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MINING DISTRICTS

OF THE

DILLON QUADRANGLE, MONTANA

AND ADJACENT AREAS

BY

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MINING DISTRICTS OF THE DILLON QUADRANGLE, MONTANA, AND ADJACENT AREAS.

By ALEXANDER N. WINCHELL.

INTRODUCTION.

The field work on which the following report is based was done during July and August of 1910 and 1911. Its purpose was to examine the mining districts of the region rather than to make a detailed study of stratigraphy or areal geology. All the important mining districts of the quadrangle and nearly all the mines in actual operation were visited, though time was lacking for careful inspection of the workings of many of them.

It is a pleasure to acknowledge hereby the numerous courtesies received from residents of the Dillon region during the course of the field work. Among many others, the following were very generous in giving time and information: Prof. D. C. Bard, of the Montana State School of Mines, Mr. R. H. Sales, chief geologist of the Anaconda Copper Mining Co., and Mr. Oscar Rohn, general manager of the East Butte Copper Mining Co., all of Butte; Mr. C. L. Dahler, of Silver Star; Messrs. J. E. Flint and C. E. Morris, of Pony; Mr. E. T. Hand, formerly Government geologist at Macassar, Dutch East Indies, now of Rochester; Mr. C. E. Kammerer, manager of the Conrey Placer Mining Co., of Ruby; and Messrs. R. E. Ober, mining engineer, and P. I. Smith, both of Dillon.

During the preparation of this report the writer has received important suggestions and assistance from Messrs. Waldemar Lindgren and H. D. McCaskey, of the United States Geological Survey. He has also had the advantage of a critical examination of the manuscript by Mr. F. L. Ransome.

GEOGRAPHY.

LOCATION AND AREA.

The Dillon quadrangle (see fig. 1) lies in southwestern Montana, directly south of the Helena quadrangle and west of the Threeforks quadrangle, between parallels 45° and 46° north and meridians 112°

and 113° west. It is about 49 miles wide east and west and about 69 miles long and has an area of about 3,200 square miles. The great copper-mining district at Butte is immediately north of it, and, indeed, the Colorado and Clark smelters at Butte are within it. The quadrangle includes within its borders the northwest third of Madison County, the northeast quarter of Beaverhead County, all except the northernmost part of Silver Bow County, and small portions of Jefferson and Deer Lodge counties.

The regions outside of the Dillon quadrangle but included in the area covered by this report lie both to the east and to the west. The Pony, Norris, and Virginia City districts are to the east, in Madison County, in the western half of the Threeforks quadrangle. The

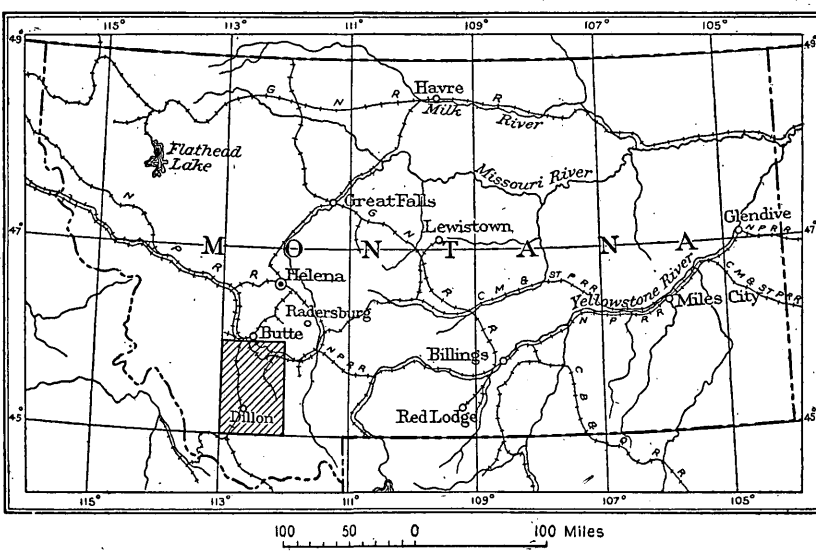

FIGURE 1.—Key map showing location of Dillon quadrangle, Mont.

Radersburg district is in the Fort Logan quadrangle, in Broadwater County, northeast of the Dillon quadrangle. The remaining districts are in Beaverhead County, just west of the Dillon quadrangle on both sides of the Bighole basin. The location of the most important districts in the region examined and their relation to railroads and streams are shown on figure 2.

TOPOGRAPHY.

The Dillon quadrangle is in general mountainous, but it contains one large valley, that of Beaverhead and Jefferson rivers from Barratt on the southwest to Whitehall on the northeast, and numerous smaller valleys, including those of Passamari River[1] from Alder to

[1] This stream is known locally as Ruby River.

Twin Bridges, of Blacktail Creek from Dillon southeastward for 20 miles, and of Divide Creek and the northward-flowing water across the divide from its head. A valley, probably once occupied by a single large river, extends from Silver Bow through Feely to Divide, and is followed by the wagon road to Melrose and by McCarthy and Nez Perce creeks to the region of Twin Bridges. The history of this old through valley, which crosses the Continental Divide at an elevation of 6,300 feet, has not yet been deciphered.

With the exception of a small area in the northwest part of the region, south and west of Butte, the quadrangle is drained by Jeffer-

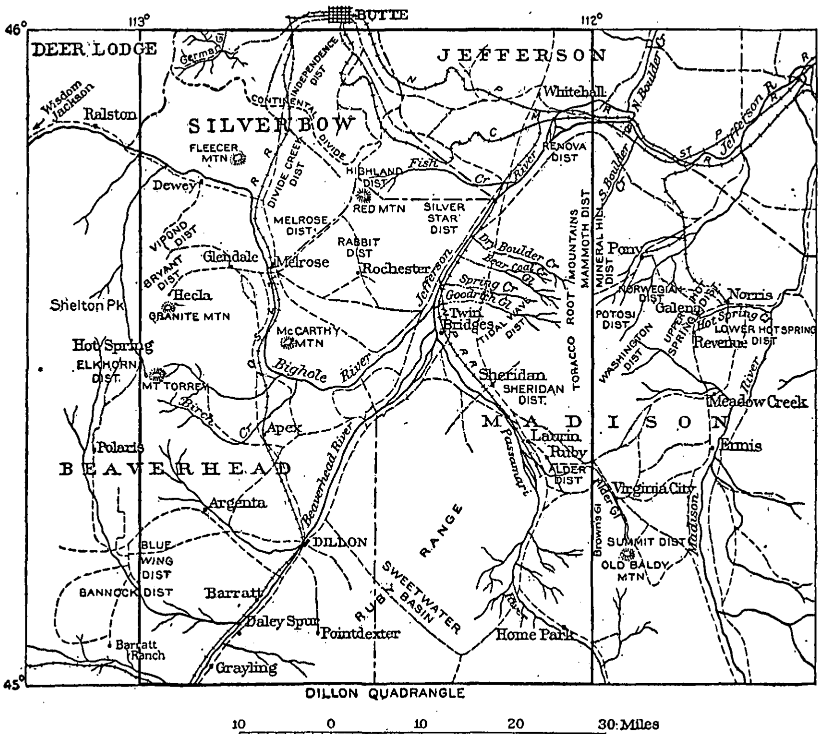

FIGURE 2.—Sketch map of the Dillon region, showing location of mining districts.

son River, which unites with Madison and Gallatin rivers to form Missouri River in the northern part of the Threeforks quadrangle. Jefferson River is formed by the junction of Beaverhead and Bighole rivers near the center of the Dillon quadrangle. German Gulch and Basin and Blacktail creeks, in the northwest part of the quadrangle, flow northward into Clark Fork, locally known as Silver Bow Creek, and thence to Columbia River and the Pacific Ocean.

Physiographically the Dillon quadrangle is a portion of the Rocky Mountain province of the United States. It includes a portion, about 50 miles long, of the main Continental Divide, which enters the quadrangle about 3 miles east of the middle of the north border and about 5 miles east of Butte, runs southerly through Homestake to Pipestone Pass, thence southwestward to the region of Highland, thence northwestward to Feely, thence westward to the head of German Gulch, thence nearly due north to the northern boundary of the quadrangle. Near the center of the quadrangle a mountain valley running southwest and northeast is joined by an abandoned valley running northwest and then north. The valleys form a Y, bordered on the southeast by the Ruby Range and the Tobacco Root Mountains, and on the west by the mountains of the Bighole National Forest, McCarthy and Fleecer mountains, and the mountains west and north of Jerry Creek. Between the forks of the Y lie Red and Table mountains and part of the main range of the Rocky Mountains. The lowest elevation in the quadrangle is about 6 miles east of Whitehall, where Jefferson River leaves the quadrangle, and the highest is probably the peak of Mount Torrey, at the head of Birch and Willow creeks near the middle of the western margin, which attains an elevation of more than 11,000 feet above sea level. Several peaks in the Tobacco Root Mountains reach nearly the same elevation.

MINING DISTRICTS.

The mining districts of the Dillon quadrangle are for the most part in or near granitic intrusions. (See fig. 2.) Thus, the Independence district is wholly within the area of the Boulder batholith, extending from Missoula Gulch (in Butte) and from Silver Bow southward to the Continental Divide. Farther south the Divide Creek district, in the area of the same batholith, extends from the Great Divide south to the region of Moose Creek. The Fleecer Mountain district is in an area of limestone and other sedimentary rocks which are cut by the same batholith. The Siberia (German Gulch) district lies near the contact of the batholith with quartzites and conglomerates.

The Moose Creek district is near the head of Moose Creek, where the batholith is in contact with Paleozoic limestones. The Highland district is not far from the head of Fish Creek, near a contact between the batholith and limestones and sandstones. The Silver Star district lies close to a similar contact south of Cherry Creek and north of Hell Canyon.

The Melrose district, on Soap and Camp creeks, lies in an area of limestone and sandstone not far from contacts with the Boulder batholith or its outliers.

The Rabbit district, at Rochester, is an area of schists and gneisses cut by numerous dikes and sills of aplitic granitic rock, probably derived from the Boulder batholith.

The Vipond district occupies a "park" between Wise River, Big-hole River, and Canyon Creek. The chief country rock is dolomitic limestone.

The Elkhorn district lies just west of the Dillon quadrangle between the headwaters of Wise River and Grasshopper Creek northwest of Comet Mountain and about 10 miles southwest of Hecla. The country rock is a porphyritic quartz monzonite.

The Bryant district, at Hecla, is near the contact of limestone with a granitic intrusion, which may be a part of the Boulder batholith that has no surface connection with the main mass. The Utopia district, on Birch Creek, is near the contact of limestone and quartzite with the same granitic intrusion, and the Argenta district on Rattlesnake Creek is at the contact of limestone and quartzite with what appears to be an outlier of the same rock.

The Mammoth district is near the head of South Boulder Creek in the northern part of the Tobacco Root Mountains in a region where a porphyritic quartz monzonite is in contact with old gneisses and schists.

The Tidal Wave district is on the western flank of the Tobacco Root Mountains between South Boulder and Wet Georgia creeks. The country rocks are limestones, schists, and a granitic intrusive which is apparently another outlier of the Boulder batholith.

The Sheridan district includes Wisconsin, Indian, and Mill creeks and Ramshorn and Bivin gulches. The country rocks are schists, quartzites, and limestones cut by intrusions of aplitic granite, diorite, and monzonite, derived partly or wholly from the same source as the granitic intrusive of the Tidal Wave district.

The Alder Gulch district terminates in the Passamari Valley at Laurin.

The Blue Wing district lies between the Dillon-Bannock road and Grasshopper Creek, within 4 miles of the western border of the Dillon quadrangle. The country rocks are limestones, quartzite, rhyolite, and diorite.

The Bannock district is on Grasshopper Creek about 20 miles west and a little south of Dillon. The ores are contact deposits about a small boss of granodiorite in limestone with some quartzite.

The Dillon district centers about the town of Dillon, on Beaverhead River at the mouth of Blacktail Creek. Dillon is an important town on the Oregon Short Line Railroad, and is the county seat of Beaverhead County.

The Whitehall district includes the Cardwell district on and near St. Paul Gulch in the southern end of the Bull Mountain Range, northeast of the town of Whitehall, and the Renova district south of Whitehall in the northern end of the Tobacco Root Mountains. Igneous rocks are present but are not abundant.

The Radersburg district is in the Fort Logan quadrangle on Crow Creek, about 10 miles west of Toston and 75 miles northeast of Dillon, in a region of intrusions and extrusions of andesite associated with Cretaceous sandstones and shales.

The Pony district is in the Threeforks quadrangle near the sources of Willow Creek, west and south of the town of Pony, which is connected by rail with the Norris branch of the Northern Pacific Railway. The Mineral Hill district extends from Pony westward for about 5 miles and includes gold deposits in gneiss, in porphyritic quartz monzonite, and in aplite, all not far from the igneous contact. The Potosi district is about 8 miles southwest of Pony, on the headwaters of South Willow Creek, in quartz monzonite. The Sand Creek district is about 10 miles northeast of Pony, in an area of gneiss.

The Norris district is in the Threeforks quadrangle. It extends for several miles in all directions from Norris, which is the terminus of a short branch of the Northern Pacific Railway, leaving the main line at Sappington. It includes the Norwegian, Washington (and South Baldy), and Upper and Lower Hot Springs districts. The Norwegian district lies halfway between Norris and Pony, about the sources of Norwegian Creek, near the contact between quartz monzonite and gneiss. The Washington district is on North Meadow Creek, about 8 miles southwest of Norris, near the same contact. The South Baldy district is about a mile south of Ward Peak in a region where old gneisses are cut by andesites. The Upper Hot Springs district is along Hot Springs Creek above Norris, in a region of porphyritic quartz monzonite. The Lower Hot Springs district is on the same creek below Norris and also on Cottonwood and Burnt creeks, in a region of gneiss near quartz monzonite.

The Virginia City district extends from Junction on the northwest to Browns Gulch and Summit, south of the town of Virginia, on Alder Gulch in the Jefferson Mountains. It includes the Junction, Nevada City, Browns Gulch, Fairweather, Highland, Pine Grove, and Summit mining districts, all of which were at one time organized. The Junction and Nevada City districts are confined to the areas immediately about old settlements of the same names on Alder Gulch. The Browns Gulch district extends the length of Browns Gulch to Alder Creek, but the more important portion is near the headwaters, where aplitic intrusions cut old gneiss. The Fairweather district is at Virginia City, the ore deposits (aside from the placers) being chiefly in gneiss and schist. The Highland district is on Alder Gulch, about 2 miles above Virginia; the Pine Grove district is next above; the Summit district is near the head of Alder Creek about a settlement of the same name less than 3 miles north of Old Baldy Mountain; in these three districts the country rock is gneiss.

LITERATURE.

The only large-scale map of the Dillon quadrangle is that prepared by Frank Tweedy in 1887 and 1888 for the United States Geological Survey. The scale of this map is 1 to 250,000, or about 4 miles to the inch, and the contour interval is 200 feet. Radersburg is in the Fort Logan quadrangle, and Pony, Norris, and Virginia City are in the Threeforks quadrangle,[1] both of which have been mapped by the survey. The following publications relate to the geology and mining industry of the Dillon quadrangle:

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[1] See U. S. Geol. Survey Geol. Atlas, Threeforks folio (No. 24), 1896.

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MINING DEVELOPMENT.

DISCOVERY.

All the earliest discoveries of gold in Montana were made within a short distance of the Dillon quadrangle. Gold Creek, where gold was discovered in 1852, 1858, 1860, and 1862, is about 40 miles north of the quadrangle. Bannock, on Grasshopper Creek, where gold was found so abundantly in 1862 as to start the first influx of prospectors, is on the west border of the quadrangle. Virginia City, in Alder Gulch, where gold was discovered in 1863, is 3 miles east of the Dillon quadrangle, but Alder Creek flows for several miles in the quadrangle and has yielded rich returns to placer miners throughout its length. At present this creek is yielding through dredging more gold than the total from all the other mines in the district.

PLACER MINING.

During the sixties the placer mines of the region were very productive. The most important placers of the Dillon region at that time were those in German Gulch, on Silver Bow, Blacktail, and Basin creeks, and at Highland on Fish Creek, all in what is now Silver Bow County; those in Alder, Bivin, and Ramshorn gulches and on Rochester Creek, in Madison County, and those on Grasshopper Creek, in Beaverhead County. This was the period of great and quick returns for small investments. It is estimated that Grasshopper Creek produced $3,000,000 in gold during the sixties. The great importance of this region at the time is indicated by the fact that the first capital of the Territory was at Bannock, where the first legislature convened in 1864. But the capital was soon transferred to Virginia City, where it remained during the sixties.

In this decade it is estimated Alder Gulch produced $30,000,000 in gold. German Gulch produced about $4,000,000 in gold during the same period, and the other gulches of Silver Bow County probably yielded an equal amount.

DREDGING.

The gold of placer mines is recovered so easily that placer gulches are very quickly worked out, at least so far as the coarse gold in accessible deposits is concerned. Even during the later part of the sixties many of the placer diggings showed great decrease in yield. By the gradual installation of ditches, flumes, and hydraulic and sluicing apparatus the life of the placer-mining industry has been extended for half a century, though with decreasing yield at nearly all places, except where new and virgin ground was opened by late discovery or by bringing water upon ground previously too dry to work. Near the close of the nineteenth century placer mining in Montana was at a low ebb, the total annual placer production of the State being only about $300,000. The introduction of dredges increased the annual output to about half a million, though the newness of the method and the many difficulties that had to be overcome caused for a time great fluctuations in the yield. Since about the first of the century, however, the product has been large and increasing, and, despite the marked decrease in the amount of gold won by other placer methods, the annual placer production has formed an important portion of the total gold output of the State. The only poor year since 1900 was 1907, when in consequence of the success of a dredge operated by electric power in 1906 work was partly suspended to permit the construction of two more electric dredges. Electric power only has been used since 1906.

DEEP MINES.

Though the first mining in the State was on the gold placers, attention was soon turned to lodes. Even during the sixties, the first decade of mining in the State, some little progress was made in opening "deep mines" or "quartz mines," among the first of which were the Green Campbell, Broadway, and Iron Rod, at Silver Star; the Noble, on Wisconsin Creek north of Sheridan (opened in 1864); the Blue Wing (discovered in 1864), Kent, Del Monte, New Departure, and Huron, in the Blue Wing district, south of Argenta; the Watseka, at Rochester; and the Legal Tender, at Argenta. Only the richest ore could be treated at a profit at this early date on account of the extremely high cost of labor and supplies, which were brought in by wagon train, at first from Pikes Peak, Colo., and later from Corinne, Utah.

The seventies were marked by a gradual increase in the importance and number of the deep mines and by a decline in production of the placers, but the decade was essentially similar to the one preceding. In 1873 the location of the Trapper lode in the Bryant district led to the discovery of the Atlantic, True Fissure, Cleve, and other mines of the Hecla group, which belonged to the Hecla Consolidated Mining Co. during the period when they produced most largely. Many quartz mines, rich only near the surface, were worked out and closed before the end of the decade. Many mines, including the Nevins, Only Chance, and others in the Highland district, were worked successfully by arrastres, which were relatively inexpensive to install and which were in favor for the treatment of gold ores during this period. Smelters to treat lead-silver ores were installed at Argenta and at Glendale. In 1871 six blast and two cupeling furnaces were in operation at Argenta, but they found it difficult to obtain a steady supply of lead ore and soon closed. The smelter at Glendale operated somewhat irregularly on ore from Hecla until about 1881, when, under a new management and under much improved conditions of transportation, it entered on a prosperous career which endured for 20 years.

The decade from 1880 to 1890 was a period of rapid development and successful operation of mines in all parts of the State. It was begun by the completion, in 1882, of the Utah & Northern Railway (now known as the Oregon Short Line, a part of the Union Pacific Railroad system) from Ogden, Utah, to Silver Bow, Mont. This road passed through Dillon and Melrose, supplying the tributary region for the first time with economical transportation facilities. The next year the main line of the Northern Pacific Railroad was completed, and a spur was built from Garrison through Silver Bow to Butte.

Stimulated by these roads the exploitation of deep mines proceeded vigorously. The Hecla Consolidated Mining Co., whose mines are at

Hecla and whose smelter, now dismantled, is at Glendale, paid dividends regularly throughout the decade. Other important producing mines in Beaverhead County during this decade were the Kent, Blue Wing, and New Departure, in the Blue Wing district, and the Legal Tender, in the Argenta district. Several mines in the Utopia district were also active. In Madison County mines that had been prospected in the sixties for gold and abandoned were opened and successfully worked when railroad construction made silver ore valuable. The mines of the Tidal Wave district near Twin Bridges were worthless in 1864 when first examined, but in 1883 and later years they became valuable as producers of lead-silver ore. Some of these mines are still producing through the activity of lessees. The Company mine, on Wisconsin Creek, was discovered in 1864 and was worked in a small way by Noble & Sons until about 1883, when it was sold to the Noble Mining & Milling Co., which for several years developed it much more rapidly. The Broadway and Iron Rod mines, in the Silver Star district, and the Hendricks and Red Bluff mines, in the Norris district, were also active at this period. In Silver Bow County the Only Chance and Nevins mines, in the Red Mountain district, gave rather discouraging results, and in consequence very little was accomplished in Silver Bow County outside of the wonderful activity and success in the Summit Valley (Butte) district.

During the next 10-year period, from 1890 to 1900, the mines of Beaverhead County reached the acme of their productiveness. About the middle of the decade the county produced more gold, silver, and copper than it has in any later year. This was in part due to the successful operations at the mines of the Hecla Consolidated Mining Co.'s properties on Trapper Creek. The production of the county showed a marked decrease in gold, silver, copper, and lead at the close of the decade. In 1895 dredging was first attempted in Montana in the placer ground on Grasshopper Creek near Bannock. On certain rich ground not easily worked by the ordinary methods of placer mining the dredges were highly successful, but when these were exhausted the dredges became less profitable, and one of them was moved to Alder Gulch, where dredging has been in progress ever since. Some work was in progress during part of the decade in the silver mines of the Blue Wing and Argenta districts. In Madison County mining was at a low ebb in 1892, but became gradually more prosperous to the end of the decade. The construction of a branch of the Northern Pacific Railway from Whitehall to Twin Bridges in 1897 and 1898 facilitated mining operations on both sides of the Jefferson Valley. The Leiter mine, on Wisconsin Creek, about 8 miles from Sheridan, was in active operation during the later part of the period. The Thistle mine, in the Rochester district, and several mines in the Silver Star, Tidal Wave, and Ramshorn districts were productive. The Monitor, Revenue, and Galena mines, in the Norris district, were in successful operation. The sensational development of this period was the Mayflower mine, situated on the border of the Dillon quadrangle about 7 miles southeast of Whitehall, which produced more than a million dollars' worth of telluride gold ores from pockets and shoots in limestone.

During the first decade of the twentieth century mining activity decreased very materially in Beaverhead County. A slight improvement occurred in 1905 and 1906 under the stimulus of high prices for metals but this did not affect the gold output. In the last years of the decade activity was checked by falling prices, and at present (1911) the output is smaller and the development work in progress is less than at any previous time since mining began on a large scale.

In Madison County, on the other hand, the decade was marked by continued activity. In 1901 a 120-ton stamp mill was erected at Pony to treat the ores of the Clipper and Boss Tweed mines. For a few years (1904–1906) during this decade Rochester was the largest town in the county, being made so by the extensive operations at the Watseka mine. Since the Watseka closed very little mining has been done in the district. The Green Campbell mine, in the Silver Star district, was reopened, but after a 100-ton mill had been built and considerable development work had been done operations were suspended. Lessees were at work in the Tidal Wave, Sheridan, and Ramshorn districts of the Tobacco Root Mountains during the decade at many mines with very satisfactory results. There was renewed activity at the Kearsarge mine in the Virginia City district in 1902, and a 60-stamp mill was erected the following year. Some mining was carried on near Whitehall. The Toledo mine on Mill Creek near Sheridan was equipped with a new 150-ton mill operated by a 640-horsepower plant which supplies electric power generated by water pressure. The mine was developed by a 750-foot inclined shaft, but the ore bodies proved unreliable.

During the decade further railroad facilities were obtained in the region through the extension of the Twin Bridges branch of the Northern Pacific Railway up the Passamari Valley to Alder. The Chicago, Milwaukee & Puget Sound Railway, which was completed to the Pacific coast in 1908, was built across the northeast corner of the Dillon quadrangle, much nearer to the old Highland mining district than any other railroad. In 1909 the Gilmore & Pittsburg Railroad, from Armstead, Mont., to Salmon, Idaho, was built up Horse Plain Creek, in the extreme southwest corner of the Dillon quadrangle.

PRESENT STATUS OF MINING.

In 1911 less work was in progress in the mines of the Dillon quadrangle than at any time for many years. The decline is due in part to the apparent exhaustion of the ore bodies, as at the Hecla mines, and in part to the present low prices of silver, lead, and copper.

STRATIGRAPHIC AND AREAL GEOLOGY.

SEQUENCE OF THE ROCKS.

The stratigraphic succession in the Dillon quadrangle is as follows:

Generalized stratigraphic section in the Dillon quadrangle.[a]

System.	Series.	Group or formation.	Lithologic character.	Approximate thickness.
Quaternary.	Recent.		Alluvium and recent gravels, consisting of sand, gravel, and clay.	*Feet.* 100
—Unconformity—	Pleistocene.		Glacial drift and moraines (sand and gravel unassorted).	100
Tertiary.	Pliocene to Oligocene(?).	Bozeman "lake beds" and possibly other Tertiary deposits.	Sand, clay, volcanic ash, conglomerate.	600
—Unconformity—	Upper Cretaceous(?).	Colorado (?) formation.	Gray sandstone and limestone with black shale.	500
Cretaceous.	Lower Cretaceous.	Kootenai formation.	Brown sandstone and red and green shales.	1,000
			Varicolored sandstones and shaly limestones.	600
			Gray limestone with sandstone and shale.	300
			Brown sandstone resting on massive conglomerate.	300
Jurassic (?) and Triassic (?).			Shale with limestone layers.	200
			Chocolate-brown limestone.	300
Carboniferous.	Permian (?).	Phosphoria formation.	Limestone with shaly and cherty layers.	350
	Pennsylvanian (?).	Quadrant (?) quartzite.	Massive gray quartzite, weathering red-brown, with spotted layers.	700
	Mississippian.	Madison limestone.	Massive bluish-gray limestone.	1,200
Devonian.	Upper Devonian.	Threeforks shale.	Reddish and gray shales.	300
	Middle and Lower Devonian.	Jefferson limestone.	Massive cream to buff limestone.	1,000
Silurian (?) to Cambrian.	(?)		Sandstone or sandy limestone.	0-200
			Limestone with flat pebble layers.	800
	Middle Cambrian.		Shales.	200
		Flathead quartzite.	Sandstone grading into quartzite.	500
Algonkian.[a]	Belt series.		Slates, thin-bedded quartzite, and schists.	3,000
	—Unconformity—	Cherry Creek group.	Schists and gneisses with interbedded limestones.	5,000
Archean (?).			May be represented but not positively identified.	

[a] The author has had no opportunity to make an adequate study of the numerous questions involved in the correlation and classification of early Cambrian and pre-Cambrian rocks in this region or elsewhere. The classification and nomenclature of these rocks as used in this report are therefore those employed by the United States Geological Survey, and it must be understood that their usage here involves neither their acceptance nor their rejection by the writer.—A. N. W.

QUATERNARY SYSTEM.

RECENT SERIES.

Alluvium and recent gravels are found along the streams, especially in the bottom lands of Passamari (or Ruby), Blacktail, Rattlesnake, Beaverhead, Bighole, and Jefferson rivers. Near Whitehall they extend also up Pipestone and Whitetail creeks. Near Ruby these sediments contain valuable placer-gold deposits. In many other places in the quadrangle placer deposits of the same age have been profitable, including those on Ramshorn and Bivin gulches, Grasshopper Creek, Fish Creek, near Highland, and in German Gulch.

PLEISTOCENE SERIES.

Glacial drift, chiefly in the form of moraines, exists in many valleys leading from the higher mountains. It is abundant along Ramshorn Gulch, Mill, Indian, and Wisconsin creeks, Bear Gulch, and Trapper Creek. But it is an interesting fact that the conditions during glaciation were such that the glaciers nowhere extended out of the mountains into the larger valleys. Some of them, as the one on Bear Gulch, reached points within half a mile of the mouths of the mountain canyons, but all that did so were aided by a steep gradient.

TERTIARY SYSTEM.

Tertiary deposits of sand, clay, gravel, conglomerate, and thick beds of volcanic ash occupy the bench lands of all the larger valleys in the quadrangle. They are separated by a slight unconformity from the Quaternary above and by a much more marked break from the Mesozoic below. In part, they are continuous with the Bozeman "lake beds" of the Threeforks quadrangle. In age they probably range from Oligocene to Pliocene. Fossils of White River (Oligocene) age have been described by Douglass,[1] from Tertiary beds at two general localities in the Dillon quadrangle, one on the southeast slope of McCarthy Mountain, about 16 miles north of Dillon, and the other at outcrops near Pipestone Springs, one about a mile to the east and the other to the south on Little Pipestone Creek. Fossils found south of Silver Bow in Tertiary beds were ascribed to the upper Miocene by Weed.[2]

It is a remarkable fact that these Tertiary deposits extend continuously from the vicinity of Silver Bow southward across the Continental Divide. They appear to be largely stream wash and subaerial deposits rather than lake beds, and their continuity across the Continental Divide is believed to indicate that during Tertiary

[1] Douglass, E., Am. Philos. Soc. Trans., vol. 20, pp. 237-279, 1902, Carnegie Mus. Mem., vol. 2, pp. 203-224, 1905.

[2] Weed, W. H., and others, U. S. Geol. Survey Geol. Atlas, Butte special folio (No. 38), p. 3, 1897.

time an important stream flowed across the line which now marks the divide.

Near the steeper mountain slopes some of the Tertiary deposits contain large amounts of material that may be ascribed to subaerial outwash from the mountains.

CRETACEOUS SYSTEM.

The only considerable area of Cretaceous rocks known in the Dillon quadrangle is that extending from Rattlesnake Creek northward about 25 miles to and beyond Glendale. It occupies part of the bench lands west of Beaverhead River and the lower mountain flanks from Birch to Trapper Creek, and extends across Bighole River to the southern flank of McCarthy Mountain. Very small areas of Cretaceous rocks probably extend a short distance into the quadrangle from the east in the north end of the Tobacco Root Mountains and in the southeast corner of the quadrangle. The Cretaceous rocks have been subjected to the major folding that has affected the area and in most places are radically unconformable in dip with the Tertiary deposits resting upon them. They strike approximately north with local variations to the northeast and northwest, and dip at variable but rather steep angles to the east or west. In a broad way, they form a syncline having a gentle pitch, apparently to the south.

The Cretaceous rocks in the Dillon quadrangle include (1) fresh-water beds containing layers of black bituminous shales, which may be referable to the Colorado group or the top of the Kootenai formation and (2) a thick series of brown sandstones, red and green shales, varicolored sandstones and shaly limestones, gray limestone, shale, brown sandstone, and basal conglomerate, which is here referred to the Kootenai formation.

Imperfect gastropods of fresh-water and possibly of land habitat, said by W. H. Dall to have an early Eocene aspect, were collected by the writer from the lower canyon of Bighole River. On Birch Creek other fossils of similar aspect were collected from gray limestone and black shale. At both places, however, stratigraphic relations and comparisons with sections in adjacent areas make it probable that the horizon represented is in the Cretaceous.

So far as known, no marine Cretaceous fossils have been collected from formations representing the Colorado and Montana groups within the Dillon quadrangle.

Fossils referred to the so-called Dakota of Yellowstone Park by Stanton were collected from the lower canyon of Bighole River by Douglass.[1] The same formation is reported to outcrop in the Frying-

[1] Douglass, E., Carnegie Mus. Annals, vol. 3, pp. 425–426, 428, 1905.

pan basin, about 8 miles northwest of Dillon. These rocks are now referred to the Kootenai.

JURASSIC AND TRIASSIC SYSTEMS.

A series of shales beneath the coarse conglomerate supposed to represent the base of the Cretaceous system is provisionally assigned to the Jurassic or Triassic or both. It occurs on Birch Creek, Canyon Creek, and Bighole River at the lower canyon.

A chocolate-brown limestone interbedded with thin layers of dark shales outcropping in the lower canyon of Bighole River southeast of McCarthy Mountain has been doubtfully referred by Douglass [1] to the Permian series on the evidence of a few fossils which he collected from the shales and which he thought correlated it with the Permo-Carboniferous of the Fortieth Parallel Survey. Later studies in Utah and Idaho, however, make it probable that these fossils are Lower Triassic. Rocks belonging to this horizon probably exist on and north of Birch Creek, but paleontologic evidence of their occurrence is not available.

CARBONIFEROUS SYSTEM.

PERMIAN (?) SERIES.

Rocks of probable Permian age have been recognized in the Dillon quadrangle in a limestone about 350 feet thick, containing shaly and cherty layers, which has been correlated by Richards and Mansfield [2] with the Phosphoria formation of eastern Idaho.

PENNSYLVANIAN (?) SERIES.

Beneath the strata correlated by Richards and Mansfield with the Phosphoria formation lies a massive gray sandstone or quartzite which has been tentatively correlated with the Quadrant formation of the Threeforks quadrangle and of Yellowstone Park, and which is regarded as probably of Pennsylvanian age. The quartzite weathers to a reddish-brown color, and includes some layers which are spotted or in a few places marked by small cavities apparently produced by leaching. A massive quartzite might be expected to be most resistant to weathering and to cap the highest ridges, but the underlying Madison limestone (Mississippian) actually occupies this position. The quartzite, however, shows its superior hardness and power to resist mechanical erosion by occupying the walls of the narrowest parts of canyons occurring in the lower canyon of the Bighole River, at the mouth of Birch Creek canyon, and elsewhere. On the east side of Jerry Creek the quartzite strikes north and dips steeply west.

[1] Douglass, E., op. cit., p. 426.

[2] Richards, R. W., and Mansfield, G. R., Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577 (in press).

MISSISSIPPIAN SERIES.

The Mississippian is represented in the Dillon quadrangle by the massive bluish-gray Madison limestone, which reaches a maximum thickness estimated at 1,200 feet. This is the formation which commonly occupies the highest ridges. Typical fossils were obtained from it in the Blue Wing district about 16 miles west of Dillon [1] and from the north end of the Ruby Range southwest of Laurin. The Madison limestone, dipping about 45° WSW., flanks the mountains just above the bench lands east of Melrose; it runs from the Blue Wing district across Rattlesnake Creek to Birch Creek; east of Jerry Creek it underlies the Quadrant (?) quartzite and probably extends southward into the Vipond district.

DEVONIAN SYSTEM.

The Threeforks shale of the Devonian has not yielded fossils, so far as known, from the Dillon region, but it is usually easily recognized by its position immediately below the Madison limestone. It occurs in the northern end of the Ruby Range; on the mountain flank east of Melrose, where it strikes north-northwest across Camp and Soap creeks and dips steeply to the west; on top of Lion Mountain in the Bryant or Hecla district, where it dips about 25° NW.; and on Birch Creek, where it dips southeast.

The Jefferson limestone, which according to Kindle [2] is of Middle and Lower Devonian age, is probably present at many localities in the Dillon quadrangle. It outcrops on Camp Creek, in the Bryant district, and at other localities. It is probably present on the western flank of the Tobacco Root Mountains near Point of Rocks; on the western flank and in places on the crest of the Ruby Range from the south end northward for probably at least 10 miles; and on the western flank of the mountains east of Melrose from the Melrose-Rochester road to Moose Creek.

SILURIAN (?) TO CAMBRIAN ROCKS.

On Camp Creek the Jefferson limestone is underlain by 200 to 300 feet of calcareous sandstone, but in the Bryant district and elsewhere in the Dillon quadrangle this sandstone is not present, and the Jefferson limestone is underlain by limestones. The sediments from the base of the Jefferson to the base of the Flathead quartzite are in large part, if not wholly, of Cambrian age, though some of them may range in age as late as the Silurian. The limestones above the Flathead quartzite occur on the western flank of the Tobacco Root Mountains from Point of Rocks to Dry Georgia Gulch, on the western flank and

[1] Douglass, E., op. cit., pp. 421–424.
[2] Kindle, E. M., Bull. Am. Paleontology, vol. 4, No. 20, pp. 23-24, 1908.

in places on the crest of the Ruby Range from the south end northward for probably at least 10 miles, and on the western flank of the mountains east of Melrose from the Melrose-Rochester road to Moose Creek. Limestones probably of the same age outcrop from the point where the Butte-Highland road crosses the Continental Divide eastward to a point about halfway between Moosetown and Divide. The same limestones form the country rock of the ore bodies at Hecla and probably extend northward into the Vipond district and the Fleecer Mountain area.

Trilobite fossils assigned to the Cambrian have been collected from these limestones in the Ruby Range by Douglass.[1]

Sufficient time was not spent by the writer in the study of these rocks to differentiate them into formations and to correlate them with the formations which have been distinguished by other writers in neighboring areas.

The Cambrian limestones are underlain by shales, which are in turn underlain by the massive Flathead quartzite. So far as known, these formations have not yielded fossils in the Dillon quadrangle. Walcott, however, states [2] that the Flathead quartzite of other areas contains a fairly well defined Middle Cambrian fauna, and the overlying shales in the adjoining Threeforks quadrangle contain fossils assigned by Peale [3] to the Middle Cambrian. The shales and the Flathead quartzite outcrop on the western slope of the Ruby Range; they occur in places on the western slope of the Tobacco Root Mountains; they are found in the mountains about 3 miles east of Melrose striking north-northwest and dipping steeply west-southwest; they are uncovered and partly eroded by the deeply incised valley of Trapper Creek near its head at Hecla; and they occur in the south end of the Bull Mountain Range northeast of Whitehall.

ALGONKIAN SYSTEM.[4]

BELT SERIES.

The shales, slates, and schists of the Belt series are nonfossiliferous. They occupy a large share of the upper portion of Red and Table mountains; they occur at the northern end of the Tobacco Root Mountains southeast of Renova and at the southern end of the Bull Mountains northeast of Whitehall; and they probably occur at the head of German Gulch, where beds of slates and thin-bedded quartzites have been provisionally assigned to the series. The formations

[1] Douglass, E., op. cit., p. 416.
[2] Walcott, C. D., U. S. Geol. Survey Mon. 51, pt. 1, p. 137, 1912.
[3] Peale, A. C., U. S. Geol. Survey Bull. 110, p. 22, 1893; U. S. Geol. Survey Geol. Atlas, Threeforks folio (No. 24), p. 3, 1896.
[4] See footnote on p. 23.

of the series which have been distinguished by other writers in neighboring areas were not differentiated in the present study of the Dillon quadrangle. According to Van Hise[1] the age of the Belt series is late Algonkian.

CHERRY CREEK GROUP.

Schists, gneisses, and quartzites, with interbedded limestones, which are correlated with the Cherry Creek of Peale as described in the Threeforks folio, occupy the whole southern end of the Tobacco Root Mountains from Dry Georgia Gulch and the head of Wisconsin Creek at least to Harris and Bivin gulches. It is thought probable that certain schists and gneisses (including no limestone beds) which occupy the Rabbit (Rochester) district, form a part of the Cherry Creek group. According to Van Hise[2] the age of the Cherry Creek group is early Algonkian.

ARCHEAN (?) SYSTEM.

Certain gneisses and schists, with interbedded quartzites and limestones, which occur in the Dillon quadrangle, are also found in the adjoining Threeforks quadrangle, where they were regarded by Peale as Archean. But as, in accordance with prevailing views, only such formations or groups of rocks as are wholly or almost wholly of igneous origin are included in the Archean, and as these gneisses and schists are interbedded with rocks more recognizably sedimentary than is usual in the Archean, they are regarded by the writer as more closely related to the Cherry Creek group of the Algonkian than to the Archean. The writer, however, is of the opinion that the Cherry Creek group may be underlain in the Dillon quadrangle by older rocks which belong to the Archean system.

IGNEOUS ROCKS.

The igneous rocks of the Dillon quadrangle include the quartz monzonite of the Boulder batholith (Butte quartz monzonite), frequently termed granite, and volcanic and intrusive rocks, such as rhyolite, aplite, quartz porphyry, andesite, andesite porphyry, and diorite, all probably related in origin to the batholith. Flows of basalt, whose relation to the quartz monzonite, if any, is not clear, and dikes of diorite porphyry and olivine diabase also occur. Outcrops of trachyte are so closely associated with rhyolite flows as to suggest a common origin.

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[1] Van Hise, C. R., and Leith, C. K., U. S. Geol. Survey Bull. 360, p. 46, 1909.

STRUCTURE.

The geologic structure of the Dillon quadrangle was determined largely by the intrusion from below of the great Boulder batholith, which seems to have penetrated by faulting or thrusting, or by assimilation of material, or by updoming important areas in the quadrangle in Tertiary time, or, more probably by a combination of all these processes.

The batholith seems to form the core of nearly all the mountains and mountain ranges of the region. In the Dillon quadrangle it outcrops along the Continental Divide everywhere except at the head of German Gulch and near Red Mountain, where remnants of Paleozoic limestones and Belt (?) slates appear. It is reported from Granulated Mountain; it exists beneath the limestones and quartzites of Fleecer Mountain; it cuts through the Belt series and outcrops near the summits of Red and Table mountains; it occupies the region of Mount Torrey at the head of Birch and Willow creeks; it is seen again on the upper parts of McCarthy Mountain; it occupies the heart of the Tobacco Root Mountains from Revenue westward to Jefferson Peak and Bear Gulch, and it underlies the limestones and older rocks of the Ruby Range. That the granitic or monzonitic cores of these mountains are all derived from the same batholith is not yet demonstrated, though such a condition seems quite possible from their known areal distribution and their petrographic similarity. All the available evidence indicates that they came to their present positions during the same geologic period (the Tertiary), but whether simultaneously or not is unknown.

PETROGRAPHY.

The igneous rocks of the Dillon quadrangle include a wide range of types. In addition to the Boulder batholith of quartz monzonite with its varying facies, extrusive equivalents, and differentiation products, there are independent intrusions and extrusions of andesite, basalt, pyroxenite, and other rocks. In this paper the igneous rocks are discussed in the order and in accordance with the terminology used in a classification recently published by the writer.[1]

PLUTONIC ROCKS.

GRANITE.

True granite is rare in the Dillon quadrangle. The quartz monzonite of the Boulder batholith is often called granite, but it is well known that such a designation is not correct.

Granite is found in the Rabbit district near Rochester, but it occurs there in the form of dikes and sills rather than in that of larger

[1] Rock classification on three coordinates: Jour. Geology, vol. 21, pp. 208-223, 1913.

intrusions such as batholiths. At this locality it contains abundant quartz and microcline, a little plagioclase, some orthoclase inclosing small patches of muscovite, a very little biotite, and traces of other minerals. Its texture is typically granitic. This rock is the granite proper of Rosenbusch, for it contains both micas; for the same reason it is the binary granite of Keyes;[1] on the other hand it contains so little of the micas that they may readily be looked upon as unessential, and the rock may be considered an example of Spurr's alaskite,[2] although alaskite commonly contains no plagioclase and is therefore regarded as an alkaline rock.

