 feet, forms a body about 2,000 feet long and 1,000 feet wide. It rests throughout on clayey and sandy lake beds, dipping gently westward at an angle of 10°. Seen from the south side of the creek, the stratification planes in the gravel appear to have a decided dip westward, amounting to 4°, or a little less than the underlying rocks. The gravel rests remarkably evenly on the lake beds, with but little sign of unconformity. The geological section in fig. 57 illustrates the occurrence, while Pl. XCV shows the gravel bank and underlying lake bed in Plowman's claim. A marked fluviatile stratification is often

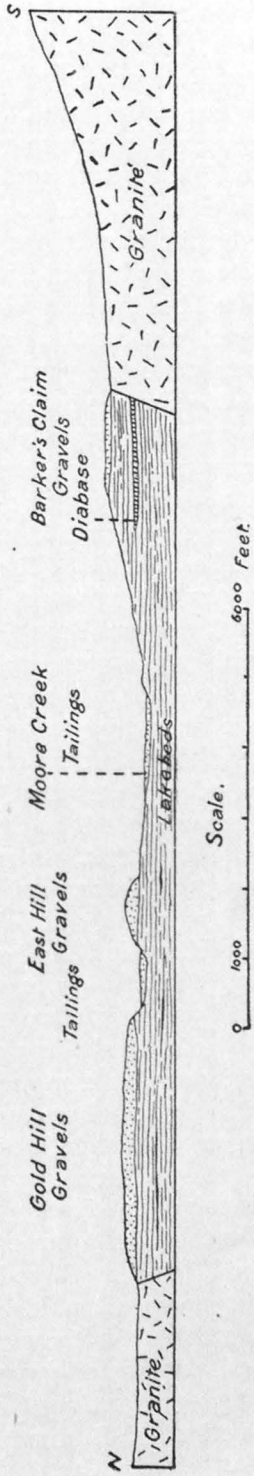
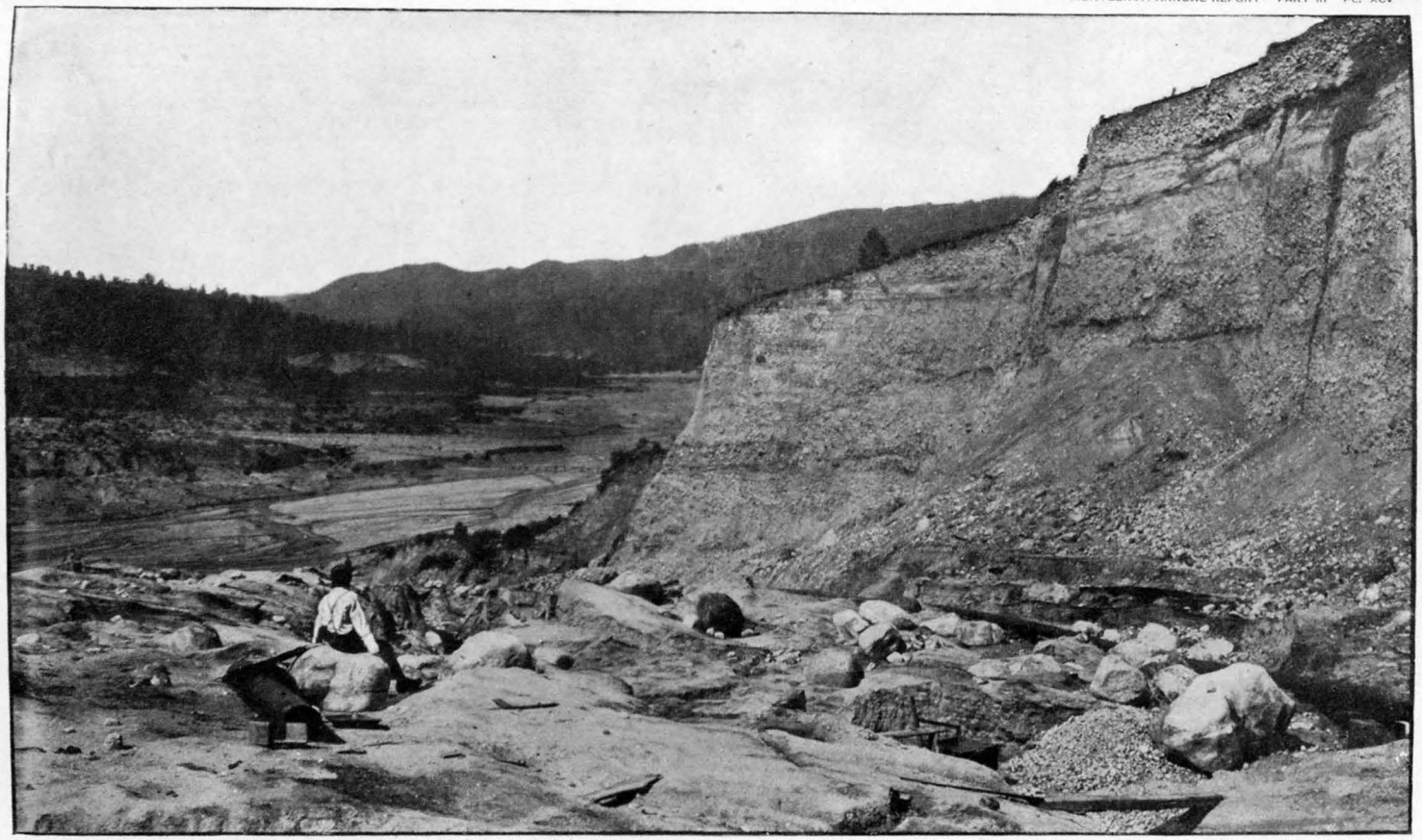


FIG. 57.—Section across lake beds and gravels at Idaho City.

visible. The gravel is medium coarse and is made up chiefly of granitic bowlders with occasional pebbles of quartz. By tracing this area around, it is found that the bed rock rises gently, being at the eastern end at least 200 feet above the creek. At the western end the exposures are not so good, as tailings and bench gravels lie up against the higher gravels and the underlying beds are not here visible. The gravel on East Hill, as this area is called, has been worked by the hydraulic process for a number of years, and the claim is reported to have produced from $10,000 to $20,000 a year. The largest part of the gold is found resting on the soft bed rock. The upper part of the gravel also contains some gold, but probably not more than about 5 cents per cubic yard. The gold is fairly coarse, and has a value of $16.50 an ounce before melting. On the surface of the gravel the gold appears to be more abundant, which is probably caused by a gradual concentration by atmospheric agencies.

Another large body of gravel is that known as Gold Hill (fig. 57), occupying about 160 acres and situated on the point between the creek and Bear Gulch. The top of this gravel body is 350 feet above Idaho City, and its greatest depth is probably not less than 200 feet. Along Elk Creek and Bear Gulch the gravel rests on the same soft lake beds which crop out on East Hill. Toward the southwest tailings lie up against it. On the northeast side, on the other hand, the gravel rests directly on granite bed rock. Here also the dip of the gravel beds is about 4°, while that of the lake beds is 10° W. Good exposures, made by hydraulic mining, are seen on the southwest side. One-fourth mile north of Idaho City the surface of the soft lake beds lies 20 feet above the creek. Above the lake beds lies 15 feet of coarse heavy gravel with many subangular fragments. Above this is 10 feet of sand with clay streaks, sometimes a little coaly, and somewhat resembling the lake beds. Capping this sand is ordinary well-washed gravel. Here, as in the other gravel bodies, the largest pay was found on the surface of the bed rock—that is, on the surface of the lake beds—and this rich bottom stratum has been mined by the drifting process both on the southeast and on the southwest side. A large body of gravel here remains, which can be worked by the hydraulic process, although it is probably of low grade. Owing to some difficulty in procuring water, the claims on this hill have not yet been extensively worked.

On the ridges above these deposits no other gravel masses have been found, but a small body rests on a sidehill to the east of Elk Creek, 3 miles northeast of Idaho City, at an elevation of about 200 feet above the creek. On the western side of Elk Creek, opposite Idaho City, small patches of gravel are occasionally found 200 feet above the creek level, and scattered pebbles occur in many places at about this elevation. Still another body of high gravel is that found on the point between Granite Creek and Moore Creek, east of Idaho City.



GRAVEL BANK WITH UNDERLYING LAKE BED AT PLOWMANS CLAIM, EAST HILL, IDAHO CITY, LOOKING SOUTHWEST.

It forms a bench-like deposit 175 feet above the creek, and the larger part of it has been worked by the hydraulic process.

Lake beds.—Near Idaho City, on both sides of Moore Creek, a considerable area is covered by soft sedimentary beds of clay, sand, and gravel. These do not bear evidence of being river deposits. The regular stratification and their general character indicate that they have been deposited in a body of water, in all probability a fresh-water lake. These beds do not contain any notable amount of gold, but the fluviatile auriferous gravels just described are deposited on their eroded surface. The dip of the beds proves that that they have been disturbed since their deposition. Recognizing their sedimentary nature, the miners call these lake beds "false bed rock." The lake beds are first met with 1 mile below Warm Springs, where they appear as semiconsolidated white sand and clays. Near Warm Springs they assume the form of coarse yellowish sandstones, evidently cemented by the opaline silica of the hot waters. In fact, sandstone cemented

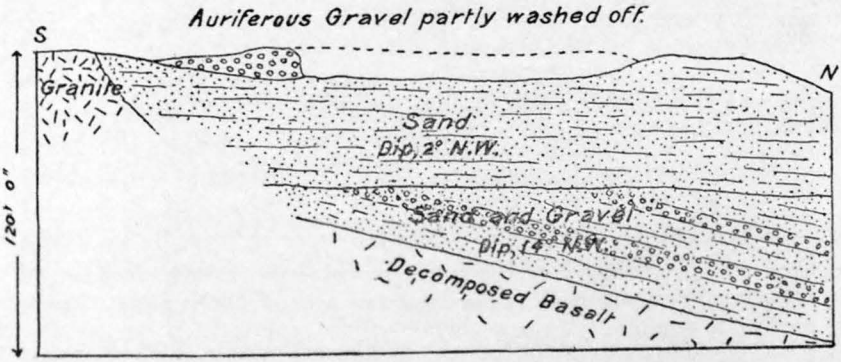


FIG. 58.—Exposure of lake beds and auriferous gravel 1¼ miles south of Idaho City. Top of gravel, 400 feet above Idaho City.

by fire opal has been collected on both sides of the creek, and the occurrence is mentioned by Mr. S. F. Emmons.[1] Owing to the very coarse character and rapid accumulation of the débris the stratification is poorly preserved. Half a mile below the hot springs these sandstones form a bluff 300 feet high, and also extend east of the road, producing a relatively narrow passage for the creek. A slide has taken place near the creek, covering an older channel, the bed rock of which lies only a few feet above the present creek and which has been mined by several tunnels. At Turner's claim the lake beds form the bed rock and are well exposed. They dip 5° NW. and consist of soft sand and clay with occasional coaly layers. The clay encloses nodules of iron pyrite containing some gold and silver.

Near Turner's claim a projecting spur of granite reaches to within a few hundred feet of the road, and in the hydraulic cuts the lake beds are seen to rest on it. Between Turner's claim and the city the

[1] Boise Statesman, March 29, 1896.

lake beds are not exposed, but the gravel of the terraces is reported to rest on them. Across Elk Creek from Gold Hill sandy and clayey lake beds again appear, the bench gravels resting on their eroded surface. Granite appears a short distance up on the hillside.

Around East Hill and Gold Hill the lake beds are well exposed, and consist largely of greenish or gray clay with arenaceous streaks and intercalated beds of black clay with coaly streaks. The dip is 10° W. A few fossil plants were found here, which were identified by Mr. Knowlton. (See Appendix, p. 721.)

These plants identify the lake beds with the Payette formation of the foothills, a correlation which the field work had shown to be very probable. Considerable masses of fossil wood are reported to have been found in the lake beds at the mouth of Steamboat Gulch, 1 mile southeast of Idaho City.

The lake beds attain their greatest development south of Idaho City, where they are more than 300 feet thick. Their character is here prevailingly sandy, with some medium-coarse gravels and with occasional coaly and clayey layers. The exposure illustrated in fig. 58

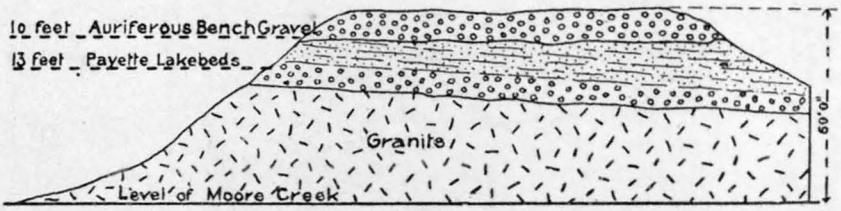


FIG. 59.—Bench gravel and lake beds at mouth of Granite Creek, 2 miles west of Idaho City.

indicates an apparent unconformity in the lake beds. They continue up the creek, decreasing in width, to the mouth of Granite Creek. Good exposures are seen at Brockhausen and Spiro's claim, between Granite and Bannock creeks, where the bench gravels rest on them. Fine gravels here appear in the lake beds, interstratified with clay and sand. At the little bench just south of the mouth of Granite Creek, 12 feet of lake beds, dipping 4° W., at first gravelly, then sandy, rest on granite, and on the eroded surface of the lake beds rests a patch of bench gravel 50 feet above the main creek. A few quartz pebbles are present in the gravel of the lake beds (fig. 59).

A small area of clayey lake beds is said to exist on the high plateau several hundred feet above Moore Creek and about 2 miles east-southeast of the mouth of Granite Creek.

The contacts of the lake beds with the granite offer points of great interest. It has already been noted that lake beds rest on granite near Turner's claim, at the east end of Gold Hill, and at the mouth of Granite Creek. Everything indicates that they were laid down on an uneven surface, and probably in a valley with configuration similar to that of the present Moore Creek Basin. But at many other places

it is clear that the lake beds are separated from the granite by normal faults. One mile below Warm Springs, on both sides of Moore Creek, there is evidence that the lake beds abut directly against the granite. The same relation is noted at the sandstone bluff, 300 feet high, back of Warm Springs. Here the almost horizontal lake beds abut against a steep granite bluff, and a little lateral valley has formed along the contact. There can hardly be any doubt that this steep bluff represents a fault-scarp. The deeply incised gulch just southward gives similar testimony as to the sharp abutment of the two formations against each other.

A small hot spring is located at a point on this fault, and the large warm springs probably also issue from this fault, though at present they break out through the sandstone a little below it. The water has a very high temperature, and the total quantity is probably not less than 100 miner's inches. The water is not rich in dissolved salts, but has a slight smell of sulphureted hydrogen. Mr. J. B. Hastings[1] thinks that this fault and the accompanying slipping down of this mass of conglomerate or sandstone caused the damming of a lake and the deposition of the lake beds. This can not be accepted as a correct explanation, for the sandstone is of the same age as the lake beds, the deposition of which was caused by events much farther reaching than a landslide.

All along the southern contact line of lake beds and granite, from Moore Creek below Warm Springs to beyond Bannock Creek, the evidence of a fault is very decided. Nearly everywhere along this line the lake beds cease suddenly, and south of them the granite rises in a steep bluff, contrasting strongly with the confused topography of the soft and sliding lake beds. The best evidence is found at the contact back of Barker's claim, where the contact plane between granite and lake beds is found to dip at an angle of 45° N. A similar and extremely well-exposed fault is shown on both sides of Elk Creek at the northern end of Gold Hill at the mouth of Lincoln Gulch.

In conclusion, the lake beds of the Payette formation in the Moore Creek basin form an area of about 7 square miles; they dip west or northwest at angles of from 4° to 14°, and they are often separated from the granite by marginal faults. They are probably a remnant of a more extensive area preserved by reason of being sunk in the granite by movement along these faults.

A total thickness of from 300 to 400 feet is exposed above Moore Creek. The idea that rich gold gravel would be found below the lake beds led in 1894 to the sinking of a shaft and bore hole at Idaho City, only about 20 feet above the level of Moore Creek. One hundred feet of shaft were sunk, and then, when the water became too difficult to handle, a bore hole continued down to a total depth of 516 feet. It is reported that granitic bed rock was struck at that depth. Samples

[1] Eng. and Min. Jour., July 21, 1894.

of boring show mainly granitic sand and clay, with nodules of iron pyrite occurring at frequent intervals. The total thickness of the lake beds would, then, be not less than 850 feet. A few miners'-inches of saline water flowed from the well, as might indeed be expected, for the geological conditions are such that a typical artesian basin is formed.

Gold in the lake beds.—It is stated that no gold is contained in the lake beds or the false bed rock. This certainly seems, at first glance, to be a strange state of affairs, considering that the sands, clays, and gravels of the lake beds consist of practically the same material as the auriferous gravels. It would seem to imply that the quartz veins from which the gold was derived were formed between the period of the lake beds and that of the gravels. It will be shown, however, that the lake beds are not entirely void of gold. Those just south of the mouth of Granite Creek, shown in fig. 59, were prospected with the pan. In the lowest bed, consisting of coarse gravel with much sand, nothing was found; but 6 feet above the granite, in a finer gravel admixed with some quartz pebbles, several colors were found in every pan. The gold is extremely fine and of a rather pale color. There is very little black sand in this gravel, but a considerable quantity of monazite. The samples were taken under conditions that made it impossible for any of this gold to have been derived from the rich gravel above. Mr. Brockhausen informed me that in a claim one-half mile below the mouth of Granite Creek a considerable amount of gold was taken out of a bed of gravel dipping below the false bed rock.

At the mouth of Noble Gulch, opposite Idaho City, there is a bed of gravel a few feet thick dipping below strata of carbonaceous clay. This gravel has been worked and is reported to have yielded some gold. Mr. Barker informs me that a little gold may occur in the gravels of the lake beds wherever quartz pebbles are present. Mr. Kramer, who owns a claim one-half mile below Warm Springs, states that John Wood, former owner of the claim, obtained good prospects in a bed of gravel dipping under the false bed rock at that place. The locality is now covered up. Mr. Turner states that nodules of pyrite, containing a few dollars in gold and silver, are often found in the false bed rock. During the sinking of the artesian well at Idaho City certain strata were found to contain much iron pyrite, which upon being washed out and assayed was found to carry as much as $12 per ton in gold and silver.

It is conceded, however, that these occurrences of pyrite do not necessarily indicate an original content of gold in the lake beds, as the precious metals may have been leached from the overlying rich gravels and deposited with the pyrite below.

It is thus certain that free gold occurs in some of the gravel of the lake beds. That there could not be much of it present is clear from the mode of formation of the lake beds, for they were deposited by

rapid accumulation in a body of water affording no opportunity for concentration. Moreover, the detritus was mostly derived from the immediately surrounding hills, which are nearly barren of mineral veins, while the overlying gravels were transported, concentrated, and assorted by streams coming from the region of auriferous quartz veins. It is probable that a system of streams existed before the lake beds were laid down. It would naturally be expected that many of these should carry gold, and it is indeed probable that if the lake beds were removed we should find auriferous gravels on the bed rock along these lines of old stream courses. But it is extremely unlikely that a random bore hole would strike any of these deposits. They could be found only by prospecting along the margin of the lake beds and following down any rich stratum that might be found. In this case, however, the cost and difficulties of mining would be very great.

Olivine-basalt (*dolerite*).—One mile above Idaho City, on the north side of Moore Creek, there are peculiar outcrops of a black or dark-green very tough rock, weathering in rounded outcrops, which are commonly referred to as "nigger heads." Decomposing, they yield a dark-red, yellow, or green clayey soil. Gravel benches rest upon this rock, which apparently forms an intercalated bed up to 100 feet thick in the lake beds. The sheet lies flat at the point indicated, crosses Moore Creek in a narrow strait 2 miles above the city, and then, probably being tilted, rises to elevations of 400 feet above the creek near Pine Gulch. Here it is evidently separated by a fault from the granite. The same rock is found again in nearly every one of the small gulches entering Moore Creek opposite Idaho City, and here it is covered by a considerable thickness of lake beds and is exposed only in the bottom. It is a medium-grained, dark-green rock, with abundant scattered crystals of greenish-yellow olivine. Under the microscope it is seen to be a coarse olivine-basalt (dolerite), and to consist of large phenocrysts of olivine and small crystals of magnetite as the earliest product of consolidation. There is, further, a large amount of violet-brown augite in large anhedral individuals, forming a sort of base, in which are embedded the irregularly distributed laths of a basic feldspar (labradorite). The olivine decomposes to brownish-red products, also to serpentine; the augite to chlorite, with beautiful radial structure. The structure of the rock is really that of a diabase. This rock was evidently poured out on the surface as a lava at the time of deposition of the lake beds.

THE VALLEY OF GRIMES CREEK.

Configuration.—Four miles below Centerville the canyon widens to a broad valley with gentle slopes, similar to that of Moore Creek, extending in an east-northeasterly direction for 11 miles. Above this Grimes Creek makes a sudden bend, and, separated only by a low ridge from the deep canyon of the Payette River, finally reaches its

headwaters at Summit Flat. Only two tributaries join it—Clear Creek, heading in the rugged mountains near Wilson Peak, and Muddy Creek, heading a few miles northwest of Pioneerville.

Present stream gravels.—A large amount of tailings lies nearly all along Grimes Creek. At Centerville they are 900 feet wide; farther up they narrow considerably, where the hills approach closer to the creek, to widen again near Pioneerville; above this place the creek enters a rather narrow canyon. A great mass of tailings also lies in Muddy Creek. Clear Creek has never been washed, and the original wide alluvial grassy flats are here preserved in the lower course of the creek. Concerning the gold content of these tailings, the same remarks apply here which were made in relation to those of Moore Creek. They can doubtless be worked profitably in many places by means of hydraulic elevators or dredges. The difficulty is to obtain a sufficient water supply. The beds of Grimes Creek and Muddy Creek are reported to have been rich throughout, while Clear Creek did not pay well. Only a few of the side gulches contained gold in paying quantities. Willow Creek was rich, and contained near its head a body of angular gravel, known as Channel's claim, which has yielded much gold. Henry Creek, leading up to Summit mine, was also rich. The bulk of the gold appears to have come down from the headwaters of Grimes and Muddy Creeks.

The tailings are very sandy, being composed of almost 60 per cent sand and 40 per cent cobbles, and the maximum depth is 15 to 20 feet. The lower part of the tailings and benches of Grimes Creek, up to 3 miles below Centerville, is owned by the Grimes Creek Bed Rock Flume Company; the upper part, as far as several miles above Pioneerville, by the Wilson Company, which for many years has carried on active operations near Pioneerville. The creek has been worked as far up as the big bend at Grimes Pass, where the gravel is characterized by a great many heavy bowlders of porphyrite. Many similar cobbles of porphyries also occur farther down on Muddy and Grimes creeks. Pebbles of obsidian have been found on Muddy Creek.

Bench gravels.—As along Moore Creek, gravel benches occur at different elevations all along Grimes Creek. The two most prominent benches are at elevations of 30 and 60 feet above the present creek bed, but scattered gravel occurs at higher elevations also. Such is the thin gravel occurring near Centerville up to 150 feet above the creek. These bench gravels have been very extensively worked, and but little remains of them near Centerville. A short distance above Centerville, at a place called Bummer Hill, they were of unusual richness. Above the narrow canyon the bench gravels appear again in the open valley; where Muddy, Clear, and Grimes creeks join the same kind of benches are noted and hydraulic work has been actively prosecuted. Pioneerville is situated on the lower bench, 25 feet above the creek. A low bench gravel, one-half mile above town,

worked in 1896, is illustrated in fig. 60. The bed rock is at the creek level, and the work was done by means of hydraulic elevators, which have been extensively utilized by this company. The gold, which is generally of the size of mustard seeds, lies often on the higher bed rock instead of in the potholes. The lower gravel carries all the gold.

Older gravels.—The low terrace separating Muddy and Grimes creeks, one-fourth mile northwest of Pioneerville, and covered by later bench gravels, is partly made up of granite, partly of an older, somewhat cemented, granitic gravel. This belt is only about one-fourth mile wide, and the gravel abuts against the granite on the northern side, showing that it is separated from it by a fault. It is evidently an older gravel sunk down along a fault-line. On the southern side it apparently rests on granite. The same fault is well shown in the creek on the eastern side, one-fourth mile above the town. It is reported that a shaft 100 feet deep was sunk in this gravel some twenty years ago, without reaching the underlying granite. The gravel contains some coarse gold. The side hill immediately east of this fault is wholly composed of granite, but above, on the narrow ridge separating Grimes and Clear creeks, lies a body of somewhat similar gravel, attaining an elevation of 200 feet above the creek. Granite bed rock is found 120 feet above the creek, and on it rests a bed of coarse gravel containing some gold. Much of this gravel has been worked by the hydraulic process.

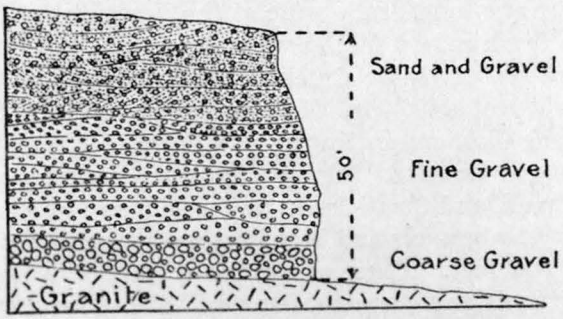


FIG. 60.—Bank of bench gravels one-fourth mile north of Pioneerville, level of Grimes Creek.

Lake beds.—No extensive areas of lake beds occur in this vicinity, but in the valley of Muddy Creek, 2 miles north of Pioneerville, a small patch of a rather remarkable deposit is found. For a distance of a mile the creek runs in a narrow canyon, which then opens to a somewhat wider valley. Here lie, chiefly along the western side of the creek, beds of soft white sands, gravels, and clays, with a little lignite. In one place where the stratification could be made out the layers seemed to dip 20° W. This small mass of sedimentary deposit has a lacustrine character, and should probably be correlated with the lake beds of Idaho City; it does not contain any gold, but the surface gravels resting on it are said to have been unusually rich, the softer beds having acted as riffles, catching the gold. On all sides the granite rises rather steeply. At Bummer Hill, one-half mile above Centerville, a granitic sand, which may possibly also belong to this lacustrine series, forms the bed rock.

Volcanic rocks.—A small dike of andesite occurs a short distance west of Grimes Pass, and fragments of obsidian have been found in Muddy Creek.

THE VALLEY OF GRANITE CREEK.

Configuration.—Granite Creek, joining Grimes Creek 3 miles below Centerville, extends from this point in a north-northwesterly direction for a distance of 8 miles, heading at the low pass north of Quartzburg. A number of tributaries join it from east and west, producing, in the middle course of the creek, a large, basin-like depression. North of Granite a narrow canyon begins. Ophir Creek, Boyles Gulch, and Wolf Creek head at the relatively low divide toward the Payette drainage, while Fall Creek, Trail Creek, and Canyon Creek head in the Boise Ridge and carry a great deal of water. A broad ridge, only 400 feet high, separates Granite Creek and Grimes Creek.

Present stream gravels.—As in the districts already described, the larger part of the present stream gravels consists of tailings. They are one-fourth mile wide at the junction with Grimes Creek, but only a few hundred feet in width from that place to half a mile below the mouth of Ophir Creek. Here they widen and attain a maximum width of 1,500 feet. The tailings also reach far up on Ophir, Boyles, and Wolf creeks, but narrow down to 100 feet or less a short distance above Granite. Along the lower courses of Canyon Creek, Trail Creek, and Clear Creek, as far as 2 or 3 miles above their mouths, are stream gravels and low terraces, attaining in some places a width of 1,000 feet. These creeks have yielded scarcely any gold, and their gravels and terraces show well the character of the river courses of the basin before the gold discoveries. Clear Creek was entirely barren in its upper course. A little gold was found in one or two places along the creek which Hawkins toll road follows from Star ranch westward. Canyon Creek has produced a little gold, and Fall Creek a considerable amount. The main creek has been rich from the junction up to Quartzburg, while no gold is found above that town. Ophir, Boyle, and Wolf creeks were very rich up to their headwaters. The east fork of Alder Creek, which flows into the Payette and heads opposite Wolf Creek, has also produced some placer gold. It appears to be the only creek on the Payette side which is auriferous. The gulches running into Ophir Creek from the east have produced scarcely anything. In fact, most of the broad ridge separating Grimes and Ophir creeks is singularly barren. As to the working of the tailings in Granite Creek, the same remarks apply as have been made in the case of the other tailings mentioned above.

Bench gravels.—Benches are found at intervals all along Granite Creek as far up as half a mile above Granite; also for some distance up Ophir Creek, and up Wolf Creek as far as Placerville. There are usually two well-pronounced horizons, the bed rock of the lower one

being 20 to 30 feet above the creeks and that of the higher one at an elevation of 50 feet. Near Granite and Placerville bowlders of porphyritic rocks are abundant. The benches opposite Granite also contain many basaltic bowlders and pebbles, which are probably derived from the basaltic areas high up on the summits of the Boise Ridge, referred to later. On the broad flood plain of Fall Creek the bench gravels are very extensive, and reach an elevation of 4,380 feet above the sea, or 50 feet above Fall Creek. All of the benches along Granite Creek and its tributaries from the northeast have been worked for gold.

Older gravels.—Near Placerville and Granite are several very interesting occurrences of gravels belonging to a stream system which differed considerably from the present one and giving evidence of having undergone disturbances since their deposition. Two small and isolated gravel patches occur close together one-fourth mile northwest of Placerville, on Sailor Gulch. Each contains but a few acres. Both have been worked by the hydraulic process. The exposures show a 30-foot bank of medium-sized gravel with excellent fluviatile stratification. The gravel contains a great number of porphyry bowlders similar to the rock cropping near Quartzburg. The granitic bed rock slopes gently westward, and extends down to the present creek. The bed rock is 150 feet above the level of Wolf Creek at Placerville. A small area of similar gravel lies at the same elevation near the Pioneerville road, 1 mile east-northeast of Placerville.

Opposite Placerville lies the Ranch Company's claim, which has been extensively washed of late years and has produced much gold. This is a mass of older, compact gravels resting in a channel-like depression, and on which, along the creek, the later bench gravels have accumulated. In the early years this gravel was considered "false bed rock," and it was not generally supposed that it could be profitably worked. The gravel body lies on the ridge separating Boyles Gulch from Wolf Creek, the top of it being one-fourth mile wide and reaching an elevation of 200 feet above the level of the tailings at Placerville. It fills a depression or channel, the bed rock rising rapidly northward and southward. The lowest bed rock is exposed in the present diggings, and is at the bank 75 feet above the tailings at Placerville, sloping from there gradually down to the débris-filled stream-bed at the rate of 6 feet per 100 feet. The character of the gravel is shown in fig. 61. The gravels bear every evidence of having been accumulated in a stream of considerable size. They are coarse at the bottom, very well rounded, and contain abundant cobbles of the peculiar altered porphyry occurring near Quartzburg. No basalt bowlders were found. The gold is fine and evenly distributed through the mass of the lower gravel. On the eastern side of the ridge there are also hydraulic pits, and the deepest bed rock lies 135 feet above the creek bed at Placerville. At this point the channel suddenly

ceases. Across Ophir Creek the bed rock rises rapidly in all directions, and no possible continuation can be suggested except down the narrow canyon of Ophir Creek. Furthermore, the nature of the pebbles indicates that the stream came from some point to the northwest, whereas the present grade of the bed rock is in exactly the opposite direction. The conclusion is almost unavoidable that the channel has been cut off by a fault and its grade reversed.

On the point between Wolf Creek and Boyles Gulch a little of the same compact gravel occurs just at the edge of the tailings. Placerville appears to be built on a similar compact gravel, in which narrow benches were cut by the present stream, though just below the town granite bed rock appears at the edge of the tailings. Due southwest of Placerville, on the slope up to the summit of the level ridge between Granite and Wolf Creek, no bed rock appears to have been found. Neither has there been any bed rock found on the opposite slope from this ridge down to Granite Creek. A broad, low bench fringes the northeast side of Granite Creek below Granite. Bed rock has never been found for some distance below Granite in the creek. All this appears to indicate that the Ranch Company's channel continues with gradually sinking bed rock across Granite Creek.

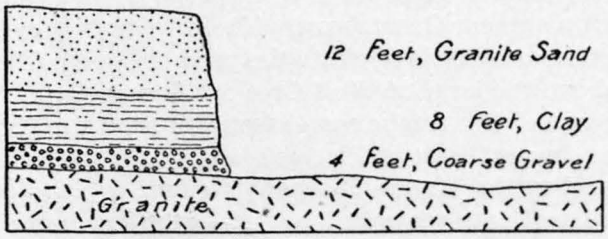


FIG. 61.—Bank at the Ranch Company's claim, Placerville.

Interesting conditions also obtain across Granite Creek on the broad flood plain of Fall Creek, where it emerges from the narrow canyon in the Boise Ridge, here suddenly rising as a steep escarpment facing west. This place, called Norwegian Flat, at present worked by the Kennedy Company, is extensively covered with rich bench gravels up to the mouth of the canyon. This bench gravel, which is rarely over 25 feet in thickness, does not rest on granite, but on a harder, more compact gravel, which contains some gold and which is of the same general character as the Ranch Company's gravel. At the upper end of the claim, near the mouth of the canyon and the foot of the escarpment, this "false bed rock" is found to suddenly abut against the granite, strongly suggesting that it is cut off by a fault. No shafts have ever been sunk in this lower gravel. It is probable that it is the same channel continuing across Granite Creek, and that it is cut off at both ends by faulting. On the hills to the right and left of Fall Creek a similar compact gravel also occurs, seemingly continuous with that of the deepest channel. Thus the low ridge between Fall and Canyon creeks is covered, up to an elevation of 80 feet above Fall Creek at the upper end of Kennedy's claim, and a similar body

reaches high up on the ridge between Fall and Granite creeks nearly to the Newburg or Lawyer quartz claim. It is said to be quite rich here, though hard, and difficult to work on that account and because of the scarcity of water. On this ridge the older gravel distinctly rests on the granite, and its thickness reaches a maximum of 200 feet. Its highest elevation on the ridge near this quartz mine is 4,900 feet, or 500 feet above the upper end of Kennedy's claim.

Gravel on the Boise Ridge.—A very remarkable occurrence of gravel was found on the summit of Boise Ridge 3 miles west-northwest of Quartzburg. The broad, flat summit extends northward from Hawkins Pass, with a winding direction, caused by the deeply incised gulches, and an elevation of from 6,500 to 7,300 feet above the sea. North-northwest of Quartzburg lie, on the summit, several hundred feet of scoriaceous basaltic flows, which extend down into Jerusalem Valley on the west. In this basalt there occurs, at an elevation of 6,900 feet, one-half mile south of the sharp point, with an elevation of 7,200 feet, a small body of gravel. It could not be determined whether this gravel is intercalated between the basalt beds or forms an inclusion in the same, but the former is more probable. At any rate, the gravel is well washed, of granitic character, and is said to contain some gold. This occurrence is of the greatest interest, as it clearly indicates that a very great disturbance has taken place since the eruption of these basalts, for the gravel could not possibly have been formed with the present topographic features. Considered in connection with the faulted old gravels at the eastern foot of the escarpment, 2,700 feet lower, it points to a great disturbance along the eastern base of the Boise Ridge.

Basalt.—The whole of the high portion of the Boise Ridge south of the latitude of Quartzburg is remarkably free from any late eruptions. At the locality mentioned in the preceding paragraph, culminating in the hill with an elevation of 7,200 feet north-northwest of Quartzburg, the very even, flat surface of the granitic ridge is capped by 300 feet of massive basalt. Above the massive basalt lie 200 feet of tuff and scoriaceous basalt, again covered by 100 feet of fresh and massive olivine-basalt. These basaltic flows slope rapidly westward, and the ridge on the north side of Brainard Creek is, as seen in Pl. LXXXIX, composed of a great number of superimposed thin basaltic flows, all dipping northwest at angles of 30° or 35°. The photograph is taken from a gap in the ridge between Brainard and Porter creeks, 3½ miles west-southwest from the high basalt peak in the Boise Ridge. Taken in connection with the probable fault along the eastern side of the range at Granite, it certainly appears as if a westward tilting had formed part of the orographic movements in this vicinity since the time of the deposition of the lake beds. The basalt is much older than the basalt of the lower Moore Creek, and in all probability is contemporaneous with the lake beds.

Other small basalt areas were noted near Hawkins toll road, 2 miles west of Star Ranch. This basalt forms a dike on the high ridge between the toll road and Clear Creek, follows the road for some distance near longitude 116°, and appears again on the ridge north of the road. Here it is in part vesicular, and appears to have flowed out from the dike. This basalt is probably also of Tertiary age.

FINENESS OF THE GOLD.

The fineness of the placer gold varies from 770 to 912. The following list gives the value at some of the principal localities:

Value and fineness of placer gold at principal localities.

Locality.	Value before melting.	Fineness per mill.
Idaho City, Turner's claim (bench gravels)	$16.75	.....
Idaho City, East Hill (high gravels)	16.50 to 16.75	.....
Idaho City, Barker's claim (high gravels)	.....	850
Pioneerville (bench gravels)	15.35	770
Placerville, Ranch Company claim (old channel gravel)	.....	912
Placerville, Granite Creek (bench gravel)	.....	850
Placerville, Fall Creek	.....	775
Placerville, Ophir Creek	.....	910
Placerville, Wolf Creek	.....	910

WATER SUPPLY.

The water available for placer work is not abundant; in fact, usually the working season is only from three to four months. The streams are not large and do not head among very high mountains, so that the flood from the melting snows soon subsides. It would be possible, but hardly practicable, to carry a ditch to the basin from the headwaters of the Boise or the Payette. The principal ditches are as follows:

MOORE CREEK.

1. The upper Moore Creek ditch. Takes water from Moore Creek 5 miles above Gambrinus Gulch. Capacity, 600 miner's inches.
2. The Lambing ditch. Dam below Illinois Gulch. Capacity, 350 miner's inches.
3. The Christie ditch. Dam above mouth of Granite Creek. Capacity 1,100 miner's inches. These three are on the northwest side of Moore Creek.
4. Thorn Creek ditch. Takes its water from Thorn Creek, dumping it across the divide into Pine Creek; used for the high gravels south of Idaho City.
5. Channel ditch. Dam on Elk Creek one-half mile above Elkhorn Mill. Capacity, 600 miner's inches. Covers divide between Elk and Grimes creeks.
6. Mann's ditch. On south side of Elk Creek. Dam 1 mile above Forest King Gulch. Ten miles long. Covers Gold Hill at Idaho City.

7. Anderson ditch. Takes water from Elk Creek below Boulder mine.
8. Cuddy ditch. Takes water from Elk Creek below Boulder mine.
9. Dunn ditch. Takes water from Elk Creek below Boulder mine.

GRIMES CREEK.

The water supply is here largely controlled by the Wilson Company. The principal ditches are as follows:

1. Wilson ditch. 12 miles long, on west side of Grimes Creek. Dam located 1 mile below Charlotte Gulch. Capacity, 2,000 miner's inches.
2. Gold Trap ditch. 7 miles long, also on west side of Grimes Creek.
3. American ditch. 6 miles long, west side of Grimes Creek. Dam at Charlotte Gulch.
4. Mountain ditch. 8 miles long, west side of Grimes Creek. Also two shorter ditches from Clear Creek.

GRANITE CREEK.

The water supply is here controlled by the Ranch Company and the Kennedy Company. The Ranch Company's ditch is 14 miles long, and takes water from Granite Creek above Quartzburg. Capacity, 1,000 miner's inches. Other ditches lead from West Fork, Fall Creek, and Canyon Creek.

The hydraulic washings use a pressure of from 100 to 350 feet. There are rarely more than 600 miner's inches used in each monitor. Hydraulic elevators have been used by the Wilson Company to work low-bench gravels and tailings. The gravel is elevated from 10 to 25 feet. Five hundred miner's inches are here used for the monitors.

GROUND AVAILABLE FOR FUTURE WORK.

The largest amounts of gravel remaining near Idaho City are on East Hill and Gold Hill. Though some of the bench gravels remain they are getting rapidly worked out. In the Grimes Creek drainage some bench gravels still remain near Pioneerville. In the Granite Creek drainage there is a considerable area of low-bench gravels yet untouched near Granite, on both sides of the creek. Considerable gravel remains at the Ranch Company's ground near Placerville. If the conclusions in this paper are correct, there is also a large amount of gravel on the ridge between Wolf Creek and Graniteville.

In all three drainage branches there are vast amounts of tailings which, with suitable appliances, may be worked over again. But there is no doubt that the placers in course of time will be exhausted. That they are not already exhausted is due to the limited water supply

THE MONAZITE SANDS.

The sand of the gravels and lake beds of the Idaho Basin is entirely derived from the granite and associated dike rocks. It consists of relatively angular and sharp-edged grains, indicating its manner of formation by extremely rapid accumulation from the deeply disinte-

grated rocks. The heavy minerals found in the granite are also found in the sand, and may be easily separated by washing in the miner's pan; they are always deposited in the sluice boxes with the gold.

In all parts of the basin a yellow or brownish-yellow mineral forms a considerable quantity of the heavy substances remaining with the gold. It is usually referred to as "yellow sand," and is also given the picturesque name of "Bummer Hill sand," from a locality near Centerville, where it was particularly abundant, but I am not aware that its true character has ever been investigated.

The mineral has been shown to be monazite, this being the first time its occurrence has been noted from the Western States. As is well known, it occurs abundantly in the granite and gneissoid rocks and gold-placer mines of the Southern Appalachians, and in several of the North Atlantic States, also in Brazil, the Ural Mountains, and other places. There is no doubt that it forms an original constituent of the granite of the Idaho Basin.

One of the samples was obtained in washing a few pans of the sandy lake beds occurring as "false bed rock" in a gravel bench at the junction of Moore Creek and Granite Creek, 3 miles east of Idaho City (see fig. 59). The heavy residue consisted largely of small yellow grains and amounted to about 2 grams per pan of 8 kilograms, which would correspond to 0.025 per cent. The microscope revealed the following minerals: Ilmenite in sharp hexagonal crystals, but no magnetite; zircon, also in extremely sharp crystals of a slightly brownish color, and abundant yellow or greenish-yellow grains rarely showing crystallographic faces. The refraction and double refraction of the latter mineral were very high; the hardness not much over 5. The ilmenite was eliminated by the electro-magnet, and the remaining powder, containing about 70 per cent of the yellow mineral, was analyzed by Dr. W. F. Hillebrand. The result showed it to be a phosphate of the cerium metals, the approximate amount of the oxides of the latter being 48 per cent; in these approximately 1.20 per cent of thoria was found. This result identifies the mineral with monazite, the only other similar mineral being xenotime, which is mainly a phosphate of yttrium with but little cerium. The samples also contained a considerable amount of titanium, which would indicate that some titanite is present. Practically all of the ilmenite was extracted by the magnet.

Another sample, furnished me by Mr. T. Myer, of Placerville, came from the alluvial gold washings in Wolf Creek, near that town. Cleaned from quartz, etc., it appeared as a heavy dark sand consisting of a black iron ore (ilmenite), rounded crystals of red garnet, sharp crystals of zircon, and irregular grains of a dark yellowish-brown mineral with waxy luster, sometimes showing crystallographic faces. It was found impossible to extract more than a small

part of the iron ore by the magnet. There was practically no magnetite present. This sand was examined qualitatively by Dr. Hillebrand, who found phosphoric acid, cerium metals, and thorium. The yellowish-brown material is therefore, in all probability, monazite.

Monazite has, as is well known, a certain economic value, as the oxides of the rare earths contained in it are used for the preparation of the incandescent gaslights of the Welsbach and other burners. A considerable amount of monazite sand has been produced during the last few years in the Southern Atlantic States, chiefly North Carolina, and in Brazil. The prices have varied from 3 to 25 cents per pound, according to the purity and the percentage of thoria. The North Carolina monazite contains between 0.17 and 6.20 per cent of this rare earth. Mr. Waldron Shapleigh, chemist for the Welsbach Light Company, kindly gives (March, 1897) the following information in regard to present production and price:

At present the monazite sand market is very dull; hardly any demand, and only in lots of a few tons. The present price in North Carolina is 6 cents per pound, but it can be bought a little lower than this. Brazilian sand is quoted in New York at 4¾ cents per pound, fully equal to the North Carolina sand, in 5 or 10 ton lots. Larger orders can be placed in Brazil at a much lower figure. The price has been steadily downward, as the supply from the mines now opened is far greater than the consumption. It is not generally known that during the first eighteen months or two years of this new industry enough sand was mined and purchased by the largest manufacturers to last several years to come, as so far it has but the one use. The manufacturers did not know how extensive the sand deposit was; therefore were desirous of securing a large and safe stock at the start.

The largest purchasers are the Welsbach Light Company of Vienna, supplying Europe, and the Welsbach Light Company of Philadelphia, which supplies America. I should hardly think that Western localities could compete with North Carolina and Brazil, unless the mineral is of a very superior quality or a by-product.

At present there would be no difficulty in placing an order for several thousand tons per year in Brazil and having it filled.

The widespread occurrence of monazite in considerable quantities in the Idaho Basin raises the question whether the deposits can be profitably worked. The present low price and the high cost of transportation and labor make this very doubtful, unless it be saved as a by-product in the placer mines. It will be necessary to extract all ilmenite by strong electro-magnets. In this manner a comparatively pure product may be obtained. It is not practicable to entirely separate the zircon and garnet from the monazite. The purest material was obtained from near Idaho City, while that from Placerville and vicinity contains a large amount of ilmenite and garnets. Many data in regard to the character and production of monazite may be found in a paper by Mr. H. B. C. Nitze, in the Sixteenth Annual Report of the United States Geological Survey (1894–95), Part IV, pp. 667–693.

RELATION BETWEEN PLACERS AND QUARTZ VEINS.

The dependence of the gold placers upon the occurrence of gold-quartz veins is very strongly brought out by a study of the occurrences of both. While there are many small quartz seams occurring throughout the granite, some of which may contain a little gold, it is perfectly evident that there are two regions in which quartz-vein deposits are concentrated. These are, first, the Gambrinus mining district, on the ridge between Elk Creek and Moore Creek, continued by the Elkhorn mining district, at the headwaters of Elk Creek; and second, the gold belt extending from the Boise Ridge near Quartzburg to Grimes Pass. Every creek and ravine leading up to these deposits has been rich, while the watercourses rising in other parts of the range are comparatively barren. It seems clear beyond doubt that most of the gold in the gravels near Idaho City came down the Illinois and Gambrinus gulches; above these Moore Creek becomes comparatively poor. What gold there is has doubtless been derived from the more distant veins at the very head of Moore Creek, near Summit Flat. In nearly every case an exceptionally rich ravine has been found to lead up to a quartz vein. Thus it is clear that the recently discovered Summit mine, on the ridge between Elk and Grimes creeks, furnished the gold found in Deer Creek and Henry Creek. The only occurrence to which some doubt is attached as to the derivation of the gold is that of the rich angular gravels at the head of Spanish Fork and Willow Creek, but it is probable that they are derived from local seams and veins.

The headwaters of Grimes Creek furnish a most convincing argument in favor of the derivation of the gold from the quartz belt. Every gulch heading along the line of that belt is rich, while every one not crossing it carries only extremely small quantities of gold.

The conclusion is that practically all of the placer gold in the district has been derived from the quartz veins in these two districts.

On an average the fineness of the gold in the quartz veins is a little less than that in the placers. This has generally been the experience in most mining districts, and is accounted for by a dissolving of the silver and baser metals from the surface of each grain of gold. The highest grade of quartz gold is found near Quartzburg, and in the gravels of Placerville, derived from the Quartzburg mines, the placer gold is of unusual fineness.

CHAPTER IV.

THE IDAHO BASIN (CONTINUED).

THE PRE-TERTIARY ROCKS.

GRANITE.

The Idaho Basin forms a part of the great granite area of the Boise and Payette drainage, and the pre-Tertiary rocks consist exclusively of granite, together with a number of porphyritic dikes, probably intruded shortly after the granitic intrusion. It has been stated before that the age of this granite is unknown. If Archean, as has been supposed, the slight amount of compression and change it has undergone is certainly remarkable. A shearing is often noticeable, dividing the rock into sheets or plates upward of a foot thick. The direction of the shearing varies considerably, and is sometimes parallel to the general direction of the quartz vein. In Gambrinus and Sub-Rosa gulches a strike of N. 20° to 24° W. and a dip of 70° E. or W. were noted. In the Ranch Company's claim at Placerville the sheeting is parallel to the direction of the Quartzburg gold belt; strike, N. 45° E.; dip, 60° SE. On Hawkins toll road, on the western slope of the Boise Ridge, the strike is N. 60° to 70° W. and the dip 70° to 80° N. or S. Conjugated systems of shear planes, having the same strike, but dipping in opposite direction, thus occur here. In the depressions and low ridges of the basin the granite is disintegrated to considerable depth, so that it is very difficult to secure good specimens. The disintegrated granite forms a coarse, yellowish-gray sand, the individual grains of which have undergone but very little decomposition, and which is easily swept down into the creeks by the rain storms. Fresher and harder rocks crop out on the high ridge between Elk and Moore creeks, upon which the Forest King and other mines are located. The outcrops form brilliant white rounded masses; but even here the disintegration has made rapid progress. On the Boise Ridge the granite is ordinarily soft and crumbling. The deepest disintegration is probably found about the head of Muddy and Ophir creeks, where a good outcrop is only rarely seen. The granite area extends northward across the Payette River and far to the north of it.

The granite has a coarse grain, the average size of the constituents being 3^{mm}. The reddish orthoclase crystals are often very prominent.

The rock is composed of gray quartz, white or reddish feldspar—partly orthoclase, partly an acid soda-lime-feldspar—and small biotite flakes, the incipient decomposition of which usually gives the rock a rusty aspect. Hornblende is rarely found. Muscovite often occurs in the more acid varieties. Of accessory constituents, which are best studied by washing the decomposed sandy granite, there are: Ilmenite in often perfect crystals (though little or no magnetite appears to be present), apatite, zircon in extremely sharp, slightly brownish crystals, small garnets, titanite, and brownish or yellowish imperfect crystals of monazite. For description of the monazite sands, see pp. 677–679.

DIKES ASSOCIATED WITH THE GRANITE.

The granite is traversed by dikes, which in some places become very numerous and large. Dikes of granite-porphyry and aplite are common, though rarely very long and wide. Many such dikes, together with others of pegmatitic character, occur; for instance, along the road southwest of Idaho City and on the hill, with an elevation of 6,200 feet, due south of the town.

Dark-colored, lamprophyric dike rocks, which generally belong to the minettes, were noted in a few localities. These dikes are, as a rule, narrow, and their occurrence is closely connected with that of the veins. From the Sub-Rosa and Forest King mines dark-gray, fine-granular dike rocks were collected, generally rich in black mica. In thin section the former appears as typical minette, consisting of biotite, augite, magnetite, and orthoclase, with panidiomorphic structure. The feldspar crystals show a tendency to radial or spherulitic arrangement. A similar minette, consisting of biotite, hornblende, and orthoclase, was collected at the Gold Dollar tunnel, 1,000 feet east of the pass leading from Placerville to Garden Valley. The dikes evidently antedate the veins.

The Boise Ridge south of Quartzburg contains scattered dikes of granite-porphyry and diorite-porphyrite, but near the latter locality begins a very important belt of dikes intimately connected with the Quartzburg belt of gold deposits. The rocks are in all respects similar to those which appear at Willow Creek mining district; the latter may in fact be regarded as the westward extension of the Quartzburg belt, having the same direction and lying in its continuation to the west-southwest, but a distance of 8 miles, barren of mineral deposits and dikes, separates them. The dikes do not follow the mineral deposits in detail and are very irregular, sometimes only a few hundred feet wide, then again expanding to a width of over a mile. Owing to unusually deep residuary soil on the divide toward Payette River, the contact of granite and porphyries is generally difficult to trace, and the areal extent indicated on Pl. XCVI must be regarded as only approximately correct.

The porphyry begins at the Mountain Chief and Belzazzar mines, where it occurs as a wide belt extending across the vein and forming a considerable part of the hill to the east of the mines. Large masses of a similar porphyry occur in the lower part of Fall Creek, and it continues eastward toward Quartzburg as a narrowing belt. The rock in this area is a characteristic light-colored hornblende-porphyrite, consisting of white plagioclase in stout prisms up to 1^{cm} long, and idiomorphic hornblende crystals up to 5^{mm} in length, embedded in a fine-grained groundmass of feldspar, hornblende, and a little quartz.

At Quartzburg the porphyry belt is only a few hundred feet wide and has undergone great thermal alteration, secondary minerals like pyrite, muscovite, and calcite being abundant. On the Gold Hill mine dump specimens of fairly fresh rocks were collected. Some of them are very similar to the above-described rock. The abundant large white feldspars are labradorite, according to extinction of numerous Carlsbad twins. There is no hornblende left undecomposed, but there is some light-brown biotite in process of conversion to chlorite. The groundmass is micropoikilitic, consisting of quartz and unstriated feldspar. Another variety, greatly altered, of a yellowish color and impregnated with pyrite, is characterized by large corroded quartz crystals, up to 1^{cm} in diameter, and large porphyritic labradorite, greatly altered by sericitization. The groundmass is fine-granular, probably micropoikilitic, of quartz and feldspar, but now greatly filled with sericite.

East of Gold Hill the porphyry belt widens considerably. Quartzburg Hill is composed of quartz-diorite-porphyrite. This rock, similar to that described from the Belzazzar mine, forms the largest part of the area. It crosses Wolf Creek as a wide belt, and is here accompanied by dikes of more basic rocks. Two miles north of Placerville a dike of norite-gabbro crosses the road and a dike of normal diabase appears in the same vicinity. East of Wolf Creek the area widens still more and reaches its maximum width. At Sweet's Claim, one-half mile west of Grimes Pass, the porphyry is narrower. A specimen from the Northern Star shaft shows the same idiomorphic large feldspar and hornblende crystals. The former are very fresh and consist of labradorite; the latter are sharply idiomorphic and partly chloritized. The groundmass is microcrystalline allotriomorphic, being made up of quartz and unstriated, clouded feldspar.

This porphyry belt was not followed east of Grimes Pass, but it is apparent that it attains great development among the high hills rising beyond it. Clear Creek contains a great abundance of porphyry bowlders. They are practically the same quartz-diorite-porphyrite which is described above. Quartz is evidently always present in the groundmass, and sometimes also as porphyritic crystals.

THE QUARTZ VEINS.

THE IDAHO CITY GOLD BELT.

In the immediate vicinity of Idaho City very few quartz veins occur, and none of importance. Mr. Plowman states that a big quartz vein was found on Wallula Flat, 2 miles east of Idaho City, on the northern side of the creek. A narrow streak in this vein carries gold. About 1 mile due south of Idaho City the Keystone mine was located on a large but apparently barren vein.

Six miles northeast of Idaho City, on the ridge between Moore Creek and Elk Creek, is the Gambrinus mining district.

The Blaine vein is situated on the Moore Creek side of the ridge. The developments are small, though some fair ore has been extracted and milled. There is a 5-stamp mill on the property.

The Chickahominy vein lies a little higher up on the ridge and a few hundred feet south of the Blaine. It was worked in the early days, and a large mill was erected on Moore Creek 4½ miles above Idaho City.

The Illinois vein.—This important deposit, which can be traced for 1¾ miles, is located three-fourths of a mile above the Blaine, and crosses the ridge at an elevation of 5,100 feet. The vein has an average strike of a few degrees north of west and dips to the south at an angle of from 45° to 50°. It is inclosed in granite throughout, though smaller dikes of porphyry occur occasionally in this granite. The vein is one of the strongest in the basin, and it is very clear that it has furnished a large portion of the placer gold in Moore Creek. It contains a great deal of finely distributed gold all along, and some good pay shoots besides. Illinois Gulch, draining this vicinity, is reported to have been extraordinarily rich.

The Eureka claim lies at the eastern end of the vein. Its production amounts to $30,000, and besides much was taken from surface diggings near the vein. A 10-stamp mill stands on the claim, which has not been worked since about 1880. The vein is a large, composite one, similar to the Illinois, to be described later. At the time of its exploitation an ore shoot in this vein was worked down to a small depth, where it is said to have been lost. The developments are slight, consisting only of a tunnel and a shaft 60 feet deep.

The Lucky Boy adjoins on the west. The developments consist of only a few prospect holes. The strike is N. 81° W. and the dip 50° S. The exposures show 8 feet of decomposed and sheeted granite, with small quartz seams. Some pay ore is found on the foot wall. Two parallel veins exist, one 30 feet south and the other 200 feet north of the main fissure.

The Illinois, consisting of two claims, is the principal producer of the vein. It was located in the early days, as it was soon seen that

the rich placers led up to the vein. The production is stated to be $225,000, which has been chiefly taken out in small batches of very rich ore. Some ore from this claim was crushed in 1895 in the Blaine mill. The deposit is characteristic of many veins in the Idaho Basin. Large masses of quartz are hardly ever seen. The strike is N. 71° W. and the dip 40° S. The vein consists of a wide zone of sheeted and fractured granite, with abundant small quartz seams between the joints of the sheets or ramifying through them. These small quartz seams carry the gold, while the granite between them, though usually altered, soft, and decomposed, contains no pay. This sheeted zone is here 30 to 40 feet wide and contains gold throughout. The principal pay shoot is, however, 400 feet long, and one streak, 2 feet wide, in this pay shoot is particularly rich. The deposit has been sluiced off on the surface and then worked by means of a crosscut tunnel from the gulch. A cross seam, also carrying some gold, joins it in Illinois Gulch, and a parallel vein is also said to exist. The ore is practically all free milling on the surface. Even when sulphurets are met with in depth it is probable that a larger proportion of the gold will remain in free condition. The developments may be said to be very slight and unsatisfactory, but it is probable that if properly opened the vein would furnish great amounts of low-grade ore, which, with suitable and cheap methods of extraction and reduction, might be made to pay. The width of the vein and the soft character of the rock would make mining somewhat expensive and difficult.

The Chicago claim, on which but a slight amount of development work has been done, adjoins on the west, beginning near the road on the summit of the ridge.

The Populist vein.—This vein is situated 1 mile west-northwest of the Illinois. It has a similar strike and dip, and some work has been done on it recently.

The Cleveland vein.—This relatively small vein is located 5 miles north-northwest of Idaho City, on the south side of Forest King Gulch, at an elevation of 5,030 feet. It is a single-fissure vein, about 1 to 2 feet wide, inclosed in granite, striking a little north of west and dipping 60° S. A rich shoot 100 feet long was found on it a few years ago, which yielded a considerable sum of money; it has not been followed below the present tunnel level. The mine is of interest as showing plainly the result of faulting, illustrated in fig. 62. The vein is thrown a distance of 60 feet horizontally in the hanging wall. At least two faults of this character are known. If movements in only a vertical direction have taken place, this fault is certainly an overthrust, the hanging wall having moved up relatively. As, however, lateral movements may also have occurred, it is possible that the present position of the vein may be due to an oblique movement to the southwest, the direction of which makes with the horizontal an angle of between 0° and 60°, the hanging wall having moved down

relatively. While this is possible, the probabilities are strongly in favor of an overthrust.

The Gambrinus (Surprise) vein.—This large deposit is situated 5½ miles north-northeast of Idaho City, on the summit of the ridge between Elk and Moore creeks and near the foot of the steep Forest King Hill. The elevation is 5,480 feet. It was discovered in 1864, and the principal work was done between 1864 and 1865. The total production is $263,000. The strike of the vein is N. 61° W., and the dip, measured on the exposed foot wall, is 45° S. It can be traced for some distance westward, and the Buckeye forms the western extension. The vein has a maximum width of 40 feet, and is of the same composite type as the Illinois, consisting of a sheeted zone in granite with a great many small and rich quartz seams between the joints, these seams containing all the pay. The surface is very greatly decomposed and has been extensively sluiced. Two chimneys or shoots of rich ore were found close together, dipping east on the plane of the vein, at first steep and then more gentle. These shoots were not nearly so long as the Illinois ore body, but richer. The ore contains antimonite, and this mineral appears to be closely associated with the gold. The vein has been developed only by short tunnels and small shafts, not over 100 feet deep, and appears, like the Illinois, to deserve much more extensive prospecting. The same difficulties in the way of water and heavy ground will probably be met with in depth.

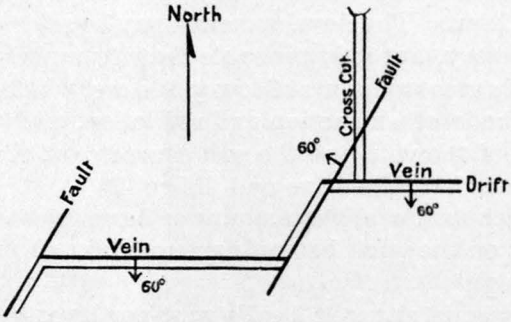


FIG. 62.—Diagram of fault in the Cleveland vein.