About 8 miles north and a little east of Whitehall is another small dikelike intrusion of granite which contains much orthoclase, considerable quartz, and a little plagioclase, with notable amounts of epidote, chlorite, augite, magnetite, and titanite. Much of the quartz is in micrographic intergrowths with orthoclase. This is an epidote granite, perhaps originally an augite granite, and is clearly much less siliceous than the granite near Rochester.

At Hecla a siliceous facies of the quartz monzonitic or an independent intrusion furnishes another granite, in which quartz is abundant, partly in micrographic intergrowth with microcline, orthoclase is also abundant, and plagioclase is very scanty. The dark minerals include only biotite and magnetite, which by alteration yield chlorite and rutile. Zircon crystals produce pleochroic halos in the biotite. The feldspars are partly altered to sericite. This rock is a fine-grained biotite granite or granitite.

TONALITE.

At Dewey, on Bighole River, where the quartz monzonite batholith comes in contact with limestone, a narrow zone of the intrusive rock is distinctly less siliceous and darker colored than the main body. This rock, which contains abundant plagioclase, green hornblende, and biotite, some quartz, a little orthoclase, and accessory magnetite, zircon, and epidote, is classed as tonalite (quartz diorite). The feldspar has cores flecked with sericite and surrounded by the unaltered mineral. Another sample from the same locality is somewhat darker and contains abundant plagioclase, brown hornblende, and biotite, with a little quartz, orthoclase, chlorite, magnetite, and apatite.

A dike in the Beal mine, at the head of German Gulch, consists of tonalite, in which the plagioclase crystallized early in euhedral to subhedral forms, the interstices being filled with ferromagnesian minerals and quartz. The ferromagnesian constituents are green hornblende, brown biotite, and magnetite. Titanite is more abundant

[1] Keyes, C. R., U. S. Geol. Survey Fifteenth Ann. Rept., p. 714, 1895.

[2] Spurr, J. E., Am. Geologist, vol. 25, pp. 210, 229, 1900; U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 189, 195, 1900.

than is general. Apatite needles are not common. Very small zircon crystals produce pleochroic halos in the dark silicates.

GRANODIORITE.

Assuming a total feldspar content of 60 per cent, Lindgren[1] has defined tonalite (quartz diorite) as a plutonic rock containing less than 8 per cent of alkali feldspar, granodiorite as containing 8 to 20 per cent, quartz monzonite as containing 20 to 40 per cent, and granite as containing more than 40 per cent. The percentage of alkali feldspar can not be accurately determined by analysis, because potash may enter the plagioclase or soda may enter the orthoclase, but must be obtained by direct microscopic measurements.

Granodiorites form an important group of rocks, which constitute large intrusions in California and elsewhere. In the Dillon quadrangle the chief intrusion is monzonitic, but granodioritic phases exist in the area and independent intrusions of granodiorite occur in neighboring regions.

On a fork of Mill Creek, locally known as Bridges Canyon, a small intrusion penetrates pre-Cambrian limestone and schists. In the same locality, near Sheridan, occur two intrusive rocks, an andesite and a granodiorite. The latter consists of dominant plagioclase, some orthoclase, quartz, green hornblende, chlorite, magnetite, notable titanite, little augite, and apatite. Much of the plagioclase is zonal.

In the Potosi mining district, diagonally across the Tobacco Root Mountains from Mill Creek, a porphyritic quartz monzonite intrusive varies locally to granodiorite. This rock is darker colored than the normal quartz monzonite and contains more ferromagnesian constituents. It consists of dominant plagioclase, orthoclase, quartz, abundant biotite, chlorite, hornblende, magnetite, titanite, apatite, and epidote.

At Bannock a small stock penetrating Paleozoic limestone seems to be chiefly granodiorite with tonalite phases; locally it has been called syenite. The quartz is not abundant and the feldspar is chiefly zonal plagioclase with some optically abnormal orthoclase. The dark constituents are magnetite, biotite, hornblende, and augite. The magnetite is unusually abundant; much of it is surrounded by biotite. The gold mines of Bannock are located along the contact between this rock and the limestone.

It is interesting and probably significant that the Marysville stock, which is considered by Barrell to be a related outlier of the Boulder batholith, should consist of the same rock type as the Bannock intrusive, which may likewise be regarded as an outlier of this batholith,

[1] Lindgren, Waldemar, Am. Jour. Sci., 4th ser., vol. 9, pp. 269–282, 1900.

from which it is separated by a distance of about 15 miles. Bannock is south of the Boulder batholith, and Marysville is about 6 miles north of it.

QUARTZ MONZONITE.

The Boulder batholith of quartz monzonite extends southward from Butte to Pipestone Springs, Silver Star, Highland, and Moose Creek and nearly to Feely. It is highly probable that it extends continuously westward beneath Tertiary deposits beyond Feely to the area occupied by the same rock about the headwaters of Divide Creek and over the Continental Divide northwestward across German Gulch into the Philipsburg quadrangle. Bighole River forms a canyon in quartz monzonite from Dewey for 3 miles eastward. Isolated areas of the same rock are found along Moose Creek, on the west slope of Table Mountain, at Argenta, and on McCarthy Mountain south of McCarthy Creek. A larger area of the same rock extends from Hecla south to Birch Creek and westward to Elkhorn and Polaris. Finally an area of porphyritic quartz monzonite similar to the porphyritic phase occurring at the Gagnon mine in Butte occupies the surface from the region of Norris and Meadow Creek west-northwest to Mammoth and the sources of South Willow Creek. The intrusion on Bear Gulch serves as a connecting link between this area and the main Boulder batholith at Silver Star. Other small intrusions of the same type occur on Mill Creek and near the head of Goodrich Gulch.

The varieties of quartz monzonite found in these areas are characterized by muscovite, or by biotite, or by biotite and muscovite, or by biotite and hornblende, or by augite, hornblende, and biotite.

The first variety, as found in the Potosi district, is highly siliceous and resembles granite. It contains much quartz and feldspar, more orthoclase than plagioclase, and very subordinate muscovite, titanite, magnetite, and chlorite.

Biotite-quartz monzonite outcrops at Hecla. It contains large orthoclase anhedra poikilitically inclosing other minerals. The plagioclase is sericitized and the biotite partly altered to chlorite; other secondary minerals include epidote and zoisite. The rock contains also a little brown hornblende, titanite, and apatite. It resembles quite closely the quartz monzonite at Butte in the first stage of its alteration. The same type forms the country rock in the Elkhorn district, where the poikilitically inclosed minerals include euhedral plagioclase, biotite, apatite, epidote, magnetite, and pyrite; the rock contains also a little chlorite and apparently a little augite.

A porphyritic biotite-quartz monzonite is the country rock of the Madisonian mine near Norris. In this type very large orthoclase phenocrysts poikilitically inclose oligoclase, quartz, biotite, titanite, magnetite, chlorite, zircon, and apatite. The titanite shows some alteration to a cloudy material resembling leucoxene.

Porphyritic biotite-muscovite-quartz monzonite is the country rock of the Revenue mine near Norris. It contains quartz, orthoclase, plagioclase, biotite, muscovite, titanite, apatite, magnetite, and epidote. This is a siliceous rock related to granite, orthoclase being in excess of plagioclase. Another sample of the same rock type was obtained in the Potosi district, which is located within the area of the same monzonitic boss. The Potosi rock contains much quartz, abundant orthoclase and plagioclase, little biotite and muscovite, and scanty titanite, leucoxene, magnetite, and zircon. The plagioclase is much sericitized; the orthoclase is slightly kaolinized.

Biotite-hornblende-quartz monzonite is the country rock at the Cayuga shaft near Divide. In this rock the orthoclase and plagioclase are nearly equal in amount; the optically abnormal orthoclase incloses poikilitically euhedral to subhedral zonal plagioclase ranging from labradorite within to andesine-oligoclase on the borders. The other minerals include quartz, abundant brown and green biotite, some green hornblende, a little magnetite, rare zircon prisms, and apatite needles. Rock of the same type occupies the top of McCarthy Mountain, where it contains more hornblende and magnetite than the rock near Divide. The andesine is somewhat sericitized and the rock contains a little serpentine. In biotite-hornblende-quartz monzonite from the Pittsmont mine (analysis 6) orthoclase is in part intergrown in pegmatitic fashion with quartz, the plagioclase is zonal, and both feldspars are flecked with sericite and kaolinite. The hornblende is more altered than the biotite. Alteration products include epidote, quartz, and calcite(?). Apatite is more abundant than is usual in the rocks of Butte.

Porphyritic biotite-hornblende-quartz monzonite occurs in the heart of the Butte district, as at the new shaft of the Gagnon mine. It was mentioned by Weed[1] as a common variant of the prevailing nonporphyritic type, and it is said to be more abundant with increasing depth. Its relation to the nonporphyritic type has not yet been certainly determined, but no evidence indicating a separate origin has been noted. The orthoclase phenocrysts reach a size of about an inch; plagioclase, slightly sericitized, is abundant; the other constituents are quartz, biotite, hornblende, magnetite, titanite, apatite, chlorite, zircon, and epidote.

Augite-biotite-hornblende-quartz monzonite is the type composing the Boulder batholith at Silver Star; it contains dominant plagioclase and is related to granodiorite. The orthoclase and quartz fill interstices between plagioclase, hornblende, biotite, and augite. Biotite

[1] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Butte special folio (No. 38), p. 1, 1897.

seems to wrap itself around altered augite. The accessory minerals include magnetite, titanite, clinochlore, and epidote. The same rock type is reported at Red Rock Creek and in the Elkhorn district in Jefferson County.

Analyses of several of these types of quartz monzonite are given below. Two (Nos. 6 and 7) are from the Dillon quadrangle; the others are from adjoining regions.

Analyses of quartz monzonite from Dillon quadrangle and adjacent areas.

	1	2	3	4	5	6	7	8	9
SiO_2	63.88	64.05	64.34	63.87	62.36	68.54	63.73	64.31	65.78
Al_2O_3	15.84	15.38	15.72	15.39	15.68	14.43	13.67	15.44	15.71
Fe_2O_3	2.11	2.20	1.62	1.93	1.93	2.03	6.31	2.43	1.83
FeO	2.59	2.74	2.94	3.08	2.81	1.75	2.13	2.58	2.22
MgO	2.13	2.08	2.17	2.23	2.17	1.76	2.43	2.21	1.57
CaO	3.97	4.30	4.24	4.30	4.27	3.58	2.80	4.22	3.76
Na_2O	2.81	2.74	2.76	2.76	2.59	2.18	2.04	2.71	3.35
K_2O	4.23	4.00	4.04	4.18	4.44	4.47	5.36	4.09	3.80
H_2O-	.22	.27	.25	.19	.85	.07	.31	.19	1.17
H_2O+	.66	.83	.76	.69	1.09	.64	1.01	.79	
TiO_2	.65	.60	.53	.65	.78	.42	.27	.71	.53
ZrO_2	....	(?)	.02	.03	....	....	....	....	....
CO_2	....	.35	.03	.15	.29	....	....	....	....
P_2O_5	.21	.21	.14	.17	.15	....	Trace.	.22	.18
SO_3	.34	....	....	....	....	....	....	....	....
Cl	Trace.	....	....	....	....	....	....	....	....
MnO	.07	.11	.12	.11	.08	....	.10	Trace.	.10
SrO	.02	.04	.03	.04	.04	....	.00	Trace.	....
BaO	.09	.08	.06	.07	....	....	.00	.07	....
Li_2O	Trace.	Trace.	Trace.	Trace.	....	....	....	Trace.	....
	99.82	100.05	99.80	99.91	100.14	99.87	100.28	99.97	100.00

1. Biotite-hornblende-quartz monzonite, Walkerville, Butte, Mont. W. H. Weed, Jour. Geology, vol. 7, p. 739, 1899. H. N. Stokes, analyst.
2. Biotite-hornblende-quartz monzonite, Gagnon mine, Butte, Mont. W. H. Weed, loc. cit. With 0.07 FeS_2, 0.005 Cu. W. F. Hillebrand, analyst.
3. Biotite-hornblende-quartz monzonite, Atlantic mine, Butte, Mont. W. H. Weed, loc. cit. With 0.03 FeS_2, 0.005 Cu. W. F. Hillebrand, analyst.
4. Biotite-hornblende-quartz monzonite, Alice mine, Butte, Mont. W. H. Weed, loc. cit. With 0.07 FeS_2, 0.005 Cu. W. F. Hillebrand, analyst.
5. Biotite-hornblende-quartz monzonite, Pittsmont mine, Butte, Mont. C. T. Kirk, Econ. Geology, vol. 7, p. 41, 1912. With 0.56 FeS_2, 0.04 Cu. N. N. Blye, analyst.
6. Biotite-hornblende-quartz monzonite, Homestake, Dillon quadrangle, Mont. C. T. Kirk, loc. cit. With trace FeS_2, 0.00 Cu. C. T. Kirk, analyst.
7. Biotite-hornblende-quartz monzonite, Timbered Butte, Dillon quadrangle, Mont. C. T. Kirk, loc. cit. L. J. Hartzell, analyst.
8. Augite-biotite-hornblende-quartz monzonite, Elkhorn, Jefferson County, Mont. J. S. Barrell, U. S. Geol. Survey Twenty-second Ann. Rept., pt. 2, p. 511, 1901. H. N. Stokes, analyst.
9. Average composition of 25 quartz monzonites from data of Clarke, U. S. Geol. Survey Bull. 419, 1910; and Rosenbusch, Elemente der Gesteinslehre, p. 123, 1910.

The normative mineral composition, as calculated from the chemical analyses according to the rules proposed by Cross, Iddings, Pirsson, and Washington and used by them in the quantitative classification of igneous rocks, may be stated as follows:

Normative mineral composition of quartz monzonites from Dillon quadrangle and adjacent areas.

	1	2	3	4	5	6	7	8	9
Quartz	19.3	20.0	20.0	18.8	18.0	28.4	22.3	20.7	21.2
Orthoclase	25.0	23.4	23.4	24.8	26.0	26.4	31.6	24.2	22.4
Albite	23.8	23.2	23.4	23.4	22.0	18.5	17.0	23.0	28.4
Anorthite	18.1	20.6	18.9	17.2	17.9	16.3	12.4	17.8	16.4
Diopside	.7	.8	1.9	2.8	1.9	1.2	1.2	1.6	.8
Hypersthene	6.8	5.2	7.7	7.7	6.8	4.7	5.5	6.4	5.4
Magnetite	3.0	3.2	2.3	2.8	2.8	2.9	6.4	3.5	2.7
Hematite							1.8		
Ilmenite	1.2	1.2	1.1	1.2	1.5	.8	.5	1.4	1.0
Pyrite	.3								
Apatite	.5	.5	.3	.4	.4			.5	.4
(Water, etc.)	.9	1.5	1.0	1.0	2.8	.7	1.3	1.0	1.2
	99.6	99.6	100.0	100.1	100.1	99.9	100.0	100.1	100.0

Calculation from the norm shows that the average quartz monzonite (9) is toscanose-amiatose in the quantitative classification, and that the common rock of the Boulder batholith is harzose, as illustrated by the samples from the Atlantic (3), Alice (4), and Pittsmont (5) mines at Butte and from the Elkhorn district (8). The rock at Walkerville (1) is somewhat more felsic, being amiatose-harzose, and that at the Gagnon mine (2) and at Homestake (6) is amiatose. The rock from Timbered Butte (7) is a representative of a rare and unnamed type (II.4.2.3,2), closely related to adamellose.

The actual mineral composition (mode) is even more important than the norm calculated from analyses and is often strikingly different from the latter. It is not easily determined, but it may be approximated by measurements made microscopically or by calculations from rock analyses, provided analyses of such minerals as augite, hornblende, and mica from the given rock are available. By these methods the approximate mode has been obtained for some of these rocks, as follows:

Approximate modal mineral composition of quartz monzonites from Dillon quadrangle and adjacent areas.

	1	4	6	8	9
Quartz	22.9	22.5	30.4	25.0	23.7
Orthoclase (sodic)	21.1	22.4	21.2	22.0	28.4
Andesine	37.0	33.9	32.7		32.2
Labradorite				34.0	
Biotite	10.9	10.9	9.0	7.0	9.1
Hornblende	3.6	7.2	5.3	9.0	3.1
Augite				2.0	
Magnetite	1.9	1.5		1.0	1.8
Hematite			1.3		
Ilmenite	.5				
Titanite		.4	.1	.5	.6
Apatite	.3	.3		.3	.4
Calcite		.3			
(Water, etc.)	1.1	.5	.1		.7
	99.3	99.9	100.1	100.8	100.0

For the quartz monzonite from Butte and vicinity (Nos. 1, 4, 6) the analyses of biotite and hornblende from this rock at Butte [1] have been used. The mineral composition of the rock (1) from Walkerville (Butte) was calculated by Cross, Iddings, Pirsson, and Washington,[2] whose results are here modified to show the amount of andesine ($Ab_{55}An_{45}$) and sodic orthoclase actually present instead of the pure molecules orthoclase, albite, and anorthite. The mineral composition of the other rocks (4, 6, 8) is derived from the chemical analyses by assigning all the magnesia to biotite and hornblende in the ratio required to prevent surplus of either lime or alumina in forming feldspars. For analysis 4 this ratio is 3 to 2, for analysis 6 it is 5 to 3, for the average analysis (9) it is 3 to 1. The plagioclase is in all cases calculated to andesine ($Ab_{55}An_{45}$) and the surplus soda added to the orthoclase. In calculating the mineral composition of average quartz monzonite (9) the same process has been used, but analyses of biotite and hornblende from this rock type from California[3] have been found more satisfactory than those from Butte. The mineral composition of the quartz monzonite from Elkhorn (8) was determined by Barrell[4] from microscopic measurements.

It may be noted that although in all the rocks here considered quartz is important, ranging from 20 to 30 per cent, and alkali feldspar is prominent, amounting to 21 to 31 per cent, plagioclase is the most abundant constituent, varying from 30 to 40 per cent. The quartz monzonite from Timbered Butte (No. 7) is unlike the other rocks included here in its high content of orthoclase and biotite, low plagioclase, total lack of magnetite and titanite, and nearly 2 per cent of hematite. The hemitite is probably not present as such in the rock but indicates a biotite or hornblende containing much ferric iron. In general these quartz monzonites contain 7 to 9 per cent of biotite, 3 to 9 per cent of hornblende, 1 to 2 per cent of magnetite, and small quantities of titanite and apatite.

DIORITE.

The rocks of the Dillon quadrangle include some diorites, but these are not common and most of them are local phases of other rocks, especially of monzonites. At the contact of the batholith with limestone near Dewey the rock seems to be chiefly tonalite, but at the contact near Highland diorite occurs. The diorite, which is somewhat finer grained than the quartz monzonite of the batholith, contains abundant green hornblende, zonal plagioclase, a little orthoclase filling interstices, rare brown biotite, and very little quartz, magne-

[1] Weed, W. H., Jour. Geology, vol. 7, p. 743, 1899.
[2] Quantitative classification of igneous rocks, p. 224, 1903.
[3] Idem, d, Table XIV, and a, Table XIII, 1903.
[4] Barrell, Joseph, U. S. Geol. Survey Twenty-second Ann. Rept., pt. 2, p. 511, 1901.

tite, and apatite. An analysis of this rock was made for W. H. Weed, but the mode can not be calculated because of lack of analyses of constituent minerals. From the norm it appears that the rock is andose in the quantitative classification.

Composition of diorite from Red Mountain, near Highland, 10 miles south of Butte.[1]

[H. N. Stokes, analyst.]

		NORM.	
SiO_2	56.41	Quartz	4.9
Al_2O_3	17.62	Orthoclase	15.0
Fe_2O_3	1.24	Albite	28.3
FeO	3.55	Anorthite	25.9
MgO	3.97	Diopside	12.0
CaO	8.66	Hypersthene	8.7
Na_2O	3.35	Magnetite	1.6
K_2O	2.61	Ilmenite	1.2
H_2O-	.14	Apatite	1.0
H_2O+	.76	(Water)	.9
TiO_2	.68		
P_2O_5	.49		99.5
MnO	Trace.		
	99.70		

GABBRO.

So far as known gabbro occurs in only one locality in the Dillon quadrangle—on the Richmond claim, in the Highland district—where it is apparently an unusual marginal variation of the Boulder batholith and has very exceptional mineral composition. The essential plagioclase and monoclinic pyroxene are abundant, but the usual accessory minerals (magnetite, ilmenite, pyrrhotite, apatite) are very rare or absent. In their place titanite is remarkably abundant. In harmony with the abundance of lime thus indicated the plagioclase present is bytownite. No analysis of this rock is available.

PYROXENITE.

Plutonic igneous rocks containing neither essential feldspar (or feldspathoid) nor olivine usually consist chiefly of pyroxene and are called pyroxenite or perknite. Such a rock occurs on the divide between Granite and South Meadow creeks near the Washington mining district. It outcrops in a small area in the midst of gneiss and is regarded as probably a small volcanic neck. The rock is crystalline and granular, being composed of hypersthene anhedra embedded in finer-grained greenish hornblende with a little magnetite. A few euhedral hornblendes are inclosed by hypersthene. This variety of pyroxenite, which is essentially composed of orthorhombic pyroxene

[1] Weed, W. H., Jour. Geology, vol. 7, p. 739, 1899. With 0.07 Cl, 0.08 SrO, 0.09 BaO. Washington, H. S., U. S. Geol. Survey Prof. Paper 14, p. 273, 1903.

and hornblende, has received no distinctive name and is very rare. As appears below, the percentage of hypersthene in the norm is very striking. In the quantitative classification this rock is cookose.

Composition of pyroxenite.

	1	2		1	2
SiO_2	51.83	49.82	NORM.		
Al_2O_3	7.98	5.12			
Fe_2O_3	1.48	1.83	Orthoclase	0.5	1.2
FeO	8.28	7.44	Albite	3.1	3.1
MgO	24.10	19.55	Anorthite	19.7	11.6
CaO	5.26	13.00	Diopside	5.1	41.0
Na_2O	.35	.37	Hypersthene	61.1	30.0
K_2O	.06	.21	Olivine	7.6	6.7
H_2O	.29	1.06	Magnetite	2.1	2.6
TiO_2	.29	1.46	Ilmenite	.5	2.8
P_2O_5	.09	.05	Apatite	....	.1
MnO	Trace.	.09	(Water, etc.)	.3	1.0
	100.43	100.00		100.0	100.1

1. Pyroxenite, divide between Granite and South Meadow creeks, Mont. Merrill, G. P., U. S. Nat. Mus. Proc., vol. 17, p. 658, 1895. With 0.31 Cr_2O_3, 0.11 NiO. L. G. Eakins, analyst.
2. Average composition of four pyroxenites. Daly, R. A., Am. Acad. Proc., vol. 45, p. 226, 1910.

PERIDOTITE.

A plutonic igneous rock which contains olivine, usually with pyroxene or amphibole but with no essential feldspar not feldspathoid, is called a peridotite from the French name (peridot) for olivine. Such a rock outcrops on the land of the Crystal Graphite Co. in the Ruby Range, southeast of Dillon. It consists essentially of colorless augite, very pale green hornblende, and a slightly greenish mineral of very large optic angle, positive sign, high relief, and no cleavages, which is probably olivine in spite of the fact that the highest interference color given by it is orange-yellow. The rock contains also a little magnetite, hematite, and strongly birefringent serpentine but shows very little alteration.

A peridotite intrusive in gneiss in the hills 3 miles northwest of Red Bluff (near Norris) was analyzed for Merrill. The results are given below. It contains olivine, diallage, brown mica, rare plagioclase, and secondary black iron oxides. Its texture is variable, with larger anhedra in the midst of smaller anhedra of the same minerals, and with broad plates of diallage poikilitically inclosing olivine and mica. In the quantitative classification this rock is wehrlose. Another dike cutting gneiss near North Meadow Creek contains rounded olivine poikilitically inclosed in large plates of pale-green hornblende, rare hypersthene, and grains of pleonaste and iron oxides. The rock has been called hornblende picrite by Merrill, but it is clearly not extrusive in origin and is therefore a hornblende peridotite or a cortlandtite. This rock also is wehrlose in the quantitative nomenclature.

Chemical composition of peridotite.

	1	2	3		1	2	3
SiO_2	44.39	48.95	46.13	NORM.			
Al_2O_3	5.14	5.69	4.69				
Fe_2O_3	3.88	1.20	.73	Orthoclase	4.5	4.7	....
FeO	6.70	12.11	16.87	Albite	5.4	13.4	0.5
MgO	29.17	23.49	25.17	Anorthite	8.9	6.1	12.5
CaO	6.31	5.33	4.41	Diopside	16.7	15.3	7.6
Na_2O	.64	1.58	.08	Hypersthene	11.1	17.8	44.8
K_2O	.76	.79	Trace.	Olivine	44.1	38.8	30.4
H_2O	1.80	.18	1.38	Magnetite	5.6	1.8	.9
TiO_2	.88	.81	.73	Ilmenite	1.6	1.5	1.2
P_2O_5	.14	.12	.07	Apatite	.3	.3	.2
MnO	.19	.08	Trace.	(Water, etc.)	1.8	.2	1.7
	100.00	100.54	100.51		100.0	99.9	99.8

1. Average composition of 49 peridotites. Daly, R. A., Am. Acad. Proc., vol. 45, p. 226, 1910.
2. Peridotite (wehrlite), hills 3 miles northwest of Red Bluff, Mont. Merrill, G. P., U. S. Nat. Mus. Proc., vol. 17, p. 652, 1895. With 0.05 Cr_2O_3, 0.16 NiO, trace BaO. L. G. Eakins, analyst.
3. Hornblende peridotite or cortlandtite, North Meadow Creek, Mont. L. G. Eakins, analyst. Merrill, G. P., loc. cit., p. 655. With 0.04 Cr_2O_3, 0.09 NiO, trace BaO, 0.24 S; sum is 100.63, from which the oxygen equivalent of S (=0.12) is deducted. Washington, H. S., U. S. Geol. Survey Prof. Paper 14, p. 355, 1903.

HYPABYSSAL OR DIKE ROCKS.

QUARTZ MONZONITE PORPHYRY.

On South Boulder Creek near Mammoth a granitic rock in dikes contains large phenocrysts of plagioclase, orthoclase, and hornblende, with anhedra of quartz in a finely granular groundmass of quartz and feldspar. The quartz phenocrysts have been so far resorbed that they no longer have crystal outlines but are rounded and present embayments, although the matrix present is very siliceous. In this rock the plagioclase is more abundant than the orthoclase phenocrysts, and the rock is closely related to granodiorite porphyry. The porphyritic quartz monzonite of the Potosi, Norris, and Butte districts has not been observed in dikes.

APLITE.

Closely associated with the Boulder batholith are many aplitic intrusions, most of which aré in dikes and the rest in irregular bodies called chonoliths. The aplites are much more abundant and much larger than the lamprophyres and diorites associated with the same batholith, and if the magma was differentiated into two complementary parts the aplitic phase must have been much the greater in bulk.

Aplite dikes and chonoliths are common in the Butte district and have been mapped and described by Weed.[1] Similar dikes are associated with quartz monzonite batholiths or stocks in the region of Silver Star, near Highland, in Soap Gulch, at Hecla, in the Elkhorn

[1] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Butte special folio (No. 38), 1897; Jour. Geology, vol. 7, p. 744, 1899.

district, near Pony, in the Mineral Hill and Potosi districts, and in Browns Gulch, near Virginia City. Some of these rocks differ from granites in mineral composition only in containing a very small proportion of femic minerals; others contain as much plagioclase as orthoclase and are properly regarded as quartz monzonite aplite.

The dikes in the Elkhorn district (Beaverhead County) illustrate granite aplite or aplite proper. They contain dominant microcline, with very little biotite and magnetite; their texture is typically aplitic, with the components very similar in size, nearly equidimensional, and euhedral to subhedral in form. In the Potosi district the aplite contains much quartz and orthoclase, with some plagioclase, largely converted into sericite. Apparently the rock contains also a little original muscovite and fluorite, as well as fluorite and pyrite of later origin. Another sample from the same district consists of abundant quartz and orthoclase with some partly sericitized plagioclase, a few crystals of zircon, and granular aggregates of a mineral resembling a dark-colored epidote.

The ordinary aplite of this region consists of 35 to 40 per cent of quartz, 40 to 47 per cent of soda orthoclase, and 10 to 20 per cent of sodic plagioclase, with trifling amounts of biotite, magnetite, and other minerals. It contains more quartz and feldspar and less mica and amphibole than granite.

APLITE PORPHYRY.

A rock composed of orthoclase and quartz, with some plagioclase and very little mica, forms dikes in the Butte district, and has been called quartz porphyry by Weed.[1] It is characterized by quartz phenocrysts commonly inclosed in still larger orthoclase crystals, which are surrounded by a finely crystalline groundmass. This rock may be designated an aplite porphyry, its aplitic character being shown in its mineral composition, its mode of occurrence, and its texture.

PEGMATITE.

The aplite of the Boulder batholith varies locally to pegmatitic phases. Such rocks may be found in special abundance on Timber Butte, about 2 miles south of Butte. They commonly contain coarsely crystalline feldspar and quartz, with some tourmaline and mica. The coarseness of crystallization is believed to be due to the decrease of viscosity resulting from the presence of such volatile constituents of tourmaline and mica as boron and fluorine. Similar pegmatites are associated with minor ore deposits at Hecla, and have been observed on South Boulder Creek at the Bismark mine, about 4 miles above Mammoth. Pegmatite without tourmaline is found at the Strawberry mine, near Pony.

[1] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Butte special folio (No. 38), p. 2, 1897.

ALKALIAPLITE.

Aplitic dike rocks, which consist essentially of quartz and alkali feldspar, without soda-lime feldspar, have been called alkaliaplite by Rosenbusch. Most of them contain also more or less acmite or arfvedsonite; a few contain no such minerals. A rock outcropping in a large dike at the head of Goodrich Gulch in the Tidal Wave district consists of phenocrysts of orthoclase largely altered to kaolinite, sericite, and amorphous material (opal) in a matrix of fine-grained quartz and orthoclase with some sericite, hematite, kaolinite, and chlorite. In the absence of soda-lime feldspar this rock is referred to alkaliaplite, though it contains no soda pyroxene or soda amphibole.

MINETTE.

At the silver-lead mines at Hecla the dolomitic limestone country rock is cut by subsiliceous dikes of two wholly different types, basalt and minette (dike No. 3). The minette is composed largely of orthoclase and biotite with small amounts of clinoenstatite, titanite, pyrite, and chlorite, and apparently a little quartz. It sparkles with scales of black mica like a mica schist but has no distinct lamination. Its texture is fine, granular, and compact.

BOSTONITE.

Fine-grained dike rocks composed almost wholly of alkali feldspar, commonly orthoclase, have been called bostonite. A dike in the Rabbit district at Rochester consists of orthoclase of somewhat variable grain. The other constituents include dustlike particles, probably magnetite, and a little obscure chloritic material. The rock has been granulated by movement; even the cementing material is orthoclase in very fine granular condition. No analysis is needed to give the composition of this rock, which is that of orthoclase, probably with soda.

A dike at the head of Goodrich Gulch in the Tidal Wave district is chiefly orthoclase with a little interstitial quartz and rare crystals of titanite. Alteration products, which are especially abundant in the rare feldspar phenocrysts, include sericite, hematite, and epidote. This rock may be called a quartz bostonite.

PLAGIAPLITE.

Dike rocks rich in light-colored siliceous minerals, especially plagioclase, are known as plagiaplite; they commonly contain also a little mica or hornblende. At the Lehigh mine, in the Washington district near Norris, a narrow dike is occupied by a white rock composed chiefly of plagioclase with some quartz, a little muscovite, and apparently a little orthoclase. In addition to primary muscovite there are flakes of secondary sericite and rare grains of hematite.

TONALITE APLITE.

Plagiaplites which contain notable amounts of mica or amphibole are known as tonalite aplites. A rock of this type fills a dike at the Green Campbell mine in the Silver Star district. It contains abundant phenocrysts of plagioclase and quartz in an aplitic groundmass of quartz, magnetite, biotite, muscovite, plagioclase, epidote, and chlorite.

QUARTZ MONZONITE APLITE.

Aplitic dike rocks containing quartz and nearly equal amounts of orthoclase and plagioclase are known as quartz monzonite aplite; most of them contain minor quantities of amphibole, mica, or pyroxene. A dike at the Revenue mine near Norris is of this type, a sample from it consisting of quartz, orthoclase, plagioclase, and some muscovite, the soda-lime feldspar being partly sericitized. The texture is aplitic and poikilitic. At the Boaz mine in the same district a very similar rock, partly kaolinized, occurs in dikes. The country rock of the Easton mine is a large dike or chonolith of similar type. It contains quartz, microcline, orthoclase, sericitized plagioclase, and a little muscovite.

VOLCANIC ROCKS.

RHYOLITE.

Volcanic rocks containing dominant alkali feldspar and quartz with some soda-lime feldspar are called rhyolite or liparite. Such rocks are abundant in the Dillon quadrangle. A large area of rhyolite forms the bluffs west of Beaverhead River near Dillon and occurs also in the Fryingpan basin about 6 miles northwest of Dillon. These two outcrops were probably once connected, and they are perhaps still connected beneath the "lake beds" that now separate them. Smaller areas occupied by rhyolite are found in the Blue Wing district; near Pipestone, in the Sheridan district; at the Birdie mine, near Norris, and elsewhere. Rhyolite is also one phase of the volcanic flows of Butte, which extend southwestward into the Dillon quadrangle and thence westward and northwestward across German Gulch and its tributaries. These flows are in large part quartz latite, but they vary to rhyolite on the one hand and to dacite on the other.

The variations in mineral composition are not wide; some types are almost wholly without micas and dark minerals, others contain muscovite, others biotite, and others hornblende. The variations in texture include pyroclastic, felsitic, and porphyritic, and in porphyritic types the groundmass varies from glassy to holocrystalline.

Rhyolite without ferromagnesian constituents is commonly rich in glassy groundmass, and the elements which would form ferromagnesian minerals under favorable conditions are probably hidden in the rock glass. Thus, such a rhyolite forms a dike near the New Departure mine in the Blue Wing district; it is partly pyroclastic in texture. A similar pyroclastic rhyolite, much brecciated, forms a conspicuous rocky hill near the Birdie mine, in the Norris district. A semivitreous grayish-white rhyolite made up of mingled flows and ash, which is used for building stone in Dillon and Butte, has been quarried from bluffs in the Fryingpan basin about 6 miles northwest of Dillon.

A very fine grained muscovite rhyolite containing few phenocrysts occurs in the Blue Wing district near the Kent mine. The muscovite seems to be in part primary and is clearly in part of later origin; quartz is not abundant; other constituents include magnetite, hematite, and pyrite. In the Sheridan district veins which are now being prospected by the Cornelia Mining Co. penetrate a similar rock, which contains quartz, orthoclase, rare plagioclase, muscovite, and rock glass.

Biotite rhyolite forms a dike now surrounded by "lake beds" near Pipestone Springs; it consists in large part of micrographic intergrowths of quartz and orthoclase, the other constituents being plagioclase, biotite, muscovite, magnetite or ilmenite, hematite, zircon, and rutile. Amygdules in a similar rock in the bluffs of Beaverhead River west of Dillon contain tridymite in six-sided basal plates of very weak birefringence. Some of the pyroclastic rhyolite near the Birdie mine in the Norris district contains biotite. The volcanic rock of the Butte and Siberia districts contains biotite; when it becomes highly potassic it forms a biotite rhyolite.

Hornblende rhyolite is the most basic type and is closely related to trachyte. It is found near the Kent mine in the Blue Wing district, where it contains abundant euhedral orthoclase phenocrysts, very little plagioclase, quartz in isolated patches of irregular grains, and little green hornblende, magnetite, epidote, calcite, and chlorite. A similar rock from the bluffs of Beaverhead River near Dillon is very fine grained with few or no phenocrysts; its groundmass consists of euhedral orthoclase, brown hornblende, and magnetite. Tridymite is abundant in the vesicular cavities.

The following analyses serve to show the composition of some of the rhyolites of the Dillon quadrangle. The rock from the Hyde Park dike is tehamose in the quantitative classification.

Composition of rhyolites of Dillon area.

	1	2		1	2
			NORM.		
SiO_2	74.34	68.68			
Al_2O_3	12.97	12.69			
Fe_2O_3	.75	1.14	Quartz	38.8	35.6
FeO	.54	1.17	Orthoclase	27.8	32.9
MgO	.86	1.14	Albite	21.0	10.4
CaO	.85	1.11	Anorthite	4.2	5.5
Na_2O	2.49	1.23	Corundum	2.2	2.6
K_2O	4.72	5.58	Hypersthene	2.0	4.1
H_2O	1.11	7.99	Magnetite	1.2	1.6
TiO_2	.18	....	Ilmenite	.3	....
P_2O_5	.07	....	Apatite	.2	....
MnO	Trace.	Trace.	(Water, etc.)	2.2	8.0
	100.06	100.73		100.0	100.7

1. Rhyolite, Hyde Park dike, Butte, Mont. H. N. Stokes, analyst. Clarke, F. W., U. S. Geol. Survey Bull. 419, p. 78, 1910; with 1.03 H_2O-, 0.05 ZrO_2, 0.03 SO_3, 0.07 BaO, trace SrO, Li_2O. Washington, H. S., U. S. Geol. Survey Prof. Paper 14, p. 133, 1903.
2. Rhyolitic ash, Gallatin Valley, Mont. H. N. Stokes, analyst. Iddings, J. P., U. S. Geol. Survey Bull. 150, p. 146, 1898; loss on ignition (7.99) is recorded as water.

TRACHYTE.

Volcanic rocks composed essentially of orthoclase with minor amounts of dark minerals—that is, trachytes—are rarely found in the Dillon region. Some of the rhyolites, especially those containing hornblende, are so low in free quartz that they are trachytes or rocks very closely allied to that type. Such a rock occurs about 2 miles southwest of Argenta; it contains abundant orthoclase phenocrysts, some plagioclase, very little quartz, and a notable proportion of epidote, magnetite, and chlorite. A similar rock from a point about a mile west of Dillon contains a very few feldspar phenocrysts in a fine groundmass of euhedral orthoclase, little plagioclase, and no recognizable quartz; its other constituents are brown hornblende, biotite, and magnetite.

DACITE.

Volcanic rocks characterized by plagioclase and quartz (dacites) are not uncommon in the Dillon quadrangle. A sample from a dike in the Gold Hill mine of the Renova district contains numerous feldspar phenocrysts now considerably altered, which are chiefly or wholly plagioclase. Other phenocrysts of quartz have been partly resorbed, and yet have been enlarged since the alteration of the rock. The groundmass contains abundant feldspar, in part orthoclase. The rock has been modified by mineralizing solutions which have produced pyrite, hematite, sericite, and a carbonate, apparently siderite.

One of the volcanic rocks of German Gulch is a dacite, composed of broken crystals and anhedra of plagioclase, quartz, brown biotite, and green hornblende in a very fine to glassy matrix.

A dacite forming a dike at the Del Monte mine in the Blue Wing district is medium grained and holocrystalline and is therefore closely allied to tonalite. It contains a few phenocrysts of green hornblende, and is thus related to tonalite porphyry. But as in dacites the bulk of the rock consists of small euhedral plagioclase crystals embedded in quartz, biotite, and hornblende. Other minerals present include nearly colorless pyroxene and magnetite or ilmenite. The brown biotite has a tendency to poikilitically inclose magnetite and plagioclase.

QUARTZ LATITE.

Volcanic rocks containing quartz and nearly equal amounts of orthoclase and plagioclase are called quartz latites; they are the extrusive equivalents of the quartz monzonites, and, as might be expected, they are intimately associated with the Boulder batholith, which is composed of the latter rock. Thus, quartz latite is associated with dacite in German Gulch; where it contains abundant plagioclase with some orthoclase and quartz and might well be called rhyodacite, expressing by this name the volcanic equivalent of granodiorite. The rock contains also biotite and hornblende with very little magnetite and apatite in an abundant glassy groundmass.

ANDESITE.

Volcanic rocks containing sodic plagioclase, biotite, and hornblende or pyroxene are called andesites. Such rocks occupy considerable areas within the Dillon quadrangle. One mass extends about 5 miles across the lower end of German Gulch, and a smaller mass forms hills about 4 miles southwest of Silver Bow. The Boulder batholith from Pipestone northward is bordered by a considerable mass of andesite, which extends across Whitetail Creek into the southern part of the Bull Mountains. Small masses of andesite form low bluffs near Divide; the same rock is abundant south of Argenta along the foothills at least as far as the Blue Wing district. It may be found in small patches near Silver Star, Sheridan, Virginia City, Norris, and west of Meadow Creek. It occupies large areas in the Gallatin Mountains and is abundant in several types at Radersburg.

The chief varieties depend upon the nature of the dominant ferromagnesian mineral; thus, there may be distinguished biotite andesite, hornblende andesite, and augite andesite.

Biotite andesite near Virginia City contains phenocrysts of plagioclase and biotite in a matrix of the same minerals with magnetite, apatite, and rock glass. Some of the plagioclase phenocrysts contain centers of calcite which are so completely surrounded by unaltered feldspar as to suggest that the carbonate is of magmatic origin. (See Pl. IV, *B* and *C*, p. 128.) A similar rock forms the roof of the workings in the McKee mine south of Ward Peak in the Washington district. Here it is highly feldspathic and holocrystalline. It contains plagioclase phenocrysts in a groundmass of tabular feldspar, with biotite, chlorite, magnetite, limonite, and sericite.

Hornblende andesite forms a flow (or dike) on the slope of Table Mountain; it contains large phenocrysts of brownish-green hornblende having a maximum extinction angle of 22° in the vertical zone. The groundmass is very fine grained and consists of plagioclase, magnetite (much of it in cubes), hornblende, and rock glass. A similar rock from the divide between Dillon and Bannock contains abundant phenocrysts of hornblende, plagioclase, and magnetite, in a matrix of the same minerals with a little augite, chlorite, apatite, and some rock glass. The plagioclase is partly altered to calcite; the hornblende, originally the reddish-brown basaltic type, is partly altered to common green hornblende and rimmed by magnetite which separates out during the change. Another sample from the same region is holocrystalline and somewhat more feldspathic. The hornblende is of the common green type. There is a little biotite, augite, and apatite. Magnetite is common, and hematite stains all parts of the rock except the feldspar phenocrysts.