The Boulder vein.—This deposit is located on Elk Creek, 6½ miles north by east of Idaho City, at an elevation of 4,830 feet. Preparations were made a few years ago to exploit this vein on a large scale, and an excellent 30-stamp mill, to be driven by water power, was built. It was run for only a short time, the ore probably being of too low grade to handle profitably; neither was there much ore in sight, so that it would have been necessary to sink below the creek level almost immediately. The vein, which crops for only a short distance and is marked on the canyon slope by quartz croppings several feet thick, strikes on the surface N. 75° W. and dips 50° S. It is opened by a tunnel 900 feet long. The general character is the same as the Gambrinus and the Illinois, being a very wide (up to 40 or even 60 feet) zone of sheeted granite filled with many small seams of quartz carrying pyrite, arsenopyrite, and zincblende scattered through it. As it was necessary to mine the whole width, though the pay was

only in the narrow seams, and as the ground was very soft and heavy, square timbering had to be used. Underground the vein appears to strike N. 20° W., from which disagreement with the surface strike it would appear that the vein has been considerably disturbed. A narrow vein in the hanging wall of the big deposit was mined during 1896 and furnished small quantities of very rich ore. This was not much decomposed, and indicated what the character of the ore will be in depth. It contained bunches of pyrite, arsenopyrite, and blende, with a gangue of quartz and some calcite. The fresh sulphurets contained much coarse gold, the ore being free milling to 70 per cent of its value. It is probable that most of the vein in the Gambrinus mining district will remain largely free milling as depth is attained. The value of the coarse gold in the sulphurets is $15 to $16. The fineness of the amalgamated bullion is 680 to 718.

Mona MacCarthy is the name of a small vein located three-fourths of a mile west of the Boulder, on the high side, and lying between the Boulder and the Forest King veins. Some work has been done on it. Many small seams are found between this vein and the Forest King.

The Sub-Rosa or Forest King vein.—This vein is traceable for a distance of 2 miles from the Washington mine on the east to beyond the Forest King on the west. It crops in hard granite throughout, though at several places dark-green, dioritic dikes appear near it or cross it. Though narrower than the Illinois and the Gambrinus, it has produced some good pay shoots.

The Forest King was located in 1875, and a 10-stamp mill was erected on it in 1884. The elevation of the mill is 6,280 feet. The United States mineral monument of the district is indicated by an iron rod in an outcrop close by. No work has been done on the vein during the last few years. The vein shows on the surface in quartzose croppings, which do not contain any pay. It is opened by a tunnel 900 feet long, through granite, which shows several seams dipping southward. The vein consists of a zone, several feet wide, of crushed granite with smaller quartz seams. It strikes N. 56° W., and dips 60° S. The drift on the vein extends several hundred feet east and west. Three hundred feet west a dike, 20 feet wide, of a dark, syenitic rock (probably a minette) apparently cuts across the vein; but from the fact that the dike is full of small quartz seams, which all contain a little gold, it is probable that the dike is really older than the vein, and that the difference in appearance of the vein in the two rocks is due to the difference in their resistance to the dislocating force. A dike of the same rock, 1 foot wide, occurs in the crosscut, and is parallel to the vein in dip and strike. A 50-foot winze was sunk below the tunnel level, some distance west of the crosscut, in the bottom of which was found altered granite, with sulphurets and small quartz seams, giving assay values of $80 to $100 per ton.

A location called the Northern Light, on which some work has been

done, adjoins the Forest King on the east. The Sub-Rosa, also called the Confederate, is a claim on the same vein, 1,500 feet long, and located on the steep side hill toward Moore Creek. The topography is very rugged, owing to the depth to which the gulches have been incised in the granite. At the line between the Sub-Rosa and the Washington the elevation is 5,500 feet. The vein was worked many years ago by Mr. William Hooten, who extracted a considerable amount of very high grade ore from a comparatively small shoot. Then the mine lay idle for many years, until 1896, when work was resumed with the intention of finding the continuation of the pay shoot from a lower tunnel level. The strike of the vein is N. 56° W., and the dip is, as usual, to the south. The vein is several feet thick, consisting of a very soft clayey mass of altered granite with quartz seams. Many smaller dikes of lamprophyric rocks, chiefly minettes, occur near the vein. In one of the older tunnels it is clearly seen how one of these dikes is sharply cut off and faulted by the vein. The exposures in the lower tunnel of 1896, 300 feet below the old workings, are interesting. A small portion of the vein was found in about normal position, but on following it toward the west, in the direction of the ore shoot, it was found to be cut off by a dike of minette 20 to 30 feet wide, across which solid granite again was met. At first glance it would appear as if a later dike had cut across the vein and faulted it, but upon close inspection of the dike it is seen to be extremely crushed and separated from the vein by fault planes, and the probability is that the dike was intruded before the vein was formed, and that a subsequent fault has thrown the vein in the hanging wall, just as happened in the Cleveland vein. This is made the more probable as extensive explorations had previously failed to find it in the foot wall.

The Washington claim adjoins the Sub-Rosa on the east. This part of the vein was exploited a few years ago, and a considerable amount of gold was extracted. The mine is equipped with a 10-stamp mill, and is developed by a tunnel following the vein for 290 feet and a vertical shaft sunk to 316 feet at the mouth of the tunnel; three levels are turned from the shaft, and extend, the first to 400, the second to 250, and the third to 170 feet toward the east. The vein is vertical, and has about the same strike as the Sub-Rosa. An ore shoot 45 feet long and from 1 to 6 feet thick was found, and has been stoped from the 200-foot level up to the surface. The yield is reported to have been $90,000 from 4,300 tons, or $20 per ton. The ore was practically all free-milling and consisted of fresh quartz. A little pyrite occurred in depth. The shoot was cut off in depth by a small vein carrying silver, and its continuation beyond this is not known. Forty feet north of the gold vein, and separated from it by altered granite, is a strong vein of solid quartz, from 8 inches to 4 feet wide, which has been exposed by crosscuts from all levels. This vein

carries silver only—as chloride on top, stephanite and ruby silver in depth—the average assays showing values of from 33 to 90 ounces per ton. Ore of the latter kind carries only $1 of gold. Though much of this silver ore is in sight, none has yet been extracted. Four hundred and fifty feet beyond the breast of the tunnel another ore body is said to show on the surface and to carry both gold and silver. This is one of the few occurrences of silver veins in the basin, and is of great interest, as the two veins evidently represent separate periods of vein filling, the silver vein probably being the later.

The Elkhorn mining district adjoins the Gambrinus and is situated on upper Elk Creek.

The Elkhorn vein is an old location at the junction of Elk Creek and Ross Fork, at an elevation of about 5,300 feet. Discovered in early days, it was worked during 1867 and 1868, and, intermittently, later. Some prospecting was done on it in 1896. It has produced a total of $500,000. The developments consist of a tunnel 1,400 feet long, and stopes above it. It is a well-defined vein, about 18 inches wide, with a northwesterly strike, and carrying decomposed quartz without sulphurets. The ore body was large and the ore high grade, containing up to $40 per ton in gold. The ore shoot was very large, but at a depth of 100 feet it was cut off by a fault plane carrying soft, decomposed granite. There are several other veins in the vicinity, which, however, can show no production.

The Summit vein is a recent discovery on the ridge between Elk and Grimes creeks, found by tracing the placer gold of Deer Creek up to its source. The vein is inclosed in granite, and strikes a little north of west, dipping 45° SW. There is a zone, 18 feet wide, of crushed granite, carrying 4 feet of pay ore, composed of the same broken granite and quartz seams, and which assays from $10 to $40 per ton in gold. The ore shoot is said to be 60 feet long on the surface. As usual, the vein carries much water and is difficult ground to timber. Prospecting was in progress in 1896, and it was proposed to sink a shaft 400 feet deep. Between the Summit vein and Centerville lie, near the road, two quartz claims, called the Golden Fleece and the Golden Star. A 10-stamp mill was built long ago to work the ore, but the results proved unsatisfactory, and the property has long been idle.

THE QUARTZBURG-GRIMES PASS GOLD BELT.

The whole lower drainage basin of Granite Creek and Grimes Creek is singularly void of gold-quartz veins. Three miles north of Centerville, at Crane's claim, a deposit carrying much sulphurets containing gold and silver is being prospected. On Clear Creek, 3 miles south-southwest of Star Ranch, at an elevation of 4,475 feet, are two narrow quartz veins (Jackson's claim), inclosed in granite and carrying silver only. A small quantity of rich silver sulphides was found

on them, and stains of copper and arsenic were noted. The strike is north to south and the dip steep to the east.

Two and a half miles southwest of Quartzburg the gold belt begins, at the Ebenezer claim. It is not known to extend west of this point, though gold-quartz float has been found 2 miles farther on, along Dead Man's Gulch. The direction of the gold belt westward would carry it directly to Horseshoe Bend, where the Willow Creek belt begins. The high Boise Ridge is very brushy and difficult of exploration, and it is by no means impossible that quartz veins will be found in the intervening stretch.

The Ebenezer vein.—This vein is continuous for a distance of nearly a mile across the gap in the ridge between Canyon and Fall creeks, and three important claims are located on it. The Ebenezer claim lies on the Canyon Creek side, and is said to have produced $150,000 from sluicing and surface workings. The vein strikes northeast and southwest and dips to the southeast, and is encased in granite. It is about 5 feet wide, and consists of sheeted granite traversed by many small and rich quartz veins. The surface ore was very rich, but at a slight depth the gold was contained in sulphides, which did not readily yield it to simple amalgamation. Only assessment work has been done during the last years.

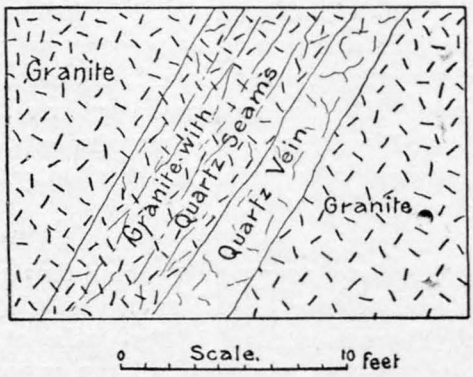


FIG. 63.—Section of Mountain Chief vein, east end of claim.

The Mountain Chief adjoins on the northeast, extending to the summit of the ridge, at an elevation of 6,000 feet, and the vein is similar to the one just described. It is stated that 10 tons of its ore were milled in 1895, yielding $100 per ton, and much gold has been obtained by sluicing the surface. Sulphurets appear here also in depth. In a surface cut the section of the vein was as shown in fig. 63.

The Belzazzar claim lies on the Fall Creek side and has been opened by sluicing and a tunnel, 200 feet below the summit. Bodies of heavy sulphurets, chiefly pyrite, are exposed along the vein. The western part of the vein lies in hornblende-porphyrite, while the eastern end has granite in the foot wall and the same porphyrite in the hanging wall.

A slightly divergent vein, called the Centennial, lies a few hundred feet southeast of the Mountain Chief, on the summit of the ridge. This vein carries more silver than gold, and shows heavy iron pyrite in a 6-inch seam.

The Gold Hill vein.—This is probably the continuation of the Ebenezer vein, though it has not been traced across Fall Creek. It is continuous from the Newburg, on the divide between Fall Creek and the west fork of Granite Creek, to at least some distance east of Quartzburg.

The Newburg claim, at an elevation of 5,000 feet, was worked extensively by surface sluicing during the early days, then abandoned, and again located. It is developed to some extent by tunnels aggregating several hundred feet in length. The vein consists of a shattered and decomposed zone in a belt of quartz-porphyrite, and reaches a width of 70 feet. Narrow seams extremely rich in gold traverse this shattered zone, giving to the whole an assay value variously stated from $4 to $12. The ore body is evidently extensive.

The Homeward Bound, Elizabeth, and Mayflower adjoin the Newburg on the northeast across West Fork. Considerable surface work with sluices and arrastres has been done on them. The vein is about 5 feet wide, and is said to contain sulphurets in large quantities in depth. A narrow streak of quartz-porphyrite follows it. The Confederate and the Dunlap adjoin Gold Hill on the west, and have a strike of N. 65° E. The developments are not extensive, but some good ore is reported to occur on them.

The Gold Hill and Pioneer claims constitute the most important quartz mine in the Idaho Basin, and the only one which has been extensively and systematically worked, having been in operation with short interruptions since 1864. The Gold Hill was first worked and yielded for a long time ore averaging $20 per ton. It was first exploited by tunnels on the northeastern side of Granite Creek, but in 1875 work began below water level in a shaft just below Quartzburg on the eastern branch of the creek, the total depth attained being 400 feet. In late years the Gold Hill vein has been abandoned and work concentrated on the Pioneer, a claim adjoining on the southeast. The total amount extracted from the Gold Hill and Dunlap claims from 1869 to 1894 is stated to have been $1,280,000, and the production from the Pioneer claim from 1884 to 1895 is stated to have been $498,000. The total production of the claims mentioned, all of which was not recorded, is believed to have been at least $2,225,000.

In the mint reports the following data are found: Raymond's report for 1872 states that Gold Hill produced $300,000 since September, 1869. In 1881 it is stated that 150 tons of ore from the Gold Hill yielded $25,000 in gold. In 1883 the Gold Hill produced $76,800; in 1884 the production was $50,000. The property was equipped with a 25-stamp mill in 1875. No work was in progress in 1896, pending a sale of the mine. The Gold Hill vein is a well-defined quartz vein with an average strike of N. 70° E., and a dip of 70° S. The foot wall is generally sharp and well defined and consists of granite. In the hanging wall lies a dike of quartz-porphyrite several hundred feet wide, described

in connection with dike rocks (p. 682). The vein is of very irregular width, from a few inches up to 6 feet, and has a great tendency to throw out stringers in the porphyry in the hanging wall; these when followed were found to be rich, but soon gave out. The ore consists of free gold and sulphurets, the latter chiefly iron pyrite, also some antimonite, which is said to be intimately associated with gold. Small traces of tellurium are also reported. About 50 per cent of the value is in free gold, and this proportion is likely to remain stable as depth is attained. The sulphurets are reported to be of high grade. The old workings of Gold Hill extend up on the steep hill northeast of Quartzburg.

The Pioneer claim adjoins the Gold Hill on the south. A vertical shaft 400 feet deep is sunk on it. It is located on a fissured zone in the same porphyry dike which forms the hanging wall of Gold Hill, and which contains a great number of small seams with very rich ore, the whole forming a large body of low-grade ore. The porphyry is yellowish and decomposed, filled with pyrite, sericite, and some calcite. The sulphurets of the Pioneer are of much lower grade than those of Gold Hill.

A short distance below the Pioneer there are several claims on a vein crossing the creek, the principal one being called Mountain Girl. The ore consists chiefly of sulphides without any free gold, but sometimes contains much silver, being similar to the Centennial, which lies in a similar position in front of the Mountain Chief vein.

Immediately adjoining the Gold Hill on the northwest is a flat vein called the Lone Star, from which, in early days, much gold was obtained by surface sluicing.

The Iowa vein.—This vein lies a short distance north of the Gold Hill, and was opened in 1896 by an 800-foot tunnel starting from the 10-stamp mill one-eighth of a mile north of Quartzburg. The tunnel is driven through granite, which near the vein is much decomposed. The vein is a narrow seam in granite filled with a soft clay gouge and containing streaks extremely rich in gold. There is also some pyrite.

In the extension of the Iowa lie the Yellow Jacket and other claims which have been less developed.

The Carroll veins.—A group of five claims lies at the head of California Gulch, 1⅛ miles northeast of Quartzburg. The surface in this vicinity was extremely rich and has been extensively washed. It can not be said that the direction and extent of the veins have been definitely established, but that rich veins exist in this ground is not to be doubted. On the Ivanhoe claim some work was done in 1896, the vein being opened up by means of a tunnel several hundred feet long and exposing a good ore shoot. In this tunnel the vein dips south at a steep angle, and lies entirely in soft, decomposed granite. Outside of the ore shoot the vein is indicated only by a black-clay seam. The character of the ore in the shoot is illustrated in fig. 64, showing the

breast of the tunnel. The valuable part consists of 2 feet of decomposed granite with seams 3 to 5 inches wide of pyrite. This contains considerable free gold, some of which appears to be in the decomposed wall rock. Outside of the principal shoot there are many streaks of iron pyrite, which do not contain any free gold.

The Kennebec claim.—This property, situated one-half mile from the Carroll, yielded some very rich ground for sluicing. Of the vein but little is definitely known.

Veins at head of Wolf Creek.—From the Iowa a string of claims extends through the Carroll and Kennebec and then farther through the Black Bear, Mountain Queen, and others up toward a high, prominent point on the divide. All these claims lie in granite, though occasional dikes cut the principal rocks; the main belt of porphyry lies a little to the south. On none of them has much work been done. The Black Bear lies at an elevation of 5,000 feet a short distance to the west of the pass between Placerville and Garden Valley. The strike is N. 70° E., and the dip 50° to the south. The vein is a well-defined fissure with a pay streak of good ore 4 to 5 feet wide, which has been followed down for 40 feet. The ore is free-milling, at present at least, and contains a little galena. Northeast of the pass lie a number of more or less prominent veins. The Gold Dollar is a perpendicular vein, the ore of which carries no free gold, and it is said to run from $2 to $20 per ton. Near by lies another vein, with flatter dip of from 20° to 40°, carrying some free gold. The Monumental and Mountain Queen are on a nearly vertical, heavy vein striking N. 81° E. It has no distinct walls, but consists of streaks of quartz and heavy iron pyrite in decomposed granite cut by some porphyry dikes. The Etna, lying a short distance southwest of the pass, is said to consist of a streak in porphyry impregnated with auriferous seams and pyrite.

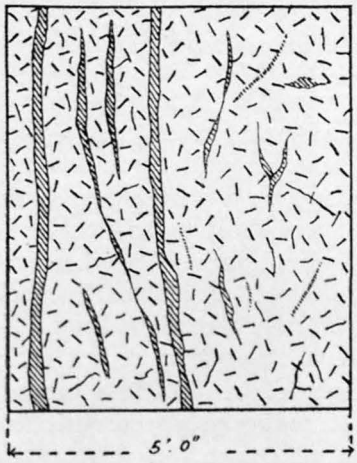


FIG. 64.—Breast of drift, Carroll veins. To the left, 2 feet of altered granite with rich seams of massive pyrite; to the right, 3 feet of altered granite with poorer seams of quartz and pyrite.

Veins in the porphyry dike east of Wolf Creek.—On the summit 1 mile east of the pass is the Golden Chariot, at an elevation of 5,300 feet. The wide dike of quartz-hornblende-porphyrite forms the country rock. In the tunnel the vein appears as a vertical streak, 2 feet wide, of brown decomposed rock, said to assay well. A similar deposit, called the Buena Vista, lies a little to the south. Half a mile eastward are the Big Six and the Mineral Hill group of claims, in

the same porphyritic dike. The Big Six appears as a brown, much decomposed vein, 1 to 2 feet wide, chiefly made up of limonite; it strikes N. 55° E. and dips steeply toward the northwest, this dip being an unusual one for the vicinity. The claim is developed by a small shaft, and some fair assays were obtained from it, one sample containing $10.33 in gold and $0.50 in silver. The Mineral Hill group adjoins on the northeast, being situated on the headwaters of Ophir Creek, at an elevation of about 5,000 feet, and consists of five claims. The surface is extremely decomposed to a brown loam, and luxuriant vegetation covers all outcrops. These claims have not yet been prospected enough to determine their character, but the pay appears to be contained in streaks in the porphyry, impregnated with pyrite and carrying free gold on the surface at least. Near the Mineral Hill claim a large extent of surface is said to contain gold. The ore is a soft, decomposed rock, principally composed of limonite, one selected sample of which assayed $154 in gold, $1.71 in silver. Lead carbonate also occurs in the ore. Where sulphurets are found they are said to be of low grade. It is probable that these deposits are similar to that of the Pioneer claim, near Quartzburg.

Claims near Grimes Pass.—For 3 miles beyond the Mineral Hill group, in a northeasterly direction, no mineral deposits are known, though the deep soil covering the region makes it probable that no thorough prospecting has ever been undertaken. About three-fourths mile west of Grimes Pass, on the summit of the ridge dividing the waters of the Payette and Boise rivers, at an elevation of 5,000 feet, lie a number of claims called the Morning Star group. There are eight claims laid out along two adjoining lines. The deep surface soil makes prospecting difficult, and the exact character of the deposit is not known. Over a large extent the surface gives good prospects, and many little shafts demonstrate the presence of a considerable body of low-grade free-milling ore. The ore has always the appearance of streaks, 4 to 6 feet wide, of decomposed and brownish porphyry, striking a trifle north of east. The deposits lie in a dike, several hundred feet wide, of quartz-hornblende-porphyrite, continuing from the vicinity of Quartzburg, but the contacts of the dike with the granite are difficult to trace. Samples of the ore washed in pan gave good prospects of free gold, with some lead carbonate. On the Morning Star a shaft 232 feet deep has been sunk. A long tunnel has been started on the Payette side, 600 feet vertically below the shaft, and is calculated to strike the vein 1,700 feet from the mouth. In 1896 it had been driven as far as a point vertically below the shaft, but work had to be suspended on account of financial difficulties. Three hundred feet back from a point perpendicularly below the shaft the contact of granite and porphyry was struck in the tunnel. The deposits are evidently similar to those of the Pioneer mine and the Mineral Hill group, and consist of a more or less shattered zone

in porphyry, which has been impregnated with auriferous sulphides by thermal action. The ore will probably be base in depth, but near the surface a considerable amount of free-milling ore exists.

The Mountain Queen mine lies on Grimes Creek, 3 miles above the Pioneer, at the southern edge of the porphyry dike and about one-fourth mile from the Morning Star claims. It is probably not the extension of the latter, but a more southerly vein. A few years ago a 20-stamp mill, driven by water power, was constructed on this property and ran two years. At first the ore is said to have been taken from a well-defined quartz vein, but later the mineralized porphyry was mined and milled and was found too poor for profitable work.

The porphyry dike extends eastward toward the high hills east of Grimes Pass, but was not followed and examined any farther. At Charlotte Gulch, on the east side of Grimes Pass, are many claims which on the decomposed surface carried much free gold. The veins contain pyrite, galena, and blende, with a small amount of free gold. Mr. Woods, of Placerville, states that there is evidence that those veins have been much disturbed by faulting.

MINING DISTRICTS EAST OF THE BASIN.

The Summit Flat mining district lies on the headwaters of Elk Creek, Clear Creek, and Moore Creek, at elevations of from 6,000 to 8,000 feet, and 12 miles north-northeast of Idaho City. At the headwaters of Elk Creek are the Barry, Peerless, King, and other veins, while the Wilson group of claims lie a little farther north. The veins generally strike east to west, or a little north of east, and dip south at steep angles. In character they are apparently well-defined, wide fissure veins carrying much quartz, chiefly free milling, though bunches of sulphurets may occur. The Mammoth claim in the Wilson group is opened by means of an incline 325 feet deep, exposing a considerable body of ore. There are two small mills in this mining district. This region was not visited by the writer in 1896.

Between Summit Flat and Kempner, 10 miles to the east, are many prospects with only slight developments, partly carrying gold ores, partly silver ores. Placer deposits occur at many places along Lost River and Bear River near Kempner. Twenty-two miles northeast of Idaho City the silver mines of Banner are located, which produced considerably before the recent fall in price of silver. Between 1882 and 1894 the total silver production of this district probably amounted to $1,500,000 or $2,000,000, reaching a maximum of over $200,000 in 1892. At present these mines are shut down. The deposits are large, well-defined quartz veins carrying rich silver sulphides.

Gold-quartz veins have been found on the southwestern slope of Sunset Mountain, and several claims have lately been located on

upper Rabbit Creek, draining into Boise River 8 miles east of Idaho City.

Fineness of quartz gold.

Mine.	Value per ounce.	Fineness.
Gambrinus	$15.50	
Boulder	15.50–16.00	680 to 718
Forest King		700
Washington	15.00	
Illinois	15.00	
Ebenezer	16.50	
Gold Hill	*a* 17.50	800 to 910

a Average.

THE GEOLOGICAL HISTORY OF THE IDAHO BASIN.

The succession of geological events to which the existence of the basin and of the gold-bearing gravels is due is neither simple nor easy to decipher. In a large degree this is owing to the very monotonous structure of the bed-rock series, which gives few clews, except those indicated by the topography, to the character of the movements that have taken place, for it soon becomes apparent, during a study of the district, that erosion alone, unaided by orographic movements, can not have produced this peculiar depression situated on the divide between two main rivers.

The doubtful age of the granite, which alone constitutes nearly the whole pre-Tertiary series in the basin, has already been alluded to. It has further been stated that a surface laid through the ridge lines of the Boise Mountains in general probably forms part of an old pre-Tertiary peneplain or land mass planed down by erosion; and, still further, that the erosion succeeding the uplift which differentiated the Boise Mountains and the Snake River plains had, prior to the lake period, cut far into this uplifted surface, so far, indeed, that the Boise Canyon at its mouth was cut to its present depth at the beginning of the Neocene. All this does not account for the depression of the basin, which lies much below the general level of that surface. It seems probable that the present upper valleys of Grimes and Moore creeks have been excavated by erosion, but this again does not account for the basin as a whole. In it the river valleys are separated by low ridges, the summits of which form, if extended, an undulating surface considerably above the creeks, it is true, but still much below the general surface of the surrounding country, as is well shown by Pl. XCI. The extent of this surface determined the existence of the basin in the first place, and as a probable working hypothesis to account for this it may be assumed that this earlier

basin was caused by a sinking of a portion of the Boise Mountains along curved fault lines between the Boise Ridge on the west, Wilson Peak and other elevations on the east, and the Thorn Creek Hills on the south. The age of the quartz veins in the basin can not be definitely indicated, but is most likely Cretaceous or Eocene. They were certainly formed before the deposition of the Payette lake beds, and it is to be expected that the rivers and creeks of the pre-Payette period of erosion in the basin carried detrital gold derived from these veins. These stream gravels are now either completely eroded or buried below the lake beds at Idaho City. As has been explained in the detailed description, there is slight chance of finding them by boring, and still slighter chance of mining them profitably if found.

The surface of the Payette lake attained a height above the present sea level of 4,200 feet at the mouth of the Boise Canyon. If the elevations and the topography were then the same as at the present time, the lake would have reached up as far as Centerville in Grimes Creek, and 4 miles above Idaho City in Moore Creek. It is almost certain, however, that the relative elevations are not the same, for near Idaho City we find the Payette lake beds at 4,400 feet, and there forming part of a smaller area which has settled down between parallel fault lines—just how much is not known. From this it appears that the basin has increased its elevation somewhat relatively to the country at the mouth of the Boise Canyon. High up near the divide, on Muddy Creek, a small remnant of inclined lake beds occurs, but it is perhaps a small local accumulation. At any rate it is certain that the Payette lake covered the lower part of the basin in early Neocene times.

The lake beds were rapidly accumulated in the bay then occupying the basin, and as no concentration of the material took place, it was natural that their content of native gold should be very slight.

The raising of the base level to the present elevation of over 4,000 feet would naturally produce extensive accumulations of gravel in the creeks draining to the lake. It is probable, indeed, that at this time of maximum lake extension the lower valleys opening into the basin were choked with gravel; and as an evidence of this may be cited the occurrence of auriferous river gravel on the summit of a ridge in the Thorn Creek drainage, at an elevation of 4,500 feet. Vast eruptions of basic lavas took place on the summit and western side of the Boise Ridge, and to less extent in the basin. All of these earlier lavas probably flowed out during the deposition of the lake beds. As the lake receded stream courses were established over its deposits, and the streams which headed near quartz veins began to carry down their precious load and concentrate the gold on the bed rock. These fluviatile deposits, which were formed very shortly after the Payette lake beds, or perhaps in part contemporaneously with them in valleys draining into the lake, have been described as "older

gravels." Among them are the deposits of Gold Hill, East Hill, and Barker's claim at Idaho City, as well as the Ranch Company's claims and other gravels near Placerville. They rest partly on the lake beds, partly on granite; and while these gravels at Idaho City may have been deposited by Moore Creek as very high bench gravels, the gravels at Placerville form a part of a drainage system differing from the present one.

During the period of general erosion following the retreat of the Payette lake important events took place. The lower canyon of Moore Creek was scoured of its accumulated gravels. The lake beds were disturbed and acquired a decided dip to the west. One block of them at Idaho City sunk down between fault lines, being thus preserved from the erosion which destroyed the larger part of them. The gravels laid down on the lake beds also show a tilting westward, though at slighter angles than the latter. Near Placerville and Granite there were extensive disturbances, which greatly changed the old drainage. Along the eastern side of the Boise Ridge these disturbances, it would appear, took the form chiefly of faulting, for along this line the old gravels are cut off; but the amount of this faulting is not easy to establish. In this connection the occurrence of a little gravel on the summit of the Boise Range is of great interest, and it is difficult to explain. It is not believed, however, that the disturbance was so great as to create the whole of this ridge at this time.

Finally, at the close of the Pliocene came the eruption of the Snake River basalts. The Moore Creek flow originated at some point on Grimes Creek a few miles below the basin, and as it dammed the stream to an elevation of 100 feet the natural result was the accumulation of bench gravels above by the checking of erosion. As the creek gradually wore through the basalt filling, the level at which bench gravels were formed gradually sunk. Thus the bench gravels, lining the stream up to 100 feet above their beds, are directly due to the Pliocene basaltic eruption, and represent in the basin the deposit of the Pleistocene times.

CHAPTER V.

THE MINING DISTRICTS OF THE BOISE RIDGE.

NEAL MINING DISTRICT.

LOCATION.

The Neal mining district is situated south of the Boise River, just east of Three Point Mountain, on the head of Wood Creek, in Elmore County, 15 miles southeast of Boise, in the southwest corner of the Idaho Basin quadrangle.

The district embraces about 10 square miles, but the productive area has been confined to the heads of Wood and Bender creeks. The camp was discovered in 1889, and has been worked since during the summer months, producing about $200,000 in gold. Three mills have been erected, a 10-stamp for the Homestake, probably the oldest mill in the State, having been first used in Idaho Basin; a 5-stamp for the Alice mine, now a custom mill; and a 10-stamp for the Lilly mine on Black Creek, now idle.

Placer mining has been confined to a few bars and the creek beds, but the product from this source forms a very inconsiderable part of the camp's output. The largest amount extracted from the placers is said to have been $800.

The western half of the district is bare of timber, and except in the main streams there is during the summer months a scarcity of water. The eastern half is better timbered.

Pl. XCVII, drawn by Mr. F. D. Howe, shows the topography, dikes, veins, and mining claims of the central part of the district.

TOPOGRAPHY.

The main topographic feature is the high ridge which, with a WNW.-ESE. trend, divides the Snake River from the South Fork of the Boise, and which only reaches an elevation of about 5,000 feet. At Three Point Mountain this ridge swings to a northerly direction, and culminates 4 miles farther north in a point 5,400 feet high, between Birch and Grouse creeks, overlooking the mouth of Moore Creek and the forks of the Boise River. A number of deep canyons separated by narrow ridges radiate from the vicinity of Three Point Mountain. To the southwest extend, at the foot of Three Point Mountain, the Tertiary formations of the Snake River Valley. The direction of the creeks seem, in some measure, to follow the lines of faults and jointing—that is, they extend from north-northwest to south-southeast and from east to west.

GEOLOGY.

The prevailing rock is the normal gray granite of the Boise Mountains, composed of orthoclase, plagioclase, quartz, and biotite; hornblende is of rare occurrence in it. A jointed structure or sheeting is often noted, the direction (N. 50° to 80° E.) and dip (up to 45° S.) roughly corresponding to those of the veins. Numerous dikes cut the granite, and may be divided into several classes.

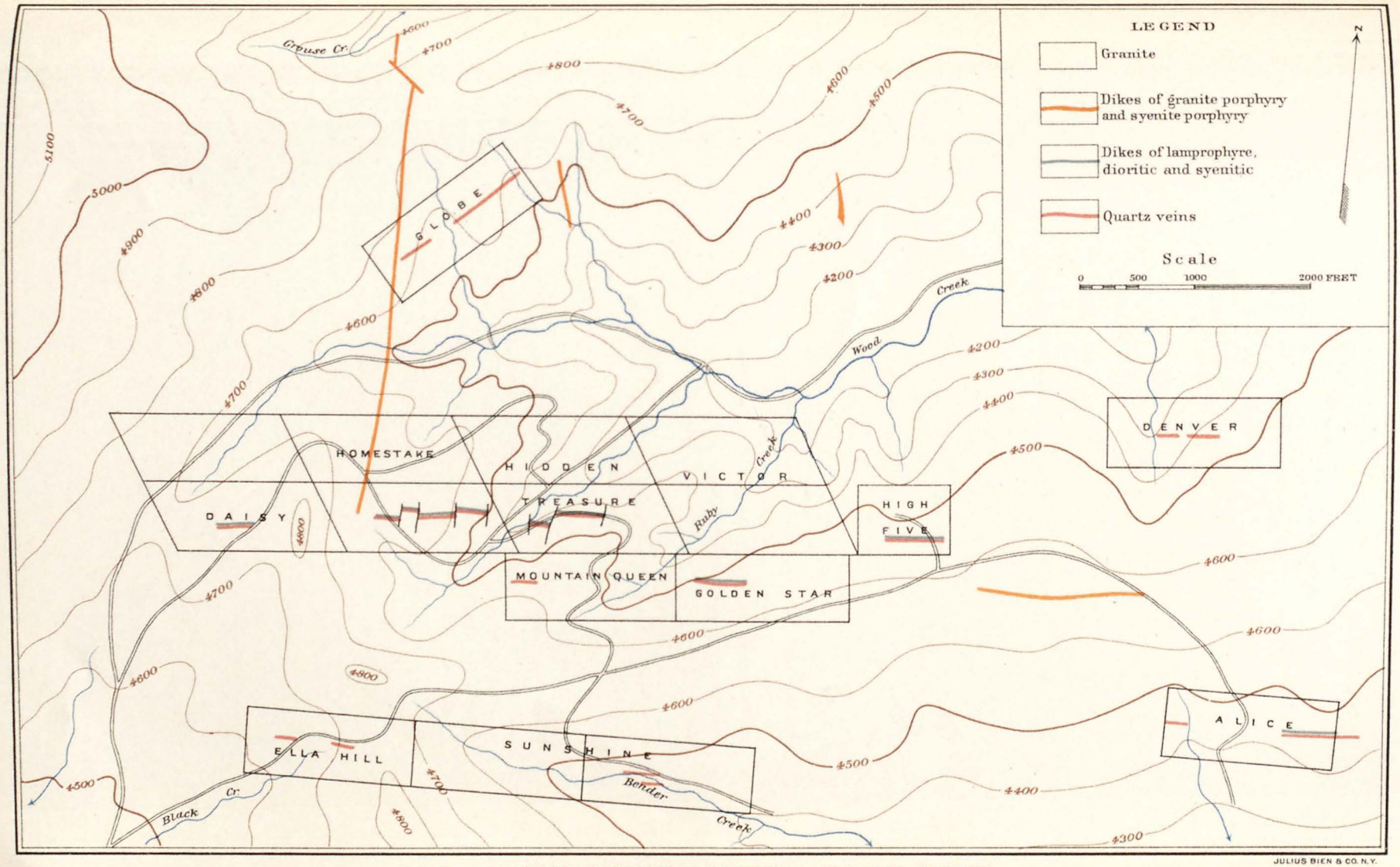
Some of the dikes consist of a harder gray granite, which carries some muscovite. Less frequent are dikes of coarser and more micaceous character than the general mass. Along the north side of Wood Creek are several dikes of a pyritiferous granite, occurring at one place as foot wall to a vein.

The most prominent dikes are those which crop so boldly on Black Creek, about 3 miles southwest of the Homestake mine, and which, according to Mr. Howe, continue for a long distance northward with a general trend of N. 5° W., one of them, the most easterly, showing on the map Their width is up to 200 feet. The rock, which has a somewhat porous character, is dark gray in color with brownish spots; phenocrysts of feldspar are abundant, and are usually about 5^{mm} long. It is almost impossible to obtain fresh rock. The microscope shows the rock to consist of sanidine phenocrysts; small, brownish, decomposed foils and prisms, probably decomposed biotite; and a holocrystalline groundmass, of spherulitic and micropegmatitic character, of orthoclase and some quartz. The rock should probably be classed as a syenite-porphyry.

Normal granite-porphyry is common and forms dikes, more rarely irregular masses, with a general direction of N. 20° to 30° W., several occurring on the divide between Wood and Grouse creeks.

Lastly, there are narrow dikes of lamprophyres, dark-green, dense rock, in which small foils of black mica are often seen. These vary from 18 to 30 inches in width and often trend with the vein N. 78° E.

A specimen of this lamprophyric dike rock from the Hidden Treasure mine is a panidiomorphic granular rock composed of brown hornblende, augite, and soda-lime feldspar in slender, lath-like forms; probably also some orthoclase. The rock is very similar to certain camptonites, or, perhaps, stands between a minette and a camptonite. Similar dikes also occur in the Homestake mine, and in the foot wall of the High Five is a dike 15 feet thick, of lamprophyric rock with abundant black mica and porphyritic orthoclase crystals. These dikes are sometimes the hanging wall of the veins, at times apparently not affected by the vein processes, at others partially or entirely replaced by ore. At one place in the Homestake mine a part of this dike, crushed and altered, lies in the middle of a 4-foot vein. Mr. Howe concludes from his observations that the lamprophyres are the oldest dikes, followed by the large dikes of syenite-porphyry, and



MAP OF NEAL MINING DISTRICT, BY F. D. HOWE

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these again by the granite-porphyry. It is probable that all of them antedate the veins. Remains of a glassy rhyolite are found on Three Point Mountain and the ridges northward.

THE VEINS.

The Neal district was visited in October, 1896, but only two days could be devoted to it, and I therefore gladly availed myself of the offer of the following notes by Mr. F. D. Howe, superintendent of the Hidden Treasure mine, who is thoroughly familiar with the district and with whose statements my own observations in the principal mines fully agree. Credit for many of the above data regarding the dikes of the district is also due to Mr. Howe.

The veins of the district have the common N. 70° to 83° E. trend and the same general dip to the south, and for form may be referred to three classes: First, veins filling larger fault fissures, on which are located the principal mines; second, veins along the minor shearing planes of the granite, more or less irregular, but generally carrying high-grade ore; and third, veins of a hard white quartz, called by the miners "bull quartz," carrying no values.

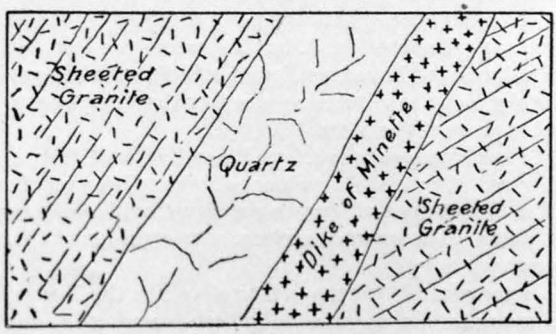

FIG. 65.—Cross section of vein in the Neal mining district.

The veins on the fault fissures are often displaced by faults of a north-south trend, which occurred subsequent to the vein filling. The position of the north-south faults is often shown on the surface by gulches of greater or less size. The dip is to the south, ranging from 30° to 54°, somewhat steeper than that of the foliation. The granite of the foot wall for some little distance away from the vein has suffered a decomposition of its mica, is harder, and is cut by cross jointing planes, in which are thin seams of a talcose mineral, giving it a blocky appearance. Garnets occur on this side of the fissure and may be of secondary origin. On the hanging-wall side the granite is darker, and the main joints follow the fissure and no cross jointing appears. On this side only appear the oxides of manganese. Beyond the sheeting or jointing of this side there is a zone of structureless granite (fig. 65).

The vein filling is separated from the walls by thin seams, but in places the mineralization extends into both walls, in which case the gold in the walls is coarser than that of the vein proper.

The vein matter consists of quartz, sulphides, and partly replaced country rock. The ordinary structure is, next the hanging wall, a clear quartz, more or less honeycombed and stained by the oxidation of the iron pyrites; next, a zone of replaced country rock, granite or one of the dark rocks described above, carrying much pyrite and other sulphides.

Pyrite often occurs in the dike rock in detached kidneys and sometimes as partial replacements. The width of the veins varies from 2 to 13 feet. The gold occurs free in the quartz; partially free in the pyrites. It varies from microscopic

to shot size, and in some of the very rich pockets the oxidation of the pyrites has left a semicrystalline form. It is worth $15 per ounce from the retort, the alloy being silver. The associated sulphides are iron pyrites and galena, and a little zinc blende appearing on the surface as iron oxides and cerussite. From the pure galena silver values as high as 160 ounces per ton have been obtained, one assay showing 0.7 ounce of gold and 44 ounces of silver. The pyrites contain as high as 21 ounces of gold per ton. An assay of clean zincblende contained 1.4 ounces of gold per ton. The pyrites constitute from 3 to 10 per cent of the ore as broken; the galena less than 1 per cent. From 40 to 65 per cent of the gold is saved by amalgamation. The values of the milled ore range from $10 to $120 in gold per ton, the larger part being between $10 and $35. Concentrates carry about 2.5 to 4 ounces in gold and 5 to 6 ounces in silver per ton.

The veins of the second class have less development, and with two or three exceptions have produced but little ore. They occur nearly parallel to the fissures at some distance on either side, and differ in having less dip, little or no complete replacement of the country rock, and less regularity to the ore bodies. Generally the values are high. Where they have been productive the veins occur along the line of dike contacts, as at the High Five and Golden Star. The foot wall is here a granitic porphyry and apparently lies parallel with the jointing or sheeting.

The veins of the third class are the most prominent in the way of outcropping, the hard white quartz having suffered but little from surface decomposition. Occasionally the quartz is heavily stained by the iron oxides, and in places scattering pyrites are found, but the values are low. In places along the sides of this "bull quartz" have been found streaks of high-grade ore, but there has been no development to determine whether the hard quartz caps softer ore, as it does in other parts of the State.

Several prospects are found northwest of Three Point Mountain, in Charcoal Ravine. The main developments have been on the Jackson property—a narrow dike, 8 to 12 feet, of quartz-porphyry, with quartz veins on the joint and contact surfaces. The quartz carries a coarse gold, and there is some impregnation of the porphyry mass.

In the central belt the principal vein is the Homestake-Hidden Treasure. On the Homestake claim one shoot of ore, varying in length from 75 to 125 feet and in width from 4 to 12 feet, has been mined through tunnels to a depth of 350 feet. To the west the vein is cut by a fault, striking N. 19° W. and dipping 60° E. Beyond this fault the vein was recently found again, thrown 100 feet to the south. Four hundred feet to the east, in which distance another shoot is opened, a section of the vein is faulted 200 feet to the north. This faulted section is another ore shoot, and is about 250 long. Beyond this, to the east, another shoot has been mined to a depth of 100 feet. The term "ore shoot" refers only to ores yielding $10 per ton and over; if made to include ores from $5 per ton and up, the vein so far as opened is practically one shoot. The greatest depth attained below the surface is 350 feet.

On the Hidden Treasure, the easterly extension of the Homestake, the vein has been opened for 450 feet, to a depth of 165 feet, varying in width from 1 to 13 feet. Several small displacements by north-south faults, between 4 and 12 feet, are shown, and one with a displacement of 60 feet. The entire top of the vein has been moved to the south on a fault plane dipping 6° or 8° to the northeast, between 60 and 100 feet. In one place this plane was filled with ore. About 90 per cent of the production of the camp has been from these two properties.

In the High Five and the Golden Star a vein has been opened, with the granitic porphyry for a footwall. It apparently dips with the foliation. The high-grade ores occur in lenticular masses of greater or less extent. The value or extent of the rest of the vein material has not been determined.

The vein is in width from 2 to 6 feet, and in form and character of ores is but little different from the Homestake vein.

On the Corder property (Sunshine) an ore shoot has been developed on a fault fissure, with the ordinary dip and trend; and 120 feet to the north a parallel vein, dipping 30° to the north, has been opened. Each vein averages 4 feet, and the ores are similar in character and value to the type ores of the camp.

On Indian Creek, 5½ miles southeast of Neal, a vein has been opened on the Stevens and Beck properties for 6,000 feet along its trend. It is a fault fissure 4 to 8 feet wide and carries ores similar in character and value to those of Neal.

On Black Creek, 4 miles southwest of Neal, several veins have been opened and some little production made. Work on them has been done only at odd times. The values are high and the limited developments indicate strong veins.

Two miles east, along Wood Creek, are two recent developments, the North Star and the Clements mines, both being of the common type of the district. In the first named arsenopyrite occurs.

Milling charges have been $5 per ton; transportation, from $1 up, and the mill saving not over 55 per cent—that is, only the free gold—thus requiring $12 to $15 ore to pay the outside expenses only. To the smelter the charges aggregate $28 to $35 per ton. It would be safe to say that nothing less than $25 rock would return more than wages to the owner unless he had a mill. The average claim owner had either to make the claim pay or limit the development to the annual assessment, carelessly done. The work in the camp is a result of this condition and fully illustrates it.

To these full notes of Mr. Howe should be added only the statement that the alteration of the country rock adjoining the veins is of the same character as that at other places within the region described. The black mica is bleached, being converted to carbonates and to white mica. The feldspars are converted to an opaque white matter, which is neither kaolin nor talc, but sericite in extremely fine-grained aggregates. The quartz grains remain unaltered in general, and pyrite and arsenopyrite are often introduced. The principal value of the veins is in the filling—that is, in the solid quartz accompanied by sulphides. But the altered granite next the filling here sometimes also carries good value.

BLACK HORNET MINING DISTRICT.

TOPOGRAPHY.

This district and its continuation northward (the Deer Creek mining district) is on the eastern side of the Boise Ridge, on the slope of the ridge culminating in Lucky Peak. It is 8 miles east-southeast of Boise, and is situated at elevations ranging from 4,500 to 5,500 feet. The topography is very accentuated; deep, sharply incised V-shaped canyons score the slope of the Lucky Peak, draining to Boise River and to Moore Creek. Scattered timber covers the hillsides at higher elevations. The topography is indicated in a somewhat generalized way on the Boise sheet.

GEOLOGY.

The geological structure of the Lucky Peak ridge is very simple. It consists nearly entirely of the normal granite of the Boise Mountains. A number of dikes vary the monotony, but consist almost exclusively of light-colored granite-porphyry, which have in general a northwesterly trend and a width occasionally attaining 100 feet, but usually much less. Placer deposits hardly found place to accumulate in the steep gulches and cut no figure in the production of the camp.

MINERAL DEPOSITS.

A number of gold-quartz veins are found in the Black Hornet district; and they are not confined to the district. Scattered small veins occur in the granite between this region and the Neal mining district, 9 miles to the southeast. West and southwest from Lucky Peak scattered prospects are also found; likewise to the north and northwest, connecting in the latter two directions with the Shaw Mountain and the Boise districts. The northern part, or the Deer Creek district, has been known for a long time. On the Montana claim an arrastre was built and worked many years ago by Mr. Plowman, of Idaho City. But the southern and lately most productive part, near the Black Hornet mine, has been known only during the last few years.

The production has been confined almost entirely to ore shipped to smelting works from the Black Hornet or Ironsides mine. During 1895 and 1896, 200 carloads are said to have been shipped, averaging $40 per ton, which would give a total product for the camp of about $24,000; the total production is probably $30,000.

The veins in this vicinity differ markedly in direction and dip from those at other camps on the range. Instead of a strike ranging from east-west to northeast-southwest, we here find veins striking north-south or northwest-southeast, and with a dip of 45° to 50° to the west. Though base ores prevail, some of the veins carry a notable percentage of free gold.

The more prominent claims begin at the Viola mine and extend for 2½ miles northward. South of the Viola are a number of prospects, some of which, such as the Fraud and the Ruby, are reputed to be promising.

The Black Hornet vein extends through the Viola and Ironsides claims, but can hardly be traced any farther. Having at first a direction of N. 20° W., it changes in the Ironsides claim to N. 40° W., the dip being to the southwest at 50°. The vein crops along a ridge leading up to Lucky Peak, and a sharply cut ravine several hundred feet deep offered excellent place for tunnels to tap the vein. The Viola shows on the crumbling granite on the surface as a strong vein of white quartz. It is developed by a crosscut tunnel 200 feet long

and a drift following the hanging wall north. A width of several feet of quartz is shown, and near the northern end of the claim a pay shoot exists 100 feet long and said to be 9 feet wide, carrying an ore which averages $15, of which about half is in free gold. The ore is is similar to that of the Ironsides. The Ironsides or Black Hornet adjoins on the north, and its principal pay shoot lies near the line of the Viola claim. It is developed by a cross cut striking the vein about 100 feet below the croppings and a winze sunk 100 feet deep ear the southern end-line in the drift. The pay shoot extends 200 feet north from the end line, but only 70 feet of it consists of shipping ore. Along the pay shoot the quartz reaches a width of 10 feet or more. This block of ore between tunnel level and surface was stoped and shipped, averaging, it is said, $40 per ton, almost entirely in gold.

North of the richest pay shoots are large amounts of lower-grade ore. The vein shows as a body of massive, fine-grained white quartz, from 2 to 10 feet wide, and contains sulphides irregularly distributed through it. The sulphides, which in the pay shoot will amount to 8 per cent of the ore, consist of arsenopyrite, pyrite, and zinc blende. The value is by no means exclusively in the sulphides, for a specimen of massive zinc blende and arsenopyrite assayed only 0.40 ounce of gold and 4.60 ounces of silver; a total value of $11.50. A sample of the quartz with scattered iron pyrite yielded 0.45 ounce of gold and 1 ounce of silver; a total value of $10. The walls are often ill defined and without a clay selvage, and consist of shattered granite and granite-porphyry altered by thermal processes. The feldspar is largely converted to sericite or white mica, and the rock contains, for a few feet on each side of the vein, much scattered arsenopyrite. This altered wall rock contains, in strong contrast to the filling, only a trace of gold and silver. The Ophir vein lies one-half mile north of Ironsides and has a similar direction. But little work has been done on it. Near the Ophir vein a long vein begins, and extends, with a westerly dip, due north across Dead Dog Creek to Deer Creek. The following claims are located on it, beginning at the southern end: McIntyre, Gray Eagle, Sorrel Horse, Golden Rule, and Montana. Most of them are but superficially developed, and the ore, though free milling on the surface, grows base at a slight depth. The Montana is opened by a cross cut 270 feet long.

BOISE MINING DISTRICT.

At a distance of from 3 to 5 miles east and east-northeast from Boise are a number of prospects which have never produced much, yet are worthy of mention. The country rock is normal granite throughout, cut by a few dikes of granite-porphyry with a general north-northwesterly direction. Dikes of dark lamprophyric rocks also occur.

Three miles east of Boise, on the north side of the stage road in Cottonwood Creek, are several claims, Morning Star, Last Chance, and First Chance, located on a narrow vein striking northeast-southwest and dipping south, the developments consisting only of two tunnels 100 feet long. High assay values in silver have been found on the first claim, while the others chiefly contain gold. One and a half miles further east, just north of the road, is another claim said to have yielded some rich decomposed silver ore.

On Picketpin Gulch, 5 miles east of Boise, are the Golden Star location and a great number of other claims. The Golden Star claim is said to cover two parallel veins and a cross vein, but the openings do not show the character of the deposit very clearly in the decomposed granite.

An arrastre was built on this claim many years ago and the soft decomposed ore treated in it is said to have yielded $33 per ton. A small mill was erected a few years ago, but it did not run long. Many of the veins in this vicinity show no quartz, but only a streak of thermal alteration on each side of a fault plane. Mr. Eldridge[1] mentions at this same locality "several narrow dikes of lamprophyre, trending N. 50° to 70° W. and dipping 45° to 80° SW. A vein of quartz lies between two of these." The dark-green, fine-grained dike rock from this locality is panidiomorphic granular, and consists chiefly of brown hornblende and orthoclase with some soda-lime feldspar. It appears to be a syenitic lamprophyre connected with the vogesites. In the lower part of Fivemile Creek many strong quartz veins appear, all of them having an east-west direction and a southerly dip of from 50° to 60°. The Scorpion is a well-defined vein showing 2 to 3 feet of solid quartz between granite walls. A tunnel 100 feet long has been driven in this vein in the western side of the creek. The quartz, which contains scattered iron pyrite and arsenopyrite, is said to assay up to $8 per ton. A dike of fine-grained, dark-green minette, a species of syenitic lamprophyre, was cut in the lower tunnel and appears to lie nearly parallel to the vein. The dike is considerably altered, filled with calcite, sericite (white mica), and pyrite, and carries about $1.65 in gold. Claims adjoining on the same vein are the Elevator and Hattie, while parallel to it and adjoining northward are the Badger and Free Gold. Parallel veins also lie on both sides of the Idaho City stage road at the mouth of Fivemile Creek, and scattered prospects extend eastward to Shaw Mountain district. The Tornado and Blizzard claims are situated 1 mile northeast of the Scorpion, and carry heavy sulphide ore, zinc blende, galena, and pyrite, having high assay value but containing no free gold.

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[1] Sixteenth Ann. Rept. U. S. Geol. Survey, Part II, 1895, p. 235.

SHAW MOUNTAIN MINING DISTRICT.

The veins in this district, apparently forming a continuation of those on Fivemile Creek, were discovered in 1877. The veins are located on the high ridge just north of the Idaho City stage road, 8 miles N. 80° E. from Boise, at elevations of about 5,000 feet. The mines were prospected only on a small scale in 1896. The country rock is normal granite, with a few smaller masses of granite-porphyry. A strong sheeting of the granite is noted in many places between Fivemile Creek and Shaw Mountain, the joints having the same strike and dip as the veins. The Rising Sun vein is the most prominent, and crops as a well-defined fissure vein of white quartz for 1 mile near the summit of the ridge with a general east-west direction and dip of 45° to 80° S. Four claims are located on it, from west to east, as follows: Rising Sun, Paymaster, North Star, and Daisy. On the first of these a 10-stamp mill was erected in 1879. It is developed by several tunnels, the lowest 400 feet below the croppings and 500 feet long. From the upper levels at least 500 tons were extracted, yielding from $14 to $100 per ton; in the lowest tunnel heavy sulphide ore was found which did not contain much free gold. From a sample of this, collected from the dump and containing pyrite, arsenopyrite, blende, and galena, an assay of 11 ounces of gold and 4 ounces of silver was obtained, a total value of $230 per ton. The pay shoot is stated to be 120 feet long, the width of the vein being not over 2 feet. Some ore of similar character has also been extracted from the Paymaster. The North Star, showing strong croppings of white quartz on the summit of the sharp ridge, is said to contain five smaller shoots of ore, and is opened by a tunnel 280 feet long, giving backs of 180 feet. A few hundred feet south of this vein, on two smaller parallel veins, lie several claims, among which are the Kessler, Gold King, and Levi. These veins, on which some good ore is said to have been found, carry the same clean white quartz as the North Star; samples of this barren-looking material gave $2 in gold and $0.49 in silver.

Near the vein the granite has undergone the usual alteration due to thermal waters. The brown mica (biotite) is converted to white mica (muscovite), and the feldspars are changed to a white opaque mass, which is muscovite (sericite) in an extremely fine-grained aggregate. Aggregates of coarse muscovite sometimes occur in the quartz from this vicinity.

MINING DISTRICTS OF WILLOW CREEK AND ROCK CREEK.

LOCATION AND TOPOGRAPHY.

The Willow Creek district lies in Boise County, 18 miles distant from Boise, in a direction N. 20° W., and is adjoined on the northeast by the Rock Creek district, the two extending in an east-northeast

direction for 8 miles. The elevation ranges from 3,000 to 5,000 feet above sea level. A ridge with northwesterly direction and culminating in Crown Point (elevation 5,300 feet) separates the two districts and also the watershed of the Boise from that of the Payette. Most of the mines of Willow Creek are located in the steep gulches at the head of the North Fork of the same creek. On the eastern side a steep descent leads down to Rock Creek, draining due northward into the Payette. The eastern end of Rock Creek district lies on the northeasterly trending ridge separating the Payette from the branches of Shafer Creek. The mining towns of Pearl and De Levan are located on Willow Creek. During the past summer there were probably 150 men in the districts. A small Huntington mill is erected on the Easter claim, and two smaller custom mills are also built lower down on Willow Creek.

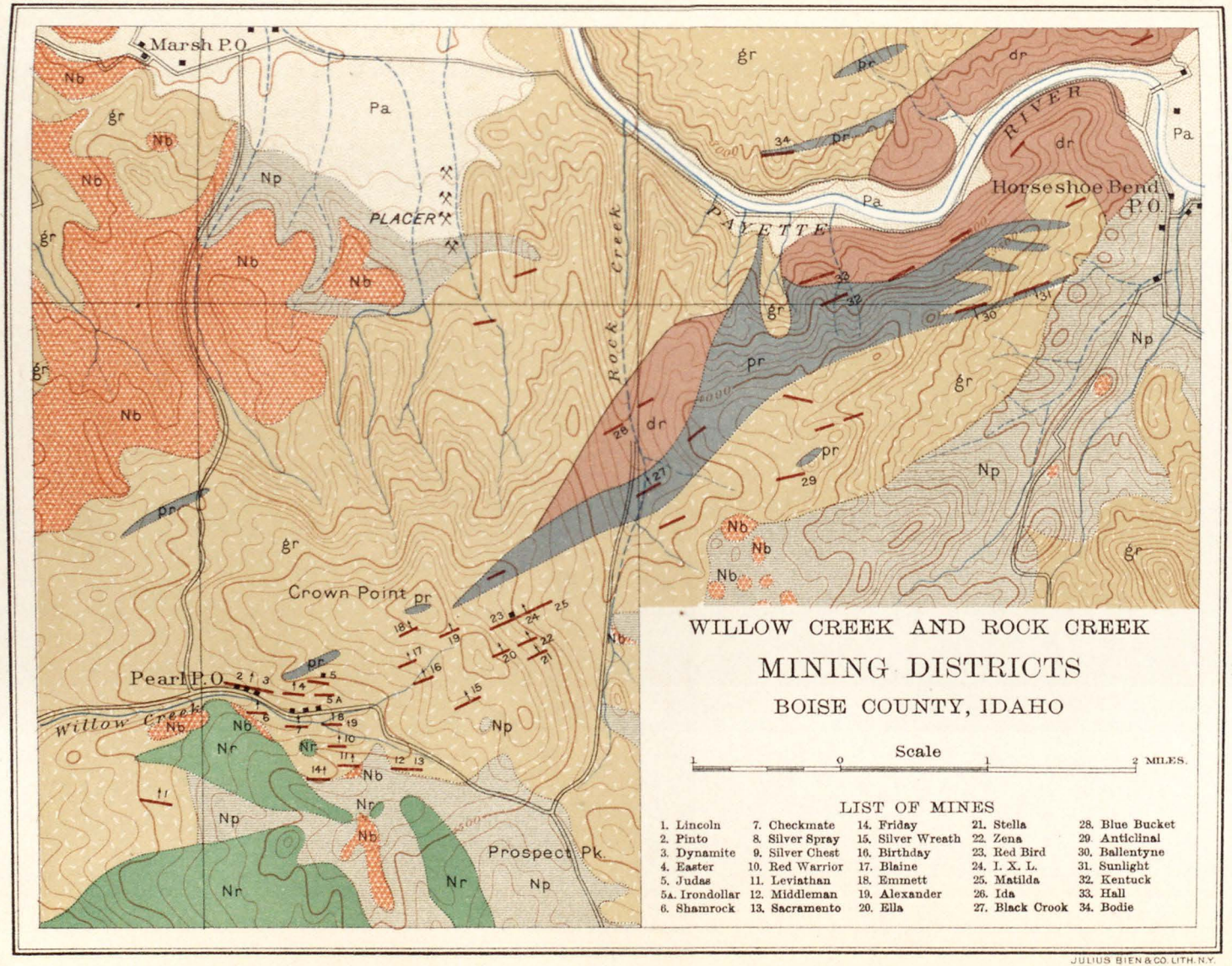
While placer deposits were worked in the vicinity of Willow Creek long ago, and one of the mines of the district, the Red Warrior, was worked in 1870, the majority of the locations have been made during the past few years, especially in 1894 and 1895. The productive mines of the districts are at present those in Willow Creek, and the total output is probably about $80,000 in gold, all extracted within the last few years. The output of 1896 is estimated at $50,000. Among the producers are the De Levan group, the Checkmate, Friday, Leviathan, Birthday, and Lincoln.

GEOLOGY.

GRANITIC ROCKS.

The formation of chief importance as containing all the veins is the granite and associated dike rocks. A few miles west of Pearl the first granite hills emerge from under the cover of the Payette sandstones and rise rapidly eastward, extending thence uninterruptedly in a northeasterly direction. The larger part of the area is occupied by a granitic rock, which is a local modification of the normal granite of the Boise Mountains.