Hornblende andesite from Mill Creek in the Sheridan district consists of phenocrysts of plagioclase in a groundmass of untwinned feldspar, whose index is higher than that of the balsam, with green hornblende, magnetite, and abundant alteration products, including sericite, calcite, chlorite, limonite, kaolinite, and quartz. A similar rock at the Noble mine on Wisconsin Creek forms a dike cutting a granitic rock. It is a highly feldspathic rock partly altered to kaolinite, sericite, epidote, chlorite, and quartz. It contains some titanite. Hornblende andesite near Divide contains phenocrysts of unaltered reddish-brown basaltic hornblende that has a large optic angle of negative sign, a birefringence of about 0.035 and an extinction angle of about 5°, measured in the vertical zone. The rock contains rare augite crystals. Abundant elongated andesine, sparse small augites, and brown rock glass form the groundmass.

A quartzose hornblende andesite from Silver Star consists of numerous much-altered phenocrysts of plagioclase and hornblende in a matrix of the same minerals with large cubes and anhedra of magnetite and much rock glass. Alteration has produced considerable epidote and sericite, with some zoisite and quartz. The rock contains also anhedra or amygdules of quartz.

A biotite hornblende andesite from Silver Star is much richer in dark minerals than the preceding types. It contains abundant green hornblende and plagioclase with some biotite and a little pyroxene and magnetite. It is completely crystalline; a few of the long prisms of hornblende are distinctly bent.

Augite andesite cuts through Paleozoic limestone near the Mayflower mine in the north end of the Tobacco Root Mountains. It contains phenocrysts of andesine, augite, magnetite, and rare hornblende. The amphibole is rimmed with magnetite and largely changed from brown basaltic to common green hornblende. The groundmass contains the same minerals with some rock glass. An opaque mineral, silvery white in reflected light, whose exact nature has not been determined, occurs in the rock and is of much interest in connection with the question of the origin of the gold ores of the Mayflower mine.

The volcanic rock near Big Butte is probably augite andesite; it is brecciated so irregularly that the texture changes from point to point. Some of the andesine phenocrysts are still large, though broken; others are unbroken because originally quite small. Most of the feldspar is much broken and scattered through a feltlike cryptocrystalline groundmass. The dark phenocrysts seem to have included pyroxene as indicated by the crystal outlines; they are now aggregates of hematite and chlorite.

The following table shows the composition of the andesite from this region and the average composition of andesite. In the quantitative classification the former is harzose-tonalose.

Composition of andesite.

	1	2		1	2
			NORM.		
SiO_2	61.45	60.78	Quartz	17.9	22.3
Al_2O_3	17.19	18.10	Orthoclase	11.4	16.2
Fe_2O_3	3.11	3.15	Albite	31.7	23.8
FeO	2.34	.97	Anorthite	24.3	19.8
MgO	2.32	2.04	Corundum	....	3.2
CaO	5.29	4.61	Diopside	.5	....
Na_2O	3.75	2.81	Hypersthene	6.3	5.1
K_2O	1.93	2.75	Magnetite	4.5	3.7
H_2O	1.45	2.62	Hematite	....	.6
TiO_2	.78	.24	Ilmenite	1.5	.5
P_2O_5	.22	.62	Apatite	.5	1.4
MnO	.17	.39	(Water, etc.)	1.4	3.5
	100.00	100.10		100.0	100.1

1. Average composition of 34 andesites (excluding "augite andesite"). Daly, R. A., Am. Acad. Proc., vol. 45, p. 223, 1910.
2. Hornblende andesite, Radersburg, Mont. Analysis by Chase Palmer. With 0.68 H_2O-, 0.16 SO_3, 0.18 BaO.

It is surprising to find that the norm indicates about 20 per cent of quartz, although the microscope reveals very little or no free silica. It may be that part of this silica is in crystal solution; more of it is probably in the rock glass; but it is difficult to account satisfactorily for such large amounts of it as appear in the norm. Having no analyses of the mica and amphibole in these rocks it is not possible to calculate the mode.

LATITE.

Volcanic rocks characterized by nearly equal amounts of plagioclase and orthoclase (without quartz) are not abundant in the Dillon area. A single sample of the andesitic flow near Pipestone Springs illustrates a phase of that rock so rich in orthoclase as to be properly designated as latite. It contains two feldspars and biotite, magnetite, a little titanite, and some chlorite and epidote.

AUGANITE.

Volcanic rocks characterized by calcic plagioclase and pyroxene are commonly called augite andesites or olivine-free basalts. It has been proposed [1] to employ the abbreviated name auganite for them. The varieties may be based on the nature of the ferromagnesian minerals. Thus if augite is present alone, the rock is auganite proper; if accompanied by biotite or hornblende, the rock is biotite or hornblende auganite; if replaced or accompanied by hypersthene or bronzite, the name is hypersthene auganite.

In mapping the igneous rocks of the Dillon region auganites have not been differentiated from andesites, with which they are very intimately associated. The volcanic rock mapped as andesite northward from Pipestone is partly auganite.

Auganite from a dike near Pipestone Springs is distinctly porphyritic, with euhedral augite and rare altered plagioclase phenocrysts. Single crystals of pyroxene show two stages of growth with some alteration of the crystal before the second stage. Chloritic masses were perhaps formerly hornblende. The groundmass contains biotite, plagioclase, pyroxene, magnetite, muscovite, and clinochlore. Samples from the same area, obtained about 8 miles north of Whitehall, show various phases of this rock; the chief variation is from a highly feldspathic type to a rock moderately rich in ferromagnesian minerals. All phases are porphyritic, with large plagioclase phenocrysts and a variable number of pyroxene crystals. As the latter are still fresh, certain phenocrysts now wholly chloritized were probably hornblende at one time. Other constituents include magnetite, calcite, epidote, and sericite.

Hypersthene auganite forms bluffs about a mile southwest of Divide. The rock contains small phenocrysts of bronzite and a few of augite in a groundmass of pyroxene, plagioclase, magnetite, and much rock glass. The rock is rich in dark minerals, and on a megascopic examination would pass for basalt.

The chemical composition and norm of auganite from the Zozell district are given below; for comparison the average composition of

[1] Winchell, A. N., Min. and Sci. Press, Nov. 22, 1912; also Jour. Geology, vol. 21, p. 215, 1913.

such rocks is also given. In the quantitative classification the auganite of the Zozell district belongs in the unnamed division II.4.4.3, closely related to harzose.

Composition of auganite.

	1	2		1	2
			NORM.		
SiO_2	54.97	54.61	Quartz	11.4	13.6
Al_2O_3	16.69	15.23	Orthoclase	13.9	16.1
Fe_2O_3	3.94	3.51	Albite	29.8	12.1
FeO	4.75	4.80	Anorthite	24.4	27.0
MgO	4.13	4.69	Diopside	2.1	7.9
CaO	8.02	7.41	Hypersthene	8.8	12.5
Na_2O	3.19	1.46	Magnetite	5.5	5.1
K_2O	1.45	2.70	Ilmenite	1.5	1.5
H_2O	1.39	2.47	Apatite	.7	0.2
TiO_2	.89	.86	(Water, etc)	1.9	4.2
P_2O_5	.28	.35			
MnO	.30	.09		100.0	100.2
	100.00	100.11			

1. Average composition of 73 auganites. Rocks containing sodic plagioclase or orthoclase are excluded and 12 olivine-free basalts are included. From data of Clarke, F. W., U. S. Geol. Survey Bull. 419, 1910; Rosenbusch, H., Elemente der Gesteinslehre, p. 382, 1910; Osann, A., Chemische Petrographie, vol. 2, 1905.

2. Auganite, Zozell mining district, Mont. H. N. Stokes, analyst. Clarke, F. W., U. S. Geol. Survey Bull. 419, p. 80, 1910. With 0.32 H_2O-, 0.84 SrO, 0.11 BaO, 1.46 CO_2.

BASALT.

Volcanic rocks containing plagioclase, pyroxene, and olivine are found as surface flows in several parts of the Dillon region. A dark-colored dike rock near Pipestone is a normal basalt with abundant partly altered olivine. A type with few small phenocrysts in a fine-grained trachytic groundmass is found at Virginia City. The phenocrysts are augite and very small serpentinized olivine of yellow to dark-brown color. A similar rock from the lower canyon of Bighole River contains more pyroxene in the groundmass and a few plagioclase phenocrysts. The olivine is so scanty that the rock is related to auganite. Near the head of Nez Perce Creek the olivine of the basalt flow is now altered completely to serpentine and limonite. South of Melrose the basalt is similar; samples available are notably vesicular. Two of the dikes cutting the Paleozoic limestone of the mines at Hecla are basaltic; in them the olivine crystals, once large and well formed, are now altered to serpentine and calcite. Holocrystalline basalt forms a mesa about 5 miles south of Bannock, near the road to Grant. It has well-formed crystals of olivine whose alteration to serpentine has only begun; the olivine is optically positive with a large optic angle. The ferromagnesian minerals, olivine and augite, are partly phenocrystic in a coarse groundmass composed largely of plagioclase ranging in composition from andesine to (calcic) oligoclase. Some pyroxene crystals show evidence of strain in having bent cleavage lines; some olivine crystals have been broken. The remaining constituents are magnetite, rare apatite, antigorite, and bowlingite.

OLIVINE TRACHYDOLERITE.

Basaltic rocks which contain orthoclase or a little feldspathoid are called olivine trachydolerites. Such rocks have been described by Merrill [1] from the region of Pony; a sample from Cottonwood Creek is said to contain phenocrysts of triclinic feldspar, euhedral augite, and altered olivine in a matrix of plagioclase, orthoclase, small augite crystals, biotite scales, iron ores, and considerable secondary chloritic material and calcite. Another sample from a locality between South Boulder and Antelope creeks contains phenocrysts of augite and olivine in a groundmass of two feldspars with apatite, augite, iron oxide, and brown mica. It is a lamprophyric rock type; that is, it contains an unusually large proportion of dark minerals. The composition of these rocks is given herewith; they may be compared with the average composition (1) of five absarokites or lamprophyric olivine trachydolerites. In the quantitative classification the rock of column 2 is a monzonose-shoshonose, and that of column 3 a pentallenose.

Composition of olivine trachydolerite.

	1	2	3		1	2	3
				NORM.			
SiO_2	50.11	52.33	50.82	Orthoclase	24.5	22.2	20.6
Al_2O_3	13.04	15.09	11.44	Albite	16.4	26.7	12.6
Fe_2O_3	4.58	4.31	.25	Anorthite	14.5	15.8	12.8
FeO	3.94	4.03	8.94	Nepheline	....	....	1.4
MgO	9.27	6.73	14.01	Diopside	14.8	10.1	22.3
CaO	7.63	7.06	8.14	Hypersthene	10.7	9.3	....
Na_2O	1.94	3.14	1.79	Olivine	5.5	4.7	28.6
K_2O	4.15	3.76	3.45	Magnetite	6.6	6.3	.5
H_2O	3.58	2.68	.58	Ilmenite	1.8	.3	1.1
TiO_2	.96	.14	.59	Apatite	1.6	2.3	.5
P_2O_5	.69	1.02	.20	(Water, etc.)	3.6	2.7	.6
MnO	.11	.09	.19				
	100.00	100.45	100.49		100.0	100.4	101.0

1. Average composition of five absarokites or lamprophyric olivine trachydolerites. Daly, R. A., Am. Acad. Sci. Proc., vol. 45, p. 231, 1910.
2. Olivine trachydolerite (augite porphyrite), Cottonwood Creek, Mont. L. G. Eakins, analyst. Merrill, G. P., U. S. Nat. Mus. Proc., vol. 17, p. 648, 1895; with 0.07 BaO. Washington, H. S., U. S. Geol. Survey Prof. Paper 14, p. 267, 1903.
3. Lamprophyric olivine trachydolerite ("lamprophyre"), between South Boulder and Antelope creeks, Mont. L. G. Eakins, analyst. Merrill, G. P., op. cit., p. 670, with 0.03 Cr_2O_3, 0.06 BaO, trace NiO. Washington, H. S., op. cit., p. 319.

ECONOMIC GEOLOGY.

INTRODUCTION.

The mineral resources of the Dillon quadrangle and adjacent areas include gold, silver, copper, and lead, and smaller quantities of zinc, iron, manganese, tungsten, antimony, arsenic, bismuth, vanadium, tellurium, and sulphur. In addition to the metals there are abrasives, including quartz, garnet, corundum, and volcanic ash; struc-

[1] Merrill, G. P., U. S. Nat Mus. Proc., vol. 17, p. 637, 1895.

tural materials, such as sandstone, limestone, volcanic ash, rhyolite, "granite," and clay; and miscellaneous materials such as phosphate rock, barite, feldspar, graphite, and mineral waters. This report deals with the chief deposits of metallic ores and of graphite, and discusses only incidentally some of the other mineral resources of the area.

The metallic ore deposits of the region are found in more or less well-defined districts, some of which coincide with mining districts established by the early miners, and are here described under the names of those districts. Others, however, are more conveniently considered in connection with some local business center, like Sheridan, or some prominent topographic feature, like Fleecer Mountain.

ORE DEPOSITS.

MINERALOGY.

No attempt has been made to prepare a complete list of the minerals occurring in the mining districts of the region, but the following table summarizes the data available:

Minerals in ore deposits of Dillon region, by districts.

Mineral.	Argenta.	Bannock.	Blue Wing.	Bryant (Hecla).	Dillon.	Divide Creek (Fleecer and Independence).	Elkhorn.	Highland (includes Moose Creek).	Mammoth.	Melrose (Soap and Camp creeks).	Norris.	Pony.	Rabbit (Rochester).	Radersburg.	Sheridan (Mill, Wisconsin, and Ramshorn).	Siberia (German Gulch).	Silver Star.	Tidal Wave.	Utopia (Birch Creek).	Vipond.	Virginia City.	Whitehall (Cardwell and Renova).
Argentite	....	....	+	+	....	+	....	+	....	....	+	+	....	....	....	....	....	....	....	+	+	....
Arsenopyrite	....	....	....	....	....	....	....	+	....	....	+	....	....	+	+	....	....	....	....	....	....	....
Asbestos	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	+	....	....	....	....
Atacamite	....	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Axinite	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....	....	....
Azurite	+	+	+	+	+	+	+	+	+	+	....	....	....	....	....	....	+	+	+	+	....	....
Barite	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....	+	....	....
Biotite	....	....	....	....	+	....	....	....	....	....	....	....	....	....	+	....	....	....	....	....	....	....
Bornite	....	+	....	....	....	+	+	+	+	....	+	....	....	+	+	....	+	+	+	....	....	....
Bromyrite	....	....	+	....	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Calamine	....	....	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Calcite	+	+	+	+	+	....	....	+	....	+	+	+	....	+	+	....	+	+	+	+	+	+
Cerargyrite	+	+	+	+	....	+	....	+	....	....	+	....	+	....	....	....	....	....	....	+	....	....
Cerusite	+	+	+	+	....	....	....	+	....	....	+	....	+	+	....	....	+	+	....	+	....	....
Chalcanthite	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+
Chalcocite	+	....	....	+	....	+	+	....	....	....	+	....	....	....	....	....	....	+	+	....	....	....
Chalcopyrite	....	+	....	+	+	+	+	+	+	+	+	....	....	+	+	+	....	+	+	....	+	+
Chlorite	....	....	....	....	....	....	....	....	....	....	+	....	+	+	....	....	+	....	....	....	+	....
Chrysocolla	+	+	....	+	....	+	....	+	+	....	+	....	+	+	....	....	+	+	+	....	....	....
Copper	....	....	....	....	....	....	+	....	....	....	....	....	....	+	....	....	....	+	+	....	....	....
Cuprite	+	+	....	+	....	+	....	+	....	+	+	....	....	....	+	....	....	+	+	....	....	....
Diopside	....	....	....	....	....	....	....	+	....	....	....	....	....	....	....	....	....	+	+	....	....	....
Dolomite	+	....	+	+	+	....	....	+	....	+	....	....	....	....	+	....	+	+	+	+	....	+
Ecdemite	....	....	....	....	....	....	....	....	....	....	....	....	+	....	....	....	....	....	....	....	....	....
Epidote	+	+	....	....	....	....	....	+	....	....	+	....	+	+	+	....	+	+	+	....	....	....
Fluorite	....	....	....	....	....	....	....	+	....	....	....	+	....	....	....	....	....	....	....	....	....	....
Galena	+	+	+	+	....	+	+	+	+	....	+	+	+	+	+	....	+	+	....	+	+	+
Garnet	....	+	....	....	+	....	....	+	....	+	....	....	+	....	+	....	+	+	+	....	....	....
Gold	+	+	+	+	....	+	....	+	+	....	+	+	+	....	+	+	+	+	....	....	+	+
Graphite	....	....	....	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Gypsum	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....	....	....	....	....	+
Hematite	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Minerals in ore deposits of Dillon region, by districts—Continued.

Mineral.	Argenta.	Bannock.	Blue Wing.	Bryant (Hecla).	Dillon.	Divide Creek (Fleecer and Independence).	Elkhorn.	Highland (includes Moose Creek).	Mammoth.	Melrose (Soap and Camp creeks).	Norris.	Pony.	Rabbit (Rochester).	Radersburg.	Sheridan (Mill, Wisconsin, and Ramshorn).	Siberia (German Gulch).	Silver Star.	Tidal Wave.	Utopia (Birch Creek).	Vipond.	Virginia City.	Whitehall (Cardwell and Renova).
Hornblende												+	+				+	+				
Hübnerite												+										
Limonite	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Magnetite					+			+		+	+	+	+	+		+	+	+	+			
Malachite	+	+	+	+		+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+
Melaconite			+			+								+	+			+	+			
Melanterite																+						+
Microcline					+																	
Molybdenite									+			+									+	
Montanite								+														
Muscovite					+	+						+	+		+	+		+				
Nagyagite																					+	
Opal																	+					
Orthoclase					+							+						+			+	
Polybasite						+																
Proustite			+																			
Pyrargyrite			+			+		+				+								+	+	
Pyrite	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+			+	+
Pyrolusite			+	+							+	+		+	+			+			+	+
Pyromorphite																	+					
Pyrrhotite					+			+														
Quartz	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Rutile												+										
Serpentine																+	+					
Siderite	+													+	+		+	+				+
Silver	+		+	+		+		+			+	+								+	+	
Smithsonite			+	+													+					
Sphalerite	+		+	+			+		+		+	+		+	+			+			+	+
Stephanite						+																
Stromeyerite																				+		
Stibnite																					+	
Sylvanite (calaverite)	+	+				+										+					+	+
Tetradymite								+														
Tetrahedrite		+	+	+			+				+				+			+			+	
Vanadinite													+	+			+					
Wulfenite														+								
Zoisite								+										+				

The list is confined to minerals found in ore deposits, but it includes some species, such as biotite, chlorite, diopside, microcline, muscovite, orthoclase, and serpentine, which are more abundant in country rock than in veins or other forms of ore deposits. Minerals not found in the ore deposits but occurring in the country rock, as a rule closely associated with ore deposits, are actinolite, anorthoclase, apatite, augite, corundum, enstatite, ilmenite, kaolinite, paragonite (?), plagioclase (chiefly andesine and labradorite), rutile, titanite, tourmaline, tridymite, and zircon. Minerals found in the Dillon quadrangle (as well as elsewhere), under such conditions that it is safe to conclude that they were formed directly from the magma, are andesine, anorthoclase, apatite, augite, biotite, diopside, hornblende (?), ilmenite, labradorite, magnetite, microcline, muscovite, orthoclase, plagioclase, pyrite, pyrrhotite, quartz, rutile (?), titanite, and zircon. The minerals formed in the Dillon area by aqueo-igneous fusion under conditions of pegmatitic intrusion are fluorite, microcline, muscovite, quartz, and tourmaline.

When an igneous magma comes into contact with sedimentary rocks, some constituents of the magma escape into the sediments and some constituents of the sediments are taken up and more or less completely assimilated by the magma. The first process is called exomorphism and results in the production of contact-metamorphic rocks and contact-metamorphic ore deposits. The second process is called endomorphism and results in the formation of contact phases of igneous rocks.

On account of changes in the chemical composition of the magma and special conditions attending crystallization, endomorphosed igneous rocks have characteristic textures and contain minerals which are more or less peculiar to themselves. Minerals formed under such conditions and found in this study include actinolite, apatite, biotite, enstatite, magnetite, muscovite, orthoclase, plagioclase, pyrite, and quartz. Other minerals of this class noted in Minnesota by the writer[1] include anomite, anthophyllite, bronzite, cordierite, epidote, graphite, spinel, staurolite, and zircon.

Minerals produced by exomorphism in contact-metamorphic zones in the Dillon quadrangle are actinolite, asbestos, axinite, calcite, chalcopyrite, corundum, diopside, epidote, fluorite, galena, garnet, graphite, magnetite, paragonite (?), plagioclase, pyrite, pyrrhotite, quartz, siderite (?), sphalerite, tetrahedrite (?), titanite, tourmaline, and zoisite.

Minerals produced in veins in the Dillon area by deposition, probably from hot solutions that were chiefly magmatic in origin, include arsenopyrite, barite, bornite, chalcocite (?), chalcopyrite, galena, gold, hübnerite, molybdenite, nagyagite, polybasite, proustite, pyrargyrite, pyrite, pyrrhotite, quartz, sphalerite, sylvanite (or calaverite), stibnite, tetradymite, and tetrahedrite. The graphite veins near Dillon contain also biotite, calcite, garnet, graphite, microcline, muscovite, and orthoclase. Hot solutions interacting with wall rock produce chlorite, dolomite (?), epidote, hornblende, rutile, sericite, serpentine, siderite (?), and tridymite. But tridymite is formed in cavities in volcanic rocks cooling at or near the surface and not, so far as known, in veins or in the wall rock of veins.

Minerals formed by cold solutions, chiefly descending from the surface, belong to two classes, namely, those formed under conditions of oxidation and those formed under conditions of deoxidation. The first are commonly known as the minerals of the oxidized zone, which lies above ground-water level, and the second as minerals of the zone of sulphide enrichment, which lies directly below the oxidized zone at and below the ground-water level. So far as noted

[1] Winchell, A. N., Am. Geologist, vol. 26, pp. 294-306, 1900.

in the Dillon quadrangle the first class includes atacamite, azurite, bromyrite, calamine, cerargyrite, cerusite, chalcanthite, chrysocolla, copper, cuprite, ecdemite, gold, gypsum, hematite, kaolinite, limonite, malachite, melaconite, melanterite, montanite, opal, pyrolusite, pyromorphite, silver, smithsonite, vanadinite, and wulfenite. The second class includes argentite, bornite, chalcocite, chalcopyrite, gold, polybasite, proustite, pyrargyrite, stephanite, and stromeyerite.

ORIGIN.

The Boulder batholith extends southward to Silver Star, Highland, and lower Moose Creek, and westward to German Gulch, with no known covering except the Tertiary deposits south of Silver Bow. Several plutonic igneous masses having no surface connection with the Boulder batholith are believed to be parts of it (see p. 29), and if they are, the batholith occupies the area from Jefferson Peak eastward to Burnt Creek, the upper slopes of McCarthy Mountain, about 7 miles south-southeast of Melrose, the upper canyon of Bighole River, and a large area from Hecla to Mount Torrey and southward. Smaller areas outcrop on Red and Table mountains, on Camp Creek, along Bear Gulch, at Argenta, and at Bannock.

The Boulder batholith in this large sense seems to be in whole or in part the source of many of the ore deposits of the Dillon quadrangle, particularly those of the following districts: Argenta, Bannock, Bryant (Hecla), Divide Creek (including Fleecer Mountain and Independence), Elkhorn, Highland (including Moose Creek), Mammoth, Norris, Pony, Silver Star, Tidal Wave, and Utopia (Birch Creek). It is probably, at least in part, the source of the ore deposits in the following districts: Melrose (Camp and Soap creeks), Rabbit (Rochester), Sheridan (Mill, Ramshorn, and Wisconsin creeks), Siberia (German Gulch), Vipond, and perhaps also Blue Wing and Virginia City. (See discussion of origin of ores in particular districts.) No connection is apparent between the batholith and the ore deposits of the Alder, Dillon, Radersburg, and Whitehall districts.

The ore deposits of the Dillon quadrangle occur chiefly in fissure veins or in irregular bodies produced by contact metamorphism in limestone or dolomite. Part or all of those of the Argenta, Bannock, Highland, Melrose, Radersburg, Sheridan, Silver Star, and Tidal Wave districts were produced by contact metamorphism; those at Hecla were probably produced in the same way, for they have some of the characteristics of contact-metamorphic deposits; those in the Blue Wing district are less clearly related to the same type. Some of the ore deposits of the Bannock, Argenta, Highland (especially on Gold Hill), Norris, Pony, Radersburg, Sheridan, Silver Star, Tidal Wave, and Virginia City districts and all the ore deposits of the Dillon, Divide Creek, Elkhorn, Mammoth, Rabbit (Rochester), Vipond, and Whitehall districts are in the form of fissure veins. The ore deposit of the Siberia (German Gulch) district and certain deposits in the Norris and Pony districts seem to belong to the type of ore disseminated in the country rock. The ore deposit of Alder Gulch is a placer stream gravel.

AGE.

The placer gravels of Alder Gulch, German Gulch, Highland, and other districts were accumulated largely or wholly during the Quaternary period; parts of the ore deposits in the Sheridan, Silver Star, Tidal Wave, and Virginia City districts seem to have originated in early geologic time, perhaps in the pre-Cambrian; other parts of the deposits in these districts and also the ores in the Argenta, Bannock, Blue Wing, Bryant (Hecla), Divide Creek, Elkhorn, Highland, Mammoth, Melrose, Norris, Pony, Rabbit (Rochester), Radersburg, Utopia (Birch Creek), and Vipond districts were probably formed during the Tertiary period, soon after the Boulder batholith solidified. The date of origin of the ores in the Dillon and Whitehall districts is uncertain.

AGE OF COUNTRY ROCK.

In regard to the age of the country rock in which the ore deposits exist the following tabulation summarizes the conclusions reached:

Age of country rock of ore deposits of Dillon region, by districts.

Quaternary	Placers of Alder Gulch, German Gulch, Highland, and other districts.
Tertiary	None.
Cretaceous	None.
Jurassic	None.
Triassic	None.
Permian (?) (Phosphoria formation).	None.
Pennsylvanian (?) (Quadrant (?) quartzite).	Argenta, Utopia (Birch Creek).
Mississippian (Madison limestone).	Argenta, Bannock, Blue Wing, Fleecer (?), Vipond (?).
Devonian (Threeforks shale).	None.
Devonian (Jefferson limestone).	Bryant (Hecla).
Silurian (?)	Bryant in part (?).
Ordovician (?)	Bryant in part (?).
Cambrian	Blue Wing (?), Highland (?), Moose Creek (?), Silver Star (?), Soap Gulch (?) (Melrose), Tidal Wave (?), Utopian (?), Whitehall.
Algonkian (Belt series)	Camp Creek (Melrose), Siberia (German Gulch) (?), Whitehall.
Algonkian (Cherry Creek group).	Dillon, Lower Hot Springs (Norris), Mineral Hill (Pony), Rabbit (Rochester), Sheridan, Silver Star, Tidal Wave, Virginia City, Washington (Norris).
Igneous rocks, chiefly quartz monzonite.	Argenta, Browns Gulch (Virginia City), Bryant (Hecla), Divide Creek, Elkhorn, Mammoth, Moose Creek (Highland), Potosi (Pony), Radersburg, Rabbit (Rochester), Tidal Wave, Upper Hot Springs (Norris).

It will be convenient to describe the districts in the order of the age of the more important country rock in each district, beginning with those districts where the chief country rock is the youngest and ending with the districts that lie chiefly in igneous rock (Tertiary).

MINING DISTRICTS.

ALDER GULCH DISTRICT.

LOCATION.

Alder Creek rises on the northern slopes of Old Baldy Mountain, at the south end of the Tobacco Root Mountains, and flows in an irregular curve north, northwest, and west to Passamari River at Laurin. In its short course of about 15 miles it has yielded an amount of placer gold estimated at $40,000,000. Gold was first discovered on Alder Creek in June, 1863, and it is said that within 20 years its gravels yielded more than $30,000,000.

HISTORY.

Six different mining districts were organized along Alder Gulch during the period of greatest mining activity in the sixties, but for the purposes of this report it is convenient to deal with that portion of the gulch which lies west of Granite Creek and within the confines of the Dillon quadrangle. In the early days of placer mining in Montana the portion of the gulch lying southeast of Granite Creek and within the Threeforks quadrangle was especially important. Ever since that time more or less placer mining has been in progress in various parts of the gulch. But the introduction of dredges at the close of the last century and the consequent radical change in the method of handling the gravel resulted in localizing the major portion of the gold recovery in the lower portion of Alder Gulch in the Dillon quadrangle. In 1910 the greatest activity was near the town of Ruby, about 3 miles southeast of Laurin, where Alder Gulch opens into the Passamari Valley.

GEOLOGY.

Alder Gulch, north of the town of Ruby, is bordered by a series of garnet schists, quartz schists, and quartzites, which strike north-northeast and dip 45°-65° W. Farther east the dip increases to vertical and within a mile becomes easterly, beyond the crest of an eroded anticline. Southwest of Alder Creek and Passamari River the north end of the Ruby Range is flanked by limestones of Paleozoic age. Southeast of Alder Creek, between that stream and Passamari River, the foothills of the Tobacco Root range consist of schists and gneiss broken in places by outcrops of limestone and quartz schists. It seems probable that a portion of this area is occupied by the Cherry Creek group; other portions may be occupied by Archean rocks.

At a geologically recent date, apparently during the Miocene or the Pliocene epoch, great volcanic activity in this portion of the West produced immense amounts of volcanic ash and dust, which were distributed widely over this area and, being light and unconsolidated, were quickly carried into the valleys and deposited there. Such a deposit at present underlies the auriferous gravels brought down Alder Gulch into the Passamari Valley. In Alder Gulch itself the bedrock of the placers is the solid rock of the adjoining hills, with considerable irregularity in surface due to unequal weathering and erosion, and the richest portion of the gravel lies on the surface of the bedrock or penetrates into its crevices and cracks. But below the point where Alder Creek leaves the gulch and flows into the valley of Passamari (Ruby) River the auriferous gravels lie upon volcanic ash beds which furnish a "false bedrock" that is smooth, with only gentle undulations and a regular slope to the west. The position of these gravels upon Miocene or Pliocene volcanic ash beds indicates that they are probably of Quaternary age, and they are continuous with the Quaternary stream deposits of Passamari and Jefferson rivers.

PLACER DEPOSITS.

The auriferous gravels extend for at least 15 miles along Alder Gulch, but the portion known to be profitable for dredging is probably only about 3 miles long. It contains more than 600 acres of proved dredging ground, most of which lies at the mouth of the gulch proper and borders the Passamari Valley. (See Pl. I, *A*.) Here the waters of Alder Creek have formed a low alluvial fan. The depth of the deposit increases gradually toward the west and is as much as 60 feet at a distance of 2½ miles from the mouth of Alder Gulch. A shallow trough running west beneath the axis of the fan may represent the channel of the stream before it was aggraded with bowlders and gravel. This trough contains bowlders of unusual size and an increased content of gold.

The dredging ground has been prospected by holes drilled at intervals of 150 or 330 feet on lines 200 or 660 feet apart. The dredges recover about 95 per cent of the gold. The gravel is not indurated but is rather tenacious, especially near the false bedrock, owing to its clay matrix. The gold varies in coarseness; the average size increases going up the gulch. In the dredging ground at present 40 to 50 per cent of the gold passes a 60-mesh screen, and 15 to 30 per cent passes a 100-mesh screen. The gold also varies in fineness, that recovered by the dredge farthest up the gulch running about

0.830 fine, that obtained by the next lower dredge about 0.850 fine, and that by the lowest dredge, about 2 miles below the upper dredge, about 0.865 fine. There seems to be no source of supply of especially high-grade gold in any of the small gulches opening into Alder Gulch along this portion of its course. Indeed, it may be questioned whether gold of any grade is brought into Alder Gulch in appreciable amounts from such sources. It is probable that the increase in fineness downstream is due to the removal in solution of part of the alloying metals (especially silver, which readily oxidizes), a removal which is favored both by abrasion, which decreases the coarseness [1] of the gold, and by the longer exposure to the solvent action of stream water.

DREDGING.

The first attempts to dredge the gravels of Alder Gulch were made with an excavator having an orange-peel bucket.[2] The machine was mounted on a large car and a long boom permitted discharge of the material from the bucket into a washer which was also mounted on a car. This attempt was a failure.

Afterward a double-lift dredge, which had been fairly successful in the Bannock district, was moved to Alder Gulch. It had open-connected buckets of 5 cubic feet capacity, weighing about 600 pounds each. This dredge, although too weak in nearly all its parts to do satisfactory work, was a commercial success and was operated for five years until the lease of the ground expired. The buckets of this dredge carried the gravel to a point about 17 feet above water level and emptied it into a revolving screen with 4 by 5 inch openings, which eliminated the large bowlders. The gravel was then elevated by a 12-inch dredging pump to a sluice about 80 feet long carried on an auxiliary scow. The gold was recovered by the ordinary sluice-box methods.

In 1899 the Conrey Placer Mining Co. installed a dredge with open-connected buckets, with a capacity of 5 cubic feet, afterward enlarged to 7½ cubic feet. Although the construction was so weak that frequent difficulties resulted, this dredge was kept in more or less continuous service for eight years. It was operated by steam power. The gravel was raised 24 feet in a single lift by means of two centrifugal pumps and discharged into a revolving screen having 5-inch perforations. The oversize went overboard and the fine material dropped into a sluice 140 feet long, carried on a separate scow.

This dredge was replaced in 1907 by a modern electrically driven stacker dredge, with buckets of 7½ cubic feet capacity and a compact

[1] Maclaren, J. M., Gold, p. 82, 1908.

[2] Hutchins, J. P., Gold dredging practice at Ruby, Mont.: Eng. and Min. Jour., vol. 83, p. 1223, 1907; vol. 84, p. 69, 1907.

system of concentrating tables. This is now (1910) in operation about 1¼ miles up Alder Gulch from Ruby. The present boat dredges to a maximum of 30 feet below water level and handles banks as much as 25 feet above water level.

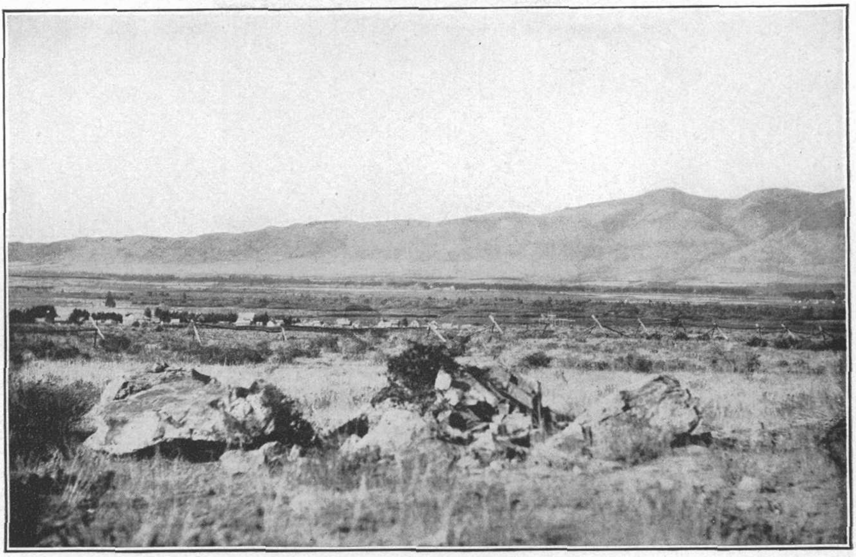
After the success of its first boat the Conrey Placer Mining Co. built one dredge after another, making each larger and stronger than the preceding one, and introducing various mechanical improvements from time to time. Cableways attached to the top of a frame erected at the stern were found to be more satisfactory as an anchorage on sluice-box dredges than the 48 by 48 inch wooden spuds previously used. Teeth of various types have been tried on the buckets but were all discarded in favor of manganese-steel lips. Devices by which friction is reduced to a minimum by the protection and lubrication of the lower tumbler boxes, the bearings of the rollers on the bucket ladder, and other wearing parts have been evolved and put into use.

The present dredge No. 2 (Pl. I, *B*) is operating (1910) just east of Ruby. It works to a depth of 35 feet below water level and takes banks 15 feet above water level. It is equipped with a stacker 90 feet long, which delivers the coarse tailings 25 feet above water level. The hull of the boat is 106 by 44 by 9 feet, and the ladder carrying the buckets is 86 feet long. It is operated by electricity, and uses an average of 225 horsepower. It is now handling gravel at an average cost of 6¼ cents per cubic yard through the year.

Dredge No. 3 (Pl. II, *A*), which was constructed about 1905, is the oldest dredge in service and the only one of the sluice-box type. It has three centrifugal pumps, 10, 12, and 14 inches in size, but all three are not able to furnish enough water to sluice all the material that it can excavate. The ladder way is a lattice girder weighing 40 tons; the close-connected buckets have a capacity of 13½ cubic feet and weigh 2,800 pounds each. The sluice box, which is paved with strap transverse and longitudinal angle-iron riffles having a 7 per cent grade, is 5½ feet wide and 135 feet long. Quicksilver is used in the riffles, over which run 12,000 gallons of water a minute. Clean-ups are made about once in 10 days.

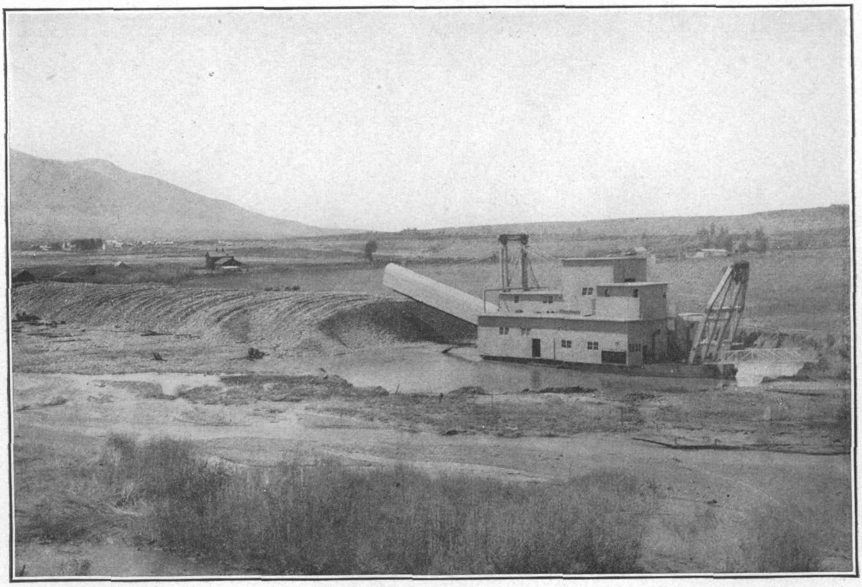
Dredge No. 3 is now working into deeper gravel at Ruby. Its ladder way is therefore to be increased to 116 feet in length at once, so as to permit its use to a depth of 60 feet below water level. This boat handles about 3,300 cubic yards a day, at an average cost of about 8 cents a cubic yard, including all charges. Generally about 1.4 kilowatt hours of electricity are used for each cubic yard dredged.

Dredge No. 4 (Pl. II, *B*) was under construction during 1910. Its hull is 150 by 58 by 13 feet, and its bucket capacity 15 cubic feet. It will dig 60 feet below water level and handle a bank 25 feet above water level, thus excavating a maximum depth of 85 feet of gravel.



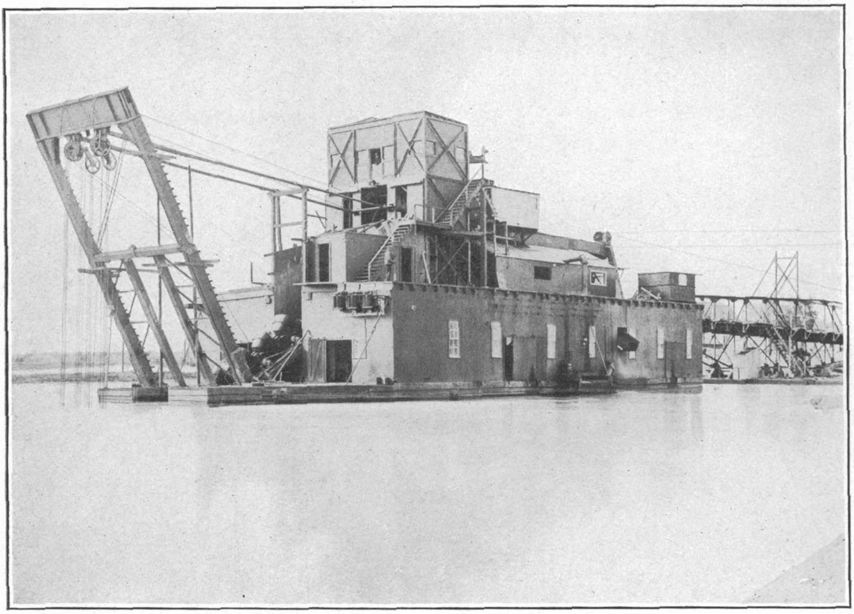
A. RUBY VALLEY, MADISON COUNTY, MONT., LOOKING SOUTH.

Ruby Range in the distance. This region is now being worked by gold dredges.



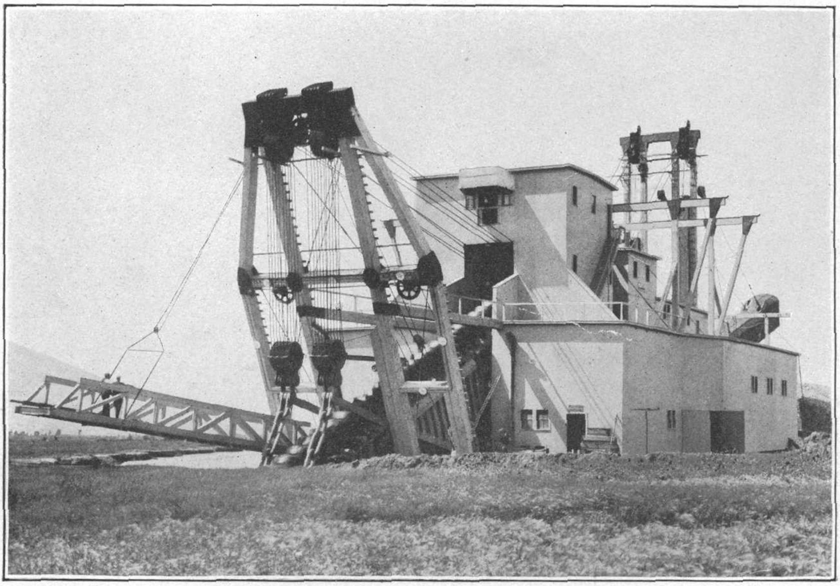
B. DREDGE NO. 2, OF STACKER TYPE, RUBY, MONT.

Operated by Conrey Placer Mining Co.



A. DREDGE NO. 3, OF SLUICE-BOX TYPE, RUBY, MONT.

Operated by Conrey Placer Mining Co.