The rock crumbles and disintegrates very easily, and the slopes of the mountains are covered by a deep mantle of disintegrated rock. During the winter rains the erosion goes on very rapidly, and deep gulches are often excavated in a remarkably short time. It is possible to obtain the fresh rock only from exposures in the bottom of the canyons or in prospect tunnels. The rock is of a light-gray color and has a coarse-grained structure, the average grain having a diameter of from 3 to 6^{mm}. It is composed of white feldspar, quartz, biotite, and sometimes hornblende. Brown titanite in small grains is universally present. Occasionally larger grains of light-red orthoclase appear among the prevailing white plagioclase. Under the microscope the following minerals are noted: Hornblende appears in brown-



LEGEND

PLEISTOCENE

Pa — Alluvium and River terraces

NEOCENE

Np — Payette formation Sandstone etc.

Nb — Basalt

Nr — Rhyolite

gr — Granite

PRE-NEOCENE

dr — Diorite, Augitediorite

pr — Diorite Porphyrite

Gold Veins

JULIUS BIEN & CO. LITH. N.Y.

ish-green anhedral grains, and biotite as irregular, yellowish-brown foils. The quartz occurs in abundant anhedral grains, frequently exhibiting undulous extinction, due to pressure. The feldspar, also in irregular grains, is quite predominantly a soda-lime feldspar, generally an oligoclase or andesine, though some labradorite was found in a specimen from the Payette River Canyon. Small plagioclase crystals are sometimes embedded in the biotite. Orthoclase and microcline both occur in the specimens from the Silver Wreath mine and near the Checkmate, but are practically absent in other specimens from the Payette River Canyon, 3½ miles east of Marsh. A little magnetite and apatite always occurs. Titanite is present in larger quantities, and sometimes, as at the Silver Wreath mine, makes up a notable percentage of the rock. In this rock it occurs in idiomorphic wedge-shaped crystals protruding in feldspar grains and also including small prisms of the same mineral. An analysis of the rock from the Silver Wreath mine is given below, and a calculation of the analysis may be found on page 641:

Analysis of rock from the Silver Wreath mine.

[Analyst, George Steiger.]

SiO_2	65.23
TiO_2	.66
Al_2O_3	16.94
Fe_2O_3	1.60
FeO	1.91
MnO	trace
CaO	3.85
BaO	.19
MgO	1.31
K_2O	3.02
Na_2O	3.57
H_2O below 100°	.18
H_2O above 100°	.88
P_2O_5	.19
CO_2	.25
	99.78

According to these data, it is clear that the granitic rock is more closely related to a quartz-mica-diorite than to a granite, and shows great similarity to the granodiorite of the Sierra Nevada in California. Being, however, only a local modification of a large area of normal granite, with which it is connected by transitions, the name granite has provisionally been retained. More basic dioritic rocks, containing an abundance of hornblende, sometimes appear as irregular streaks and masses near Pearl. This is well shown in the tunnel at

the Easter mine, as well as in the bottom of the creek near the Silver Spray claim.

A still more basic facies occurs at Horseshoe Bend on both sides of the river, and extends for a distance of 3 miles down along the canyon, bordering on the south against the porphyritic dike subsequently described and on the north against the dioritic granite, with very indistinct and ill-defined outline. This rock varies much in appearance, from dark-gray, medium-grained, or slightly porphyritic to coarse-granular, the latter consisting apparently of white feldspar and rather abundant green hornblende. The peculiarity of these dark, granular rocks is that besides being poor in quartz they also carry augite, and may be designated pyroxene-diorites. The rock at the Horseshoe Bend bridge carries imperfectly idiomorphic augite and a little hypersthene, the crystals being of a maximum length of 1^{mm}, but usually less. There is also a little biotite. These three constituents are embedded in a clear feldspar mass, which consists of short prisms of labradorite, with zonal extinction, cemented by smaller anhedral grains of probably the same feldspar. The structure in this, as in other specimens, is hypidiomorphic granular. The coarse-granular rock three-fourths mile west of Horseshoe Bend consists of white feldspar, green hornblende, and a smaller amount of biotite in large sheets. The microscope shows a few large, irregular grains of orthoclase, in which are embedded smaller prisms of labradorite. In this specimen there is a little quartz between the large feldspars. Most of the feldspar grains doubtless consist of labradorite. The augite is largely converted into hornblende, and but little of the original mineral remains.

DIKE ROCKS.

A series of dikes extends diagonally across the districts. Beginning as narrow dikes near the Horseshoe Bend post-office, these rocks extend in a widening belt over toward Rock Creek, there attaining their maximum development at the crossing of Rock Creek. The belt is here fully one-fourth mile wide, and practically forms one dike, though with smaller included masses of diorite. From Rock Creek this same dike extends up toward Crown Point Hill, but gradually contracts and ends before reaching the summit. Scattering dikes are, however, found on that hill, and appear to continue from there in a southwesterly direction, the last prominent dike appearing near the Dynamite claim at Pearl.

The dike rocks are of somewhat varying character. Pegmatitic dikes hardly occur at all, and light-colored granite-porphyry, so common elsewhere, is not abundant here. The usual dike rock is a coarse diorite-porphyrite. The rock occurring on the river hill between Horseshoe Bend and Rock Creek is prominently porphyritic by large white feldspar crystals, up to 1^{cm} long, and by smaller crystals of

hornblende and biotite, all embedded in a reddish groundmass. Under the microscope the feldspars are shown to be a plagioclase of medium basicity. The hornblende and the biotite are of normal character, while the groundmass is microcrystalline, consisting of quartz and unstriated feldspar. The structure of the groundmass often is approximately micropoikilitic. In certain of these porphyrites hornblende is very abundant and occurs also as small prisms embedded in the groundmass.

Another kind of porphyry contains quartz as rounded phenocrysts, and in this variety no quartz occurs in the groundmass. At the crossing of Rock Creek the dike is wide and fresh and the rock is of somewhat different character. It is dark green and fine grained, with feldspar prisms up to 8^{mm} in length and a few black, shining crystals of hornblende. The feldspar is chiefly labradorite in sharp, short prisms and very fresh. The crystals are of all sizes, grading down to those which form a part of the groundmass. Augite occurs as idiomorphic crystals, many of them decomposed; a little hornblende is also present, and magnetite is quite abundant. Between the closely crowded feldspars lies very little groundmass of quartz and unstriated feldspar. The structure of this rock is intermediate between holocrystalline porphyritic and panidiomorphic granular. The rock is thus an augite-diorite-porphyrite, closely connected with the lamprophyric dike rocks.

At the Dynamite claim, near Pearl, dense, dark-green dikes appear, consisting of clouded and altered feldspar in lath-like form, between which lie the decomposed ferromagnesian silicates replaced by chlorite and epidote. This rock has somewhat the appearance of an altered, fine-grained diabase. Scattered dikes occur in other parts of the district, one large dike cropping on the road to Marsh, 1½ miles north of Pearl. On the whole, the dikes may be said to be most abundant for a distance of half a mile north and half a mile south of the main belt of porphyritic rocks above described.

THE PAYETTE FORMATION.

The loose sandstones of the Payette formation (early Neocene) are laid down upon the very irregular granitic surface and begin at the western edge of the Willow Creek district, extending far westward. Sandstones and fine gravels of the same age are also found high up in the vicinity of Prospect Peak, and cover, in fact, the pass leading from Willow Creek to Boise. A branch of the Payette sandstones extends in a northeasterly direction as far as Horseshoe Bend. The Payette formation locally contains gold placer deposits, as at Church's ranch, at the southern edge of Marsh Valley. The gold in these placers has doubtless been washed down from quartz veins on the northern slope of Crown Point Hill. Other placer deposits occur 1 mile southwest of Marsh in the sands and conglomerates of the Payette formation.

These placers also probably have their origin in the gold veins of Crown Point Hill.

RHYOLITE.

The sharp point of Prospect Peak and the hill 1 mile to the west of it consist of rhyolite. They are necks from which large flows of the same rock poured down the southern slope of the ridge during the period of the Payette lake beds. In South Willow Creek the sandstone is seen to overlie the rhyolite. A smaller flow of rhyolite reached down as far as one-fourth mile south of Pearl. The rock is usually reddish or reddish-gray, and is of the ordinary compact lithoidal variety. In the last-mentioned flow occur, associated with it, rhyolite glass and loose tuffs.

BASALT.

The eruption of rhyolite was followed, during the same early Neocene period, by extensive eruptions of andesitic basalt. Smaller masses and necks of this black massive rock occur on the ridge one-fourth mile west of Prospect Peak, near the Leviathan, and at several other places to the west.

The Payette formation and accompanying eruptives are later than the mineral deposits, and contain no veins.

THE ORE DEPOSITS.

GENERAL CHARACTER.

The gold deposits in the Willow Creek and Rock Creek districts are fissure veins of somewhat varying character. Most of them occur in a belt parallel to that of the porphyry dikes, extending in a northeasterly direction, and being in no place much over 1 mile in width. The veins at Willow Creek are most frequently entirely in the dioritic granite. Sometimes a vein follows a porphyry dike for some distance in foot or hanging, but rarely for a long distance. Again, a vein may cut through a dike, in which case it often splinters up. The porphyry dikes are evidently all older than the veins. The fissures which carry gold strike east-west or northeast-southwest. In the Willow Creek district the dip is always to the north from 45° to 80° and the direction east-west, but toward Rock Creek the direction gradually changes to northeast-southwest. Toward Horseshoe Bend the direction changes again to east-northeast to west-southwest, and the dip is frequently steep to the south. The individual veins can rarely be traced for a long distance, and though it is probable that some of the veins are a mile long, this can rarely be satisfactorily proved. Narrow veins predominate in the Willow Creek district, while wider deposits occur on Rock Creek. The best exposures are, however, found in the former district, owing to more extensive development. In Rock Creek the developments are relatively slight, and

the decomposed surface material does not always allow satisfactory conclusions as to the character of a deposit. A large number of locations have been made in both districts, which, in fact, contain a very great number of veins. The ordinary type of the Willow Creek deposits consists of one or more fault fissures, on both sides of which there is a zone a few feet wide in which the country rock has been thoroughly altered (see Chapter II) and impregnated with pyrite. Along the main fissure, or, if there are two or more, chiefly along the foot wall, there are narrow seams filled with sulphides (pyrite, zincblende, arsenopyrite, and galena), which constitute the ore. The altered country rock, though often studded with pyrite crystals, usually contains only $1 or $2 in gold, while the value of the solid sulphides in the seams may reach $100 per ton or more. The deposit may thus be characterized as narrow veins of high-grade sulphide ore. There is usually but little gangue along these seams; calcite and quartz both occur. In other deposits the zone of altered diorite or granite is traversed irregularly by numerous small seams carrying arsenopyrite, blende, and galena, and in this manner the wider deposits of medium-grade ore are formed. The veins of Rock Creek are generally wider than those of Willow Creek.

The surface decomposition attains 50 to 100 feet in depth. In this zone the vein matter forms a brown ferruginous mass, which contains free gold and partly decomposed sulphides, often also lead carbonate. In many cases the fresh sulphide ore is found less than 50 feet from the surface. The fresh ore contains a very small percentage of free gold, and sometimes, in rich ore, not even a color is obtained by the pan. It follows from this that the amalgamation process is, as a rule, applicable only to the surface ores, though some veins will be found to contain more free gold than others. At present the rich ore—all above $30—is sacked and shipped to smelters.

The minerals consist of the following combination, so common in the Boise Ridge: pyrite, arsenopyrite, zinc blende, and galena; chalcopyrite is rare. The first two often occur as crystals. The zinc blende is black, brown, or greenish-yellow, usually not crystallized. The galena is less common than the others, and is considered an indication of rich ore. Ruby silver is reported as a rarity from the Shamrock and the Lincoln.

Shipping ore often contains 5 ounces of gold and 5 ounces of silver to the ton. A sample of pyrite, arsenopyrite, and galena from one of the best mines gave 0.85 ounce of gold and 28.35 ounces of silver per ton, a total of $37.42. Some galena carries 60 to 70 ounces of silver, and generally also much gold. Much of the arsenopyrite and zincblende is poor. The principal value appears to be in the pyrite and galena. Of the extent and direction of the ore shoots but little is known at present, but it is clear that the high-grade shoots are not of great lateral extent and that they are rather irregular.

TREATMENT OF THE ORES.

At present only the shipping ores can be utilized, and the question how to make $10 to $20 ore pay is one of the greatest importance to the camp. If it should contain any notable amount of free gold, amalgamation and concentration will probably be found most economical. Experiments should be made as to the applicability of the cyanide process to these ores. In the absence of notable amounts of copper and antimony the process might be of advantage, but experiments are necessary to prove this.

DETAILED DESCRIPTION.

The Lincoln vein is one of the most westerly locations in Willow Creek, being situated about a mile south-southwest of Pearl. The strike is N. 76° W. and the dip steep to the north, the vein being traceable in granite for a distance of one-fourth mile, with good ore at close intervals. The tunnel shows 2 to 10 feet of altered and pyritic granite, with smaller streaks and veins (1 to 6 inches wide) of pyrite, arsenopyrite, and blende, associated with a little drusy quartz; ruby silver has been noted. The developments consist of a crosscut tunnel 200 feet long, with drifts on the vein, and a small winze. Fifteen tons of ore were shipped, averaging $100. A sample of poor ore gave 0.1 ounce of gold and 5.30 ounces of silver, a relatively large amount of silver for this camp.

The Shamrock is situated a few hundred feet southwest of Pearl post-office, and is developed by an 80-foot crosscut from the creek level, from which drifts extend on the vein. The country rock is very much disturbed granite containing rich but irregular seams of ore. Some tons of the latter were shipped to smelters.

The Pinto lies a short distance north of the Bishopric mill, in Pearl, and has been opened by 225 feet of tunnels and a 50-foot winze. Sixty tons of ore are said to have been milled, yielding $23 per ton. The vein is about 2 feet wide. The Pearl claim, showing some very good ore, is located in this vicinity.

The Dynamite, said to be the extension of Pinto, is situated on the north side of Willow Creek, a short distance east of Pearl, the croppings being 250 feet above the stream. The vein is opened by a tunnel 200 feet long, strikes N. 68° W. and dips 45° N., and shows 16 inches of decomposed vein-matter in granite. A large porphyry dike lies close by to the north.

The Easter lies very nearly in the continuation of the Dynamite, and is one of the producing veins of the district. The croppings lie in granite 250 feet above the creek and the vein is developed by a tunnel 100 feet below the croppings. Another tunnel was started at the creek level, but has not yet reached the vein, work being suspended in 1896 on account of litigation. A considerable amount of

ore was stoped and milled in 1895. The vein strikes N. 81° W., dips 60° N., and shows 2 to 3 feet of decomposed vein matter which, in the pay shoot, yielded, it is said, $38 per ton of free gold. Pockets carrying extremely rich ore occurred at intervals. On the west side the vein is said to splinter up in a porphyry dike.

The Iron Dollar is located a short distance east of the Easter, and is probably the continuation of the same vein. The development consists of short tunnels and surface cuts. A few tons have been milled, yielding $58 in free gold. The vein, which strikes N. 71° W. and dips 60° N., lies in granite with occasional porphyry dikes in the hanging wall. The decomposed ore consists of altered granite, with streaks of arsenopyrite, pyrite, and galena, as well as a little calcite and quartz. A sample of good ore gave 2.50 ounces of gold and 7.15 ounces of silver to the ton, a total of $56.68.

The Judas lies a few hundred feet north of the Iron Dollar, and is at present (1897) being developed by a shaft intended to reach a depth of 400 feet. Excellent ore is reported to have been milled from this vein. The strike and dip are nearly the same as in the Iron Dollar, and the vein shows from 1 to 2 feet of decomposed granite carrying rich seams.

The Checkmate crops in granite on the south side of Willow Creek, due south of the Judas. This vein is one of the productive properties, shipping ore during the whole summer of 1896. It is reported that 300 tons, averaging $80 per ton, have been shipped. The mine is developed by a tunnel 100 feet long on the level of the creek, giving about 100 feet of backs. The deposit consists of a zone several feet wide of altered and pyritic granite, containing rich seams of heavy sulphides, arsenopyrite, pyrite, blende, and galena. At the time the mine was visited most of the ore came from a seam of solid sulphides 4 to 6 inches wide. The strike is N. 84° W.; the dip to the north.

A short distance east of the Checkmate is the Silver Spray, from which some good ore has been shipped. The vein is opened by a short tunnel, and strikes east-west, dipping 40° N. The country rock is dioritic granite, with streaks of dark diorite and dikes of diorite-porphyrite. The character and the minerals are similar to the Checkmate.

A little farther east is the Golden Chest, showing a wide zone of altered and pyritous granite with narrow seams of zinc blende.

South of Willow Creek, opposite the last-named claim, lies the Red Warrior, the oldest location in the district. No work was done on it in 1896.

One mile southeast of Pearl, on the summit of a ridge, lies the Leviathan claim. This is developed by a shaft 75 feet deep, and a few tons of rich ore have been shipped. The width of the mineralized granite is 13 feet, with seams of pay ore on both walls. In the continuation of this claim lie the Middleman and the Sacramento, which

have the same east-west strike. Both of these claims have shipped some rich ore, containing much galena. The pure galena assays 8 ounces of gold and 67 ounces of silver to the ton. The developments are slight.

The Friday is located on a flat 100 feet south of the Leviathan and is developed by a 100-foot shaft and drifts on the vein. Thirty tons of ore are said to have been shipped and some rich surface ore has been milled. The deposit shows 8 feet of altered granite, with a seam of heavy sulphides on the foot and hanging walls. The ore contains pyrite, arsenopyrite, and blende, with much calcite. This vein is said to be nearly vertical. The mine was not accessible during the present examination.

Beyond the claims mentioned, for a distance of about 1,000 feet, there are but few locations, but a number of strong veins are found on the summit of the ridge separating Willow Creek from Rock Creek.

Beginning on the north, the Emmett vein is located near the summit of Crown Point Hill, on the southwesterly slope. Good ore is reported to have been found in this claim and shipments were made during the winter of 1896–97. An incline shaft is sunk to a depth of 100 feet.

The Ida lies on the Rock Creek slope, at an elevation of 4,700 feet, and appears to be a wide vein in a dike of mineralized porphyry. It is developed by 175 feet of tunnels and shaft, and excellent assays have been obtained from average samples. The Blaine, on the Willow Creek side, a short distance north of the road to Rock Creek, is a promising prospect from which some ore was shipped in 1896. The Alexander, located on the divide, showed some good ore, a brown decomposed mass containing lead carbonate and milling $40 per ton. The vein is 4 feet wide, striking N. 74° E. and dipping north.

The Birthday, a few hundred feet south of the Blaine, has produced some rich shipping ore, composed of solid pyrite, zinc blende, and galena.

The Silver Wreath lies on the Willow Creek side, three-fourths of a mile southeast of Crown Point Hill, and is opened by a crosscut 170 feet long, cutting the vein at a depth of 75 feet. The croppings show distinctly by quartz, colored greenish by arsenic. The strike is N. 79° E. and the dip steep to the north. The deposit consists of a zone of decomposed dioritic granite, 8 feet wide, containing seams of the usual minerals. Some ore shipped yielded $40 per ton.

The IXL is situated on the Rock Creek side, three-fourths of a mile east-southeast of Crown Point Hill. An incline shaft is being sunk on this vein, and has at the present writing attained a depth of 200 feet. The vein, which strikes on an average northeast and dips 50° N., is contained in granite with a dike of granite-porphyry in the hanging wall. Four feet of brown decomposed vein matter are shown in the shaft. About 25 per cent of the total value is in free gold, and, according to average samples, there is a considerable body of medium-

grade ore. A tunnel is located on the eastern extension, 900 feet east of the incline. It is claimed that several ore bodies occur between the incline and the shaft. The vein is one of the longest in the district, being traceable for at least 2,000 feet.

The Zena, Stella, and Ella claims are located 600 feet south of the IXL, about in the continuation of the Birthday and Silver Wreath, on the Willow Creek side, and are opened by several short tunnels. The Zena shows a well-defined fissure with a dike of diorite-porphyrite 5 feet wide in the hanging. The ore consists of narrow streaks of blende, pyrite, and arsenopyrite in an altered and pyritous granite. The ore appears fresh near the surface, in contrast to the decomposed ledge matter of the IXL and the Alexander.

A number of veins are located along Rock Creek. The Black Crook lies 1½ miles northeast of Crown Point Hill, and is opened by a drift on the vein 140 feet long. The vein strikes N. 62° E. and has a maximum width of 8 feet. It has diorite-porphyrite in the hanging wall and granitic granite-diorite in the foot wall. The gangue is a grayish quartz and a pink calcite colored by manganese. The ore body was reported to be large but of low grade. Some assays show a relatively large amount of silver in the ore. The vein is reported to be traceable for a long distance eastward.

The Blue Bucket lies 1,500 feet farther down the creek, at an elevation of 3,500 feet, in diorite and dioritic granite. Some very rich ore is said to have been taken from it, but the claim was not worked during the examination of the district.

East of Rock Creek lie a large number of claims, on most of which but little work had been done in 1896. Among them is the Anticlinal, under the Liberty Cap Hill, and the Lambertine, Bobtail, and Mint claims, three-fourths of a mile east of Rock Creek. On the Bobtail claim a tunnel 200 feet in length has been run, cutting an 8-foot vein of good ore.

Many claims are also located on the ridge between Shafer Creek and the Payette River. There appear to be two principal lines of deposits. One begins one-half mile southwest of Horseshoe Bend post-office, where the granite emerges from the Payette lake beds and continues in a west-southwest direction up to the summit of the ridge. Among the claims located along this line are the Sunny Side and the Ballentyne, both on the same vein. The vein dips 70° to 80° S. and is about 2 feet wide. The vein matter is soft and decomposed, carrying free gold and some lead carbonate. The country rock is granite, but in the foot wall lies a dike of quartz-diorite-porphyrite a few feet wide. Another vein lies a short distance southward. A large number of prospects are found on the steep river hill toward the Payette, about one-fourth mile north of the Ballentyne and opposite McFarland's ranch on the river. The following claims are located on this vein system, from east to west: Mammoth, Apex, Atlanta, Claggett, Topeka, Kentuck. These are at an elevation of about 1,000 feet above

the river. Hall's claim lies a little lower down, about 700 feet above the river. Some of these claims appear to be promising properties, but the developments are slight. The ores are decomposed, carrying on the surface a considerable amount of free gold. Some antimonite, carrying no gold, was also found in this vicinity.

The above are by no means all of the claims and prospects of the district, but only such as showed any notable development or production of ore. It is quite possible that some of these prospects may develop into paying mines.

SILVER DEPOSITS.

The Boise Mountains contain many notable silver deposits, chiefly well-defined quartz veins with finely distributed rich sulphides and antimonides. But it is not intended to take up the study of them in this paper. The principal locality where silver mining has been carried on is at Banner, 25 miles northeast of Idaho City.

Many scattered quartz veins with silver ores, either galena or rich silver sulphides, occur in the area here described, but none of them have produced much. A few deposits of this kind occur along the Idaho City road 3 or 4 miles from Boise, and another in north fork of Dry Creek a few miles southwest of Shafer Butte. Other silver prospects are located 2 miles south of Church's placers, in Marsh Valley, and at several places near Horseshoe Bend, notably on the western side of the Payette 2 miles north of the bridge. Many silver prospects occur 1 mile east of Halfway House in the Moore Creek Valley, and some of them are said to contain rich ore (Sunlight group).

The occurrence of occasional silver deposits in the Idaho Basin has already been mentioned in the detailed description in Chapter IV.

PLACERS OF THE BOISE RIDGE.

RECENT PLACERS.

The bars of the Boise and Payette rivers were worked in the early days, and on some of them work is still progressing. The large gravels of the lower reaches of both rivers contain a little gold, but scarcely enough for profitable working. A dredger built some years ago to work the gravels of the lower Payette near Marsh proved a failure. The placers of the Moore Creek drainage were discussed in Chapter III. Most of the creeks of the Boise Range have carried a little gold, but few of them have been rich.

Benches along Dry Creek and Willow Creek are worked at intervals, even now, when water is available. Shafer Creek, at least the branch heading near Cartwright ranch, carried a little gold. The richest placers probably occur at the northern base of Crown Point Hill at Church's in Marsh Valley; but the whole output of the recent placers of the Boise Ridge is, if we except the basin, of small importance.

NEOCENE PLACERS.

The shore and old gulch gravels resting on granite in the early Neocene Payette formation carry a little gold at many places—for instance, in several gulches about 2 miles eastward from Boise, north and south of the Idaho City stage road. Similar old placer deposits are found in the Payette formation at Church's, in Marsh Valley, and the old gravels at Johnson's, 1 mile southwest of Marsh, contain some gold which has been concentrated in the gulches and washed by the hydraulic process.

Gold-bearing gravels of late Neocene (Pliocene) age are found below the remnants of the several basalt flows on both sides of Boise River, those in Moore Creek having already been mentioned. The top of the lowest flow, which is probably the oldest, lies at the "New York House," 10 miles southwest of Boise, at the level of the river, and is not visible farther west. Eastward it rises slowly, and near the mouth of Moore Creek is 40 feet above the river (in August). Below this flow, which is about 20 feet thick, lie 2 to 10 feet of coarse, heavy gravel, resting on granite. This gravel is in places rich in coarse gold, part of which probably comes from seams and small veins in the surrounding granite. There are only a few exposures of this low flow below the mouth of Moore Creek, and it is reported that only one or two are known above. The flow came down the south fork of the Boise. At low water this gravel below the basalt has been mined with profit at several places, notably at the Holy Terror mine, 2 miles below the mouth of Moore Creek, and at Tarents, 2 miles farther down. There is only a limited amount of this gravel below the lower flow. The two other flows, 30 to 60 feet thick, are at elevations of 120 and 300 feet above the river. Underlying both of them, wherever they are preserved, hanging along the banks of the canyon, are heavy masses of late Neocene gravels, 20 feet or more in thickness. This gravel contains some gold throughout, and though much of it is fine, it may in places be found rich enough for the hydraulic process wherever water can be brought to it. In 1896 an attempt was made at the mouth of the canyon, 8 miles southeast of Boise, on the northeast bank of the river, to mine the heavy mass of gravel and sand here underlying the basalt flow, and should this attempt be successful there are probably many other similar deposits a little farther up the river which could be worked in the same manner.

THE FOSSIL PLANTS OF THE PAYETTE FORMATION.

By F. H. Knowlton.

The following report is based on a collection of fossil plants obtained during the past season by Mr. Waldemar Lindgren from the lake beds of the Snake River, in western Idaho, to which the name Payette formation has been given. The matrix in which the plants are preserved is in general a fine-grained clay, which has retained their outline and nervation with remarkable fidelity.

Following is a list of localities from which the plants were obtained:

1. Two miles southeast of Marsh post-office, Boise County, Idaho. From a coal prospect.
2. One mile southeast of Marsh post-office, Boise County, Idaho. From a canyon on the road to Willow Creek and several hundred feet above the Payette River.
3. Robb's coal prospect, 1 mile south of Horseshoe Bend post-office, Boise County, Idaho.
4. Cartwright's ranch, on Shafer Creek, 4 miles southeast of Horseshoe Bend post-office, Boise County, Idaho.
5. Near Idaho City, Boise County, Idaho.

SYSTEMATIC ENUMERATION OF SPECIES.

Dryopteris idahoensis n. sp.

Pl. XCIX, figs. 1, 2.

Outline of frond unknown; frond twice pinnate, pinnæ approximate, subopposite, deeply pinnate, the segments oblong, obtusely acuminate, or upper pinnæ lobed at base, the remainder entire or undulate; secondary rachis strong, curved upward; each segment with a strong midvein giving off forked veins.

As may be seen from the figure, this species is represented only by a fragment, which, were it not for the fact that it is so distinctly unlike any previously described American form, would be almost too fragmentary for notice. The original form of the frond can not be determined. The specimen consists of a portion of the rachis with parts of four pinnæ, only two of which are approximately perfect. The pinnæ are close together, subopposite in attachment, and slightly

arching upward. The lowest pinna is lanceolate, deeply cut, with oblong, obtusely acuminate segments. It is 2^{cm} in length. The other most perfect pinna is 1.5^{cm} in length, and is also lanceolate in outline, but has only one pair of segments at base, the remainder being merely undulate. The nervation consists of forked veins arising from a rather strong midvein in each segment.

As no fruit is preserved, its proper generic reference becomes questionable, and dependence must be placed on its resemblance to the described forms of which the systematic position is known. It has, for example, some resemblance to what has been described as *Lastræa fischeri* Heer, from the Swiss Tertiary, and also John Day Valley, Oregon, but differs in being hardly one-half the size and in having forked instead of simple nerves.

On the whole, this appears to approach most closely certain species of Aspidium (now Dryopteris) from the Tertiary of Switzerland. Among them may be mentioned *A. filix-antiqua* Heer, *A. meyeri* Heer, and *A. elongatum* Heer, all described and figured in Heer's Flora Tertiaria Helvetiæ, Vol. I, Pl. XI.

Locality: One mile southeast of Marsh post-office, Boise County, Idaho.

EQUISETUM sp.

There are several Equisetum stems in the collection. They are all underground portions of stems, showing the scars of rootlets. From one stem that is shown in cross section it appears that they are about 12-ribbed. They vary in width from 1^{cm} to 2^{cm}.

These stems appear to most resemble *E. wyomingense* Lx.,[1] from the vicinity of Green River, Wyoming, also identified by Newberry[2] at probably the same locality, but there are differences, which make it advisable to keep them apart. I have not given a name to this form, hoping that more and better material could be obtained.

Locality: Idaho City, Idaho.

PINUS sp.

Pl. XCIX, fig. 3.

The collection contains a single nearly perfect fruit.

Locality: Idaho City, Idaho.

SEQUOIA ANGUSTIFOLIA? LX.

Pl. XCIX, fig. 4.

Sequoia angustifolia Lx., Cret. and Tert. Fl., p. 240, Pl. L, fig. 5, 1883.

This species was described by Lesquereux from Elko Station, Nevada, in strata supposed to be of Green River Group age. He also reported the same species from Corral Hollow, California. The figure

[1] Tert. Fl., p. 69, Pl. VI, figs. 8–11.
[2] Cf. plates ined., Pl. LXV, fig. 8.

of a specimen from this last locality, as cited above, agrees closely with the one under discussion, but it does not appear to be identical with the Elko specimens. It is likely that on a revision of American fossil Sequoias this will have to be made a new species, unless it can be correlated with some known form.

Localities: Two miles southeast of Marsh post-office, Boise County; Cartwright's ranch, on Shafer Creek; Idaho City.

SEQUOIA, Cones of.

The collection contains a single example, which bears three broken cones that appear to belong to this genus. They are too fragmentary to make an identification of value.

Locality: One mile southeast of Marsh post-office, Boise County, Idaho.

JUGLANS HESPERIA n. sp.

Pl. XCIX, fig. 8.

Leaflet coriaceous, elliptical-lanceolate in outline, unequal-sided at base, probably acuminate at apex (broken); margin finely serrate; petiole short, thick; midrib thick; secondaries numerous, about eighteen pairs, opposite below, alternate above, emerging at a low angle, but curving upward, and running along the border and sending weak branches to the teeth; intermediate secondaries numerous, often two between secondaries, either soon lost, or running nearly to the margin; nervilles numerous, mainly percurrent; finer nervation quadrangular.

This fine species is represented by the single example figured. It is nearly perfect, lacking only the apex. The part preserved is 8^{cm} long and was probably 10^{cm} or 11^{cm} in length when perfect. It is broadest in the middle, at which point it is 3.75^{cm} in width. It is broadly lanceolate, rounded and unequal-sided at base, and probably acuminate at apex. The margin is finely serrate, with rather obtuse teeth.

This species is closely related to, if not, indeed, identical with, *Juglans oregoniana* Lx., from the Chalk Bluffs of California. Almost the only difference is that *J. oregoniana* is enlarged upward, whereas the one under discussion is narrowed above and enlarged below. The configuration of the base, the serrate margins, and the nervation are very similar. There are, however, no intermediate secondaries in *J. oregoniana*. On account of these differences, slight though they are, and from the further fact that the material is very scanty, it has been thought best to regard them as distinct, at least for the present.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

MYRICA LANCEOLATA n. sp.

Pl. XCIX, figs. 5, 6.

Leaf of firm texture; linear-lanceolate, tapering below into a long wedge-shaped base which passes into a thick petiole 1^{cm} to 2^{cm} long; apex broken but apparently long acuminate; margin irregular, faintly toothed; midrib very thick, straight; secondaries obscurely preserved, but apparently alternate, at an acute angle, and passing up for long distances near the margin; finer nervation not retained.

This species is based on the two fragments figured, both of which represent the basal portion. The smaller of the two specimens (fig. 6) is 6.5^{cm} in length including the petiole (1^{cm}), and was probably at least 9.5^{cm} in length when perfect. Its width is about $.75^{cm}$. The nervation, with the exception of the thick midrib, is not preserved. The larger leaf has only 5.5^{cm} preserved, including the petiole of 2^{cm}. Its length must have been at least 12^{cm}. The midrib is very thick and straight, as in the other. The width of this specimen is a little more than 1.5^{cm}.

This species is very closely allied to a species not yet published, from the Lamar flora, in the Yellowstone National Park. The leaves are of about the same size, the main point of difference being the more pronounced teeth in the Lamar species.

Locality: Cartwright ranch, on Shafer Creek, Boise County, Idaho.

MYRICA ? IDAHOENSIS n. sp.

Pl. XCIX, fig. 7.

Leaf thickish, obovate-lanceolate, obtuse at apex, narrowed below to a wedge-shaped base and a long, thick petiole; margin obscurely crenate; midrib thick, straight.

This leaf is preserved entire, and is 9^{cm} in length, including the petiole, which is 2^{cm}. In outline it is long, obovate-lanceolate, with obtuse apex, and narrowed from above the middle to a long, wedge-shaped base. The petiole is thick and much curved to one side. The margin is rather remotely and faintly crenate, the teeth short and obtuse. The midrib is the only nervation preserved, and this is thick and straight.

In absence of better nervation there is some doubt as to the generic reference of this leaf. It has been referred to Myrica provisionally, until better material can be obtained. It has considerable resemblance to the living *M. cerifera* L. (common wax-berry), but it is impossible to carry the comparison beyond similarity of shape, dentation, and midrib.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

POPULUS LINDGRENI n. sp.

Pl. C, fig. 3.

Leaf of firm texture, coriaceous, nearly circular in outline, being only a trifle broader below the middle, whence it is rounded to a truncate base, and above to a very obtuse apex; margin somewhat irregularly but finely crenate-toothed, the teeth obtuse; petiole over 2^{cm} in length, very large, flattened; palmately five-nerved or ribbed from the top of the petiole, the central or midrib strongest, very thick, the two lateral ribs also strong, the lowest pair being the slightest; the central or midrib with two pairs of subopposite secondaries high above the middle; the large lateral pairs of ribs each with about six secondaries on the outside, emerging at a very low angle and arching near the margin; finer nervation obscure.

The fine specimen figured is the only one obtained of this characteristic species. It is nearly circular in outline, being 5.25^{cm} in length without the petiole, and nearly 5.5^{cm} in width at the broadest portion, which is just below the middle. The petiole is a little more than 2^{cm} in length, 2^{mm} in width as it emerges from the base of the leaf, and 3.5^{mm} in width at the other end. It appears to be preserved entire and is clearly flattened.

The margin of the leaf is closely crenate-toothed, the teeth being obtuse. The nervation is markedly five-ribbed from near the top of the petiole, the three central ribs being by far the stronger. The lowest lateral ribs or nerves are small and soon lost in the blade of the leaf.

Among living species this appears to approach most closely to *P. balsamifera candicans.* It differs in being much more obtuse, in having a more marked crenate border, and in the stronger nervation. The relationship is, however, quite marked, the two leaves being of the same type, but with strong specific differences.

There is no fossil American species with which this is to be closely compared. There are several with approximately the same shape, yet differing clearly in serration, nervation, etc.

I take pleasure in naming it after Mr. Waldemar Lindgren, of the United States Geological Survey.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

POPULUS EOTREMULOIDES n. sp.

Pl. C, figs. 1, 2; CI, figs. 1, 2.

Leaves membranaceous yet firm-textured, broadly ovate in outline, rounded regularly to the base and contracted above to an obtusely acuminate apex; margin entire for lower fourth of leaf, remainder obscurely crenate-toothed; petiole very long, flattened; midrib rather

strong; secondaries about four or five pairs, the lowest pair arising from the very base of the blade, thin, soon lost in the blade; second pair very strong, arising from the petiole some distance above the base and arching up for two-thirds the length of the leaf, probably branched outside; the other secondaries, probably two or three pairs, arising some distance above, strong, alternate, at an angle of 45°; finer nervation not retained.

This well-marked species is represented by the four specimens figured. The larger of these (fig. 2 of Pl. CI) is 10.75^{cm} in length without the petiole, which is 5.25^{cm} long. The margin is not all preserved, but the leaf appears to have been about 7^{cm} in width. The other nearly perfect leaf (fig. 1) is a little less than 10^{cm} in length and is 6.5^{cm} in width. About 3.5^{cm} in length of petiole is preserved, but it is not all present.

The leaves are all broadly ovate, with rounded bases and obtuse apices. The margin is crenate-toothed from above the base. The petiole is very long, as may be seen from the figures, and is obviously flattened. The nervation is not well preserved, but enough can be made out to show its general character. The strong pair of secondaries arise some distance above the base, while the thin basal pair arise near the top of the petiole. There are also two or three pairs of secondaries arising from the midrib some distance above the strong pair. None of the ultimate nervation is retained.

Among living species the relation of this fossil form is unquestionably with *P. tremuloides* Michx. In the herbarium of the National Museum there is a specimen, consisting of a young seedling plant of this species, collected on the Aquarius Plateau, Utah, at an altitude of 9,000 feet, that can hardly be distinguished from the fossil leaves under consideration. The size, outline, petiole, and nervation are practically identical. The only difference, and this is of minor importance, appears to be in the margin. In the fossil form the teeth are absent from the lower fourth of the leaf, while these specimens of *P. tremuloides* are toothed from base to apex and the teeth are rather larger. The leaves of this seedling differ somewhat from the normal mature leaves of the species, but it would seem, in view of their evident relationship to the fossil leaves, that they represent a reversion to an ancestral type, or perhaps rather a survival of this type, which disappears in the mature plant. There certainly can be no doubt of the intimate relationship between the living and fossil leaves.

There seems to be no fossil American species with which it is at all intimately related. It is perhaps closest to *P. zaddachi* Heer, but differs markedly.

I have given this species the name *eotremuloides* in view of its evident relation to the well-known *tremuloides*.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

POPULUS OCCIDENTALIS n. sp.

Pl. XCIX, fig. 14.

Leaves evidently of firm texture, long-ovate in outline, rounded below to a truncate base and narrowed above (apex broken); petiole not preserved; margin faintly or rather obscurely crenate-toothed, with obtuse teeth; midrib slender, straight; secondaries seven or eight pair, subopposite, at an angle of about 45°, curving upward; finer nervation not preserved.

This species is represented by the single example figured. The part preserved is 8^{cm} long and was probably not far from 10^{cm} in length when perfect. It is broadest at a point much below the middle, where it is 6^{cm} broad. Both base and apex are wanting, but it appears that it was rounded or truncate at base and acuminate at apex. The margin is rather obscurely crenate-toothed, the teeth obtuse. The nervation consists of about eight pairs of subopposite secondaries.

This species seems to approach quite closely to *Populus monilifera* Ait., the cottonwood so abundant in the West. It differs slightly in dentation of the margin, and in the fact that the secondaries arise at a greater angle and apparently do not anastomose near the margin.

Among fossil species it is somewhat related to *P. balsamoides* Göpp., from the Miocene of California.[1] But this differs in being more heart-shaped at base, more obtuse at apex, and more strongly dentate at margin.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

SALIX ANGUSTA Al. Br.

Pl. XCIX, fig. 12.

There are a number of somewhat defective leaves that are referred with little doubt to this species.

Localities: One mile southeast of Marsh post-office, Boise County; Cartwright's ranch, on Shafer Creek, Idaho.

BETULA ANGUSTIFOLIA Newby.

Proc. U. S. Nat. Mus., Vol. V, p. 508, 1883; plates ined., Pl. XLVI, fig. 5.

This was described by Newberry from Bridge Creek, Oregon. The specimen here referred to it is broken, but is probably correctly identified.

Locality: Idaho City, Idaho.

BETULA, Fruit of.

Pl. XCIX, fig. 9.

Fruit (pistillate ament) cylindrical, 3^{cm} in length, 9^{mm} in diameter; bracts rather few, acutish, about 3^{mm} long.

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[1] Lx., Cret. and Tert. Fl., p. 248, Pl. LV, figs. 3, 5, 1883.

This appears to represent the pistillate ament of a Betula, agreeing, for example, quite closely with the living *B. alba*, *B. papyracea*, etc. This view is further strengthened by the finding of leaves of Betula in the same beds.

I have not thought best to name it specifically, as it is somewhat obscure and better material is necessary for the determination of the minute characters.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

BETULA ÆQUALIS? LX.

Pl. CII, fig. 5.

Betula æqualis Lx., Mem. Mus. Comp. Zool., Vol. VI, No. 1, p. 2, Pl. I, figs. 2–4, 1880.

I am somewhat in doubt as to the correctness of this reference. There is but a single specimen in the collection, and this, as may be seen from the figure, is not perfect, lacking the apex and most of one side and the base. It, however, agrees quite closely with Lesquereux's figures, being only a little more obtuse. The base appears similar as far as can be made out.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

QUERCUS SIMULATA n. sp.

Pl. CI, figs. 3, 4; CII, figs. 1, 2.

Leaves coriaceous, lanceolate-acuminate, slightly unequal sided at base, obtuse or obtusely acuminate at apex; margin undulate or remotely shallow-toothed; petiolate, petiole short, thick; midrib strong, straight; secondaries numerous, 12 to 16 pairs, alternate or subopposite, at an angle of 20° to 45°, irregular, camptodrome, each joined by a simple bow to the one next above; intermediate secondaries occasional, soon vanishing; ultimate nervation obscure, but apparently quadrangular.

These leaves appear to have been quite abundant in the beds, for four or five very perfect examples, and numerous more or less fragmentary ones, occur in the collection. They were evidently thick, coriaceous leaves, suggestive at least of having been evergreen. They range considerably in size, the smallest being 3^{cm} in length and 1^{cm} in width, and the largest 9^{cm} in length and 2.25^{cm} in width. The average size, represented by figs. 1 and 4, is about 8^{cm} in length by 2^{cm} in width. In the smaller specimens the petiole is scarcely 2^{mm} long, while in the larger ones it is nearly or quite 1^{cm} in length. They are slightly unequal-sided at base, and obtuse (fig. 1) or somewhat acuminate (fig. 4) at apex. The margin is undulate, or very slightly and remotely toothed.

The nervation is marked at once by the great number of close camptodrome secondaries that arise at various angles from perhaps 20° to 45°. The finer nervation is obscure.

Among living species this appears to approach most closely to *Q. imbricaria* Mx., which has the same shape, the inæquilateral base, and the undulate margin. The differences in the primary nervation are, however, marked. In *Q. imbricaria* the secondaries are not nearly so numerous; they emerge at a more acute angle and are more irregular in their course. They are camptrodrome, somewhat as in *Q. simulata*.

Among fossil species the one under discussion approaches *Q. simplex* Newby., from Bridge Creek, Oregon,[1] which differs in being narrower, with more acuminate apex, and in having fewer secondaries. Ours is also somewhat like *Q. convexa* Lx., of the auriferous gravels of California, which differs, however, in being rather oblanceolate with more obtuse apex. The nervation is of the same character in both, and they are evidently related.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

QUERCUS CONSIMILIS Newby.

Pl. CII, fig. 6.

Quercus consimilis Newby., Proc. U. S. Nat. Mus., Vol. V, p. 505, 1883; plates ined., Pl. LXIII, figs. 2–5.
Quercus breweri Lx., Cret. and Tert. Fl., p. 246, Pl. LIV, figs. 5–8, 1883.

This species is represented by the very perfect figured specimen and also a number of equally well preserved but broken specimens. There can be no doubt as to its belonging to Newberry's species, which is from Bridge Creek, Oregon.

Localities: Two miles southeast of Marsh post-office; 1 mile southeast of Marsh post-office, Boise County, Idaho.

QUERCUS IDAHOENSIS n. sp.

Pl. CII, fig. 4.

Leaves coriaceous, broadly oblong in general outline, rather abruptly rounded at base, obtusely acuminate at apex, margin sharply serrate to just below the apex; the teeth large, almost bristle-pointed, directed upward, sinuses deep, rounded; midrib rather thin, straight; secondaries about 10 or 12 pairs, straight, parallel, craspedodrome, entering the larger teeth, arising at an angle of about 45°, subopposite; finer nervation not preserved.

This species is represented by the single example figured. It is 8^{cm} long and 3^{cm} wide. It lacks only a very small portion of the base. It

[1] Proc. U. S. Nat. Mus., Vol. V, p. 505, 1883; Plates ined., Pl. XLIII, fig. 6.

is quite a striking leaf, being made so by the regular, sharp-pointed teeth and the parallel craspedodrome secondaries.

This species is closely allied to the preceding species, *Q. consimilis*, and it is possible that it may belong to it. It appears to differ in its larger size, larger and stronger teeth, and particularly in being toothed entirely to the base, whereas *Q. consimilis* is without teeth for nearly or quite one-third of its length. A larger series may show them to be identical.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

QUERCUS SIMPLEX Newby.

Proc. U. S. Nat. Mus., Vol. V, p. 505, 1883; plates ined., Pl. XLIII, fig. 6.

There are two or more fairly well preserved examples that appear to belong to this species.

Locality: One mile southeast of Marsh post-office, Boise County, Idaho.

QUERCUS PAYETTENSIS n. sp.

Pl. CII, fig. 9.

Leaves of firm texture, lanceolate in outline; margin deeply sinuate-toothed, the teeth rather obtuse, the sinuses deep, rounded; midrib strong; nervation craspedodrome; secondaries as many pairs as there are teeth, alternate, at an angle of about 45°, passing straight to and entering the teeth; finer nervation not retained.

This species is founded on the example figured and one or two additional fragments. The figured specimen is the most perfect, though lacking both base and apex. It is now about 4.5^{cm} in length and 1.75^{cm} in width. It was probably not far from 7^{cm} in length when perfect.

This species has comparatively little resemblance to either of the species of Quercus detected thus far in the Payette formation. It is perhaps closest to *Q. consimilis* Newb. (Pl. IV, fig. 6), but differs markedly in being longer, narrower, and in having much stronger teeth. *Quercus furcinervis* Rossm.,[1] from Bridge Creek, Oregon, is somewhat similar, being, however, very much larger and with relatively much smaller teeth.

Locality: Silicified shale, Jackass Creek, 1½ miles above its junction with the Payette River, Boise County, Idaho.

QUERCUS ? sp.

There is a single fragment that appears to belong to this genus, but it is too much broken to permit identification. It is a leaf that must have been 12^{cm} or 14^{cm} in length and about 5^{cm} in width. The basal

[1] Lx., Cret. & Tert. Fl., Pl. LIV, fig 2.

portion only is preserved. The leaf appears to have been obovate-lanceolate, extending below into a wedge-shaped base. It appears to have been entire in the lower portion and toothed above.

Locality: One mile southeast of Marsh post-office, Boise County, Idaho.

ULMUS SPECIOSA Newby.

Proc. U. S. Nat. Mus., Vol. V, p. 507, 1883; Plates ined., Pl. XLV, fig. 8.

A single, somewhat fragmentary specimen, but with no doubt this species.

Locality: Idaho City, Idaho.

FICUS UNGERI Lx.

Pl. CI, fig. 5.

Lesquereux, Suppl. to Hayden's Ann. Rept. 1871, p. 7 (1872); Tert. Fl., p. 195, Pl. XXX, fig. 3; Cret. & Tert. Fl., p. 163, Pl. XLIV, figs. 1–3.

The collection contains three specimens that undoubtedly belong to this species, being especially like fig. 2 of Pl. XLIV in the Cretaceous and Tertiary Flora. They are of about the size of this, and have the slightly unequal base and identical nervation.

Locality: Cartwright's ranch, on Shafer Creek, Boise County, Idaho.

CASSIA OBTUSA n. sp.

Pl. C, figs. 4, 5.

Leaflet small, of firm texture, elliptical; margin entire, obtuse at apex, obtuse or subcordate at base; petiole short, thick; midrib thick, straight; secondaries numerous, about 14 pairs, the lowest pair short, nearly at right angles to the midrib, the others alternate, at an angle of 20° to 30°, probably curving and anastomosing at their extremities; finer nervation not preserved.

The two examples figured are all of this species that were contained in the collection. The smaller is about 3.5^{cm} in length and 1.5^{cm} in width. It is nearly regularly elliptical in outline, with obtuse base and relatively obtuse apex. The petiole is a little more than 1^{mm} in length and is rather thick. The midrib is also thick and carries about fourteen pairs of alternate parallel close secondaries. The other specimen is a little longer, with a subcordate base, but is otherwise similar.

There seems to be no American species with which this can be closely compared, but in the Swiss Tertiary a number of forms approach it quite closely. Thus *Cassia phaseolites* Heer[1] suggests this, but differs in size and in the fact that it is more wedge-shaped at base and apex. The nervation is quite similar. *C. ambigua* Heer[2]

[1] Fl. Tert. Helv., Vol. III, Pl. CXXXVII, figs. 1–12.
[2] Loc. cit., figs. 29, 32.

is also similar, but differs in outline and in having fewer secondaries. As nearly as can be made out, the leaflets under consideration belong to this genus and are provisionally so placed.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

PLATANUS ASPERA? Newb.

Proc. U. S. Nat. Mus., Vol. V, p. 509, 1883; Plates ined., Pl. XLII, figs. 1-3.

The collection contains several fragments of Platanus leaves, but hardly enough to be certain of their reference to this species. It is probable, however, that the identification is correct.

Locality: One mile southeast of Marsh post-office, Boise County, Idaho.

CELASTRUS LINDGRENI n. sp.

Pl. XCIX, fig. 13; C, fig. 6.

Leaf membranaceous; lanceolate-oblong in outline, narrowed below into a wedge-shaped base and prolonged above into an acuminate apex; margin obscurely serrate, the teeth small, obtuse; midrib rather thick and strong; secondaries about 10 or 12 pairs, suboppo-site, emerging at an angle of 45° or more, camptodrome, each arched and joined to the one above by a broad loop some distance within the border, with one series of smaller loops outside from which weak branches pass to the teeth; intermediate secondaries occasionally present, soon lost; nervilles much broken, forming large, irregular areolæ.

The somewhat fragmentary leaves figured are the only specimens of this form in the collection. The smaller appears to have been about 6.5^{cm} in length, and a little more than 2^{cm} in width at the broadest point, which is a little below the middle of the leaf. The larger leaf was 8 or 9^{cm} in length, and is about 3.8^{cm} in width. The nervation of both is finely preserved, and is quite characteristic of the genus Celastrus.

The species with which this is to be compared is *Celastrus fraxinifolius* Lx.,[1] from Florissant, Colorado. The general resemblance is very marked, the differences being rather of minor or specific importance. They are as follows: In *C. fraxinifolius* the leaves are broadest below the middle, the petiole is winged (broken in *C. lindgreni*), the teeth are fewer and stronger, and the secondaries fewer.

Among the numerous new species of this genus found in the Yellowstone National Park, but still unpublished, there are several to which this is evidently related.

Locality: Idaho City, Idaho.

[1] Cret. and Tert. Fl., p. 184, Pl. XXXIII, figs. 2-4; XL, fig. 10.

ACER TRILOBATUM PRODUCTUM ? Heer.

Pl. CII, fig. 3.

The collection contains only the single specimen figured of this form. It is unfortunately broken at the apex, so that its reference to this variety of *Acer trilobatum* is more or less uncertain. From the configuration of the part preserved there is, however, little doubt as to its correctness.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

RHUS PAYETTENSIS n. sp.

Pl. CI, figs. 6, 7.

Leaflet coriaceous, ovate in outline, abruptly rounded or truncate at base, and slightly unequal-sided, obtuse (?) at apex; margin nearly entire on one side, remotely toothed on the other, the teeth small, sharp, pointing upward; midrib thin, somewhat irregular; secondaries about 6 or 7 pairs, opposite or subopposite, emerging at an angle of 35°, much curved upward, and ending in or sending weak branches to the few marginal teeth; nervilles strong, mainly percurrent; finer nervation quadrangular.

The smallest leaflet is 5.25^{cm} in length as now preserved, and was probably not far from 6^{cm} in length when perfect. It is just 3^{cm} in width. The whole base is unfortunately not preserved, but from the configuration it appears that it was slightly unequal-sided.

This species is referred to the genus Rhus on the strength of its resemblance to the living *Rhus toxicodendron*, the common poison ivy. This small leaflet resembles certain small forms of this species in quite a marked degree. The living form has usually more strongly-cut leaflets, but in general outline and nervation they are quite similar.

This species does not appear to be particularly close to any of the numerous fossil species that have been described from similar beds.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

TRAPA AMERICANA n. sp.

Pl. CII, fig. 7a.

Fruit two-horned, the horns long, slender, acuminate, pointing upward at an angle of about 45°; central prominence between the horns obtuse, prominently striate; body of fruit thick, wedge-shaped below.

This fruit belongs to the two-horned Asiatic type of the genus. It is obverse-deltoid or broadly wedge-shaped in outline. The distance from base to extremity of horn is just 2^{cm}, while the distance between

the horns is about 17^{mm}. The length from base to tip of central prominence is 16^{mm}. The length of the horns is about 7^{mm}, and the length of the central prominence about 4^{mm}.

Thus far only two specimens of Trapa have been described from North America—*T. borealis* Heer,[1] from the Eocene of Port Graham, Alaska, also detected by Dawson in the Laramie of Red Deer and Rosebud rivers, Canada, and *Trapa* (?) *microphylla* Lx.,[2] described from Point of Rocks, Wyoming, and since detected near the mouth of the Yellowstone River in Montana, in the Yellowstone National Park, in the Ceratops beds of Wyoming, and along the Red Deer and Rosebud rivers in Canada. Some doubt attaches to the correctness of the reference of the last to Trapa, as the specimens are leaves or leaflets only; but as they have been found by Dawson associated with fruit, it may be correct.

The ordinary form of *T. borealis*, as described and figured by Heer (loc. cit.), is quite different from the one in hand, being very thick and obtuse at base, with irregular horns and a greatly enlarged central projection. One of Heer's figures (op. cit., fig. 11), however, is quite like ours in shape, but is more than twice the size.

The species from Idaho is perhaps more like *T. silesiaca* Göpp., described from Schossnitz, Silesia, and also detected by Heer in Portugal.[3] It is about the same size, but differs slightly in the slenderer horns and entire central prominence.

Locality: Idaho City, Idaho.

TRAPA ? OCCIDENTALIS n. sp.

Pl. CII, fig. 7b.

Fruits two-horned, or in effect three-horned, the lateral horns slender, acute, at right angles to the central prominence or horn, which is nearly twice the size of the lateral ones; body of the fruit but little prolonged below the plane of the lateral horns, slightly wedge-shaped.

These fruits are decidedly anomalous. They are deltoid or triangular in general outline. The width is 2^{cm}, each lateral horn being 5 or 6^{mm} in length and 2^{mm} in width at the base. The central projection is 1.5^{cm} in length and about 5^{mm} in width at the base.

I am much in doubt as to whether these fruits should be referred to the genus Trapa. They are found in the same piece of matrix as the one previously characterized, and in fact, as may be seen from the figure, one of them overlaps one of the horns of *T. americana*. Close association of unconnected fossils does not, of course, argue affinity, but these are so close together and have such a general

[1] Fl. Foss., Alaska, p. 38, Pl. VIII, figs. 9-14.

[2] Bull. U. S. Geol. and Geogr. Surv. Terr., Vol. I, p. 369, 1875; Tert. Fl., p. 295, Pl. LXI, figs. 16-17*a*; Ward, Bull. U. S. Geol. Surv. No. 37, p. 64, Pl. XXVII, figs. 2-5, 1887.

[3] Contr. Fl. Foss. Portugal, p. 37, Pl. XXII, fig. 11, 1881.

resemblance that it has been thought best to describe them under this name. A more obvious affinity will be accepted if pointed out. For geological purposes this species will serve admirably.

Locality: Idaho City, Idaho.

PHYLLITES FLEXUOSUS n. sp.

Pl. CII, fig. 8.

Leaf membranaceous, outline probably broadly lanceolate; base and apex destroyed; margin undulate-toothed; midrib strong, straight; secondaries many pairs, alternate, straight or oftener very flexuose, camptodrome or subcraspedodrome, entering the obscure blunt teeth; finer nervation not retained.

This is only a fragment, and perhaps should not be given a name, but it appears to be quite characteristic, and hence has been given this preliminary name pending the discovery of more perfect material. The width is about 6.5^{cm}.

No attempt has been made to search for affinities, as it is too fragmentary to afford satisfactory diagnostic characters for comparison.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

PHYLLITES OBSCURUS n. sp.

Pl. XCIX, figs. 10, 11.

Leaves small, elongated-elliptical, with entire margins; petiole long, thick; midrib thick, straight; other nervation not preserved.

The two little leaves figured are all that were contained in the present collection. The smaller is 2^{cm} in length, and about 6^{mm} wide. The petiole is about 4^{mm} in length. The larger leaf was about 3.5^{cm} in length and about 8^{mm} in width. The petiole is about 8^{mm} in length.

As the nervation is not preserved, it is impossible to refer these leaves to a known genus with any degree of certainty. They are consequently not of great importance.

Locality: Two miles southeast of Marsh post-office, Boise County, Idaho.

DISCUSSION OF THE FLORA AND ITS BEARING ON THE AGE OF THE BEDS.

As here enumerated, the flora of the Payette formation embraces 32 forms. Of this number, 17 are described as new, while 5 are not specifically named, thus leaving only 10 species, or nearly 33 per cent,

having an outside distribution. The following table shows graphically the distribution of these species:

Distribution of the flora of the Payette formation.

	Carbon, Wyoming.	Sedalia, Colorado.	Green River, Wyoming.	Auriferous gravels, California.	Bridge Creek, Oregon.	John Day Valley, Oregon.
Sequoia angustifolia Lx			×	×		
Salix angusta ? Al. Br			×	×		
Betula angustifolia Newb					×	
Betula æqualis Lx				×		
Quercus simplex Newb					×	
Quercus consimilis Newb					×	×
Ulmus speciosa Newb					×	
Ficus ungeri Lx			×			
Platanus aspera Newb					×	
Acer trilobatum productum ? Heer	×	×				×?

From this table it appears that 9 of the 10 species are found in the Ione formation (auriferous gravels) of California, or the Miocene of Bridge Creek and the John Day Valley, Oregon, and that 6 of the species have never before been found outside of these places. Of the 3 species also reported from the Green River group, *Sequoia angustifolia*, as reported from California, is probably not the same as the original from Nevada, as stated in the systematic portion. *Salix angusta* is open to more or less question, being difficult of positive identification at all times. The remaining species, *Ficus ungeri*, appears to be found in the Green River group and the Payette. *Acer trilobatum productum* is doubtfully identified from the collection under discussion, and is therefore entitled to but little consideration.

Several of the species here described as new to science are related, in some cases closely, to certain Miocene species. Thus, *Quercus idahoensis* is close to *Q. consimilis* Newb.; *Populus occidentalis* is related to *P. balsamoides* Göpp.; *Quercus simulata* is somewhat like *Q. simplex* Newb.; *Myrica lanceolata* and *Celastrus lindgreni* are clearly related to species not yet published from the Lamar flora of the Yellowstone National Park.

The evidence of the fossil plants points, therefore, to the Upper Miocene age of the Payette formation, a view which is confirmed by the stratigraphy. In fact, the close relation brought out between this flora and that of Bridge Creek and John Day Valley and the fact that the western limit of these beds as now explored is in the direction of these localities make it more than possible that they may be parts of a formation of wide extent.

PLATE XCIX.

PLATE XCIX.

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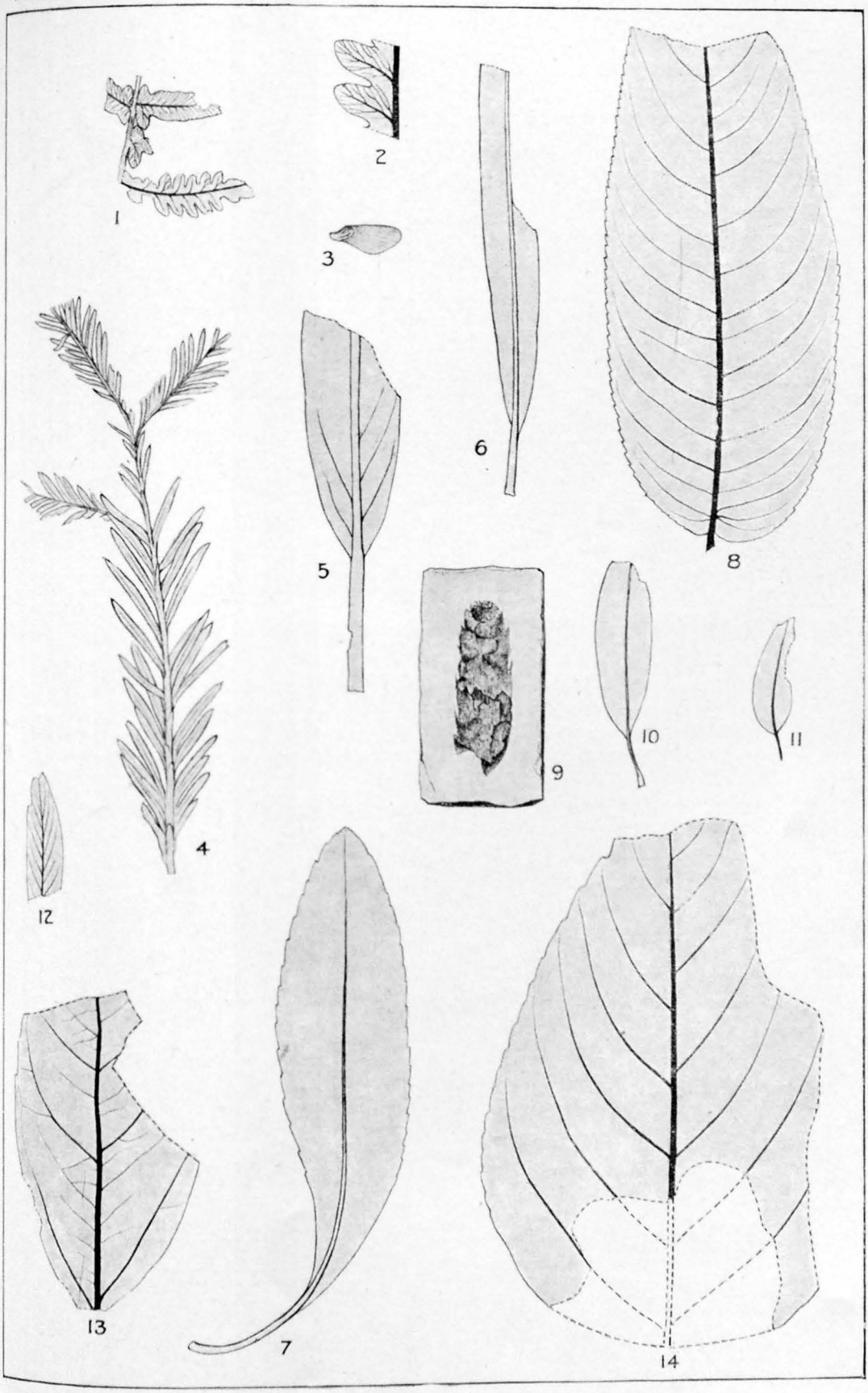

FOSSIL PLANTS OF THE PAYETTE FORMATION.

PLATE C.

PLATE C.

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FIGS. 1, 2. Populus eotremuloides n. sp	725
FIG. 3. Populus lindgreni n. sp	725
FIGS. 4, 5. Cassia obtusa n. sp	731
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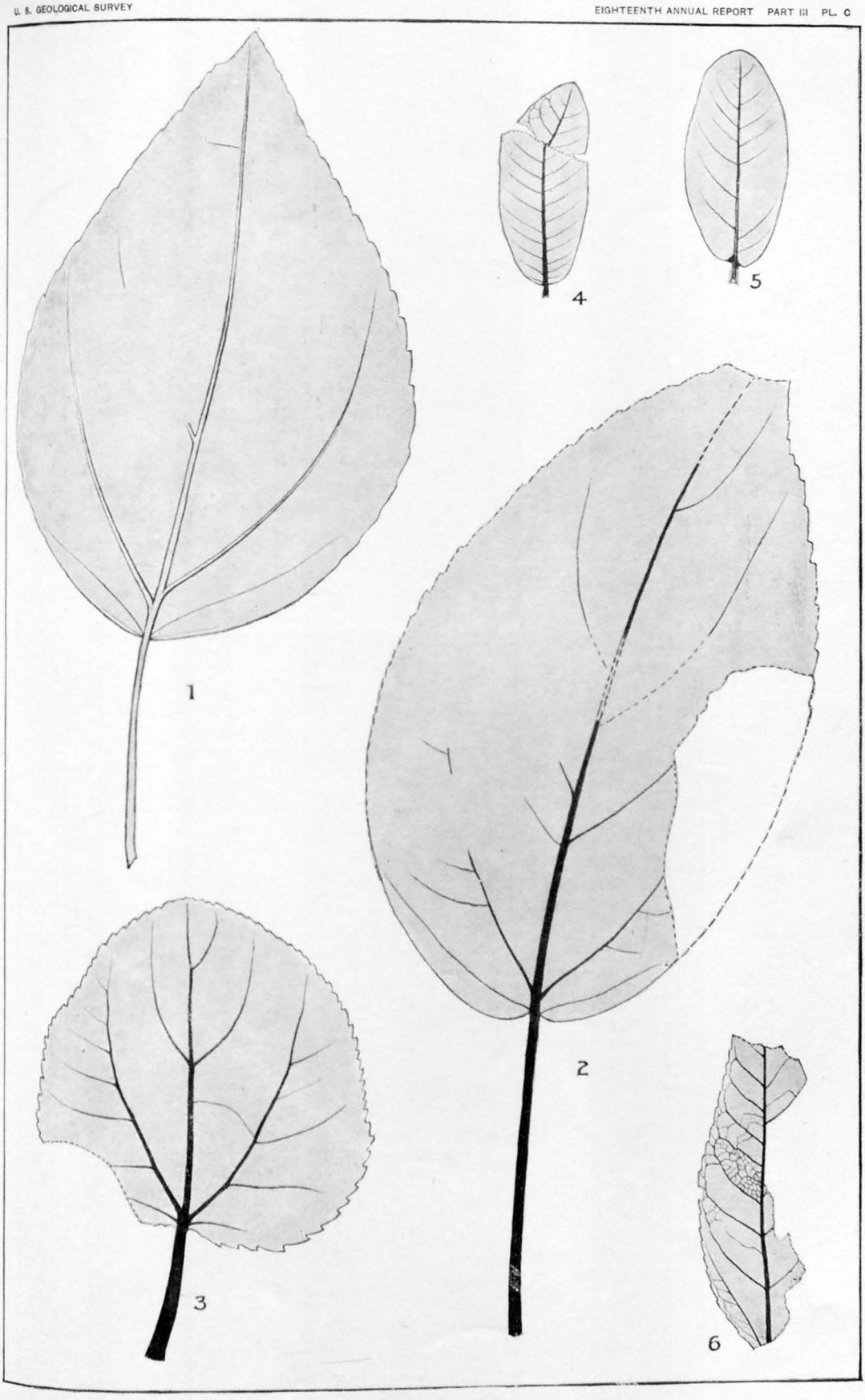

FOSSIL PLANTS OF THE PAYETTE FORMATION.

PLATE CI.

PLATE CI.

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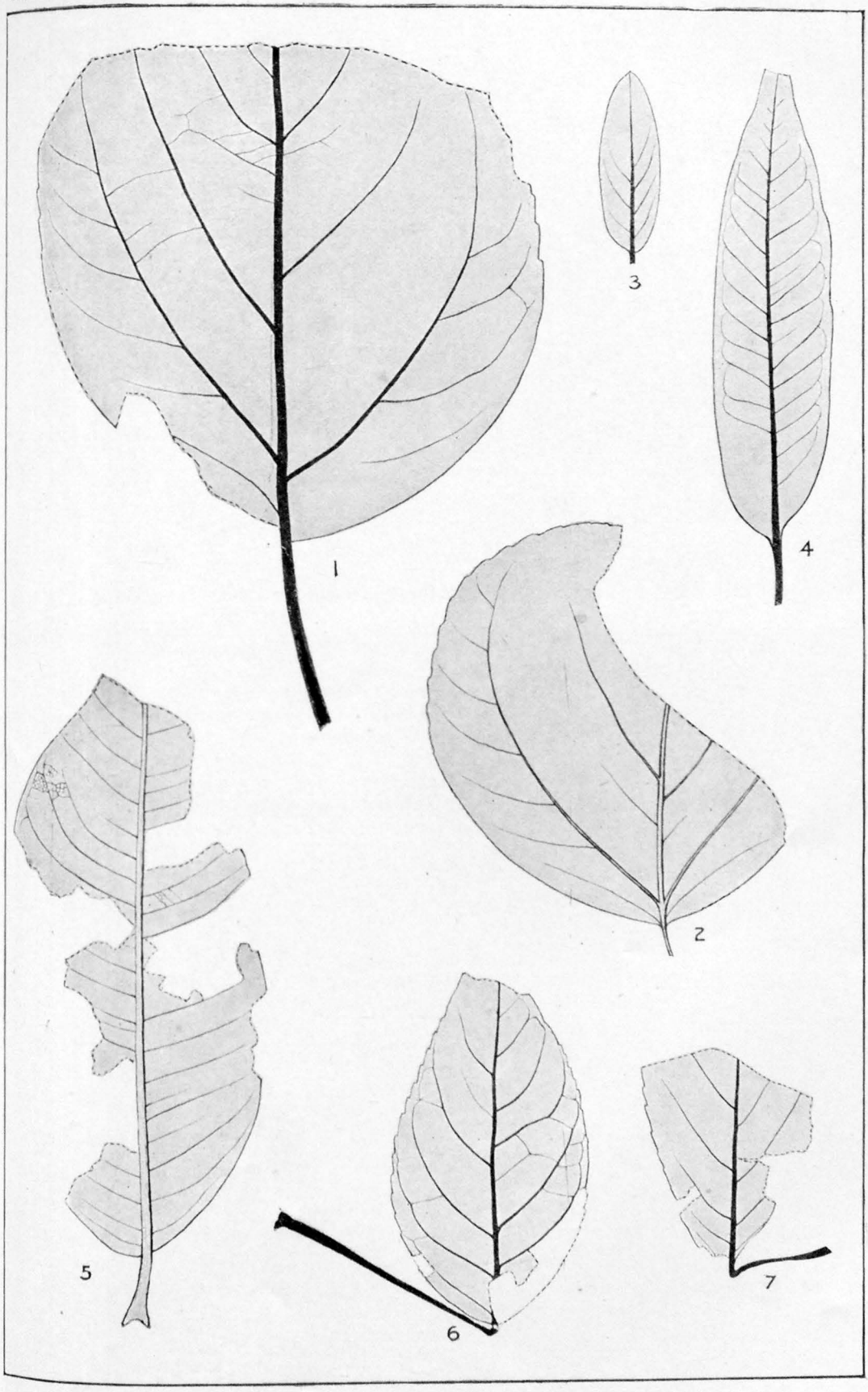

FOSSIL PLANTS OF THE PAYETTE FORMATION.

PLATE CII.

PLATE CII.

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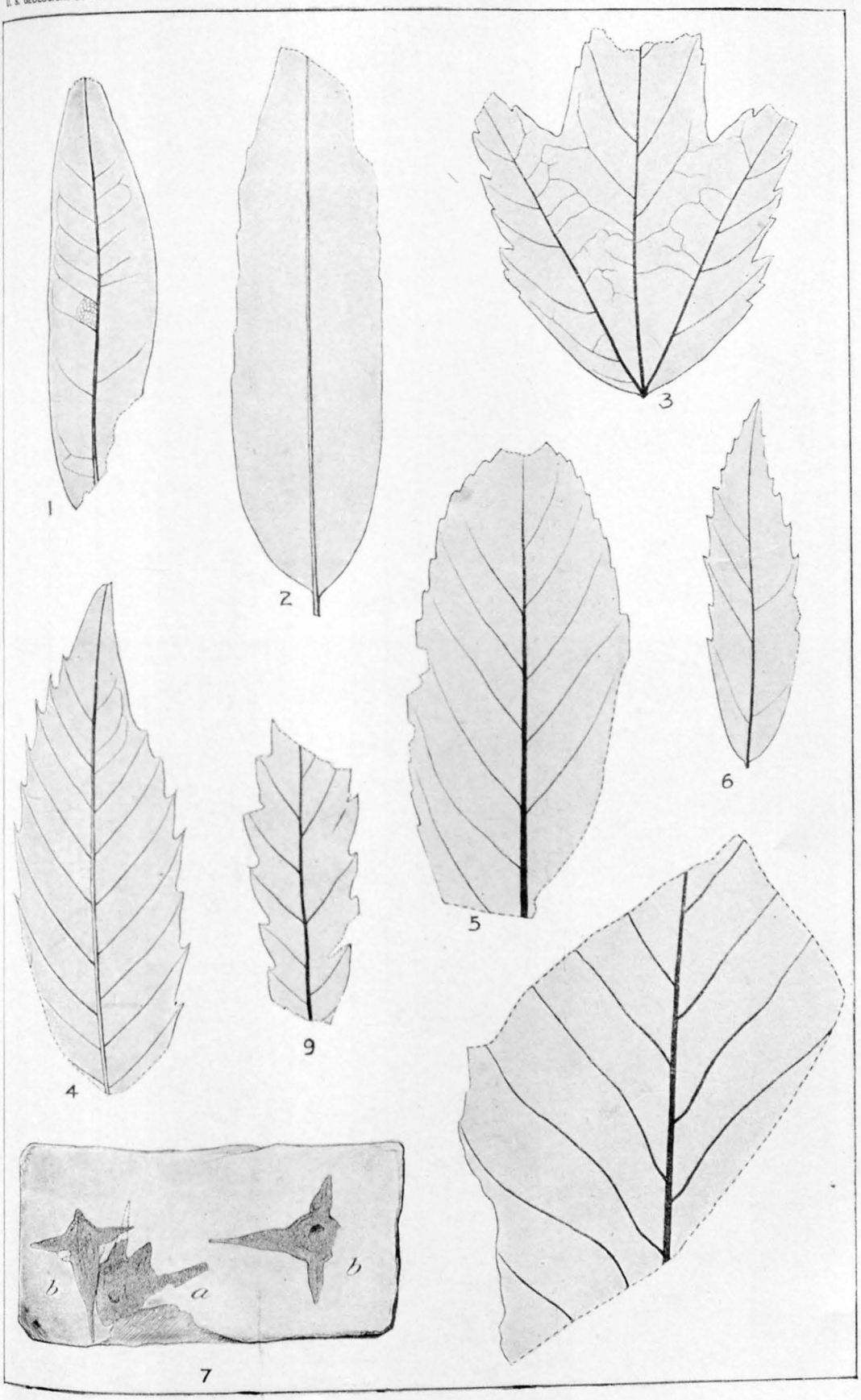

FOSSIL PLANTS OF THE PAYETTE FORMATION.

PRELIMINARY REPORT ON THE MINING INDUSTRIES OF THE TELLURIDE QUADRANGLE, COLORADO.

BY

CHESTER WELLS PURINGTON.

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VERMILION PEAK, FROM THE SAN BERNARDO MINE.

PRELIMINARY REPORT ON THE MINING INDUSTRIES OF THE TELLURIDE QUADRANGLE, COLORADO.

By C. W. PURINGTON.

FIELD WORK AND ACKNOWLEDGMENTS.

The field work on which the results embodied in the present report are based occupied the months of October and November, 1896, and was undertaken in connection with, and as supplementary to, the general geological investigation of the Telluride quadrangle, in charge of Mr. Whitman Cross, which was completed in 1896. The Telluride folio is now in process of publication.

The chemical analyses and investigations were made by Messrs. H. N. Stokes and George Steiger.

I wish to acknowledge the uniformly courteous assistance which has been received from mine owners, superintendents, and engineers throughout the district, and to tender my special thanks for aid during this investigation to Mr. Franklin Guiterman, of Durango, and Mr. H. C. Lay, of Telluride.

GEOGRAPHICAL POSITION.

The Telluride mining district is located in southwestern Colorado, and, as described in this report, is limited by the confines of the Telluride quadrangle of the Geologic Atlas now in course of preparation by the United States Geological Survey. This quadrangle, defined by parallels 37° 45′ and 38° and meridians 107° 45′ and 108°, includes the greater part of San Miguel County and portions of Ouray, San Juan, and Dolores counties. It contains head waters of the San Miguel, Animas, and Dolores rivers, which empty into Grand River or the San Juan, tributaries of the great Colorado River. The Rio Grande Southern Railroad traverses it in a bow-shaped line, entering at the northwest corner and going southeast to about the center, leaving the quadrangle in the southwest corner in its course toward Durango. In the northern part a branch line runs from the main road eastward to the town of Telluride, in the northeastern part of the quadrangle. Telluride, a town of about 1,500 inhabitants, is in the heart of the mining district, near the head of the north fork of the San Miguel River. It is 200 miles in a straight line from Denver and 180 from Pueblo.

The productive veins of the region are situated for the most part north of the parallel 37° 50′, or, in other words, in the northern two-thirds of the quadrangle. These veins may be roughly classified, for convenience, in five groups, namely: (1) The Mount Wilson group, near the western border of the quadrangle; (2) the veins of Yellow Mountain; (3) those of Silver Mountain and its outlying ridges; (4) the veins of Marshall and Savage basins and Canyon Creek, and (5) bedded deposits at Sawpit, in the northwestern corner. By far the greater product hitherto has come from the veins belonging to the fourth group, as above classified, although important amounts of the precious metals are mined in all the districts enumerated.[1]

HISTORY AND STATISTICS.

The Telluride district differs from many of the districts of the middle West in having made a steadily increasing output from its first discovery to the present time. It has never been in any sense a "boom" camp, with the fluctuations of prosperity and population which that term usually implies. Statistics of the early development are not plentiful. Mr. H. C. Lay, of Telluride, has kindly collected for this report such data concerning the early history of the district as are available. In addition, a few data have been obtained from early Mint reports, and a pamphlet entitled "Telluride and San Miguel County, Colorado," published in 1894 by the Telluride Board of Trade, has been utilized, as well as copies of the Telluride Journal.

It is stated that the first prospector entered the region of the San Miguel in 1875. Although no definite mention of mineral finds occurs before this, white men are known to have been in the region as early as 1833, and it is highly probable that the district was more or less hunted over for veins by that ubiquitous and indefatigable explorer, the American prospector. The part of the San Juan Mountains just east of the Telluride quadrangle—that now included in the Silverton quadrangle—had been somewhat developed in the years immediately preceding 1875, and a short account of the mining development is given by Mr. F. M. Endlich in a Government publication dated 1875.[2] The only reference to the area now covered by the Telluride sheet is to veins on Lime Creek, which heads in the southeast corner of the Telluride quadrangle. Prospecting was being done there for chloride ores, presumably in 1874. Endlich remarks the existence

[1] In the southeastern part of the quadrangle in the Ice Lake Basin, and near the head waters of Lime and Mineral creeks, there has been more or less development of the gold and silver veins. Although this region is areally included in the Telluride quadrangle, the topography confines it to the Silverton district, and owing to the limited time allowed for the field work of the present investigation it was not deemed advisable to undertake an examination of this region. In fixing the position of the mines about Ice Lake Basin and vicinity on the accompanying economic map (Pl. CIII), the map compiled by E. B. Fischer (map of Red Mountain and the mining region of San Juan, Ouray, San Miguel, and Dolores counties, Colorado, U. S. A., 1891), has been utilized.

[2] U. S. Geol. and Geog. Surv. Terr., Bull. No. 3, 2d series, 1875.

throughout the area as far west as Mount Wilson of veins of great width, extending sometimes for miles, but often without remunerative contents in metals.

Locations on what is now the Smuggler vein were made in 1875, and a ton of ore worth $2,000 was shipped to the smelter at Alamosa. After this, about 60 tons of ore were shipped, of which the yield is not known. The Nevada and Wat Cheer claims were located in 1876. Various small shipments were made in 1877, principally to Silverton, the ores being mined for silver, and running from 75 to 125 ounces to the ton. In 1878 Marshall Basin produced 200 tons, and small lots were sent to the Silverton smelter from the mines about Ophir, some of the ore being exceedingly rich in silver.

In 1879 the first attempt was made at milling the ores. Two arrastres were built in the vicinity of Ophir, and to one the Gold King shipped 3 tons of gold ore daily in 1879. The precipitous nature of the country and the lack of railroad communication retarded development, as machinery could be gotten in only on the backs of animals, and the erection of mills in the district was well-nigh impossible. Ore could be treated only by "packing" to distant smelters, a tedious and expensive process. As early as 1881, however, the Virginius mine, at the head of Canyon Creek, was worked by three levels and two shafts, and in 1882 the amount of development amounted to 2,000 feet, with a product of $75,000 in silver.[1]

By 1883, 100 men were at work in Marshall Basin, and a small smelter was built at the old town of Ames. This apparently did not prove successful, as it ran only a year. At this time it is noted that a shipment of 4 tons of ore from the Smuggler vein gave a return of 800 ounces in silver and 18 ounces in gold to the ton. Development was steady and in increased ratio as the years went on. After the advent of the railroad mills became numerous, although several had been brought in by the rough transportation methods of mule and burro trains.

The statement of the output of any mining district may or may not afford an index to its value as a profitable field for labor and the investment of capital. It has been the history of many ore-producing regions that much more money has been expended in the mining operations than has been extracted from the ore taken out. In such cases the statement of products, which may have been themselves large, is apt to give erroneous impressions, no mention being made of the expenses which have been incurred. The Telluride district is emphatically one where the money value represented by the labor and capital expended has not equaled or even approached in amount the product of the mines in the precious metals. Individual cases of ill-considered expenditure without results are to be seen here, as in every mining camp, but the instances are rare. It is probable that

[1] Production of Gold and Silver in the United States, by F. Hall, in U. S. Mint report for 1881.

the attempts at placer mining along the San Miguel and its branches have met with the least success of any of the ventures where determined efforts have been made to win the precious metals. Placer mining has never been extensively developed, for reasons which will be especially referred to in describing the placers. According to the estimate of Mr. W. Wheeler, an old resident of the region and of long experience there, not over $100,000 has been taken out.

In a district where the mines and prospects of small product are so numerous it is very difficult to get at even an approximate estimate of the amount of the precious metals which have been extracted. The fact that not a little of the producing area lies in Ouray and San Juan counties, while the greater number of mines are in San Miguel County, causes additional difficulty in getting at the mineral statistics. Where, as in the Telluride district, a portion of the ore is bought by smelters and a part of the product is deposited at the mint by the producers, it is sometimes impossible to arrive at an estimate from the Mint reports. Again, as has been pointed out to me by the Director of the Mint, the product figures sent from the mines frequently include ore on the dump, which is, of course, in a sense, product, but from which bullion has not been extracted.

A liberal estimate for the amount produced previous to 1882, so far as it can be ascertained, is $50,000. This estimate has been made up from data collected by Mr. H. C. Lay, of Telluride, and from Mint reports. This product was almost all silver. Mr. N. T. Mansfield, superintendent of the Smuggler-Union mines at Telluride, has estimated the total product of San Miguel County to be $19,585,000. From comparison with the figures given in the report of the Director of the Mint for the several years, county records, and statistics collected at the mines the above appears to me a very conservative estimate. It does not, moreover, include the entire product for 1896, since all data were not at hand when it was given. Mr. H. W. Reed, superintendent of the Revenue Tunnel Company, has kindly compiled for this report an estimate of the amount produced by the mines in Virginius Basin, which area comprises practically all the productive part of Ouray County included the Telluride quadrangle. He states that the product was not far from $4,000,000. For the portion of San Juan County included within the quadrangle I have roughly estimated the product to be $300,000.

The product of the quadrangle for 1896, estimated from statistics received from the district itself, is about $3,000,000, of which over $2,000,000 is in gold, the remainder in silver and in lead.

In regard to the relative values of the product in silver and in gold no definite statement is possible. During the years from 1882 to 1892 the greater value was in silver. During the last four years the proportion of gold to silver produced has been rapidly increasing.

From the foregoing $25,000,000 appears to be a moderate estimate for the total product of the quadrangle in the precious metals.

RECENT GROWTH OF THE DISTRICT.

Within five years the increased facilities for the transportation of ore from the mines to the mills by means of wire-rope trams have been a large factor in the causes of larger production. The plan which has been pursued at several of the larger mines of running long adits to cut the veins at comparatively low elevations has, wherever attempted, proved successful. Most remarkable is the Revenue tunnel in Canyon Creek, 7,500 feet in length, which cuts the Virginius vein at an elevation of 10,800 feet, more than 2,000 feet below its surface outcrop.[1]

Electricity has been successfully generated by water power on a large scale in the district, and the transmission of the power thus generated over considerable areas and to mills situated at high elevations has greatly facilitated milling operations and lessened their cost. Where mines are situated at such altitudes as in the Telluride district mills should have positions not far below. At the mines and mills situated at high altitudes water power is seldom available without transmission for greater or less distances. The application of electricity for this purpose has attained high development in the region, there being three plants of importance, all of which are successfully operated. That of the Telluride Electric Power Transmission Company is situated at the comparatively low elevation of 9,000 feet. Thus the water, which at a higher elevation would be frozen for a considerable time in the winter, is always available for power. Two dynamos, of 1,000 horsepower capacity each, are operated by two Pelton water wheels, one 62 and the other 84 inches in diameter. The power is furnished to half a dozen of the mills in the district, one of the largest of which is at an elevation of 12,000 feet and a distance in a straight line of 10 miles. In Pl. CV, from a photograph, the path of the pole line over which the electric current is conducted from the generating station to the town of Telluride is marked by a long strip bare of trees. This surmounts the top of Gold Hill, and somewhat resembles the trail left by a snowslide. Many of the principal mine tunnels are lighted by electricity, and the town of Telluride is also supplied with electric lighting from the same plant. Even the cabins of prospectors, situated high on the sides of the mountains, may occasionally be seen supplied with a complete outfit of electric lights.

The Virginius mill is run by electricity generated in a similar manner in the bed of Canyon Creek. At this mine the electric power has also been utilized for the transportation of ore by trolley car through the long adit tunnel, and the mine buildings are lighted by electricity.

[1] Recent advices from the district state that the plan of running long adit tunnels to cut many veins is to be prosecuted to a still greater extent during the coming season. Although enterprises involving such large expenditures should be entered upon with great caution, it can not be denied that the Telluride region presents conditions which appear in some cases to render the driving of long cross cuts advisable.

The Silver Pick Company has established a small electric plant of similar character for running its mill on Bear Creek, Mount Wilson.

No better illustration could be had than is afforded by the Telluride mining district of the fact that conservatism in mining is poor policy, and that new methods and devices to meet new conditions, for which no rules can be laid down, are necessary for the successful production of ore in newly exploited districts. New methods have certainly been tried in the Telluride district with ability and success, and the greater part of them may now be said to be entirely beyond the experimental stage.

TOPOGRAPHY.

Most striking topographic forms are exhibited in this region. By reference to the map and the contoured lines there laid down it will be seen that the area represented is of an exceedingly mountainous character. From the comparatively level mesa country of the western portion, at an elevation of 9,000 feet, the mountains rise to heights of over 14,000 feet, while some of the streams have cut channels down to 7,500 feet. Deep canyons and steep ridges, with sharp and precipitous peaks, have been carved from the rock formations, nearly horizontally bedded, of which the area is composed. The heads of the many streams generally occupy mountain cirques, or basins, as they are commonly called, of glacial origin. These are comparatively level, and are situated usually at elevations of from 11,500 to 12,000 feet, being about 1,000 feet below the dividing ridges of the mountains, which rise, with steep walls, immediately above them. The area of the basins varies from half a square mile to 2 square miles, and the surface of them is characterized by hummocky topography. Being above timber line, the floors of the basins are covered in summer with a luxuriant growth of grass. Countless wild flowers interspersed with this impart to these high lawns a most beautiful appearance.

From the level of the basins the streams descend abruptly into deep gorges and canyons, whose walls gradually lessen in height as the streams get larger and farther away from the mountains in which they take their rise. The change from the basin to the canyon topography is often very abrupt, resulting in waterfalls of no inconsiderable size. The highest of these is the Bridal Veil Fall, near the head of the San Miguel Valley, an exquisitely beautiful cascade of more than 300 feet in unbroken fall. Local glaciers of small size have undoubtedly exerted considerable influence in molding the present topography, especially of the basins, and their former existence is well proved by groovings, scratches, and polished faces along the rock walls of the present gorges. Along the trail which gives access to the Bridal Veil Basin such evidence is remarkably well developed. The intense and long-continued action of frost in the high basins gives even now an approach to glacial conditions which in the matter

MOUNT WILSON; GOLD HILL IN THE FOREGROUND.

of transportation and rearrangement of residual rock material are effecting changes in the topography.

Talus heaps of immense size, and gigantic blocks and scales of the rock, sometimes many hundred feet in length, which have slipped down from the faces of cliffs, have assumed distinct forms of land surface, of hummocky and carunculated[1] nature, which superficially resemble the forms left by glacial blankets in the shape of moraine. Where these masses extend down into the valleys they have become covered with heavy vegetation, consisting largely of aspen trees. That no part of the material causing this low hummocky topography is of morainal matter becomes immediately evident to one who examines the angular fragmental character of the component rock pieces. Indeed, an observer does not need to be long in the field before he can distinguish without difficulty between this slide-rock topography and that resulting from the weathering of the rock in place. The largest single area covered by slide material is that occupying the triangular space bordered by the two forks of the San Miguel River and the northwest face of Silver Mountain, representing about 15 square miles of surface.

The ridges of the mountains present exceedingly irregular, sharply cut and jagged lines, whose appearance is better represented by the photograph reproduced in Pl. CIX than by any description. The sharp gaps are generally the result of the more rapid weathering and wearing down of metalliferous veins and zones of mineralized rock. Such zones have usually the most brilliant colors—red, white, and yellow—and are visible across country for a distance of 20 miles.

A word seems not out of place in regard to the scenic beauty of the region in general. Where so much of the area lies above timber line, as is the case in this district, the rock displays whatever of variegated coloring it may possess to the greatest advantage. The striking colors referred to above are supplemented by the more sober red and brown of the sedimentaries, while the dark gray masses of the igneous rocks afford a worthy background. The delicate green shades of the grassy slopes, and of the aspen trees in the valleys, are superbly offset by the heavy growths of spruce trees, which appear almost black by contrast. It is in the fall of the year, when dazzling snow wreaths begin to appear on the highest mountains and the leaves of the aspens turn to their characteristic golden yellow, that one sees the region at its best. Such beauty of form and coloring as is then exhibited is unsurpassed in the mountain regions of the world.

CLIMATE.

As is the case in all elevated areas where much snow falls, the climatal conditions are sometimes of considerable importance from

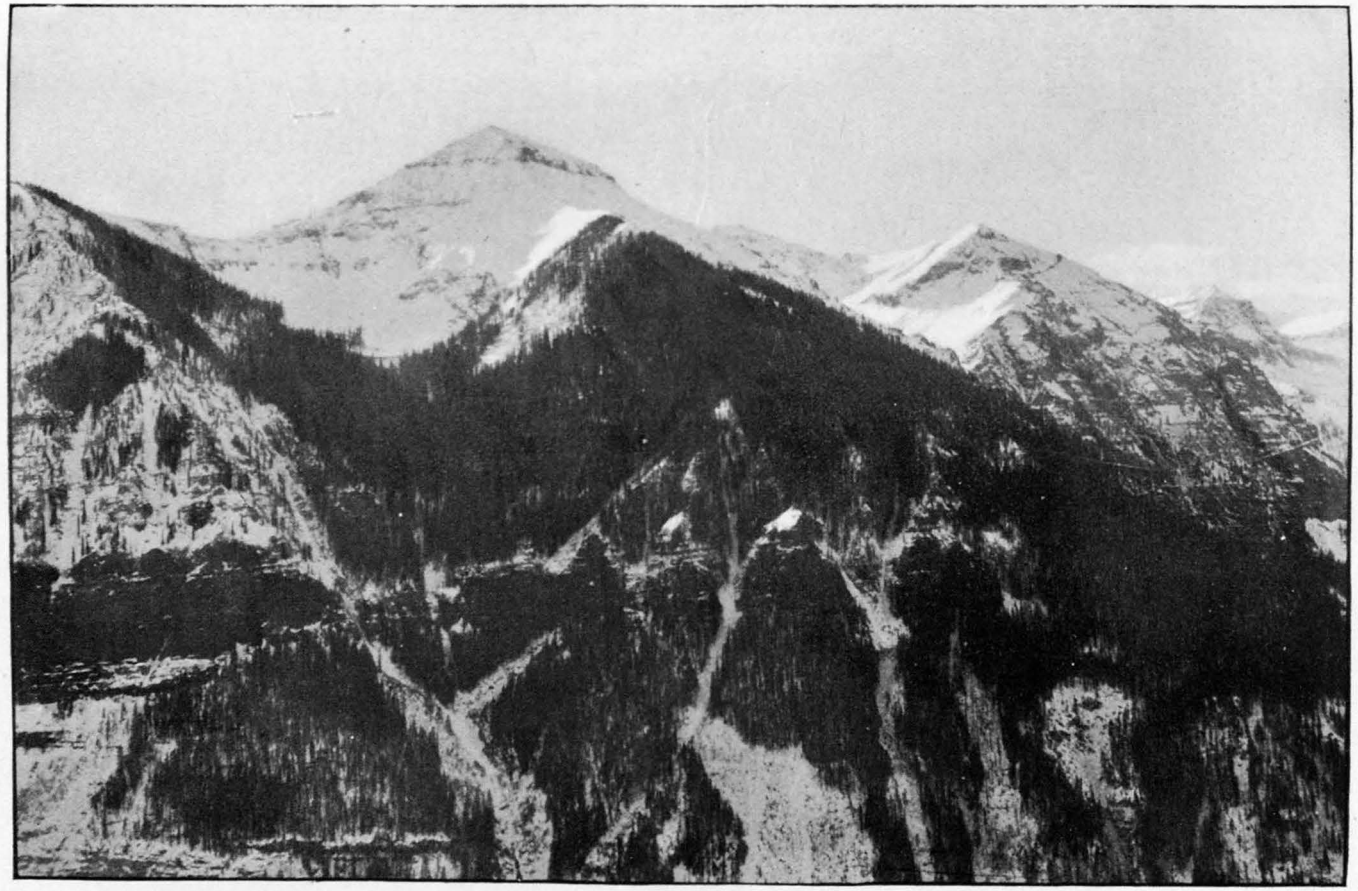
[1] A term used by Prof. N. S. Shaler to characterize the topography of the front face of terminal moraines.

an economic standpoint. So steep are the slopes of the dividing ridges that the direct action of the sun's rays is often shut off from the northward-facing slopes during a considerable portion of the day. Thus the early falls of snow accumulate on these slopes and in the basins below them with much greater rapidity than in the corresponding areas which face to the south. On the other hand, the southward-facing slopes are much covered by vegetation during the summer months, while those to the north are frequently bare. Vast accumulations of snow are made every winter where favorable conditions exist, and snow slides of considerable magnitude occur. Yet where good trails have been made, mines are worked throughout the year at elevations of 12,500 feet, and even higher. In common with high altitudes in the interior in general, very cold weather is experienced in the winter, the thermometer often sinking to 40° F. below zero. Little discomfort from the cold is, however, felt by men working in the district, owing to the exceeding dryness of the air.

THE ROCKS.

Mr. Whitman Cross, in the course of the past two seasons, has made an exhaustive study, both in the field and in the laboratory, of the rocks represented in the Telluride quadrangle. Although the results of Mr. Cross's investigations are not as yet ready for publication in an extended form, by his permission an account of them sufficient for the needs of the present report is given.

The San Juan Mountains rise on the northern edge of the great plateau region which has such widespread development in southwestern United States. This plateau is composed throughout of nearly flat sedimentary beds, extending in geological age from those lying directly on the Archean to the latest Tertiary. This vast formation has been in places tilted up, deformed, injected, and broken through by igneous rocks, the relics of whose activity have aided in making up the immense areas of rock which erosion, far-reaching and long continued, has now exposed to view. In the San Juan region, particularly, flows of volcanic lava are strongly developed, while dikes and sheets of rocks of dioritic type have been intruded into and are intercalated with the sedimentary beds, and deep-seated massifs or laccoliths of diorite have deformed and rent the clastic beds with which they are associated. The San Juan Mountains owe their origin and present elevation to the igneous agencies referred to above, and, in the Telluride quadrangle especially, the geological sections exposed by erosion, many hundreds and sometimes thousands of feet in vertical dimension, serve to exhibit in a striking and diagrammatic manner the relations which the sediments bear to the plutonic and volcanic rocks.



SOUTH WALL OF TELLURIDE VALLEY, BALLARD MOUNTAIN.

SEDIMENTARY ROCKS.

With the exception of a small outcrop of Algonkian quartzite in the bed of Canyon Creek, in the northeast corner of the quadrangle, the lowest horizon of sediments represented by exposure is the Trias. This formation has a maximum exposed development of about 850 feet in thickness in the northwestern corner of this district. It consists mostly of sandstones, of prevailingly fine texture and colored deep red by the iron oxide cementing the siliceous grains. A few layers are somewhat conglomeratic, and beds of impure limestone occur quite uniformly at this horizon wherever it has been examined in the San Juan. As may be seen from the map, the Trias prominently outcrops along the course of the north fork of the San Miguel, as well as along the main stream below the junction of the two forks. In the canyons of the San Miguel the greatest thickness is shown just above the town of Sawpit, in the northwest corner of the quadrangle. By contact with igneous rocks, such as the laccoliths of diorite which cut through them, certain of the sandstone beds are in places converted into hard, jasper-like hornstone.

Lying directly on the Trias comes the lower member of the Jura, as represented in the region. This consists of friable, medium-grained, white sandstone, of massive appearance, which has a thickness of from 50 to 100 feet. It has been called the La Plata sandstone by Mr. Cross, owing to its extensive development in the La Plata Mountains to the south. It includes a layer of black, impure limestone about 8 feet in thickness. The upper member of the Jura, the Gunnison shale, makes a thickness of about 700 feet, and consists of a rather ill-defined series of gray, shattered, siliceous shales with interspersed layers of more friable, light-colored sandstone. The shale does not make good outcrops, but is characteristically recognized by the presence of small green fragments, which have occasionally been mistaken for indications of copper.

Areally the Jura has a wider extent than the Trias, as the map shows, but its distribution, compared with the area of the quadrangle, is not great. Owing to the comminuted character of its beds, as well as its neutral color, its outcrops are not easily seen and do not compare favorably in appearance with those of the red Triassic beds which form prominent cliffs along the canyon walls.

The members of the Cretaceous which appear in the area are the Dakota sandstone and the Mancos shales. The Dakota is about 150 feet in average thickness, and is, like the La Plata, white and of friable nature. Its distribution may be seen from the map. Toward the southern part of the quadrangle workable seams of coal occur in it, which will be further described under a special heading.

The Mancos shales cover about two-fifths of the surface of the

quadrangle, and are practically limited to the western or mesa portion. This series is composed of dark-gray, thin-bedded shales of partly siliceous, partly limy nature. The formation includes the indivisible shale complex between the Dakota and Fox Hills, and probably comprises equivalents of the Benton, Niobrara, and Pierre formations of other regions. The name is proposed by Mr. Cross.

The material is seldom seen in its original beds, for so easily broken into small fragments is it that talus usually conceals effectually the outcrop of the layers.

Its greatest thickness, as exposed in the area, is about 2,000 feet; this does not, however, represent its original total development. It forms low, rounded hills and weathers to a fertile soil.

The sedimentary beds above described are overlain, in the eastern part of the quadrangle, by a heavy conglomerate. It lies unconformably on the sediments, dipping gently to the east, while the dip of the Cretaceous, Jurassic, and Triassic beds is to the west. Mr. Cross has described[1] the occurrence of this conglomerate, to which he has given the name San Miguel formation. After stating his agreement with the views of Mr. R. C. Hills,[2] that the age of the conglomerate is early Eocene or post-Laramie, Mr. Cross says:

> The San Miguel formation is characteristically a coarse conglomerate in which pebbles of many kinds are easily recognizable at a glance. Granite, schists of various kinds, hard, bluish quartzites, limestones, red sandstones, and some dense porphyritic eruptive rocks are the commoner constituents. The pebbles vary greatly in size in different places, being bowlders of more than a foot in diameter at some points and often measuring several inches. The beds grade, on the other hand, into finer-grained sandstones or grits, and in one extreme locality many strata are shales. The thickness of the complex varies from 200 feet to nearly 1,000 feet, the latter thickness being reached where the beds are of the finest grain at their western observed occurrence, in the Mount Wilson group.
>
> A great unconformity occurs at the base of the formation. Its base was first found resting on the Colorado Cretaceous shales and from that horizon gradually descends, transgressing the edges of the Colorado and Dakota Cretaceous, the entire thickness of the Jura, and was seen in contact with the Trias. In the district south of Silverton it is believed that the San Miguel conglomerate passes over the entire Paleozoic section, and may come to a contact with the Algonkian quartzite of the Needle Mountain area.

The San Miguel formation being especially developed in that part of the area which is rich in mineral veins, many references will be made to it. The cement of the pebbles is in some cases of a less consolidated character than in others, and this difference has in some places resulted in a greater or less impregnation of the conglomerate by ore.

Pl. CVII exhibits the unconformity as it appears just to the east of Bear Creek above Telluride. The San Miguel formation, dipping slightly to the east here, lies on the red beds of the Trias, whose dip is to the west.

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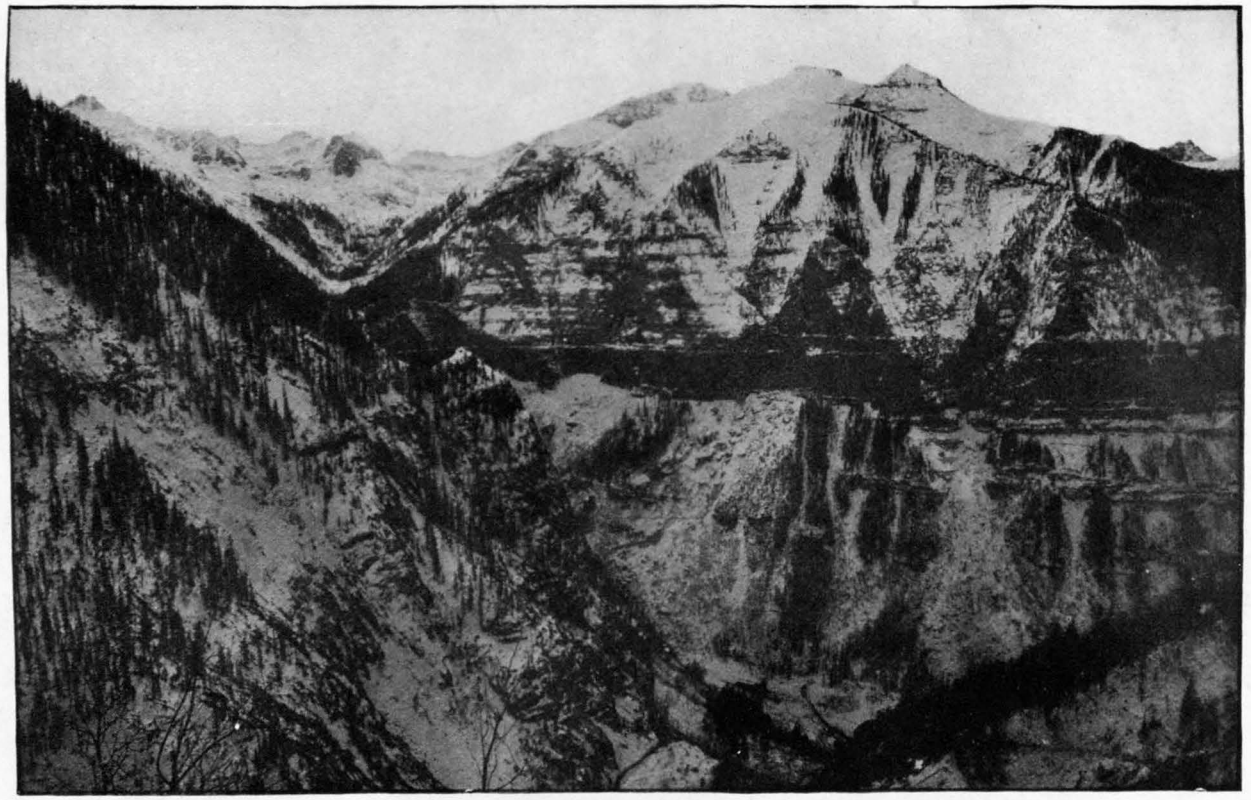
[1] Proc. Col. Sci. Soc., Sept. 7, 1896.

[2] Ibid, Vol. III; Dec. 15, 1890.



VIEW SOUTHWARD FROM THE BULLION TUNNEL, SHOWING UNCONFORMITY OF TRIAS AND SAN MIGUEL FORMATIONS.

ROCKS OF IGNEOUS ORIGIN.

The most remarkable rock horizon developed in this region is that to which Mr. Cross has given the name San Juan formation. This consists of a series of tuffs and breccias and massive flows of andesite, the lower member of which lies directly on the San Miguel conglomerate and is conformable with it. The thickness of this formation varies from 2,000 to 3,000 feet, and it is made up of many separate beds. The constituents of the brecciated layers are large and small subangular blocks and fragments of andesite inclosed in tuffaceous cement. The phases vary from layers in which the fine-grained tuff composes most of the mass, and contains no large fragments, to those in which the cementing material is subordinate in amount, and the blocks are numerous and large. The prevailing colors of this, the lower and most heavily developed portion of the formation, are dull green and red, which seem to have been induced by decomposition since the original extrusion of the materials making up the mass. Some of the larger included blocks, however, retain a black color. In regard to the distribution and origin of this formation, as well as concerning the flows of volcanic rock which lie above it, I quote from Mr. Cross's paper, "The igneous rocks of the Telluride district, Colorado," published at the same time as the description of the San Miguel formation, which has been referred to.[1]

The microscopical study of the material of the San Juan formation shows a considerable variety of hornblende, mica, and augite-bearing andesites. Apparently hornblendic forms are most common, and I incline at present to the opinion that such rocks as that of the first massive andesite flow above are rare, if not wanting, in the San Juan fragmental beds of this region. Certainly no extremely basic rock, such as basalt, nor the more acid forms, such as trachyte or rhyolite, were observed; nor were granular igneous rocks, corresponding to the later stocks, found among the fragments.

The general conclusion as to the origin of the San Juan formation is that it represents the fragmental ejectamenta of one or more volcanic centers situated at some little distance from the Telluride region, and that these fragmental materials thus far examined received their stratified arrangement in the waters of a lake which may have been the same body of water in which the San Miguel conglomerate was laid down immediately before the volcanic outburst. The regularity in stratification and the absence of any distinctly chaotic area of coarse fragmental material lead me to believe that the rocks are waterlaid. It is, of course, possible that a part of them are waterlaid and that others received their regular arrangement, in large degree, through falling in showers on slopes adjacent to the volcanic vent. This point can only be determined on the basis of further exploration.

The San Juan formation forms the floor of Marshall, Savage, Bridal Veil, and Virginius basins. * * * The same formation appears on both sides of Howard Fork of the San Miguel, about Ophir, where, however, the relations are much complicated by intrusive stocks of diorite. The San Juan beds also appear in Sheep Mountain south of Trout Lake, in the western cliffs of Vermilion Peak, and form the upper part of the mountain called the Twin Sisters, at the head

[1] Proc. Col. Sci. Soc., Sept. 7, 1896.

of Lime Creek. A thin remnant also appears locally in various parts of the Wilson range of the San Miguel Mountains. From present indications it would appear probable that the San Juan beds form the lower fragmental portion of the San Juan eruptive mass through a large area to the eastward of the Telluride district, but, as will appear from subsequent statements, it is not improbable that their place may be taken in some localities by later fragmental deposits of similar character.

Above the San Juan fragmental beds comes a succession of massive flows and thin, intermediate tuff beds of two different types of rock. The two massive rocks are augite-andesite and rhyolite, and the tuffs are in some places mixtures of materials of both types, or may be almost entirely of one. There were apparently two centers of volcanic eruption, probably to the eastward of the Telluride area, producing different rock magmas during one general period of eruption.

The augite-andesite sheets are well exposed in the walls surrounding the Marshall Basin. Here their variable thickness is well illustrated, and the thin layers of tuff, which occasionally separate flows, are quite well exposed near the Sheridan mine and in many other places in the mountains to the westward of Marshall Basin. The first sheet of augite-andesite is exposed almost continuously, resting on San Juan beds, from Marshall Basin to White Mountain [Campbell Peak], 1 mile east of Iron Mountain, north of the San Miguel River. On White Mountain it has a thickness on the southern ridge of only 4 feet and is quite vesicular. It is probably not quite continuous in its exposures in the cliff faces, but all that is seen may be referred to one originally continuous sheet. Above this lower sheet comes a thin layer of tuff containing some rhyolite material, and above that is a thicker sheet of augite-andesite, which forms the principal part of the ridge west of the Sheridan mine, and also forms a bench no the eastern side of the basin. In tracing out the lava flows of this horizon to the southward it was found that there were in many places flows of massive augite-andesite separated by rather fine-grained tuff, well stratified and not unlike parts of the breccias below, except that they seem much more irregular in their bedding and have a much more homogeneous composition as regards the character of the rock fragments. In almost all places there is at least a thin flow at the base of this augite-andesite complex, serving to mark the termination of the San Juan formation, as it has been defined.

Above the augite-andesite series comes the rhyolite series, consisting, first, of a tuff containing also abundant fragments of augite-andesite. This grades upward into a lava flow containing very many small fragments of augite-andesite, and in many places it is impossible in the field to distinguish between the indurated rhyolitic tuff and the first flow, both containing fragments of andesite. This lower flow varies considerably in thickness, but often reaches 100 feet. It is succeeded by a heavier rhyolite flow, comparatively free from included fragments, possessing a very distinct fluidal structure and forming marked cliff exposures distinguishing it easily from the andesite outcrops.

On the divide separating Marshall and Virginius basins a very distinct bench is formed just above this flow by a thin sheet of augite-andesite seldom more than 15 feet in thickness, which can be seen from a distance as forming a thin band separating the lower rhyolite flow from one of identical character above it. Viewing the range north of the San Miguel from a little distance, the two rhyolite flows separated by this distinct band, due to the augite-andesite, form a very distinct feature. Above this upper flow of rhyolite, which may be 200 or 300 feet in thickness, there comes a succession of thin flows of rhyolite, often glassy and dark in color, and tuff beds, also variable in texture and color, usually containing some andesitic material. These tuffs and thin rhyolite sheets break down on weather-

ing much more rapidly and evenly than the more massive rocks below, and form, as a rule, smooth conical points or even-sloped ridges on the crest above the most massive rhyolite flow. These characteristics are especially well exhibited in the divides bounding Virginius basin on the west and south.

The two flows of massive, banded rhyolite form the crest of the ridge from Silver Mountain from near Ophir eastward, and that separating the drainage of the San Miguel from that of Mineral Creek. The same rock also forms the very sharp summits of Vermilion Peak, Castle Point, and U. S. Grant Peak, to the east of Trout Lake. Very small remnants of the rhyolite flow are also seen in some of the sharp points east of Sheep Mountain, and it is clear that this complex of rocks once covered the entire region.

The rock of the region which is latest in age is a quartz-bearing augite-diorite having in places granitic facies, and again, through an increase in the basic constituents, passing into gabbro. The texture of the diorite is also variable, being sometimes coarsely, sometimes finely, granular, and occasionally porphyritic.

The rock occurs mostly in stocks and massifs of large dimensions, which cut, in one or another place, all the other rocks of the area. The great masses have in places sent off arms which are intruded into the surrounding sediments in the form of sheets and dikes. These subordinate manifestations are, however, much less developed than in the other parts of the San Juan country which have been studied, especially the La Plata Mountains to the south. As they do not bear any special relation to the distribution of the ore deposits, so far as has been yet determined, further details of their occurrence will not be given here. The great stocks of diorite, however, contain many of the veins, notably those of the Mount Wilson group and to the west of Ophir. The map exhibits the wide extent of the diorite masses and the great depth to which they are exposed.

From the nature of the rock it must be supposed that the masses cooled from a state of fusion while still covered by other rocks, and it is thus natural to infer that the volcanics now represented in the eastern part of the quadrangle once extended farther to the west than the Mount Wilson area. As the diorite peaks here rise to more than 14,000 feet, the conclusion seems unavoidable that an immense amount of erosion and transportation of residual material has occurred since the close of the volcanic activity.

RESIDUAL ROCK MASSES.

These have already in part been described under the heading of topography. They may be roughly divided into two classes. Talus masses, composed of entirely angular blocks which rarely exceed 10 inches in greatest diameter, are universally distributed, and are of such immense proportions as to form prominent landmarks even in this region of gigantic topographic forms. The material of the talus is generally known as slide-rock, and it in many cases effectually

conceals the rock in place which composes the lower portions of cliffs. Disintegration, especially along the high basins and divides, progresses at a rapid rate, and the small fragments which go to make up the talus may be heard falling from the cliffs at frequent intervals. The action of frost is the principal cause of this rapid destruction, the water percolating through the rocks being subjected to continual freezing, melting, and refreezing during a considerable portion of the year. There is, consequently, expansion and loosening along the innumerable cracks by which the rocks are penetrated, and breaking up is the inevitable result.

The second class of residual rock masses is that of large blocks of rock which appear to have slipped bodily, and without much disturbance, from the sides of the mountains. These blocks are in some cases many hundred feet in length, and show no greater amount of displacement or rupture in any single case than is exhibited by the rock in place. The valley of the Dolores River, just to the north of the town of Rico, affords a most striking instance of this superficial faulting, if such it may be called. As some of the ore bodies there worked bear intimate relation to it, a detailed account of the occurrences must be reserved for publication in the report on the Rico district.

THE FISSURES.

The description of the veins of the Telluride quadrangle is dependent on that of the fissuring, since the veins themselves are, almost without exception, fissures in the rock which have been subsequently filled, to a greater or less degree, with ore. I shall therefore treat first of the fissuring of the rock, and secondly of the veins and their relation to the fissures.

EFFECT ON TOPOGRAPHY.

That certain features of the topography in this district are dependent for their origin on the presence of fissure systems in the rock is, I think, subject to little doubt. Although the conformity in direction between the ridges and valleys and the fissure systems may often be a matter of accidental coincidence, and although undoubtedly the courses of many streams have been determined by causes which it is difficult if not impossible to trace, yet many observations in the field have shown in a few cases a marked relation between topographic forms and fissured zones. Thus, as may be observed from the map, prominent mountain ridges along the central part of the quadrangle have an east-west direction, and this is also the direction of the best-developed fissured zones in this part of the quadrangle. In a less marked degree relations of an apparently similar character may be observed in other parts of the quadrangle, but further correlations seem unjustifiable, considering the limited study which they have received.

DISTRIBUTION.

The number of fissures in the area of the quadrangle is large, and their directions are very numerous. Examination of a limited tract in the field would very probably result in the conclusion that the fissures have a haphazard occurrence, and that no systems are present. From the fact, however, that fissures have been found at distances of several miles from one another having nearly or precisely the same directions, and that in several places exposures on cliff faces show a vast number of fissures extending over a considerable distance, making, as it were, a slaty cleavage, it seems impossible to doubt that a definite arrangement exists.

Although nearly twenty different directions have been noted parallel to which fissuring occurs at widely separated points, the data collected are not sufficiently numerous or detailed to warrant a record of all the observations. From a table of the readings, however, it is at once evident that a few of the systems of fissures much predominate over the remainder, both in numbers and in strength of development. It is important to note also that the distribution of the fissure systems is by no means equal over all parts of the area studied, but that, although representative members may occur in all parts of the quadrangle, certain areas are subject to multiplied fissuring in one direction more strongly than another. In regard to the vertical distribution of the fissures it may be said that they penetrate all the rocks, from the lowest sedimentaries exposed through upper volcanic flows. A marked difference is sometimes found in the character of the fissuring at the passage from one rock horizon to another, but the description of this phenomenon properly belongs in another place.

ENUMERATION OF SYSTEMS.

The main directions of fissuring and the parts of the quadrangle in which each system appears especially developed are as follows:

N. 87° W.—This system, having a steep southerly dip, is especially prominent from the head of Bilk Creek Basin eastward as far as Swamp Canyon, in Ophir Valley. It will be noticed that the long ridge of Mount Wilson, the main ridge of Sunshine Mountain, and the line of Ophir Valley correspond approximately to this direction. Although the dip of these fissures is not in the same direction throughout the area, being steeply to the north in the northern portion of the quadrangle, the system is the most strongly represented of any, and the constancy of the strike at points far from one another is truly remarkable. In the northern part of the area the development is well shown in the high cliffs forming the east-west walls of Bear Creek Canyon south of Telluride. A strong fissure zone bearing this direction has also been noted in the Revenue tunnel of the Virginius mine. One of the two sets of fissures developed

at Sawpit, in the northwest corner of the quadrangle, has also an east-west direction.

N. 38° E.—This system I have seen exemplified mainly in the Mount Wilson region, on the ridge between Bear Creek and Navajo basins. It is so remarkable in its development there that especial mention should be made of it. Crossing the long axis of the ridge at about right angles, it shows a steep dip to the west up to a point a few hundred feet to the west of and above the Special Session mine. From here east the fissures have a steep easterly dip, so that a sort of broken anticlinal effect is given, the sides being very steep. As the fissures are spaced at intervals of not more than 2 feet the fissuring has the appearance of an immense schistosity, or of a series of great laminæ of slate. This can not, however, be called one of the more common directions along which fissuring has taken place, although the Mayflower and Junebug veins run approximately the same, and likewise a set of fissures seen in the workings of the Columbia mine.

N. 53°–63° E.—Although no such conformity of direction has been observed along the northeasterly fissures, as is the case with those running nearly east and west, and although it may even be possible to make well-marked subdivisions, when detailed observations are at hand, yet it is thought best, in this general treatment, to consider the joints running in directions within the range above given as belonging to a single group. The dip is either very steep to the north or the fissures stand vertical. Along this line one of the most prominent sets of fissures of Bilk Creek Basin is developed. On Silver Mountain, north of Ophir, from Ophir loop to the end of the ridge between Bear Creek and Prospect Basin, its presence is very marked, while the veins of the Summit mine follow its line. On the ridge north of Ice Lake Basin, terminating in U. S. Grant Peak to the north, zones of mineralization follow this direction, as does also the vein of the Lewis mine, on the south side of Bridal Veil Basin. Toward the north the development of the system becomes less marked, although I have noted the presence of northeast fissures in the Virginius Basin. Many of the veins in the mines about Rico, southwest of the Telluride quadrangle, and within 4 miles of its southwest corner, have a strike within this range. The Rico mines may be, however, somewhat too distant for correlation.

Fissures which range in direction from N. 17° W. to N. 2° E. may be placed in another group, although they might be further subdivided, if specific deductions were the purpose of this paper. This set is particularly in evidence in the northeastern part of the field, while in the western portion I have not seen it at all. From Silver Mountain northeast to Stony Mountain the joints of general north-south strike are very numerous, and it seems possible that the directions of Bear and Bridal Veil creeks have been determined by these fissures

or fissured zones. A prominent set of joints following the north-south direction is developed at Sawpit, in the very northwest corner of the quadrangle. It is also worthy of mention that at Porter, 3 miles northwest of Durango, on the Rio Grande Southern Railroad, fissures running from N. 10° W. to N. and S. occur with extraordinary regularity of spacing and sharpness of cutting in the coal layers of the Fox Hills sandstone, but, curiously, the fissures do not penetrate the sandstone layers immediately above and below. They have been noted at distances along the strike of more than a mile.

N. 25°–51° W.; dip almost without exception SW.—There are included in this group four sets of fissures, namely, N. 25° W., N. 36° W., N. 41° W., and N. 51° W. The group will be considered as a whole, however, for the reasons stated before. This group is of the most interest from an economic standpoint, as will be set forth under the heading "The veins." The northwest fissuring does not attain great prominence except in the northeastern part of the quadrangle, in the region immediately about and to the northeast of the town of Telluride. It will be noticed that in this part of the area there is a marked conformity of the topography to a northwesterly direction, and it is difficult to escape the conviction that, not only here, but in other intensely jointed parts of the area, some of the valleys and canyons owe their origin to lines of weakness and points of attack due to fissuring. The result of the northwesterly fissuring has been to produce complicated sets of joints, in many places forming well-developed prisms, and double schistosity, the elucidation of which, although difficult, is by no means impossible, and the detailed study of which would doubtless lead to interesting and important results.

From the foregoing it is evident that there are four general directions of fissuring; (1) east and west and (2) northeast, best developed in the central and southeastern portions of the quadrangle, and (3) north and south, and (4) northwesterly, best exemplified in the northeastern portion.

SPACING.