B. DREDGE NO. 4, OF STACKER TYPE, RUBY, MONT.

Operated by Conrey Placer Mining Co.

The total cost will be about $270,000. It is expected that it will handle gravel, at an average cost of about 4½ cents a cubic yard, including all charges.

It is estimated by the manager of the dredging company that the proved dredging ground will keep all the dredges in constant operation for about 10 years.

PRODUCTION.

The auriferous gravels constitute the chief ore deposits of the Alder Gulch district. In 1911 they were yielding a larger annual production than all other gold deposits in the Dillon quadrangle. Separate figures for Alder Gulch are not available, but the production of placer gold and silver from Madison County, to which the gulch has for years been the largest contributor, is as follows for 1904–1912:

Placer production of Madison County, Mont., 1904–1912.[a]

Year.	Gold.		Silver.		Total.
	Fine oz.		*Fine oz.*		
1904	13,489.05	$278,843	15	$9	$278,852
1905	13,122.13	271,258	1,985	1,199	272,457
1906	18,916.74	391,044	3,020	2,023	393,067
1907	9,462.59	195,699	1,569	1,035	196,734
1908	20,072.67	414,939	3,238	1,716	416,655
1909	20,700.97	427,927	3,328	1,731	429,658
1910	22,553.49	466,222	2,468	1,333	467,555
1911	28,296.86	584,948	4,516	2,393	587,341
1912	....	689,197	5,094	3,133	692,330
	....	2,720,077	25,223	14,572	2,734,649

[a] U. S. Geol. Survey Mineral Resources, 1904–1912.

It should be remembered that Alder Gulch produced in the early days of placer mining at least $30,000,000 in gold, and later probably at least $10,000,000 more.

UTOPIA (BIRCH CREEK) DISTRICT.

LOCATION.

The Utopia district is situated on Birch Creek about 6 miles west of and from 1,000 to 1,400 feet above Apex station on the Oregon Short Line Railroad. Copper mines extend from Birch Creek northeastward about 2 miles; magnetite iron ores occur south of the creek.

HISTORY.

The district was discovered not long after the influx of miners into the region in 1862 and 1863 caused by the opening of the rich placer mines at Bannock and Virginia City, but for years it was not developed, because mines yielding principally copper were then too far from smelters and from markets to be of much importance. Progress in the development of the district was very slow; a few shafts of a maximum depth of about 100 feet were sunk and a few tons of ore were shipped for testing purposes at various times during the later sixties and the seventies. Even the advent of a railroad within about 6 miles of the district in 1882 caused no marked activity for several years. Finally, about the close of the century, the Beaverhead Mining & Smelting Co. opened the Indian Queen mine. Previous development work was directed largely to opening the Greenwich and Treasury claims, about 2 miles northeast of the Copper Queen, in the foothills overlooking the Beaverhead Valley, and not directly on Birch Creek. Early in 1903 the company installed a 50-ton blast furnace which produced 990,000 pounds of copper matte and metal in 1903 of a net value of $57,600, and 770,000 pounds in 1904 of a net value of $40,900.

GEOLOGY.

In the Utopia district sedimentary rocks are in contact with an intrusive batholith of monzonitic type. The intrusive mass extends into the mountains on the northwest (Pl. III, *A*), and the upturned sedimentary rocks rest in eruptive unconformity upon it, striking northeast and dipping southeast. The sedimentary series may be summarized as follows:

Stratigraphic section on Birch Creek.

[Thickness approximate.]

	Feet.
Sands, gravels, clays, volcanic ash, nearly flat (Tertiary)	(?)
Green shale, dipping about 75° SE	1,700
Gray sandstone weathering grayish brown	200
Fossiliferous gray limestone, grading downward to black shale	250
Red and green shales, with limestone layers	350
Gray limestone, with shaly layers	150
Red and green shales, with gray sandstone layers	400
Reddish-gray sandstone	250
Red shale	150
Reddish shaly sandstone	350
Folding and overthrust faulting.	
Covered, probably shale	500
Hard brown sandstone	120
Yellowish-green shale	40
Quartzite, showing folding, dipping 45° (Quadrant?)	700
Gray limestone (Madison?)	600
Dark shale (Threeforks?)	50
Gray to blue limestones (Jefferson and older)	1,000
Quartz monzonite (intrusive).	

Poorly preserved unios and fresh-water gastropods were collected from the fossiliferous gray limestone and the underlying black shale but proved insufficient to determine the age of the beds.

The Indian Queen mine is on the contact between the quartz monzonite and the Paleozoic limestones. The monzonite is cut by aplitic dikes, somewhat irregular in form. The Greenwich mine is ocated on a contact between the quartz monzonite and the Pennsylvanian (?) (Quadrant?) quartzite.

The areal geology of the Utopia district is shown in figure 3.

ORE DEPOSITS.

COPPER.

The Indian Queen mine is located on a limestone and monzonite contact along which some faulting has occurred. The limestone lies on the east side and the monzonite on the west side of the contact, which here runs irregularly north and south. The ore occurs in irregular shoots and bunches in the fault proper or in the limestone near the contact. The ore has been developed to a total depth of about 500 feet from the surface. Most of it has come from the oxidized zone, although some very rich massive chalcocite ore was found just below that zone. The ore minerals include native copper, malachite, azurite, chrysocolla, cuprite, and melaconite in the oxide zone, and chalcocite, bornite, and chalcopyrite in the sulphide zone. The gangue minerals include quartz, calcite, hematite, garnet, epidote, diopside, and axinite.

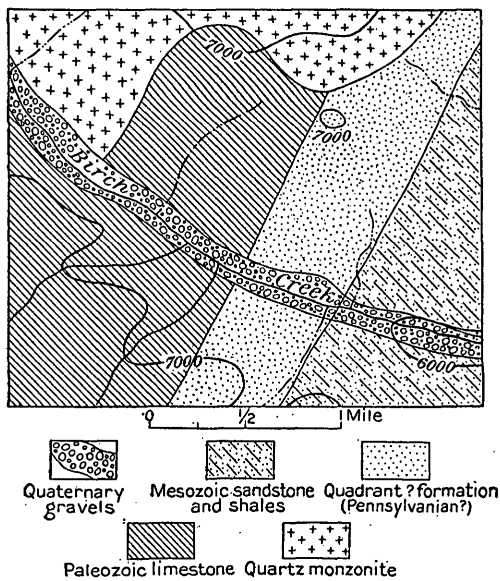


FIGURE 3.—Geologic sketch map of the Utopia (Birch Creek) mining district, Mont.

The Indian Queen mine is opened by an adit tunnel reaching a vertical depth of about 300 feet, with raises and winzes, and by several shallow shafts near the top of the hill.

The Greenstone mine is about 2 miles northeast of the Indian Queen mine, along the contact between monzonite and quartzite, at an elevation of about 7,200 feet above sea level. The lead strikes east and dips north, and the main contact strikes north. Quartzite of this horizon seems to outcrop continuously south-southwestward across Birch Creek at the narrowest part of the canyon, and north-northeastward at least to Barber Gulch, about halfway between Birch Creek and Willow Creek. On the Fairview claim on Barber

Gulch the monzonite is cut by numerous aplite dikes, and is in contact with quartzite which contains layers curiously spotted brownish red and gray, apparently by unequal distribution of iron oxide. Other layers close at hand consist of dense gray quartzite, filled with numerous small rudely ellipsoidal openings which average about 0.5 millimeter in diameter and lie in all positions. Some of them are partly filled by a pale-greenish mineral which weathers brownish. These quartzites are strikingly similar to the Weber quartzite[1] of the Pennsylvanian of Utah, and seem to represent the same horizon. They probably belong to the Quadrant formation.

IRON.

Deposits of magnetite iron ore occur in limestone on the south side of Birch Creek about half a mile south of the Indian Queen mine. They have been worked from time to time to obtain fluxing material for copper or lead smelters. They occur as irregular pockets and are opened by shallow pits and shafts.

ORIGIN OF ORE DEPOSITS.

The ores of the Indian Queen and Greenstone mines are very plainly of contact origin—that is, they have been produced by solutions escaping from the intrusive magma along its contacts with sedimentary rocks. Chemical action between these solutions and the sedimentary rocks concerned is probably important in many cases in producing precipitation and localization of ores. The evidence of such an origin for these ores is unusually complete. It may be outlined as follows:

1. The ores are restricted in occurrence to the zone of contact between the intrusive and the sedimentary series.

2. The ores include, in addition to minerals due to enrichment, sulphide minerals intimately associated with oxides; that is, chalcopyrite and bornite are mingled with magnetite and hematite. This association is well known in ores produced by contact metamorphism and is unknown or rare in other deposits. It is, of course, common also in the ores of pegmatites, which are closely related to contact-metamorphic ores.

3. The ores of the Indian Queen mine are intimately associated with minerals such as garnet, epidote, diopside, and axinite, which are often produced by contact metamorphism of limestone. Axinite is an indication of the close relationship between contact-metamorphic ores and the ores of pegmatites.

4. The ores are closely related in occurrence to intrusions of aplitic dikes which are probably differentiation products from the monzonitic magma.

[1] Blackwelder, Eliot, U. S. Geol. Survey Bull. 430, p. 540, 1910.

According to Vogt[1] the contact-metamorphic iron deposits of the Christiania region of Norway were formed before the solidification of the igneous intrusive from which they came. In the Utopia district the contact ores were formed after the solidification of the quartz monzonite, for they extend a short distance from the contact into the monzonite. Such ores seem to be associated rather closely with aplitic intrusions. In Bear Gulch (Tidal Wave district), in the Moose Creek district, in the Bryant (Hecla) district, and in the Argenta district the evidence is clear that ores of contact-metamorphic origin were formed after the solidification of the igneous intrusive.

PRODUCTION.

The production of metals in the Utopia district in 1903 may be estimated from the known output and net value of copper matte and metal; for the years 1904 to 1909, inclusive, the production of metals may be tabulated from the records of the United States Geological Survey. The following statistics, thus obtained, show that the district has produced metals having a total value of more than a quarter of a million dollars:

Production of metals in the Utopia district.

Year.	Ore.	Gold.		Silver.		Copper.		Total.
	Tons.	*Fine oz.*		*Fine oz.*		*Pounds.*		
1903	1,600	40.00	$828	16,500	$8,844	700,000	$92,750	$102,422
1904	1,200	30.14	623	12,579	7,198	525,639	67,403	75,224
1905	....	....	....	....	....	....	....	....
1906	707	14.52	300	3,975	2,663	191,926	37,042	40,005
1907	471	.69	14	2,449	1,616	103,207	20,642	22,272
1908	341	74.45	1,539	1,249	662	107,172	14,147	16,348
1909	199	3.09	64	420	218	28,765	3,739	4,021
1910	35	.24	5	46	24	10,885	1,382	1,411
1911	65	.87	18	154	82	14,877	1,860	1,960
1912	31	2.47	51	194	119	4,627	764	984
	4,649	166.47	3,442	37,566	21,426	1,687,098	239,729	264,647

In addition to the output stated in the above table the district in 1912 produced 1,102 pounds of lead, valued at $50.

ARGENTA DISTRICT.

LOCATION.

The Argenta district is situated at the mouth of the canyon of Rattlesnake Creek, about 12 miles west-northwest of Dillon, which is the county seat of Beaverhead County and an important station on the Oregon Short Line Railroad. The Argenta mines are at an elevation of 6,000 to 6,500 feet, just above the bench lands south of the creek, which are so evenly graded between Argenta and Beaverhead River that the region looks like a flat plain.

[1] Vogt, J. H. L., Am. Inst. Min. Eng. Trans., vol. 31, p. 138, 1902.

HISTORY.

The mines of the Argenta district were discovered soon after the beginning of placer mining in the region in 1862. The St. Louis & Montana Mining Co. erected lead smelters at Argenta in 1865, A. M. Elsler built a 6-ton furnace there in 1866, and two more lead furnaces were constructed in 1867. Within a short time there were six blast furnaces and two cupeling furnaces at Argenta. But the district did not supply enough lead ore to run them, and one after another shut down. Near the surface the ore was rich in lead, largely as galena, but with increasing depth the lead is reported to have decreased even more rapidly than the silver. Consequently, the district was almost deserted in 1875 for districts like the Bryant and Blue Wing, which produced ores of higher grade.

Placer mining on Rattlesnake Creek in the vicinity of Argenta was prosecuted successfully on a small scale for a short time in the seventies.

Relatively little activity was shown in mining in the district during the next two decades, but the high prices of lead and silver in 1906 and 1907 led to renewal of operations in some of the mines in these years and in 1908 and 1909. When the district was visited in 1910 practically no mining was in progress.

GEOLOGY.

Argenta is located in the midst of a small outlier of the great batholith of quartz monzonite which occupies the mountains more or less continuously from Hecla southward for about 20 miles. At Argenta an area extending less than 1 mile north and south and about 2 miles along the creek is occupied by monzonite, which, however, does not everywhere outcrop at the surface, being covered in places by a thin uneroded remnant of the original roof of limestone or quartzite. The existence of the monzonite beneath this cover is established by natural sections in gulches and by artificial sections in shafts and tunnels.

On the north side of the monzonite area the igneous contact on the property of the Butte Argenta Mining Co. dips about 50° N. at a depth of about 150 feet, but the dip decreases with increasing depth. Northwest of the monzonite quartzites and limestones outcrop, dipping 10°–45° SE. Southeast of the monzonite area the evenly graded bench lands are occupied by Tertiary deposits, consisting of alluvium and volcanic ash. The areal geology of the district is shown in figure 4.

It is believed that the quartzite of the Argenta district belongs to the Quadrant formation and that its age is Pennsylvanian, and that the underlying limestone is to be referred to the Madison, of the

Mississippian series. Fossils of Madison age were collected in a similar limestone in the Blue Wing district about 10 miles south-southwest of Argenta.

Sandstone which is apparently of Cretaceous age outcrops in a low hill about 1 mile south of the road between Argenta and Dillon about 5 miles west of Dillon. To the north and to the east extensive rhyolite flows cover the sediments.

ORE DEPOSITS.

When the Argenta district was visited in August, 1910, no mines were in operation. At the Midnight mine, which had been operated a short time previously by the Gladstone Mining Co., under lease from the owner, a vein in quartzite strikes N. 45° W. and dips about 85° NE. The quartzite is capped by limestone striking northeast and dipping about 30° SE. It is highly probable that this quartzite rests on monzonite. The mine is opened by an inclined shaft on the vein 265 feet deep. At a depth of about 200 feet the change from oxidized to sulphide ore occurs. The chief value of the oxidized ore is in gold, but it contains also considerable silver and lead. Native gold occurs in limonite, hematite, and quartz, with cerusite carrying silver. In the sulphide zone the chief value is in lead and silver, with much less gold. Galena is the principal ore mineral, but some pyrite is present.

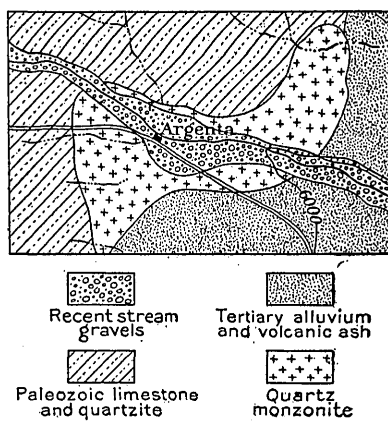


FIGURE 4.—Geologic sketch map of the Argenta mining district, Mont.

Ore from the Gold Day claim at Argenta contains cerargyrite, native gold, and telluride of gold (sylvanite?). The native gold occurs in calcite associated with hematite and apparently siderite or ankerite. Other claims in the district produce some copper ores, including malachite, azurite, and chalcocite.

At the Iron Mountain mine, formerly worked by the Butte Argenta Mining Co., the main adit tunnel crosscuts monzonite for about 500 feet and extends 200 feet farther in limestone. Small veins of pyrite occur in the monzonite. The main ore body is at the contact, which strikes east and dips about 50° N., the dip decreasing with depth. Some faulting occurs along the contact; in the fault gouge on the tunnel level cubes of pyrite are abundant and are not at all oxidized. Cerusite occurs along the contact nearer the surface. Other ore minerals found here include chrysocolla, malachite, cuprite, and a little galena.

At the property of the Dillon Argenta Mining Co., on Rattlesnake Creek just east of Argenta, a vertical shaft has been sunk 150 feet in monzonite. Some pyritic ore was encountered, but the gold content was low. Some of this ore was used at the copper smelter of the Indian Queen mine on Birch Creek to supply sulphur. Across Rattlesnake Creek to the north are several adits and a shaft 130 feet deep. These openings are on veins containing lead and zinc ore, chiefly in the form of galena and sphalerite. Without separation the ores are unsatisfactory. The veins strike north and dip about 60° E. The monzonite and limestone contact is about 1,000 feet north of these veins.

ORIGIN OF ORE DEPOSITS.

With regard to the origin of the ores in the Argenta district a very significant fact is the intimate association of ores that lie directly on the contact between monzonite and sediments with ores that occur in veins in the intrusive rock. It is clear that the ores were produced after the main mass of the monzonite solidified in this place, for the ores occur in part in veins cutting the monzonite. Furthermore, ores occurring along contacts and filling fault fissures on those contacts must have been formed after the intrusive rock solidified, for the faults could not have been produced before solidification.

If it is admitted that contact-metamorphic deposits are produced by solutions, either gaseous or liquid, escaping from magmas, the close association between contact-metamorphic deposits and vein deposits makes it probable that the veins were produced in the same or a similar way. Again, if it is admitted that the veins and contacts in the Argenta district were filled with ore deposited by uprising solutions, such solutions must have come, at least in part, through fissures in the upper part of the solidified batholith. Accordingly, if these premises are admitted, it seems probable that the ore-bearing solutions come from within and probably from the central or lower portion of the magma. This conclusion is in harmony with the theory that ores produced by contact metamorphism have been concentrated by remaining in solution in the constantly diminishing unsolidified residual magma during the crystallization of the latter, and that they have finally escaped by means of fissures in the solidified portion due to shrinkage from cooling. Such fissures will naturally be especially abundant and important along the contacts of the magma with sedimentary rocks, because these contacts are regions of weakness and because both cooling and shrinking will proceed at unequal rates in the igneous and sedimentary rocks, on account of differences in the chemical and mineral composition of the rocks of the two types.

PRODUCTION.

The production of metals in the Argenta and Blue Wing districts for the years 1904 to 1911 inclusive is given on page 72.

BLUE WING DISTRICT.

LOCATION.

The Blue Wing district is located about 8 miles southwest of Argenta and 15 miles west of Dillon, in the region of the divide between Rattlesnake and Grasshopper creeks, just south of the Dillon-Bannock road. The district, which lies at an elevation of about 7,000 feet above sea level and overlooks the Beaverhead Valley, takes its name from the Blue Wing mine, which was discovered in 1864 and yielded considerable native silver and silver ores.

HISTORY.

The district was the scene of considerable mining activity in the later sixties and the seventies, and some of the mines have been in operation on a small scale more or less continuously ever since that time. It is estimated that the district produced metals of a gross value of at least $200,000 within 10 years of its discovery, and the value of metals produced to 1910 is probably at least $7,000,000. The chief metal recovered from the ores of the district has always been silver, with minor quantities of lead, gold, and copper. No smelter or mills have been erected in the district; for a time during its early history the ores were treated at the smelters at Argenta, and after these were closed the ores were sent to Swansea, in Wales, to Germany, and to California. Later they were sent to smelters in Utah, and finally they obtained a better market when a lead smelter was erected at East Helena. At present most of them are sent to East Helena or to Utah.

GEOLOGY.

The mines of the Blue Wing district are situated on or near contacts between igneous and sedimentary rocks. The igneous rocks include rhyolite, trachyte, andesite porphyry, and quartz diorite, and the sedimentary rocks include quartzite and limestone. In general the igneous rocks occupy the eastern part and the sedimentary rocks the western part of the district. The sedimentary rocks strike north or northeast and dip 20°–35° W. or NW.

In a rapid reconnaissance of the district no quartz monzonite was encountered, but the igneous rocks found include rhyolite, andesite, porphyry, and diorite, which elsewhere are known to be closely associated with the quartz monzonite of the Boulder batholith. Rhyolite is abundant in the Butte district and occupies much of the eastern border of the batholith in the Helena quadrangle from Gregson Springs to Rimini. Andesite porphyry occupies a large part of the western border of the same batholith from Pipestone Springs to the mountains about 6 miles east of Clancy. Diorite is known as a border facies of the monzonite at Highland and near Dewey. It is believed that an isolated portion of the Boulder batholith occupies the region from Hecla about 25 miles south-southwest. The small boss of granodiorite at Bannock, which is considered probably an outlier of the Boulder batholith, is only about 2 miles from the Blue Wing district. Accordingly, it seems reasonable to suggest that the igneous rocks of the Blue Wing district are closely related in origin to the great Boulder batholith.

Rhyolite with trachyte phases or perhaps an independent intrusion of trachyte occupies much of the foothills from a point about 2 miles south of Argenta southwestward for about 6 miles. In some places rhyolite breccia is found, indicating that this rock was an extrusive. Along the Dillon-Bannock road andesite porphyry occurs in columnar outcrops at a point about three-quarters of a mile north of the New Departure mine. On the western border of the rhyolite area, between it and the Paleozoic sediments, quartz diorite outcrops at the Del Monte mine. At the Kent, New Departure, and other mines it is clear that the igneous rocks are intrusive into and in large part lie irregularly beneath the sediments, whether these are limestone or quartzite.

The sedimentary rocks of the district include limestones and quartzites, the former being largely referable to the Madison limestone, which seems to have a thickness here of about 1,000 feet. On the crest of the north-south ridge just west of the Kent mine, on ground formerly known as the Snowdrop claim, fossils were collected, concerning which George H. Girty has reported as follows:

Lot F7 contains the following fauna, which is clearly of early Mississippian age, and represents the horizon of the Madison limestone:

Crania lævis?	Productus lævicosta.
Schuchertella inflata?	Syringothyris carteri.
Rhipidomella sp.	Spirifer centronatus.
Productella arcuata?	Spirifer peculiaris?
Productella concentrica?	Composita humilis.
Productus aff. newberryi.	Eumetria marcyi.

At the point where these fossils were collected the Madison limestone strikes north, but within a mile it seems to swing to northeast. The dip is at a moderate angle to the west. About half a mile north-northeast, at the Kent mine, the Madison limestone strikes north and dips 35° W.

At the New Departure mine, about 1½ miles northeast of the Kent mine, limestone striking N. 20° E. and dipping about 32° WNW.

occurs. No fossils were discovered and dense smoke from forest fires prevented determination of the age of these beds from their field relations.

ORE DEPOSITS.

At the New Departure mine the ore occurs in shoots in veins in limestone lying on quartzite. Certain veins strike east-northeast and dip south-southeast; later fault veins, carrying about a foot of red fault clay, strike N. 60° W. and dip 20°–40° SW. Another important fault strikes N. 60° E. and dips about 25° NW. Later faults strike north and dip nearly vertically. The ore is chiefly cerargyrite, associated in a few places with gold. The greatest depth reached is about 250 feet; all the ore so far excavated is from the oxidized zone, but incompletely oxidized fragments show remnants of sphalerite and galena. The gangue materials include smithsonite (some of it carrying enough silver to be an ore) and either quartz or calcite.

The Kent mine is located about 3 miles northeast of Bannock, at an elevation of about 6,800 feet, near the base of the Madison limestone, which strikes north and dips about 35° W. and rests irregularly upon intrusive rhyolite. The ores, which occur in irregular chambers roughly parallel with the bedding not far above the limestone and rhyolite contact, are chiefly cerargyrite, cerusite, atacamite, tetrahedrite, galena, and sphalerite. They commonly carry about 15 per cent of lead and 5 to 6 per cent, or in places in the deepest workings 8 per cent, of copper. Small amounts of manganese are present.

At the Del Monte mine a quartz diorite is apparently intrusive beneath Madison limestone. This igneous rock differs from quartz monzonite in having no pyroxene and in the dominance of plagioclase over orthoclase; in all other respects it is very similar to the quartz monzonite found so extensively in the quadrangle, and it is considered probable that, as at Highland and Dewey, it represents a marginal phase of the monzonite batholith. Rhyolite occurs on the same property, which is opened by an incline shaft having a vertical depth of about 300 feet. The ore, which is in a shoot in a vein 16 inches wide, striking east and dipping about 75° S., was rich near the surface, where it contained much cerargyrite, but at about 60 feet its silver content declined notably, the ore being leached; at 80 feet it changed to sulphide ore, chiefly pyrargyrite.

The minerals found in the ore in the Blue Wing district include native silver, native gold, cerargyrite, bromyrite (?), pyrolusite, quartz, calcite, atacamite, malachite, azurite, melaconite, smithsonite, cerusite, galena, pyrargyrite, proustite, argentite, tetrahedrite, pyrite, and sphalerite.

ORIGIN OF ORE DEPOSITS.

The evidence at hand is not sufficient to establish definitely the origin of the ores of the Blue Wing district. So far as known, the ore occurs in veins, most of which are in limestone, near its contact with porphyry, though some are in igneous rock, as rhyolite. Commonly the ore is concentrated in shoots and is not continuous along the vein, which may be parallel to the bedding or may lie at varying angles with it. Minerals characteristic of contact-metamorphic zones are lacking, though epidote may be found in some of the rhyolite. It seems possible that the ores were deposited by solutions escaping from the intrusive igneous rocks, and that contact-metamorphic effects are lacking because the solutions were at lower temperatures and under less pressure than they are at greater depths.

PRODUCTION.

As the Argenta and Blue Wing districts are near together and have similar ores and as separate publication would disclose the production of some individual properties, the statistics of production of metals in the two districts have been combined by the United States Geological Survey into a single tabulation. The annual production of the districts during the sixties and seventies was probably much larger than during recent years, but statistics are available only for the years 1904–1911, inclusive:

Production of metals in the Argenta and Blue Wing districts.

Year.	Ore.	Gold.		Silver.		Copper.		Lead.		Total.
	Tons.	*Fine oz.*		*Fine oz.*		*Pounds.*		*Pounds.*		
1904	200	232.20	$4,800							$4,800
1905	40			7,200	$4,349					4,349
1906	178	7.93	164	7,049	4,723	371	$71	29,754	$1,696	6,654
1907	857	16.88	349	39,898	26,333	166	33	32,439	1,719	28,434
1908	87	9.10	188	7,189	3,810	1,164	153	24,789	1,041	5,192
1909	223	15.63	323	20,282	10,547	8,636	1,123	96,484	4,149	16,142
1910	157	97.58	2,017	13,948	7,532	7,573	962	37,283	1,640	12,151
1911	9	.24	5	1,099	582	130	16	778	35	638
1912	84	1.69	35	3,565	2,193	10,039	1,656			3,884
	1,835	381.25	7,881	100,230	60,069	28,079	4,014	221,527	10,280	82,244

BANNOCK DISTRICT.

LOCATION.

The Bannock district is on the extreme western border of the Dillon quadrangle about 22 miles by road west-southwest of the town of Dillon. The mines are on both sides of Grasshopper Creek and are chiefly within the quadrangle. The town of Bannock is north of the creek, just west of the quadrangle, at an elevation of 5,800 feet above sea level. Bannock is connected with Dillon by a daily stage. Grasshopper Creek has cut a narrow canyon through Tertiary volcanic rocks east of Bannock, but the stage is compelled to climb over a 2,000-foot divide between Grasshopper and Rattlesnake creeks. A better freight road leads southward from Bannock across the low divide between Grasshopper and Horse Plain creeks for about 16 miles to Grant, on the Gilmore & Pittsburgh Railroad. This divide is about 500 feet above Bannock, as measured by aneroid, and has very gentle slopes on both sides.

HISTORY.

The first discovery of gold in Montana was made in the Bannock district in 1862, and the placers of Bannock are reported to have yielded in that year $600,000 worth of gold. The next year placers were discovered on Horse Plain Creek, to the south. At about the same time deep mining of ore in place began in Bannock, and this marked the beginning of "quartz" mining in Montana. In 1863 a 6-stamp mill made on the spot was erected to treat ore from the Dakota mine; the next year another mill was installed, and by 1870 the district had five plants for treating ore. The Dakota mine was opened by several adits and shafts, one of which had reached a vertical depth of 300 feet in 1868. In that year the mine produced 1,200 tons of ore averaging $18 a ton, chiefly in gold. In 1895 the first dredge was installed at Bannock and proved successful for a time but soon exhausted the dredging ground. The placers which could be worked by water that was directly available were soon worked out, and ditches and flumes, one 15 and another 30 miles long, were constructed to bring in water at a higher level from Horse Plain Creek. For a short time Bannock was the capital of Montana Territory; in 1869 it was the county seat of Beaverhead County and had a population of 500 people. The district has been comparatively inactive during the last ten years.

GEOLOGY.

The rocks of the Bannock district consist of Paleozoic limestone intruded by a small boss of granodiorite. Fossils obtained from this limestone less than 2 miles to the northeast, in the Blue Wing district, are, according to George H. Girty (see p. 70), clearly referable to the Madison limestone of early Mississippian age. Immediately above the limestone lie a few remnants of the Quadrant (?) quartzite, but the underlying red and gray shales of the Threeforks formation were not discovered within the Bannock district. At Bannock the limestone strikes N. 75° E. and dips about 30° NNW. About 2 miles to the northeast the limestone strikes about north and dips about 30° W.

The main granodiorite intrusion is nearly circular in surface outline. A minor intrusion of the same type occurs across the creek to the north, and part of the western edge of the main mass is faulted northward a few hundred feet, as shown in figure 5. The rock itself is of granitic texture and consists of dominant zonal plagioclase, a small amount of optically abnormal orthoclase, some quartz, abundant magnetite (much of which is inclosed in biotite), and some hornblende and augite. It has been called syenite and is locally so known, but it contains far too much quartz for a syenite, and moreover its feldspar is chiefly plagioclase.

West of Bannock the Tertiary deposits occupy the surface for miles both north and south. To the south they extend over the divide between Grasshopper and Horse Plain creeks and beyond into the valley of the latter. East of Bannock Grasshopper Creek follows a new course instead of the north-south valley west of the town which it (or some larger stream) probably once occupied. A basalt flow now forming a small mesa just east of the divide may have caused the change.

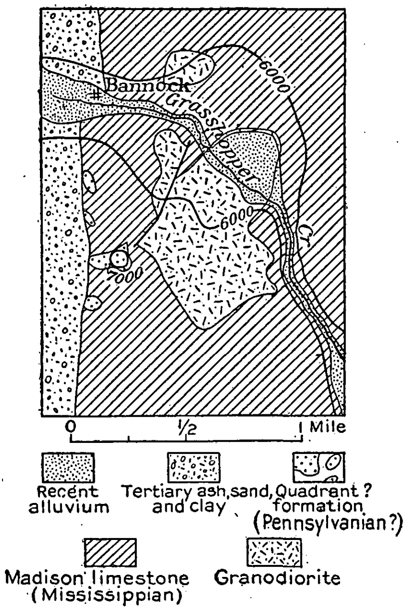


FIGURE 5.—Geologic sketch map of the Bannock mining district, Mont.

ORE DEPOSITS.

Most of the ore deposits at Bannock are contact deposits, but minor ore bodies on the Dakota, Wadams, Montana, and Empire claims are on fissures and are not so clearly referable to contact action. The ores have been of value almost wholly on account of their gold, but they contain also some silver, lead, and copper. The ore bodies are along the contact between limestone and granodiorite, or in irregular masses in the former, or in stringers or small fissures. The contact is marked in places by abundant garnet and some epidote.

The Golden Leaf mine has small bodies of copper ore containing chalcopyrite, bornite, tetrahedrite, pyrite, galena, hematite, malachite, azurite, chrysocolla, cerargyrite, native gold, and cerusite. All the ore is on the contact or in shoots running short distances into the limestone. The metals recovered have been chiefly gold and silver, though occasionally the owners have received pay for lead. Ore containing tetrahedrite was of especially high grade.

The Excelsior and Lookout mines are reported to have produced gold telluride ores and auriferous pyrite from deposits along the contact. The pyrite is associated with garnet, calcite, specular hematite, and a little epidote and bornite.

At the Wadams mine a tongue of granodiorite extends westward into the limestone. The copper minerals along the contact include chalcopyrite, cuprite, malachite, azurite, and chrysocolla. Associated minerals are galena, cerusite, and abundant garnet and epidote.

The ores of the Bannock district occur in a mountainous region and much of the mining has been done through tunnels. The Wadams mine is over 600 feet above creek level, but no great depth has been attained by the tunnels, and it is said that the deepest mining by either tunnel or shaft has gone only a little more than 300 feet below the surface.

PRODUCTION.

Records of production of the Bannock district are incomplete, and it is impossible to make a trustworthy tabulation of the output by mines or by years. A reasonable estimate from the data available puts the total production of the district to 1905 at not less than $4,000,000, of which about $2,500,000 is placer gold and the remainder gold bullion from deep mines. This estimate excludes the production of the Blue Wing, Argenta, Bald Mountain, and Horse Plain districts, which have been included in some previous estimates because Bannock was for many years the commercial headquarters and milling center for all of them. In 1870 the mill bullion product was $130,000 and the placer output $281,400, and two years later the total production was $250,000 in gold and $50,000 in silver. The production decreased rather irregularly from this date until 1897, when it was increased $130,000 by dredging, but after that year it again decreased. Of the total product, about $500,000 was obtained in 1862 from placers, and $1,000,000 more before 1870 from placers and deep mines. Another million was obtained from 1870 to 1875 largely from deep mines; from 1875 to 1905 the annual production was smaller, reaching $100,000 in only a few years. During 1896 to 1899 the Western Mine Enterprise Co. recovered $142,111 in gold from 6,442 tons of ore extracted chiefly from the Excelsior mine. The recent production of the district as reported to the United States Geological Survey has been as follows:

Production of Bannock district.

Year.	Crude ore.	Gold.	Silver.	Copper.	Lead.	Total value.
	Tons.	*Fine oz.*	*Fine oz.*	*Pounds.*	*Pounds.*	
1907	19	12.21	125	200	....	$376
1908	....	....	....	....	....	....
1909	35	170.28	311	136	1,696	3,773
1910	467	2,569.21	7,643	1,955	56,542	59,963
1911	839	2,103.55	6,889	3,013	38,349	49,239
1912	632	3,729.04	9,238	328	7,870	83,175

OUTLYING MINES IN BEAVERHEAD COUNTY.

POLARIS DISTRICT.

The Polaris group is about 8 miles south of the Elkhorn mining district, in T. 5 S., R. 12 W., about 15 miles nearly due west of the Indian Queen mine of the Utopia or Birch Creek mining district. It is near Bald Mountain, in a region sometimes known as the Lost Cloud or Polaris mining district.

The chief mines of the group are the Silver Fissure and the Dakota. The Silver Fissure is opened by a tunnel about half a mile long and has about 5,000 feet of workings. The ores, which carry silver with minor amounts of other metals, occur in irregular deposits in limestone at and near its contact with quartz monzonite. The mine produced about $60,000 worth of silver in 1886. The Dakota is opened by a tunnel about 1,000 feet long and has ores similar to those of the Silver Fissure. A 100-ton smelter with 4 blast furnaces was erected near the mines in 1907, but both mines and smelter have been idle or inactive since 1908.

BALD MOUNTAIN DISTRICT.

The Bald Mountain mining district is 3 to 5 miles south-southeast of the Polaris mine. Quartzites and limestones probably referable, at least in large part, to the Quadrant and Madison formations, are prominent in the district but in the southern part are covered by Tertiary deposits. The quartz monzonite of Elkhorn and Polaris probably extends southward into the northern part of the Bald Mountain district.

Placer mining began in this region as early as 1869. Ore in place was found soon after and from 1876 to 1885 yielded a moderate output chiefly valuable for its silver content. The Emerald mine produced 1,800 ounces of silver in 1875; the district yielded $8,000 worth of silver in 1880 and $51,000 worth in 1885. The Garrett and Faithful mines have not been operated for many years.

BLOODY DICK CREEK.

The Monument mine is on the north side of Bloody Dick Creek, at the mouth of the canyon, at an elevation of about 7,000 feet. It is about 5 miles northwest of Brenner, on the Gilmore & Pittsburgh Railroad. The country rock is gneiss. The mine was closed in 1909.

The Puzzler mine is on Bloody Dick Creek, about 10 miles from Brenner, at an elevation of about 7,500 feet. It is said to have been opened 40 years ago, but it has never been a large producer. Chalcopyrite, bornite, chrysocolla, cuprite, and malachite are irregularly distributed in seams and as coatings on sandstone, probably of pre-Cambrian age.

The Dark Horse mine is at the head of Bloody Dick Creek at an elevation above 9,000 feet. It may be reached by road up the creek from Brenner, a station on the Gilmore & Pittsburgh Railroad, about 25 miles to the southeast, or from the west by way of Salmon, Idaho, and across the Continental Divide, which is only half a mile from the mine. Mining has been conducted on both sides of the divide, and considerable work has been done on a 2,800-foot tunnel which is to open the Dark Horse mine to a depth of 800 feet below the crest of the mountain and allow its ores to be transported from the Idaho side of the divide to the Gilmore & Pittsburgh Railroad. The ore is chiefly chalcopyrite, with some bornite, in quartz in fissure veins in sandy slates. Near the surface the ore is altered to malachite in hematite and limonite and quartz.

JAHNKE MINE.

The Jahnke mine is at the head of Swede Creek, about 20 miles south-southwest of Jackson, a small town near the head of the Bighole basin in T. 5 N., R. 15 W., about 35 miles due west of Apex. The Montana Oreway Co. is opening it by a crosscut which has not yet reached the ore, though it has been driven 1,700 feet S. 20° W. into the divide between Montana and Idaho at an elevation of about 9,000 feet.

The country rock of the Jahnke mine is a pre-Cambrian argillaceous sandstone, which strikes N. 25° W. and dips 65° SW. It is cut by a conspicuous dike which strikes about N. 25° W. and dips about 35° SW. The dike rock is dark grayish green and contains abundant micrographic intergrowths of quartz and feldspar, chiefly orthoclase, with some microcline and plagioclase, abundant ilmenite or titaniferous magnetite, and considerable chlorite. Less abundant constituents include yellowish-brown to dark-blue tourmaline, abundant secondary sericite, and a little epidote and calcite. The ore occupies a mineralized zone beneath the dike about 100 feet thick in places. The gangue is largely quartz, and the metalliferous minerals include chalcopyrite, galena, malachite, azurite, and chrysocolla.

In this region the interstate boundary follows the Continental Divide, which is sharply defined, and consists of pre-Cambrian argillaceous sandstone and slate striking northwest and dipping southwest. The topography is strikingly different on the east and west sides of the divide. To the west the grassy land slopes perhaps 10° to open valleys only a few hundred feet below the divide. To the east the descent is precipitous down the sides of glacial cirques to narrow valleys at least a thousand feet below the mountain ridge. Glacial drift from these sources may be followed down the narrow valleys for several miles, but does not extend into the broad valley of Bighole River, which is occupied by Tertiary deposits.

AJAX MINE.

The Ajax mine was not visited by the writer, but deserves mention because it has been productive recently. It is near the head of Lake Creek, about 15 miles west of Jackson, or 50 miles west of Apex, on the Montana side of the Continental Divide. It is reported to have a strong quartz vein carrying argentiferous galena in slates. It was equipped with a 10-stamp mill and concentrator in 1905.

VIPOND DISTRICT.

LOCATION.

The Vipond district occupies a "park" or plateau-like region lying about 2,000 feet above Wise River, Bighole River, and Canyon Creek, which nearly surround it. It is not a true plateau, for it is hemmed in by higher land in several directions—to the east and south by mountains that rise 1,000 feet or more above the town of Vipond. Canyon Creek occupies a narrow and very deep gorge in these mountains, but has not yet eroded back far enough to drain the Vipond district. Its gorge, like that of Trapper Creek, is lined with glacial moraines. South of Vipond a moraine forms a ridge, resting upon and rising 50 to 100 feet above the solid rock on the north side of the gorge.

HISTORY.

The first mining claim in the district was located in 1867 by two brothers named Vipond. No mining was in progress in the district during the field season of 1910, but the Benton Mining & Milling Co. is reported to have been active in 1909. The low price of silver has practically stopped mining operations in this district.

GEOLOGY AND ORE DEPOSITS.

The veins commonly strike north and dip steeply west. The ore is in shoots in a gangue of quartz and siliceous limestone. The metals present are chiefly lead and silver, with a little copper and gold. The ore minerals in the oxidized zone include cerusite, wulfenite, cerargyrite, native silver, malachite, azurite, and chrysocolla, and in the sulphide zone galena, argentite, pyrargyrite, and sphalerite. Silver-copper glance,[1] or stromeyerite, is reported from this district.

The country rock in the northeastern part of the district is a bluish-gray Paleozoic limestone. Much of the "park" is covered with glacial gravel, probably derived from the mountain west of Vipond, locally called Sheep Mountain. Along the northeastern base and slope of this mountain are outcrops of slates and quartzites,

[1] Raymond, R. W., Mineral resources west of Rocky Mountains, 1872.

which probably belong to the Cambrian but which may include part of the Belt series (Algonkian). They are overlain by shales and these by limestones, probably Cambrian. The northern slope of the mountain is occupied partly by gneiss, which appears again near its southern base.

The Queen of the Hills mine lies just south of Sheep Mountain, at an altitude of about 8,200 feet, in gneiss and schist cut by aplitic dikes. Its ore, unlike that of most of the mines in the district, is valued chiefly for its gold, though it contains also native silver, argentite, cerusite, galena, pyrite, and chalcopyrite.

The vein on the Rich Hill claim strikes east or east-southeast and dips north. The ore is said to be pockety and irregular.

About 3 miles northeast of Vipond prominent outcrops of silver-bearing veins occur along the summit of Quartz Mountain, a southeast-northwest ridge about 2 miles long and half a mile wide, sloping gently to the southeast. The country rock is Paleozoic limestone dipping about 30° S. The veins, consisting chiefly of quartz with some barite, are nearly vertical and strike either north or east. They fault the limestone and contain the same ore minerals as are found elsewhere in the district. At the Benton mine the ore is highly quartzose and contains barite, malachite, chrysocolla, galena, and pyrolusite.

The Quartz Hill mine, which is reported to have produced considerable concentrating ore prior to 1894, is situated in the southwest corner of sec. 30, T. 1 S., R. 10 W. A mill for treatment of the silver ore of this mine was first erected at Dewey, on Bighole River, and later was moved up the creek to the mine. The mill, now dismantled, was evidently at one time well equipped for handling a moderate tonnage of ore. The size of the waste dumps and ponded tailings indicates that it ran for several years. The waste dumps consist mainly of decomposed sandy limestone, but fragments of ore were found showing cerargyrite, embolite, galena, and bornite in a quartz-barite gangue. The workings were not accessible at the time of examination, but it is locally reported that work was suspended because of the low price of silver.

BRYANT (HECLA) DISTRICT.

LOCATION.