The distances across strike between the fissures of any one system are exceedingly variable, but I shall try to show that, at least in some instances, the intervals are not without some rule of occurrence. As the spacing is of no little importance in relation to the ore-bearing veins, it merits considerable attention. The illustrations of narrow spacing have been in part referred to in the enumeration of the various systems, but a few examples where the relation of the wide to the narrow spacing has been well observed will be in place here.

In the Silver Pick mine, as one goes southwest on the strike of the main vein, which runs N. 40° E. and dips SE., one sees crossing the drifts fissures which are practically vertical and strike N. 83° E. One notices that these fissures, from being 30 feet or more apart, become

nearer and nearer together, the spaces between them gradually decreasing to 3 or 4 inches, causing a sheeting or slating of the rock, while still farther on the spaces increase again in width. This alternation is many times repeated in the distance traversed by one of the longer drifts. Again, in the Japan mine, in Savage Basin, the main vein, striking N. 38° W., is crossed by a series of fissures striking N. 58° W. Northwestward, in the drift, the spaces between these fissures, at first wide, become gradually narrower, until the laminæ of rock are less than 1 inch in thickness between the joints. These spaces gradually increase again toward the west. In the Revenue tunnel of the Virginius mine a similar alternation of fissure spacing was observed. Many instances have been seen, both over and under ground, where narrow and wide zones of fissures alternate, the spaces between the fissures varying from several hundred feet down to 1 inch.

It will be seen that these variously spaced fissures may be roughly classified for the sake of convenience in zones or belts, of which one zone shall include only the very narrowly spaced fissures, another those which are somewhat more widely spaced, and so on. Thus, where the spaces between the fissures are narrow the zones are narrow, rarely exceeding 7 feet in width. Where the spaces are wider, having, say, 2 feet between each fissure, the zone is wider, being perhaps 70 or 80 feet. Where the widest intervals occur the width of the zone must be reckoned in hundreds of feet, sometimes thousands. In regions of old rocks which have been rendered schistose and in which joints and cleavage directions are constant over long distances, scores and even hundreds of miles, it is on many accounts an easy matter to say in what quarter the dynamic action which produced the fissuring had its origin. For example, in the Appalachian Mountains, where the slates and schists have their laminæ striking northeast from Alabama even to Nova Scotia, and where folding of the less metamorphic rocks has taken place in the same direction, it is impossible not to believe that forces acting either from the southeast or from the northwest over extended distances have produced the slaty cleavage, the folds, and the schistosity. In a comparatively small area, such as the San Juan country, however, where the rocks are of much more recent geological age, are comparatively flat-bedded and little metamorphosed, such manifestations of fissuring and cleavage as there are become more difficult of explanation. Indeed, it may seem hazardous to attempt explanation of such complicated fissure phenomena as are here observed. However, many observations throughout the Telluride, Rico, and La Plata quadrangles have left little doubt that the fissuring was produced by dynamic action having its source or sources in an area apart, but probably not far removed, from the field under consideration.

How much the difference in spacing is due to the laws of strain

resulting from pressure on a mass considered, in a large way, homogenous, how much to the distribution of the responsible forces, and how much to differences in strength of various portions of the rock mass itself, are questions to be solved only by detailed study of the district in which every main fissure system shall be taken up separately. In any case, however, whether the alternation is governed by the nature and distribution of pressure irrespective of the consistency of the mass, or by irregularly situated areas of weakness in the rock acted on, or, as is most probable, in part by both, it will be seen that one in traveling across the strike of one of the fissure systems would come upon a recurrence of zones of fissuring. The narrow zones of fissures would be most rarely met with; the moderately spaced zones would be more frequently encountered, while the belts of single widely spaced fissures would be traversed most of the time. If the fissuring be due to pressure, the inference would be that the largest amount of open space would occur in connection with the narrow zones, since crushing and trituration of the rock would be most active along these lines. Observations in the field have borne out this hypothesis, and as the veins of the region are for the most part fissures subsequently filled with ore, it is along the zones of narrowly spaced fissures that the veins occur.

Although more observations are highly desirable in this region in regard to the spacing of fissures, it seems justifiable to suggest that here is exemplified a rhythmical recurrence of fissures and fissured zones similar to that mentioned by Mr. G. F. Becker[1] as the probable explanation of the arrangement of certain veins in North Carolina. This arrangement has also been noted in the schistose rocks of Vermont by Prof. T. Nelson Dale, as communicated orally to me by him.

INTERSECTIONS.

It is evident that where two or more of the systems of fissures are well developed in the same locality continual intersections of the fissures on different systems must occur, and where the more narrowly spaced zones on two or more systems intersect, especially if these systems have direction within 50° or 20° of one another, there will result a large amount of crushing of the country, and of consequent open space, and a puzzling complexity of multiplied cleavage and jointing.

ORIGIN.

It has been said that the fissuring is of dynamic origin; also that the joints penetrate all rocks, and consequently are later than any in the district. It can not from present evidence be asserted, however, that certain of the fissures may not be earlier than the latest volcanic

[1] Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, Part III, 1895, p. 58.

flows and diorite stocks. By far the major part are of recent origin. From all observed phenomena it seems probable that the fissuring was made by forces acting at time intervals not far apart and at localities not far removed from one another. Since the fissuring is later than all the rocks of the quadrangle, volcanic disturbances whose product is now visible can not be cited to account for it, but it is entirely possible that later disturbances of volcanic nature, which did not result in surface flows of lava, have produced a straining to the point of rupture in the tract under consideration. It is thought, with great reason, that in the area directly east and northeast of the Telluride quadrangle there are centers and necks of volcanic eruption. Such evidence as has been collected in the present investigation points to those quarters as the source from which the pressure came.

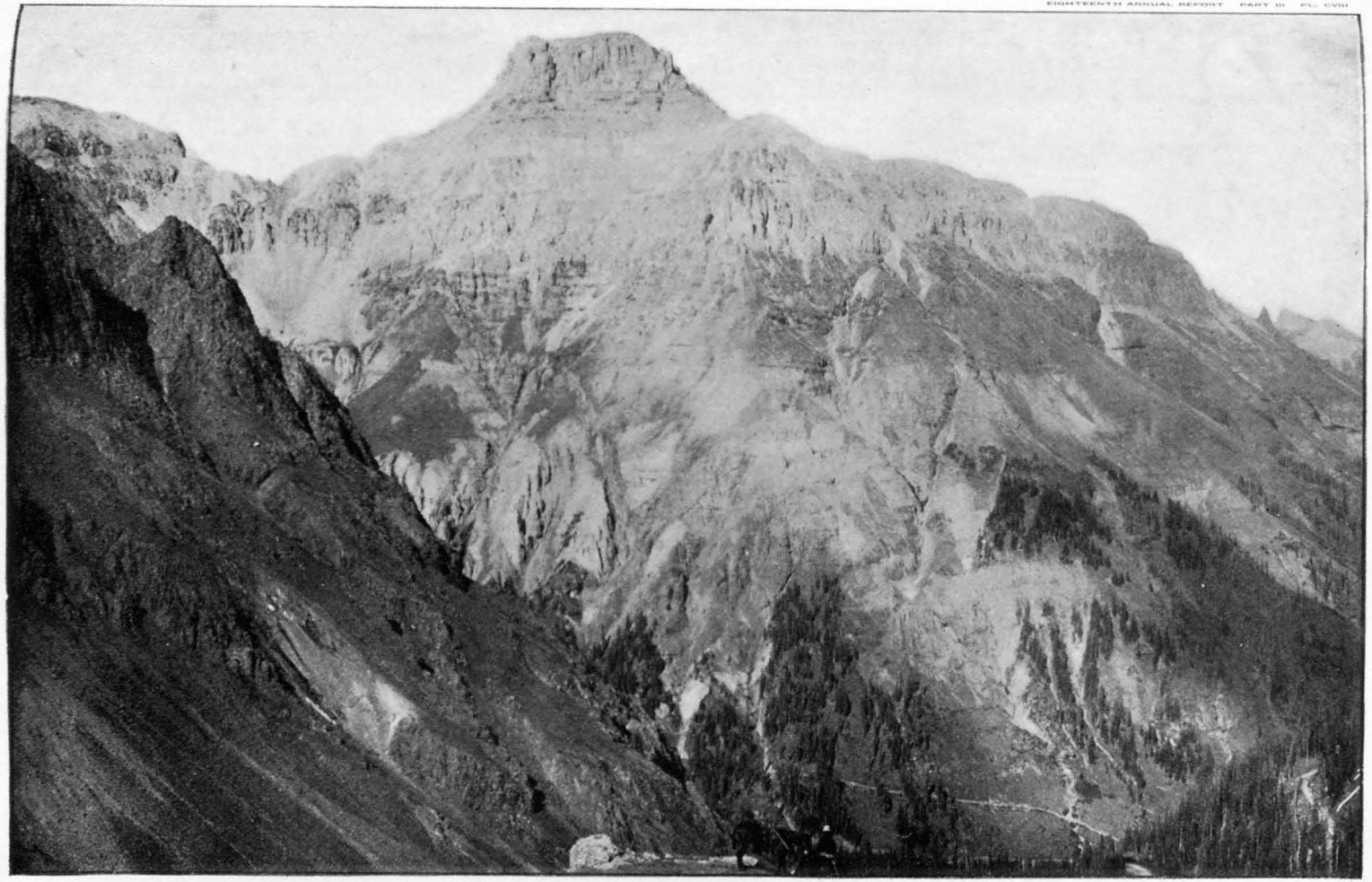
Mr. G. F. Becker[1] has shown that where prisms have been developed in a rock mass by stress resulting from a single set of forces the forces acted in a direction parallel to a line bisecting the obtuse angles of these prisms. From a cursory examination of such prisms, well developed in certain parts of this area, I think it likely that the force producing rupture was in most cases from either the northeast or the southwest. Inasmuch as groovings and slickensides seen on the vein walls pitch mostly to the southwest, and as no available source from which pressure could come is to be looked for in that direction, it seems probable that the volcanic sources to the northeast are to be regarded as having produced disturbances acting at time intervals not far apart and from localities not far removed from one another, resulting in the splitting up of the rock by many fissure systems.

FAULTING.

The evidence from dislocations of the fissures as to movement since their formation is very meager, and the cases I have observed are not such as may be correlated. They will be further referred to under the description of the veins.

As has been said, the fissure systems penetrate even the upper flow of rhyolite, and are consequently later in age than any of the rock. Since the veins are filled fissures, and since it was of course necessary that the fissures should exist before the ore could fill them, it follows that the fissuring is earlier than the infiltration of the ore-bearing solutions. Again, if, as seems most likely, the ore was deposited not long after the extrusion and intrusion of the last igneous rocks, it follows that the fissuring took place shortly subsequent to the cessation of the outflow of volcanic rock. As to whether or not all the fissuring was contemporaneous, the large number of systems seems to afford strong evidence to the negative, for it has been shown

[1] Finite homogeneous strain, flow, and rupture in rocks: Bull. Geol. Soc. America, Vol. IV, 1893, pp. 13-90.



POTOSI PEAK, FROM THE WEST.

by Mr. G. F. Becker[1] that not more than four fissure systems can result from one force, and of these the relative directions would be defined. It is probable, then, that more than one force had a part in the production of the Telluride fissures, and it would be highly improbable that the several forces should act simultaneously. From the premises, however, it must be supposed that no great time interval elapsed between the successive disturbances. As has been frequently noted in the study of other areas, and in fact as dislocations to be described appear to show, there have doubtless been renewals of movement along the same planes, which would tend to increase the amount of interstitial space. From the field evidence it seems unlikely that such movements have occurred to any extent since the filling of the fissures by the ore.

In the study of rock fracturing, as exemplified in such an area as the one now being considered, confusion may be caused by the presence of columnar jointing in the lava flows. This jointing, the result of contractional cooling, may develop columns of great size, the cracks between which it is not easy to distinguish from the fissures subsequently induced by external forces. Mr. Cross has pointed out to me that the upper lava flows developed in the Telluride quadrangle exhibit inherent columnar structure, often masked by the effects of subsequent disintegration. Such structure may often obscure the observation of sheeting in these upper rocks, in illustration of which fact the section presented by Potosi Peak (Pl. CVIII) is given. This is from a photograph taken by Mr. Cross in 1895. The inconvenience caused by the lateness of the season and almost incessant falls of snow prevented me from studying in detail the structure of the upper lavas. Thus I am unable to give the results from my own observations on the features of the rhyolite.

THE VEINS.

The well-known definition of Von Cotta, that veins are filled fissures, and that ore veins are fissures filled with ore, has been generally accepted by the most authoritative writers on ore deposits since his time. It is in this sense that the word vein is used in the present report; consequently the greater part of, but not all, the ore deposits of the district fall under this head. Those that do not, namely, the impregnations accompanying the veins, and the replacements of limestone at Sawpit, will be treated separately.

Properly speaking, the term vein is limited in its application to the filling by material of extraneous origin of that space which has existed between two walls. In the case where fissured zones have been thus filled, it is somewhat difficult to decide whether the term "vein" or the term "zone of veins" should be applied to the resulting phenomenon.

[1] Op. cit., p. 13.

The distinction must be based on the relative amounts of country rock included as "horse" matter and of true vein material. For the deposits now under consideration it has been thought advisable to make use of the word vein, in referring to the majority of occurrences. Where necessary, qualifying phrases have been introduced, and the more inclusive term "lode" has been frequently employed.

FILLED FISSURES.

Nearly all the important ore deposits of the Telluride district fall under this head, and their description bears a direct relation to that of the fissures described just above. The narrow zones of narrowly spaced fissures are well defined by limiting planes, to the outside of which no appreciable amount of open space was developed. Where ore-bearing solutions have deposited ore along such zones, taking advantage of the open space, these limiting planes now form the walls of veins. It is rarely the case that the ore—under which term is included, for the present, everything between walls which is not country rock—fills the entire width of the zone. The filled space within the zone varies from the whole width between walls to small seams, less than 1 inch in width. Usually the ore, especially its metallic contents, follows one side of the vein rather than the other, preferably the foot wall, while the accompanying decomposing influences have so affected the rest of the rock included between the walls that the resulting material, often called "gouge" matter, is comparatively easy to work, and is found convenient for blasting and "stripping" the vein. The width of the veins varies from 12 feet down, but an average of nearly 100 veins from which ore has been produced, examined during the past season, is 3½ feet. It is, however, impossible to give a correct idea of the width of fissure zones which vary between such wide limits as do these. Many zones are 8 feet in width, while many are not more than 1 foot.

The detailed structure of the veins in the Telluride quadrangle offers interesting features, but not in great variety. All gradations of ore filling are seen in the fissured zones, from cases in which the entire width is occupied by ore to those where the ore seam may only with difficulty be traced in the interstices between the fragments of country rock. Local ore chambers, where the country rock has suffered more than usual crushing, and where the result has been a breccia, with ore for the cementing material, are common. These are rarely greater in lateral extent than the widest parts of the fissured zones. Some of the best examples of these brecciated masses occur in the diorite and in the various sedimentary rocks, but are not so frequent in the breccias and volcanics. In the upper drift of the Carribeau mine an excellent illustration of an ore breccia may be seen; also in the San Bernardo mine, where the country rock is the Mancos shale. In the last case only certain small portions of the vein

are brecciated, the greater portion having the character of a linked vein. The linked-vein structure is the most prevalent type illustrated throughout the region. In the majority of the zones the parallel streaks of country rock are separated by streaks of ore of greater or less width, while cross streaks of ore and stringers of vein material having a course slightly divergent from the general parallelism connect the wider and more regular seams of ore. No sharp line can be drawn between this linked-vein structure and that in which the ore fills the larger part of the fissure zone, and the fragments of country rock, or "horses," are in small proportion. The size of the included fragments varies within wide limits. In the Mendota claim, on the Smuggler vein, Mr. J. A. Porter has noted the presence of a mass of country rock several hundred feet in length and from 30 to 40 feet in width included in the vein.[1] In the Seventy-Six claim, worked on the Smuggler vein, a lenticular body of country rock 8 feet wide and 30 feet in length occurs in the vein, bodies of ore 3 feet wide or more running each side of it. From these large "horses" the fragments included in the veins descend to microscopic size. The evidence furnished by the appearance of the included fragments as to whether substitution has taken place or not will be treated of under the description of the ore.

The feature called by Pošepný "crustification"[2] is very common, and open druses and vugs occur in parts of nearly all the veins examined. In fact, where decomposition has not affected the country rock so as to render the exposure indistinct most beautiful examples of vein structure may be seen. In the northern portion of the workings on the Smuggler vein, in the Cimarron lower levels, and in the Silver Chief mine in Bear Creek, most remarkably well defined exposures are afforded, while in the workings of the Silver Pick and Special Session mines the presence of the blue copper sulphate in the vein renders the appearance especially brilliant.

Microscopic study of the vein material has revealed the fact that the parallel fissuring of the rock has not reached minute dimensions, as is the case in ore-bearing rocks which have been reduced to slaty or schistose form. The limiting width of the sheeted slabs of rock is probably never much less than 1 inch. Very minute fissures filled with ore may be seen under the microscope, but they have always an irregular disposition, showing that the rock has been crushed into a mass of fragments entirely without order. Fig. 71, p. 800, from a thin section of ore from the Royal mine in Bridal Veil Basin, illustrates the types of microscopic structure of much of the ore.

There is much to say concerning both the macroscopic and the microscopic structure of the ore, but the description of these belongs properly to the account of the ore itself.

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[1] The Smuggler-Union mine: Trans. Am. Inst. Min. Eng., Sept., 1896.

[2] F. Pošepný, The Genesis of Ore Deposits: Trans. Am. Inst. Min. Eng., Aug. 1893. Pošepný proposes the word "crustification" to indicate the structure assumed by mineral deposits on the walls of open cavities.

EFFECT OF COUNTRY ROCK ON THE FISSURING.

In the Smuggler and Tomboy veins it is evident that the same fissured zones are continuous from the breccias of the San Juan formation through the andesite and rhyolite flows above. It seems highly probable that the country rock exerted an influence on the character of the fissuring, due to the greater or less amount of resistance which each horizon interposed to the pressure. This is well shown in the workings of the Smuggler vein, in the Mendota and Humboldt claims. No especial difference was noticed in the amount of fissuring between the breccias and the overlying andesite; but in the upper rhyolite, although the fissures are constant in direction, and although the zone is of uniform width, the amount of space now filled with ore is much less, the fissures themselves apparently not having afforded as much open space as has been the case below. It is possible that the effect of the pressure was much weaker in its upward extent, but in view of the fact that an abrupt change in the width occurs at the contact of the andesite and rhyolite, rather than a gradual change, it is more probable that the upper rock has offered a greater resistance than those below. Consequently there has been a less amount of trituration, and open space has not been so largely developed.

Owing to the fact that in very few of the mines has any single vein been worked in both the horizon of the San Juan and that of the San Miguel formation below, the comparative effect on the nature and width of the fissured zones interposed by the andesite breccia and by the conglomerate below is not well illustrated. On Silver Mountain, although the fissure zones are not well marked, veins of the same width and character seem to be present in both horizons. If any difference is apparent, it is that in the conglomerate the vein is more of a crushed zone or breccia, while in the San Juan it has more the appearance of a linked[1] vein, where the fragments of country rock included between the walls are fewer, larger, and may properly be called "horses." In the Contention and Champion mines, which are worked only in the conglomerate, the fissured zone has also the character of a breccia. At the Silver Chief mine, where the vein is exposed only in the conglomerate and the underlying Triassic sandstone, the central portion of the zone shows a brecciated character, with small, sharply angular fragments, while the edges are ribbons and linear streaks of ore interbanded with the country rock. Thus, in the horizon of the San Miguel the difference appears to be in the nature of the yielding, and not in the width of the fissures. Veins which are exposed in the Mancos shale are generally well defined, with good walls; for example, the San Bernardo vein, and the Magpie

[1] "Linked veins"—veins which "are linked together by direct continuations of divergent strike or by small stringers intersecting the layers of rock which intervene between them." G. F. Becker, Quicksilver Deposits of the Pacific Slope: Mon. U. S. Geol. Survey, Vol. XIII, 1888, p. 410.

vein in the Mount Wilson district. I have no means of comparing the width of any vein in this rock and that of those named above. The Badger, Carribeau, and Alleghany mines exhibit the veins in the Gunnison shale, and although, except in the case of the Carribeau, no opportunity for comparison is given, the width of the zones does not vary from the average of those in the whole district.

In Bear Creek the veins of the Canton and Northern Ohio claims are worked in the Trias red sandstone, as is also that of the Silver Chief, in the lower drift. The Silver Glade mine, on the south side of the San Miguel Valley, is also in this horizon. Although the red Trias beds underlie the conglomerate and San Juan formation at the head of the San Miguel, and also underlie Marshall and Savage basins, no vein, so far as I know, has been traced from the sandstones through the highest horizons. In the Silver Chief mine the zone of fissures in the sandstone is unusually wide, being over 9 feet in places, and averaging 6 feet. In such other exposures as have been seen the veins did not have the character of zones, but were narrow single seams, with well-marked walls. Grooves and slickensides are well developed on the walls of the Canton vein.

It will be seen that, owing to the paucity and disagreement of the observed exposures, it is impossible to draw conclusions as to the probable width, going down, of the fissured zones now worked in the upper rocks. From occurrences observed in other parts of the San Juan, however, the effect interposed by the sandstone to the rupturing force appears to have caused a greater diffusion of the energy, and consequent less-marked definition of the fissured zones, than in the overlying rocks.

It has been shown by Mr. G. F. Becker[1] that, since variation in the tenacity of the rocks subjected to strain has a marked influence on the physical form of the resultant rupture, the upper portions of strained rock masses will contain comparatively large areas of rupture, forming "chambered veins." In the lower and deeply buried portions the resistance will be greater, and instead of large areas of crushing, single fissures will be found. In such a manner, it seems probable that the Telluride area has been affected. What are now the upper rocks, being nearer to the original surface, have yielded more readily to the sectionizing forces. In these upper rocks the manifestation of the rupturing force is in fissure zones, while in the sandstones below, for the most part, single fissures occurred.

In the diorite masses, although the zones are generally of a width not different from that developed in the volcanics, the amount of open space which has been filled by ore is subject to much more variation. Thus in the veins which are worked in this rock one may see local bunches of ore swelling to the width of 12 feet, followed by a marked pinching of the vein to narrow seams. Another feature is

[1] Loc. cit., p. 414.

the reticulated structure of the veins in diorite, fissures making off into the country quite irregularly from the normal strike. In the Carribeau mine the change from regularity to irregularity in width as the vein goes from the Gunnison shales into the diorite is quite marked.

In the Silver Pick mine the width of the main vein has been locally affected many times where the narrowly spaced zones of the cross fissures, before referred to, occur. These have always lessened the size of the main fissure zone, while the ore, on account of the greater amount of space presented in these closely fissured portions of the cross system, goes out for a short distance along the cross joints. When the wide spacing of the cross fissures again recurs, the main vein resumes its normal width.

The continuity of the veins of the Telluride quadrangle longitudinally is a matter of economic interest. The evidence of continuity in one direction for a distance of 2 miles, furnished by the Smuggler vein, naturally gives weight to the opinion that more veins exist here equally continuous. In fact, other veins have been worked along their strike continuously for more than half a mile. Although, as has been shown by the continuity of directions in the fissuring, the strained rocks in this area acted as a mass having a remarkably close approach to homogeneity, it is not to be expected that all, or even the majority, of fissure zones which penetrate the rock continue for long distances unchanged in strength and direction. Such a condition could exist only in an ideally homogeneous solid, which rock certainly is not. From observations on the fissuring in general in the quadrangle it would seem that the conditions for continuity of length of the workable veins are better than in the majority of the regions of metalliferous veins which have been exploited.

EFFECT OF WEATHERING OF VEINS ON TOPOGRAPHY.

I have already spoken of the probable relation which some of the topographic forms bear to the fissure systems. With reference, however, to those topographic features which seem dependent on the mineralized fissure zones or veins, a few words here will be in place. Of course the decomposition which usually accompanies the deposition of ore renders the mineralized fissure zones more liable to disintegration. It is on the divides particularly that the most striking results are produced. On the ridge of Mount Wilson, which divides Bilk Creek Basin from Navajo Basin, a fissure zone not more than a foot in width has been worn out to the depth of 30 feet, causing a sharp canyon-like cut in the very top of the divide. This is one of the veins which strike N. 87° W., and over all the upper part of Bilk Creek Basin such miniature canyons occur on veins belonging to this system, though none have the striking appearance of the one described. In Bridal Veil Basin, where the veins that run N. 17° W.

OPHIR AND YELLOW MOUNTAIN, FROM LOOKOUT PEAK.

are especially developed, a steep-walled canyon on the east side of the main valley owes its origin to a small vein, less than 1 foot wide, which now occupies the central line of it. The canyon is more than 100 feet deep, and not more than 30 feet wide at the top. One of the more noticeable veins, which is well marked on the surface, is the Cimarron. Where this outcrops in Marshall Basin, near the trail, an exceedingly sharp cut is made in the rocks, where the ore has been taken out. This can not, of course, be cited as an instance of natural disintegration, but the distinctness with which its walls are defined is none the less worthy of note. Numbers of examples of deep cracks and ravines formed on cliffs and ridges by the wearing out of veins might be quoted, but space does not allow. Wherever a marked notch or cut is seen in the ridges which surround the basins, it is safe to infer that it indicates the presence of a mineralized fissure zone. Further evidence is usually, as would be supposed, furnished by the discoloration of the rock along these zones. Pl. CIX, reproduced from a photograph by Mr. Cross, shows in a striking manner the effect of the wearing out of the veins on the topography.

In an area of rocks so thoroughly permeated by ore-bearing solutions as that of the Telluride quadrangle appears to have been it is not to be supposed that all the deposition took place along the zones of narrowly spaced fissures. These, containing the greatest amount of interstitial space, were naturally the channels preferred. But there is no part of the mineral-bearing area in which some of the single, widely spaced fissures have not been the seat of the deposition of ore, while in those portions where intense mineralizing influences have affected the rock there probably exists no fissure in which some ore would not be found. The result of this general penetration of the ore, together with its accompanying decomposing influences on the rock, has been to afford lines of weakness along which the disintegrating forces of the atmosphere have been able to attack the rock with comparative facility. Between the height of 11,000 and 14,000 feet, in an area situated geographically as the San Juan Mountains are, the rock-disintegrating influences are excessively violent on account of the continual melting and freezing of the percolating water. Thus it will be seen that where a considerable vertical extent of the joints and fissures is exposed, as on the faces of cliffs, the disintegration, wearing away the rock along the mineralized single fissures, will have the tendency to produce a columnar structure. If two or more systems of the fissures intersect, the columns will become more pronounced, will be separated from one another more and more, and will finally stand quite alone. In the high basins of the mountains in the Telluride quadrangle, especially in the horizons of the San Miguel and the volcanics above, the long rows of columns, cones, and pinnacles fronting the cliffs are, I think, in large measure a result of

this process of disintegration. The weathering goes on at a rapid rate, and immense talus heaps result from the accumulation of fragments at the bases of the cliffs. On the dividing ridges the weathering out of the fissured zones has produced notches and passes of considerable width. That of the single fissures has resulted in long lines of needles and indentations, like the teeth of an enormous comb.

RELATION OF FISSURING TO VEINS.

The practical interest in the theory that there is a regularity in the spacing of the fissures and a recurrence of wide and narrow zones lies in the fact that, as has been shown, the workable ore veins are situated for the most part along the narrowly spaced zones. It seems reasonable to suppose that, in the case of a single fissure, there has not been sufficient open space developed to admit of ore being deposited to any considerable extent. On the other hand, where a zone of narrowly spaced fissures occurs the amount of open space would naturally have been larger, especially if there has been relative motion of the walls, which, as will be shown, has been the case in at least a portion of the veins. Where several systems of the fissures, varying in direction by only a few points of the compass from one another, are developed in the same area, the conditions become somewhat complicated. In the region occupied by Marshall and Savage basins, where the four fissure systems, N. 25° W., N. 36° W., N. 41° W., and N. 51° W., are so well marked, certain of the veins follow more than one set of the fissures, the ore switching from one to another set as it found space for deposition. Intersections of the two sets are in several places illustrated, but in only one instance have I seen the deposition of ore along a well-marked zone caused by the intersection of the narrowly spaced portions of three sets of fissures. This is the Tomboy vein, where the three sets most prominent run N. 25°, N. 41°, and N. 51° W. Although it is not possible to reproduce an exact plan of an occurrence showing the departure of the ore from one set of fissures to another, since clean exposures were not accessible in the mine, the drawing (fig. 66) is, it seems to me, justifiable as illustrating the type. At the turning point, although most of the ore

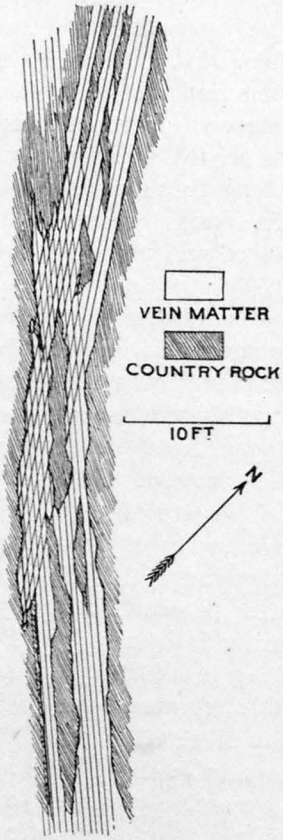


FIG. 66.—Plan showing intersection of fissured zones in the Tomboy mine.

which has been following one course goes off on the second direction, a small portion continues its first course, gradually pinching out as the amount of open space to be filled decreases. The feature illustrated in the Tomboy is, as already said, repeated in the workings of other mines.

Even in the Smuggler vein, which has a remarkably straight course for the greater part of its length, certain zones of fissures which cross it at small angles are thought to carry small stringers of ore, making off from the main vein. In the instance of the Silver Pick mine, already quoted under the head of fissuring of the rock, the ore several times departs from its normal course of N. 38° E. to follow for a short distance, 4 to 8 feet, toward the west fissures which strike N. 87° W., assuming again, after the offset, its normal course. In this case two explanations are possible: either the ore has merely switched over from one fissure to another of the same system, or the N. 38° E. set of fissures was faulted by the N. 87° W. set, by motion along the last-named set subsequent to the formation of the ore. The intersections affect the amount of ore sometimes for the better, sometimes for the worse. This shifting of the ore may, I think, be explained on the hypothesis that forces acting subsequent to those which produced the fissuring, and along the same lines, have had, along these zones of intersections, especially good opportunity to develop open space where the intersection happened to be that of the narrowly spaced portions of the component fissure system. Where the crossing was merely of single fissures, no opening of any extent was produced.

FAULTING OF THE FISSURES.

The evidence bearing on the question whether all the fissuring is contemporaneous in origin or not is very scant. Apparent displacements of the fissures may often be interpreted in more than one way, as in the case of the Silver Pick, quoted above. Besides this occurrence, I have observed displacements of the fissures in the Terrible, Santa Cruz, and Suffolk mines. In the last three cases the east portions of fissures running approximately east and west are offset to the south along the planes of north-south fissures. No correlation can thus be established between these and the faulting of the Mount Wilson area. In only one case has evidence been seen which is regarded as conclusive that a difference in the age of the fissuring exists. The Pandora vein, running approximately east and west, which crosses the workings of the Alleghany, Valley View, Smuggler, and Cimarron mines, faults three and probably four of these veins, throwing the northern part of each to the east distances varying from 40 to 65 feet. In this case it is the ore of the northwest veins which is faulted by that of the Pandora vein. As the ore in the Pandora vein is of a different character from that in the veins which it faults, the indications are that its fissuring had origin later than the filling

of the northwest veins by ore. As noted above, since it is highly improbable that all the fissuring was produced at precisely the same time, and as successive forces acting from nearly the same direction naturally caused more or less motion along joint planes already formed, displacements of one set by another are to be looked for. Evidence collected in the field is, however, with the exception of the Pandora occurrence, too meager and fragmentary to afford ground for hypothesis.[1]

Vertical displacements, the slipping up or down of one wall with reference to the other, are well evidenced, but the instances of their occurrence are few. In the San Bernardo mine, normal faulting of the layers of Mancos shale which compose the vein walls has taken place, the south foot-wall being about a foot lower than the north. Vertical slickensides were also seen in this mine. A most interesting feature was observed in the workings of the Virginius mine, and in a

FIG. 67.—Ideal sections showing comparative distribution of open space produced by normal and reversed faulting.

less marked degree in the Smuggler mine. Where the dip, which varies in amount considerably in places along the strike, flattens the vein pinches; where the dip is steep the vein swells. From similar occurrences in veins seen in other localities, and in regard to which correlative evidence has left no doubt as to the cause, this case is cited as an evidence of normal faulting. By the accompanying drawing (fig. 67) it will be seen that the hanging wall must have moved down relatively to the foot, in order to produce the arrangement of open space actually filled by ore. A movement in the contrary direction would have resulted in large spaces on the flat dips and narrow slits in the steep places.[2] It is to be regretted that other occurrences

[1] The occurrence of the Pandora fault in the Smuggler workings has already been noted by Mr. J. A. Porter (The Smuggler-Union mines, Telluride, Colo.: Trans. Am. Inst. Min. Eng., Vol. XXVI, 1896, p. 452). The faulting by the Ansborough vein on the Seventy-six claim is not so well defined; its effect on the Smuggler vein is similar to that of the Pandora vein, but the throw is only a few feet. I was unable to determine its exact character in the mine.

The faulting of the Virginius vein, seen in the Revenue drift, will be described in the detailed notes on that property.

[2] Cf. von Cotta, Erzlagerstätten Lehre, 1859, p. 161.

were not seen which would bear on the subject of the vertical displacement. It will be one of the points worthy of study when a more detailed examination of the area shall be made.

An interesting feature, and one that has direct bearing on the origin of the fissuring of the region, was observed by Mr. J. A. Porter, of Denver, and imparted to me by him in conversation. Along the course of the Cimarron vein overground, in a place where all ore and gangue material between walls had been taken out, Mr. Porter noticed a sort of cleavage, a series of parallel cracks which had opened, alongside and parallel to the walls of the vein, since the extraction of the ore. This appears to indicate that there exists in the rock, particularly near the veins, a latent schistosity, the result of strain, which if carried farther would have produced a slaty cleavage. In fact, it seems to me that little doubt can be entertained by one who notes closely the phenomena to be observed in the field that the rock-fracturing of the Telluride quadrangle is due to an extensive, far-reaching cause.

THE ORE.

THE MINERALS OF THE VEINS.

These do not offer a great variety, either of gangue minerals or of ores. In making up the subjoined lists I have tried to include only those which have been deposited originally from the solutions, while decomposition products have been excluded. In a few cases where secondary minerals are of a type not usually encountered they are mentioned. Quartz and iron pyrite have been omitted, as there seems to be no vein among those worked within the limits of the Telluride quadrangle in which these two minerals do not occur. The list of ores is intended to include only those minerals with which the precious metals are chemically combined, and since none of the tellurides or other possible rare compounds of gold occur in the area, so far as the present investigation has been able to determine, this list of ores must be taken to include only ores of silver. As is well known, however, no silver ore occurs which has not present, in the free state, more or less of gold. For example, galena, while it is to be considered an ore of silver, is merely the gangue or mechanical matrix of gold.

Owing to the paucity of references in literature to the mines of this area, very few specific notes on minerals of the veins exist. Where such references have been found they are referred to by the author's name, and the date of the record is given.

In the preparation of the list the ordinary methods of determination have been supplemented by the microscopic examination of slides, and the result has been, in some cases, the detection of minerals, perhaps in considerable quantity, of such minute physical pro-

portions that they are not at all visible in the hand specimen. Allowing for the unavoidable sources of error, namely, the possibility of omission on account of difficulty of observation on decomposed veins, the error in determination, and the occasional confusion of a gangue mineral with one that naturally belongs to the original minerals of the wall rock, it is hoped the list will be found fairly complete. Where the authority for an occurrence is a publication other than the present report the author's name and date of writing have been given.

Ore minerals of the Telluride district.

Mineral.	Mine.	Locality.
GALENA	San Bernardo	San Bernardo Mountain.
	Garibaldi	Do.
	Silver Pick	Mount Wilson.
	Tam O'Shanter	Do.
	Independence	Do.
	Silver Horn	Do.
	Magpie	Do.
	Terrible	Ophir Loop.
	Silver Bell	Do.
	Carribeau	Ophir.
	Montezuma	Do.
	American Frenchman	Do.
	Attica	Do.
	Badger	Do.
	Santa Cruz	Do.
	Silver King	Alta Basin.
	Alta	Do.
	Summit	Do.
	Silver Chief	Bear Creek.
	Lewis	Bridal Veil Creek.
	Columbia	Savage Basin.
	Tomboy	Do.
	Big Elephant	Do.
	Japan	Do.
	Bradley Pioneer	Do.
	Cimarron	Do.
	Smuggler	Marshall.
	Yankee Boy	Canyon Creek.
	Trust Ruby	Do.
	Virginius	Do.
	Belle Champion	Do.

Ore minerals of the Telluride district—Continued.

Mineral.	Mine.	Locality.
FREIBERGITE	San Bernardo	San Bernardo Mountain.
	Garibaldi	Do.
	Terrible	Do.
	San Juan	Ophir Loop.
	Silver Bell	Do.
	Carribeau	Ophir.
	Montezuma	Do.
	American Frenchman	Do.
	Japan	Savage Basin.
	Smuggler	Marshall Basin.
	Cimarron	Savage Basin.
	Virginius	Canyon Creek.
POLYBASITE	Smuggler	Marshall Basin. J. A. Porter, 1896.
PROUSTITE	Smuggler	Do.
PYRARGYRITE	San Bernardo	San Bernardo Mountain.
	Smuggler	Marshall Basin.
STEPHANITE	Smuggler	Do.
	Humboldt	Canyon Creek.

Earthy and metallic gangue minerals (excepting quartz and pyrite) of the Telluride district.

Mineral.	Mine.	Locality.
AMPHIBOLE	Japan	Savage Basin.
APATITE	Special Session	Mount Wilson.
	Carribeau	Ophir.
BARITE	Silver Bell	Ophir Loop.
	Carribeau	Ophir.
	Lewis	Bridal Veil Basin.
	Smuggler	Marshall Basin.
BIOTITE	Badger	Ophir.
FLUORITE	Fairview	Deer Trail Basin.
	Waterfall	Bridal Veil Basin.
	Trust Ruby	Canyon Creek.
CALCITE	Silver Pick	Mount Wilson.
	Lakeside	Do.
	Silver Horn	Do.
	Terrible	Ophir Loop.
	Badger	Ophir.

Earthy and metallic gangue minerals (excepting quartz and pyrite) of the Telluride district—Continued.

Mineral.	Mine.	Locality.
CALCITE	Santa Cruz	Ophir.
	Gold King	Alta Basin.
	Alta	Do.
	Silver Chief	Bear Creek.
	Champion	Do.
	Northern Ohio	Do.
	Japan	Savage Basin.
	Smuggler	Marshall Basin.
	Wonder	San Miguel Valley.
	Boomerang	Do.
	Crescent City	Deer Creek.
	Yankee Boy	Canyon Creek.
	Trust Ruby	Do.
	Virginius	Do.
CHALCOPYRITE	San Bernardo	San Bernardo Mountain.
	Silver Pick	Mount Wilson.
	Terrible	Do.
	Silver Bell	Ophir Loop.
	Carribeau	Ophir.
	American Frenchman	Do.
	Santa Cruz	Do.
	Silver King	Alta Basin.
	Silver Chief	Bear Creek.
	Lewis	Bridal Veil.
	Tomboy	Savage Basin.
	Boomerang	San Miguel Valley.
	Crescent City	Deep Creek.
	Virginius	Canyon Creek.
CHALCANTHITE (SECONDARY.	Silver Pick	Mount Wilson
	Special Session	Do.
CHLORITE	Lakeside	Do.
	Single Standard	Ophir.
	Badger	Do.
	Smuggler	Marshall Basin.
COPPER (NATIVE)	Smuggler	Marshall Basin.
DOLOMITE	Carribeau	Ophir.
GARNET	Terrible	Ophir Loop.
GYPSUM	Belle Champion	Sawpit.
MAGNETITE	Badger	Ophir.

Earthy and metallic gangue minerals (excepting quartz and pyrite) of the Telluride district—Continued.

Mineral.	Mine.	Locality.
MAGENTITE	Royal	Bridal Veil.
MISPICKEL	Silver Pick	Mount Wilson.
	Tam O'Shanter	Do.
	Colorado	Do.
	Lakeside	Do.
	Silver Chief	Bear Creek.
	Yankee Boy	Canyon Creek.
ORTHOCLASE	Royal	Bridal Veil Basin.
RHODOCHROSITE	San Bernardo	San Bernardo Mountain.
	Silver Bell	Ophir Loop.
	Butler	Do.
	Carribeau	Ophir.
	American Frenchman	Do.
	Badger	Do.
	Japan	Savage Basin.
	Smuggler	Marshall Basin.
	Cimarron	Savage Basin.
	Trust Ruby	Canyon Creek.
	Virginius	Do.
SERICITE	Terrible	Ophir Loop.
	Single Standard	Ophir.
	Suffolk	Do.
	Gold King	Alta Basin.
	Silver Chief	Bear Creek.
	Northern Ohio	Do.
	Pulaski	Bridal Veil Creek.
	Horatio	Do.
	Telluride	Do.
	Royal	Do.
	Tomboy	Do.
	Smuggler	Marshall Basin.
	Yankee Boy	Canyon Creek.
	Trust Ruby	Do.
	Virginius	Do.
SIDERITE	San Bernardo	San Bernardo Mountain.
	Garibaldi	Do.
	Silver Pick	Mount Wilson.
	Silver Bell	Ophir Loop.
	Butler	Do.
	Carribeau	Ophir.

Earthy and metallic gangue minerals (excepting quartz and pyrite) of the Telluride district—Continued.

Mineral.	Mine.	Locality.
SIDERITE	American Frenchman	Ophir.
	Suffolk	Do.
	Little Olla	Prospect Basin.
	Smuggler	Marshall Basin.
	Trust Ruby	Canyon Creek.
SPINEL-PICOTITE	Lakeside	Mount Wilson.
STIBNITE	Magpie	Do.
ZINCBLENDE	San Bernardo	San Bernardo Mountain.
	Garibaldi	Do.
	Lakeside	Mount Wilson.
	Silver Pick	Do.
	Tam O'Shanter	Do.
	Prudence	Do.
	Colorado	Do.
	Silver Horn	Do.
	Magpie	Do.
	Terrible	Ophir Loop.
	Silver Bell	Do.
	Butler	Do.
	Carribeau	Ophir.
	Montezuma	Do.
	Attica	Do.
	Badger	Do.
	Santa Cruz	Do.
	Silver King	Alta Basin.
	Silver Chief	Bear Creek.
	Lewis	Bridal Veil.
	Columbia	Savage Basin.
	Tomboy	Do.
	Big Elephant	Do.
	Japan	Do.
	Bradley Pioneer	Do.
	Cimarron	Do.
	Smuggler	Marshall Basin.
	Gold and Silver Chief	Royal Gulch.
	Yankee Boy	Canyon Creek.
	Trust Ruby	Do.
	Virginius	Do.
ZOISITE	Carribeau	Ophir.
	Horatio	Bridal Veil Basin.
	Yankee Boy	Canyon Creek.

QUARTZ.

Quartz is of universal occurrence in these veins, both as vein filling and, less often, as the result of silification of the wall rocks. Its physical appearance in the field appears to be to some extent an indication of the metallic contents of the vein. Where the veins carry gold values quartz is white; where the values are greater in silver the quartz has generally a dark-gray to bluish and even black color. This distinction must not, however, be applied specifically, but is an inference gathered from the majority of observations. Under the microscope the only apparent causes for this difference in color are that the dark-colored quartz is usually very fine-grained, and often contains aggregations of minute crystals of iron pyrite, while the white quartz is much coarser, and less frequently accompanied by pyrite. It should be noted, however, that silver ore of a given value would contain thirty times as much silver, by weight, as gold ore of the same value would contain of gold. It would also contain sulphur, antimony, or arsenic in corresponding quantities. Hence silver ore would very naturally show its mineralization more clearly than gold ore.

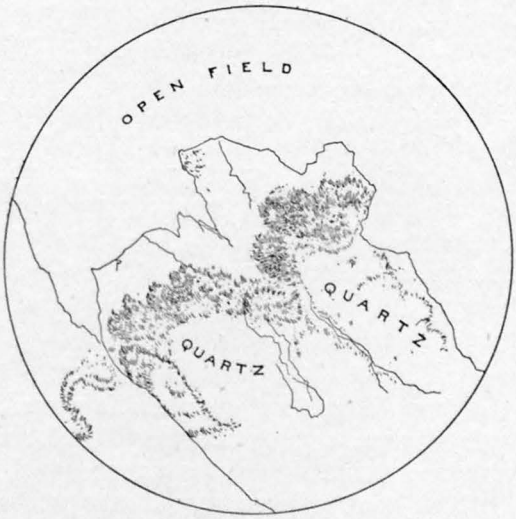


FIG. 68.—Thin section showing arrangement of inclusions in vein quartz, from the Fairview vein. ×48.

There is much evidence of repeated deposition of quartz, but never of more than three separate crystallizations. In specimens from the Virginius vein fragments of vein-quartz crystals may be seen inclosed in quartz which is later in origin. In many veins microscopic examination shows regular lines of inclusions which are arranged on surfaces parallel to the pyramid faces of the crystal-ends, these surfaces occupying positions varying from half way down the length of the crystals to very near their terminations. (See fig. 68.)

In some cases two successive lines of these have been observed, and in a comparatively large number of instances, one line. The inclusions consist of gas in the majority of cases, probably carbonic acid gas, while some are liquid. Mineral inclusions are very rare, and irregularly arranged. Those gaseous inclusions which show a distribution without order are of rarer occurrence, and usually smaller.

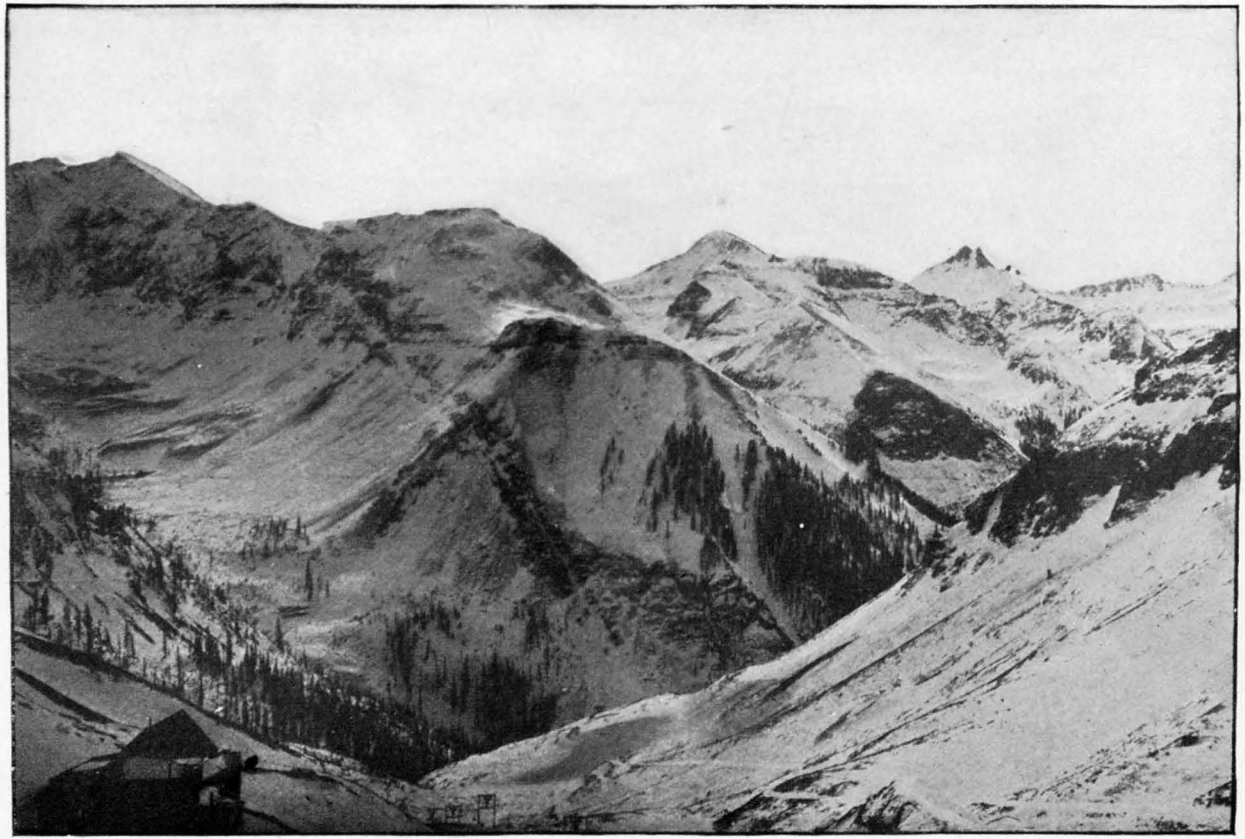
In fact, all the inclusions are of the minutest dimensions, and are indeterminable except with the highest powers. It is worthy of mention that those veins which show the regular arrangement of inclusions in the quartz are principally gold producers, while from the mines which have their greater values in silver almost no specimen of the quartz exhibits this feature. The following gold veins exhibit well the inclusions: Summit (gold vein), Contention, Aurora, Champion, Ohio, Fairview, Waterfall, Tomboy, Cimarron (gold streak), Waters Lode, Alleghany, Trust Ruby (Circassian Girl vein). In the silver veins such an arrangement has been found only in the Virginius, Lewis, and Silver Chief mines. In the Smuggler vein, although quartz is by far the most important gangue mineral, and occurs beautifully crystallized, inclusions are notably lacking, especially toward the north, or in the more argentiferous portion.

In the matter of silification of the wall rocks, the influence of the ore-bearing solutions has in some cases been considerable. From distances varying from 1 to 15 feet laterally along the sides of the larger veins the sedimentary rocks have been silicified, with accompanying impregnation of iron pyrite and development of solfataric decomposition. In the volcanic rocks and the diorites, however, silicification is subordinate to the development of carbonates and sericite as an accompaniment of the veins. Under the subheading "Impregnations," the metamorphism of the wall rocks is discussed in considerable detail.

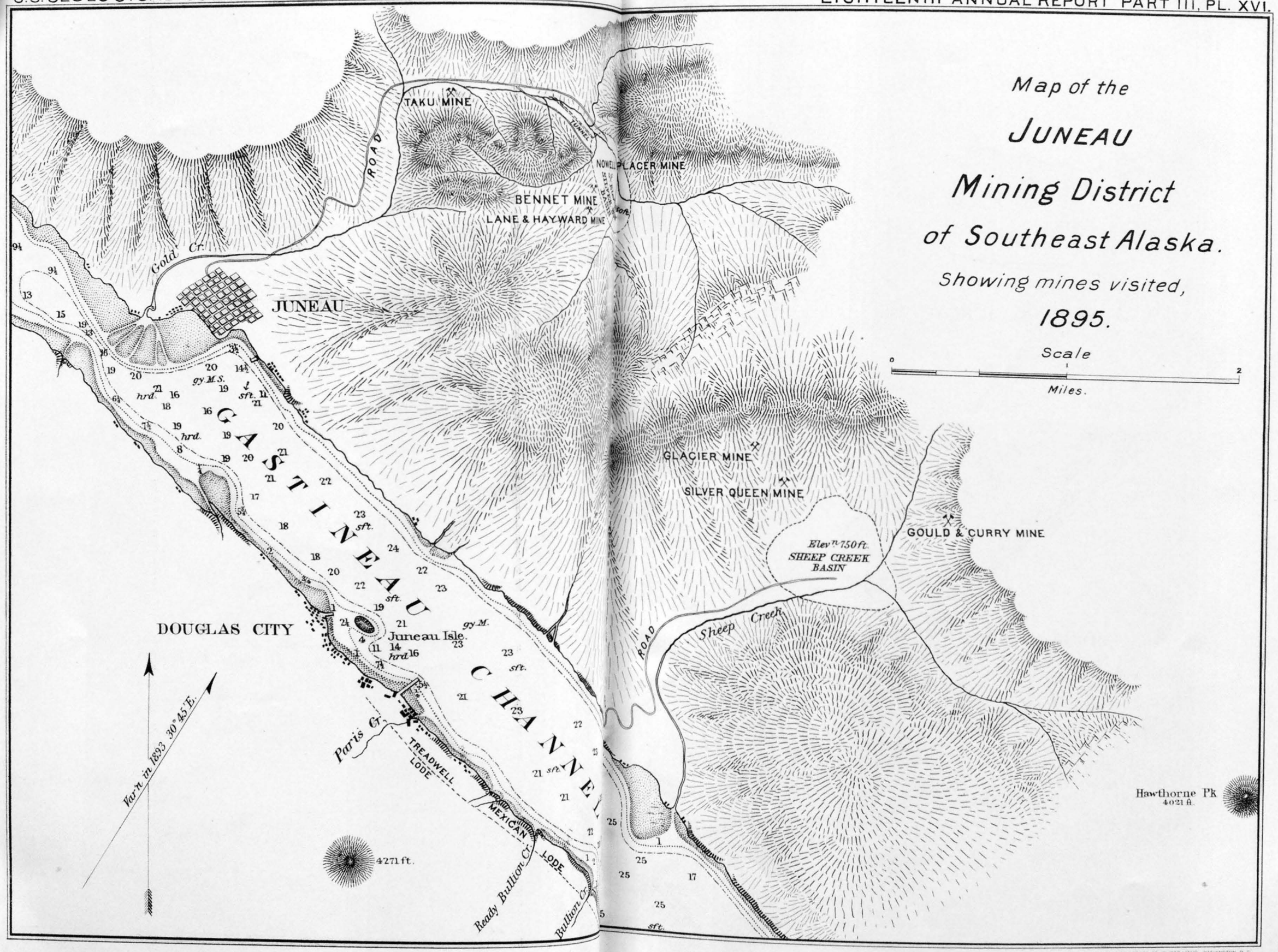
MICA.

Although much of the mica now seen in connection with the veins and impregnations is undoubtedly biotite which was originally in the wall rocks and which has undergone bleaching, still it can not be doubted that a large part of the white mica now found in direct association with the vein quartz has been introduced by the ore-bearing solutions as part of the gangue. In fact, in two cases shreds of mica have been observed entirely inclosed in quartz crystals. In certain of the veins which penetrate the San Juan formation I am led to believe that an accession of alkalies has taken place in the wall rocks, due to the ore infiltration. This has resulted in a carbonization and sericitization of the rock similar to that described by Mr. W. Lindgren as accompanying the ore deposition in the Ophir, California, quartz veins.[1] Especially is this the case in the diorites, where a large amount of carbonates and white mica has been developed in the impregnated zones near the veins, whereas in the normal fresh rock the only mica is biotite, and this in much less amount than the white mica of the impregnation zones. A considerable amount of effervescence with dilute cold hydrochloric acid was observed on a specimen of the impregnated diorite near the Silver Bell vein, while none takes place in fresh diorite at a distance from the veins.

[1] The gold-silver veins of Ophir, California: Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1893, p. 274.



SAVAGE BASIN, FROM MENDOTA MINE, SHOWING CIMARRON VEIN.



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Although the varieties of white mica are not easily distinguishable, it seems most probable that the mineral occurring here in such quantity is sericite, and it will be so referred to. In the veins themselves large amounts of soft clay-like material occur. This material is white, except where discolored by iron or manganese oxide, and it has a greasy feeling. Although some of it is undoubtedly merely the finely ground country rock, and not to be referred to any single mineral species, there is little doubt that much is of more definite composition and has been introduced with the ore-bearing solutions as a gangue mineral. The material forms, when wet by the mine water, a sticky mass which sometimes causes serious difficulty in the treatment of the ore. The consensus of opinion in the district, however, and in the Rico and La Plata districts to the south, is that the influence of this material in the veins makes for enrichment, especially in the gold values. The material gives tests for alumina, and with hydrosilico-fluoric acid, for potassium. I am convinced that this is largely sericite, and has been introduced as a gangue mineral, especially as the microscope shows that mica shreds are exceedingly common in direct association with the vein quartz. The name talc, which has generally been applied to this material, is evidently erroneous, as the presence of magnesia is not evident in it, and the percentage of water is not sufficiently high. In the field it seemed probable that a large part of the material was kaolinite, but repeated tests on specimens from numerous veins have failed to show the presence of water in sufficient amount to establish this species. Kaolinite does occur probably as an alteration product, but its amount is comparatively small, and the greater part of the feldspar alteration is to be referred to the processes of carbonization and sericitization.

CARBONATES.

The earthy carbonates, especially calcite, play an important part among the gangue minerals. Especially in the silver veins along the central east-west belt in the quadrangle, carbonates form a large percentage of the gangue. A mixture of the carbonates siderite and rhodochrosite has been observed in the veins penetrating the diorite stock of Yellow Mountain, while no trace of lime was given by chemical tests. Calcite does, however, occur separately in these veins.

As seems to be generally the case, the calcite is associated with zinc and lead sulphides wherever it is found, although iron pyrite frequently occurs in it. In many parts of the Terrible vein the carbonates exceed in amount the quartz. If any distinction of association may be drawn, it is that sphalerite is the sulphide usually associated with manganese carbonate, and galena with calcite.

In the Fairview and Tomboy veins the calcite occurs associated with fluorspar. The best example seen of association of sphalerite and rhodochrosite was in the Big Elephant vein, in Savage Basin. Rhodochrosite does not appear to influence the values in the veins,

nor to be connected with one of the precious metals over the other. In the Cimarron vein the parallel streaks, the one carrying almost entirely silver values, the other gold, both contain rhodochrosite in the gangue. In the sediments below the horizon of the San Miguel conglomerate calcite is usually associated with copper pyrite.

BARITE.

Barite is not widely distributed, as will be seen from the list.

ORTHOCLASE.

The one occurrence of orthoclase deserves notice on account of the rarity of this mineral as part of the gangue of metalliferous veins. This mineral was found in Alaska as a gangue mineral with the gold quartz of the Apollo mine, in the same form, namely, microscopic hypidiomorphic crystals of fresh appearance in small veins of quartz and iron pyrite.

FLUORITE.

This mineral, rather rare as an accompaniment of gold ores, occurs abundantly in the Tomboy vein, and probably has considerable development in the other localities quoted. It is of a light-green color, and has none of the purple pigment noted in its occurrence at Cripple Creek. It is sometimes in streaks more than 2 feet in width in the vein, and does not appear to carry any values, though its occurrence in the Tomboy vein is regarded as a favorable sign, as indicating the proximity of gold values. The mode of occurrence indicates that its crystallization was connected in point of time with that of the quartz. Microscopically, the fluorite is seen in single sharp-cut crystals surrounded by rims of very fine-grained quartz, which are in turn surrounded by radiating, well-formed crystals of quartz, whose outer ends meet in open vugs with those inclosing other fluorite crystals. Fluorite is, as is well known, more often an accompaniment of fumarolic deposits in large stocks of granitic rocks, where it occurs with tourmaline, wolframite, columbite, tin stone, etc.; consequently its occurrence as a gangue mineral in metalliferous veins, which are undoubtedly formed by deposition from percolating waters, is interesting, and I shall treat further of it when describing the features connected with the origin of the ore.

IRON PYRITE.

Iron pyrite, by far the most abundant and important of the metallic minerals occurring as gangue, varies greatly in the manner of its crystallization and occurrence. It is proposed to treat here of only that pyrite which occurs in the veins, leaving that of the impregnations, etc., to be further dealt with under the description of the

impregnations. As will be shown later, the vein pyrite is considerably different, genetically, from that now found impregnating the wall rock. As is usual in veins which carry both gold and silver values to a considerable extent and in varying proportions, it is the pyrite which is the auriferous gangue, or which is at least an almost constant accompaniment of the gold values. A notable exception to this is, however, the Tomboy vein, in which the presence of sulphides is no indication of the gold values, and where a large part of the gold is free. In many of the veins which bear almost entirely gold values, for example those of Ballard Mountain and the opposite wall of Bear Creek, very little pyrite is to be seen, and the ore is free-milling. But close examination will show the presence of pyrite, and consequently it is only by its oxidation that the gold has been set free. This condition will, of course, obtain until the water level is reached. In the case of the Tomboy, however, but a small per cent of pyrite has ever been present; it is in narrow streaks along with other sulphides, and does not, so far as I know, carry any large proportion of the values.

It is well known that different varieties of pyrite oxidize and decompose at different rates. Such a difference is marked in a comparative study of the Telluride veins. Moreover, the pyrite of auriferous veins appears to oxidize with much more readiness than does that of the veins which carry mostly silver. In the last-named veins the pyrite plays a small part in the values, although it is usually somewhat auriferous. This difference seems well illustrated in the Smuggler vein, in which, in common with other veins in the immediate vicinity, a rather remarkable change in values occurs from south to north. In the southern or auriferous portion a large amount of decomposition has affected the pyrite, and consequently almost none is to be seen in original state. In the northern portion of the vein, where values are almost wholly in silver, the pyrite of the ore is fresh, even at points near the surface, as in the upper workings of the Humboldt mine.

As to the manner of crystallization of the pyrite, I have not found that observations lead to any definite results. The veins in the diorite of the Mount Wilson area and in that of Yellow Mountain have, perhaps, the most coarsely crystallized pyrite, but even in these cases there is no conformity of occurrences.

Coarsely crystallized vein pyrite is not characteristic of the region in general, and especially in the silver-bearing veins north of the Telluride Valley a portion of the pyrite is exceedingly fine in crystallization. It is arranged in strings and lines which branch out from a central bunch or mass in all directions, always inclosed in finely crystallized quartz. In the parts of the San Juan region which have been visited the opinion seems general that the finely crystallized pyrite carries better values than the coarse, the latter being in places

practically barren of either gold or silver. The coarse galena is likewise generally poor in value. The importance of these relations should not, however, be overestimated, since many observations from various regions of ore deposits have shown no agreement of conditions in this regard. In many of the veins where pyrite is finely crystallized the cubes seem very much distorted, so that long prisms with square sections are presented. These are visible only under the microscope. In certain of the numerous specimens taken from the Smuggler and Virginius veins, cruciform pyrite of microscopic dimensions is fairly abundant, which is very probably mispickel. But in both gold and silver veins the specimens of the higher-grade ore show the most minute crystals of pyrite arranged in bunches and long rows, which often radiate from a common center. The distribution of the pyrite is, as a rule, quite irregular. Usually it has been formed later than the quartz, as it cuts all quartz in the vein quite promiscuously, and sometimes includes pieces of vein quartz within itself. Pyrite which is apparently quite massive occurs in immediate connection with that which is well crystallized, as, for instance, in a specimen in the collection from the Butterfly vein of the Terrible mine. About the edges of the larger crystals quartz crystals of minute size are arranged with their longer axes perpendicular to the edge of the pyrite crystal. As these quartzes are in immediate contact with much larger quartz crystals which the pyrite itself appears to cut, it can only be inferred that in this particular place two depositions of silica have taken place, one previous and one subsequent to the formation of the pyrite. Indeed, the field evidence, combined with that of the microscope, seems to show that not only two but several different depositions of ore have occurred in many of the veins, and this evidence is always best shown in those veins which now bear both gold and silver in workable quantities. It is, moreover, probable that the several periods of deposition are not to be correlated over large areas, but are of local manifestation, and perhaps embraced within a very short period of time. In the mines located in the watershed of Canyon Creek these evidences are especially strong.

Although the evidence is very strongly in favor of the hypothesis that the pyrite in the vein is due to causes differing from those which made the pyrite in the impregnated wall rock, there is much to show that, as is usual with natural phenomena, a sharp division can not be made. Thus, as shown in Pl. CXVIII, *B* (p. 850), the tiny veinlets which make off from the main channels wherever a fissure has permitted a passage are filled for the most part with quartz grains, but contain sometimes bunches, more often single crystals, of pyrite. Where, as here shown, such a single grain of pyrite has crystallized at the side of the quartz stringer, and on the contact between it and the country rock, it is difficult to tell whether the pyrite in question has been substituted for a part of a ferromagnesian silicate or is the product of the FeS_2 brought by the ore solutions from extraneous sources.

The criterion of the presence of a border of calcite or mica about the pyrite may often be applied, as noted under the heading "Impregnations," but this is sometimes impracticable. The question of the relative tenor in the precious metals of the two kinds of pyrite will be discussed in treating of the gold and silver.

Crusts of iron pyrite coating fragments of country rock included in the vein and having botryoidal form, with very little sign of crystallization, were seen in the workings of the San Bernardo mine. In this mine it is intimately associated with mispickel. As a rule the pyrite of this region does not associate itself with any of the other metallic minerals. Intimate connection with zincblende is occasionally seen, but the last-named mineral is more frequently associated with galena.

In the veins of the Bear Creek region and those of the west side of Bridal Veil Basin and the Alleghany mine pseudomorphs of limonite after iron pyrite crystals occur, the metallic luster of the pyrite being entirely gone.

Of the other sulphides, galena is the most general matrix of the silver, while gray copper, argentiferous tetrahedrite, or freibergite, ranks next in breadth of occurrence. Chalcopyrite and zincblende are seldom argentiferous, but in several cases carry more or less of the gold values. It has been generally noted that the resinous zincblende is more auriferous than the blackjack. Of the rarer silver sulphides the occurrence is not widespread. Stephanite and ruby silver were reported from several mines which do not appear in the list, as the occurrences were not deemed of sufficiently certain character to record.

MAGNETITE.

This has been rarely found as a gangue mineral in gold veins, but its occurrence in the Telluride mines is highly probable, and doubtless more general than has been ascertained in the present investigation. Its occurrence is not, however, to be confounded with that contained originally in the rocks of volcanic origin, where it is occasionally present in such abundance as to violently affect the compass needle.

NATIVE COPPER.

Native copper is exceedingly rare in connection with gold veins, only two occurrences, so far as I know, having been noted in print, one in the list of gangue minerals in the Orange Grove mine, Virginia, compiled by Mr. G. F. Becker,[1] and one mentioned by Prof. Henry Howe.[2] On the Survey expedition sent in 1895 to investigate the gold mines of the Alaskan coast, beautiful specimens of native copper were obtained from the Apollo gold mine on Unga Island. Mr.

[1] Sixteenth Ann. Rept. U. S. Geol. Survey, Part III, 1895, p. 29.
[2] Mineralogy of Nova Scotia, 1868, pp. 39 and 61.

N. T. Mansfield has shown me a specimen of native copper from the Smuggler vein, and pieces of small size are said to have been found from time to time in the placer deposits along the San Miguel River. It has likewise been found in the placer beds of the La Plata River.

SECONDARY MINERALS.

Of the secondary minerals the copper sulphate noted from the Silver Pick and Special Session mines is the most unusual. Its presence is due to the constantly frozen condition of the ground, where the percolating water carries but a small part of it away in solution. Yet the water necessary for the existence of the sulphate is constantly present. When removed from its position in the mine the chalcanthite is soon reduced to a pale-green powdery substance, losing the brilliancy of color which gives it a beautiful appearance in the vein. Small amounts of copper carbonate are not uncommon in those veins bearing copper pyrite.

Lead carbonates and sulphates are both present in the ores which carry galena, and represent its decomposition products. Massive cerussite occurs in the flat-ore beds at Sawpit, and specimens may be seen showing its change from galena. Minium, the red oxide of lead, also occurs to a limited extent in these beds.

Limonite is very common as a secondary product in nearly all veins, and is, of course, best developed where the veins outcrop at the surface. The amount to which iron oxide has penetrated the interstices of the vein crystals is exceptionally large. Microscopic examination shows that the finest quartz grains are bordered with golden-yellow films of limonite, giving the mass an appearance similar to imbricated aggregates of tridymite.

Kaolinite has been found in the specimens of ore from the Tomboy vein. According to a partial analysis by Mr. H. N. Stokes, some of the clay-like material which gives tests for aluminium contains 12 per cent of combined water. This mineral has not been included in the lists because it is regarded as of uncertain genesis. Moreover, it is mixed with finely-ground country and with the mineral sericite already described.

A description of the precious metals, their distribution, and their mode of occurrence will be given under a separate heading.

DISTRIBUTION OF ORE IN THE VEINS.

The ore is distributed in the veins in a manner by no means uniform. The ordinary type of vein consists of a filled fissure zone, as has been stated. This zone is only in part filled with ore which may be profitably extracted. Although the veins are seldom vertical, the dip is steep, and the pay ore or "pay streak" lies, as a rule, next the foot wall. This phenomenon is by no means peculiar to the veins in

question, as the majority of recorded observations show it to be the rule in gold veins. Here it is not always true, as several cases have been observed where the better ore was on the hanging wall, and in some instances the ore changes from one wall to the other of the fissured zone. In both the Japan and the Virginius mines this shifting has been observed. That part of the zone which is not occupied by the pay streak is sometimes, it is true, mere closely fissured and triturated country rock, but it more often consists of alternate bands of country rock and seams of ore which are so narrow that their extraction from the vein and separation from the accompanying barren material is unprofitable. The barren portion of the veins, often referred to as "gangue" material, is sometimes of considerable advantage in the mining of the ore. In many parts of the Smuggler vein a remarkably good division exists between the ore on the foot wall and the barren portion of the fissured zone next the hanging. The barren part is generally more decomposed, and contains so much soft clayey material that it is easy to strip the vein along this, everything being taken out to the "blasting course," which is, as it were, a second or pseudo hanging wall directly in contact with the ore. A drift is thus run for a considerable distance alongside the ore before the ore itself is touched. This method greatly facilitates the final getting out of the ore which is to be taken from the mine.

Mr. S. F. Emmons, in notes taken on the Smuggler vein in 1888 but not published, records the fact that in places a seam of pay ore shifts from one wall to the other and is intersected by a seam containing clay or gangue matter, which crosses in the opposite direction. Although I did not note this especial form of occurrence, I observed parts of the Smuggler vein with pay ore along both walls, the gouge matter being in the center. In the more argentiferous portion of the Smuggler, toward the north, it has been occasionally observed that the narrow streak following the hanging wall carries gold values, while that along the foot wall is rich in silver. I could not see that any great difference in mineralogical composition distinguishes the gold from the silver streak. In the Tomboy vein, the values do not seem to be especially associated with any metallic gangue, and as the greater part of the vein consists of white auriferous quartz, it can hardly be said to possess any pay streak. In fact, so far as can be learned, the vein stuff, except where larger "horses" of country rock occur, is milled from wall to wall. A streak of galena, 10 inches wide, with some associated iron pyrite, is quite constant in the vein, and crosses at times from one wall to the other. It does not, however, bear any especial relation to the value of the ore.

The presence of local segregations of ore within the lodes, or ore shoots, in this region has been proved in a few cases where the veins have been extensively worked. The data collected from different mines do not, however, allow of any correlation whatever, with the

exception that in the systems of northwest veins, south of Mount Sneffles, the veins become more argentiferous and less auriferous as one proceeds north. On this point I shall speak further under the heading "The gold and silver," (p. 809). Ore shoots are characteristic of veins in general, and no satisfactory theories have been advanced to account for their occurrence, except under certain purely local conditions. Speaking generally, I should say that the veins of the Telluride district are not characterized by alternations of barren and rich zones within the walls. The Tomboy vein, which has been continuously worked a longitudinal distance of more than 2,000 feet, has exhibited no intermittence in the richness of the ore outside of that caused by the mechanical narrowing of the fissured zone. If this vein contains ore shoots at all they must be of extraordinarily large dimensions. In the Smuggler vein it has been noted that the ore lies in horizontal bodies in the vein. These are called "floors," and are similar to the occurrences which, according to J. A. Phillips,[1] are called courses of ore in the west of England. The dimensions of these courses I do not know, but their longitudinal extent is very considerable. No large amount of difference in values is experienced on account of them, however, the ore being, according to the statement of Mr. J. A. Porter,[2] in a recently published description of the Smuggler-Union mines, of remarkably uniform grade over long distances. In the Virginius vein, according to the observations taken while getting out the ore, shoots are arranged successively in the vein, pitching to the south. Prof. P. H. Van Diest[3] mentions the fact that the ore of the Nelly mine, in Bear Creek, lies in shoots in the vein, pitching to the west. In the majority of the mines where any considerable amount of work has been done observations do not appear to have been taken frequently, and it is not likely that markedly barren zones alternate with rich ones.

SUCCESSION OF MINERALS IN THE VEINS.

In this regard the veins of the district do not differ from the majority of deposits on which observations are recorded. As in von Cotta's tables of the succession of minerals in the Freiberg veins, and as noted in many investigations of gold and silver veins, quartz is usually the first mineral deposited next the walls, and the carbonates occupy the center of the veins. In the Mount Wilson district the type of succession is fairly uniform. From the wall toward the center the order is as follows: 1, quartz with mispickel; 2, iron and copper pyrite; 3, calcite with galena and zinc blende; 4, occasionally quartz crystals lining open vugs.

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[1] A Treatise on Ore Deposits, by J. A. Phillips, 1896.

[2] The Smuggler-Union Mines, Telluride, Colorado, by J. A. Porter: Trans. Am. Inst. Min. Eng., Vol. XVI, 1896, p. 449.

[3] Notes on a trip to Telluride, San Miguel County, Colorado: Proc. Colorado Sci. Soc., Vol. II, 1885, p. 30.

In the Silver Pick and Special Session mines there are often on either side of (2) bands of the brilliantly colored secondary chalcanthite. The minerals are symmetrically arranged, being repeated in the same order from the two walls toward the center. In the silver-bearing veins of Yellow Mountain, south of Ophir, a frequent succession observed is as follows: 1 (next the wall), freibergite; 2, an intimate mixture of iron and manganese, having reddish-brown color, and bearing copper and iron pyrite; 3, galena, sometimes accompanied by zinc blende; 4, barite; 5, quartz, usually carrying zincblende. The succession is variable, however, at places not far removed on the same vein, the

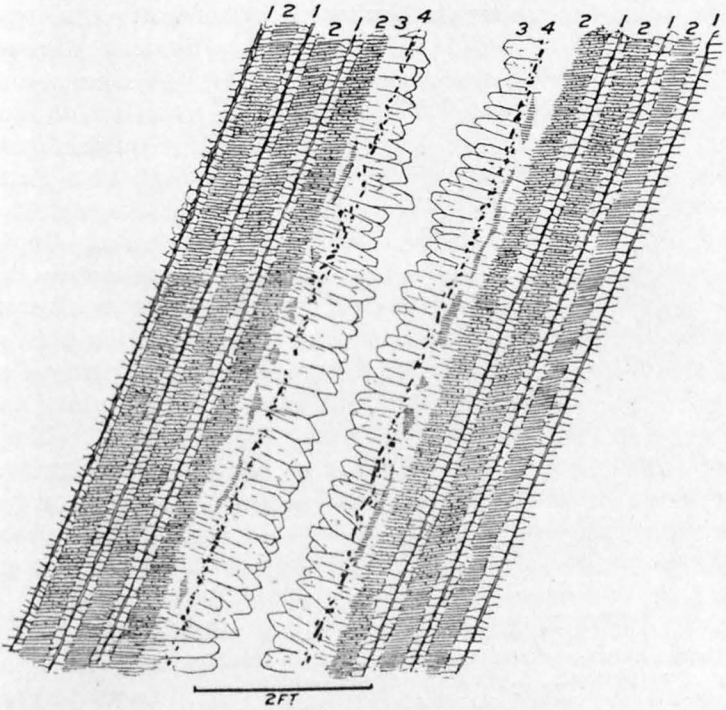


FIG. 69.—Section showing arrangement of ore in Silver Chief vein. 1, quartz, with galena and zinc blende; 2, country rock; 3, vug quartz; 4, iron pyrite disseminated through quartz.

quartz occupying the space next the walls and the argentiferous tetrahedrite being often intimately associated with the carbonates. Calcite does not always occur in these veins, but when seen it is associated with barite. In the Silver Chief vein, noteworthy as being the best exposure of ore in the horizon of the red Triassic sandstone, considerable regularity of arrangement of the banded ore and country rock is apparent, as shown in the partial section from the west breast in the lower drift represented in fig. 69. Alternating bands of ore and country rock occur with remarkable distinctness, although the position of the banded ore, with reference to the more freely crystallized quartz, is not always the same.

In the gold-quartz veins of Silver Mountain and the outlying ridges to the north the vein stuff consists almost entirely of white quartz with disseminated iron pyrite. In the mines of Savage and Marshall basins which bear silver values the succession of minerals is variable. The following is probably the most representative: 1, quartz; 2, quartz with iron pyrite and a small amount of copper pyrite; 3, occasionally rhodochrosite; 4, calcite with galena and zinc blende. In the Circassian Girl vein of the Trust Ruby mine the manganese carbonate contains finely disseminated galena and resinous zinc blende. In the Cimarron vein beautiful crystals of rhodochrosite are crystallized on large quartz crystals. A similar association occurs in part of the Virginius vein, the carbonate having a sort of botryoidal arrangement on the quartz. A specimen in the collection from the Sheridan workings of the Smuggler vein exhibits crystals of stephanite intimately associated with iron pyrite, held in a sort of setting of calcite crystals of tabular habit, which are themselves crystallized on quartz. The succession here illustrated is valuable as showing that the carbonates were not always subsequent in deposition to the metallic constituents. Quartz is, in all the veins, of most frequent occurrence, and accompanies in greater or less amount all the other minerals, whether earthy or metallic. In the fissured zones which exhibit the alternation of ore and country rock a definite succession of minerals is often repeated several times across the width of the zone. Fig. 70, from the Smuggler vein, eighth level, Mendota workings, exhibits one part of such an occurrence, which is at least three times repeated across the face of the vein.

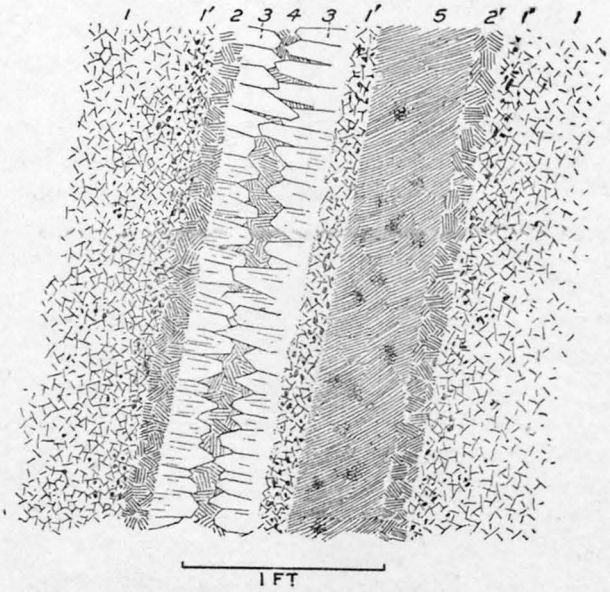


FIG. 70.—Section showing succession of ore minerals in Mendota workings, Smuggler vein. 1, country rock; 1', sericitized and impregnated country rock; 2, zinc blende with calcite; 2', zinc blende and galena; 3, white quartz; 4, rhodochrosite; 5, blue quartz with finely disseminated sulphurets.

Many examples of spheroidal crystallization, especially of quartz, may be seen in the Tomboy and Smuggler veins. In the Tomboy ore, specimens show a nucleus composed of saccharoidal quartz with finely disseminated metallic gold, and from this radiate quartz crystals

perhaps 2 inches in length. These crystals mutually interfere with one another, and the ends closely interlock with the ends of other and similar crystals composing other spheroids. The whole width of the vein is occasionally a mass of these mutually interlocking spheroids of various size. The fluorspar of this vein is always associated with and usually inclosed between bands of calcite.

As has been generally noted in the descriptions of metalliferous veins, it is not possible to lay down rules for the succession of deposition of the mineral constituents. In the Telluride veins quartz has been apparently deposited all through the process of vein filling; the carbonates, fluorspar, and heavy spar have been for the most part the latest minerals formed. The metallic minerals seem to have been particularly irregular in the order of sequence, although if any may be selected as those latest deposited they are galena and zinc blende. On the whole, it appears that the metallic minerals were paragenetic in crystallization.

Some of the occurrences noted above appear to indicate a succession of movements, with a second and even a third deposition of ore along the reopened fissures. The minerals deposited in this secondary manner were, it is probable, of the gangue sort, and there seems no necessity for deriving them from sources far removed from that of the material which already existed in the veins. As I shall further explain in treating of the origin of the ore (p. 819), it is likely that such successive depositions occurred at periods not far apart.

The elaborate researches of Prof. F. Sandberger[1] on veins have shown that the pyrite of the veins has been there generated at several different epochs, and that quartz and carbonates have occurred repeatedly in the same veins. Especially the metallic sulphides of the Telluride veins appear to offer analogies in this regard, as two and sometimes three successive bands containing galena, iron pyrite, zinc blende, etc., may be seen in the same vein, the different bands appearing to offer physical characteristics by which they differ one from another.

MANNER OF DEPOSITION.

Probably no region will afford better illustrations of the filling by ore of interstitial space in crushed and sheared zones of rock than the Telluride quadrangle. The attempt has been made in the description of the veins to render it clear that the majority are formed by closely spaced zones of fissures, in which open space has been developed by subsequent greater or less relative movement of the walls. The crushed and fissured areas are combined in the following manner. As before stated, the parallel fissuring does not seem in any observed case to be spaced more closely than 1 inch. At the same time there are, as shown by microscopic examination, veinlets of the most minute

[1] Untersuchungen über Erzgänge, p. 86 et seq.

size existing in these zones. These small veins occupy the irregular interstices between fragments into which the rock between the fissures has been crushed. The accompanying drawing (fig. 71), from a microscopic section of the ore of the Royal mine in Bridal Veil Basin, is typical of the minute structure of many of the veins. The irregular ore breccias sometimes occupy the entire width of the vein, as is well shown at certain places in the San Bernardo mine. The majority of veins, however, show a banding from wall to wall, with a relative amount of ore and of country rock varying gradually from point to point. The Smuggler and Cimarron veins present exposures well worthy of reproduction, as illustrating this banding of ore. It is to be regretted that lack of time prevented the photographing of certain of the ore breasts in the mines.

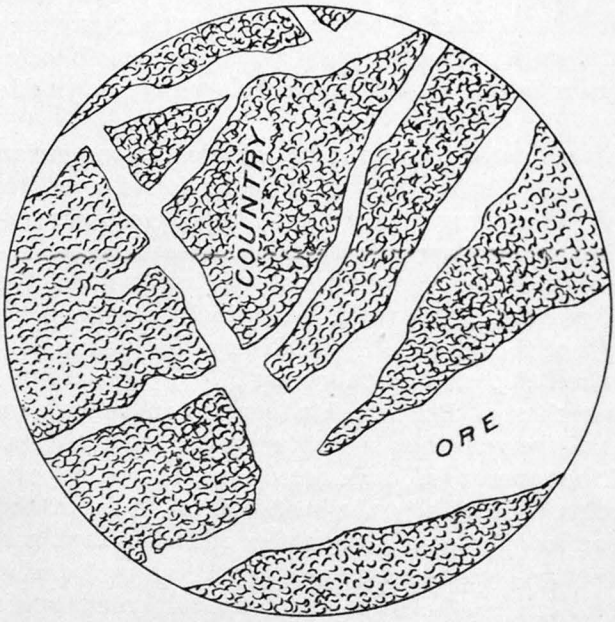


FIG. 71.—Thin section illustrating microscopic structure of veins, from the Royal mine. × 96.

It would scarcely be expected that in a region of siliceous rocks, such as that of the Telluride quadrangle, any great amount of metasomatic action should have taken place, resulting in molecular substitution of ore for country rock. Yet it must be said that evidence pointing toward replacement in connection with the ore has been found to a limited extent. It is based mostly on the result of microscopic study, although the substitution in connection with the filling of previously formed open space was once or twice suspected in the field. The criteria which have been applied to determine whether or not any sign of replacement was visible are perhaps not so well known but that they merit some explanation here. In fig. 73 (p. 840), drawn from an exposure in the Tomboy vein, it will be seen that the larger lenticular fragment of country rock has sharply angular ends, and that the smaller irregular fragments are sharply bounded with angular corners. It is impossible to conceive how a corrosion of the country rock could have taken place without a rounding off of the corners and disappearance of the angular character of the included fragments.

Moreover, the distinct lines of division between the quartz or other gangue and the included fragments would have been in large measure obliterated. Besides this important means of distinction, open vugs or druses occur in the ore, which are generally lined with quartz, but frequently with spar and other crystals. The presence of these vugs necessitates the belief that open space existed and has been partially filled. No feature is more common in the Telluride veins than vug structure, and, as has generally been found to be the case in all metalliferous veins, the vugs are more often than not the seat of deposits of especially rich pockets of the precious metals and their ores. It is not true, however, that vug structure indicates values in the veins of this area, since most typical druses are found equally well developed in both rich and barren veins. It is very apparent that areas occupied by the vugs lined with crystals projecting from the walls represent former open spaces, which the infiltrating solutions have attempted to fill by the deposition of minerals crystallized out. Where such vugs exist, therefore, it is impossible that any general molecular replacement should have taken place. Even where the drusy structure is not visible to the eye in the hand specimen the thin section under the microscope shows in many cases a convergent orientation of quartz crystals, forming a druse whose interior has been subsequently filled by a mixture of very fine-grained quartz, evidently the latest residue of the ore solution.

Specimens from the vein in Bridal Veil Basin, on which the Waterfall claim is located, exhibit a frequent type of the vug structure as seen microscopically. It differs only in size from druses seen in the veins during the underground examinations. The largest of the druses are occasionally several feet in longitudinal extent. These merge into regular comb structure, and finally to interlocking crystals of the component material.

Vug structure with accompanying open space being so extremely common and of such widespread occurrence, it is practically certain that all veins in the district were, at least in part, formed by the subsequent filling of open space. How this space was formed is to be considered separately. By far the greater part of it originated, as has been shown, by the fissuring of the rock due to external stresses and subsequent relative movement of the walls of these fissures. In no case have the spaces, called by Pošepný[1] "spaces of dissolution," been seen developed in the siliceous rocks. In the northwestern corner of the quadrangle, however, at Sawpit, such spaces do occur. Here the 9-foot layer of limestone occurring in the La Plata white sandstone has been acted upon by surface waters carrying carbonic acid. As the bed itself is approximately horizontal, so are the greatest dimensions of the dissolved cavities. They are usually 3 to 4 feet in height, 50 feet wide, and from 100 to 200 feet in length. As they seem to

[1] F. Pošepný, The genesis of ore deposits: Trans. Am. Inst. Min. Eng., Vol. XXII, 1893, p. 197.

follow in longest direction the fissure system running east and west, which is prominently developed here, it is likely that the water causing the solution has followed these cracks. As a rule, it is only in the upper portion of the limestone that the cavities have been formed, although occasionally the whole width of the layer appears to have been affected.

Ore which has been introduced as metallic sulphides occupies portions of these cavities. It is not difficult to see that the limestone bed has been replaced by sulphurets, by the oxidation of which the space originally occupied by the ore has been partially left empty, while percolating waters have carried away the more soluble salts and have doubtless dissolved out the cavities to a somewhat greater size than that of the original ore deposit.[1] A redeposition of the secondary oxides and carbonates of the metals has taken place within the cavities, giving them a stratified and banded arrangement, which is at times conformable with the walls of the cavities. In this sense, then, are these deposits in cavities of dissolution—that the rearranged metallic oxides and carbonates, carrying values and now mined as ores, occur in the spaces formerly subjected to metasomatic action by ore-bearing solutions. This deposit will be especially treated of under a separate heading.

IMPREGNATIONS.

The depositions of the ore by substitution and by impregnation will be considered together, these processes being rather intimately associated in the field under consideration. The term impregnation has been used in a somewhat general sense by writers on ore deposits since its introduction by Von Cotta in 1859. His definition[2] of the term would seem to imply that the separate metallic crystals which occur in impregnation zones may either fill preexisting space, making room for themselves, if need be, by the power of crystallization, or may replace another mineral. As now used, however, the word is restricted to those occurrences where separate crystals, usually of metallic sulphides, fill spaces, however small, which previously existed in the zones of rock forming and laterally bounding the walls of metalliferous veins. As a necessary accompaniment of the formation of impregnations, channels by which the metallic particles are capable of being introduced must exist. But it is not necessary that such channels should be visible, even microscopically. If, as is now more and more advocated, the percolation of ore-bearing solutions takes place in rocks under the influence of osmotic pressure, it is quite conceivable that no visible evidence should exist in an impregnated rock of the manner in which its exogenous constituents have been

[1] J. S. Curtis, Silver-Lead Deposits of Eureka, Nevada: Mon. U. S. Geol. Survey, Vol. VII, 1884, p. 101.

[2] B. von Cotta, Die Lehre v. d. Erzlagerstätten, 1859, p. 216.

introduced. On the other hand, in a large number of cases the paths by which the impregnating sulphides have finally reached their places are very clearly to be seen, usually filled with silica, calcite, or whatever material has served as the gangue. In many instances, also, such channels are now filled by the silica residual from the original silicates of the subject rock. In the course of microscopic examination of several hundred slides of ore impregnations from widely different localities I have found the majority to show the channels by which the impregnating material has come in.

Partial replacement, or substitution[1] in the proper sense, is intimately related to, and, in the San Juan region at least, almost inseparably connected with, impregnation of the wall rock. It is especially characteristic of the igneous rocks and those of volcanic origin, and its principal manifestations are the replacement of the feldspars by carbonates and sericite and of the ferromagnesian silicates by iron pyrite. In the Telluride quadrangle the diorite, the San Juan formation, and the volcanics exhibit this type of alteration almost invariably where these rocks form the walls of the mineral veins. In the field the wall rock may often be seen sprinkled with sharply crystallized separate crystals of iron pyrite, less often of galena. The crystals of pyrite never exceed one-sixteenth inch in dimension, and from this decrease to microscopic size. Usually the crystals are separately dispersed, but not infrequently bunches of pyrite crystals occur. As has been stated, much of the area formerly filled by the ferromagnesian silicates is now occupied by pyrite, but it is difficult to tell in such rocks where the partial replacement ends and the impregnation proper begins—in other words, where the line should be drawn between the pyrite that fills previously empty space and that which does not. All rocks are porous, and rocks of igneous origin more particularly so. In a series of waterlaid breccias of immediate volcanic origin, such as the San Juan formation, porosity must necessarily be a prominent characteristic. Thus, unquestionably, much of the pyrite now visible in this rock has been deposited in spaces, however minute, which were unoccupied previous to the subjection of the rock to the hydrothermal action accompanying the deposition of ore in the veins. Pyrite was likewise developed in other wall rocks in the area in a similar manner, but to a less degree. As the rocks in the district have been subjected to so much crushing, however, and as minute fissures have been so irregularly developed, it is impossible to distinguish sharply between pyrite filling original spaces of porosity and that occupying minute fissures. There is probably in all rocks a much larger amount of interstitial space than is generally taken into consideration.

[1] The term "substitution," as used by chemists, denotes the replacement of one or more elements or radicals of a compound by other elements or radicals. It is not equivalent to complete replacement, metasomatosis, or pseudomorphosis.

Mr. G. F. Becker[1] has shown that compact sandstone consisting of quartz grains of equal size would contain at the least 25.95 per cent of interstitial space. It is not possible to estimate the amount that would exist in igneous rocks, owing to the heterogeneity of the constituents, but the amount would be very considerable excepting in obsidians. This space is, in the impregnated zones of the Telluride rocks, now filled by the products resulting from the infiltration of solutions charged with hydrogen sulphide and alkaline carbonates. No line can be drawn on the one hand between the veins and the impregnations, or on the other between the impregnations and partial substitutions. They imperceptibly grade from one to the other, and examples of all the processes may be seen in a single thin section cut from rock contiguous to the ore. Complete pseudomorphosis and metasomatism, the entire replacement of one mineral substance by another without change of form, does not, so far as I am aware, occur, unless, perhaps, in the limestone. Nor have I observed in any case the spreading apart of the matrix by the pyrite crystals in process of crystallization, referred to by von Cotta,[2] and often described in connection with the pyrite of fahlbands and impregnation zones generally which occur in schistose rocks. In the impregnations of the schists of the Appalachian gold belt it is a common thing to see, under the microscope, the schistose laminæ bending around the edges of pyrite crystals which have evidently pushed themselves, as it were, into the space they now occupy. The appearance presented is similar to that in the case of the basic segregations in augen-gneiss.

Pl. CXVIII, *A* (p. 850), represents an occurrence in a thin section from a specimen taken in the workings of the Gold King mine. The original mineral included as a phenocryst in the groundmass of the andesitic rock was probably augite; water bearing hydrogen sulphide has attacked the ferromagnesian silicate, and a partial substitution of components has been the result; the iron and sulphur have, in part at least, combined as iron pyrite; some of the silica still remains in the form of quartz;[3] chlorite has been formed to some extent, but the greater part of the border now consists of exceedingly fine flakes of sericite, the potash mica. It is necessary to suppose an accretion of potash, as an accompaniment of the hydrothermal process, and it is highly probable that such accretion has occurred, as I shall try to make clear. The drawing is here given to illustrate the character of the partial substitution which is so general in connection with the Telluride impregnations. In some cases very minute crystals of pyrite arranged in lines are seen tracing the cleavage cracks of former ferromagnesian silicates, while the mass of the area is free from pyrite.

[1] G. F. Becker, Quicksilver deposits of the Pacific Slope: Mon. U. S. Geol. Survey, Vol. XIII, 1888, p. 399.

[2] Loc. cit., p. 216.

[3] This substitution has been enlarged upon by Mr. Becker in his Comstock memoir: Mon. U. S. Geol. Survey, Vol. III, 1882, p. 210.

In a specimen from the diorite wall of the Terrible vein this feature is well brought out. It must be remembered that magnetite is a very prominent constituent of igneous rocks in general, and, as stated above, its presence was strongly indicated in the area under consideration at a point where the San Juan breccia is comparatively fresh and free from impregnation. Alkaline solutions bearing hydrogen sulphides must have affected the iron strongly, and the resulting combination of this with the sulphur must have been another prolific source of the iron sulphides. Thus many rocks exhibit now an exceedingly large amount of pyrite, not by any means confined to the areas of the former ferromagnesian silicates, but penetrating the feldspars, and in the case of porphyritic rocks, the groundmass. The crystals when included in feldspars often show an arrangement which corresponds to the cleavage or other physical structure of the host, but these pyrite crystals are usually very much more finely crystallized than are those in the ferromagnesian silicates, and in no case have I seen evidences that they represent any substitution whatever.

It will be seen from the foregoing that it is not necessary to suppose an accretion of iron pyrite in the impregnation zones by means of the ore bearing solutions in order to account for its presence. All the conditions and materials necessary for its formation were supplied except the sulphur, which was added from the charged heated waters. The pyrite of the veins was probably entirely different in origin, being exogenous. It is occasionally very coarsely crystallized and associated with quartz or, less frequently, with gangue calcite. Under the microscope, occurrences of pyrite in the wall rock are often entirely apart from either of these minerals, while microscopic, sharply defined quartz veins have crystals of pyrite in their midst. In connection with the California quartz veins it has been noted that the vein pyrite is almost invariably much richer in gold values than is that of the impregnations. So far as I know, this is generally true of the Telluride deposits. On Silver Mountain, however, much of the gold ore milled is merely the impregnated rock, which of course contains the values, for although veins occur they are very small and play a subordinate part in the constitution of the ore bodies. A microscopic distinction between the pyrite of impregnation, formed by hydrothermal processes, and that formed in other ways has been noted by Mr. Waldemar Lindgren in the description of the gold veins of Grass Valley and Nevada City, California.[1] He states that an occasionally available criterion for the recognition of the wall-rock pyrite is that a border of quartz or calcite often surrounds each crystal. In the andesitic impregnations from the Shumagin Islands, Alaska, this peculiarity is very marked. In the Telluride impregnations the rims are seldom of quartz, but frequently of calcite and of white mica.

[1] Gold-quartz veins of Nevada City and Grass Valley districts, California: Seventeenth Ann. Rept. U. S. Geol. Survey, Part II, 1896, p. 147.

The usual type of impregnation in the rhyolite is illustrated by a specimen of the rhyolite wall of the Smuggler vein, taken in the eighth level of the K. C. Humboldt claim. The normal rock, seen in a specimen of the rhyolite from near by, collected by Mr. Cross, consists of predominating orthoclase phenocrysts, with a subordinate number of plagioclases, which are for the most part indeterminable, but of sodic character. One was determined by the method of Michel Lévy as andesine. Rarely quartz occurs as phenocrysts. Hornblende is the prevailing ferromagnesian silicate of the phenocrysts, and augite occurs in small, well-formed crystals. The groundmass is a fine-grained aggregate of feldspar and quartz, with white mica, which is probably secondary for the most part. Magnetite occurs in rather unusually large crystals and masses, usually surrounded by rims of red iron oxide. Iron pyrite does not occur. Within the zones of impregnation, as judged by a specimen from the Humboldt mine, the rhyolite has undergone a thorough change. The flow structure which is apparent in the mass of the rock is seen under the microscope to have been obliterated. The feldspar phenocrysts have been changed, both orthoclase and plagioclase, to a very finely felted mass of sericite flakes, the separate components being visible only with the very highest power. Occasionally lines and dots of dead-white opaque material occur, which is probably finely divided carbonates of lime and magnesia. The presence of kaolin I am not able to deny, but if it exists its amount is entirely subordinate. Quartz particles are rare in the feldspar areas, but not entirely wanting. Pyrite, usually in separate crystals, occurs scatteringly in the feldspars. One phenocryst of quartz occurs in the slide referred to, and it is notable that it is entirely fresh, notwithstanding the intense sericitization of the rock in general. There are areas in which pyrite is developed in bunches of crystals associated with carbonates. These represent the former hornblende of the rhyolite. Areas so filled usually have approximately the outlines of the ferromagnesian silicates affected, although oftentimes eaten into by the material impregnating the groundmass. The pyrite contained in the areas of former ferromagnesian silicates is always more coarsely crystalline than that of the groundmass, which occurs in minute separate grains, which are, however, in this slide densely packed. Besides the pyrite, there is in the groundmass much sericite, in larger flakes than that in the feldspars, mixed with finely divided particles of various carbonates and some quartz. It is to be remarked of the impregnations of this region in general that a noticeably small amount of silica is present in the rock, notwithstanding the immense quantity in the accompanying veins. That impregnations of remarkably siliceous character do occur, however, may be seen by the following description.

A specimen from the hanging wall of the Butterfly vein in the Terrible mine exhibits a phase of impregnation which is uncommon not

only for this region, but for mineralized areas in general.[1] The country rock is diorite, which has locally assumed a porphyritic habit, although it is a part of the large intrusive mass which forms the west end of Yellow Mountain. This diorite in its unchanged condition consists of labradorite feldspar and hornblende, with subordinate amounts of biotite, and considerable magnetite in small crystals. Varying amounts of quartz are present, but always subordinate. The altered specimen in question looks in the field very siliceous and much metamorphosed, not a trace of the original feldspar phenocrysts being visible. On the other hand, in the general type of impregnation the feldspars are especially prominent on account of the white, chalky appearance of the sericite to which they have decomposed. Under the microscope the pyrite is distributed in the customary way, except that more and finer crystals than usual are contained within the areas formerly occupied by the feldspars. The usual partial substitution of the ferromagnesian silicates by pyrite is most noteworthy, as is the extraordinary amount of silica. The outlines of the feldspars are entirely distinct, and a very finely subcrystalline mass of silica fills the space of the former plagioclases. The mass is very feebly polarizing, and unquestionably a part of it is of hydrous nature, perhaps chalcedonite. With high powers spherulites may be seen in places. None of the sericite or carbonates of the type-impregnation are here seen, and the areas seem to represent a replacement of the elements of the feldspars by silica. The ground mass of this slide shows also more quartz than anything else, in much coarser grains than that of the replaced phenocrysts. Mixed with it, between the crystals, are many sericite shreds. Of carbonates or other material there are no traces. A partial analysis of this rock, by Mr. H. N. Stokes, is here given:

Partial analysis of impregnated diorite from the Butterfly vein, Terrible mine.

	Per cent.
SiO_2	70.30
Al_2O_3 with Fe_2O_3, TiO_2 and P_2O_5	20.00
MgO	.31
CaO	.27
K_2O	1.78
Na_2O	.64
Li_2O	strong trace

This is a very exceptional type of impregnation, and although the impregnated diorite seems to have been slightly more silicified than the other rocks which have been subjected to mineralizing conditions,

[1] Mr. Lindgren (ibid.) states that replacement by silica is not one of the processes recognized in the wall rocks of the Nevada City and Grass Valley districts.

I have not seen elsewhere so siliceous an occurrence as is this of the Terrible. The diorite wall rock of the Silver Bell vein, very nearly on the same strike, and a few hundred yards to the east, so far from being silicified, shows an unusual amount of carbonization.

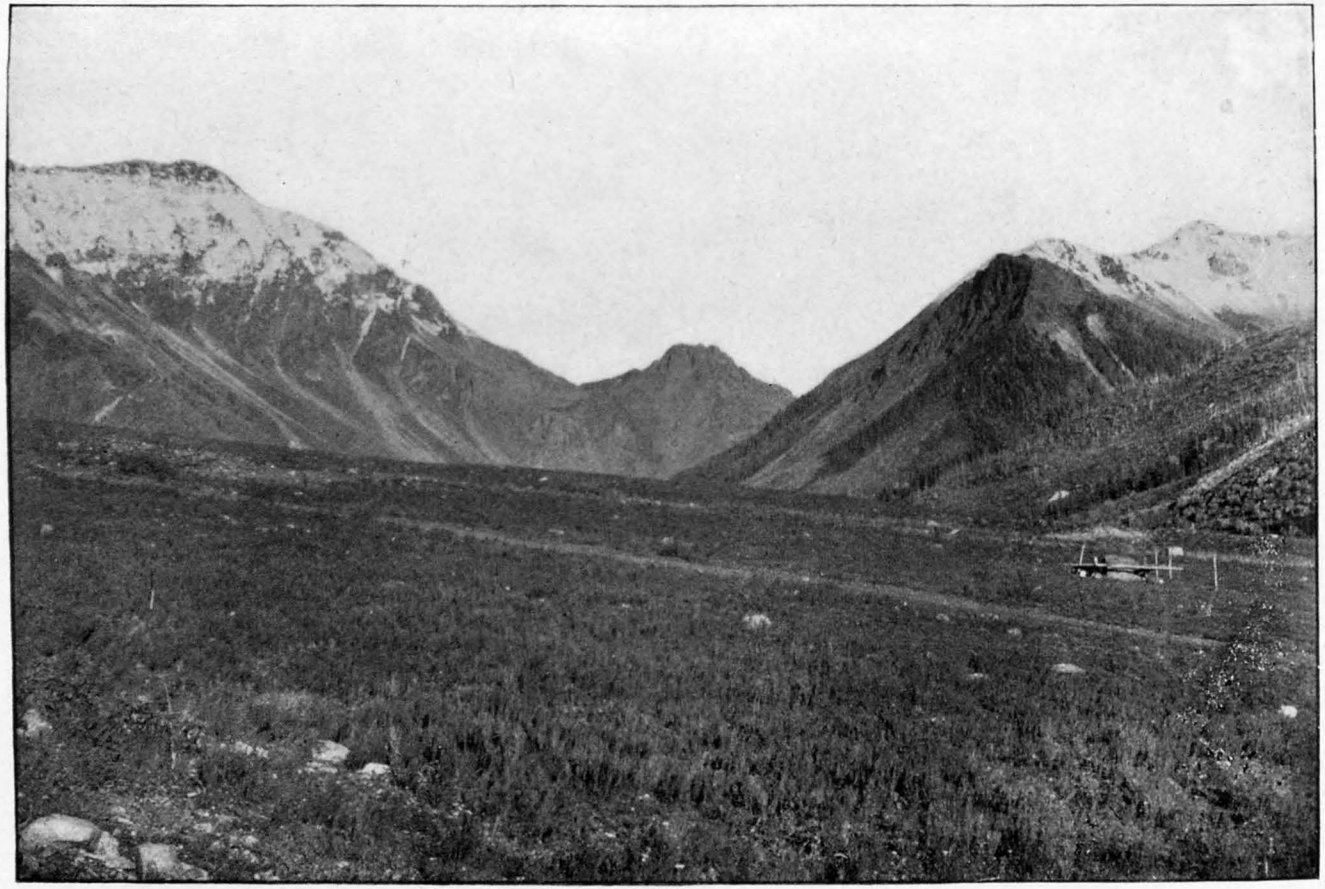
It may be said that, apart from the exception noted above, the character of the impregnations is similar over the whole field. Many scores of thin sections of the wall rocks of the veins present a monotony of appearance, both as to structure and constituents. The question of the economic value of the impregnation zones, considered independently of the veins, will be dealt with under the next heading, "The gold and silver."

Something has already been said of the distribution and extent of the zones of impregnated rock. They exist usually along all the veins of any considerable size. None of the veins examined appeared to be unaccompanied by some impregnation of the walls, although the manifestation of this was in places very slight. The auriferous veins in Bear Creek Basin showed perhaps the least of any, while, as has been said, the mines worked to the north of Ophir and on the opposite side of Silver Mountain take out much ore which is merely the impregnated country rock. The Silver Mountain impregnation follows certain joints of the rock along which small quartz veins have been deposited, and which have doubtless afforded channels for the mineralizing solutions penetrating the rock. Thus the impregnation is heaviest along these planes, but I have been unable to collect a specimen, at whatever distance from the veins, in which some sign of the penetration of mineralizing solutions did not appear. Among the stronger zones of impregnation which traverse the area is one which, appearing on the crest of Silver Mountain north of Ophir, strikes southeast, crossing the Ophir Valley at its upper end, and forms prominent buttes and cliffs on the east wall of Swamp Canyon. The decomposition due to hydrothermal action which has accompanied the mineralogical changes in the rock has produced brilliant white, yellow, and red coloring, causing the path of this and other similar zones of impregnation in the region to be indicated in a striking manner. The width of the zone referred to above is difficult to determine, but it should be reckoned in hundreds of feet. Many such zones exist in the Telluride quadrangle, and are indeed very characteristic of the San Juan Mountains in general; but as they have not, except in one or two instances, been proved of economic importance, it was not deemed practicable in the present investigation to devote a large share of attention to them.

On the south slope of Silver Mountain, above the town of Ophir, the San Miguel conglomerate, as will be seen by reference to the map, outcrops with a thickness of from 300 to 400 feet for a distance of many thousand feet. This rock is composed of pebbles, varying in size from 1 inch to 12 inches, consisting of igneous rocks and quartz,

List of minerals, other than quartz and pyrite, detected in the Alaska gold deposits during this expedition—Continued.

Mineral.	Mine.	Locality.
MISPICKEL	Bear	Berners Bay.
	Bennet	Silver Bow Basin.
	All the mines of Uyak Bay	Kadiak Island.
	Duncan's prospect	Douglas Island.
	Glacier	Sheep Creek.
	Haley & Rogers	Silver Bay.
	Liberty	Do.
	Lucky Chance	Do.
	Silver Queen	Sheep Creek.
	Stewart	Silver Bay.
ORTHOCLASE	Apollo mine	Unga.
PYRRHOTITE	Bald Eagle	Sumdum.
	Bennet	Silver Bow Basin.
	Gould & Curry	Sheep Creek.
	Silver Queen	Do.
	Taku	Silver Bow Basin.
	Tellurium	Admiralty Island.
	Thetis	Baranof Island.
SIDERITE	Treadwell	Douglas Island.
	Lane & Hayward	Silver Bow Basin.
	Lucky Chance	Silver Bay.
SERICITE	Apollo	Unga.
	Glacier	Sheep Creek.
	Lucky Chance	Silver Bay.
	Mexican	Douglas Island.
	Taku	Silver Bow Basin.
	Treadwell	Douglas Island.
	Willoughby	Admiralty Island.
SILVER	Occurs in alloy wherever gold does.	
PYRARGYRITE	Silver Queen	Sheep Creek.
	Glacier	Do.
ZINCBLENDE	Apollo	Unga.
	Bald Eagle	Sumdum.
	Glacier	Sheep Creek.
	Gould & Curry	Do.
	Lane & Hayward	Silver Bow Basin.
	Silver Queen	Do.
	Taku	Do.
	War Horse	Admiralty Island.



VIEW LOOKING EAST UP THE OPHIR VALLEY.

limestone, schist, etc., which have been described by Mr. Cross.[1] As developed in this particular locality, the conglomerate has an arenaceous and apparently very porous cement. In the workings of the Gold Crown mine it may be seen that the cement of the conglomerate has been strongly impregnated by the mineral solutions, and that much decomposition has taken place, due to the oxidation of the iron pyrite. In fact, the greater part of the ore taken from this mine is the impregnated rock from the walls of the principal fissures. In the Lookout tunnel, a few hundred feet to the southeast of the Gold Crown, a fresh exposure of the impregnated conglomerate may be seen. The pebbles are but very little mineralized, but the cementing material is heavily charged with iron pyrite, and, as seen in thin sections, the metallic sulphide is accompanied by sericite and calcite. How much silicification has accompanied the impregnation it is difficult to say, as the cement itself is composed largely of quartz grains. But the introduced material partakes more of the character of true vein and gangue stuff than of the material generally developed, as above described, by mere impregnation. It seems probable that, on account of the large amount of open space afforded by the porosity of the cement, there has been a considerable introduction of the ore and gangue minerals from extraneous sources, as is the case in the veins filling fissures. The impregnated conglomerate has been traced along the mountain side for more than 1,000 feet, and, judging from the large amount of residual ferric material which has been redeposited in the Ophir Valley, its extent toward the east is much greater. The conglomerate is not impregnated to any extent in the exposures which have been seen to the north, in the area included by the drainage of the North Fork of the San Miguel River, although several exposures where veins traverse the conglomerate have been carefully examined. This impregnation on Silver Mountain is probably a locally developed phase in which the cement of the pebbles is less firmly consolidated than usual.

THE GOLD AND SILVER.

As has been shown in the record of the statistics of production from this region, the ratio of the silver product to that of the gold has rather rapidly changed during the last five years in favor of gold. This increase of gold product is largely owing to the exploitation of the remarkable Tomboy vein, but the statement is also warranted that gold-bearing veins have been sought for with increased vigor during the last few years, it having been impossible to work low-grade silver mines at a profit, owing to the depreciation in value of that metal. In the belt of veins south of Mount Sneffles the curious fact has been noted that the gold values increase from

[1] The San Miguel formation, by Whitman Cross: Bull. Colorado Sci. Soc., Sept. 7, 1896.

north to south, while the silver values decrease. Further than this, it may be said that nearly all the veins of Silver Mountain and its outlying ridges and the walls of Bear Creek and Bridal Veil basins are gold-bearing, in most cases to the almost entire exclusion of silver values. In this immediate locality the north-south veins are thought to be the best, while I am informed by Mr. P. A. Lillie, who has had considerable experience in the Telluride district, that on Yellow Mountain, at the head of Waterfall Gulch, north-south veins occur which carry high values in gold. In the workings in the Smuggler vein the change in values is well illustrated. In the Humboldt mine, which is the most northern claim on this vein from which ore has been produced, the gold value is not over 5 per cent that of the silver, while the values are in silver sulphides. There is a much less amount of iron pyrite at this northern end of the vein, as I have observed in the Humboldt, Mendota, and Sheridan claims. In the south end, where the Smuggler-Union Company is now prosecuting extensive developments, by far the larger part of the value is in gold. Although the vein matter and country rock are much more decomposed in this part of the vein, which is covered by the Seventy-six claim, the observations appear to leave no doubt that both ore and country rock carry much more iron pyrite than there is present farther north. In fact, it is probably largely due to the greater amount of impregnation of the country here by hydrothermal action that the extensive decomposition is due. A considerable amount of the country on both sides of the vein is here milled as ore, and it is most likely that the gold is or has been contained in the iron pyrite, and that the increase of this mineral southward is the cause of the auriferous character of the vein. Although the general statement made above concerning the relative distribution of the gold and silver is thought to be warranted by the observed phenomena, a very large number of exceptions occur to which no rules are applicable. Thus the extended belt of veins situated on the northern slopes of Yellow Mountain and reaching westward to Sunshine Mountain, including the San Bernardo, Terrible, Silver Bell, Butler, Carribeau, Montezuma, Nevada, and American Frenchman mines, carries silver ores almost entirely, although these mines represent nearly the southern limit of the productive veins within the area, as hitherto developed.

The veins of Mount Wilson, many of which have the same east-west direction as the Yellow Mountain veins, are far more productive in gold than in silver. Remarkable cases occur where gold veins lie in proximity to silver viens, and even where the same vein carries on one side of a horse of country rock gold values, on the other side silver. The two streaks in the Smuggler vein have already been mentioned. In the Terrible, Summit, Cimarron, and Trust Ruby mines there occur veins having only slightly divergent directions,

lying near together, and carrying markedly different relative values in the precious metals. I was unable to see an intersection of a silver and a gold vein at any point, although in the Terrible mine, where the two veins are only 20 feet apart, a cross fissure carrying quartz and calcite was seen in contact with both veins, and there appeared to be no cutting off of one by the other. Wherever two veins of different character occur, however, the physical appearance and mineral contents vary according to the precious-metal contents, the silver veins carrying either argentiferous galena, tetrahedrite, or the sulphides of silver, or an association of these minerals; the gold veins carrying iron pyrite, and less commonly copper pyrite. Throughout the Telluride quadrangle, as well as in the mines of Rico to the southwest, an increase of copper pyrite is generally accompanied by an increase of gold. According to information received at many mines the resinous variety of zinc blende is also quite generally auriferous.

The physical appearance of the gold veins as compared with that of the argentiferous ones deserves a somewhat extended notice. Although differences in this respect are not constant throughout the field certain distinctive features are so common as to almost serve as criteria for the recognition of the character of the lodes. Although all the veins are genetically the same—that is, open fissures and fissured zones which have been filled with ore—the relative amounts of ore and included country rock now within the zones are widely variant. This variation bears a rough correspondence to the character of the values. Veins of argentiferous ore are banded and correspond more generally to linked veins. The gold-bearing lodes, on the contrary, are more often filled from wall to wall with solid ore, the greater part being quartz with gold in the free state, or with disseminated auriferous sulphides. In gold veins, although the banded structure of alternating ore and country rock frequently occurs, its development is far less than in the more argentiferous veins. The gold veins of the Mount Wilson district present the only marked exception to this rule. There the ore invariably lies in streaks interlaminated with country rock. For long distances in the stopes of the Tomboy mine solid white quartz to the width of 4 to 6 feet, and even more, may be seen, with no sign of intercalated sheets of country rock. Finely developed linked-vein structure does occur, but it is exceptional. In the same belt of veins the Virginius, Japan, Big Elephant, and the Smuggler toward the north end present the appearance of linked veins, the values being principally in silver. At the outcrop of the Elizabeth vein, on the cliffs of the east side of Bear Creek, 7 feet of solid quartz may be seen filling the width of the vein. The Contention, La Junta, Champion, Fairview, and other veins in this immediate vicinity, which have all been gold producers to the exclusion of any considerable amount of silver, present the same appearance. On the other hand the Silver Chief vein in Bear Creek presents a typical linked

vein structure. Its principal values are in silver. In the Trust Ruby mine, the Big Elephant, and the Terrible, the relatively large amount of space actually filled with ore and gangue in the gold veins is very noticeable.

Another difference which is worthy of mention is the amount of drusy structure in the gold veins. Open vugs, especially those of entirely irregular form, seem much more developed in the white gold quartz than in the ore of silver veins. As already noted under the description of the vein quartz, a black color seems generally characteristic of the quartz of silver veins, white of the gold quartz. Again, microscopic examination shows the presence of large numbers of regularly arranged gaseous inclusions in the gold quartz, while such inclusions are rare and irregularly dispersed in the quartz of argentiferous veins.

Although it is recognized that whatever conclusions are drawn from such scattering data as were obtainable in the present reconnaissance are in a sense of only temporary value, it yet seems advisable to offer a suggestion with reference to the observations above recorded. The difference in width of the bands of ore in the gold and silver veins appears to indicate that the wider chambers and clefts which existed in the rock have been filled with gold ore more often than with silver ore and vice versa. This being the case, a possible deduction is that a selective influence was exercised on the precipitation of the values by the volume of open space in the fissured zones. This influence was perhaps the local difference in temperature induced in the ore-bearing solutions. Since precipitation from solutions is largely dependent on temperature, even a slight change in this important factor would have gone far toward determining the final positions of the more stable and less stable compounds. The whole subject, however, requires further investigation.

Negative evidence of the foregoing is afforded by the fact that there are no indications of more than one distinct widespread period of ore infiltration, and that, consequently, all the ore must be referred to one general source. Further, there seems no relation between the nature of the country rock and the argentiferous or auriferous character of the ore.

It will be seen from the descriptions above given that the veins of the Telluride quadrangle offer excellent opportunity for the comparative study of auriferous and argentiferous veins, and it is to be hoped that the speculations here set down will lead to further study of this interesting field.

VALUE OF THE ORE.

To estimate the value of the ores contained in the veins of the Telluride quadrangle is difficult. The investigator must always depend upon the statement made by those best informed in regard to the several mines, and these statements are in many cases not easily obtained.

Information has been freely given by mine owners and mine superintendents in general for the preparation of the present report, but in many cases where little development existed the results were not accurately known even by those in charge. A still greater cause of uncertainty has been the different methods of handling the ore. Where ore is milled and concentrated at the mine the whole width of the fissured zone is usually mined as ore; while in the case of those mines where the ore is sorted and packed on the backs of animals for a considerable distance only a portion, the pay streak, is regarded as ore. Thus the figures given have not always represented the same values, and although it has usually been possible to reduce the statistics to some degree of uniformity especial difficulties are encountered where a part of the ore is milled on the ground and the richer portions are hand-sorted and shipped for smelting. This, as has been explained by Mr. Porter,[1] is the customary method of working the ore of the Smuggler vein. The intimate relation of the gold to the silver and the abrupt changes from one value to the other introduce a further complication in making estimates of average values.

It must be borne in mind that the approximate values of the ores, as given below, are not an index of the value of the mines. Even were it possible to gain in every case a true estimate of the yield of the ore, such an estimate would represent but one factor in the decision as to the value of the property as an ore producer. Although the last statement partakes of the nature of a truism among those familiar with mining as a business, its enforcement in regard to a region so precipitous and difficult of access as that of the San Juan is not regarded as out of place. I shall say more in regard to this in estimating the value of the Telluride region as a whole.

The gold veins of the Mount Wilson district have usually a pay streak varying from 5 to 15 inches in width. Estimates from the several mines and prospects from which ore has been produced give the yield of the pay streaks as from $40 to $150 to the ton in gold.

In the silver-bearing veins of Yellow Mountain the pay streak of the veins averages 2 feet in width, and has an average yield of 75 ounces in silver and from $3 to $12 in gold, accompanied with small values in lead. Occasionally the silver values in small portions of the veins are much higher.

In the veins of Silver Mountain and the ridges to the north the values are, as has been noted, mostly in gold. These veins are characterized in general by an equal distribution of the ore throughout the fissured zones, rather than by barren and rich streaks. The veins vary from 1 to 4 feet in width when well defined, although in certain cases no sharp line can be drawn between vein matter and country rock.

[1] The Smuggler-Union mines: Trans. Am. Inst. Min. Eng., Vol. XXVI, 1897, pp. 449-459.

An average of the run of 22 productive veins in this part of the area gives $14.50 to the ton in gold.

The veins of Savage and Marshall basins and those situated in the drainage of Canyon Creek have, as has been noted, a change in values from silver to gold southward. Exclusive of the Tomboy vein, however, gold has been a subordinate product. As at the principal mines now worked, the ore is milled and concentrated. It has been thought best to estimate the value of the veins of this particular area on a milling basis. In this way the average of all the data collected concerning the northwest belt of veins in these basins gives 20 ounces in silver and $9 in gold to the ton.[1]

The yield of the large zones of impregnation is probably not great in any case. These have been very little exploited, and all that can be learned about this value is from scattering assays made by various persons at different times. Mr. J. P. Colp, of the Silver Pick mine, states that an impregnated mass of diorite on the ridge to the north of Navajo Basin has yielded, on repeated assays, $5 to the ton in gold. The impregnated zones in Ophir Valley, at the horizon of the San Juan formation, have been found to carry from $2.50 to $5 in gold, while the impregnated portion of the San Miguel conglomerate on Silver Mountain has been tested in one or two places with the result of $2.50 in gold. From personal examination I am of the opinion that the impregnations of the igneous rocks of this and other parts of the San Juan are not different in character from the deposit on which the Alaska-Treadwell mine on Douglas Island, Alaska, is situated. This has been successfully operated for some ten years as a low-grade gold mine. Although no comparison in an economic sense may be instituted between ore deposits which have such entirely different environment, it seems advisable to suggest that more attention be paid by prospectors to low-grade ore deposits in general. No value whatever may be attached to single assays of such deposits, and it is only by trial of material which represents as large a volume as possible of the deposit in question that a trustworthy statement of the value of the ore may be made. Further than this, it should be remembered that a thorough study of the surrounding conditions must be made before a decision as to the economic importance of such a low-grade deposit can be arrived at.

In the limestone deposits of Sawpit the ore taken out and shipped for smelting has averaged 11 ounces in silver, $22 in gold, and 20 per cent in lead.

All the estimates given above are of the most general character, as nearly representative as possible, considering the nature of the work. Errors which may have entered into the results are in placing the yield too low rather than too high.

[1] That it is impossible to give a representative estimate by means of a single figure will be seen by reference to the special notes on the Tomboy mine, where the yield of its ore is given.