The Bryant mining district is situated at an elevation of 8,500 to 9,500 feet above sea level, near the head of Trapper Creek, at the town of Hecla, about 12 miles nearly due west of Melrose. The district is reached by wagon road from Melrose by way of Glendale, a total distance of about 14 miles.

HISTORY.

The district was discovered in August, 1873, by James Bryant, from whom it took its name. Ten tons of ore carrying 140 ounces of silver to the ton and a high percentage of lead were obtained almost immediately, and the district has continued to produce every year since that time. In 1875 Dahler & Armstrong built a 40-ton lead smelter at Glendale and began treating ores from their own and other mines, including those at Highland, Vipond, and Hecla. About 1880 the smelter passed into the possession of the Hecla Consolidated Mining Co. Two years later a concentrator, with a capacity of 150 tons in 24 hours, was built by the company about 3 miles from Hecla, with which it was later connected by tramway. The published reports of the company show that, with the single exception of the year 1898, it paid dividends regularly for 21 years, from 1881 to 1901, inclusive, amounting in the aggregate to $2,250,000, or 150 per cent of the capital stock. The known ore bodies have been worked out and no dividends have been paid since 1901. The company ceased operations in 1904, but lessees have continued to obtain small amounts of ore to the present time.

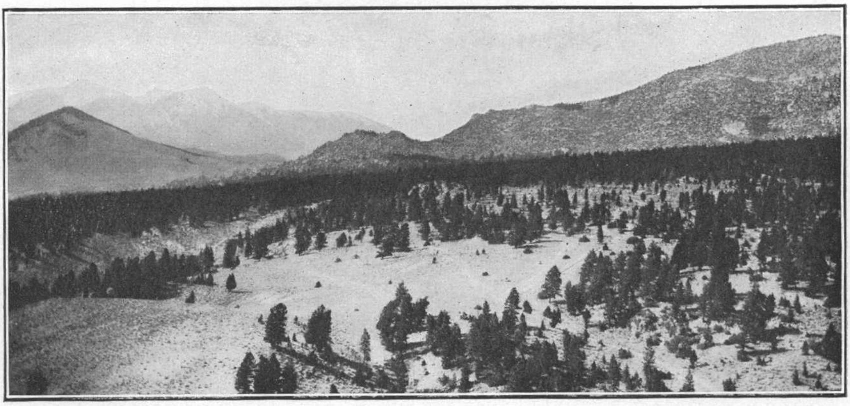
GEOLOGY.

The town of Hecla lies in a basin which is apparently the lower part of a glacial amphitheater. A ridge of Paleozoic limestone running north and swinging around well toward the east limits the basin on the west and north. Another ridge, slightly higher, composed of quartz monzonite, limits the basin on the south and southeast. Trapper Creek flows out of the basin to the northeast. A good idea of the topography may be obtained from Plate III, *B* and *C*, which shows two views from the top of Lion Mountain. The basin itself is occupied chiefly by dark-gray sandstones and slates, cut in places by intrusions of pegmatitic or even monzonitic character, apparently derived from the quartz monzonite magma.

A section from the top of Lion Mountain eastward and downward into the basin yields the following succession:

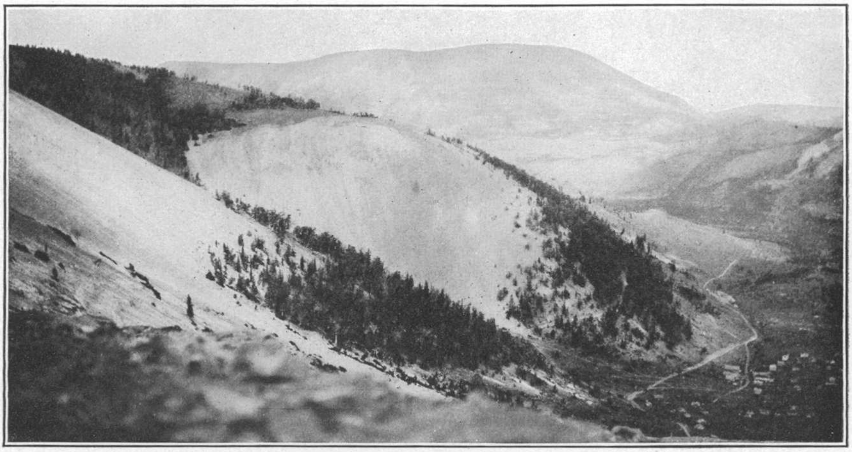
Section eastward and downward from top of Lion Mountain.

	Feet.
Blue shaly limestone	200
Buff and white dolomitic limestones; near the base one or more highly quartzose layers and layer containing flat limestone pebbles	1,700
Dark-gray shaly slate	100
Quartz conglomerate, with sandy shale cement	15
Fine-grained gray sandstone varying to slate and to dense quartzite weathering reddish	300
Quartz monzonite (intrusive).	



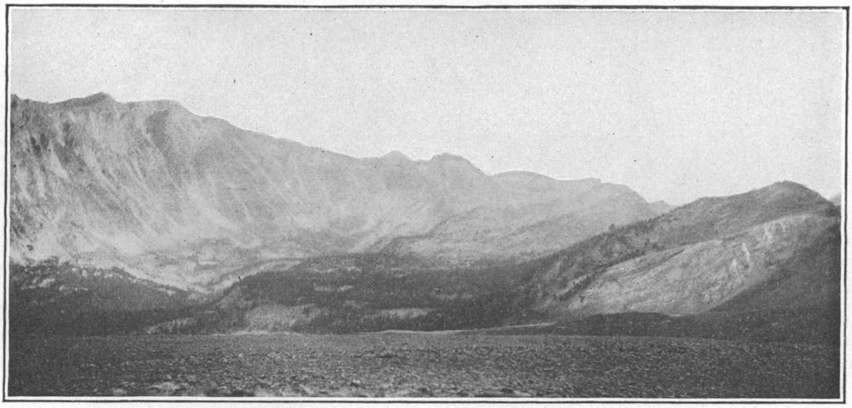
A. NORTH SLOPE (GRANITIC) OF BIRCH CREEK VALLEY, BEAVERHEAD COUNTY, MONT.

Looking northwest from Indian Queen mine at Farlin. Mount Torrey in the distance.



B. VALLEY OF TRAPPER CREEK, BEAVERHEAD COUNTY, MONT.

From top of Lion Mountain, Hecla. Paleozoic limestone cliffs in the foreground.



C. GRANITE MOUNTAIN AND GLACIAL CIRQUE, BEAVERHEAD COUNTY, MONT.

Looking southwest from Lion Mountain, Hecla. Paleozoic limestone at the right.

No fossils were found in this series, as lack of time prevented careful search, but it seems highly probable that the uppermost member is the equivalent of the Threeforks shale of the Devonian, and that the thick limestone series includes the Jefferson (Devonian) and older limestones (probably Silurian, Ordovician, and Cambrian). Elsewhere the Gallatin limestone, which is believed to be represented in this series, is said to contain Upper Cambrian fossils. The flat-pebble layer of the section seems to constitute an intraformational conglomerate and therefore does not imply any important interruption in sedimentation. Thus the limestone series contains no evidence of discontinuous sedimentation, and it is probable that the Ordovician and Silurian are represented by some of the central parts of the limestone beds.

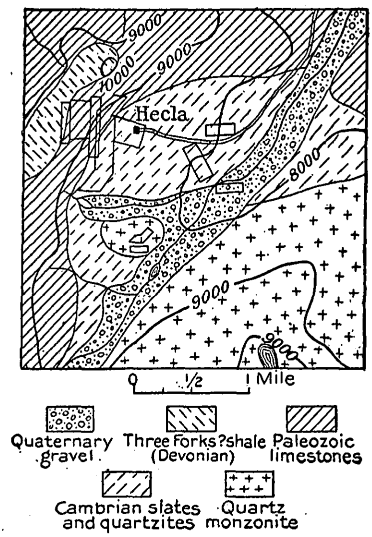


FIGURE 6.—Geologic sketch map of the Bryant (Hecla) mining district, Mont.

The correlation of the underlying slates and sandstones is more difficult. No unconformity has been discovered at the base of the limestones at Hecla, and it may be assumed that the underlying slates and sandstones belong to the Cambrian. If so, there seems to be reason to distinguish two parts of the Cambrian separated by an unconformity. This seems on the whole to be the most satisfactory interpretation; but it should not be forgotten that the sandstones and slates below the conglomerate may belong to the Belt series. The areal geology of the Bryant district is shown in figure 6.

Structurally, the most prominent feature at Hecla is the intrusive quartz monzonite that occupies the ridge to the southeast and underlies the basin itself. This intrusion seems to have made a place for itself, not only by assimilation, as indicated by xenoliths, but also by thrusting the limestone northward, thus producing large folds that strike east and west and pitch generally west. There seems to have been also some updoming of the sediments, with the production of folds pitching northward. This folding has not been accomplished without producing some faults, which, as indicated by underground mining, are chiefly of the gravity or normal type, though the igneous intrusion might be expected to produce overthrust faults.

Northeast and east of the border of the intrusive granite at Hecla the rock section along the road to Melrose is as follows, the older beds being given first:

Section along road from Hecla to Melrose.

	Strike.	Dip.	Thickness.
			Feet.
Blue slaty limestone	N. 25° W.	60° NE.	150
Yellowish limestone	do	45° NE.	500
Slaty quartzite	do	35° NE.	500
Red and green shales	do	25° NE.	300
Sandstone and shale	do	do	2,000
Do	N. 20° E.	60° NW.	(?)

The sandstones and shales, which are probably of Mesozoic age, outcrop eastward continuously to the recent alluvial deposits of Bighole River near Melrose. About 4 miles from Hecla the northwesterly dip is interrupted by an anticline trending nearly parallel with the valley and pitching about 15° or 20° ENE. About half a mile west of Glendale the pitch of the anticline becomes the dip of the strata, and then the dip sharply steepens. It is nearly vertical at Glendale and for about half a mile beyond, then turns to the west for a half a mile, then east again for half a mile, then west as far as Melrose. West of Melrose slates and quartzites outcrop, striking north and dipping west. They are overlain by brown limestone, which underlies red and green shales. Sedimentary rocks of this type, apparently Mesozoic in age, outcrop continuously along the west side of Bighole River from Divide to Glen; thence they seem to extend southeastward to the lower canyon of Bighole River and south-southwestward to and at least a mile beyond the mouth of Birch Creek canyon. From comparison with sections in the Philipsburg quadrangle it is considered by T. W. Stanton that the horizon of these beds is probably low in the Cretaceous.

ORE DEPOSITS.

Most of the ore at Hecla occurs in dolomitic limestone of lower Paleozoic age, but a small amount has been found in the intrusive quartz monzonite. The ore in the limestone does not occur in veins but in ore shoots and pockets. On Lion Mountain the shoots usually dip 20°–30° N. 60°–70° W., but trend in all directions. Six dikes are known to cross one or more of the ore shoots, faulting most of them a little. Most of the dikes strike about N. 25° E. and dip about 60° NW. Faults parallel the dikes or cross and offset both ore shoots and dikes. Only one fault is known which seems to be offset by a dike.

The limestone is dolomitic in general. In some layers it contains large amounts of quartz; adjoining dikes it may be enriched in biotite, or even converted in places into radiating groups of white diopside (?), with occasional accessory epidote.

The dikes are of two types petrographically. One type is an olivine diabase in which the olivine is completely altered to serpentine, and in which the pyroxene occurs in clusters of small phenocrysts. In this rock the labradorite feldspar is abundant in small lath-shaped forms inclosed in a matrix consisting largely of fine-grained pyroxene. Some nests of calcite are due in part to alteration and in part probably to included small fragments of wall rock. The second type of dike is a very fine grained aggregate of biotite and orthoclase, with small amounts of enstatite, titanite, magnetite, calcite, and chlorite, and apparently some quartz. It seems to be a minette, in which the mica shows microscopically a tendency to parallel arrangement; megascopically the rock shows no schistosity.

The main intrusive mass at Hecla consists of a quartz monzonite of coarsely granitic texture containing about equal amounts of orthoclase and plagioclase with quartz, biotite, hornblende, magnetite, and titanite. Near the ore deposits this rock undergoes alteration which results in the production of sericite, epidote, chlorite, and quartz. It is a curious fact that the sericite replaces the plagioclase more abundantly than it does the orthoclase. It must be concluded that the potassa (K_2O) entering into sericite has been carried in solution from the orthoclase crystals or anhedra to the place of formation of the sericite, for the sericite is in many places too abundant to be referred to the small quantities of potassa found in some unaltered plagioclase.

The quartz monzonite seems to grade upward into pegmatitic phases penetrating its former roof. Mining operations have exposed these phases in the Hecla basin, disclosing, at points where the uneroded sedimentary roof of the batholith is thin, pegmatitic offshoots that reach the present surface. It is an interesting and significant fact that some of these pegmatites are so much mineralized that they have been explored for ore bodies. That none of them have been found to contain important deposits may be explained by the hypothesis that ore bodies are formed at lower temperatures than those existing during the formation of pegmatites.

The quartz monzonite also exhibits a phase which resembles an aplite. This rock is fine grained and is distinctly more siliceous than the main batholith. It contains more quartz and more orthoclase than the batholith and in places includes perthitic or eutectic intergrowths of quartz and microcline. The other minerals in this phase do not differ from those in the ordinary quartz monzonite except that hornblende and epidote are absent and rutile is present.

The ore found in shoots in the limestone is valuable chiefly for silver and lead but contains minor amounts of copper and gold. It contains also zinc, antimony, arsenic, sulphur, and manganese. The presence of manganese in these ores is very interesting in view of the importance attributed by Emmons [1] to this element in the secondary concentration of gold ores by surface waters. The fact that the gold in these ores has undergone enrichment and that placer deposits are unknown or unimportant along Trapper Creek is in harmony with the theory that manganese is an important agent in promoting solution of gold by surface waters.

The ore in the limestone is largely oxidized, but some sulphide ore occurs, especially in the lower levels. The oxidized ores include native silver, native gold, cerargyrite, cerusite, malachite, azurite, chrysocolla, cuprite, smithsonite, and calamine; the sulphide ores include galena, tetrahedrite, argentite, pyrite, sphalerite, chalcocite, and chalcopyrite. The gangue is made up chiefly of calcite, dolomite, hematite, and limonite. The gangue minerals apparently produced by contact metamorphism include epidote, chlorite, sericite, quartz, and a mineral, not yet identified, which in a hand specimen resembles tremolite. In thin section this mineral shows one good cleavage; it is colorless in section and white in mass; it has moderately high relief, and a birefringence which produces first-order orange as the maximum interference color in a section apparently about 0.025 millimeter in thickness. It is biaxial and positive with an optic axial angle of moderate size. A section normal to Z, the acute bisectrix, shows two cleavages about 35° apart, with the optic plane parallel to the poor cleavage.

Another mineral intergrown with the one just described seems from its optical properties to be paragonite. It is colorless, negative, and apparently uniaxial;[2] its relief is slightly above that of balsam, and its birefringence may be roughly estimated at 0.03. It has excellent cleavage with parallel extinction, and the optic axis or acute bisectrix is sensibly normal to the cleavage.

ORIGIN OF ORE DEPOSITS.

The mines in the limestone on Lion Mountain west of Hecla are opened by an adit tunnel 3,200 feet long, and by four important and numerous minor shafts approximately following the ore shoots at an average dip of about 20° or 25°. As the ore shoots are in general roughly parallel with the bedding of the limestone they have been called contact deposits[3] between limestone and dolomite[3] or dolomite and "quartzite." If these ore bodies are properly contact deposits, it

[1] Emmons, W. H., Am. Inst. Min. Eng. Bull. 46, pp. 767-837, 1910.

[2] A. Johnsen (Centralbl. Mineralogie, p. 35, 1911) states that paragonite, in contrast with muscovite, is apparently uniaxial.

[3] Raymond, R. W., Statistics of mines west of Rocky Mountains, p. 242, 1877.

is not because they happen to lie in part along bedding planes of a limestone series which includes considerable dolomite and a few quartzose layers, some of which are adjacent to the deposits, but only because they have been produced by the action of gaseous or liquid solutions escaping from an igneous magma through limestone with which it was in contact. The evidence that the ore deposits of Hecla were produced by such contact action may be summarized as follows:

1. They occur in the limestone only where it is near a contact with the igneous batholith.
2. They are associated in places with pegmatites clearly derived from the magma.
3. They are associated in places with minerals such as epidote, which have evidently been produced by contact action.

It must be admitted that this evidence is not conclusive, and that, furthermore, the deposits in Lion Mountain are closely associated with igneous dikes and are not strictly on the contact of the batholith. Indeed, solutions from the batholith must probably have traveled 2,000 to 3,000 feet and perhaps much more to reach the main region of deposition in Lion Mountain. It seems probable that the ore-bearing solutions would be considerably cooled in traveling this distance, and it may be owing to this cooling that the solutions produced relatively little epidote and, so far as known, no garnet tourmaline, and fluorite which are so abundant in ordinary contact-metamorphic deposits. If the deposits at Hecla were produced by solutions notably cooler than those in ordinary contact zones, though still hot, they may be compared in this respect with vein deposits.

The Hecla deposits, indeed, seem to represent a type that is intermediate between contact ores and true veins and that has some of the characters of both. In form they are not in veins, but locally they occur in shoots in fairly regular seams or veins roughly parallel with the bedding.

That the ultimate source of the ores must be sought in the magma and not in the limestone is shown by the fact that similar ores occur in places in the batholith away from the limestone but do not occur in the limestone away from the batholith. This also shows that the ores were produced after the solidification of the quartz monzonite.

The ore deposits of the Cleve and Avon mines, at the base of Cleve Mountain north of Hecla, are evidently of the same origin as those of Lion Mountain, though they contain a larger amount of gold. They are closer to the monzonite outcrop than the Lion Mountain deposits. Their greater richness in gold may be due to the greater abundance of manganese in this portion of the district. The Cleve and Avon mines are opened by a vertical shaft and an inclined shaft reaching a depth of about 600 feet.

On the Hecla claim, about 1 mile south of the town of Hecla, a vein of sulphide ore occurs in quartz monzonite. The vein, which seems somewhat irregular, but which has not yet been extensively opened, contains a shoot of ore apparently pitching about 45°–60° E. or SE. The sulphide ore consists of a mixture of galena, pyrite, and sphalerite and runs nearly to the surface. On the hanging wall the ore shows some oxidation, especially of the pyrite.

PRODUCTION.

The total production of metals from the Bryant district is not accurately known, but the actual recovery of metals by the Hecla Co. during the years 1881 to 1903 is given in its published reports. The tonnage of ore produced annually during the years 1877 to 1880 is given in the same reports. By assuming this ore to be of the same grade as the ore produced in 1881 and estimating from incomplete data the production in the years 1873 to 1876, the metallic output from the discovery of the district to 1904 may be closely approximated. The data obtained by the United States Geological Survey give the production for the years 1904 to 1912.

Production of metals in the Bryant district.

Year.	Ore.	Gold.		Silver.		Copper.		Lead.		Total.
	Tons.	*Fine oz.*		*Fine oz.*		*Pounds.*		*Pounds.*		
1873	10	1.00	$21	1,400	$1,820	300	$84	7,000	$441	$2,366
1874	101	5.00	103	28,280	36,198	3,000	660	70,000	4,200	41,161
1875	1,812	90.00	1,860	200,000	248,000	77,000	17,479	1,466,000	85,028	352,367
1876	2,000	90.00	1,860	200,000	232,000	70,000	14,700	1,500,000	91,500	340,060
1877	2,069	100.00	2,067	150,000	180,000	60,000	11,400	1,500,000	82,500	275,967
1878	5,426	150.00	3,100	250,000	287,500	100,000	16,600	2,500,000	90,000	397,200
1879	11,067	200.00	4,134	350,000	392,000	150,000	27,900	3,200,000	131,200	555,234
1880	11,413	200.00	4,134	350,000	402,500	150,000	32,100	3,200,000	160,000	598,734
1881	8,831	300.00	6,202	534,197	603,643	215,067	39,142	4,843,646	232,495	881,482
1882	16,470	307.26	6,352	547,754	624,440	229,708	43,874	4,984,697	244,250	918,916
1883	24,564	402.53	8,321	662,836	735,748	308,519	50,906	5,203,919	223,769	1,018,744
1884	17,148	248.26	5,132	656,849	729,102	339,928	44,191	4,589,280	169,803	948,228
1885	19,240	712.74	14,734	686,845	734,924	177,567	19,177	5,528,653	215,617	984,452
1886	19,717	799.79	16,533	398,707	394,720	64,786	7,191	4,102,040	188,694	607,138
1887	21,284	441.69	9,131	474,719	465,225	123,642	17,063	4,663,148	209,842	701,261
1888	28,349	1,210.74	25,028	716,860	673,848	208,605	35,046	6,884,857	302,934	1,036,856
1889	24,463	1,098.62	22,710	579,431	494,665	228,380	30,831	6,138,258	239,392	787,598
1890	20,698	691.50	14,295	480,904	504,949	159,981	24,957	4,298,176	193,418	737,619
1891	30,122	666.25	13,774	485,209	480,357	89,674	11,478	4,030,947	173,331	678,940
1892	20,149	343.56	7,102	364,397	317,025	157,516	18,272	3,304,040	132,162	474,561
1893	12,003	210.84	4,358	226,240	176,467	94,095	10,162	1,973,851	73,032	264,019
1894	18,067	343.34	7,098	616,809	388,590	362,897	34,475	2,941,912	97,083	527,246
1895	15,964	339.58	7,020	347,342	225,772	239,631	25,641	1,175,523	37,617	296,050
1896	10,525	547.83	11,325	365,223	248,352	315,702	34,727	1,331,645	39,949	334,353
1897	5,914	405.84	8,390	215,431	129,259	184,836	21,071	1,090,175	39,246	197,966
1898	7,361	517.97	10,707	367,979	217,108	121,039	14,646	1,582,450	60,133	302,594
1899	3,477	219.12	4,529	242,738	145,643	155,719	27,718	838,894	37,750	215,640
1900	2,357	149.93	3,099	134,089	83,135	186,165	30,903	579,106	25,481	142,618
1901	1,944	304.54	6,295	236,168	141,701	108,426	18,107	1,025,562	44,099	210,202
1902	1,581	152.29	3,148	118,084	62,585	54,713	6,675	512,781	21,024	93,432
1903	1,546	162.75	3,364	140,122	75,666	104,267	14,284	444,312	18,661	111,975
1904	300	25.97	537	21,227	12,312	17,487	2,238	103,980	4,471	19,558
1905	540	40.00	827	36,000	21,960	24,000	3,744	144,000	6,768	33,299
1906	577	67.13	1,388	46,987	31,481	44,275	8,545	209,726	11,954	53,368
1907	149	3.64	75	22,648	14,948	17,240	3,448	55,800	2,957	21,428
1908	181	27.09	560	17,473	9,261	14,112	1,863	54,005	2,268	13,952
1909	574	63.32	1,309	45,053	23,428	53,399	6,942	287,470	12,361	44,040
1910	328	10.60	219	29,808	16,096	38,900	4,940	180,160	7,927	29,182
1911	1,095	44.31	916	90,480	47,954	98,126	12,266	766,883	34,510	95,646
1912	949	50.55	1,045	69,382	42,670	66,423	10,960	541,067	24,348	79,023
	370,365	11,743.58	242,802	11,507,671	10,653,052	5,215,125	756,406	87,853,963	3,772,215	15,424,475

HIGHLAND AND MOOSE CREEK DISTRICTS.

LOCATION.

The discovery of placer diggings along the upper course of Fish Creek in 1866 resulted in the establishment and rapid growth of the town of Highland, near the head of the creek. In 1869 and 1870 Highland was larger than Butte. Its decline was coincident with the decline of successful placer mining along Fish Creek, although some lode claims were located even in the early days.

The placer deposits of Fish Creek are at an elevation of about 7,000 feet, on the east side and within 2 miles of the main Continental Divide between the headwaters of the Missouri, flowing to the Gulf of Mexico, and those of the Columbia, flowing to the Pacific Ocean. On the slopes of the divide itself several lode claims have been located. Fish Creek, which flows east, drains the northern slopes of Red Mountain, and Moose Creek, which flows west, drains its western slopes; but the waters of both finally flow eastward in Missouri River. The gravels of Moose Creek have supplied some placer gold but not so much as those of Fish Creek. The miners on Fish Creek early established the Highland mining district; those on the west slope of the mountain established the Moose Creek district. As the mines of the two districts are on adjoining slopes of the same mountain they may be conveniently described together.

Some of the placer gold from Highland is remarkable for its purity, running as high as 0.970 fine and coining over $20 an ounce.

GEOLOGY.

The rocks of the Highland district consist of a series of slates and quartzites underlying a thick limestone, all of which are cut by numerous intrusions of quartz monzonite, diorite, pegmatite, and aplite. The sediments are faulted and displaced repeatedly, and along the northern border of the district they are cut off entirely by the quartz monzonite of the Boulder batholith. Along the road from Butte to Highland and on the steep slopes of the divide the limestone, which is Paleozoic, clearly lies upon the quartz monzonite, which is Tertiary.

It is highly probable that the quartz monzonite batholith extends beneath the slates and quartzites as well as beneath the limestone. Indeed, outliers of the batholith cut through the slates on Red and Table mountains and even through those on Camp Creek, still farther from the main mass. In other words, the Highland district is a remnant of the original roof of the batholith, probably near its southeastern border.

No fossils have been found in the district, but the thick-bedded limestone undoubtedly belongs to the Paleozoic, probably to the early

Paleozoic. It is bluish gray in color and is locally marmarized. Where the road crosses the main divide quartz monzonite underlies the axis of a closely folded syncline of limestones pitching southwest. The fact that the lowest limestone observed is overlain by about 300 feet of quartzose slates and these by massive limestone suggests that the series may be correlated with the similar succession of rocks which occurs in the Threeforks quadrangle and is called the Gallatin formation by Peale.[1]

The thick series of slates and quartzites exposed in the Highland district is believed to belong to the Belt series. So far as observed the large outcrops of Paleozoic limestone nowhere in the district overlie the slates and quartzites but seem to have been faulted down into a position beside them. However, a small patch of limestone at an elevation of about 10,000 feet on top of Table Mountain apparently lies on top of the slates. Furthermore, the same series of slates and quartzites underlies the Paleozoic rocks in regular position on Camp Creek, where the Paleozoic is continuous from the Madison limestone of the Carboniferous to the Flathead quartzite of the Cambrian.

On the divide between the headwaters of Fish and Moose creeks, well down toward the base of the slates and quartzites, this series includes a distinct quartzite conglomerate, which outcrops about half a mile south of the Murphy claim.

PETROGRAPHY.

On an east fork of Basin Creek, on the road about halfway between Butte and Highland, the quartz monzonite of the Boulder batholith includes numerous dark spots which are similar to those in the "granite" of Bear Gulch (p. 148), and which are believed to be of similar origin—that is, they are believed to be incompletely assimilated fragments of limestone now changed into dioritic rocks similar to the more basic portions of the magma itself by expulsion of CO_2 and diffusion of oxides into and out of the fragments.

The relations between the igneous intrusives, which are especially abundant as dikes and chonoliths[2] in the slates, and the Boulder batholith lying just to the north have already been mentioned (p. 29). The derivation of the intrusives from the batholith, at least in large part, can not be seriously questioned. Nevertheless, many of the intrusives are not identical petrologically with the quartz monzonite (commonly called Butte granite) of the batholith—that is, the unmodified batholithic magma did not penetrate into fissures and form dikes. Wherever the unmodified magma has penetrated the slates it has done so not in the form of dikes but as small stocks or

[1] Peale, A. C., U. S. Geol. Survey Geol. Atlas, Threeforks folio (No. 24), 1896.
[2] Daly, R. A., Jour. Geology, vol. 13, p. 498, 1905.

choliths. The fissures now filled with dikes of aplites, pegmatites, and diorites were formed after the solidification of the main batholith, as shown by the fact that the aplites and pegmatites locally cut the batholithic quartz monzonite. It appears, therefore, that the aplites and pegmatites filled fissures probably formed as a result of the shrinkage due to the cooling of the batholith and of the overlying rocks. Diorites are much less abundant than aplites in such dikes, but they occur on the northern slope of Red Mountain, where a sample collected by Weed [1] and analyzed by Stokes proves to be a dark-gray granular rock consisting of green hornblende and moderately calcic plagioclase with small amounts of orthoclase, biotite, quartz, apatite, and iron ore. In places this rock grades insensibly but rather rapidly into the ordinary quartz monzonite of the batholith. An analysis is given on page 38.

The rock is dominantly salic and highly feldspathic in norm; it has about equal quantities of lime and alkalies, but the soda dominates the potassa, and in the quantitative classification it is an andose. A rock apparently of this type was collected by the writer from the Richmond claim in the Highland district; it contains abundant plagioclase, a little orthoclase, and considerable diopside altering to hornblende. Accessory minerals include remarkably abundant titanite and small amounts of pyrite and apatite.

ORE DEPOSITS.

HIGHLAND DISTRICT.

In addition to the placers, which are still being worked in a small way, the Highland district contains numerous veins and irregular ore deposits, which are chiefly valuable for gold.

The Murphy mine is located at the head of the main fork of Fish Creek at an elevation of about 7,900 feet above sea level. The country rock is Paleozoic limestone, and the ore is not directly on a contact; but the Boulder batholith is less than a mile away, and the deposit is clearly of contact type. The ore occurs in veins, in joints, and in chimneys, the latter having apparently been formed by solution of limestone along watercourses and its replacement by ore deposited from solution. In some places the ore in chimneys is broken and recemented, indicating movement through the region of deposition during the period of formation. The veins, which are planes rather than shoots of contact ore deposition, are irregular, running in several directions, and are locally faulted. The largest strikes about east and dips about 80° N. Chimneys pitch with the veins, and are in places offset nearly horizontally to the east.

The Highland district contains a remarkable variety of minerals. Besides those composing the quartz monzonite, slates, quartzites,

[1] Weed, W. H., Jour. Geology, vol. 7, p. 737, 1899.

and limestones, namely, orthoclase, plagioclase, quartz, hornblende, augite, biotite, muscovite, magnetite, zircon, apatite, titanite, rutile, kaolinite, chlorite, talc, calcite, and dolomite, there are the minerals peculiar to contact metamorphism, such as garnet, zoisite, epidote, diopside, and actinolite; those found especially in pegmatites, such as green mica, tourmaline, and fluorite; those found in oxidized veins and ore deposits, such as malachite, azurite, chrysocolla, cuprite, cerusite, montanite, native gold, native silver, hematite, and limonite; and those in sulphide ores, such as chalcopyrite, bornite, galena, pyrite, pyrrhotite, arsenopyrite, tetradymite, argentite, and pyrargyrite. The rarest mineral in the list is montanite, which is a basic tellurate of bismuth reported by Genth[1] as occurring in crusts on tetradymite at Highland. No additional samples of this mineral could be obtained.

MOOSE CREEK DISTRICT.

In the Moose Creek district the mines north and northwest of the nearly deserted settlement called Moose Creek or Moosetown are in Paleozoic limestones or the adjoining quartz monzonite; the ores have clearly been produced by contact action of the batholith. The deposits are irregular and yield uncertain returns.

The Harvey, Day, and Dixie lodes were discovered in 1867 in the edge of the bench overlooking and north of Moose Creek; they have yielded chlorides and sulphides of silver as well as some gold-bearing quartz.

At Gold Hill, about 2½ miles southeast of Moosetown, where the Montreal group is under development, an outlier of the main batholith penetrates the slates and quartzites in the form of a chonolith. Most of the ore occurs in the quartz monzonite in irregular veins, pockets, and shoots near the contact and is chiefly valuable for its gold, though it carries a little silver and copper. Development is chiefly or wholly in the oxidized zone, in which the gangue minerals are hematite, limonite, and quartz. The ore is closely associated with aplitic dikes cutting the quartz monzonite and slates; indeed, such dikes in places constitute the leads and assay a few dollars in gold. The sedimentary rocks on Gold Hill have a general strike to the north and dip about 80° W. Other properties on Gold Hill are of the same general type as the Montreal group.

MELROSE DISTRICT (CAMP AND SOAP CREEKS).

LOCATION.

The town of Melrose, situated on the Oregon Short Line Railroad about 25 miles south of Butte, is local headquarters for miners of Camp Creek and Soap Gulch, and the two localities may conveniently be

[1] Genth, F. A., Am. Jour. Sci., 2d ser., vol. 45, p. 318, 1868.

grouped under the name Melrose district. Camp Creek forms the southern boundary of Silver Bow County; the mines are along its northern side and are therefore in Silver Bow County. Soap Creek is wholly in Silver Bow County. Melrose, which is in the extreme southern angle of the same county, has also been the railroad headquarters for the miners at Hecla and for the smelter and concentrator at Glendale, in Beaverhead County.

GEOLOGY.

Melrose is built on alluvial gravels deposited by Bighole River in Quaternary time. East of the gravels are uneroded bench lands occupied by Tertiary deposits, consisting largely of gravels, clays, and volcanic ash, which lie nearly or exactly horizontal. Farther east the foothills are occupied by Paleozoic limestones which strike northwest and dip southwest. South of Camp Creek the strike is locally nearly due south rather than southeast, but everywhere the dip is to the west. At Camp Creek the dip is about 45°, and this gradually increases to about 60° at Soap Gulch.

The Paleozoic rocks on Camp Creek show no apparent unconformity nor any evidence of interruption of sedimentation. They may be tabulated as follows, beginning with the youngest. The thicknesses given are approximate or estimated.

Stratigraphic section on Camp Creek.

	Feet.
Carboniferous: Madison limestone (massive limestones)	1,200
Devonian:	
Threeforks shale (reddish and gray shales)	300
Jefferson limestone (massive dark limestone)	1,200
Cambrian and later(?):	
Sandstone	200
Limestone	1,800
Shales	200
Sandstones grading into quartzite	500
Algonkian: Belt series (schists, quartzite, slates)	3,000

The series is cut off by an intrusion of "granite," which is probably an outlier of the Boulder batholith. East of the "granite" the schists and quartzites outcrop continuously to the head of the creek. In this region the quartzites contain some bands of coarse material and some distinct conglomerates of quartz pebbles in a quartzite matrix showing distinct bedding.

Between the head of Camp and Soap creeks the Belt series contains quartzites, sandstones, and much small conglomerate. These rocks outcrop abundantly on the high ridge southeast of Soap Creek, where they lie nearly flat upon slates. Along Soap Creek there are small areas of "granite" and aplite.

ORE DEPOSITS.

The Clipper group of claims is on a north fork of Camp Creek called Wickeyup Creek. The vein which strikes northwest and dips about 30° NE. in slates of the Belt series is 4 to 10 feet thick, but the ore is scattered irregularly through it. The hanging wall is marked by about 6 inches of fault clay. About a quarter of a mile to the southwest the slates are underlain by a conglomerate of quartz, quartzite, and slate pebbles in a cement of micaceous arkose. Here the slates strike north and dip east. The Clipper vein is opened by a vertical shaft 300 feet deep, near the bottom of which the slates are more massive, as if they were near an igneous contact, but no quartz monzonite is visible and none is known to outcrop in the immediate vicinity. Some of the ore from the Clipper vein carries as much as 25 per cent of copper. The ore minerals in the oxidized zone are malachite, azurite, and cuprite, and those in the sulphide zone are chalcopyrite and pyrite. The copper pyrites extend some distance above the water level, showing little oxidation. The gangue is chiefly quartz. At the 200-foot level the ground is much broken and crushed by movements.

Very little mining has been done on Soap Creek since the closing of the Glendale smelter in 1900. Before that date ores of various types were obtained along the gulch and were used at the smelter as fluxes. Thus iron ores were obtained from the King and Queen claims on the plateau between the heads of Camp and Soap creeks from "blanket leads" in quartzite—that is, from deposits lying flat or parallel with the surface. Furthermore, some lead-silver ores were mined along Soap Creek when the Glendale smelter furnished a convenient market. Thus the Pandora claim supplied such ore; it is located just below the flat-lying quartzite of the top of the ridge between Soap and Camp creeks, and it overlooks Soap Gulch, being at an elevation of about 7,000 feet above sea level and 500 to 700 feet above the creek. The Horn Silver, Gold King, and others are similar properties in the limestones and shales near the base of the Paleozoic limestones about 2 miles southwest of the Pandora.

Mr. R. W. Richards, formerly of the United States Geological Survey, has kindly supplied the following notes in regard to the Gold King, Berlin, and other mines on or near Soap Creek:

The main ore body, as explored by the Gold King mine, is a nearly vertical spiral, chimney-shaped mass, which has a diameter reported to range from 6 inches to 8 or 10 feet. The ore becomes lean toward the margin with an increase in the amount of iron oxides; outside of this "iron casing" the limestone has a leached aspect and in places consists mainly of loosely cemented grains. Ore has been removed from this chimney through a vertical distance of about 140 feet.

The development consists of a series of tunnels in a N. 50° W. direction, one above another at intervals of 50, 55, and 40 feet.

The uppermost is called the winze tunnel and is connected by a winze with the stope at the end of the next lower tunnel, which is known as the "upper." A winze follows the spiral ore body down for 55 feet from the floor of the "upper tunnel." The lower tunnel is 260 feet long, and a 75-foot raise 200 feet from the portal represents an attempt to connect with the winze. About 9 tons of ore is reported to have been removed from a stope about 30 feet up in this raise. The middle tunnel is nearly 100 feet long and does not connect with the other workings.

It appears that most of the ore in the Gold King chimney above the level of the lower tunnel has already been removed, and future tonnage will depend largely on the dimensions of the chimney in the ground lying between the floor of the winze and the top of the lower stope. Exploration may demonstrate the downward extension of the chimney below the level of the lower tunnel. The possibility of encountering other similar chimneys in the limestone should not be lost sight of, as the geologic conditions are favorable and the tenor of the ore already recovered shows that the locality is one of exceptional mineralization.

The ore occurs chiefly in monoclinal limestones and calcareous shales, probably of Devonian age, lying in faulted relation on schists and slates of the Belt series, which are also mineralized and show veins carrying both copper and silver. In 1909 to 1911 shipments amounting to 504,194 pounds of ore were made from Soap Gulch, which, according to smelter certificates, averaged 0.69 per cent of copper and 1.43 ounces of silver and 2.63 ounces of gold to the ton. The ore consists of an iron-stained quartz showing some pyrite, galena, and occasionally visible specks of gold. The galena is medium coarsely crystallized, has curved faces, and has been crushed. It is abundant only in the upper workings.

The principal deposit of silver ore in the Soap Gulch locality was mined by an inclined shaft not over 150 feet long, which is situated about a third of a mile north from the Gold King mine. It is reported that 200 tons of ore taken out at this point netted $13,000. The deposit is in the schists of the Belt series and was not examined in detail. Horn silver is the principal ore mineral.

The Emma Nevada mine, situated about half a mile N. 30° E. from the mine just mentioned, is in the gray argillites of the Belt series. This mine is reported to have produced $46,000 (net) worth of horn silver ore from shallow workings, and nearly all the ore was obtained within 50 feet of the surface. The ore body is said to have been cut off by a talclike deposit, presumably a fault selvage. The subsequent exploration failed to develop the continuation of the ore.

The Old Glory, another silver mine located on a hilltop about a mile nearly due north of the Emma Nevada, is reported to have yielded about $100,000 worth of ore from a deposit near the surface. The ore body is said to be cut off at a depth of 75 feet by a selvage similar to that in the Emma Nevada.

In Soap Gulch near the township line in sec. 7, T. 2 S., R. 8 W., just east of the fault between the supposed Devonian limestones and the schists of the Belt series, there are two sets of prospects known as the Little group, one set on the north side of the canyon and another on the south side. The bearing between the two is N. 35° E. The developments on the north side consist of a nearly horizontal tunnel about 30 feet long in decomposed schist and show an irregular mass of copper-stained rock containing some chalcopyrite. This without doubt represents ledge matter nearly in place. Near the mouth of this tunnel a vertical shaft, which was filled with water at the time of the writer's visit, is reported to have a depth of about 150 feet. At the 140-foot level a crosscut about 415 feet toward the west is supposed to have cut the copper-bearing ledge, the thickness of which is further reported to be 40 feet. H. S. Gale, of the Geological Survey, reports the presence of a dike of basic igneous rock in the immediate vicinity of these workings.

On the south side of the gulch there is a tunnel with two branches, one about 200 feet long and the other about 145 feet. A winze extends 15 feet below the floor of the longer tunnel and shows fragments of copper ore embedded in decomposed schist. The fragments are made up of "copper-pitch" ore, chalcopyrite, with traces of the carbonates malachite and azurite, in a quartz gangue. The face of the shorter tunnel, which is inclined and follows an irregular course until it ends about 15 feet below the longer tunnel, shows about 2 feet of mineralized rock.

No assays are available from these deposits, but the amount of copper minerals visibly present undoubtedly warrants further exploration in order to demonstrate the size of the ore bodies.

On the hill about half a mile slightly north of west of the deposits above described a number of openings on copper leads (the Christiansen group) have produced about 30 tons of ore averaging 20.4 per cent of copper and about 9 ounces to the ton in silver. The total value of this ore was about $1,200. About 1 ton of low-grade ore running a little over 2.5 per cent of copper and 0.2 ounce of silver to the ton has also been shipped. The ore consists of chalcopyrite fragments in brown "copper pitch" ore, a light-green kaolinite (?) and limonite, included with and cementing fractured quartz with scattered stains of malachite. The lodes appear to strike nearly north and dip about 52° E. Two openings about 700 feet apart are supposed to expose the same ore body, which consists of siliceous vein matter inclosed in a gray decomposed conglomeratic schist. The northern working is an open cut which exposed the metalliferous lode apparently in place near its west side, and the other opening consists of a tunnel running south along the vein for about 100 feet, with a raise at its face which follows the richer part of the ore body to the surface 35 feet above, 2 feet 6 inches being its average thickness in this distance. About 50 feet from the portal of the tunnel the rich streak of ore pinches down to a minimum thickness of about 6 inches. The low-grade ore, which is estimated to run 2 per cent of copper, is said to be about 15 feet in average width.

Another copper prospect, known as the Glory Copper, is located about 1¼ miles north of the occurrence just described. The development at this place consisted of a timbered shaft partly filled with water. Reddish-gray quartz schist and argillite and perhaps 3 tons of copper ore which possibly would average 10 per cent appear on the dump. This ore consists mainly of limonite intermixed with copper-pitch ore, partly filling the interstices of brecciated quartz and quartzite. Occasional specks of chalcopyrite and stains of malachite and azurite are present.

A bed of barite 3 inches thick occurs near the top of the Jefferson limestone in sec. 7, T. 2 S., R. 8 W. It is conspicuous because of its whiteness, which contrasts strongly with the color of the 10-foot bed that directly overlies it. This fact, together with the float fragments of heavy white spar, makes the horizon easy to trace.