Data concerning the fineness of the gold were not available in many instances. It varies, according to the figures collected, from 650 to 800 fine. The variation does not appear to bear any relation to the areal distribution.

INFLUENCE OF THE COUNTRY ROCK ON THE VALUES IN THE VEINS.

The rocks in which the greater number of the veins of the Telluride quadrangle have been found are the diorite of the stocks along the central east-west portion and the heavy andesitic breccias now included in the San Juan formation, having its greatest development in the northern half. A few veins are exploited in the overlying flows of andesite, and the upper workings on the Smuggler vein are in the rhyolite which caps the highest peaks. In the San Miguel conglomerate few veins have been worked, and in the underlying sedimentaries only one or two. No one vein of the region has been worked throughout the whole section of igneous and sedimentary rocks exposed, although, as has been stated, there can be little doubt that the fissuring of the region has affected all the rocks represented. The different ways in which the rocks have been affected mechanically by the forces which produced the fissuring have already been discussed. It now remains to consider the country rock in regard to its influence on the values of the ore.

Although the question of the origin of the ore has been reserved for a separate discussion, it may be stated here that such evidence as has been gathered points to the conclusion that the inclosing rocks are not to be considered as the source of the material now filling the fissures. Since a marked change of values has been in several cases noted to occur where the vein goes from one rock horizon to another, it is natural to infer that the country rock itself must have exercised to some extent an influence on the precipitation of the ore from solutions. The results of prospecting in the district have induced the belief that the value of the ore is less in the sedimentary rocks than in the breccias and igneous rocks. In the Contention and Gold Crown mines the values of the veins in gold are less where conglomerate is the country rock than where the andesitic breccia forms the walls. In the Mount Wilson district it has been found that veins which penetrate both diorite and Mancos shale are richer in the diorite than in the sedimentary rock. In the Carribeau and Montezuma mines the ore is slightly better in diorite than in shale. On the other hand, rich ore bodies occur in the shale, as in the San Bernardo, Badger, and American Frenchman mines. Such openings as I have seen in the Triassic sandstone have afforded poor opportunity for observation, with the single exception of the Silver Chief mine, where alone work was being prosecuted. Although this mine has as yet produced very little, sufficient ore has been taken out in the 100 foot or more

of drifts to give a fair result. The returns show that here at least is evidence that productive veins exist in the red sandstones. The unusual width of this vein has already been referred to. It seems exceptional in the matter of width, since the other veins seen in the sandstone are mostly single fissures, as has been stated. There is a marked increase in the relative amount of copper pyrite in the veins penetrating the red sandstones, and values are usually in gold, which is entirely free, not being even mechanically combined with iron pyrite.

It is well known that veins in many districts of metalliferous deposits carry different values within different rocks. In Cornwall the tin veins are productive only where association of granite and slate occurs, and are unprofitable in either of these rocks alone. In the Dacian gold field, in southwest Transylvania, the country has a marked influence on the value of the veins. At Vöröspatak porphyry and underlying sediments are auriferous, while overlying andesites and trachytes carry no values. At Vulkoj, in the same eruptive series, gold is found in the andesites, while in the deeper rocks the fissures have become barren. Pošepný, in discussing these deposits, makes the observation that "any fissure in passing from one rock to another is likely to exhibit a certain irregularity in both direction and filling, and that a change of this kind should not be allowed to discourage at once all further exploration."[1] The deposits of Transylvania offer many points of similarity to those of the San Juan, and are especially noted on this account. A most striking example of the influence of country rock on the values of ore is afforded by the Iron mine vein at Rico, a few miles southwest of Telluride. Here a vein traversing upper Carboniferous limestones, which have a rather steep dip to the north, is argentiferous in a certain fossiliferous heavy bed of limestone, while in the overlying and underlying adjacent beds it contains comparatively barren sulphurets and gangue stuff.

It is evident that in a metalliferous region, such as that of the Telluride quadrangle, where the veins traverse successive horizontally arranged formations of widely different character, the question whether the country does or does not influence the values and width of the veins is of importance. I have stated in describing the veins that, owing to extraneous conditions entirely independent of the nature of the rocks, the fissures and fissured zones are not likely to be as well developed in depth as in those rocks or portions of rock masses which are nearer to what was the surface when the fissuring of the country was induced. As to the values, it has been proved by exploitation that in the diorite, the breccias, and volcanic flows they are generally good. In view of the immense thickness of the volcanics and breccias, it seems likely that many years' work will be necessary to exhaust the product of the veins within these rocks. From the limited study

[1] F. Pošepný, The genesis of ore deposits: Trans. Am. Inst. Min. Eng., Vol. XXIII, 1893, p. 197.

THE ALASKA-TREADWELL MINE.

The Alaska-Treadwell and the Alaska-Mexican mines lie on the same lead and are worked under the same superintendence. They are separated by the Alaska claim, 700 feet in length, upon which little work has been done. The Alaska-Treadwell is justly famous both for its large yield and for its economical working. Thus, for the year ending May, 1894, the profit was nearly 60 per cent of the total yield; yet the ore ran only $3.20 per ton; but the total expense of treatment was only $1.35. Such results could not be attained were the mine not situated as it is. The deposit runs nearly parallel to the shore of Gastineau Channel, at a distance of a few hundred feet from it, leaving just convenient space for offices and storage. Thus, coal, machinery, and other supplies can be procured with ease. Water power is also available for a portion of the year, but it must be supplemented by steam power, involving the consumption of two or three thousand tons of coal annually, at some $9 per ton. On the other hand, the climate is severe (450 inches of snow fell in the winter of 1893–94) and wages are high. The pay of some of the men is as follows: Blacksmiths, $5; amalgamators, $4; roasters, $3.50; miners, $3.50; Indians, $2. That the expense per ton should, nevertheless, be so small is a real triumph of intelligent organization and labor, largely due to Mr. Thomas Mein, who was formerly superintendent. The total product of the Alaska-Treadwell, as shown in the statistical notes in the earlier part of this paper, amounted to $7,028,649 up to the end of 1896.

A plan and section of the Treadwell as it was developed in 1895 are given on Pls. XVII and XVIII, and a view of one of the pits is shown on Pl. XIX.

The Alaska-Treadwell deposit has been described by Dr. George M. Dawson, and his specimens were examined under the microscope by Prof. F. D. Adams.[1] The following quotations from Dr. Dawson's paper give his opinion of the origin of the deposit:

> The impression formed from such examination of this remarkable deposit as I was able to make is, in fact, that it represents the upper portion or "feather edge" of a granitic intrusion, probably contemporaneous and connected with the characteristic granites of the neighboring coast ranges, but which, owing to peculiar conditions, has become decomposed and silicified by solfataric or hydrothermal action, to which the concentration of gold in it and the deposition of pyrites are also due. * * *
>
> It is conceivable that the hydrothermal action which has affected this part of the original granitic magma may have been due to the water included by the mass itself while in a state of "aqueo-igneous" or "granitic" fusion, the escape of such water through the substance of the upper part of the intrusive mass being rendered possible by the relief from pressure consequent on the approach of the intrusion to the actual surface.

[1] Am. Geologist, August, 1889.

of the region permitted in the present reconnaissance, I do not feel justified in asserting that veins which have been found good in the San Juan formation suffer impoverishment of values in the underlying sedimentaries. The various chemical and physical properties of rocks, such as specific gravity, density, porosity, composition of the component minerals, etc., which often have been adduced as influencing the precipitation of ore in veins, may have played a part in the distribution of values here. It seems not at all impossible that when more opportunities for comparison shall be afforded by farther exploration, and detailed study shall have been given to this subject, evidence of such partiality may be collected. The observations and statistics from the Contention and Gold Crown mines cited above are not regarded as sufficient in themselves to afford ground for the belief that the values decrease downward from the breccias into the conglomerate and sandstones below.

If, as from the present results seems most likely, the conclusion be accepted that the ore is of comparatively deep-seated origin, then the question to what depth the veins may profitably be worked is worthy of consideration. The red beds of the Trias have probably a development of more than 2,000 feet in thickness in the valley of the San Miguel. Several hundred feet of this thickness is represented in the walls of the canyon at the head of the Telluride fork of the river. As seen in the section exposed on Dolores Mountain to the east of the town of Rico, 300 feet of gray sandstone and impure limestones with heavy reddish conglomerate beds form the upper portion of the upper Carboniferous, underlying the Triassic beds. Then come 500 feet of very pure fossiliferous limestones, still of the upper Carboniferous. These beds at Rico, where traversed by veins, have been heavily replaced by sulphurets, argentiferous to greater or less extent, and bedded ore deposits, not unlike those at Leadville, have been formed. The Black Hawk and Iron mines in Silver Creek, at Rico, afford excellent opportunities for the study of the replaced limestone. The ore is found in vertical or nearly vertical veins, which cut all the beds. It seems a reasonable suggestion that the heavy series of Rico limestones has a similar development vertically beneath the town of Telluride at a depth somewhat exceeding 1,500 feet, and that these beds underlie the surrounding country for considerable distances. Further, that the greater number of the veins now worked in the volcanic flows and breccias penetrate these limestones, as well as still deeper rocks below. From a comparison with the Rico and other districts where veins penetrate soluble limestones, it seems possible that the Carboniferous limestones beneath the Telluride volcanics and tuffs may have been replaced by metallic sulphides to greater or less degree. There is, of course, no means of ascertaining without exploration the value in the precious metals of these deposits, if such deposits exist. It is not probable that these values would pay for the sinking of the deep

shafts necessary to reach them, yet it can not be denied that a possibility exists of the occurrence of workable ore in depth.[1]

As to the permanence in depth of metallic veins in general, no evidence has yet been brought forward to show that, as a rule, veins grow poor downward. It has been proved that the gold veins of California and of Australia are as rich in depth as in their upper portions. The Lake Superior copper deposits have been worked to over 4,000 feet with no tendency to impoverishment, and at Přzibram, in Bohemia, the best ore has been found below the 3,000-foot level. Although it has been many times stated, and is still believed by many mining men and students of ore deposits, that veins grow poorer with depth, such a conclusion does not seem warranted by experience.

A factor which is perhaps more important than any other with reference to the distribution of the productive veins, is their relation in position to the centers of igneous intrusion and eruption. The discussion of this point belongs under the head of the origin of the ore.

VALUE OF THE TELLURIDE MINING DISTRICT.

Few regions where mining is prosecuted present such various topographic conditions or are characterized by such successions of deeply carved gorges and precipitous mountains as the metalliferous portions of the San Juan. From the levels of 8,000 to 9,000 feet, at which the valleys are situated, the mountains rise abruptly to the height of 13,500 to 14,000 feet, the greater portion of their slopes being bare of vegetation. The influence of the multiplied fissuring on the topography has been already described and need not be enlarged upon here. The metalliferous portions of the rocks of the Telluride quadrangle are largely exposed to view, so that one familiar with the region may stand on a sightly peak and point out by name many of the well-known veins, conspicuous by the notches which they cause in the divides and by their long cracks and brilliant streaks down the sides of the mountains.

Such a region has both advantages and disadvantages, as compared with a less precipitous country. Transportation of supplies, timber, etc., from the valleys to the high mines is difficult and expensive. In the basins above 11,000 feet water is not plentiful, and it is usually found inexpedient to mill the ores at the elevation of the mines. Mills must be in the valleys, or at least much lower than the mines themselves. Consequently much transportation of crude ore from the mines must be resorted to. Wire-rope tramways working by gravity have been found most expedient for ore transportation. Railroad facilities are good, but freight rates on ore and concentrates shipped to smelters are necessarily high, on account of the mountainous char-

[1] As has been stated, certain layers of the Trias itself are calcareous to a considerable degree, and the presence of carbonates is shown in even the arenaceous layers, by effervescence with dilute hydrochloric acid.

VIEW EASTWARD FROM TELLURIDE, UP THE NORTH FORK OF THE SAN MIGUEL.

acter of the country traversed. The district is one of excessively heavy snows, which accumulate to great depth in the winter and do not melt away until late in the spring.

On the other hand, for mining the ore from any of the horizons now exposed in the region no sinking is necessary. All development is done by means of drifts, which either themselves open to the air or are connected with adits. The only shafts are those connecting the various levels in some of the large mines. No pumping is necessary, for, in addition to the fact that there are no shafts, the opportunity for the dissemination of water through the innumerable fissures is so great, that generally no considerable amount is encountered along a single fissured zone. The Revenue tunnel, which has cut the Virginius vein at an elevation of 10,800 feet, has proved a successful venture, notwithstanding its great length and the moderate tenor of the ore in the vein.

Summing up the result of observations in regard to the permanency of the veins, it seems likely that a portion of the veins continue in length for considerable distances and that others become broken and peter out into mere stringers, although further prospecting on the strike line beyond the cross zone of fissures along which the breaking up occurs would sometimes result in finding a continuation of the vein. More permanent veins will doubtless be discovered. It is one of the best-known laws of ore occurrences that veins are formed in groups, and that where one or two veins have been found productive others similar in character usually exist. It is not, however, possible to lay down rules for a region where such a complexity of fissuring exists, and it is only by the most careful examination of each individual vein, including the study of its relation to others in the vicinity and to the general systems of fissures, that any opinion as to its degree of economic importance may be arrived at.

ORIGIN OF THE ORE.

The attractive hypothesis which supposes ores to be derived from certain of the constituent minerals of the wall rocks of the veins appears at first sight very applicable as an explanation of the conditions at Telluride. But even the present preliminary investigation has, it is thought, afforded evidence that the minerals of the veins, and in part those of the impregnations, have come from sources extraneous to the immediately inclosing rock, and that the hypothesis of lateral secretion, whether in the limited sense advocated by Sandberger, or even in its more comprehensive manifestation advanced by Becker for the Comstock and Emmons for Leadville, does not seem a plausible explanation for the origin of the deposits now under consideration.

The conditions necessary for an ore deposit in a previously empty space are assumed to be wide differences in temperature, the presence

of circulating water, and the transportation in solution of chemical elements from one part of the earth's crust to another and final deposition as minerals from solution in the spaces where now the mineral combinations composing ore deposits are found. In order to effect this transfer the water must probably contain in solution alkaline sulphides and perhaps sulphydric acid, and must be supposed, in the majority of cases, to pass from hotter to cooler zones in its journey through rock masses, in order that the precipitation may be effected. Thus, where one seeks to find the source from which ore was derived in any particular region, he should look to those causes by which the above conditions were most probably produced.

The region now under discussion and the adjacent portions of the Silverton quadrangle to the east will furnish, it seems to me, when an exhaustive study of the area as a whole shall have been made, exceptionally good opportunity for speculations on the genesis of the ore, and such study will doubtless contribute materially to the knowledge of ore deposits in general, especially as regards their connection with eruptive rocks. What seems, as judged from the observations made, the most probable genesis will be outlined, but first it should be stated what objections to the hypothesis of lateral secretion appear to exist.

In the Northern Ohio drift and in the lower drift of the Silver Chief mines in Bear Creek, both at the horizon of the Trias sandstone, very small, black, angular fragments, not over one-fourth inch in longest diameter, are included in the vein. The only source from which these can have been derived appears to be one of the black-shale layers of the underlying Carboniferous. In the upper drift of the Silver Chief, at the horizon of the San Miguel conglomerate, small but very distinct fragments of the immediately underlying sandstone are included in the vein.

To argue that the occurrences above noted indicate that the ore-bearing solutions have brought up fragments greater or less distances in the open spaces of the fissures would be unjustifiable, considering the small number of observations, but it is difficult to account otherwise for their presence. In this connection it may be noted that Mr. G. F. Becker cites the presence of mica scales in the spring deposits at Sulphur Bank as evidence that material is brought up in suspension through vein channels from the underlying granite.[1]

Whether or not minute quantities of the precious metals are contained in the San Juan formation, or in the diorite or eruptive flows, as original constituents, is by no means certain. No valuable data concerning this matter can be obtained without a thorough assay of the minerals, especially the ferromagnesian silicates of the fresh rocks, which are unaffected by the ore deposition. Work involving such detail is impracticable in the present investigation, and even were it

[1] Quicksilver deposits of the Pacific Slope: Mon. U. S. Geol. Survey, Vol. XIII, p. 345.

done it is doubtful if the results would have great value. The diorite is very fresh in places, but the San Juan breccias and the volcanics are made up of material so decomposed that no specimen has yet been taken from which an analysis of any value might be made. A specimen of the San Juan formation which in the field appeared entirely barren of any ore was carefully assayed for me through the kindness of Mr. Mansfield, of the Smuggler-Union Company. It was found to contain traces of both gold and silver. This specimen, however, when examined under the microscope, showed sufficient impregnation to account for the contents in precious metals, and consequently it can not be inferred that the gold and silver were contained originally in the rock.

Although the ore of the district should not, I think, be derived from the inclosing rocks, yet it is not necessary to suppose its original source to be at great depth. Mr. T. E. Schwarz[1] refers the deposition of the ores of the Red Mountain district to heated water solutions, but does not give an opinion as to their source. It appears most reasonable to refer this to the great subterranean tract from which all the igneous rocks of this portion of the San Juan have come, whether they be the surface manifestations of andesites and rhyolites or the laccolithic masses now partly disclosed to view as diorite and diorite-porphyry. That the lavas of the region are Tertiary or post-Tertiary in age is well proved, and, as has been shown, it is likely that both the fissuring and the ore are subsequent in age to all the rocks. Springs, both hot and cold, heavily charged with minerals in solution, occur in various parts of the San Juan, bearing evidence that mineralizing agencies are still active.

Pošepný[2] is of the opinion that surface waters descend by capillarity through rock interstices over large areas, mounting again through open channels at a few points. He cites Daubrée's experiments in this regard. The effect of osmotic transmission of water in rocks has doubtless been underestimated in the consideration of vein phenomena. Nevertheless, in the Telluride district, it seems entirely possible that the fissures themselves, if they can be supposed to extend in depth to the horizon of the heated magma, may have assisted in the passage of surface waters to that depth. These surface waters, by whatever method they descended, must have become continually hotter as they penetrated to deeper regions. Their solvent power naturally increased with depth, and their contact with feldspathic rock of the andesitic composition must have been accompanied by their taking into solution the alkalies derived from these feldspars, probably in the form of sulphides. This action would have gone on while the waters were still at ordinary temperatures, since, as is well

[1] Notes on the ore occurrence of the Red Mountain district: Proc. Colorado Sci. Soc., Vol. III, 1888, p. 84.

[2] Op. cit., 1893, p. 222.

known, the alkalies are soluble in surface water. Thus becoming in depth heavily charged with alkaline sulphides, the heated waters would take up whatever of the bases and of silica they came in contact with, until, in reascending, cooling and relief of pressure allowed the redeposition of the elements as mineral combinations along the walls of the channels. Sulphydric and carbonic acids derived from the volcanic sources were doubtless also present in the ascending solutions. Thus the metals—gold, silver, lead, copper, iron, and zinc—and sulphur, lime, silica, and the alkalies, were probably all brought up from the subterranean region to be deposited as various combinations as the waters approached the surface. The gold, quartz, carbonates, and more rarely barite and fluorite, and sulphides of the metals, were deposited in the veins themselves, while the penetration of the wall rocks by the alkaline solutions containing sulphydric acid resulted in changes in the form of the iron of the ferromagnesian silicates of the rock and the deposition of potash in the form of silicate. The soda has largely disappeared. Carbonates, especially of lime, were deposited, probably from the action of the percolating solutions on the lime feldspars, with possible accretions of some carbonate from the vein. Silica was set free from the bisilicates and feldspars, and has mostly passed away from the wall rocks, being only exceptionally present as partial replacement of the feldspar phenocrysts and groundmass, as in the instance at the Terrible mine, already cited. The silver was carried scarcely at all into the walls; the gold to some slight extent; but as the pyrite of the veins has almost invariably been found richer than that in the walls, it must be inferred that usually gold was deposited in the veins. The impregnations of Silver Mountain, as already noted, appear to offer an exception to this generality.

The well-known connection of fluorine with volcanic action, and its occurrence as fluoride of calcium in granitic fumaroles, make it still more probable that the ore of this region was of deep origin. No fluorite has, so far as is known, been found in connection with the rocks now visible in the district, yet it has been found in greater or less amount in well-marked occurrences in four of the veins which lie wholly within the igneous rocks and near the probable center of eruption. Hydrofluoric acid, or other fluorine compounds in which silica forms a part, may, as suggested by Mr. Penrose for the Cripple Creek occurrence,[1] have accompanied the other elements in solution, and, uniting with the lime, have deposited in the veins the fluorine in the form of fluoride of calcium—fluorite. No purple color was observed in the fluorite of this region, as is the case at Cripple Creek. The deep color is there accounted for by the probable influence of organic matter. Here the mineral is almost colorless—a very light green.

[1] Geology and mining industries of the Cripple Creek district, Colorado, by Whitman Cross and R. A. F. Penrose, jr.: Sixteenth Ann. Rept. U. S. Geol. Survey, Part II, 1895, p. 157.

At Rico, in the ore of the Black Hawk mine, fluorite of a very deep purple color has been found, and as that ore is a replacement of limestone it is very likely that organic matter has induced the color. Fluorite is known to occur in the lava of Vesuvius, and the fluoride, cryolite, occurs in Greenland entirely within the periphery of a granite mass. Fluorite is by no means uncommon in veins, but its occurrence has been rarely noted accompanying deposits of the precious metals.

The sericite is not difficult to account for in the vein if it is admitted that the hot water which deposited the minerals contained in solution the alkaline sulphides. Potash mica may have resulted from this, the sulphur uniting with the bases and forming sulphides of stable character. A portion of the solutions penetrating the walls formed, in the zones of impregnation, sericite from the decomposition of the feldspars. That kaolin occurs as a part of the gangue has been proved in the case of the Tomboy vein, but it is regarded as subordinate in amount, and is probably confined to the upper zones, which have been strongly affected by atmospheric agencies. Its occurrence in the wall rocks I do not regard as proved by the present investigation. So great an authority as Tschermak denies that kaolin is a product of the decomposition of plagioclase, since the resulting hydrated aluminium silicate contains but a single molecule of water. The rarity, or even absence, of chlorite in the wall rocks is remarkable, since it is usually a prominent product of the hydrothermal decomposition of the bisilicates. Its absence may perhaps be accounted for on the hypothesis that the ore solutions were heavily charged with sulphydric acid, which has combined with the resultant ferric iron as sulphides. Silica is a very prominent constituent of the veins, as shown by microscopic examination. The analysis of Smuggler ore, quoted in the special description of the Smuggler vein, shows the predominance of silica in the ore of that vein.

In the recently published description of the Silver Cliff mining district, Mr. S. F. Emmons[1] has given valuable observations and analyses of deep-mine waters in which the alkalies play a prominent part and appreciable amounts of the metals were found in solution. The well-known experiments of Becker have proved that in solutions of sodic sulphides, with sodic hydrate sometimes added, arsenic, antimony, zinc, mercury, copper, and iron sulphides, and gold, are soluble, under conditions obtainable in the laboratory, and it is to be supposed that lead and silver could be acted on under different pressure and temperature.

The hypothesis urged by Mr. Penrose to account for the ore deposits at Cripple Creek, namely, that there has been a general segregation of ore material from all the surrounding rock, both granite and vol-

[1] The mines of Custer County, Colorado: Seventeenth Ann. Rept. U. S. Geol. Survey (1895–'96), Part II, 1896, p. 462.

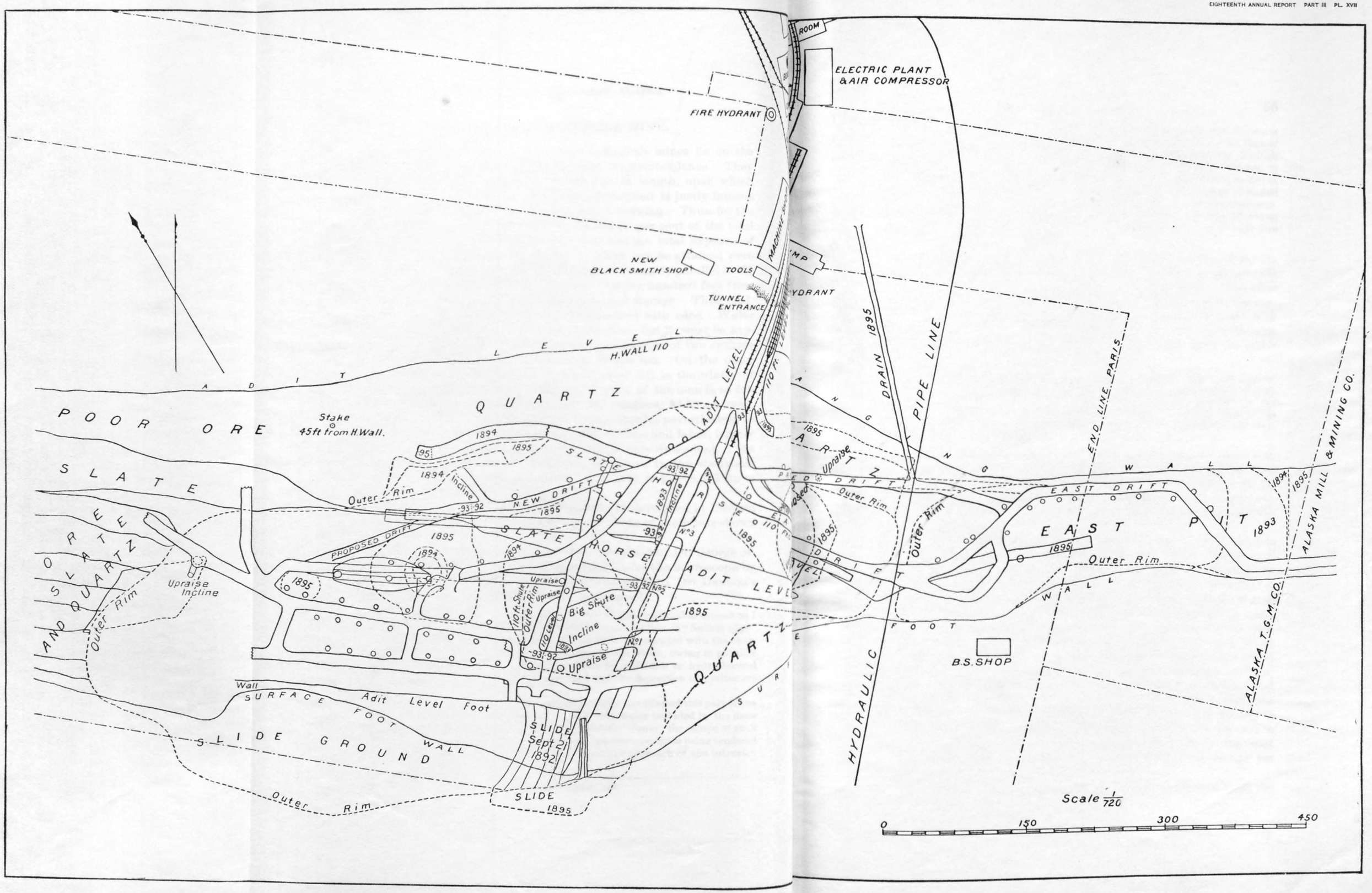
canic, and that the sources drawn upon probably extend to as great a depth as does the magma from which the igneous rocks were derived, is perhaps to some extent applicable to the Telluride region. However, the facts that direct connection has existed in comparatively recent time with volcanic vents, and that the ore deposits appear to have been not greatly subsequent in age to the latest of the eruptions, together with the more detailed evidence above stated, make it probable that the major part of the ore came from a deep source, probably the more basic phases of the magmas now partially represented by the igneous rocks seen at the surface to-day. That much more basic phases exist than those generally represented by the surface flow or the mass of the laccolithic rock is evidenced by the inclusions in the body of the diorite, seen well exposed near Ophir Loop, along the Rio Grande Southern Railroad, and to be described by Mr. Cross. The dike at Sawpit, with which the bedded ore deposits seem to be intimately connected, is of unusually basic character. All tests made upon wall rocks, and especially their separated mineral constituents, in connection with previous investigations of ore-bearing districts in order to determine their contents in the precious metals, have shown that the basic bisilicates contain the greatest amount of metallic contents, the quartz and feldspar being comparatively barren. Gold has been found as original constituent in granite, the most notable case being that of a granite from Sonora, Mexico, recently described by Mr. G. P. Merrill.[1] In a thin section kindly loaned me by this gentleman for examination I have seen native gold included in the quartz, feldspar, and biotite. Such occurrences must, however, be regarded as exceedingly rare, and rocks or magmas of more basic composition are to be looked to as the more likely sources of the metals.

The transporting agencies, heated waters charged with reagents, which were instrumental in bringing the ore to its present position, have already been alluded to. Doubt has been expressed by Lindgren,[2] from his study of the California quartz veins, and by Emmons,[3] from phenomena observed at Silver Cliff, concerning the hitherto generally accepted theories that relief of pressure and lowering of temperature are the principal factors determining the precipitation of ores in the veins, for those localities at least. Such suggestions are important to consider, but if causes other than those cited above led to the deposition of ore from solution in the Telluride veins, more detailed examinations than the present are necessary for their determination.

AGE OF THE ORE DEPOSITS.

The vein filling of the Telluride region took place (necessarily) later than the fissuring, and this has been shown to be later than any of the rocks, even the latest lavas now exposed in the region. As the

[1] Am. Jour. Sci., 4th series, Vol. I, April, 1896.
[2] Nevada City report (cited in footnote on p. 805), p. 262.
[3] Loc. cit., p. 465.



PLAN OF ALASKA-TREADWELL MINE

last eruptions occurred in late Tertiary time, and as it is probable that both the fissuring and the ore filling closely followed the close of the eruptions, a comparatively recent age must be assigned to the ore. No evidence of ore deposition at the present time is seen in this district, although heat phenomena in the form of hot springs are present in parts of the San Juan. Whether these springs deposit material from deep sources is not, so far as I know, determined. The absence of shafts below the present levels of the valleys in the Telluride quadrangle precludes any observation of even relatively deep phenomena. A more intimate connection between the ore and the volcanics probably exists in the Red Mountain district directly to the east, where the chimneys of ore are in some cases thought to be portions of true volcanic necks.

As the study of ore deposits has become more and more developed and as an increased number of occurrences have come under observation and their phenomena have been recorded, the old restrictions as to age of veins have been overthrown. That veins are characteristic of ancient rock formations, or of any special rock horizon, is no longer held. It is well known that sands and gravels scarcely consolidated, and of Pleistocene age, have been found to contain quartz veins, as well as the oldest rocks exposed in the visible section of the earth's crust. Just as it is now being realized that old volcanic rocks, formerly regarded as of a character distinct from that of recent lavas, should be correlated with these and referred to similar genetic conditions, so it is more and more apparent that it is rock associations, and chemical conditions connected with these associations, independent of age, which throw light upon the genesis of ore deposits.

SURFACE ALTERATION.

Considering the amount of decomposition to which the breccias appear to have been subjected, it is remarkable that so little alteration from surface atmospheric causes appears to have affected the ore. The other rocks of the district seem not to have suffered this alteration to so marked a degree, yet near veins the amount of decomposition of the walls increases. It appears most reasonable to suppose that atmospheric decomposition has played little part in the alteration of either the rocks or the ores, and that hydrothermal action has caused the greater part of the decomposition where it occurs. This is evident in the mines or parts of mine workings where the pyrite impregnations become heaviest. In the seventh level of the Gold King workings, at a spot more than 1,000 feet vertically underground, from which ore was being extracted, the rock is very soft, although not "picking ground," and all the ore taken out is characterized by decomposition, being stained with iron oxide and showing almost no metallic sulphides. This ore, as has been stated, is, in much the greatest proportion, the impregnated country rock. In the

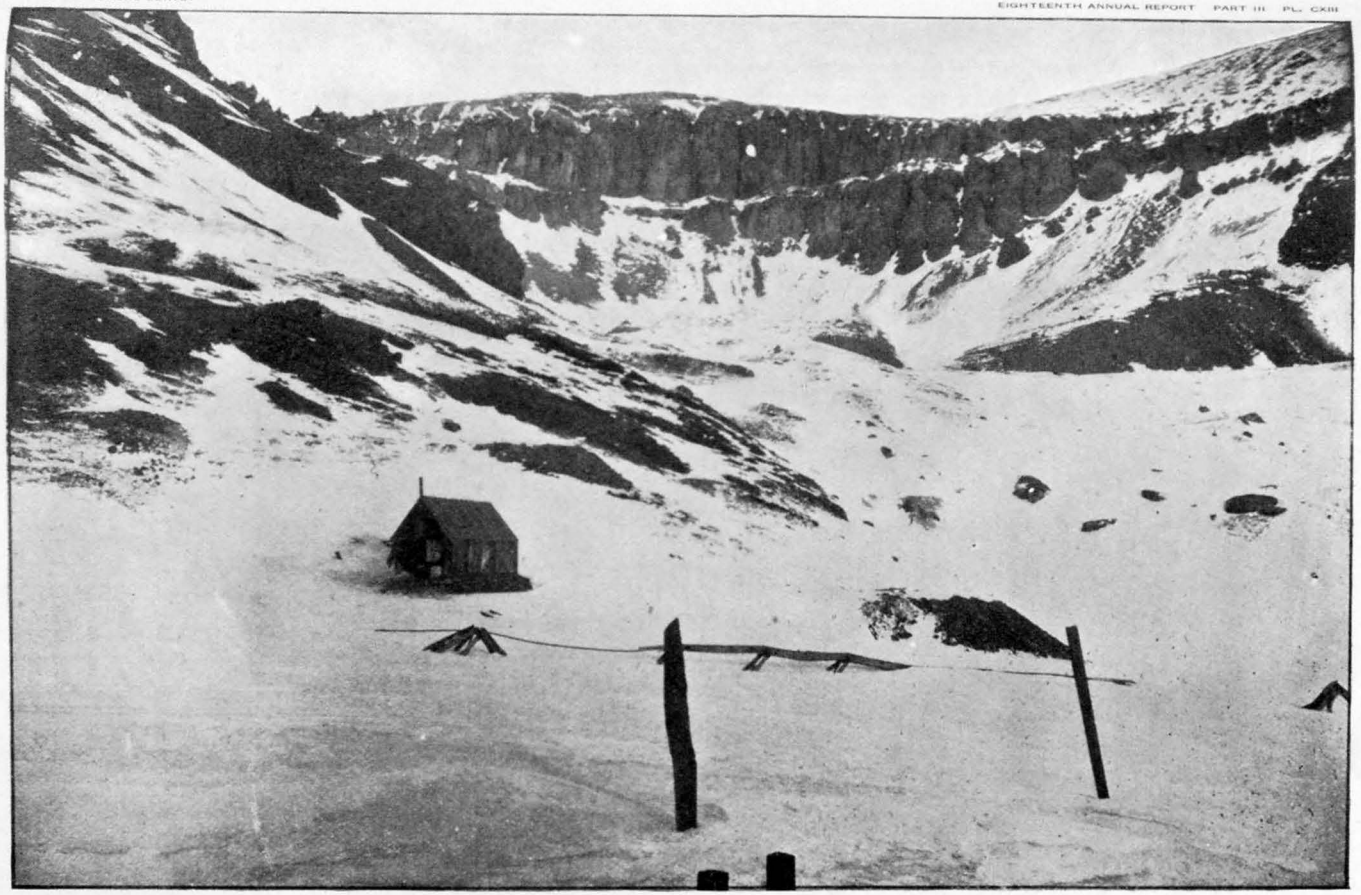
Seventy-six claim, at the south end of the Smuggler vein, the ore presents a similar appearance, and the ground is likewise soft and decomposed.

On the other hand, in the Sheridan, Mendota, and Humboldt claims, farther north on the Smuggler vein, at points still nearer the surface, where impregnation has been less developed, the ore and rock are little decomposed. These places are, moreover, far above the permanent water level. In the workings of the Silver Pick mine, which are at a high altitude, as may be seen from the map, surface decomposition has probably had greater effect than in any other part of the district. Even here the ore is very little affected by decomposition, although the presence of the soluble copper sulphate in the vein indicates considerable secondary action of atmospheric influences. The fact that this mineral remains also shows that water does not percolate to any extent through the mine workings. The presence of large stalactites of ice, sometimes tinged blue, and bitter to the taste, and of beautiful layers of frost crystals on the walls of the drifts, indicates that the waters do percolate more or less. Continual melting and refreezing of the water probably goes on, which accounts for the decomposed character of the walls. Impregnation of the diorite wall rocks is of less development in the Mount Wilson region than elsewhere, so that hydrothemal action has not produced the decomposition there observed.

WATER LEVEL.

The water level is hard to define in a region with such sharply accentuated variations of topography. Great amount of water is never encountered in tunnels driven into the mountain sides at any considerable height above the valleys where these lie in immediate proximity. The strongest flow was found in the lower adit of the Carribeau mine, on Yellow Mountain. The Revenue tunnel of the Virginius mine has in places encountered much water. In a region where such altitudes are attained, and where there are necessarily sharp variations of temperature, with vast accumulations of snow in winter, the rock, even of the highest peaks, must remain saturated, as it were, with water during a large part of the year. Alternations of melting and freezing, combined with the effect of the great amount of fissuring, must cause the breaking down of the rocks in fragments. Thus the immense talus heaps of the region result. On the other hand, from the same causes there is not a large amount of chemical atmospheric decomposition.

In Ophir Valley a considerable flow of water comes to the surface about three-fourths of a mile east of the town. This forms a pool 150 feet across, and the water has deposited an iron sinter, which has spread out to considerable distances over the valley. It is a feature not uncommon in the San Juan in general, although I know of no



CLIFFS AT THE HEAD OF MARSHALL BASIN.

other case in the Telluride quadrangle. The deposit consists of hydrated ferric oxide, being practically bog-iron ore, and undoubtedly owes its origin to the iron sulphides in the impregnation zones, which are strongly developed in the immediately surrounding rocks. Surface waters containing carbonic acid have dissolved the iron from the rock, transporting it as carbonate and sulphate, and by oxidation precipitating it in the form of limonite. As this deposit had no value in an economic way, it was not especially studied; but its occurrence is interesting, and when a detailed investigation of the San Juan region shall be made, the systematic study of these hysteromorphous deposits throughout the field may have some important results. It is worth while mentioning that in the La Plata Mountains such a deposit is found at the head of the East Mancos River. It has there been found to be auriferous, and I saw in it minute specks of iron pyrite, perhaps reduced from the sulphate form by the influence of decayed vegetation included in the layers.

In general it may be said that the ores of the Telluride veins are not much affected, as regards facility of extraction, by the situation of the ground-water level. It is, of course, well recognized that precious-metal ores, especially auriferous pyrite ores, may be of a free-milling character above the permanent water level, since the sulphide has suffered oxidation; the sulphur is gone, and roasting is not necessary in order to liberate the gold. Below the level where oxidation ceases the more expensive methods necessary for extraction of the gold frequently lead to abandonment of the mine. As has been shown, however, the Telluride ores are not likely to be largely thus affected in depth. The sulphide ores of the veins show little decomposition even at the surface, while in the majority of the veins with only gold values the gold is not combined with iron pyrite, but is free in the quartz.

THE ORE BEDS OF SAWPIT.

In the northwest corner of the Telluride quadrangle, along the northeast wall of the canyon of San Miguel River, the impure limy layer included in the horizon of the La Plata sandstone has been partially replaced by ore. The discovery of the ore bodies has been made within two years, and ore has been taken out to the amount of about $75,000, four-fifths of the value being in gold.

Although the deposits are to be referred to the same general origin as those of the veins farther east, they differ so essentially in structure and general characteristics as to merit a special description. The ore bodies, as they have been found up to the present time, occupy the upper portion of the 8-foot layer of limestone. Their dimensions are usually 100 to 200 feet in length, 25 feet in width, and 3 to 5 feet in height. They lie parallel to one another, the longest dimensions corresponding in orientation to east-west fissures which form one of the systems here prominently developed. Where ore has

been taken out cavities with well-marked walls, characterized by smooth, undulating surfaces, are left. According to report, open cavities are frequently found over the ore, and such cavities were seen in one or two instances. In the Lizzie G. mine specimens of the limestone partially replaced by ore were obtained. In the cavities a subordinate amount of the original sulphurets, principally iron pyrite and galena, now occur. The ore occurs mostly in the form of oxides and carbonates of the metals, whose lamellar structure shows rearrangement by water. These oxides and carbonates are often accompanied by a honeycomb of siliceous character, which undoubtedly represents the portion of the impure limestone residual after the dissolution of the limy constituents by water. Masses of the original iron pyrite and galena may be seen inclosed entirely by massive cerussite and limonite, and, as is usual in similar deposits, specimens may be taken showing galena changing directly to the carbonate. In general, a mixture of secondary ferric material having the appearance of a light-brown mud is the richest in gold, while the subordinate amount of gray massive cerussite carries the silver values.

From smelter returns kindly supplied by the owners of the principal properties here the average tenor of the ore appears to be as follows:

SiO_2	per cent	26
Fe	do	17
Pb	do	18
Au		$20
Ag		$5

The ore is shipped to Durango for smelting. So far as has been learned, gold is never visible in the ore, and none has been obtained by panning.

Along the east-west fissures may be seen, in a few cases, attrition breccias, which fill a space of 12 inches in width and consist of fragmental material as firmly consolidated as that of the sandstone beds which the fissures cut. Moreover, the filling of these fissures—a rather coarse, sandy, conglomeratic stuff—appears to maintain its character through horizontal beds of various nature. Physically the occurrences bear a resemblance to the sandstone dikes described by Cross, Diller, Pavlow, and others, but the filling material doubtless in this instance had a source near by and from above. Minute stringers of quartz containing disseminated sulphurets penetrate the bodies described, in sparse amount. A few veins of considerable width filled with calcite were seen toward the western end of the belt of mines. The widest of those seen is 18 inches. It is vertical, and has nearly a north-south direction. It is said that these veins are entirely barren of any value, and their appearance goes to confirm the statement. I am also told that veins carrying copper and iron pyrite have been found cutting the red beds beneath some of the deposits. They are narrow, not exceeding one-half inch in width.

In discussing the possible origin of these deposits attention should be called to a dike which, having a strike a little north of west and a width of about 3 feet, penetrates the rock. Although not actually found in contact with the ore lenses, it has a course which carries it directly in front of the cliff in which the tunnels to cut the ore are driven. The rock consists of labradorite, of limy character, with subordinate augite. These constituents are altered to secondary products, which obscure the determination of any other minerals. The rock is, however, a more than usually basic phase of the diorite rocks of the region. It is possibly an offshoot of the laccolithic mass directly to the east. In places contiguous to the ore deposits the dike shows much decomposition, due to hydrothermal action, which can have been produced in no other way than as an accompaniment of the infiltration of the ore. From the analogy to the similarly affected rocks of the eastern portion, it is possible that the ore came from a source not different from that of the dike itself.

As it has been considered most likely that the greater part of the ore of the entire district was derived from the more basic portions of the magmas now partially in evidence at the surface, I suggest that the Sawpit ore is a more direct product of metallic constituents contained in the basic minerals of a mass from which the dike in question is an offshoot. These may have been transported to the limestone by the agency of the soluble sulphides in hot waters, following more or less closely the path of the dike. It is, moreover, very probable that more dikes of this nature exist in the vicinity. The major part of the deposition of the ore has been by replacement of the limestone by sulphides, although there is some evidence that a portion of the deposition has taken place in preexisting dissolved cavities. The fact that exactly the same horizon of limestone is developed in the mineralized district about Telluride, and that examination of the limestone there, where cut by veins, failed to reveal the presence of any replacement by ore, suggests to the observer that somewhat different conditions of ore deposition existed at Sawpit. No distinctly ore-bearing fissures have been found penetrating the underlying rocks at Sawpit, but the veins above referred to, although barren of ore now, may have served in part as channels for the mineral solutions.[1] Since the Carboniferous limestones at Rico contain ore deposits of considerable importance, and since their mode of occurrence is generally

[1] An interesting case of the mineralizing influence produced by a dike has been observed in connection with the study of the ore deposits of the Rico quadrangle. On the south side of Bear Creek, 2 miles above its junction with the east branch of the Dolores River, a dike consisting of a rather basic phase of the diorite-porphyry cuts the Triassic sandstone. The dike is about 150 feet in width, and strikes N. 40° W. Where it cuts one of the impure limy layers of the Trias it has partially silicified the rock directly in contact with it. Plant remains contained in the limestone bed have been replaced by the copper sulphide, chalcocite. Calamites stems have also in part been converted into a mixture of calcite and a hydrocarbon compound which is probably a near approach to anthracite. In the last-named occurrence the calcite occupies small irregular areas completely inclosed by the anthracite. The metamorphism is directly due to the dike's influence, and does not extend more than 15 feet away from it laterally. The locality is a long distance from any other occurrence of igneous rock.

similar to that of the deposits at Sawpit, it is not impossible that such mineralizing influences as have operated at Sawpit may have caused similar deposits in the Carboniferous beds which may be fairly assumed to underlie the Trias.

The confirmation or nonconfirmation of this suggestion is, however, only to be had by actual exploration.

PLACERS.

As has been stated, much of the gold of the San Juan region is in a very finely divided state, and from all evidence it can not be doubted that large quantities of it have been deposited along the courses of the streams draining the region. The area over which it has been distributed is probably large, and, indeed, alluvial gold is known to occur along San Juan River and Grand River hundreds of miles below the sources of their tributaries. It is probable that a large part of this gold owes its origin to the veins in the San Juan Mountains. The high percentage of loss in values in some of the gold mines appears to indicate that more or less finely divided gold is carried down the streams in the form of tailings. The alluvial plain which fills the valley of the San Miguel from Pandora nearly to Vance Junction is a repository for much of the gold which comes from the sides of the mountains, yet this ground has been explored with considerable thoroughness without profitable results. In fact, placer mining has been conducted along the course of the San Miguel River for many miles beyond the limits of the Telluride quadrangle ever since the district was first explored. Although something over $100,000 has been taken out in alluvial gold, many times this sum has been spent in the operations.

These causes have been noted to account for the difficulties experienced in working the placers in general. With the exception of the Telluride Valley itself, the auriferous gravels are not found at the level of the present streams, but as local small areas at a greater or less distance above. There are three levels at which these gravels occur—one 30 feet, one 75 feet, and one about 200 feet above the present drainage. One of the causes of difficulty is the getting of water up to the banks. Another is the weight of the gravel, one cubic yard sometimes weighing 4,500 pounds. The third difficulty experienced is the great size of the bowlders which have to be handled. The gold itself is easily saved, and its yield is from 10 to 20 cents to the cubic yard, the amount lessening as the distance from the source increases.

In the Keystone Placer, which is located below and about 1,000 feet to the west of the flat alluvial plain of Telluride, the best example of the placers worked in this valley is seen. Here a series of water-laid gravels several hundred feet in thickness has been deposited in the bed of the north fork of the San Miguel, filling up the

previously formed canyon. A somewhat abrupt fall of about 400 feet divides the level plain to the east from the gorge to the west, in which is excavated the pit of the Keystone. The noticeable topography here has been studied in some detail by Dr. A. C. Spencer, of Mr. Cross's party, and it is his opinion that the remarkable accumulation of gravels and their well-defined limit are due to a glacial dam which has practically closed the lower end of the Telluride Valley. This dam was a result of an ice-flow which came down the south fork of the San Miguel River, its direction of motion being toward the north. Dr. Spencer is of the opinion that the ice itself caused the primary obstructions. The filling of this lake has formed the present level plain. In the Keystone workings an excavation about 150 feet in depth, 400 in width, and 100 in length has failed to disclose the underlying rock, although, as the map indicates, this mine is some 300 feet below the level of the plain. The rim-rock is seen to be the Gunnison shales, and beds of the gravel may be seen resting on projecting ledges of the shales. The gravel was found more productive as depth increased, and, as is usual in placer deposits, it was the lower portions of the coarser layers which were most productive.

The same difficulties of working which are stated above were experienced in the Keystone, with the exception that water was plentiful. The large size of the bowlders offered the greatest obstacle. No difficulty was encountered in saving the gold, which is round, though in very fine grains. About $50,000 has been produced from the mine, but never at a profit. As I found by panning, coarse gold does occur, and appears associated with a large amount of fine magnetite. Mr. W. Leslie, of Telluride, informs me that native copper in grains has been occasionally found in the workings. No garnets or other of the rarer minerals were found. The mine was worked by a hydraulic giant, for which water was, I am informed, supplied in abundance, and with sufficient head, by the river. The tail sluice was about 1,000 feet in length.

It is generally believed in the district that a considerable concentration of the residual gold of the valley has occurred in the deep portions of the fossil lake bed. Although this is not impossible, and would be not without precedent, yet any considerable amount of concentration of the metallic particles coming from various tributaries into a lake is unlikely. Favorable conditions for such concentration would, it is true, have been presented by the small extent and relatively considerable depth of the former Telluride Lake. It is difficult to say at what depth the bed rock lies; indeed, it is improbable that anything like a flat foundation of rock exists. The physiography of the surrounding canyons renders it likely that the rock surface grades downward from Pandora toward the west at a fairly steep angle. It does not, on the whole, seem probable that placer mining, according to the methods now generally employed, will ever attain to much importance in the Telluride region.

DETAILED DESCRIPTIONS OF MINES.

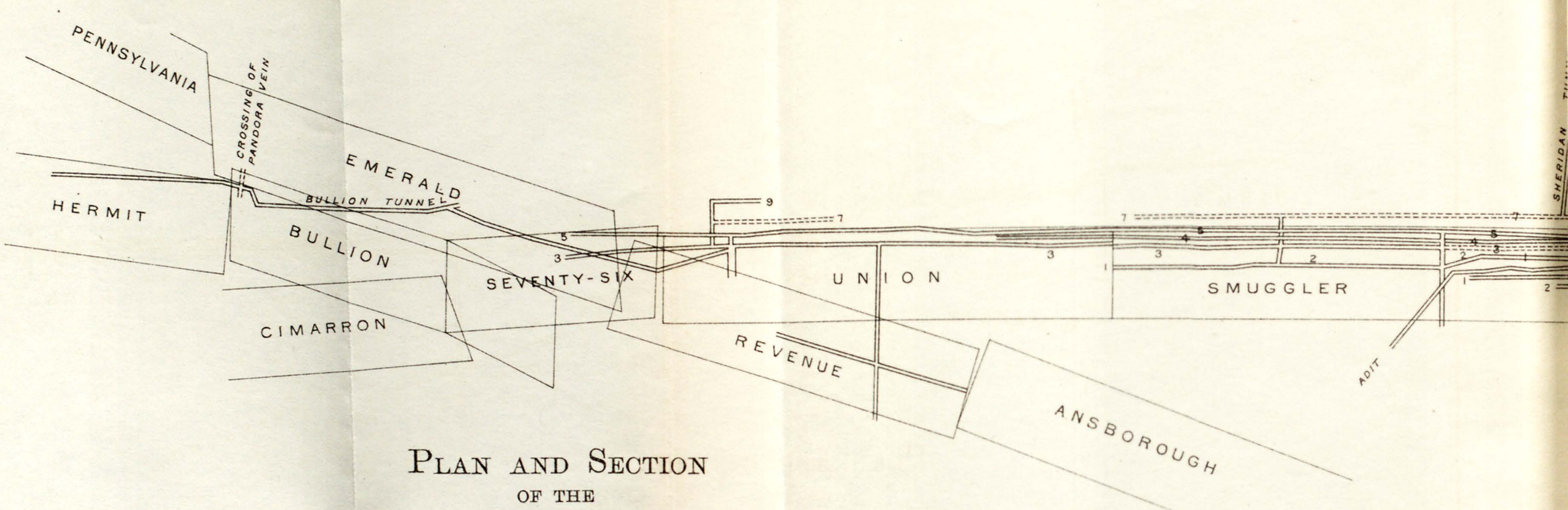
The mines which have been selected for special description represent, it is thought, the various types of deposits occurring in the district. They form only a small per cent of the number of productive mines, and many others might be described. In view of the limited scope of this report, however, it has not been deemed advisable to insert the description of a long list of individual properties.

THE SMUGGLER VEIN.

The Smuggler vein has been referred to many times in the foregoing text, and several of the interesting features which it possesses have been described. Its unusually continuous and productive character, however, gives it a claim to more extended notice in the present description of the region. It has produced ore along a distance represented by six mining claims of 1,500 feet each, namely (in order from south to north), the Seventy-six, Union, Smuggler, Sheridan, Mendota, Humboldt (subdivided into the K. C. Humboldt and the Humboldt). Besides these it has produced ore from two other claims, the Cimarron at the south end and the Sailor's Fortune at the north end. The total length thus represented by productive mining is about 2 miles. Workings have been made on it, especially in the northern continuation, for much longer distances. Mr. J. A. Porter,[1] in the paper already referred to, states that the total distance exposed by mining work is more than 4 miles. The section accompanying shows by the actual workings the amount of profitable development. It also exhibits the relation which the developed portion of the vein bears to the topography. Its surface outcrop cuts the divide between Marshall and Virginius basins at 13,200 feet. Mr. Porter says: "The vein continues south * * * across the Savage Fork of the San Miguel, and is plainly visible at the outcrop for more than a mile farther in that direction. On the north side of the divide the vein * * * can be traced at intervals on the surface for more than 2 miles."

The workings on the vein are now conducted by four different organizations. Of these the Smuggler-Union Company operates that portion of the vein included in the Seventy-six, Union, Smuggler, Sheridan, and Mendota claims—by far the larger portion of its developed extent. These claims were until within the last four years under different ownerships, but the entire product is now handled over the wire-rope bucket trams which extend from the Mendota No. 3 level, at 12,300 feet, down to the terminus of the branch of the Rio Grande Southern Railroad at 9,000 feet, in the valley below, the total length of the tramway being about 2 miles. From the Humboldt mine ore has, as yet, been gotten down only by means of animal transportation,

[1] The Smuggler-Union mines: Trans. Am. Inst. Min. Eng., Vol. XXVI, 1897, pp. 449-459.

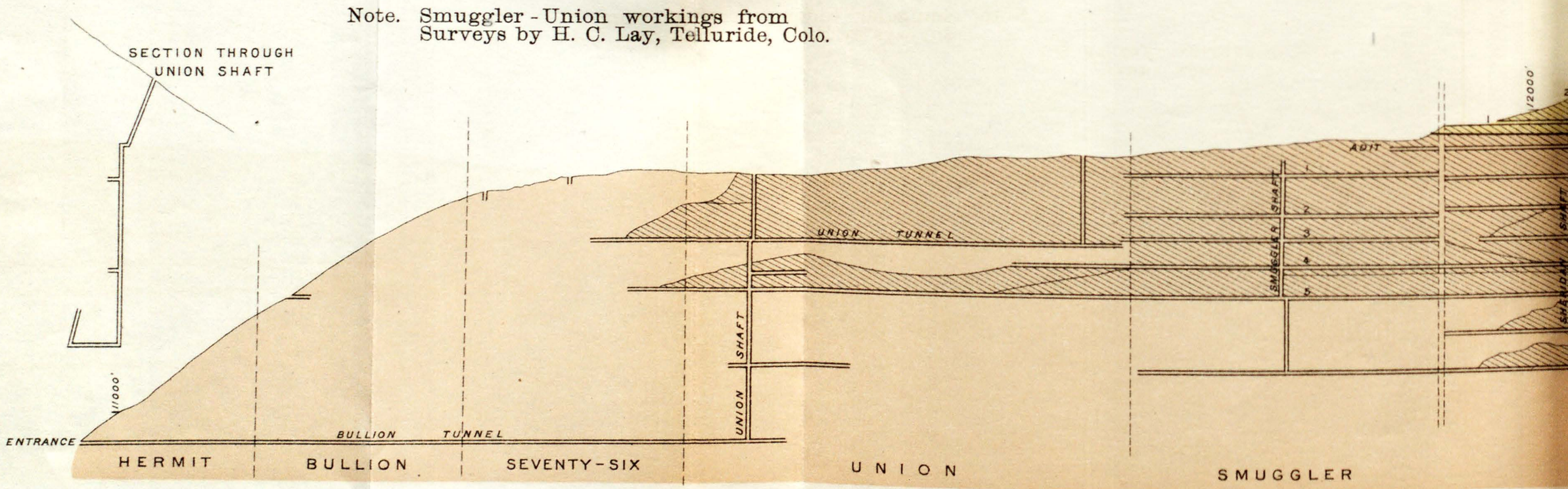


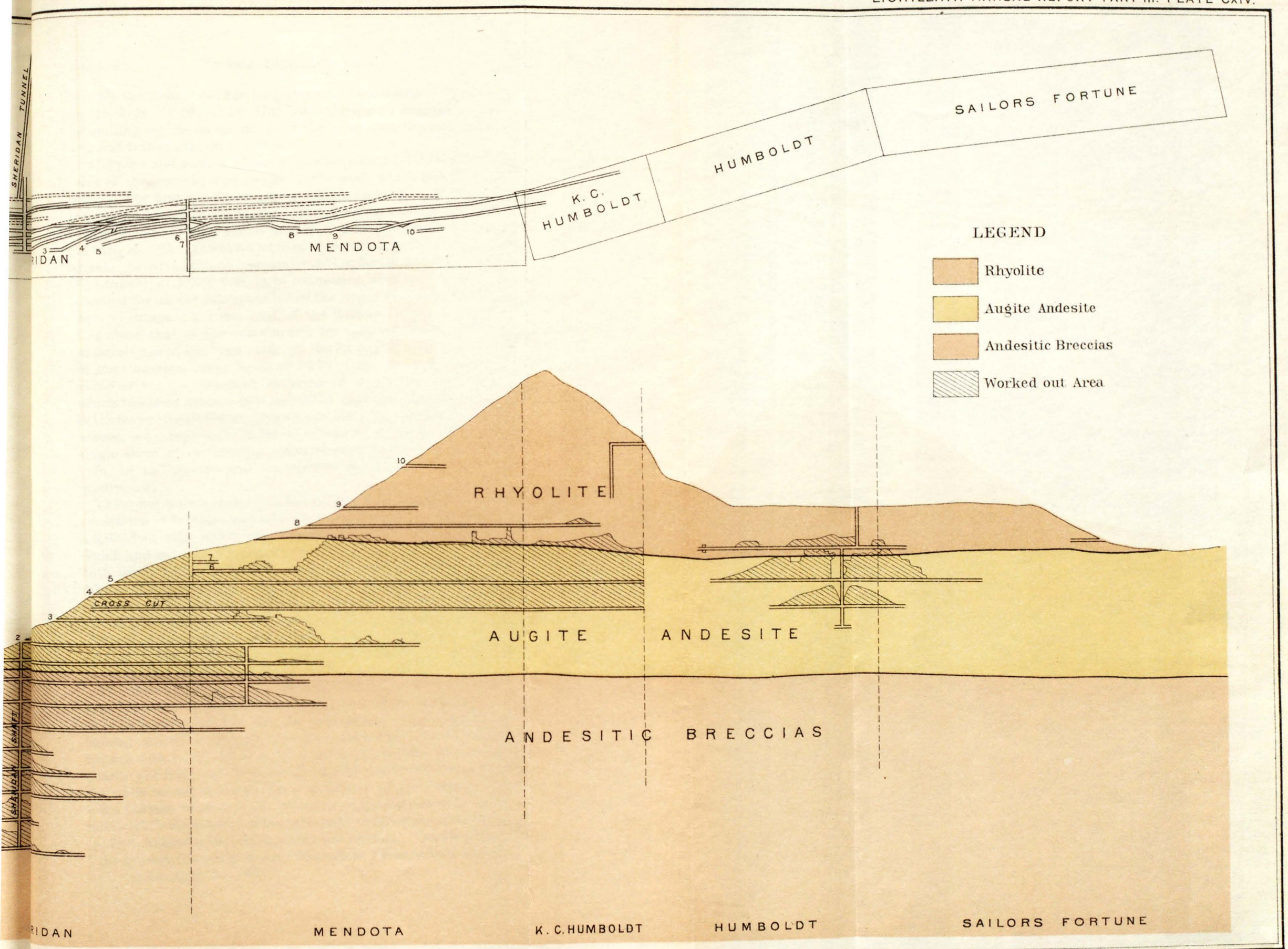
Plan and Section
of the
WORKINGS ON THE SMUGGLER VEIN
INCLUDING THE
SMUGGLER-UNION, K. C. HUMBOLDT AND HUMBOLDT MINES
TELLURIDE, COLO.

Scale

400 300 200 100 0 400 800 1200 FEET

Note. Smuggler-Union workings from Surveys by H. C. Lay, Telluride, Colo.





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so only the richest ore has been treated. According to the statement of Mr. J. B. Farish, of the Humboldt Company, many thousand tons of milling ore lie on the dump of the mine, awaiting adequate milling and transportation facilities.

The plan and section of the vein shown in Pl. CXIV give a better idea of the amount and nature of the work which has been already done. The first developments on this, as on most of the lodes of the region, were high in the basins, where the vein most prominently outcropped. It has been stated that ore was shipped from the Smuggler as early as 1875. It was found to be economical, as the product became greater, to drive adits at comparatively low levels, and the present Bullion tunnel, at 10,900 feet, is, in connection with the Union shaft, the channel for all ore taken out below the upper Sheridan and the Mendota workings. Yet the level of the Bullion tunnel is nearly 2,000 feet above that of the mill site and the railroad below. No attempt at development has been made on the Smuggler vein below the level of the Cimarron lower level, at 10,700 feet. No diminution of the value of the ore has been experienced in the deepest exploitation which has been made. It is estimated that the present development in the Smuggler-Union workings alone, including levels, stopes, shafts, winzes, etc., represents a linear extent of more than 22 miles. A single sheet of ore-bearing material such as that of the Smuggler vein, in its present and prospective development, is no common occurrence.

The country rock of the vein has been sufficiently described, and the succession of breccias and volcanic flows is shown on the section. In a 3,000-foot adit, which runs east-northeast from the head of Royal Gulch and cuts the Smuggler vein at the Sheridan shaft on the seventh level, a dike of andesite was seen cutting the breccias. The dike is of blackish color, and fine grained in appearance. Under the microscope the feldspars are too decomposed for determination, but the rock is seen to be of the andesitic type. Its direction is 20° east of north, with steep dip to the west. It is accompanied, in part, by a vein of calcite about 12 inches in width. The width of the dike is considerable, but was not determinable in the mine.

The characteristics of the fissured zone along which the Smuggler vein has been formed have been pretty thoroughly described. It need only be mentioned here that the lode possesses all gradations, from banded structure through linked structure, and that of predominating ore with horse material, to solid vein material, with a minimum quantity of fragments of country. Evidences of relative motion along the walls is not lacking. Such striations as were observed on the walls indicate motion in the direction of the dip—that is, nearly vertical—while the relation of the poor zones to flat dips, as shown in fig. 67 (p. 780), indicates that the faulting was normal. Quoting Mr. Porter, "the average thickness of the vein is about 5 feet, seldom narrowing to

less than 2 feet and rarely widening to as much as 10. * * * In the Mendota claim a mass of andesite several hundred feet in length and 30 or 40 feet in thickness divides the vein; or as usually expressed, the lode forks and comes together again in several hundred feet." This occurrence is an extreme case of the inclusion of a mass of country rock within the fissured zone. Where the Revenue vein crosses the Smuggler, in the middle of the Seventy-six claim, a slight dislocation of the Smuggler occurs, the north part being thrown to the east. As exposures showing the contact of the two veins were not seen, it is uncertain whether the occurrence is a faulting of the ore or merely one of the fissures. The marked displacement of the Smuggler by the Pandora vein has already been discussed in the general description. A considerable amount of work has been done on the Ansborough vein, which has been found remunerative, and it is so decomposed as to be easily operated.[1] No remunerative values have, so far as has been ascertained, been found in the Pandora vein.

The main average strike of the Smuggler vein is N. 25° W., with an average dip of 75° to the west. It keeps its course with remarkable directness. This exact course has not been observed elsewhere in the region, although northwesterly fissuring is characteristic of the immediate neighborhood. Doubtless other fissure zones are parallel to the Smuggler, but they are not conspicuously ore-bearing. The Ansborough or Revenue vein strikes 2° east of north, and dips 78° W.

The structure of the Smuggler vein is that characteristic of filled fissures in general. Comb structure, with open vugs and interlocking quartz crystals, is exceedingly common. Breasts of the ore exhibit successions of such bands across the entire face. The decreased amount of ore in the fissured zones where seen in the upper rhyolite has been referred to, as has the otherwise remarkably even distribution of ore in the vein.

Quartz largely predominates as a gangue mineral. Besides this, calcite, siderite, barite, and rhodochrosite occur. Mr. Porter says: "When this mineral [rhodochrosite] is present in sufficient quantity to color the vein, that portion is seldom rich in the precious metals." In the investigation for this report pyrargyrite and tetrahedrite have been determined, the last in very small quantity. Mr. Porter mentions proustite and polybasite, and the probable occurrence of all the arsenical silver minerals.

From specimens showing orthorhombic crystals it seems probable that stephanite occurs. Silver rarely occurs native; it is usually combined as sulpharsenides and with galena. Besides galena, a small amount of copper pyrite occurs. Zinc blende is common, while iron pyrite is the most abundant sulphuret. Native gold is occasionally

[1] Recent information comes that a drift has been started on the surface outcrop of the Ansborough vein (on the Pennsylvania claim) at a point 660 feet below the level of the Bullion tunnel.

encountered. As before stated, the gold values seem especially associated with the iron pyrite of the vein. Impregnation of the walls with iron pyrite is a universal occurrence in connection with this vein. The clayey material, "talc," has been determined in part as the white mica, sericite. The following analysis of the ore as taken from the mine is quoted from Mr. Porter's paper:

Assay and analysis of sample from the Smuggler vein.

(Battery sample.)

	Oz. per ton.
Au	0.53
Ag	13.10

	Per cent.	Probably combined as—	Per cent.
Insoluble	80.26		
Al_2O_3 in insol	8.52		
SiO_2	70.42	SiO_3	70.42
Total Fe	5.20	FeS_2	5.57
Fe as Fe_2O_3	2.55	Fe_2O_3	3.64
Mn	0.81	$MnCO_3$	1.69
Total Al_2O_3	9.94	Al_2O_3	9.94
CaO	1.98	$CaCO_3$	3.54
Mg	0.28	$MgCO_3$	0.98
Zn	1.02	ZnS	1.52
Pb	0.66	PbS	0.76
Cu	0.06	$Cu_2SFe_2S_3$	0.17
S	3.77		99.23

Alkalies undetermined.

The average value of the ore throughout the vein is "slightly over one-half ounce gold and 12 ounces silver per ton." The richest streak lies on the foot wall, called "shipping ore;" this is not milled, but hand sorted and shipped for smelting. The concentrates average 2½ ounces in gold and 51 ounces in silver. The remarkable change in values from north to south has been commented on. From Mr. Porter's description,[1] notes concerning the handling and milling of the ore have been extracted:

From the chutes (in the mine) ore is hauled by mules to the shaft, in cars containing about 1 ton each. From the collar of the shaft, which starts on the third level (Union) the distance down to the tunnel is 700 feet, and all ore is lowered to that level.

From the bottom of the shaft a train of 12 cars is hauled to the sorting house at the head of the tramway. A very rough hand-sorting here takes place while the ore is being filled out of the chutes over aprons into cars which load into tram

[1] Since the writing of the above a second tramway for the high levels has been brought into use for the handling of some of the ore.

bins. About 10 to 15 per cent of high-grade ore is thus selected for shipping and goes over the tram direct to the railroad, and then to the smelter.

From the sorting house the lower-grade ore is transported over a Bleichert tramway, at a cost of 25 cents per ton, to the mill. The tramway is 1 mile in length. The buckets used are 38 in number and contain 500 pounds each. The monthly capacity of the mill is 5,000 tons, and this amount the tramway delivers in ten hours daily. The cost of the wire tramway was $30,000. Upon arrival at the mill, the ore is broken to a suitable size through a Blake crusher, and is thence carried by an automatic feeder to stamps which crush to 14-mesh. This entire product is passed over Triumph and Frue tables, producing about 15 per cent of concentrates, which contain an excess of silica. No further method of concentration is used, except that a rough sizing of the tailings from the vanners is made; the coarser part which will not pass through a 40-mesh screen being reground in a Huntington mill and then re-treated on a second series of vanners. The stamps are 800 pounds in weight, and drop 8 inches with 95 drops to the minute. The 50 stamps crush 150 tons daily.

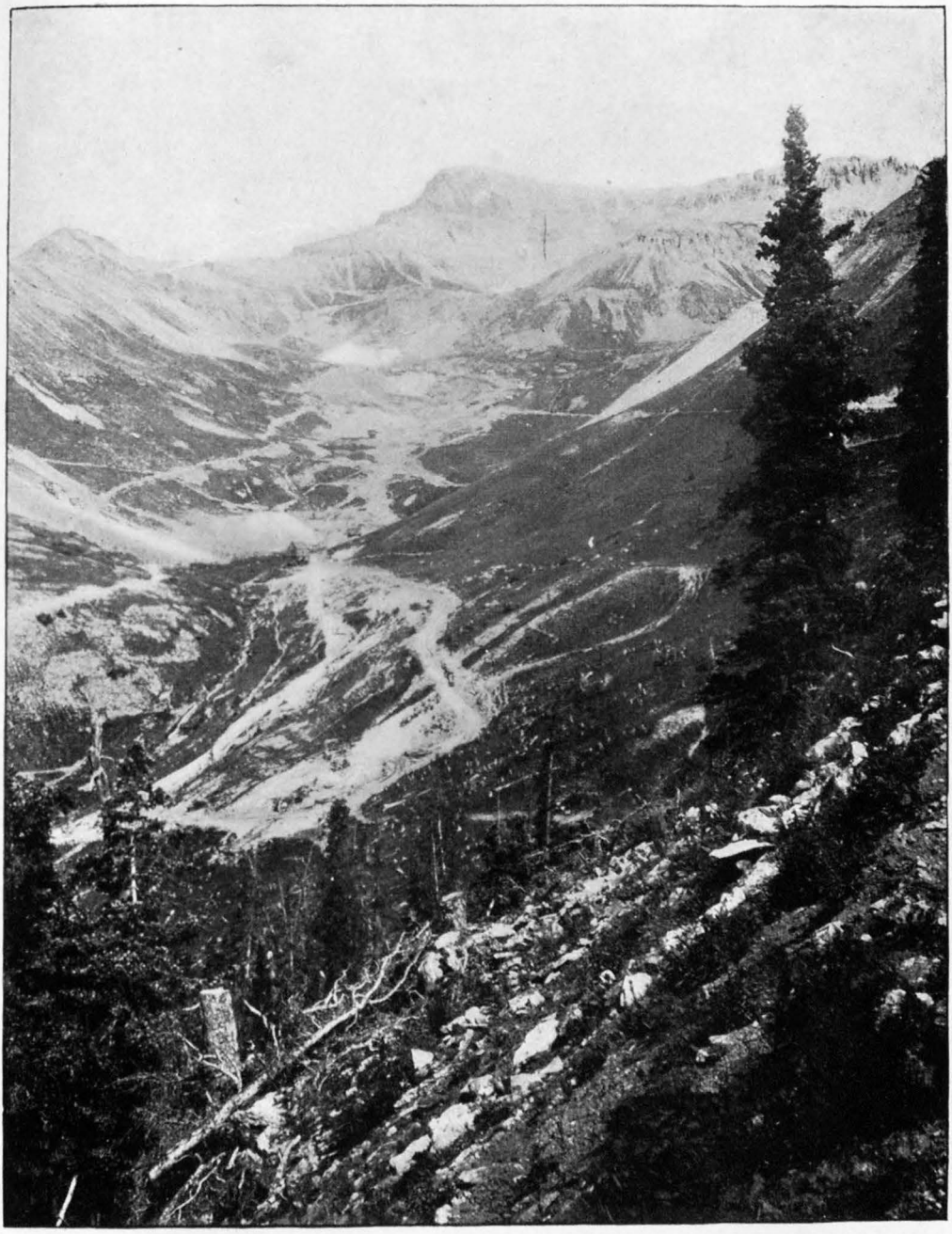
It has been found necessary to resort to very fine crushing in order to free the concentrates, on account of the intimate dissemination of the sulphurets and gangue. The microscopical examination of much of the rich ore exhibits crystals of iron pyrite 0.012^{mm} in diameter. There is, of course, much that is larger, up to 4^{mm} in diameter. But there is, compared with most ores which have been examined in this way, an unusual amount of the finely divided pyrite.

It is possible that this extremely fine dissemination of the sulphurets may in a measure account for the large amount of loss of values which, according to Mr. Porter, is sustained in the treatment of the ores, and which has proved the most serious difficulty in the winning of the precious metals from this mine.

The total product of the Smuggler vein is estimated by Mr. N. T. Mansfield, manager of the Smuggler-Union mines, to have been $12,000,000.

THE VIRGINIUS MINE.

This property, situated in Virginius Basin, in the drainage of Canyon Creek, was one of the first developed in the district. In 1881, according to the United States Mint reports, its product had been $75,000. Formerly the vein was worked at the upper level at 12,500 feet in Virginius Basin, and all ore was taken out through this opening. It is only within three years that the Revenue adit tunnel has been completed, starting at an elevation of 10,800 feet in the bed of Canyon Creek. This tunnel runs in the direction indicated on the map for a distance of 7,500 feet, cutting the Virginius vein at a depth of over 2,000 feet vertically below the surface. The Revenue tunnel is situated approximately 1,000 feet above the lower limit of the San Juan formation. The vein has been worked a longitudinal distance of about 3,000 feet, and at the point where the lowest drift lies under the divide between the Virginius and Marshall basins the vertical section of rock above the level, or, in other words, the depth gained, approaches closely to 2,500 feet. The vein has been worked



MARSHALL BASIN; VIEW LOOKING NORTHWEST.

through a distance vertically of about 2,000 feet, although to a much less extent than the Smuggler vein. No diminution in the values of the ore or the width of the vein have been encountered in depth. The ore extracted during the season of 1896 was entirely from the lower level.

The country rock of the Virginius lower workings, which were the only ones accessible, is the San Juan formation. The upper part of the vein is in the augite-andesite, and although it is stated that the vein does not outcrop at the surface, there is nothing in its appearance to indicate that it differs in age from those in the Marshall and Savage basins. It is possible that the fissured zone is so poorly developed in the upper rhyolite that its outcrop is not apparent. As the surface was covered with deep snow at the time of my visit, I am unable to speak with certainty from observation. It seems, however, hardly likely that the vein was formed and the ore injected earlier than the latest flow of volcanic rock. The indication of the vein's outcrop on the map must be regarded as hypothetical.[1]

The average strike of the vein is N. 46° W.; the average dip, 60° SW. It is not nearly so direct in its course as the Smuggler, and has not the recurrence of parallelism on different fissure systems, as has the Tomboy. The fissured zone averages 4 feet in width, of which 12 inches on an average is "pay streak," usually following the foot wall. The notable relation of the rich and barren places to the local changes in degree of dip has been described. The unusually long section afforded by the Revenue tunnel presents an excellent exposure of the fissuring in this region, and alternations of the differently spaced zones are graphically displayed. Two veins worth noting are cut by the tunnel; one, at 1,800 feet from the mouth, striking N. 24° W. and dipping 80° NE.; the second, at 3,600 feet from the mouth, with strike N. 68° W. and dip 55° NE. The last of these is said to show at its surface outcrop a considerable width of solid quartz, carrying free gold. In the north drift, adit level, on the main Virginius vein, a cross vein, striking about 15° east of north, faults the vein, throwing the north portion 20 feet to the west.

The minerals occurring in the vein are quartz and calcite, zinc blende and iron pyrite, while the silver values are in argentiferous tetrahedrite and galena. It is probable that other minerals occur in less quantity, but they must be determined by more detailed examination of the mine. The value of the ore is said to average about $14 in silver, with varying amounts of gold.

[1] A dike consisting of dark-colored, rather finely porphyritic andesite, about 30 feet in width, appears on the west side of the Virginius vein, at a point 1,600 feet in the south drift. It follows the course of the vein to a point 200 feet in the north drift. Its contact with the inclosing rock is not well defined, but it is of markedly different appearance from the San Juan breccia, and contains no fragments of any kind. Under the microscope this rock is rather indeterminable, on account of decomposition, but may be seen to contain feldspar phenocrysts, with a much chloritized groundmass in which there is a large quantity of magnetite. The dike much resembles that seen in the Sheridan tunnel, before described.

It may, however, perhaps with greater probability, be supposed that the water included in the adjacent sedimentary deposits became vaporized by the heat of the intrusive mass, and found its way to the surface, in the form of steam, through the substance of that mass. It will be noticed that Mr. Adams finds evidence, in the microscopical character of the rock, of much crushing and fracture, so that in any case it must have afforded a convenient channel for the passage of heated waters or steam; and this appears to have been one of the more important circumstances leading to its mineralization. * * * This deposit therefore affords an interesting example of the manner in which intrusive masses may directly give rise to ordinary metalliferous veins.

As I understand him, Dr. Dawson supposes the formation of the ore body to have followed immediately upon the intrusion of the granitic mass, without any interval of time, and either just before or just after its solidification. Professor Adams, on the other hand, seems to consider the ore as consisting of a mass of fractured rock, filled with veinlets in the ordinary manner, and finds in the slides no indication of a genetic connection. He concludes his remarks upon the slides as follows:

It may therefore be stated that the ore of the Treadwell mine is a granite, probably belonging to the class of the hornblende granites, much crushed, altered, and impregnated with secondary quartz, calcite, and pyrite; that the "kernels" are portions of the rock in which alteration is less complete than in the mass of the granite, and that at least a considerable portion of the gold present in the ore is contained in the pyrite as free gold.

It has already been shown in the portion of this report dealing with the rocks that this rock is to be regarded as a sodium-syenite or, more logically, as an albite-diorite. It will be shown below that the ore deposition occurred much later than the intrusion of this syenite, two other intrusive masses having followed it before the deposition of the ore was complete.

The main mass of the country at this locality and the oldest rock is a carbonaceous slate of very uniform texture. While it is unquestionably sedimentary in origin, it does not display any variations in lithological features, such as calcareous or sandy facies, sufficient to mark the original lines of bedding, and it was found impracticable to discover whether or no the bedding and principal cleavage coincide. At Juneau Island, close by, slaty cleavage and bedding do not coincide. At many points in the mine the slate passes into what I term a schist, being affected with more than one pronounced cleavage of less regularity than that of true slate. The strike of the slate is N. 50° W., true, being nearly the same as that of Gastineau Channel and coinciding with one of the two fissure systems which affect nearly the whole of the Alexander Archipelago. The cleavage dips steeply to the southeast. The age of the slate was thought by Dr. Dawson to be very probably Triassic, from its analogy with rocks on the coast of British Columbia. There is no direct evidence as to age yet available.

After the sediments had been reduced to the condition of slate, the

The ore is milled and concentrated by a mill of 60 stamps, 5 Huntingtons, and 30 Woodbury vanners, with a capacity of 200 tons a day; 170 tons is the average daily run. The concentrates are shipped for smelting.

All the mine buildings are lighted by electricity, and a trolley car has been run in the tunnel by the same power. The long tunnel is in part supplied with incandescent lights. A wagon road connects the workings of the mine with the town of Ouray, and as far as the Revenue tunnel it is kept open during the winter, notwithstanding the excessive snow.

It is impossible to get an estimate of the product of this mine, owing to the somewhat desultory manner in which it has been worked. As before stated, $4,000,000 is the estimated product for the mines of Virginius Basin. The gold product of the Virginius has been inconsiderable.

THE TOMBOY MINE.

It is only within the past four years that the property known as the Tomboy has made any considerable product; especially in the last two years the output of the mine has surprisingly increased. The workings now on the vein comprise the length of two claims, very nearly, namely, the Belmont and the Tomboy, and several more claims have been located on the vein in its southern extension. The history of this mine is somewhat remarkable, considering its present large output.

The original location on the vein was the Belmont claim; made in 1880, and in 1886 the Tomboy claim, to the south of the Belmont, was located. Since the original discovery of the lode, and up to the year 1892, no considerable product was obtained; in fact, the vein was generally regarded as of little value and interests in the claim were sold and resold at very low figures. The Tomboy Gold-Mining Company, which bought the mine in 1894, had it profitably working by April, 1895. In that year the product was nearly $600,000, and in 1896 the product was nearly $800,000. Recently the mine has again changed hands, and it is stated that the present monthly output averages about $90,000.

The workings are shown in the accompanying plan, fig. 72. The main adit is at 12,130 feet elevation, very near the head of Savage Basin. The greater portion of the work has been done on one level, consisting of a drift over 3,000 feet in length, with stopes extending up to a height of 200 feet above the drift. As indicated on the map, a second adit, 381 feet vertically below, the upper one is being run to cut the vein. At the time of my visit this was 1,128 feet in length. Its starting point is directly above the site of the Tomboy mill. All the portions of the vein worked during 1896 were in the upper augite-andesite, although the contact of this with the top of the San

Juan breccias lies not far below. The lower adit is certainly in the breccias, but the exact level at which the contact occurs it is impossible at present to state. A specimen collected in a winze sunk 100 feet from the main level, although it contains fragments, is of the normal color characteristic of the augite-andesite, and is altogether so decomposed that its microscopic determination is impossible. It was stated that a dike accompanies the Tomboy vein for a part of its length, as now developed. Although I can not say that the observations in the mine confirmed this statement, nor that the microscopic examination revealed any rock differing from that of the country in general, yet in view of the limited examination which was made, it can not be denied that a dike may exist.

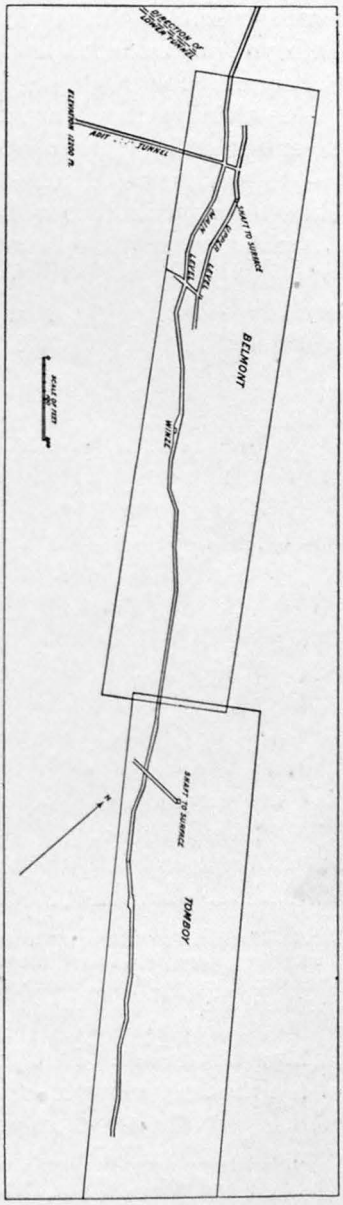


FIG. 72.—Plan of the Tomboy mine.

The peculiarities of the Tomboy vein, considered with reference to the fissure systems which it follows, have been described and illustrated. So constantly does the vein shift from one to another set of fissures that it is impossible to get, at any one point in the workings, a compass reading which represents its average course. This is, however, as may be measured from the surveys plotted on the map, N. 41° W., while the dip averages 77° to the southwest. The limits of the narrowly cleaved zones, which have been filled by ore, are fairly well defined and it is only occasionally that stringers accompany the main lode, separated by any considerable amount of wall rock. Such stringers have been found, however, at as great a distance as 10 feet from the main vein. The width of the main lode is variable, but is generally from 4 to 7 feet. It sometimes attains the width of 12 feet, and in one place pinches to less than 1 foot. This vein presents more the character of a solid filling between two walls than most of those seen in the district. The linked-vein type is very well shown in some places, but is subordinate. Angular fragments

of the country rock are frequent, and are especially well shown in the faces of the stopes and drifts, on account of the whiteness of the surrounding quartz. Fig. 73 shows such a fragment included in the quartz. As before stated, the angular character of these fragments is one of the strongest pieces of evidence that the ore is the filling of open spaces, unaccompanied by molecular replacement of the country rock.

The vein minerals are remarkably few in number and, with the exception of the quartz, do not appear to bear much relation to the values, which are almost entirely in gold. The quartz is by far the largest constituent, is white, and may be described as coarsely saccharoidal, with the spheroidal arrangement of crystals noted above. It is remarkable that much of the quartz, which is commonly referred to as "bony" and is ordinarily barren of values, is in the Tomboy vein rich in gold, and often contains free gold visible to the unaided eye. Accompanying the quartz there is much blackish, soft material, which has been determined as peroxide of manganese. Although no manganese carbonate has been found in this vein, its general occurrence in neighboring veins makes it probable that it was formerly present, and the oxide is in part the result of its decomposition. The vein, on the whole, presents an unusually decomposed appearance, as does the wall rock in contact with it. Much white, clay-like material, usually of a sticky consistency, from its saturation with water, is of universal occurrence in the vein. This is, indeed, present in such quantities as to give considerable difficulty in the milling of the ore. It is usually known as "talc." Doubtless much of it is merely material residual from the trituration of the country rock along the fissured zones. Some is, however, of more definite composition, and chemical tests prove it to consist largely of finely divided sericite, one of the potash micas. Kaolinite has been shown to occur with it, its presence being probably due to surface decomposition of portions of the wall rock included in the lode. The greater or less amount of this material in the vein does not appear to bear any relation to the value of the ore.

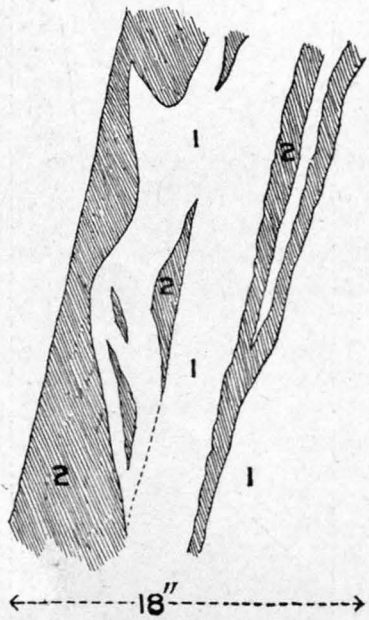
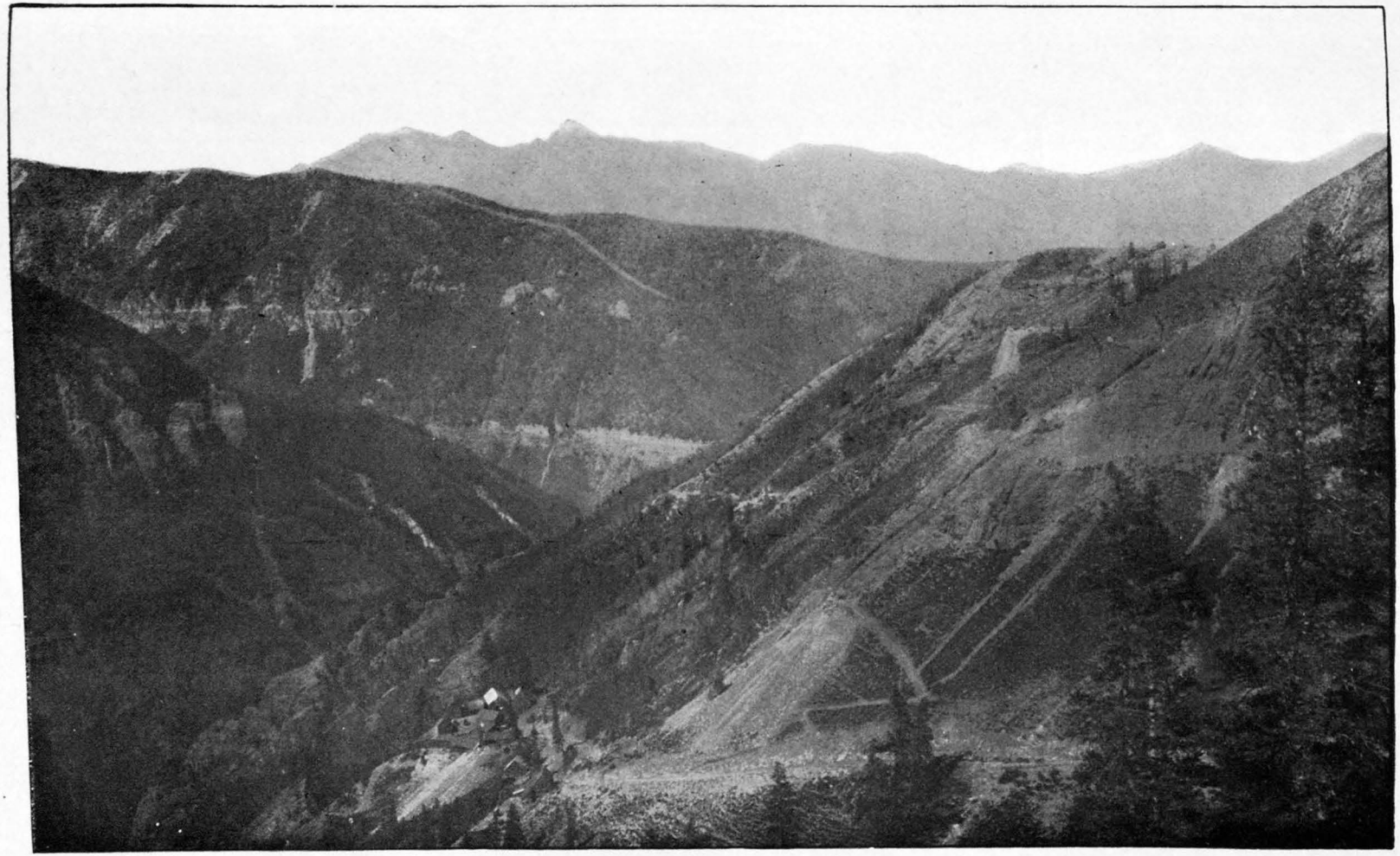


FIG. 73.—Section illustrating macroscopic vein structure, Tomboy mine. 1, quartz; 2, crushed and impregnated country rock.

Calcite and probably siderite occur. The occurrence of fluorite has



MARSHALL TRAIL AND BULLION TUNNEL ENTRANCE.

already been described at some length. Iron pyrite is present in small amount and the gold values do not appear to be associated with it to any extent. More often than otherwise it occurs associated with galena and zincblende in a narrow streak, which crosses from one wall to the other in the vein, and is fairly continuous through the workings. Small quantities of sulphurets are, however, disseminated throughout the vein. The gold is more than three-fourths free, its total value being about $20 to the ton. The concentrates run $40 to $45. The gold averages 0.735 fine. The gold has not been found in the iron pyrite except in small amount. Much of it is extremely finely divided and hitherto difficulty has been experienced in saving it at all. The ore is worked by a set of Huntington mills, which are said to be the equivalent of 80 stamps. Amalgamated plates are used in connection with these and the crushed ore is then treated on 24 vanners. The mill has a daily capacity of about 200 tons and is run by electric power, which is transmitted from Ames, 12 miles away. The capacity of the dynamo is 150 horsepower. A 120-horsepower Corliss engine is provided to run the mill in case of accident to the electric plant.

In working the mine much timbering has been resorted to for the filling of worked-out stopes. Rock filling has also been used to some extent. Much scaling of the walls has occurred, owing to the decomposed nature of the country rock. Situated as it is, more than 3,000 feet above the level of the Telluride Valley, this mine must needs be rich to pay for the cost of transportation of supplies. All the concentrates are packed on mule trains from the mill to the railway below. It has been necessary to haul the timbers for the mine up the steep trail by teams of horses, at a cost of 27 cents per foot of stick. Doubtless in view of the present increased output many improvements will be made tending to lessen the cost of production.

As to the linear extent of the Tomboy vein it seems likely that a rather definite conclusion might be arrived at by a detailed study of the fissure system along which the lode has been formed. Its continuance in depth at the present width seems highly probable, judging from the concordance in dip of the component fissure systems.

THE CIMARRON MINE.

This property, operated by the Hector Mining Company, is situated at the junction of Marshall and Savage creeks. The lowest level is at 10,700 feet, and there are four levels above it. The three lower drifts are below the level of the Bullion tunnel; the two upper ones are above it. Vertical distances between the levels vary from 125 to 250 feet. Not over 3,000 feet of drifting in the vein has been done. It was one of the first developed mines in the district, but was not a large producer until 1891.

The rock is the San Juan formation and presents no features differing from those described in connection with the Smuggler vein. The fissured zone is not wide, about 3 to 4 feet on an average, but is remarkably well defined. Its strike is somewhat variable in different parts of the workings, but averages N. 40° W., with a dip 78° SW. At 500 feet in the fourth level (the next to the lowest) a streak of ore follows a N. 26° E. direction for 60 feet. The streak then takes again the normal strike of the main vein, but dips 80° to the east. The veins are both valuable, the eastern one running high in gold, the western in silver. The converging dip brings the two streaks together higher up. There appears to have been a slight breaking up of the fissure systems and an opportunity for the ore to spread somewhat into fissures crossing the main lode. In both the Cimarron and the Bradley-Pioneer mines, the last of which is worked on the same vein, on the south side of Savage Creek, unusually straight walls may be seen, the walls often presenting surfaces like slabs of slate. The occurrence noted by Mr. Porter at the surface outcrop of the Cimarron of the development of a slaty cleavage in the walls after the taking out of the ore has already been referred to.

At a distance of 450 feet in the first level of the Cimarron the Pandora vein crosses, cutting off the main lode as already described. Although the northern continuation of the Cimarron beyond the Pandora crossing has never been found, very little prospecting appears to have been done for it. In view of the evidence afforded by the Alleghany, Valley View, and Smuggler veins, in the case of all of which the northern portion of the veins has been thrown to the east by the Pandora vein, or Memphis, as it is sometimes called, it seems probable that the northern continuation of the Cimarron lies from 50 to 100 feet to the east of the part south of the Pandora vein. Drifts have been run to the west, to the Smuggler vein, about 175 feet, which has been followed to the north. As in the Bullion tunnel, it is seen to be faulted by the Memphis vein. The Smuggler vein is worked on all levels in the Cimarron mine. The converging directions pursued by the two veins, the Smuggler and the Cimarron, would indicate that an intersection of the two must occur at no great distance toward the north. So far as I was able to learn no such intersection has been observed in the workings of the Smuggler-Union mine. It is stated, however, that in the Smuggler, at the place where it is most reasonable to suppose the intersection occurs, there is an unusual local impoverishment of the vein. It is possible that there exists some such relation between the Smuggler and the Cimarron lodes, as is exemplified and has been described in the Tomboy and other veins, where fissure systems differing in direction by only a few degrees intersect. Although continuous workings on the Cimarron vein do not exist to the south, it is most probable, not only from all the observed phenomena but from the statements of those

most familiar with the district, that the Bradley-Pioneer and the Columbia mines, the last nearly a mile to the southwest, are on the same vein. On the other hand productive mines have not so far been developed on the Smuggler vein in its continuation to the south of Marshall Creek. Lack of time and the lateness of the season prevented, during the present investigation, the detailed study and elucidation of the relations which those two important veins bear to each other. Such an investigation should form a part of a final eport on the resources of the district.

The ore of the Cimarron vein does not differ greatly from that of the Smuggler. Its arrangement is, however, more regular than in any other vein observed in the district. In the lower levels the "gold streak" contains bands of white quartz, with rhombohedral crystals of calcite and manganese spar covering the faces of the larger quartz crystals. These bands are generally barren. Alternating with them across the face of the ore breasts are bands of slightly pinkish quartz with disseminated iron pyrite and small amounts of other sulphides. These last-named bands are rich in gold. In the "silver streak" the ore consists of many parallel laminæ, the borders of each band being of quartz, while the center is occupied by a mixture of metallic sulphides, zinc blende, galena, and argentiferous tetrahedrite. In the upper levels of the mine it is stated that the values are almost wholly in gold, and the character of the ore appears somewhat different from that seen directly below. A considerable amount of the peculiar white, coarsely saccharoidal quartz noted in the Tomboy vein is seen, and is said to carry free gold. The width of the "pay streak" in this vein is variable, and is said to average about 2 feet. It is occasionally much wider, as exposures were seen in the lower tunnel of the Bradley-Pioneer of more than 6 feet in width. As usual, the pay streak follows the foot wall. The values of the ore are mostly gold. it is milled on the spot and the concentrates shipped for smelting; No attempt is made to save the gold by amalgamation.

THE AURIFEROUS IMPREGNATIONS OF SILVER MOUNTAIN.

THE GOLD KING AND SUFFOLK MINES.

The gold deposits of Silver Mountain, although in part of normal vein type, are mainly impregnations of the country rock, arranged in zones along certain of the fissures. The Gold King and Suffolk mines are the properties in which the greatest product has come from these deposits, and a few words of special description should be given them.

The Gold King mine, situated in Alta Basin at 11,000 feet, was one of the first developed in the district. It has always been a productive mine, though not one of the largest. Many thousand feet of development have been done on it, mostly on seven different levels. Its workings now connect with those of the Suffolk mine, as shown in

the accompanying plan (fig. 74). The mine workings lie mostly within the San Juan breccias, but the upper levels extend into the andesite above. So decomposed is the country in general, however, that it is impossible to tell underground where the contact occurs. Decomposition is an almost invariable accompaniment of the veins on Silver Mountain, and in the seventh level of the Gold King mine, at a vertical distance underground of more than 1,000 feet, the rock is so decomposed as to be almost "picking ground." Specimens of the rock may be seen to be thickly sprinkled with dots of iron oxide, which have resulted from iron pyrite, and with crystals of the pyrite itself. Strong evidences that the extraordinary amount of decomposition was an accompaniment of the ore deposition is offered by the

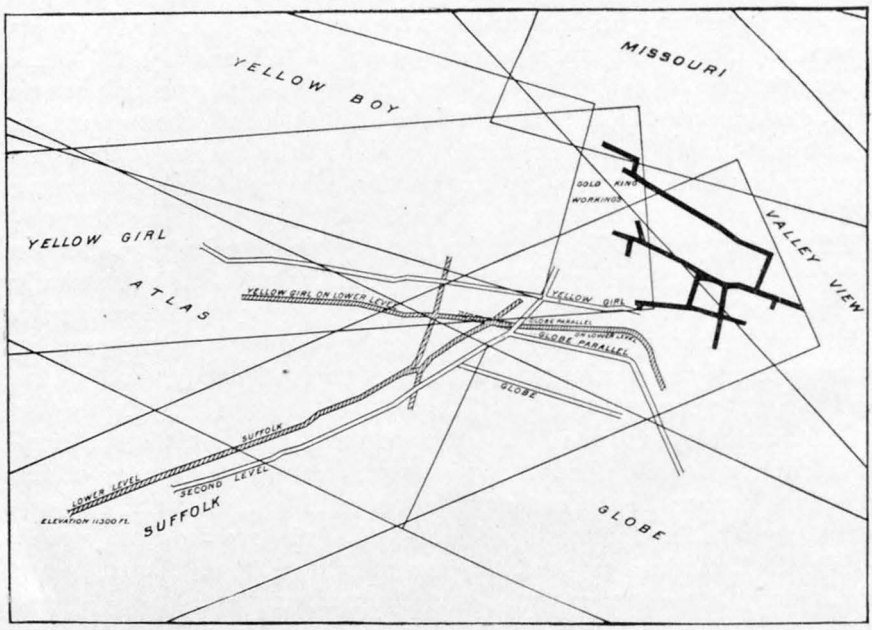


FIG. 74.—Plan of Gold King and Suffolk mine workings.

fact that it does not decrease as one gets deeper in the mine, but rather is much stronger along the vein than at the very surface exposures of the breccias away from the vein. Careful search was made for vein material in these workings, but, except narrow stringers of white vug quartz showing comb structure, there appeared to be little material which had filled previously open space. Walls were not seen well defined, and ore was difficult to recognize by its appearance. A piece of the ore taken from the crusher was carefully examined in the field, and a microscopic slide has been made of it. A description of some of the features observed in this rock has been given,[1] but it may be here restated that it is the San Juan breccia impregnated with iron

[1] See pp. 804–805, and Pl. CXVIII, *A*, p. 850.

pyrite. Remnants of the phenocrysts are yet visible. The feldspars are a mass of sericite and carbonates, the ferromagnesian silicates are partially replaced by iron pyrite, which forms sometimes one, sometimes several crystals inside of their original boundaries. With the pyrite is associated calcite and some chlorite. The groundmass is an indeterminate mass of very fine felty mica, minute pyrite crystals, and silica, partly in a hydrous form, spherulitically arranged. Much iron oxide, having the appearance of a brown pigment, is seen throughout the slides. In the workings of the Suffolk mine the country has been affected in almost identically the same manner; quartz stringers of microscopic dimensions are more plentiful, and the quartz of the veins is more prominently developed. In neither of these mines, however, could I learn that a sharp definition occurs between ore and barren country rock. In the Gold Crown mine, where the country rock is the underlying San Miguel conglomerate, the ore appears to be largely the decomposed impregnated conglomerate, and littie vein quartz is to be seen.

From the observations stated above the conclusion seems inevitable that there has been in this part of Silver Mountain an auriferous impregnation of the country rock. The impregnating solutions have affected all the rocks, but the favorable conditions presented by porous material, such as the breccias and the cement of the conglomerate, have resulted in an especial development of the phenomenon. It is said that the small diorite mass forming a part of the country rock of the Badger mine, on the lower slope of the mountain near Ophir, runs $8 to the ton in gold. This diorite is much impregnated with iron pyrite crystals. Well-defined fissures are always followed by the drifts in the Gold King and Suffolk mines, and these usually contain narrow seams of quartz. It is on both sides of those fissures that the impregnation forming the ore occurs. The part which it is profitable to mine and mill is usually from 3 to 6 feet in width, occasionally widening to 10. In the Suffolk the narrow quartz stringers carry much free gold, and frequently run $50 to $60 per ton. As a rule, the impregnated zones are low grade, and could not be profitably worked without the facilities which both these mines possess for handling the ore on a considerable scale. Some of the Suffolk ground is worked by individual leasers, who select the high grade quartz and sack and ship it for milling.

The fissures of Silver Mountain form a more complicated network than has been met with in any other part of the area, and the narrow zones of fissures are here less developed than those which occur singly. It is difficult to see why the impregnations in this particular locality should have a more auriferous character than the impregnations in general. As has been stated, the impregnation of the country rock by iron pyrite is an almost universal accompaniment of the gold and silver veins of the Telluride quadrangle. It is possible that

syenite was intruded into them. This intrusion was of a very irregular character, although it may be called a dike. In the Alaska-Treadwell it swells out to 450 feet in width, including, however, large "horses." To the northwest and to the southeast it narrows, and is sometimes reduced to a system of parallel dikes divided by slate. The lithological character of the syenite has already been described in sufficient detail.

After the syenite intrusion came one of gabbro. It forms a dike a couple of hundred feet in width and follows the northeast wall of the deposit pretty closely, though sometimes separated from it by slate. This rock has been turned to "greenstone" by the action of solutions, seemingly those attending the ore deposition. The color, due to chlorite and epidote, and the granular structure, make its identification easy. At some points it is porphyritic or semiporphyritic, and would then, strictly speaking, be known as a diabase, but the granular modification seems to be the prevailing one. This gabbro contains some fragments of the granite. Though decomposed and intersected by a considerable number of quartz stringers carrying a little pyrite, it is nowhere converted into profitable ore, and relatively to the syenite it is but slightly mineralized. Calcite is more abundant in the gabbro than in the syenite. The gabbro appears as a cropping on the northerly side of Glory hole, or the northwesterly of the open pits. It appears again in the adit level and on the 110-foot level of the Treadwell, in the south pit of the same property, at a watercourse on the Alaska claim, and in both levels of the Alaska-Mexican. It is always on the hanging-wall side of the deposit.

Latest of the intrusions is the analcite-basalt, of which a petrographical description has been given. This dike is seen in the south pit of the Alaska-Treadwell, which it crosses at a moderate angle, striking N. 20° W. and dipping steeply to the northeast. This dike is very regular and from 4 to 6 feet in width. It cuts slates, diorite, and gabbro, and at one point contains numerous slabs of the diorite. The rock evidently chilled rapidly and has a fine-grained selvage. For the most part the dike rock is decomposed to a brown-black earthy mass, which can be crumbled in the fingers. Portions of it, however, are fresher, and the fine-grained selvages are less decomposed than the body of the dike. At some points it contains hard, bean-shaped bodies, which look as if they might be spherulites, but under the microscope there seems to be no essential difference between these bean-shaped masses and the fresher specimens of the solid rock. I infer that they have been formed by decomposition of the basalt, starting on shrinkage cracks and acting more rapidly upon the edges and corners than upon flat surfaces. I have discussed the effects of such decomposition on a former occasion.[1]

The structure of the Treadwell is complex in detail, but shows some

[1] Mon. U. S. Geol. Survey, Vol. XIII, 1888, p. 68.

the unusual and complex nature of the fissuring of Silver Mountain may have some relation to the fact that here the impregnations carry values, while ordinarily they are rather barren.

The ore of these mines is nearly free milling, owing to its decomposed nature above described. The concentrates are said to run very low, and the ratio of concentration is large. The gold is said to run .650 to .700 fine. Several other mines have been opened on lodes similar to those of the Gold King and Suffolk, but have not produced largely. There is much evidence of the extension of impregnated zones along Silver Mountain to the east and to the southeast across the head of Ophir Valley, but as yet they have not been proved sufficiently auriferous to pay for working. In common with low-grade deposits in general, such ore bodies can be worked at a profit only when the ore is handled on a large scale and under the most favorable conditions.

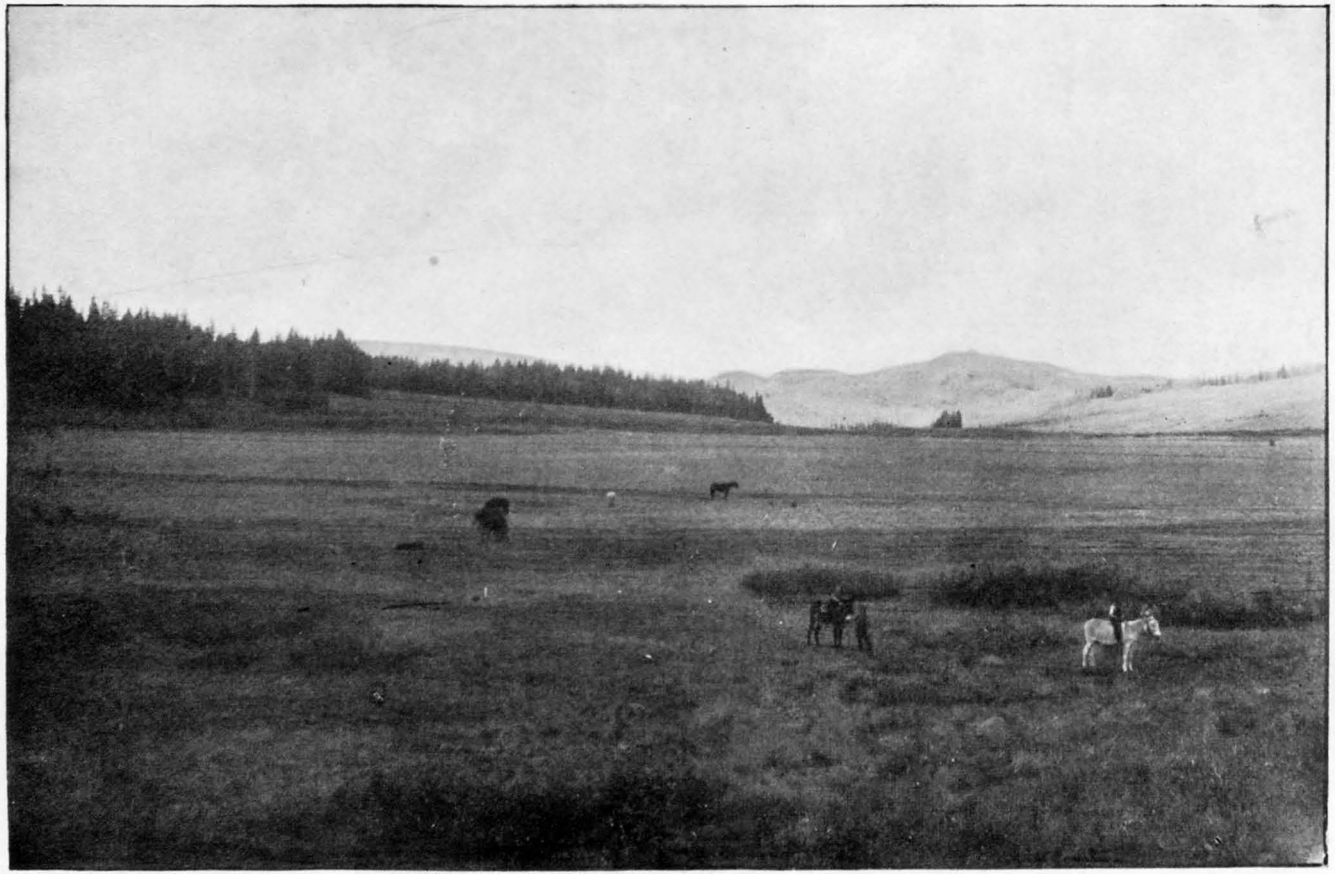
THE SILVER PICK MINE.

This property is situated on one of the western spurs making out from the mass of Mount Wilson. Its lowest workings are at 12,600 feet, and the highest drift is at over 13,000 feet. There are six levels, representing about 5,000 feet of work, besides a considerable amount of stoping. All workings are on the lode itself. The mine has been worked since 1890, and the product has been about half a million dollars. A wire tram 5,900 feet in length is used for carrying the ore from the mine to the mill, which is situated in the valley of Big Bear Creek. The diorite forming the mass of Mount Wilson and composing the country rock of this vein has been referred to. It differs not materially from that of the great stocks in general, but is coarser textured in many places, as is well shown in the Special Session mine.

There has been considerable saprolitic[1] decomposition of the diorite, which is markedly different from that induced by hydrothermal action in the rock of Silver Mountain. The altitude is so great that the ground remains frozen, it is said, throughout the year. This is true even in the lowest level, which in places attains a vertical depth beneath the surface of 700 feet. It has been observed that the rock becomes less and less decomposed as depth is gained. The rock, it should be said, shows less impregnation in the walls by iron pyrite than is generally the case in the district.

Special references have already been made to the influence which cross fissures have on the Silver Pick vein. The lode itself is more than usually well defined, and is characterized by good walls. It is characterized by a series of offsets, which have been described in connection with the general remarks on veins. Double schistosity was seen in parts of the mine, and groovings on the walls pitch 80° to the

[1] The word *saprolite* was introduced by Mr. G. F. Becker to designate rock in place which has been decomposed by surface agencies. Reconnaissance of the gold fields of the southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey (1894–'95), Part III, 1895, p. 289.



MANCOS SHALE COUNTRY, DOLORES MEADOWS.

southwest in the plane of the vein. The structure of the vein is markedly banded, or linked; strips of country rock alternating with those of ore. Rarely does the vein assume the character of an irregularly crushed mass, forming an ore breccia. Open vugs and comb structure are not common. The zone of fissures is usually about 4 feet wide, while the metallic contents appear to be usually confined to a strip along the foot wall, about 12 inches in width. This occasionally reaches the whole width of the zone, but ordinarily that part of the zone not occupied by "pay streak" is filled with more or less sheeted, crushed, and loosened country rock, some of it finely triturated, and known as "gouge" matter. Even to the surface the sulphurets in the vein are remarkably unaffected by decomposition. In a gangue of white quartz and subordinate calcite occur mispickel, galena, zincblende, and copper and iron pyrite. The mispickel predominates, and there can be little doubt that the gold values are intimately associated with it. The ore is notably refractory, and the iron pyrite is not in sufficient amount to account for the high average of the ore in gold. Copper pyrite, although occurring in considerable amount, does not appear to indicate gold values. It is largely decomposed to the sulphate, chalcanthite, to which reference has been made. Galena is a sufficient factor in the ore to give a considerable amount of lead, and carries silver values. It is said the pay streak runs from $100 to $150 per ton in total value, much the largest part being in gold. The whole width of the zone, 4 feet, is, however, sent to the mill, making $25 to $30 the run of the ore as mined. It is treated in a 10-stamp mill, with vanners for concentrating. The entire product of the stamps is shipped for smelting. Plate amalgamation has been tried, but has been unsuccessful, the gold appearing to be intimately combined with the sulphides.

There are many veins in the diorite stock of Mount Wilson to which the description of the Silver Pick vein will apply. Of those that I have seen, however, the width was not so great. The auriferous arsenical pyrite, mispickel, appears to have a wide distribution in the Mount Wilson area.

MILLING.

A few mills were brought into the district by means of wagons and pack trains before the railroad was built, but it is only within the last six years that milling has attained to considerable development.

The Smuggler-Union mill is of 50 stamps, with Huntingtons and vanners, as described under the heading of special mine notes. This was the first mill of any importance which came into the district.

In Bear Creek, south of Telluride, a 120-stamp mill has been erected by the San Miguel Consolidated Gold Mining Company. This was not running during the summer of 1896.

The Japan Mines Company has recently put up a mill, consisting of crushers, rolls, and jigs, of 60 tons capacity.

The Columbia mine has a mill of 30 stamps, with plates and vanners.

The Gold King mill has 40 stamps and the Turkey Creek mill 20 stamps.

The Tomboy mill of the Huntington pattern has been referred to in the description of that mine.

The Valley View mill, near the Cimarron, 20 stamps and tables.

The Cimarron mill, 40 stamps and vanners; no plates are used.

The Alleghany mill, 20 stamps, plates, and vanners.

The Silver Pick, 10 stamps and jigs.

The Suffolk, 40 stamps and vanners.

The Carribeau, 10 stamps and concentrators.

The San Bernardo, 20 stamps and concentrators.

The Virginius mill, consisting of 4 Blake crushers, 60 stamps, 6 Huntington mills, and 30 Woodbury concentrating tables.

The Yankee Boy mill, Huntington pattern, 60 tons daily capacity.

The Trust Ruby mill, 20 stamps.

The mill of the Golden Horn Company in Ice Lake Basin, 20 stamps and 4 vanners.

In the season of 1896 some of the above-mentioned mills were in process of completion. Few were idle. Over 400 stamps were dropping. Water is the power most used, either directly or through the medium of electricity. The Smuggler-Union mill is run by steam; the coal used is mined at Porter, at the horizon of the Fox Hills beds of the Cretaceous.

There are no reduction plants of any sort in the area. In view of the increased gold product of the last few years, it would seem advisable to consider the possible introduction of cyanide or chloridation works.

COAL.

In the southwest corner of the quadrangle the Dakota sandstone of the Cretaceous formation contains lignitic coal. The coal has been worked at two points, the one on the east, the other on the west side of the Dolores River, near the station called Coke Oven. Here the coal layer occurs at an elevation of about 800 feet above the river bed. The coal bed is from 20 to 30 inches in thickness, and, like the inclosing beds, in approximately horizontal position. It occurs about 100 feet above the base of the Dakota. It is said to be a fairly good coking coal, makes little clinker, but a large amount of ash. Its appearance is very lignitic. About 20,000 tons of it have been mined.

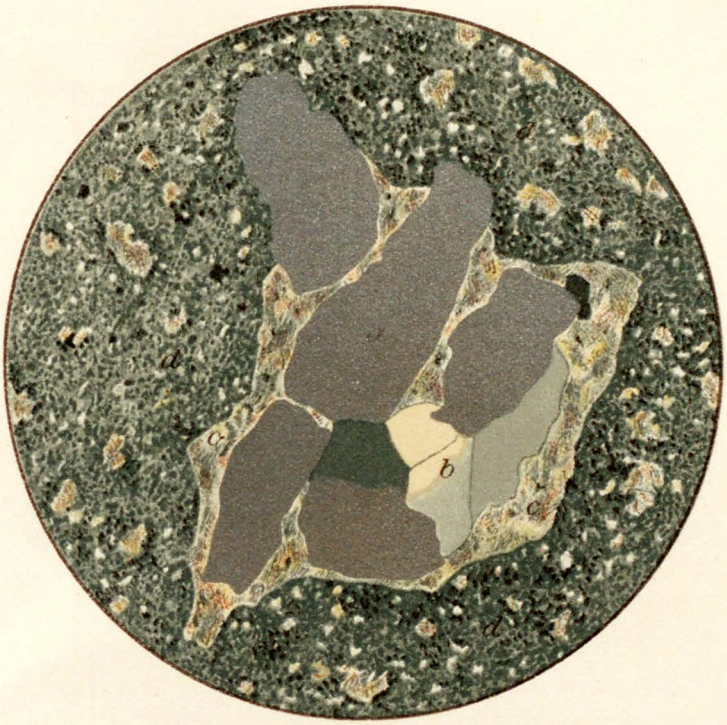
The Dakota formation does not anywhere in this section of Colorado contain as good coal as that found in the Fox Hills member of the Cretaceous which is worked farther south, at Hesperus, in the La Plata quadrangle, and at Porter, near Durango. Seams of lignite do, however, extend in the Dakota as far north within the quadrangle as the Telluride Valley. They are not, so far as has been ascertained, of economic importance.

PLATE CXVIII.

PLATE CXVIII.

A.—Thin section showing partial replacement of a ferromagnesian silicate by pyrite. Gold King mine. *a*, pyrite; *b*, quartz; *c*, felty aggregate composed of calcite and muscovite with a little chlorite; *d*, feldspathic ground-mass, partially sericitized and carbonatized. (See under "Impregnations," p. 804.)
Section magnified 155 diameters.

B.—Thin section showing iron pyrite of doubtful genesis. Cimarron mine. *a*, pyrite; *b*, vein quartz; *c*, calcite in the groundmass; *d*, feldspathic groundmass, partially sericitized and carbonatized, with probably a small amount of silicification. (See under "Iron pyrite," p. 792.)
Section magnified 92 diameters.



A

B

A. PARTIAL REPLACEMENT BY PYRITE.

B. PYRITE OF DOUBTFUL GENESIS.

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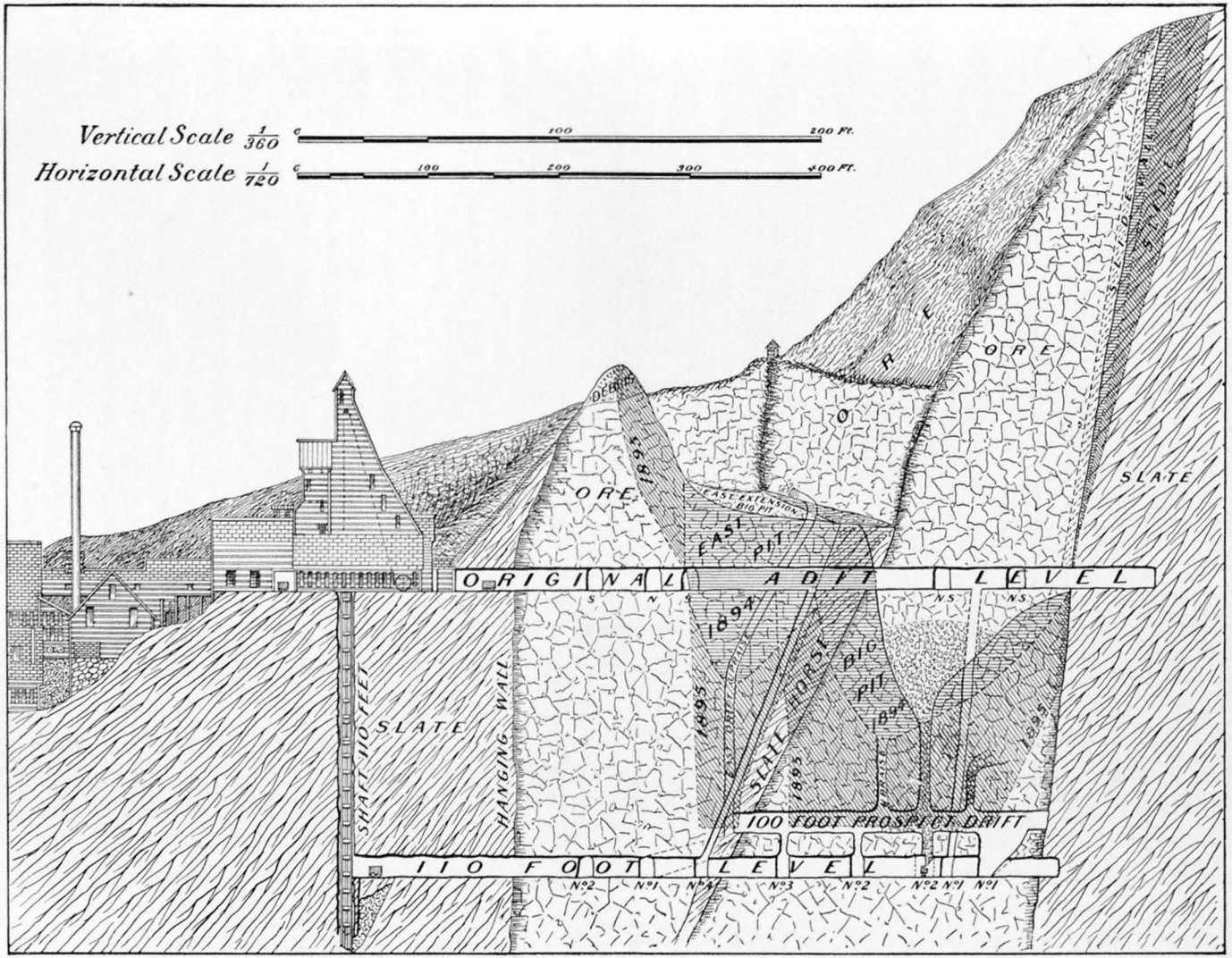

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