The Berlin claim, west of Bighole River near the mouth of Soap Creek, in sec. 10, is said to have yielded some very fine specimens of gold ore. This claim is located on a jagged contact of a small outlying mass of "granite" with shales, sandstones, and limestones of the Kootenai formation. The greater portion of this contact is concealed by a thin cover of gravels. Considerable prospecting has been done by shafting and tunneling, and although considerable good ore has been found in pockets no well-defined ore body has been discovered. The minerals noted on the dumps at the openings on the Berlin claim consisted mainly of quartz, stained with malachite, and limonite. The quartz is in part anhedral in long, slender crystals with which the sulphide from which the limonite was derived was apparently intergrown. Bunches of finely crystalline galena are scattered through the more massive quartz. The sedimentary rocks near the contact exhibit metamorphic changes; the shales are represented by knotted schists and the limestones have recrystallized. The sandstones appear to have yielded dense glassy quartzites which are in part spotted with sericite. The granitic rock has a more basic appearance here than elsewhere but is so altered that its original character is difficult to determine. The remnants of the ferromagnesian silicates are more suggestive of pyroxene than of amphibole, both in the hand specimen and in the thin section. Plagioclase feldspar is a prominent constituent of the rock.

In the vicinity of the Berlin claim the granitic rock appears to be intermediate in composition between the gabbrolike facies found in sec. 6 and the true granite found in sec. 15, at about the center of the granitic mass.

Prospecting has been done within the "granite" area as well as along its border, and here the metallization has taken the form of thin lenses or sheets of siderite, now altered to limonite. These sheets have been deposited along rifts in the "granite" and vary in thickness from a mere film to possibly a maximum of 1 foot. Some of the ore taken from the pit in the NE. ¼ sec. 15 is said to have contained gold in visible quantities. A shallow inclined tunnel in the NW. ¼ NW. ¼ sec. 15 shows a sheared zone which is filled with what appears to be a decomposed granitic selvage with several ¼-inch iron-stained streaks. This zone measures 3 feet 6 inches in cross section and is reported to have yielded assays showing a total value of $32 to the ton.

In the vicinity of the Berlin claim there are three types of ore deposits—contact, rifts, and fault zone. Of these perhaps the rift deposits are the more promising and warrant further investigation. The rifts in which these deposits are included appear to represent upward convex planes of jointing which developed in the "granite" roughly parallel to its contact with the sedimentary rocks, and they suggest that similar parallel rift deposits will probably be found by exploration by drilling or shafting.

A tunnel in the SE. ¼ SW. ¼ sec. 10, T. 2 S., R. 9 W., exposes the contact of the "granite" intrusion with the dark-colored shale of the Colorado (?) formation. The shale has been altered into a black greasy substance which has a clayey odor and is cut by numerous gray metallic surfaces that have the appearance of being slickensides. This black substance has been locally regarded as graphite and it yields several of the tests characteristic of that mineral, namely, it marks readily on paper, soils the fingers, and is black; but the odor indicates that it is composed largely of clay, and the streak lacks the metallic luster which is possessed by the graphite streak. The black color suggests that carbonaceous matter is present, but it is not feasible to demonstrate that this is in the form of graphite.

The Tertiary and Quaternary gravels and sandy clays on Soap Gulch are reported to contain from 5 cents to $3 in gold to the cubic yard. The gold is concentrated on top of thin clay partings. Nuggets worth $1.50 have been found, but most of the gold occurs in small flakes, large enough, however, to be easily recovered. The scarcity of water has prevented the extensive washing of the gravels.

The extensive gravel benches east of Divide and Melrose will doubtless be worked at some future date by the development of an adequate water supply from Bighole River.

WHITEHALL DISTRICT (CARDWELL AND RENOVA).

LOCATION.

For convenience the region tributary to the town of Whitehall may be called the Whitehall mining district, although this name is not used by the Land Office. This area includes the Cardwell district, in the south end of the Bull Mountain Range northeast of Whitehall, in Jefferson County, and the mining district in the north end of the Tobacco Root Mountains southeast of Whitehall, in Madison County, appropriately called the Renova district, from the station of that name on the Alder branch of the Northern Pacific Railway. The two districts are separated by the Jefferson River valley, but while they are thus quite distinct geographically and politically they are similar geologically, as will appear from the description given below. The mines near Whitehall are chiefly on the lower slopes of the mountains, at elevations varying from 5,000 to 6,000 feet above sea level.

Neither in the Cardwell nor in the Renova district was there any notable activity in mining during the early history of Montana, but in 1896, when the Mayflower mine was discovered by an assayer in limestone country rock quite unlike that of the other mines of the Whitehall district, the region sprang into considerable prominence as a source of gold. The Mayflower was soon sold to W. A. Clark for $150,000, and within a year produced twice as much as it cost. Since 1905 it has been closed, and other mines of the district have been productive only intermittently and on a small scale.

GEOLOGY.

The rocks of the Cardwell district, in the south end of the Bull Mountain Range, are a series of shales, sandstones, and sandy limestones which apparently belong to the Belt series. They have a prevailing and fairly constant strike of about N. 40° W. and a dip of about 25° NE., and are overlain by a pink quartzite (Flathead?), succeeded by a thick series of Paleozoic limestones. Many of the mines of the Cardwell district are in St. Paul Gulch, about 3 miles northeast of Whitehall. The rocks here exposed, from the lowest beds just above the bench lands to the Paleozoic limestones, are shales weathering yellow, brown, or gray, black shales, thin-bedded sandy limestone, sandstone, gray shales, arenaceous limestone, argillaceous shales, calcareous shales, and pink quartzite (Flathead?). The Paleozoic rocks rest upon the Belt series without apparent unconformity.

The bench lands are occupied by coarse conglomerate lying nearly flat upon the upturned edges of the Tertiary deposits (Bozeman "lake beds"), which consist of sands, clays, and volcanic dust.

The rocks of the Belt series vary considerably in character from place to place, but they contain no massive thick-bedded sediments and are dominantly shaly and sandy in thin beds. In some places the sandstones are very fine grained, resembling novaculite. In the Whitehall district they are penetrated by numerous dikes, both acidic and basic, such as quartz porphyry, andesite, and even basalt, which appear to be closely associated with the ores, though their mutual relations and age have not been determined.

ORE DEPOSITS.

CARDWELL DISTRICT.

The Cardwell district is in and east of St. Paul Gulch, 3 to 4 miles east of Whitehall, in the south end of the Bull Mountain Range.

The Hudson mine, near the mouth of St. Paul Gulch, is in black shales, which are broken and impregnated with gypsum and melanterite produced by oxidation and hydration of sulphide ores, especially pyrite, and by resulting reactions of solutions carrying sulphuric acid with calcareous shales. The ore carries galena and pyrite and occurs in a breccia of shale and limestone apparently produced by faulting. The Burlington mine, close by, is in limestone. The ore is pyrite and galena with some sphalerite.

At the Columbia mine, farther up St. Paul Gulch, the country rock is shale dipping about 30° NE. and striking about N. 40° W. The vein strikes N. 10° E. and dips about 80° E.; it is highly quartzose, containing pyrite with some gold. Adjoining the vein to the southeast is a dike of mica andesite, but both the dike and the vein are rather narrow. A crosscut tunnel runs about 300 feet to the vein.

At the Gold King mine a vein of quartzose ore carrying auriferous pyrite occurs in calcareous shale and is closely associated with a dike of porphyritic rock, apparently quartz porphyry, striking about east and west. There are several faults and dikes in the vicinity that trend in various directions.

At the Kronholm claim, at an elevation of more than 6,000 feet, a quartz vein in calcareous shales dipping about 25° E. carries auriferous pyrite and a little galena and sphalerite. There are faults close by, but they do not affect the vein so far as developed.

The Golden-Sunlight-Ohio group of claims lies east of St. Paul Gulch near the extreme southern point of the Bull Mountain Range. The developments consist of several long tunnels and much other underground work and of ore bins, power house, stamp mill, and other structures on the surface. The ore is auriferous pyrite in a quartz vein in slates and sandstones. The vein strikes nearly north and is closely associated with dikes and intrusions of porphyritic rocks. Near the surface much of the ore that is low in pyrite is rich in gold, probably through enrichment. On the Sunlight No. 3 a tunnel about 1,200 feet long, running N. 75° W., cuts a basaltic dike at 15 to 100 feet from its portal and a similar dike near its face. About 250 feet south of this tunnel the vein is offset about 200 feet to the west by a well-marked fault, containing a little ore. The tunnel cuts two veins called the east and the west; the former strikes N. 15° E. and meets the west vein about 120 feet south of the tunnel; the latter dips about 70° W. At the junction of the two veins ore has been stoped out for a vertical distance approximating 500 feet. On the Ohio claim tunnel No. 1 cuts through shales and sandstones of the Belt series, which are intruded by a porphyry dike. The general dip of the shales is about 15° N. and of the dike about 50° N. The minerals present include quartz, pyrite, pyrolusite, limonite, hematite, malachite, chalcanthite, and gypsum. Some layers of the sandstone are so fine grained as to resemble novaculite. Near the dike the sandstone is more compact and is mineralized in places. Some parts of the porphyry dike are so much mineralized as to furnish valuable ore.

RENOVA DISTRICT.

The Renova district is in the north end of the Tobacco Root Mountains, near Renova railroad station, about 6 miles south of Whitehall.

The Mayflower mine is about 8 miles southeast of Whitehall, very near the eastern boundary of the Dillon quadrangle. Its ore was extraordinarily rich and yielded more than a million dollars in gold during the few years the mine was worked, in 1896 to 1905. The geologic section along Mayflower Gulch toward the mine consists of slates belonging to the Belt series, overlain by Cambrian and possibly later rocks, consisting of a basal conglomerate, in places feldspathic and chloritic, grading rather abruptly into quartzite and a thin layer of shales, which is succeeded by bold outcrops of massive grayish-blue limestone in which the ore occurs. The mine workings consist of tunnels and shafts which are said to have reached a depth of 1,000 feet but which are now caved and filled with water. The ore lies in a fault that cuts the limestone nearly parallel with the bedding, which here strikes about N. 50° E. and dips 80°–85° SE. Northwest of the fault plane the limestone is massive and unmodified, but on the southeast side it is so greatly crushed as to be somewhat shaly in appearance, and it has been silicified and mineralized. The gold in the Mayflower ore was almost exclusively in the form of tellurides.

There seem to be other faults in the vicinity. The existence of one running about parallel with Mayflower Gulch and crossing the strike of the formations nearly at right angles is indicated by a radical change in the strike and dip of the formations. According to C. E.

Damours, of Virginia City, another fault, later than the ore and having a northwest strike and a northeast dip, displaces the upper part of the Mayflower ore body about 300 feet to the east. No evidence of this fault was observed by the writer, who was unable to examine the underground workings of the mine.

About 1,000 feet southeast of the mine the limestone is displaced by an igneous intrusion of augite andesite, containing large phenocrysts of andesine and smaller ones of augite, rare magnetite, and remnants of hornblende phenocrysts now bordered by magnetite, all contained in a fine groundmass of the same minerals. This rock may furnish the key to the origin of the Mayflower ore; it contains a minute amount of an unknown mineral of a silvery metallic color.

The Surprise mine is located at an elevation of about 4,700 feet in the foothills of the Tobacco Root Mountains, about 1½ miles southeast of the head of Jefferson Island. It is in a feldspathic sandstone or arkose, probably belonging to the Belt series which here strikes north and dips about 25° W. The country rock is cut by a quartz porphyry dike 200 to 600 feet wide, which can be easily traced northward for about a mile. The sandstone is interbedded with narrow layers of sandy shale, and both rocks are distinctly hardened by contact metamorphism due to the intrusive igneous rock. The vein strikes about east and dips about 85° S. The ore at the surface is free gold in hematite and limonite mixed with quartz.

On the Mary Ingaber, Colorado, Blue Bird, and Gold Hill claims the same feldspathic sandstone occurs, interbedded with bands of sandy shales and cut by quartz porphyry dikes, which, on the Gold Hill claim, are parallel to and adjoin or even include the vein. All the ore of the Surprise and Mary Ingaber mines so far excavated is oxidized. It occurs in limonite, clay, and quartz, and in some places the vein material seems to be decayed quartz porphyry. The vein is remarkably constant in strike and dip and is only rarely faulted. The Gold Hill claim has two veins alike in ore and gangue, which lie about 50 feet apart and dip about 65° S. The high-grade ores are on the footwall in the oxidized zone and on the hanging wall in the sulphide zone. The ores decrease in value from the surface to the lower part of the oxidized zone, and the upper part of the sulphide zone is richer than the overlying part of the oxidized zone. In the Gold Hill property the sulphide ores, pyrite, chalcopyrite, and galena, come within 30 feet of the surface. The gangue is largely calcite with dolomite and siderite.

In this district (except in the Mayflower mine) the ore is said to be richest very near the surface. Enrichment in silver and gold extends to the base of the oxidized zone, but the silver is concentrated more than the gold. Much of the sulphide ore is of too low grade to work at a profit.

The steep cliff about 4 miles northeast of Parsons Bridge consists of Paleozoic rocks. Near its base a cave in the limestone, on the walls of which are pictures apparently made by Indians, seems to be the former outlet of a hot spring that now escapes near the level of the river. Crinoid stems are abundant in the bluish-gray limestone just above the cave. A fault runs about north and south just east of the cliff and in general separates the Paleozoic quartzite and limestones from the feldspathic sandstones and shales of the Belt series. West of the fault the prevailing strike is northwest and the dip steep to the southwest. East of the fault the prevailing strike is north or east of north and the dip is more gentle to the west.

About a mile south of the cliff the Paleozoic limestones strike nearly east and dip very steeply south; farther south they strike uniformly a little east of north and dip 25°-65° W. In this position they form the western flank of the mountains southward to Dry Georgia Gulch.

PRODUCTION.

The production of the Cardwell district was valued at $5,939 in 1909 and $4,702 in 1910. Most of the value is in lead and gold, but silver and copper are also produced.

Statistics of production of the Renova district for years prior to 1896 are not available. Between 1896 and 1904 the chief production of the district came from the Mayflower mine, whose owners have furnished the figures given below. Since 1904 the production of the district has been recorded by the United States Geological Survey.

Production of Renova district.

Year.	Crude ore.	Gold.		Silver.		Total.
	Tons.	*Fine oz.*		*Fine oz.*		
1896	(?)	13,781.72	$284,894	21,282	$14,472	$299,366
1897	(?)	11,067.78	228,791	20,374	12,224	241,015
1898	(?)	21,812.73	450,909	34,031	20,078	470,987
1899	(?)	3,667.20	75,808	8,677	5,206	81,014
1900	(?)	2,561.37	52,948	9,192	5,699	58,647
1901	(?)	4,461.04	92,218	11,205	6,723	98,941
1902	730	274.39	5,672	208	110	5,782
1903	(?)	118.29	2,445	391	211	2,656
1904	400	1,048.47	21,674	1,378	799	22,473
1905	887	1,101.46	22,769	1,632	996	23,765
1906	368	626.17	12,944	1,193	799	13,743
1907	2,175	663.71	13,720	1,219	805	14,525
1908	135	361.02	7,463	890	472	7,935
1909	101	108.31	2,239	332	173	2,412
1910	90	78.70	1,627	197	106	1,733
1911	168	213.62	4,416	635	337	4,753
1912	109	76.67	1,515	174	107	1,887
	5,163	60,022.65	1,282,052	113,010	69,317	1,351,634

In addition to the gold and silver small amounts of copper and lead were recovered from ores of the Renova district, especially during the years 1905-1911. The total output of copper from the district is 12,481 pounds, valued at $1,881, and the total production of lead is 30,782 pounds, valued at $1,545.

SIBERIA (GERMAN GULCH) DISTRICT.

LOCATION.

The placers in German Gulch, which were discovered in 1864 by a small party returning to Bannock from Kootenai, lie along a southern tributary of Clark Fork, in the northwest corner of the Dillon quadrangle and the western part of Silver Bow County, about 14 to 18 miles west-southwest of Butte, at an elevation of 6,000 to 8,000 feet above sea level. The gulch was worked actively by bedrock flumes and hydraulics for about 10 years, after which its yield began to decline. It is estimated to have yielded $5,000,000 in gold. White miners gradually deserted it, and Chinese began to work parts of the gravel a second or even a third time. Being satisfied with smaller returns, they are still washing and sluicing.

Near the head of the gulch some of the early placer miners discovered gold in the rock and attempted to develop deep mines. The ore, however, seems to be of low grade, and thus far no deep mine has been established, though apparently large quantities of gold ore are available.

GEOLOGY.

The lower end of German Gulch is occupied by volcanic rocks of rhyolitic type, apparently the same as and nearly continuous in outcrop with the rhyolites of the Butte district. They contain a small amount of pyroclastic material, but in general they appear to have been flows or intrusions; however, on Silver Bow Creek, about 2 miles above the mouth of German Gulch, rhyolite tuff occurs in bedded deposits. Rhyolite extends up German Gulch to a point about 2 miles above the three forks.

The rhyolite of the Siberia district is gray and semivitreous and lines the gulch with ragged cliffs. It contains phenocrysts of quartz, orthoclase, and plagioclase. The quartz phenocrysts are commonly corroded or partly resorbed, and some of them are broken. Much of the feldspar shows zonal development probably due to varying composition. Hornblende, biotite, apatite, obscure chloritic material, and rock glass are the other constituents. The plagioclase is so abundant as to make the rock transitional between a true rhyolite and a quartz latite.

At the head of German Gulch the northeast side of the Continental Divide is flanked by quartzite; between this rock and the rhyolite the creek runs through quartz monzonite similar to and probably continuous in outcrop with the Boulder batholith found at Butte, Boulder, Elkhorn, and elsewhere. The quartz monzonite weathers into rounded slopes that contrast with the cliffs cut by the creek in the rhyolite.

The quartzites at the head of the gulch contain near their base a quartz conglomerate and a quartzite conglomerate. They strike east and dip 70°–75° S. All of them except some tough dark slaty quartzites are much broken by faults. They are penetrated by a few sills of quartz diorite, probably a border facies of the great batholith. The quartzite in many places contains considerable amphibole, some chlorite, hematite, and limonite, and small amounts of zircon, calcite, and a mineral resembling titanite. Feldspar is rare but occurs in places, especially adjoining the intrusive sills. The quartz diorite contains abundant feldspar, all or nearly all of which is plagioclase, some hornblende and biotite, rather sparsely disseminated quartz, and a little pyroxene. Among the accessory minerals titanite is relatively abundant, and zircon, apatite, and magnetite are found.

Paleozoic limestones overlie the quartzites and indicate that they are to be correlated with the Flathead quartzite or the Belt series or both. The writer prefers to correlate them, at least in part, with the Belt series, for the following reasons:

1. The quartzites of German Gulch have a thickness of several hundred feet, while the Flathead quartzite of the Threeforks quadrangle has a maximum thickness of about 125 feet.

2. The quartzites of German Gulch contain at least two conglomerates. If the base of the Flathead is marked by the upper one the underlying rocks must belong to the Belt series.

3. The top of the series examined at the Beal mine is still several hundred feet below the base of the limestone, and it is to be expected that the Flathead quartzite, if present in this area, would occupy the upper part of this horizon, which was not examined in detail.

ORE DEPOSITS.

In addition to the placer deposits of German Gulch large bodies of low-grade gold ore are contained in the quartzites at the head of the gulch, which are here provisionally referred to the Belt series. On the northwest side of the gulch the whole side of the hill for at least 1,500 feet along the strike is lead material or is stained with limonite so as to resemble vein stuff. The same is true for at least 1,000 feet and apparently for 2,000 feet across the strike and up the hillside. Furthermore, an adit near the creek level that cuts 780 feet across the strike and reaches a depth of over 400 feet vertically is said to be in ore all the way except for certain dark slaty quartzite beds that make up less than 30 per cent of the total. The ore is said to average about $2.50 in gold per ton.

Some years ago a 20-ton mill to test these ores was erected but was not operated.

In addition to native gold and a telluride of gold, apparently sylvanite, the ores contain less important minerals such as pyrite, chalcopyrite, malachite, melanterite, gypsum, serpentine, talc or sericite, hematite, limonite, and quartz.

DILLON DISTRICT.

LOCATION.

The town of Dillon is situated on Beaverhead River at the mouth of Blacktail Creek, in the southern part of the Dillon quadrangle. It is about 60 miles south of Butte on the Oregon Short Line Railroad, and is the county seat of Beaverhead County.

There are no important placer or quartz mines in the immediate vicinity of Dillon and no mining district of that name has ever been organized. Nevertheless, mineral resources of some economic importance, including metalliferous veins, building stone, clay, and graphite, occur within the area tributary to Dillon.

METALLIFEROUS VEINS.

About 10 miles southeast of Dillon, in the Ruby Range, on Carter and Hoffman creeks a few claims have been located on veins carrying copper ore. On the Log Cabin claim on Hoffman Creek chalcopyrite and pyrrhotite occur with a gangue of calcite and quartz in a fault vein in limestone. On the Mayflower claim magnetite, quartz, and calcite fill a vein in limestone. On the Ursa Major claim on Carter Creek magnetite, calcite, and quartz are reported in a contact vein 20 to 60 feet wide, dipping about 22° E. between dolomitic limestone and overlying "gneiss." A fissure on the adjoining Attorney claim carries chalcopyrite and pyrrhotite in a quartz gangue. Unless the formations here are overturned the existence of "gneiss" or schist above limestone indicates that the rocks belong to the Cherry Creek group. There are several other metal mining claims in the Dillon district, none of which can be described in this place; few or none of them have been productive..

CLAYS AND BUILDING STONES.

Bricks are made from alluvial clay in two kilns, one at the edge of Dillon and the other about a mile from town. They are of a light salmon color, are fairly hard, and supply the local demand.

Sandstone and a rhyolitic volcanic ash are quarried for building stone near Dillon. The sandstone is obtained in large quantities at Daley Spur, about 12 miles southeast of Dillon on the Oregon Short Line Railroad. Some of the stone resembles quartzite and is said to have a high crushing strength. It is very fine grained and is light gray in color. A variety that is nearly pure silica has been used in large quantities for fluxing and converter linings at the Washoe smelter in Anaconda. As a building stone this sandstone has been used in Dillon and Salt Lake.

Sandstone for building is obtained also from deposits 5 miles west of Dillon and 1 mile south of the Dillon-Argenta road. Here the sandstone, which is apparently of Cretaceous age, strikes N. 40° E. and dips about 25° NW. The color varies from nearly pure white through yellow and brown to dark red, and careful sorting is necessary to secure uniformity in tint. The nearly white variety has a siliceous cement and an even, fine-grained texture; it is nearly pure silica. The yellow varieties are cemented by limonite, and the red by hematite. The latter have been used in several large buildings in Dillon and in Butte.

In the Fryingpan basin about 7 miles northwest of Dillon, rhyolitic volcanic ash is mingled with rhyolite flows, which strike north and dip about 10° E. The deposit is from 30 to 50 feet thick. The lower portion is chiefly rhyolitic ash and the upper portion principally very light colored rhyolite. The ash is nearly pure white, and is so soft as to be very easily worked, but hardens gradually when exposed to the weather, although it never becomes as hard as most building stones. Nevertheless, it has been used with satisfaction in several buildings in Dillon and in a few houses in Butte.

Some parts of this rhyolite contain many small amygdules lined or partly filled with crystal aggregates of small hexagonal basal plates of tridymite. The formation of this uncommon mineral was probably aided by the gas (H_2O ?) present in the amygdule. Tridymite is stable only at high temperatures, hence the rock probably solidified at high temperature and cooled rapidly.

GRAPHITE DEPOSITS.

LOCATION.

The graphite deposits near Dillon[1] lie chiefly on the ridge between Van Camp Creek and Timber Gulch, near the southwest end of the Ruby Range. They are reached from Dillon by a drive of about 15 miles to the southeast over a good mountain road.

GEOLOGIC RELATIONS.

The rocks exposed in the Ruby Range are chiefly the thick limestone formations of the Paleozoic of Montana, which have been repeatedly faulted in the southwest end of the range, perhaps at the time when they were arched and folded into mountains. At the mouth of Van Camp Canyon, limestone, apparently of lower Paleozoic age, dips northwest; farther up the canyon it appears to be underlain by quartzite (the Flathead quartzite?), which overlies quartz schists and slates, apparently pre-Cambrian in age. By faulting, this series is repeated so as to outcrop at least three times within about 2 miles. Igneous rocks are uncommon, only one basic

[1] Winchell, A. N., Econ. Geology, vol. 6, pp. 218-230, 1911; U. S. Geol. Survey Bull. 470, pp. 26-30, 1911; Bastin, E. S., Econ. Geology, vol. 7, pp. 435-443, 1912.

dike being observed. At the graphite property, at an elevation of 7,500 to 8,000 feet above sea level and about 2,500 feet above Dillon, the average strike is about N. 70° E. and the average dip about 45° NNW.

OCCURRENCE OF THE GRAPHITE.

The graphite is remarkable in occurring in several different ways in this single locality. One mode of occurrence is as seams in sedimentary rocks. The seams are rather persistent, though ordinarily not more than an inch or two thick, and lie strictly parallel with the bedding. On the Faithful claim they are in marmarized limestone, and on the Lucky Boy in the underlying quartz schists, mica schist, and garnet schist. At another outcrop on the Lucky Boy the graphite is in somewhat irregular seams on both sides of an intrusion of graphic granite, apparently a sill in rather massive garnetiferous quartz schist. A basic dike 30 to 40 feet wide cuts across the formations a short distance to the west and faults all of them.

West of this dike the graphite is chiefly in veins and along faults not parallel with the bedding, which here strikes about north and dips about 50° W., while one fault vein strikes N. 70° E. and dips about 60° NNE., and graphite also occurs in veins and along faults in several other positions. Some of the veins containing graphite are cut by faults. A tunnel opening some of this ground discloses graphite in irregular bunches, pockets, stringers, and veins, which have no relation to bedding but whose mode of deposition is similar to that of vein material in zones where rocks have yielded to stresses, not by clean fracturing but by irregular shearing. In such places irregularly lenticular masses may reach 6 to 8 inches in thickness and 2 to 4 feet in diameter. At the time the deposit was visited (1910) the sheared rocks had only recently been penetrated. The shearing affects a thickness, at least locally, of some 3 to 5 feet. Its continuity in a well-defined zone is not yet established.

At another outcrop the graphite is intimately associated with garnet. In places it completely surrounds large crystals of garnet; but more commonly a crystal of garnet is surrounded by quartz, which in turn is nearly surrounded by graphite. Again, graphite occurs in seams in garnet, or with garnet and quartz in intimate admixture. Schists form the country rock in these places.

At another outcrop graphite is intimately intergrown with microcline, quartz, and biotite, making a sort of graphitic gneiss. In places the mica is absent and the graphite is more abundant, amounting perhaps to one-third of the rock, and serving as a matrix in which lie feldspar anhedra, with more or less associated quartz. Such graphitic gneiss is not known to be abundant.

Near the east end of the property graphite occurs above a fault containing pegmatite in a decayed quartz-feldspar rock resembling a pegmatite. This rock lies in layers more or less parallel with the pegmatite, which intrudes the limestone in sills. The graphite separates the layers and in places cuts across them. The graphitic material here is usually narrow; and it rarely exceeds an inch or two in thickness.

Graphite, in float, is found nearly to the top of the ridge between Timber Gulch and the head of Van Camp Creek. A wide outcrop of aplite-pegmatite on the same ridge contains small flakes of graphite.

ORIGIN OF THE GRAPHITE.

Smith [1] has called attention to two graphite deposits in Maine which illustrate different modes of origin of the mineral. More recently, Hayes and Phalen [2] have described an occurrence of graphite in Georgia which illustrates one mode of origin very clearly. Bastin [3] has described a graphite mine at Ticonderoga, N. Y., which illustrates a wholly different mode of origin.

The peculiarity of the Montana graphite property is that it seems to illustrate different modes of origin in a single deposit. Thus, the seams of graphite strictly parallel with the bedding in marmarized limestone and in quartz schist may well represent the result of metamorphism of carbonaceous layers in those rocks. It is doubtless true that the metamorphism of such carbonaceous layers usually results in producing the so-called "amorphous" graphite, which is very fine grained and usually impure. But it seems probable that more intense metamorphism would produce coarser and purer graphite, such as that found in the Dillon deposit.

If metamorphism has converted the carbonaceous matter of shales into graphite in place, it is very probable that it has also caused considerable movement of some of the graphite of this deposit. For it is clear that the graphite surrounding garnet crystals in quartz schists nearly devoid of graphite must have moved to its present position, probably through a process of concentration which brought sparsely disseminated carbonaceous matter into concentrated layers of graphite around garnet crystals. If this explanation is correct, the movement or at least the deposition of the graphite must have occurred near the end of the period of metamorphism, for it is not inclosed by garnet but is in and outside of the outer portion of the quartz which incloses the garnet crystals.

If the carbonaceous matter of shales can be moved by metamorphism as just described, there seems to be no reason why carbon in some form should not get into veins and into the solutions which deposit veins. It may be that the graphite in veins near Dillon has originated in this way. It may even be that the graphite in

[1] Smith, G. O., Graphite in Maine: U. S. Geol. Survey Bull. 285, p. 480, 1906.
[2] U. S. Geol. Survey Bull. 340, p. 463, 1908.
[3] U. S. Geol. Survey Mineral Resources, 1908, pp. 729–731, 1909.

pegmatite and other igneous rocks may have originated in a similar way, that is, by the entrance of carbon in some form into the solutions which form such igneous rocks.

The graphite of igneous rocks and veins is just as truly a primary constituent of the rocks or veins as quartz or feldspar or mica. It is well known that the constituents of igneous rocks have crystallized at high temperatures from silicate solutions. But graphite is practically insoluble in silicates at the ordinary temperatures of magmas—it is on this fact that its value as a refractory material partly depends.

How, then, can the occurrence of graphite as a constituent of igneous rocks and veins be explained? Numerous answers have been made to this question, but many of them are probably incorrect. The intimate intergrowth of the graphite with quartz and feldspar is evidence that it is not a later introduction into the rock. That the graphite did not exist in the silicate solution in the form of crystal flakes is indicated by the fact that some of the constituents of the rock are inclosed by the graphite, and also by the fact that the graphite is in many places very uniformly distributed through the rock. The refractory character of carbon, whose temperatures of liquefaction and vaporization are known to be above 3,000° C., indicates that the graphite did not go into solution in the vein magma from the liquid or the gaseous state of carbon, for the present condition of the minerals and rocks associated with the graphite shows that they were not subjected to any such temperature at the time when they, together with the graphite, assumed their present condition. It seems highly improbable that the graphite went into solution in the vein magma from any solid state of carbon, because carbon in the solid state is known to be insoluble in slags and graphite crucibles are in current use as containers of slags. On the contrary, receptacles made of silica are promptly attacked and dissolved more or less completely in slags. It is well known that pressure has very little effect upon solubility [1] and that water has no appreciable solvent action on carbon. Furthermore, direct experiments [2] have shown that carbon is insoluble in silicates of potassa and soda, though apparently somewhat soluble in such silicates mixed with at least half as much calcium fluoride and moistened with water. Such a mixture is, of course, distinctly unlike a magma, and even in such a mixture the solution of the carbon without preliminary oxidation has not been proved. Therefore, the suggestion [3] sometimes made that sublimation from carbon vapors can explain the formation of graphite in veins seems highly improbable.

[1] Gouy and Chaperon, Annales chim. et phys., vol. 12, p. 384, 1887. Cohen, E., and Sinnige, L. R., Faraday Soc. Trans., vol. 5, p. 269, 1910.

[2] Luzi, W., Deutsch. chem. Gesell. Ber., vol. 24, p. 4093, 1891.

[3] Bastin, E. S., U. S. Geol. Survey Mineral Resources, 1908, pt. 2, pp. 718, 731, 1909.

The writer has presented elsewhere[1] the arguments supporting his view that graphite deposits may be produced through the interaction of magmatic gases, and that the usual state in which carbon exists in magmas and in the solutions which form veins is in combination with oxygen. If this view is correct it follows that all the conditions necessary for the formation of graphite are present in the cooling of an ordinary magma. Under the usual conditions the amount of the gases CO_2, CO, and H_2 present in magmas is too small to produce any appreciable quantities of graphite; and in so far as they escape into the atmosphere without mutual reaction no deposits of graphite can form. But when any magma containing abnormally large amounts of these gases solidifies at a depth so great that the gases can not escape, graphite deposits are to be expected.

Furthermore, any magma which contains sufficient water, on coming into contact with bituminous or carbonaceous shale or slates, may be expected to convert all that portion of the carbon which is heated above about 600° C. to the oxide state through the agency of water. The resulting gaseous hydrogen and oxides of carbon, being soluble in water and silicate solutions under pressure, may be expected to move about with, and as freely as, the magmatic solutions themselves. Finally, when these solutions cool below about 600° C., graphite may be expected to crystallize out in much the same way as other materials crystallize from the cooling magma.

In summary, it appears that—

1. Graphite is probably formed in nature in several different ways. Graphite in sedimentary rocks may have an origin wholly different from graphite in veins and pegmatites.
2. The most probable mode of formation of graphite in veins and in pegmatites is believed to be by the deoxidation of oxides of carbon.
3. The deoxidation of carbon dioxide may be caused by hydrogen or other reducing agent.
4. The partial deoxidation of carbon monoxide occurs in the absence of any reducing agent at temperatures below 900° C., according to the reaction $2CO = C + CO_2$.
5. The oxidation of the carbon of bituminous shales by water (aqueous gas) at high temperatures, its mobility as a consequence of the formation and solution of the oxides, and its reprecipitation in places where the solutions reached lower temperatures may be explained by appealing to the reversible reactions $C + 2H_2O \rightleftarrows CO_2 + 2H_2$ and $C + H_2O \rightleftarrows CO + H_2$.

[1] Winchell, A. N., Econ. Geology, vol. 6, pp. 218–230, 1911.

ECONOMIC CONSIDERATIONS.

At present development has not proceeded far enough to prove the existence of large deposits of graphite on the property of the Crystal Graphite Co., near Dillon, Mont. But the prospecting done proves that considerable graphite, all of very high grade, occurs there in several different ways. A better understanding of its probable mode of origin would be of much value in guiding further exploration, both at this locality and elsewhere. It is particularly desirable to recognize the probable importance of water (aqueous gas) in carrying the heat which metamorphoses carbonaceous shales and in oxidizing the carbon and thus rendering it soluble and mobile. At the deposits near Dillon the importance of pegmatite dikes, as the probable source of at least a part of the water concerned, should also be recognized. Some of these dikes may serve as guides in exploration work. In other places veins and shear zones must be followed to find the graphite. Where the mineral occurs in seams in bedded deposits there should be no difficulty in following it, though even here it is important to restrict work to the region in which the water was sufficiently active to produce the change and not sufficiently abundant to carry the graphite away.

NORRIS DISTRICT.

LOCATION.

Norris, a small town on Hot Spring Creek at the terminus of the Pony-Norris branch of the Northern Pacific Railway, about 25 miles south of Threeforks and 35 miles west of Bozeman, is the business center for four mining districts. The Lower Hot Springs district extends eastward from Norris about 6 miles to Madison River, and includes the region around the old town of Red Bluff. The Upper Hot Springs mining district extends southwestward from Norris about 6 miles to Sterling and Revenue. The Washington district is about 12 miles southwest of Norris and includes the region about Ward Peak between North and South Meadow creeks, the southern portion of which is sometimes called the Bald Mountain district. The Norwegian district is about 7 miles west of Norris and includes the area in which Norwegian Creek has its sources. The Madisonian mine is about 8 miles south of Norris; it overlooks the Madison Valley but is not clearly within the limits of any of these four mining districts.

The town of Norris lies at an altitude of about 5,000 feet above sea level. The mines of the Norwegian and Upper and Lower Hot Spring districts are between 5,000 and 6,000 feet and those of the Washington district between 6,000 and 9,000 feet above the sea.

HISTORY.

The placer mines of Norwegian Gulch and Washington Bar on South Meadow Creek were discovered early in 1864, and the same year some of the quartz mines of the region were found. The next year the Cope mill was erected, and within five years there were at least eight mills in the Norris district. Norwegian Gulch is estimated to have yielded $150,000 in placer gold by 1874. In that year the prominent deep mines included the Hendricks (later called the Madisonian), Red Bluff, Rising Sun, Boaz, Galena, Pine Tree, Sterling, and Stevens. By 1876 the Hendricks had a shaft 200 feet deep with 1,200 tons of ore on the dump. During the eighties the mines near Red Bluff were in active operation. The chief mine was finally shut down on account of striking a large flow of water. During the nineties the Monitor and Revenue mines were operated successfully. Between 1895 and 1905 the Galena mine at Sterling yielded about $150,000 worth of gold and silver. During recent years mining has been carried on chiefly by lessees and individual owners with more or less success. The McKee group in the Washington district is probably the most important discovery since 1900. There is very little activity in placer mining, the available ground having been largely exhausted.

GEOLOGY.

The rocks of the Norris district are of many types. About the head of Norwegian Creek they are gneisses and schists, bordered on the south by quartz monzonite. The deep mines of this region are near the contact between the igneous and metamorphic rocks. The Galena mine at Sterling in the Upper Hot Springs district is near the same contact, but the Monitor and Revenue mines are within the quartz monzonite area. The mines of the Lower Hot Springs district are in a region of gneisses and schists, penetrated and capped by intrusions and flows of volcanic rocks, chiefly rhyolite and basalt. The Madisonian mine is in quartz monzonite near its contact with gneiss. The Lehigh mine in the Washington district is in gneiss near the igneous area. The McKee group of mines in the same district is in gneiss cut by andesite.

The writer has seen no evidence in this region that the gneisses and schists are not Archean, and they are doubtless very old; but limestone or marble was observed in them in the cliffs near the source of South Meadow Creek by Prof. D. C. Bard, of the Montana State School of Mines. They include abundant granitic gneiss, hornblende and chlorite schists, and some garnet schists.

The terrestrial deposits known as the Bozeman "lake beds," of Tertiary age, extend westward from Norris about 2 miles up Hot Spring Creek, southward about 3 miles up Burnt Creek, and northwestward across the divide to Norwegian Creek and thence eastward to the bench lands of the Gallatin Valley.

The quartz monzonite occupies a large part of the Norris district. It extends westward from Burnt Creek and the Madisonian mine past Revenue and Sterling to the Mammoth district in the eastern part of the Dillon quadrangle. It occupies a large part of the Upper Hot Springs district, but is only on the northern border of the Washington district and on the western edge of the Lower Hot Springs area. At the Madisonian mine the rock contains orthoclase phenocrysts as much as an inch across which poikilitically inclose oligoclase, quartz, biotite, titanite, magnetite (or ilmenite), apatite, and chlorite. At the Revenue mine there are two varieties of quartz monzonite porphyry, one with biotite and the other with muscovite and biotite. At many of the mines the monzonite is cut by aplitic dikes, which are commonly quartz monzonite aplite but which, at the Lehigh mine, are plagiaplite, though apparently containing a little orthoclase.

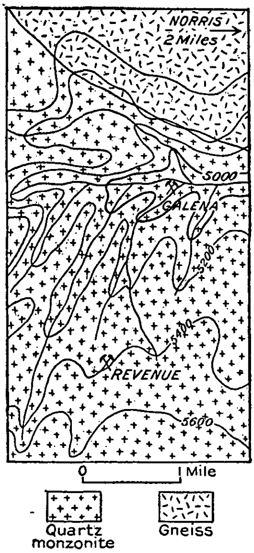


FIGURE 7.—Geologic map of the Upper Hot Springs mining district, Mont. Based on maps of the Threeforks folio.

The volcanic rocks of the region are rhyolite, andesite, and basalt. Near the Birdie mine rhyolite forms a cliff in which the rock is partly glassy rhyolite-obsidian and partly rhyolitic breccia. Andesite containing phenocrysts of acidic plagioclase and shreds of biotite forms a nearly horizontal intrusion in gneiss at the McKee mine. The groundmass of the rock consists of tabular plagioclase, scales of biotite altering to chlorite, magnetite, or ilmenite, and some limonite. A basalt flow occupies a small area about halfway between Norris and Red Bluff.

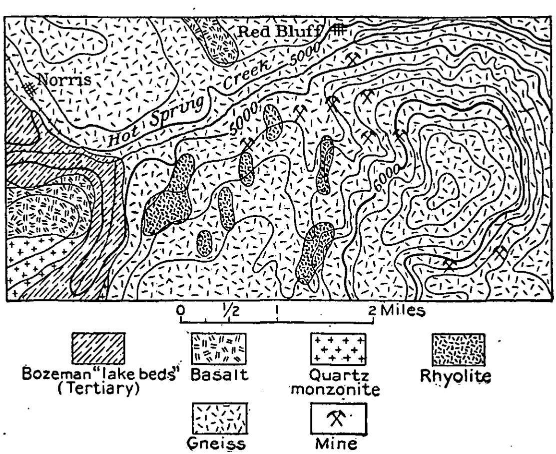


FIGURE 8.—Geologic map of the Lower Hot Springs mining district, Mont. Based on maps of the Threeforks folio.

The areal geology of the Norris district is shown in figures 7 and 8.

ORE DEPOSITS.

NORWEGIAN DISTRICT.

In the Norwegian district gold ore occurs in quartz veins in porphyritic quartz monzonite very near its contact with gneiss. The high-grade ore is found near the surface and the leaner ore below. One of the veins on Norwegian No. 2 claim dips with the hill side and, where mined, is less than 20 feet from the surface. The strike is S. 75° E. and the dip is about 20° NE. Another vein strikes N. 25° E. and dips about 17° SE. These veins are at an elevation of about 5,600 feet and contain gold (with a little silver) in quartz, with chalcopyrite, malachite, and chrysocolla. On the Sunlight claim the vein strikes S. 55° W. and dips about 45° SE. It contains the same kind of ore and the same minerals.

WASHINGTON DISTRICT.

In the Washington district the Lehigh mine is in gneiss and schist where it is cut by granitic and aplitic dikes near the gneiss and monzonite contact. The ore is in quartz veins 1 inch to 4 feet wide, and the pay streak is usually about half the width of the vein. The oxidized ore, which extends to a known depth of about 150 feet, has been largely mined out, but very little sulphide ore has been removed. The veins strike in various directions—N. 90° E., dipping 30° N.; N. 80° E., dipping 52° N.; N. 50° E., dipping 60° NW.; and N. 20° E., dipping 45° WNW. Later unmineralized faults cut off these veins, but the offset is commonly only 8 or 10 feet down on the hanging wall of the fault. One fault system strikes N. 60° W. and dips about 60° SW. The mine is opened by about 2,000 feet of drifts. It is equipped with a 10-stamp mill having amalgamation plates and two Wilfley concentrating tables.

The McKee claims are on the east slope of South Bald Mountain, from which a narrow ridge runs northeastward to Ward Peak. They are about 18 miles southwest of Norris and about 8 miles west of McAllister post office, on Madison River, and are at an elevation of about 4,000 feet above the river or 9,000 feet above sea level. The ore, which occurs in a vein of very uniform thickness lying between gneiss and andesite porphyry, consists of honeycombed quartz and iron oxides. The hanging wall is definite and the footwall rather indefinite, with abundant indications that the footwall gneiss was replaced to some extent during the formation of the vein. Quartz stringers carrying gold penetrate a foot or two into the gneiss, usually following its banding, which is here rather flat. The andesite, which has a thickness of 50 to 75 feet, also lies nearly horizontal, dipping into the mountain on two sides and running down ridges to the south and east on a somewhat steeper dip. The ore occurs mainly along its lower contact, which can be traced for about 4,000 feet continuously along the mountain side. Only a little ore is known along the upper contact, which can be traced by disconnected outcrops for about 2,000 feet. On the McKee claim the ore body strikes about east and dips about 12° S. The minerals in the ore body are quartz, hematite, limonite, native gold, and rare remnants of pyrite. The ore is thoroughly oxidized, and the oxidation has probably been accompanied by enrichment.

The Last Chance claim is about 2 miles north of the McKee group in the Washington district. It has a quartz vein 5 to 9 feet wide which strikes N. 90° E. and dips about 70° N., cutting across nearly flat-lying gneiss. In places the ore is less quartzose and follows the banding of the gneiss.

The High Bluff mine is about a mile north of the McKee group. Its ore body, which follows a gently dipping banding plane in the gneiss, contains quartz, hematite, limonite, gold, and silver. In another part of the claim a tunnel follows the contact between gneiss and (andesite?) porphyry for about 50 feet, and then passes into the gneiss footwall. The ore here is a quartz-pyrite impregnation of gneiss below a gently dipping porphyry intrusion, as on the McKee. The pyrite is now oxidized to hematite and limonite.

On several other claims in the vicinity ore has been found along the contact between gneiss and (andesite?) porphyry or along quartzose bands in the gneiss.

The fact that most of the ore in this region impregnates gneiss just below andesite intrusions makes it reasonable to believe that the ore was deposited by upward-moving waters at the time of the igneous intrusion or soon after that event. It is probable that the ore-bearing solutions were related to the porphyry in their origin.

UPPER HOT SPRINGS DISTRICT.

In the Upper Hot Springs district the chief mines are the Monitor, Revenue, and Galena. The first two were consolidated in 1903, and they have been controlled since then by the Montana Revenue Gold Mining Co. The vein, which here strikes about N. 70° E. and dips about 10° to 25° NNW., is cut by seams of about the same strike, dipping 40°–70° NNW. Near the east end of the property some seams strike about north and dip about 60° W. The ore occurs in the flat-lying vein, particularly near intersections with the "verticals." The vein, which is in general narrow, ranging from 2 to 24 inches in thickness, is quartzose and is accompanied in many places by aplitic intrusions. Where thoroughly oxidized the ore is commonly of good grade, but where the oxidation is slight or lacking the ore is invariably of low grade. It contains about equal parts by weight of gold and silver. In places it impregnates the wall rock, especially as aplitic intrusions next to the vein. The mine is opened by a vertical shaft 300 feet deep and by extensive workings. No high-grade ore has been developed on the 300-foot level, though ore shoots have been followed nearly to this depth. The zone of oxidation and enrichment extends to the 200-foot level and in general not much deeper. Large amethyst-quartz crystals are found in pockets of loose pyrolusite near the base of the zone of oxidation, not far above the 300-foot level. The country rock is quartz monzonite porphyry. The mine is equipped with a stamp mill having amalgamating plates and concentrating tables and also a 75-ton cyanide plant.

The Red Rose claim, near the Revenue mine, has a vein which generally strikes N. 20° W. and dips about 30° WSW., but which varies considerably in strike and dip, becoming flat and changing gradually to an east strike and a dip of about 20° N. It is a quartz vein carrying gold ore in a quartz monzonite aplite dike in quartz monzonite porphyry. The ore shows evidence of enrichment near the surface.

The Galena mine, at the forks of Hot Spring Creek, near the former site of Sterling, has a quartz vein carrying gold, about an equal weight of silver, pyrite, and small amounts of chalcopyrite, bornite, malachite, cuprite, chrysocolla, and pyrolusite. The vein is in quartz monzonite porphyry, associated with coarse leucocratic monzonite. It strikes N. 65° E. and dips about 25° NNW. It is 1 to 6 feet thick, its thicker portions being somewhat lenticular in shape. The mineralization may occupy all or only a part of the vein, high-grade ore seeming to be more abundant near the surface, where concentration has had an opportunity to affect the vein. Several smaller veins and a larger one striking northwest cut the country rock near the Galena. The latter is opened by an incline shaft said to be about 375 feet deep on the incline.

On the "mound" north of Sterling several quartz veins in gneiss, cut by porphyritic dikes, have been opened by shafts and tunnels to a maximum depth of about 100 feet.

MADISONIAN MINE.

The Madisonian mine (formerly known as the Hendricks) is in quartz monzonite, near its contact with gneiss, about 2 miles north of Meadow Creek post office. The quartz fissure vein carries gold, a little silver, copper, and lead. The ore minerals include auriferous pyrite, galena, chalcopyrite, bornite, malachite, and chrysocolla, and associated quartz, hematite, limonite, and pyrolusite. The vein strikes about N. 75° E. and dips about 45° NNW. The mine, which has been idle for most of the time since 1893 and whose workings are now much caved and inaccessible, is equipped with a 12-stamp mill having amalgamation plates and concentrating tables.

LOWER HOT SPRINGS DISTRICT.

In the Lower Hot Springs district some of the more important mines are the Red Bluff, Boaz, Red Chief, Water Lode, Mohican, Grubstake, Montana Boy, Birdie, Josephine, Tippecanoe, Hecla, and Calamont. Several of these mines, notably the Red Bluff, Red Chief, Water Lode, Mohican, Grubstake, Montana Boy, and Tippecanoe have been idle or nearly so for many years, and their workings are now much caved and partly filled with water.

The Red Bluff mine was an important producer during the seventies and eighties. It is in a region of gneiss and schist, but according to A. C. Peale[1] its hanging wall is "gray granite" and its footwall gneiss. As in other mines in the region the ore was largely an iron-stained quartz, carrying free gold, and, at greater depth, pyrite and galena. Some blue chalcedony and opal were associated with the ore. The vein strikes east and dips to the north. The Red Bluff vein was opened by tunnels and incline shafts to a depth of about 300 feet.

The Water Lode and Mohican mines, near the Red Bluff, are located on veins striking northwest and dipping northeast.

The Grubstake and Montana Boy are about 3 miles south of Norris, in gneiss. The vein on the Grubstake strikes about N. 45° W. and dips about 60° NE. It has been opened chiefly by tunnels and is said to have produced about $200,000, chiefly in gold. Free-milling oxidized gold ore from the Montana Boy was treated in a 10-stamp amalgamating mill.

The Boaz claim, which was located when the maximum width of a claim was only 100 feet, is reported to have produced about $200,000 in gold and some silver, chiefly between 1870 and 1880. The quartz vein in gneiss strikes N. 55° W. and dips about 60° NE., but receives stringers or "feeders" striking about N. 45° W. The ore is oxidized and carries gold and silver, and that from the deepest part of the vein yet opened contained about 3 per cent of lead. Directly west of the Boaz there is an intrusion of quartz monzonite aplite at least 50 feet wide. The Josephine adjoins the Boaz on one side and is on a smaller quartz vein.

The ore on the Birdie claim is in a quartz vein in gneiss. It is opened by a tunnel about 600 feet long which reaches a depth of nearly 200 feet. The ore is chiefly valuable for its gold, but contains also a little silver, copper, and lead. The ore minerals include pyrite, chalcopyrite, cerusite, malachite, and chrysocolla. The vein, which

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains for 1871, p. 284, 1873.

averages about 2 feet in width, strikes east and dips about 80° N. but receives stringers striking northwest. The Birdie is reported to have produced about $100,000, chiefly between 1900 and 1905.

The Calamont Copper Mining Co. has claims about half a mile above the mouth of Cottonwood Creek, which enters Madison Canyon about a mile above the mouth of Hot Spring Creek. The vein, which contains quartz and arsenopyrite, is in gneiss and strikes about N. 10° E. and dips about 45° W. The Hecla Mining Co. has run a tunnel on a pegmatite dike cutting gneiss. The dike contains a remarkable amount of magnetite, pyrite, chalcopyrite, and hematite, and is said to carry 8 per cent of copper in selected samples. Faulting and later mineralization have followed the dike along part of its course. On the adjoining Madison group of claims numerous quartz veins are associated with dikes of aplite and aplite porphyry cutting gneiss. Some of them carry argentiferous galena, and others contain auriferous pyrite, sphalerite, and a little argentite; tetrahedrite was reported in one of them. A vein on the Big Jack claim striking N. 75° E. and dipping 45° SSE. contains chalcopyrite, little chalcocite, some galena, little bornite, and malachite. It has been opened by an incline shaft 300 feet deep.

ORIGIN OF ORE DEPOSITS.

With the exception of the mines in the Washington district south of Ward Peak the ore deposits in the region of Norris are either in or near the quartz monzonite intrusion, which extends from this district westward to Mammoth and the summits of the Tobacco Root Mountains. Some important deposits, such as the Revenue and Madisonian, are in fissure veins in the igneous rock; others are in veins in gneiss near its contact with the quartz monzonite and are in many places closely associated with granitic and aplitic dikes, which are themselves impregnated with ore in places in the Montana-Revenue mine. Other deposits are a few miles from the main monzonite intrusion, but are associated with pegmatitic and aplitic dikes. The mines near Red Bluff are about 4 miles from the nearest quartz monzonite known at the surface, but the hanging wall of the chief mine is reported by Peale to be "gray granite."

From all these facts it seems probable that these ore deposits are genetically related to the quartz monzonite, and more closely related to the aplitic and pegmatitic derivatives of the quartz monzonite magma.

In the gneiss in this region, especially near its contact with the monzonite intrusion, ore deposits are remarkably numerous but, so far as known, are not extensive. These numerous small deposits show abundant evidence of enrichment, and in many of them only the enriched portion has proved to be of value. It seems possible that the same processes which produce enrichment may have served in this region to scatter the deposits to some extent.

The larger deposits in fissures in the quartz monzonite have also benefited by enrichment; and, in consequence, successful mining has extended only a short distance into the sulphide zone. In the Revenue mine the connection between the solution and redeposition of gold and the presence of manganese seems to be close; commercial ore extends as deep as the secondary pyrolusite, and search for ore in the sulphides below that depth has thus far been fruitless.

The ores of the Washington district near Ward Peak were probably deposited by ascending solutions derived from or made active by the intrusion of andesite porphyry. The ores were apparently formed soon after the intrusion, and were enriched in the oxide zone by meteoric waters.

PRODUCTION.

No accurate statistics of the production of the Norris district are available prior to 1902, but it may be conservatively estimated that the placer production has exceeded $300,000, and that of deep mines has exceeded $3,000,000. Since 1902 the production has been $470,824, according to the records of the United States Geological Survey.

Production of Norris district.

Year.	Crude ore.	Gold.	Silver.	Copper.	Lead.	Total value.
	Tons.	*Fine oz.*	*Fine oz.*	*Pounds.*	*Pounds.*	
1902	2,022	5,204.18	7,862	9,000	5,680	$112,622
1903	153	391.50	300	....	....	8,243
1904	3,316	1,453.22	2,657	10,000	726	35,589
1905	10,779	7,122.68	27,115	7,877	38,843	166,821
1906	497	1,500.50	2,867	....	15,513	33,823
1907	781	859.95	4,552	260	....	20,833
1908	666	825.03	1,704	1,341	2,240	18,223
1909	2,886	1,309.55	1,722	1,045	....	28,102
1910	1,602	567.12	1,510	127	4,706	12,761
1911	719	829.39	5,018	740	3,823	20,069
1912	472	786.67	1,540	883	901	13,738
	23,893	20,849.79	56,847	31,273	72,432	470,824

PONY DISTRICT.

LOCATION.

The town of Pony is about 40 miles west of Bozeman and the same distance southeast of Butte, on the Pony-Norris branch of the Northern Pacific Railway, at an elevation of 5,600 feet above sea level. Three mining districts, the Mineral Hill, the Potosi, and the Sand Creek are tributary to it. The Mineral Hill mining district, in the Tobacco Root Mountains west of Pony at elevations ranging from 6,200 to 9,000 feet, contains the chief mines of the area. Some of the veins are said to extend westward about 3 miles to the Mammoth district in the Dillon quadrangle. The Potosi mining district is in the mountains north of the headwaters of South Willow Creek, about 7 miles in a straight line southwest of Pony, but about twice as far by road, and about 5 miles above Potosi Hot Springs, at elevations ranging from 8,000 to 9,500 feet. The Sand Creek mining district is about 3 miles south of Sappington, or nearly 10 miles northeast of Pony.

The Norwegian mining district is about halfway between Pony and Norris, near the source of Norwegian Creek. Its mines are described (p. 113) in connection with the Norris district, although they are only about 6 miles from Pony.

HISTORY.

The mines of the Pony region were discovered and opened some years later than the other mines in this part of Montana. The Potosi silver mines were found in 1875 and the Mineral Hill veins a few years earlier. During the eighties and nineties exploitation of the latter was active. The Clipper mine was especially productive during the latter half of this period, and the Garnet from 1897 to 1905. A mill was erected at the Garnet in 1898. Three years later a 120-stamp mill was built at Pony for the ores of the Clipper and Boss Tweed group, but it was not used, and the region has been less active since the opening of the new century. However, many of the mines have been worked by lessees and, by erecting a 15-stamp mill near the tunnels, work on the Clipper-Boss Tweed group has been successful for several years.

GEOLOGY.

The Pony district is a region of old schists and gneisses cut by quartz monzonite. Below Pony the bottom lands of Willow Creek are made of alluvium and stream-carried glacial drift. About 2 miles above the town a little morainic material indicates the former existence of a local glacier at the head of North Willow Creek. The Sand Creek district is occupied by gneiss and schists cut by dikes and bordered by lower Paleozoic sediments. Most of the mines of Mineral Hill are in gneiss near its contact with quartz monzonite (see fig. 9), but the Garnet group is in igneous rock near gneiss. The mines of the Potosi district are in quartz monzonite associated with aplitic dikes.

Evidence within the Pony district discloses only that the gneisses and schists are older than the Flathead quartzite. But their lithologic similarity to the gneisses of the Norris, Virginia City, and Sheridan districts, and the fact that they are probably continuous with those rocks around the west end of the quartz monzonite area, indicate that they are of the same age (Cherry Creek).

The gneiss of the region is commonly dark colored and banded, being composed chiefly of quartz, feldspar, and hornblende in variable proportions with local abundance of chlorite or garnet. In some samples the quartz is granulated, the feldspar is sericitized, and epidote and rutile are present. In the Mineral Hill district the general strike of the banding of the gneiss is about east and the dip is north at varying angles dominantly steeper than 60°.

The quartz monzonite of the Pony region contains sporadic phenocrysts of orthoclase which inclose other minerals poikilitically. It contains much quartz, some plagioclase, little biotite, muscovite, titanite, magnetite (or ilmenite), and sericite, especially in the soda-lime feldspar. It varies in two ways in the Potosi district; one phase

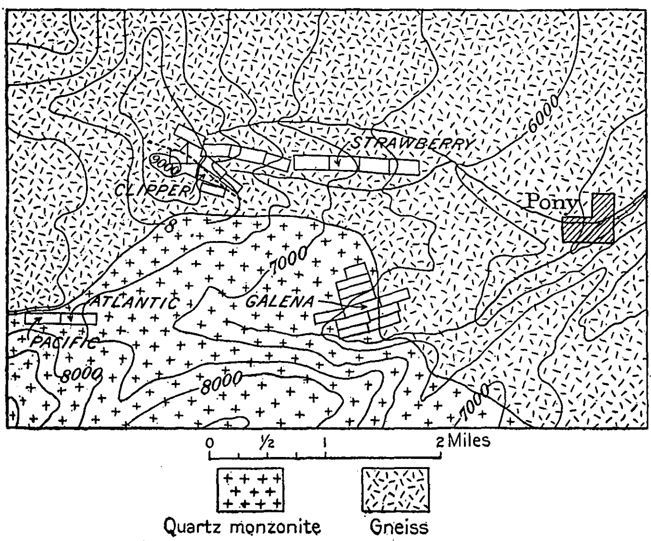


FIGURE 9.—Geologic sketch map of the Mineral Hill mining district, Mont.

is somewhat more acidic and contains, with feldspars and quartz, only a little magnetite (or ilmenite) and titanite; the other phase is a granodiorite, somewhat more basic than the usual quartz monzonite, containing dominant plagioclase, some orthoclase, and hornblende, biotite, chlorite, little apatite, magnetite (or ilmenite), and titanite.

The dike rocks are aplitic or pegmatitic. In the Potosi district they are of rather coarse grained quartz monzonite aplite, grading in places toward a pegmatite that contains fluorite and pyrite. In the Mineral Hill district, at the Strawberry mine, pegmatite is closely associated with the ore; indeed, in places the ore is in pegmatite.

ORE DEPOSITS.

SAND CREEK DISTRICT.

The mines of the Sand Creek district are now idle and were not seen by the writer. In 1897 the Chile mine had a shaft 100 feet deep opening free-milling gold ore, which was treated in a 5-stamp mill. A few years later the Whippoorwill mine was operated for about two years.

MINERAL HILL DISTRICT.

In the Mineral Hill district near Pony it is possible to distinguish two types of ore deposits—vein deposits and ores apparently produced by replacement. Both types are found in gneiss and also in igneous country rock, but the first type is much commoner in this region.

The Atlantic and Pacific claims have an ore body which consists of oxidized and altered aplitic rock impregnated with gold and silver. The deposit has not been opened below the zone of surface alteration, but it illustrates the occurrence, apparently by replacement, of disseminated ore in igneous rock.

On the Boss Tweed claim a large deposit of gold ore in gneiss is associated with faults. There is very little quartz or vein material in the faults, and the main fault has a few inches to 6 feet of soft "clay" or gouge and serves as the hanging-wall limit of the ore. At some distance from this main fault, which strikes about N. 65° W. and dips about 45° SSW., another fault, or in places a series of nearly parallel faults, approximately limits the ore on the footwall side. This ore body has the distinction of having a somewhat indefinite footwall, which dips in the wrong direction where opened in the vicinity of the ore on the sixth level. In general the footwall and hanging wall converge to the west and diverge downward; on the upper levels the footwall strikes about N. 75° W. and dips about 60° SSW.; on the sixth and seventh levels it dips about 80° NNE. The ore body in this mine has been developed by about 15,000 feet of work, being opened along the strike for 1,500 feet, and on the dip for 800 feet. It has already yielded about $500,000 in gold and silver in about equal parts by weight. The distance between foot and hanging walls varies from 10 to 160 feet, and the mineralization has a thickness varying from 1 foot to 100 feet, as measured on the horizontal, and from 1 foot to at least 40 feet as measured in the narrowest way. In general the ore does not extend into the hanging wall, but in many places it extends into the footwall, and its limits must be determined by assays. The ore consists of mineralized gneiss which has been silicified and pyritized. Locally there are some stringers of quartz and others of pyrite which are properly called veins, but in general the ore is merely modified gneiss. The greater the silicification the more obscure are the bandings and original characters of the gneiss. All the gneiss between the walls contains more or less gold, but the pay ore is in shoots, the determination of whose position, size, and pitch has been of the first importance in mining. The shoots seem to be associated with two sets of cross fractures which do not extend beyond the main walls; one set strikes about N. 25° W. and dips about 20° ESE.; the other set strikes about N. 65° W. and dips about 40° NNE. The ore shoots seem to be localized by the first set of fissures; they pitch about 20° SE. and cross from the foot to the hanging wall in about 300 feet.

The ore is simple in its mineralogy, consisting of auriferous pyrite and quartz disseminated and in veinlets in a rock composed of quartz, orthoclase, little plagioclase, chlorite, muscovite, and rare epidote. Where more intensely mineralized the quartz is more abundant, and is commonly associated with chalcite, chlorite, pyrite, and rutile.

In the Boss Tweed mine oxidized ores are of no importance, for sulphides reach within a few feet of the surface. From this fact and from a study of the sulphide ore it is evident that there has been no appreciable enrichment.

These ores were probably produced by ascending solutions, for they are found below the main impervious rock (the fault gouge of the hanging wall) of the region. It is considered probable that these solutions came from the quartz monzonite magma, whose northern limit is only about half a mile south of the Boss Tweed. This conclusion is reached not from a study of the Tweed mine alone, but from an examination of conditions in the mines of the district.

In the Clipper mine, which adjoins the Boss Tweed on the south and belongs to the same group, the ore deposit is quite similar to that in the Tweed. It consists of silicified and pyritized gneiss between two approximately parallel fault planes 10 to 40 feet apart, which serve as footwall and hanging wall. The ore is somewhat oxidized, and enrichment has played a part in producing the best ores of the mine; but much of the ore mineral has been unoxidized auriferous pyrite. The faults strike about N. 60° W. and dip about 40° SSW. The mineralized zone has been opened along the strike about 1,200 feet and on the dip about 500 feet. The Clipper is said to have produced at least $1,500,000 in the nineties, largely from milling ores running about $10 to the ton, taken from two main ore shoots pitching nearly in the direction of the dip. One shoot 6 to 30 feet in width extended from the surface to the 600-foot level.

The Garnet group is about 2 miles west-southwest of Pony on North Willow Creek. The ore deposit is in a fractured zone in quartz monzonite 5 to 20 feet wide, mineralized by quartz and auriferous pyrite. The ore is found both in small fissure veins and also impregnating the quartz monzonite in the fractured zone. The deposit, which strikes northeast and dips about 70° SE., has been opened along the strike about 600 feet and on the dip about 500 feet. The mine is equipped with a 20-stamp mill having Frue vanners for concentration. About half of the gold was recovered by amalgamation and nearly as much more from the concentrates, which amounted to one-twentieth of the ore milled. The mine is said to have produced about $150,000, but it is not now in operation.

The Old Joe mine is nearly 3 miles west of Pony, and is very near the quartz monzonite and gneiss contact. The ore is in a quartz vein which strikes N. 65° W. and dips about 25° SSW. The vein is about 2 feet wide and has been opened by a crosscut 125 feet long, at a depth of 300 feet, measured on the dip. The footwall quartz monzonite is impregnated with quartz and pyrite for about 5 feet from the vein. It is said to have produced about $10,000, chiefly gold.

The Strawberry-Keystone group is about 2½ miles west-northwest of Pony, at an elevation of about 7,000 feet above sea level. At this mine, which is in gneiss, there are two main veins and several smaller ones, all nearly parallel in strike. The Strawberry vein strikes about east and dips 60°–70° N.; on the upper level it is 4 to 7 feet wide with 1 to 3 feet of fault gouge along the footwall. At both ends of the lower level, which is at least 200 feet long and is about 400 feet below the surface, the vein is filled with fault gouge and carries very little quartz or sulphides.

The Keystone vein is of exceptional interest, not only because it has been more productive than the Strawberry, but also because it illustrates the gradation from pegmatite to quartz vein within the walls of a single fissure. The vein is opened by two tunnels. On the upper level, about 100 feet below the surface, the fissure has been followed for more than 300 feet, and shows a width of 2 to 20 feet; on the lower level, about 400 feet below the surface, the vein is opened about the same distance, and has a thickness of 30 to 35 feet. On the upper level the fissure filling is dominantly vein material consisting of quartz and pyrite with fault gouge; on the lower level the filling is chiefly pegmatitic, consisting of a coarsely crystalline aggregate of quartz, microcline, a little muscovite, and more or less pyrite and chlorite. On the upper level, in the wider portion of the fissure, there is some pegmatitic filling, which carries finely disseminated subordinate pyrite near the hanging wall and quartz and abundant pyrite near the footwall; in the narrower portion of the fissure the filling is wholly vein quartz and fault gouge. On the lower level there is some vein quartz with abundant pyrite in shoots on the footwall side of the fissure. The Keystone vein strikes N. 80° E. and dips about 50°–60° S. The Strawberry and Keystone veins diverge in dip; on the upper level they are 120 feet apart; on the lower level they are 420 feet apart.

Several smaller veins, most of which strike about N. 50° E. and dip 45°–55° SE., have been cut in the upper workings of the mine, and some of them have produced good ore. They are perhaps simply cross fractures, for they have not been found to extend beyond the main veins. It seems probable that all the veins were simultaneous in origin, though the filling of the cross veins is different from that of the main veins, consisting of solid pyrite, or pyrite with a little quartz, or fault gouge. The direction of fault movement seems to have been about 75° from the horizontal on the Strawberry and Keystone veins and nearly horizontal on the cross veins. The best ore shoots are found where the cross veins meet one of the main veins.

The Strawberry-Keystone group is reported to have produced about $150,000; in 1910 the ore averaged 1½ ounces of silver to 1 ounce of gold; it also contained 0.4 per cent of copper and 48.9 per cent of iron. The ore has been considerably oxidized and the oxidized ores have been much enriched, but mining has now passed chiefly into sulphide ores, which are apparently primary in origin.

The Willow Creek claim is about half a mile west of the Strawberry group. This claim and the Ned, which adjoins it on the east, are reported to have produced about $250,000 each, chiefly from milling ore derived from surface cuts and shallow drifts. Several nearly parallel veins on these claims, striking about N. 75° W. and dipping about 50° SSW., contain quartz and auriferous pyrite except where the latter is oxidized to hematite and limonite. Their average width is about 2 feet.

The Mountain Cliff claim is about 4 miles west of Pony, at an elevation of nearly 9,000 feet above sea level. There are at least three veins on this claim and some of the gneiss country rock is so highly mineralized as to be good ore. The veins strike nearly west and dip about 45° S. One of them, which is 3 to 4 feet wide and which has been opened for about 300 feet, has been found, unlike other veins of the district, to contain considerable galena associated with the auriferous pyrite. Another vein dips about 65° S. and contained oxidized ore in a shoot 4 to 5 feet wide, 100 feet long, and 40 feet on the dip. One vein, which has been cut below the zone of oxidation by a lower tunnel and opened for 300 feet, is said to have contained quartz and auriferous pyrite assaying about $5 a ton—too low grade to be mined.

On the White Pine claim ore was found in a vein dipping about 65° S. near its termination against a vein dipping about 65° N.; both veins strike about east. This ore shoot is reported to have produced $50,000.

POTOSI DISTRICT.

In the Potosi mining district, about 14 miles by road southwest of Pony, mining for silver began in 1875. The ores are in quartz veins in quartz monzonite associated with dikes of quartz monzonite aplite. Although originally mined for silver, these ores are of interest now chiefly because they contain tungsten, the recent discovery of which the writer was able to confirm at the time of his visit to the region in July, 1911. None of the veins of the district are opened by extensive workings and descriptions of individual mines are therefore omitted.

The Potosi region is remarkable for the large number of minerals which it affords, the list including quartz, pyrite, chalcopyrite, galena, sphalerite, pyrargyrite, molybdenite, fluorite, hübnerite, cerargyrite, native silver, pyrolusite, and limonite. The tungsten ore (hübnerite and its oxidation products) is found in quartz veins on at least a dozen different claims, including the Green Jacket, Mountain Rose, Keystone, Crown Point, Granite Mountain, Sunnyside, and Rockefeller. In the western part of the region the veins strike about east and dip 60°–80° N.; in the eastern part they strike about north and dip about 60° W. The veins are in general persistent in strike and dip. They are highly quartzose and vary from 1 to 6 feet in thickness. The hübnerite is commonly confined to streaks 1 to 18 inches thick, but a width of 20 inches was found on the Rockefeller claim, a sample from which assayed 4.5 per cent of tungstic acid. Apparently the tungsten ore was formed late in the history of the vein; some thin layers of chalcedony were formed later, and some quartz crystallized simultaneously with the tungsten ore, but the other minerals, including the silver ores, were formed earlier. Pyrolusite and fluorite are commonly associated with the hübnerite and are also found without tungsten ore in a large quartz vein on the contact of quartz monzonite and gneiss. The fluorite varies in color remarkably, being purple, green, blue, white, or black.

ORIGIN OF THE ORE.

The ores of the Pony district were probably formed by solutions proceeding upward and outward from the quartz monzonite magma. This is indicated by their geographic position near the margin of the quartz monzonite; by their gradation to pegmatite at the Strawberry mine; and by their association with the pneumatolytic mineral fluorite in the Potosi region. That the ores were produced by uprising solutions is indicated by their occurrence beneath impervious fault gouge 1 to 6 feet thick in the Boss Tweed mine. That they were formed after the crystallization of the quartz monzonite is proved by their presence in veins cutting the latter, but that their formation took place not long afterward is indicated by their association with fluorite, pegmatite, and aplite, all of which were probably derived from the residual magma after crystallization of the portion now penetrated by these veins and dikes.

PRODUCTION.

Statistics of production prior to 1902 are not available, but estimates based on considerable information are submitted in the tabulation below. It may be estimated that 90 per cent of the production of the Pony region has come from the Mineral Hill mining district, in which the output of gold, by weight, has been nearly equal to that of silver. In the Potosi district silver was the chief metal recovered. For the years since 1902 the statistics of production have been compiled from the records of the United States Geological Survey.

Production of Pony district.

Year.	Crude ore.	Gold.	Silver.	Copper.	Lead.	Total value.
	Tons.	*Fine oz.*	*Fine oz.*	*Pounds.*	*Pounds.*	
1874-1880	4,000					$200,000
1881-1890	10,000					400,000
1891-1901	150,000					2,000,000
1902	1,575	1,994.60	1,141		21,000	42,437
1903	685	663.70	600		25,000	14,532
1904	1,491	3,326.50	4,023			57,012
1905	16,936	4,321.78	4,356	3,205	65,326	96,480
1906	11,132	4,008.37	8,893	50,383	112,007	104,927
1907	4,924	2,541.82	4,325	28,580	7,500	61,513
1908	5,796	2,585.40	3,956	11,315	15,103	57,690
1909	7,474	4,283.85	3,891	9,925	1,145	91,917
1910	15,301	6,573.19	6,651	20,671		142,098
1911	15,386	4,060.02	5,606	8,545	8,021	88,328
1912	14,187	2,791.96	5,263	4,066	273	61,634
	258,887	37,151.19	49,705	136,690	255,375	3,418,568

RABBIT (ROCHESTER) DISTRICT.

LOCATION.

The town of Rochester is 10 miles northwest of Twin Bridges, a town on the Alder branch of the Northern Pacific Railway, and about 10 miles east of Melrose, a station on the main line of the Oregon Short Line between Butte and Salt Lake. Rochester may be reached by a good road from Twin Bridges up Rochester Creek, gaining elevation at the rate of about 100 feet in a mile, or by a road from Melrose which crosses the divide between Bighole and Jefferson rivers. Rochester is located at the outlet of a basin nearly surrounded by spurs running southward from Red and Table mountains. It is at an elevation of about 5,800 feet above sea level, in a region too arid to support more than scanty vegetation. Snowfall as well as rainfall is deficient, so that very little snow lies on the ground in winter. The country rock is rather open and porous, as shown by the fact that in 1903 and 1904 the pumps in the lower levels of the Watseca mine drained all the wells and springs near the town, making it necessary to haul water for domestic use from springs about 2 miles away.

HISTORY.

The Watseca lode was discovered in the sixties and has been worked more or less constantly since that time. But the greatest activity in the district was from 1901 to 1905, when the Watseca mine attained a vertical depth of 600 feet and when numerous other mines in the district were in operation. Rochester was then the largest town in Madison County, but it is now small, and mining near it has almost ceased.

The region around Rochester is relatively flat, so that lode mining is carried on by means of inclined or vertical shafts, in sharp contrast to methods prevailing in the Tidal Wave district, across the Jefferson Valley, where mining through adits is the rule.

Stamp mills with plate amalgamation, chlorination mills, various types of concentrators, and even smelters for lead ores have been installed in or near Rochester.

GEOLOGY.

The geology of the Rabbit district is simple. The whole adjacent region is underlain by schists and gneisses. But the correlation of this series of metamorphosed rocks is not obvious. They have been commonly regarded as of Archean age, and they are elsewhere covered by Paleozoic limestones, as about 4 miles west of Rochester and on Camp Creek. But they include some mica schists which seem to have been derived from quartzites, and petrographically they resemble closely the series which, in the Tidal Wave and Sheridan districts, is correlated in this report with the Cherry Creek group. The most important objection that may be raised to this correlation is the fact that no limestone beds are known to be included in the series in the Rabbit district, whereas limestone is characteristic of the Cherry Creek as exposed elsewhere. However, it is not known that limestone occurs in all parts of the Cherry Creek group. Furthermore, the mica schists in the Rabbit district, where less thoroughly metamorphosed, show evidence of having been feldspathic quartzites originally. Their chief constituents are quartz, biotite, orthoclase, and plagioclase, and they contain abundant garnet and some chlorite, accessory apatite and zircon, and secondary sericite and chlorite. The feldspars are notably altered and many of the quartz grains show undulatory extinction due to strain. Schistosity is well developed. This petrographic character neither proves nor disproves that the rock is an altered sediment.

Further evidence as to its origin has been derived from a detailed study of the contained zircon. As shown by Thurach,[1] zircon is very widely disseminated in rocks. Derby [2] argues that its presence in a metamorphic rock indicates that the rock is a metamorphosed igneous rock and not a metamorphosed sedimentary rock. But Trueman[3] has shown that zircon occurs abundantly in some sandstones and in some metamorphic rocks known to be derived from sandstones. However, zircon in sandstones and quartzites is characteristically weathered and rounded, and nearly all zircon in igneous rocks and their metamorphic equivalents is clear and sharply angular. As the mica schist here discussed contains abundant well-rounded and weathered zircon (see Pl. IV, *A*) it would appear to be derived from a quartzite despite the fact that it contains abundant feldspar. The sample was taken from the schist near an intrusion of aplitic granite, and more or less of the feldspar may have been developed in the rock by contact action.

With this evidence that the schists are of sedimentary origin it seems desirable to correlate them with the Cherry Creek group of the Algonkian rather than with the Archean.

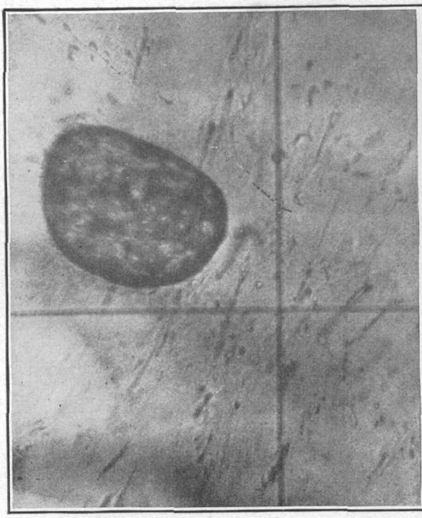
The schists are interbedded not only with gneiss but also with slaty rocks. Where these rocks are modified by contact metamorphism produced by aplitic granite they contain abundant amphibole and plagioclase, garnet (more or less completely surrounded by plagioclase), some magnetite, epidote, and chlorite. The amphibole is of two types, one of which is colorless or nearly so, and the other is pleochroic in distinct green tints. The colorless amphibole has a birefringence of about 0.017 and the pleochroic variety only about 0.013. Both are monoclinic, and the latter has an extinction angle of about 14° with positive elongation.

Granitic intrusives have already been mentioned. Geologically the district is characterized by the abundance of such intrusions, generally in the form of sills, which vary from thin seams to sills 300 feet or more in thickness. The prevailing strike of the sills is northeast with a dip of 15°–40° NW., but many of them vary from this position. A few fork or cut across the formation, but their characteristic position is that of a sill. One about half a mile west of Rochester contains much quartz and microcline, a little muscovite and biotite, and some orthoclase, which commonly surrounds the muscovite. The texture is medium-grained granitic, and the rock, although occurring in sills—some of them narrow—is mineralogically and texturally a true granite. It resembles an aplite in being com-

[1] Thurach, H., Ueber das Vorkommen mikroskopische Zirkone und Titanmineralien in den Gesteinen: Phys. Med. Gesell. Würzburg Verhandl., new ser., vol. 18, 1884.

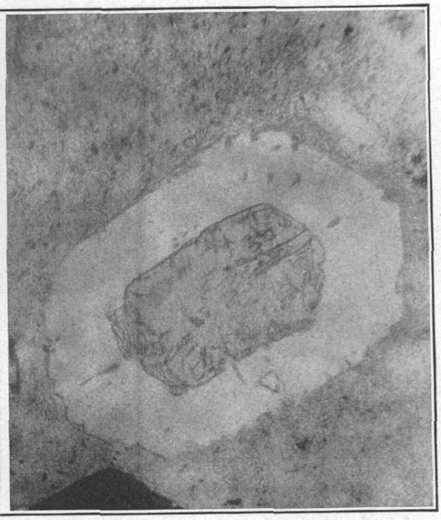
[2] Derby, O. A., On the separation and study of the heavy accessions of rocks: Rochester Acad. Sci. Proc., vol. 1, pp. 198–206, 1891.

[3] Trueman, J. D., Thesis, submitted for doctorate degree at University of Wisconsin, 1911: Jour. Geology, vol. 20, pp. 228–258, 300–315, 1912.



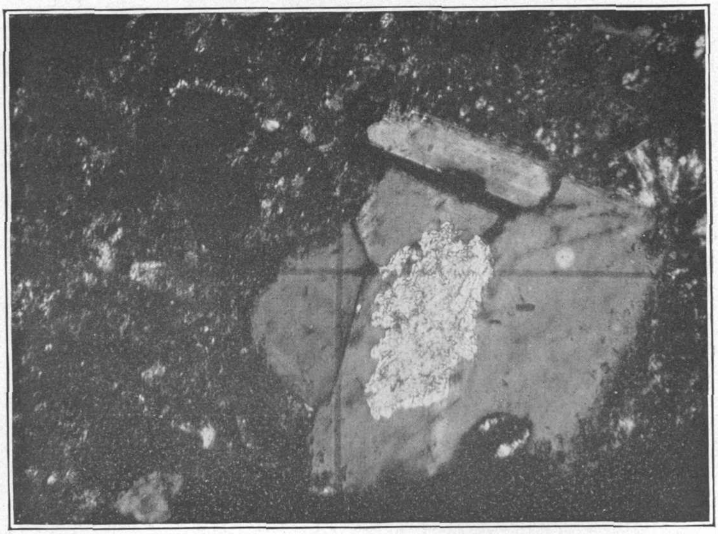
A. PHOTOMICROGRAPH OF ROUNDED ZIRCON IN THIN SECTION OF MICA SCHIST FROM RABBIT DISTRICT, ROCHESTER, MONT.

One nicol. Enlarged 400 diameters.



B. CALCITE INCLOSED BY FRESH ANDESINE IN ANDESITE PORPHYRY FROM VIRGINIA CITY, MONT.

One nicol. Enlarged 100 diameters.



C. CALCITE INCLOSED BY FRESH PLAGIOCLASE IN ANDESITE PORPHYRY FROM VIRGINIA CITY, MONT.

Crossed nicols. Enlarged 100 diameters.

posed chiefly of quartz and potash feldspar with a little mica and in its mode of occurrence in sills and dikes, and it may therefore be called an aplitic granite. It resembles the aplites[1] associated with the Boulder batholith at Butte and elsewhere in mode of occurrence and in mineral composition and differs from them only in being of slightly coarser texture and in containing a little more biotite.

Some larger masses of these aplitic granites are perhaps not sills but merely intrusive bodies of irregular shape, such as the chonoliths of Daly.[2] Similar chonoliths of aplite are well known at Butte.

It seems probable that these aplitic granite intrusions are derived from the Boulder batholith, which is easily traced on the surface southward to Fish Creek, Red Mountain, Moose Creek, and Silver Star. Isolated intrusive masses of "granite" also outcrop on Camp Creek and McCarthy Mountain, and are reported from Hell Canyon. Rochester seems to occupy a position near the border of the original roof of the batholith, where erosion has not yet carried away the whole covering. On this view the batholith itself should be found beneath the Cherry Creek group in this region, and the aplitic sills may be considered the upward fingering out of the magma into its roof. During the period of active intrusion of the magma such upward extrusions may be regarded as the advance guard of the intrusion. That they are more siliceous than the main magma may result from a greater mobility and lower specific gravity of more acidic parts of the magma due to a greater content of water (aqueous gas) or other volatile mineralizing gases.

Petrographically the district presents one more point of similarity to the area of Butte. Rhyolitic extrusives, like those in Butte, occur on Niggerhead, a hill about 3½ miles south-southeast of Rochester, and also on a hill at the margin of the basin of Rochester about 3 miles north-northeast of the town. In both places the field relations indicate that the rock forms the solidified neck or plug of an ancient volcano whose surface flows and pyroclastic materials have been, at least for the main part, eroded and carried away since the period of volcanic activity. On Niggerhead the rhyolite both forms a sill and occupies a volcanic neck. The rhyolitic capping on the adjoining hill to the west is a remnant either of a sill or a surface flow. The relation in time between the rhyolitic and aplitic intrusions of the Rochester district is not yet determined. The rhyolite of the district, like the aplitic rock, seems to be more basic than the corresponding rocks of the Butte district. The rock from Niggerhead contains phenocrysts of orthoclase, plagioclase, quartz, biotite, and brown hornblende. The quartz phenocrysts are somewhat corroded, probably through partial resorption. Plagioclase appears to be

[1] Weed, W. H., Jour. Geology, vol. 7, p. 737, 1899.

[2] Daly, R. A., idem, vol. 13, p. 498, 1905.

subordinate to orthoclase in amount, but its presence with biotite and hornblende indicates a gradation toward a quartz latite.

A curious dike occurring about half a mile west-northwest of Rochester consists of almost pure potash feldspar. It is at least 75 feet thick in places and strikes N. 50° W., with a dip of about 65° NE. Another dike of the same kind, apparently not connected with the first on the surface, is nearly in the same line of strike about 1,000 feet to the southeast and strikes about N. 50° W., with a dip of about 75° NE. Microscopically this dike consists of a fine to medium grained aggregate of anhedra of orthoclase, with a little quartz. It is remarkable in consisting almost entirely of a single mineral—orthoclase. It seems to represent that type of igneous rock illustrated by plagioclasite and dunite and called by Vogt[1] anchimonomineralic. That is, on the assumption that eutectics exist in rocks, it is probable that differentiation, produced by crystallization aided by other processes such as gravitation, diffusion, and convection, will tend to produce two types of rocks, one consisting essentially of constituents in eutectic proportions (Vogt's anchieutectic rocks), and the other consisting essentially of one constituent which was present in excess of the eutectic proportions and which was separated from the first type through crystallization during the period of cooling preceding the solidification of the eutectic aggregate.

ORE DEPOSITS.

The ore deposits of the Rabbit district are well-defined veins, usually of steep dip, closely associated, although not contemporaneous, with dikes of aplitic granite. The dikes are clearly older than the veins, which lie within them or intersect them. Thus the Watseca vein is in gneiss at the main shaft, but runs into aplitic granite to the northeast. It strikes about N. 50° E., and dips at about 50° NW. So far as past production and known continuity in depth are concerned the Watseca vein is easily the most important in the district, but the mine has been closed and slowly filling with water since 1905. The chief value of the ores of the district is in gold, but silver and lead occur in notable amounts, and small amounts of copper are occasionally found.

The Longfellow, Badger, Cooper, Shoemaker, Thistle, Concentrator, and Mutch mines lie within a mile or two south and southeast of Rochester. The Longfellow lead is in an aplite dike cutting gneiss. The dike strikes about north and dips about 70° W., and the vein runs nearly parallel. It is opened by an incline shaft about 300 feet deep. From the dump it appears that low-grade ore, carrying pyrite and galena with gold and silver, was obtained in the lower levels.

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[1] Vogt, J. H. L., Norsk. Geol. Tidsskr., vol. 1, No. 2, 1905.

The Cooper mine is about half a mile southeast of Rochester. It has a lead of galena ore in an aplite dike cutting gneiss. The vein strikes north and dips about 50° W., and the dike follows about the same course. About 300 feet to the northeast a larger area of aplitic granite occurs in contact with the gneiss. Cerusite and ecdemite occur in the oxidized ore of the Cooper.

The Mutch mine lies at a granite and gneiss contact about 2 miles south of Rochester. The ore is galena, but carries some gold and silver and small amounts of copper, in the form of malachite and chrysocolla. The oxidized ore contains cerusite, vanadinite, and ecdemite. The mine is opened by an incline shaft about 325 feet deep. The vein strikes about N. 40° E. and dips about 37° NW.

A little more than half a mile southwest of Rochester is the New mine, where there are many aplite dikes and sills, commonly striking about north and dipping 15°–40° W. in gneiss. They vary in width from 1 foot to 300 feet, or even more. The vein strikes east, at about right angles to the dikes, and dips about 60° W. The vein of the New mine has in places a gneiss hanging wall and an aplite footwall; elsewhere this is reversed, or both walls are gneiss. Some very rich wire gold ore has been obtained from the New mine, which is opened by an incline shaft about 300 feet deep.

The Germania mine, east of Rochester, has a conspicuous quartz vein about 30 feet thick, which strikes about N. 30° W. and dips about 30° NE. The vein material is chiefly compact white quartz, said to carry about $1 in gold to the ton. Small pay streaks are said to carry $20. The vein is opened by an incline shaft on the footwall about 150 feet deep. The country rock is "granite." Another quartz vein nearly parallel with the first occurs only about 50 feet to the north.

Numerous other properties in the district were not examined, because they were idle at the time of the visit to the region (August, 1910).

ORIGIN OF ORE DEPOSITS.

The ores of the district seem to have a common origin and a genetic relationship with the aplitic dikes. The evidence of this relationship is not conclusive, consisting only in the fact that the ores are so closely related to the dikes in their areal distribution and mode of occurrence. It seems probable that the ores owe their origin to the same source as the aplite dikes—that is, to the Boulder batholith. The fact that they are later than these dikes in time of origin is not in discord with this view, for many ores which are produced by escaping igneous solutions are of later date than the pegmatites and aplites derived from the same magma. This fact is entirely in harmony with the conception that such ores are produced by a residual concentration, the precious metals originally dissolved in uniform amount throughout a large magma becoming gradually more and more concentrated during the progress of crystallization, because they remain constantly in the steadily diminishing liquid residue of the magma.

PRODUCTION.

The production of metals in the Rabbit district was probably greater during the years 1901 to 1904 than at any other time since mining began in the region. Unfortunately, statistics of production during this interval are available only for the year 1904. From the records of the United States Geological Survey the production for the years 1904 to 1912, inclusive, has been tabulated as follows:

Production of metals in the Rabbit district.

Year.	Ore.	Gold.[a]		Silver.		Copper.		Lead.		Total.
	Tons.	*Fine oz.*		*Fine oz.*		*Pounds.*		*Pounds.*		
1904	3,090	2,492.09	$51,516	1,093	$625	....	....	6,000	$259	$52,400
1905	5,484	339.51	7,018	4,753	2,899	88	$14	99,900	4,695	14,626
1906	501	1,026.40	21,218	4,611	3,089	751	146	39,884	2,273	26,726
1907	223	325.08	6,720	6,078	4,011	....	....	666	36	10,767
1908	100	120.90	2,499	502	266	....	....	14,448	607	3,372
1909	291	295.49	6,108	1,470	764	18	2	18,700	804	7,678
1910	260	94.91	1,962	557	301	321	29	101,093	4,448	6,740
1911	98	91.28	1,887	732	388	161	20	21,612	973	3,268
1912	267	107.44	2,221	5,127	3,153	664	110	79,783	3,590	9,074
	10,314	4,893.10	101,149	24,923	15,496	1,913	321	382,086	17,685	134,651

[a] Includes the small output of placer gold.

SHERIDAN DISTRICT.

LOCATION.

The town of Sheridan, on the Alder branch of the Northern Pacific Railway, is a supply point for several mining districts in the neighboring gulches of the Tobacco Root Mountains. As here used, the Sheridan district includes the Wisconsin district, on Wisconsin Creek; the Indian district, on Indian Creek; the Brandon district, near the mouth of Mill Creek Gulch; the Mill Creek district, covering the upper portion of Mill Creek Gulch; the Quartz Hill district, a knob terminating a ridge between Mill Creek and Indian Creek; the Ramshorn district, along Ramshorn Gulch; and the Bivin district, along Bivin Gulch. As thus defined the Sheridan district extends 10 miles north of Sheridan at the upper end of Wisconsin Creek and 10 miles east of Sheridan at the upper end of Ramshorn Gulch. Except for Bivin Gulch and the lower end of Ramshorn Gulch a triangle made by connecting these two points with Sheridan outlines the area. Elevations in the district vary from about 5,500 feet to more than 10,000 feet above sea level.

HISTORY.

The Sheridan district is very close to Alder Gulch, which was one of the first centers of mining activity in Montana. Within a year after the discovery of gold in Alder Gulch in 1863 quartz veins were located in the Sheridan district. The Company mine, on Wisconsin Creek, was opened in 1864; the Branham mill was erected on Mill Creek (which thus obtained its name) in 1865. This mill had 12 stamps of 500 pounds each, and a capacity of 12 tons a day; it was driven by water power at a cost of operation of about $2 a ton. The gold was caught on tables and blankets. In 1869 the Whittacker mill was running in the Quartz Hill district. It had three light stamps and crushed ore yielding $15 to $18 per ton in gold. During the seventies the favorite mode of treating gold ores was by means of arrastres. About 1883 the Company mine was sold to the Noble Mining & Milling Co., which operated it on a rather large scale for nearly 10 years. The Leiter mine, on Wisconsin Creek, about 8 miles from Sheridan, was equipped with an aerial tramway, stamp mill, and cyanide plant, and was in active operation during the later part of the nineties. During the last decade the most extensive operations in the district have been carried on at the Toledo and Lake Shore properties.

GEOLOGY.

The Sheridan district is occupied almost exclusively by an extensive series of schists and gneisses with interbedded quartzites and limestones, cut by various granitic igneous intrusions. This series of metamorphosed rocks has a prevailing strike north and a westerly dip at moderate angles. The interbedded crystalline limestones, which dip in places as steeply as 40°–50° W., are locally incorrectly known as limestone "dikes," probably from their position and their long, narrow form, few of them being more than 80 feet thick. That these rocks have not been recognized locally as sediments is probably due to their metamorphosed condition. The quartzites of the series grade in places into quartz schists and mica schists.

This series extends without change to the eastern border of the Dillon quadrangle and into the Threeforks quadrangle, where it has been mapped as Archean. From the description given by Peale[1] it appears that he discovered no limestone in this series in the south end of the Tobacco Root Mountains north of Virginia City. No study of the Granite Creek region has been made by the writer, but there are limestone ledges in this series within a mile of the eastern border of the Dillon quadrangle in the area about the headwaters of Bivin and Ramshorn gulches. Limestone ledges in schists and gneiss outcrop also within a few miles south of Virginia City on Alder Gulch and are reported south of Ward Peak at the head of South Meadow Creek.

[1] Peale, A. C., U. S. Geol. Survey Geol. Atlas, Threeforks folio (No. 24), 1896.

In accordance with prevailing views only such formations or groups of rocks as are wholly or almost wholly of igneous origin are included in the Archean in the sense here employed. It may be noted, however, that this procedure seems to imply the acceptance of the Laplacian theory rather than the planetesimal hypothesis of Chamberlin and Moulton. Later pre-Cambrian rocks contain in general more recognizable sediments than earlier pre-Cambrian rocks. Partly on the basis of this distinction the term Algonkian has been applied to the younger, and the term Archean has been modified from its original meaning to apply to the older.

The series of schists and gneisses exposed in the south end of the Tobacco Root Mountains contains quartzites and limestones so abundantly that they are much more closely related to the later than to the earlier pre-Cambrian formations. Without attempting distant correlations, they are therefore here called the Cherry Creek group in accordance with the usage of that term in the folio on the Threeforks quadrangle, which adjoins the Dillon quadrangle on the east. The Cherry Creek group is regarded by Van Hise as of early Algonkian age.

It is very clear that this series of schists and gneisses with interbedded quartzites and limestones is not the equivalent of the Belt series, for it is much more highly metamorphosed and consists of rocks which are siliceous and calcareous rather than argillaceous.

The only other formations in the Sheridan district are certain limestones on the northwest border of the district, on the ridge west of the headwaters of Wisconsin Creek, which may be Paleozoic, and the sands, clays, and gravels of the bench lands between the mountains and Passamari River. No fossils have been found in the limestones here classed as Paleozoic, but they lie above the Cherry Creek group and are nearly if not quite continuous with the Paleozoic limestone of the west flank of the Tobacco Root Mountains. The deposits on the bench lands have been called the Bozeman lake beds by Peale,[1] and referred to the Neocene. In this region they contain considerable volcanic ash; in the vicinity of Whitehall they also contain conglomerate and calcareous beds; and in many places along the base of the mountains they contain large amounts of outwash material.

The granitic intrusive rocks of Bear Gulch in the Tidal Wave district outcrop along the border of the Sheridan district to the northeast about the headwaters of Boulder Creek. Granitic rocks apparently of the same type penetrate the Cherry Creek group in several places within the district; thus "granite" occurs on the ridge west of the head of Mill Creek, in Bridges Canyon (which empties into Mill Creek about 5 miles from Sheridan) within a mile of its lower end, at the Company mine on Wisconsin Creek, near the Bedford

[1] Peale, A. C., loc. cit.

mine at the upper end of Ramshorn Gulch, and elsewhere. At most of these outcrops aplite with some pegmatite is associated with the "granite." The distribution of these rocks and the occurrence here and there of the overlying Cherry Creek group suggests that the quartz monzonite batholith extends beneath the Cherry Creek group under a large part of the district.

Glaciation has produced cirques and small lakes at the heads of several of the streams, notably on Wisconsin and Mill creeks. It has also filled the gulches with débris that extends from the cirques to or nearly to the bench land but that nowhere forms moraines upon the bench lands. On some creeks, Indian Creek for instance, the glacier did not reach the mouth of the gulch. The failure of the glaciers to travel farther from centers of accumulation was probably due not to lack of gradient, nor to extremely warm air above the bench land, but to deficient snowfall. (See pp. 151–152.)

ORE DEPOSITS.

PLACERS.

The Sheridan district contains placers that have been productive and are still worked in a few localities. Much of the gravel below the forks of Wisconsin Creek has been washed by hydraulic giants. On Ramshorn Gulch placer mining has been in progress since early times, though now confined to the upper end of the gulch.

WISCONSIN CREEK.

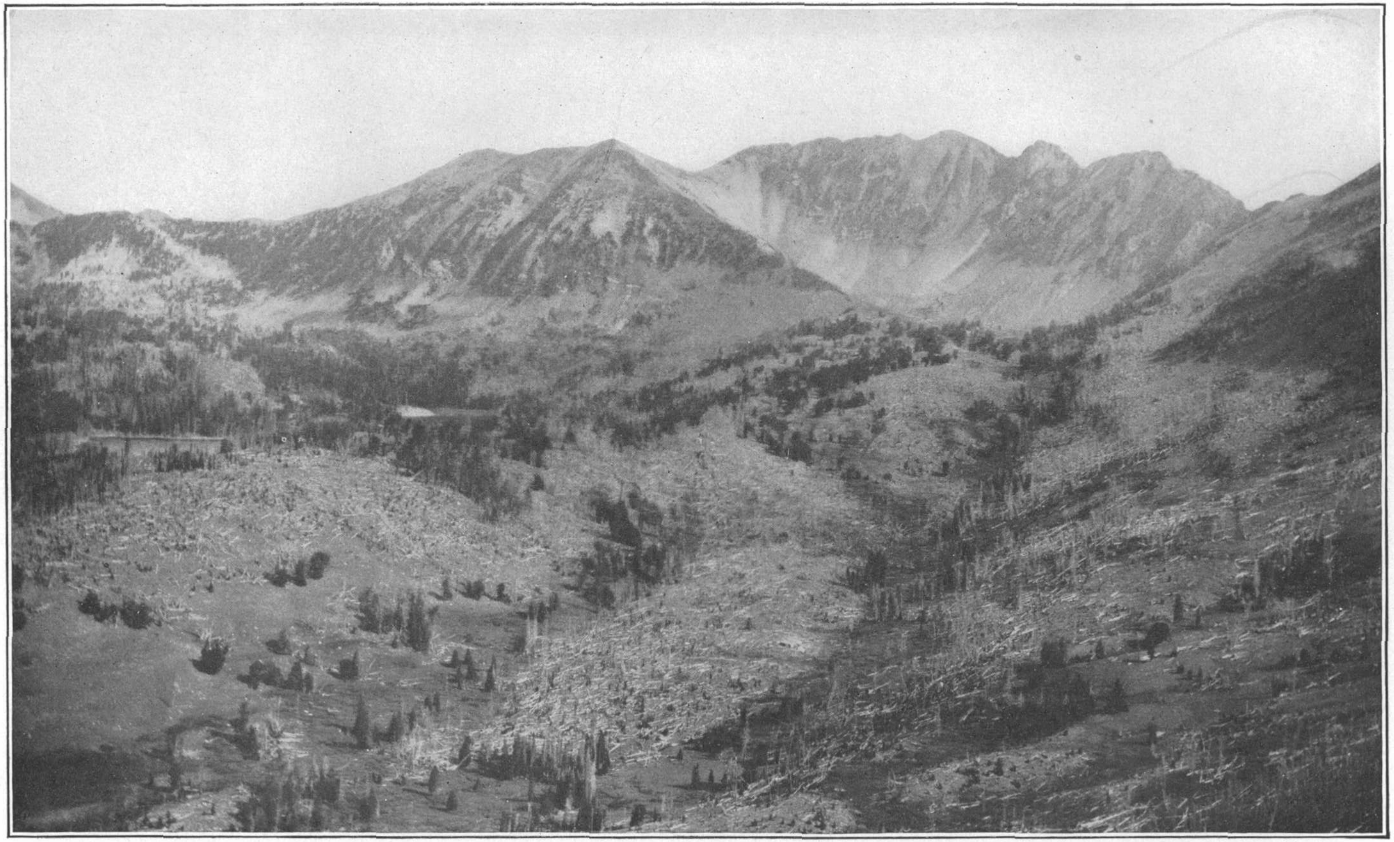
On Wisconsin Creek the chief lode mines are the Fairview at the forks, the Company mine on the south fork, and the Montana, Lake Shore, and Leiter mines on the north fork. The important constituent of the ore in all these mines is gold. The workings of the Fairview mine consist of an adit about 400 feet long, a winze of 60 feet, and drifts and stopes. The adit begins in limestone and encounters ore at the gneiss and limestone contact, the limestone forming the footwall and the gneiss the hanging wall. The mine has a mill, a tramway, and a power plant, but it has been idle since 1906.

The Company mine is on the west side of the south fork of Wisconsin Creek, at an elevation of about 7,800 feet above sea level. It is at present operated by lessees. The Noble Mining & Milling Co., which operated it for some years, installed a 10-stamp mill with plates, but the recovery was not entirely satisfactory. A crosscut was driven 2,700 feet to a 4-foot vein carrying auriferous pyrite with very little chalcopyrite and bornite. A raise, begun at 2,200 feet, struck the vein about 100 feet vertically higher and followed it at an angle of about 45° for about 1,100 feet to the upper level, where the vein is about 300 feet from the surface. At the south end of the claim the lead strikes about N. 30° E. and dips about 45° NW.; at the north end it strikes nearly due north and dips about 45° W. The change in strike occurs at a fault which strikes about N. 45° W. and dips about 45° SW. Near the fault the ore is of very low grade. The chief ore now obtained is gold in hematite with some argentiferous tetrahedrite. The oxidized ore contains native gold, cerargyrite, and malachite, and the sulphide ore contains pyrite, tetrahedrite, sphalerite, bornite, and chalcopyrite. The chief gangue minerals are hematite, limonite, quartz, mica, feldspar, garnet, and epidote. A thin bed of limestone borders the north side of the south fork of Wisconsin Creek from the forks northward for at least 3 miles; its dip is westerly and is rather steep at the Company mine. It is overlain by quartzites and slates containing sills and dikes of quartz porphyry and trachyte and underlain by quartzites and schists resting upon intrusive granite. The main vein seems to be closely associated with a sill of trachyte, which in some places forms both the footwall and the hanging wall and in other places forms but one wall, the other wall consisting of quartzite in which distinctly rounded grains of quartz and zircon are still discernible.

The property of the Montana Gold Mining Co. is near the head of one of the small headwater forks of Wisconsin Creek, just over the divide from the head of Bear Gulch, on a vein in the schists and quartzites of the Cherry Creek group. The property is now abandoned.

The Cornelia Mining Co. is reopening the Roach-Miller mine, near the head of another fork of Wisconsin Creek about due east of the head of Goodrich Gulch. The ore contains chalcopyrite, galena, cuprite, malachite, melaconite, and pyrolusite. The vein is in a porphyritic muscovite rhyolite which cuts gneiss.

The Gladstone mine (formerly called the Lake Shore) is located on the shore of a tiny lake held in the bottom of a glacial cirque by a morainic dam. It is equipped with a 10-stamp mill with plates and concentrators. A crosscut tunnel just above the mill penetrates gneiss and schists and opens a vein which strikes about N. 25° E. and dips about 80° WNW. The walls are marked by fault clay and the vein material consists chiefly of quartz and pyrite. This vein is well defined, straight, and persistent so far as disclosed by the underground workings. It shows little enrichment. Another tunnel at an altitude of about 9,000 feet, 1,000 feet higher than the mill, opens a vein which strikes N. 86° E. and dips about 40° N. It has an average thickness of about 3 feet, in which the ore shoots occupy 5 to 15 inches or more and pitch to the east. The vein filling is quartz and pyrite, with a little arsenopyrite and some chalcopyrite in places. The gneiss country rock is cut by a dike of diorite near this vein.



CIRQUE AND GLACIAL LAKES AT HEAD OF MILL CREEK, MADISON COUNTY, MONT.

Gneiss, schist, and aplitic granite.

The Leiter property is on Wisconsin Creek, about 3 miles south of the Gladstone mine. The mine is about half a mile from the mill, with which it is connected by means of an aerial tramway, both mill and tram being operated by a power plant. Tailings were treated in cyanide tanks. The vein is in gneisses and schists of the Cherry Creek group. The mine has been idle for several years.

INDIAN CREEK.

Indian Creek has no important mines, though lessees at times work on the Blue Bird and Red Pine claims, near the head of the creek, at an elevation of about 9,000 feet above sea level. These mines are located on veins in schists and limestones belonging to the Cherry Creek group.

MILL CREEK.

On Mill Creek mining has been in progress at three localities—about the headwaters of the creek, in the region of Quartz Hill between Mill and Indian creeks near Bridges Canyon, and in the foothills just north of the mouth of Mill Creek canyon. About the headwaters of Mill Creek veins traverse the walls of a glacial amphitheater, the center of which is filled with glacial débris which contains two small lakes. (See Pl. V.) The old creek channel is filled with drift to such an extent that the creek now forms a waterfall over solid rock in escaping from the cirque. Mill Creek flows through mica schists and gneiss, interbedded with a few limestone layers, probably referable to the Cherry Creek group, all the way from its sources to the bench lands of the Passamari Valley. About 10 miles from Sheridan these rocks are cut by local intrusions of granite, diorite, and aplite, and at the forks of Mill Creek wide veins of barren quartz occur. The Belle mine is in the northern wall of the glacial cirque at an elevation of about 9,500 feet above sea level. The chief vein, which strikes about N. 20° E. and dips about 45° W., is in gneiss and is closely associated with aplite and with a dike of pegmatitic feldspar that strikes about N. 20° W. and dips about 70° E. The feldspar dike is said to be cut off by the vein, which contains its richest ore where the vein and dike come together. The ore on this property is nearly all auriferous pyrite, showing little evidence of enrichment. A limestone ledge, dipping 35° NW. and probably belonging to the Cherry Creek group, extends from the ridge west of the head of Mill Creek nearly to Bridges Canyon, which opens into Mill Creek from the north about 5 miles from Sheridan. The ledge is modified to garnet rock by intrusive underlying granite and aplite and is overlain by schists. Veins occur here and there in the aplite and along the aplite and limestone contact. Near the head of Bridges Canyon the sedimentary series is cut by two intrusives, one of which is a trachyte with phenocrysts of orthoclase showing considerable alteration, and the other the so-called "granite" of the region, which is probably, as in the Boulder batholith, a quartz monzonite. It contains unusually abundant titanite, much zonal plagioclase, orthoclase, hornblende, pyroxene, quartz, and other minerals.

QUARTZ HILL.

In the region of Quartz Hill the schists are cut by numerous large quartz veins, which have yielded a good grade of gold ore in some places near the surface. No mines were in operation in 1910.

On Mill Creek, about half a mile below the mouth of Bridges Canyon, a marmarized limestone from 100 to 200 feet thick, is interbedded with schists and gneisses. Its dip is about 25° W., but both strike and dip vary considerably in short distances, forming anticlines and synclines. It also shows evidence in some places of having been thrust toward the east over underlying rocks.

BRANDON DISTRICT.

In 1903 and 1904 the town of Brandon, at the mouth of Mill Creek Canyon, was the center of the "Brandon district." The Toledo mine, which was then in operation, is about half a mile north of the town, in the foothills at the edge of the bench lands. The mine is opened by a shaft 400 feet deep and has been explored 300 feet deeper by a diamond drill. A crosscut at the 400-foot level runs west 280 feet to the vein, on which a drift runs north about 400 feet. The vein dips about 45° W. The ore consists of argentiferous galena with some auriferous pyrite and sphalerite. The property is equipped with a ditch and pipe line, which gives a fall of 300 feet with sufficient water to run the mill and supply electric lights for Sheridan. The country rocks belong to the Cherry Creek group and consist of limestone, quartzites, and schists cut by aplitic dikes.

RAMSHORN GULCH.

On Ramshorn Gulch the most important mine at present is the Bedford, near the head of the gulch, at an altitude of 7,800 feet. A crosscut is now (1910) being driven S. 80° E. through mica schist, garnet-quartz schist, and hornblende schist, whose banding strikes N. 70° E. and dips about 32° NW. Limestone on the ridge above the crosscut strikes about N. 15° E. and dips west. The strike and dip of the schists vary considerably; in places (for example, on top of the hill east of the tunnel) the schists are nearly parallel with the limestone. Granite cuts the schists, but the ores, instead of being along the granite contact, have a limestone footwall and a gneiss or hornblende schist hanging wall. The limestone here exposed is one of several beds which can be traced for considerable distances in the midst of the schists of the Cherry Creek group. The prevailing strike is about north and the dip is to the west. The ores carry lead and silver with gold, and the vein materials include galena, pyrite, chalcopyrite, bornite, quartz, hematite, limonite, siderite, talc or muscovite, and a little epidote.

Other claims across Ramshorn Gulch from the Bedford and to the southeast include the Betsy Baker and the Walker. The latter has ore along contacts of limestone with gneiss and schist; the former has a vein in schist which strikes about east, whereas the limestone strikes north and dips west. The vein is known for at least 100 feet away from the contact.

BIVIN GULCH.

On the ridge between Ramshorn and Bivin gulches there are at least two beds (or possibly one bed repeated by faulting) of limestone striking north and dipping about 45° W. at elevations between 7,000 and 9,000 feet above sea level. At lower elevations the ridge consists of schists cut by coarse quartz veins and pegmatites.

PRODUCTION.

The Sheridan district has yielded a regular production of metal annually since about 1865, and it may be expected to continue productive for many years to come. Unfortunately no statistics of production are now available for the years 1864 (when the Company mine, on Wisconsin Creek, was opened) to 1904. During a large part of this period the average annual production was probably several times as great as it has been in recent years. The statistics for the years 1905 to 1912, given below, have been compiled from the records of the United States Geological Survey.

Production of metals in the Sheridan district.[a]

Year.	Ore.	Gold.[b]		Silver.[b]		Copper.		Lead.		Total.
	Tons.	*Fine oz.*		*Fine oz.*		*Pounds.*		*Pounds.*		
1905	6,864	1,982.42	$40,980	10,358	$6,565	1,000	$156	78,944	$3,710	$51,412
1906	552	1,065.89	22,034	3,917	2,624	3,000	579	8,608	490	25,727
1907	73	189.48	3,917	902	595	....	....	6,106	324	4,836
1908	702	848.40	17,538	4,818	2,554	641	85	364	15	20,192
1909	421	707.82	14,632	2,975	1,547	1,069	139	2,128	92	16,409
1910	530	794.90	16,432	2,707	1,462	3,491	443	243	11	18,348
1911	1,055	872.20	18,030	4,343	2,302	4,077	510	19,785	890	21,732
1912	293	445.92	9,218	2,404	1,479	4,596	758	1,764	79	11,534
	10,490	6,907.03	142,781	32,424	19,128	17,874	2,670	117,942	5,611	170,190

[a] Includes the Wisconsin, Mill Creek, and Ramshorn districts.
[b] Includes small amounts of gold and silver obtained from placer mines in Ramshorn Gulch.

SILVER STAR DISTRICT.

LOCATION AND HISTORY.

The Silver Star district is one of the oldest quartz-mining districts in the State. It lies on the west side of Jefferson River about 50 miles above Threeforks. Even in the sixties the Green Campbell, the Iron Rod, and the Bowery (later named the Broadway) were well known. The Green Campbell was opened in 1867, and in 1870 was considered the most valuable quartz mine in the county. At that time it was equipped with a 10-stamp mill, with 4 Horn pans and 2 settlers. At the same time the Iron Rod ores were worked in the Stevens-Trivitt 12-stamp mill, and the gold was recovered by arrastres and blankets. In those days Silver Star was the only town between Virginia City and Helena.

In spite of many vicissitudes the district has been producing almos constantly. From 1883 to 1898 the nearest railroad point was Whitehall, about 18 miles to the northeast. Since 1898 there has been a station at Iron Rod, on the Jefferson Valley branch of the Northern Pacific Railway, only 4 miles from the town of Silver Star.

The mines of the Silver Star district formerly included several quartz and placer properties along Hell Canyon, but these mines have been idle for many years. The Broadway and Green Campbell mines are 2 to 3 miles west and the Iron Rod about 4 miles southwest of Silver Star.

GEOLOGY.

Situated on the southeastern slope of Table Mountain, just above the level of the Jefferson Valley, the Silver Star district is occupied by schists, slates, and quartzites, and by a small area of limestone, partly surrounded by a granitic intrusion. The schists, slates, and quartzites are apparently continuous in outcrop and identical in age with the schistose rocks of Table and Red mountains, which underlie Paleozoic limestones and are believed to be pre-Cambrian, either in whole or in part. The limestone of the area is not seen in direct contact with the schists, but the surface relations indicate that the two are separated by a fault. Lithologically, the limestone resembles beds elsewhere in the Dillon region that are known to be Cambrian, but, so far as known, it contains no fossils in the Silver Star district. The granitic intrusive rock has been traced continuously from Silver Star northward to Butte and is clearly a part of the Boulder batholith, the rock of which is commonly known as Butte granite, although its correct designation is quartz monzonite. On these premises the rocks of the district may be designated Butte quartz monzonite, Cambrian limestone, and pre-Cambrian schist, slate, and quartzite.

The schists include highly quartzose types, mica schists, hornblende schists, phyllites, and slates. In places the schists grade into gneisses, the lamination becoming coarser, more irregular, and less distinct. The limestone is usually bluish gray and, along its contact with the granite, is metamorphosed to garnet, epidote, and similar minerals. The quartz monzonite varies in places along its borders to diorite and similar basic types. It is cut by dikes of fine-grained rhyolite porphyry, which also penetrate the quartzite and the schists.

In several places, not adjoining the quartz monzonite area, the schists are cut by more basic intrusive rocks, such as basalts. The surface distribution of these rocks is shown in figure 10.

Quartz monzonite occupies the northern limits of the area and extends indefinitely northward. Limestone occupies a rudely palette-shaped area, about 1½ miles long north and south and about the same distance east and west, with Butte quartz monzonite on

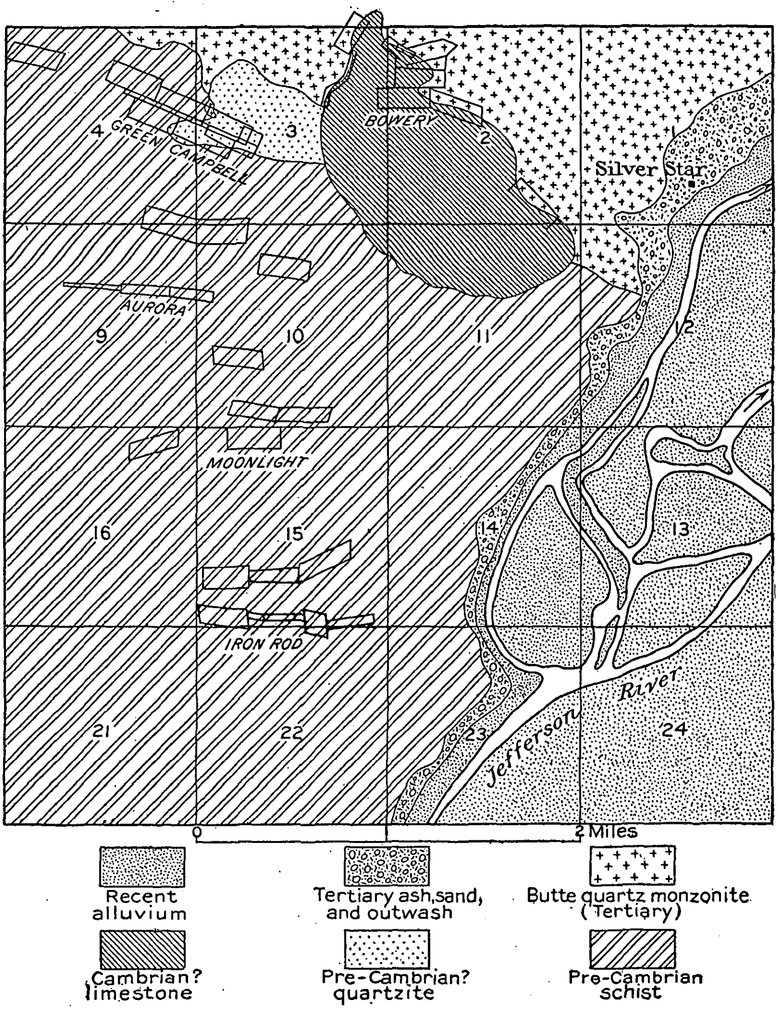


FIGURE 10.—Geologic sketch map of the Silver Star mining district, Mont.

the northwest, north, and east, and schists and quartzite on the south and southwest. One small area of quartzite lies west of the limestone, and more or less quartzite also occurs interbedded with the schists.

The schists dip about 45° S. The main mass of quartzite dips very gently east. The limestone forms a basin or trough, whose axis pitches south or southeast, the structure being apparent all along the northern edge of the limestone and in the mines. Thus at the Broadway mine the contact, which is nearly parallel with the bedding, dips 30° SW. for the first 500 feet on the incline and then straightens up to about 65° for the next 150 feet, beyond which development has not proceeded. At the Morning and Sample Orr claims, on the northwest side of the limestone area, the dip of the contact and of the bedding is very steep—nearly vertical—but tending southeast. Along the southern edge of the limestone the dip was not observed.

ORE DEPOSITS.

The most important constituent of the ores is gold, and there are minor amounts of silver, lead, and copper.

The gold in the oxidized ores is free and associated with quartz, limonite, siderite, and hematite, but in the unoxidized ores it is chiefly in pyrite, which occurs alone in quartz or with magnetite, bornite, serpentine, and galena. The silver is closely associated with gold or with lead. The copper is in malachite, azurite, and chrysocolla in the oxidized zone and chiefly in bornite in the sulphide zone. The lead occurs as cerusite with a little pyromorphite or vanadinite in the oxidized ores, and as galena in the sulphide ores.

The ore deposits of the Silver Star district are of two different types. The ores of the Broadway and neighboring mines, such as the Hudson, Delaware, Keystone, Ajax, and Fagan, are contact deposits between limestone and quartz monzonite. The ores of the Green Campbell and Iron Rod properties are in fissure veins which cut through a series of metamorphic rocks, chiefly schists. The ores of the first type form irregular shoots and bunches along the contact and in the limestone adjoining the contact. The ores of the second type are more regular in form, occupying well-defined fissure veins with high-grade ore in shoots. The oxidized ores of the Iron Rod mine have yielded small amounts of copper (as well as gold) in the form of malachite, mixed with smithsonite and quartz. The contact ore deposits contain oxide of iron (magnetite) as well as sulphides of the metals below the oxidized zone, but the fissure vein deposits contain no such association of oxides and sulphides. The contact ore deposits are further characterized by the presence of such minerals as garnet, epidote, siderite, asbestos, serpentine, and calcite in the gangue, whereas the gangue of the vein deposits is chiefly quartz, with some serpentine and chlorite.

A rather unusual feature of the vein deposits is the fact that, at least in the Iron Rod and Green Campbell properties, they dip and strike with the schistosity and approximately with the apparent bedding of the formation in which they occur. At the Green Campbell the vein is a slaty shale or serpentine lead having a quartzite footwall and a mica schist hanging wall. Apparently, after the formation of the fault fissure and the introduction of the ores by circulating waters, the original clay or gouge of the fault was partly recrystallized into chlorite and serpentine. That the deposit is not in an original clay seam of the sedimentary series appears from the fact that the course of the ore deposit both on the strike and on the dip is not everywhere parallel with the bedding.

The vein on the Green Campbell mine strikes nearly due east and dips 20°–40° S., the dip increasing to the westward. The country rock is in places a very micaceous schist, but as a rule it contains little or no mica, much quartz, and locally abundant hornblende. The quartz monzonite is in general below the schist, but the latter is cut by dikes of aplitic and lamprophyric types. Faults are abundant, and the Green Campbell vein lies apparently between two major faults. Oxidation extends to greater depths on the footwall than on the hanging wall; in places it extends to a depth of 400 feet on the incline, but this may be only about 100 feet vertically on account of flat dip and surface topography. In the sulphide ores the gold is associated closely with pyrite.

The vein on the Iron Rod mine strikes about N. 70° E. and dips about 50° S., the dip becoming somewhat steeper at a depth of about 150 feet. The vein follows rather closely the banding of the gneiss. It varies from a thin seam to a thickness of about 4 feet. Two other veins of less importance run nearly parallel with the main vein. The shaft is 700 feet deep on an incline of about 40°. The ore is more completely oxidized below the 500-foot level than it is between the 300 and 500 foot levels, but all the ore is notably oxidized. The ore has been treated by amalgamation and then concentrated, 12 to 14 into 1. About 66 per cent of the gold has been saved on the plates and 10 to 12 per cent more has been recovered from the concentrates.

The ore deposits of the Silver Star district occur in rocks which seem to be marginal remnants of the roof of the Boulder batholith. The main mass of this batholith lies north of Silver Star, but igneous activity, apparently from the same source, is important more or less continuously from Silver Star southwestward for at least 15 miles. It is evident that the ore deposits of the Broadway group are of contact origin and are due to the mineralizing effects of the igneous intrusion to the north. But the origin of the ores in the Green Campbell and similar properties is not so clear. They are located near an igneous contact, but they do not contain the minerals characteristic of contact deposits; on the contrary, they have the characteristics of deposits formed by circulating waters filling fissures. That the ores of the Green Campbell mine were not formed by solutions escaping from the magma of the neighboring batholith but existed before the batholith came into place is suggested by the indications that recrystallization, probably due to the metamorphosing effects of the batholith, has converted the fault clay of the fissure veins into serpentine and chlorite. It appears probable, therefore, that some of the ores of the Silver Star district date from the time of formation of the batholith and that others originated before, perhaps long before, that date. If this view is correct, the close geographic association of the two types of ore deposits is fortuitous.

The ore deposits of the Silver Star district are not exhausted. Mining has thus far penetrated only to shallow depths—vertically to about 350 feet on the Broadway, to less than 200 feet on the Green Campbell, to about 400 feet on the Iron Rod, and to similar or shallower depths on other mines in the district. Enrichment by the solution and reprecipitation of metals by downward-moving surface waters has undoubtedly increased the metallic contents of the surface ores, but has probably been more effective in the contact ores than in the veins, because the former are more pervious than the latter. The metallic contents below the zone of enrichment are therefore likely to fall off more rapidly in the ores of contact origin; which hitherto have been mined almost exclusively from the oxidized zone. It is a fact that augurs well for the future of the district that recent work in a relatively impervious portion of the contact zone on the Keystone claim has disclosed sulphide ores of sufficiently high grade to be profitable.

PRODUCTION.

Accurate records of the production of the Silver Star district in early years are not available, but detailed records of one mine (the Green Campbell) during certain years between 1867 and 1881 show a production of about $270,000, chiefly in gold. It is not known how much was produced by this mine in other years, nor how much has been produced by other mines, especially the Bowery, Iron Rod, and Hudson, to the year 1904. According to the Tenth Census [1] the production of the district for the year ending May 31, 1880, was 4,250 tons of ore, from which 1,946.10 fine ounces of gold, valued at $40,230, were recovered. During the nine years from 1904 to 1912, inclusive, statistics of the total production of the district have been published by the United States Geological Survey, as follows:

Production of metals in the Silver Star district.

Year.	Ore.	Gold.		Silver.		Copper.		Lead.		Total.
	Tons.	*Fine oz.*		*Fine oz.*		*Pounds.*		*Pounds.*		
1904	1,272	2,083.15	$43,062	768	$439	....	....	....	....	$43,501
1905	1,918	3,189.58	65,934	4,435	2,679	6,000	$936	83,330	$3,917	73,466
1906	1,919	1,668.11	34,482	2,847	1,909	22,733	4,387	123,925	7,063	47,841
1907	2,307	2,115.97	43,741	2,319	1,531	4,237	848	9,691	513	46,633
1908	1,049	1,620.13	33,491	2,660	1,410	2,038	269	13,004	546	35,716
1909	990	1,580.22	32,666	2,255	1,172	2,891	376	13,130	565	34,779
1910	601	1,112.09	22,989	1,211	654	6,261	795	4,298	189	24,627
1911	1,222	1,302.64	27,928	1,702	902	4,096	512	25,174	1,133	30,475
1912	2,891	1,272.17	26,298	1,012	622	1,859	307	2,554	115	27,343
	14,169	15,944.06	330,591	19,209	11,318	49,115	8,430	275,106	14,041	364,381

[1] Tenth Census, vol. 13, p. 338.

TIDAL WAVE DISTRICT.

LOCATION AND HISTORY.

The Tidal Wave district, one of the largest districts in the region, lies east of Twin Bridges, extending about 7 miles north and south and about 5 miles east and west. It is named from a mine on the ridge north of Dry Georgia Gulch, but includes half a dozen gulches from mouth to head along the western slope of the Tobacco Root Mountains. Its elevation ranges from less than 6,000 to more than 10,000 feet above sea level.

The district was prospected as early as 1864, but at that time little attention was paid to ores other than those carrying free gold. Within a decade, however, the importance of argentiferous lead ores was demonstrated at Argenta and later at Hecla and the mines of the district were rapidly located. The Tidal Wave and High Ridge mines were among the first to be developed. Nearly all the mining in the district has been carried on by owners or lessees operating on a small scale without large investments of capital.

The names of some of the gulches in this district are incorrectly given on the editions of the topographic map of the Dillon quadrangle issued by the United States Geological Survey in 1893 and 1909. The stream shown on that map as Coal Creek is Dry Boulder Creek; the next creek to the south is Coal Creek; the first gulch north of Spring Creek is Bear Gulch; and the stream shown as Bear Canyon Creek is Goodrich Creek. (See fig. 2, p. 13.)

GEOLOGY.

In a general way the west flank of the Tobacco Root Mountains as far south as Dry Georgia Gulch is occupied largely by Paleozoic limestones resting upon quartzites, schists, and gneisses, with some interbedded layers of crystalline limestone. In part of the central region, west of Jefferson Peak, the underlying siliceous rocks are replaced by granitic rocks similar in type to the Butte quartz monzonite or "granite." It seems quite possible that this granitic intrusion is of the same age and source as the Boulder batholith. Though referred to in places in this report as "granite," it is probably really a quartz monzonite with local dioritic phases.

The rocks underlying the Paleozoic limestones were mapped as Archean in the Threeforks folio, but the presence of interbedded quartzites and limestones makes this correlation improbable. On the other hand, they correspond well with the beds described by Peale as the Cherry Creek and assigned by him to the Algonkian and they will be provisionally classified as Cherry Creek in this report. It is possible that the Archean occurs beneath them in some places, but its existence there has not yet been established.

ORE DEPOSITS.

The ore deposits of the Tidal Wave district are of three types. The first type is confined to the region along Bear Gulch, where granitic intrusives come in contact with limestone and produce typical contact deposits containing copper and lead and subordinate gold and silver. The second type occurs at the head of Bear Gulch, and perhaps to some extent in other gulches of the district, in vein deposits in gneiss or schists or, more rarely, in "granite," all closely associated with intrusions of "granite" or of differentiation products from the granitic magma, such as aplite. The veins carry chiefly gold, with some lead, silver, and copper. The third type is found on Dry and Wet Georgia creeks and on Goodrich Gulch, in vein deposits in gneiss or schists, in many places closely associated with igneous intrusions, apparently unrelated to the granitic magna and of much earlier date. Ore deposits of the first type are clearly due to the mineralizing action of gases and liquids escaping from the great magma now consolidated to the granitic intrusive mass extending from Bear Gulch across the Tobacco Root Mountains to the vicinity of Norris, Mont. Ore deposits of the second type were probably due to mineralization produced in more siliceous country rock by the same agencies. Ore deposits of the third type were probably due, at least in part, to mineralization from other intrusive igneous bodies perhaps even before the deposition of the Paleozoic limestone, in the post-Cherry Creek erosion interval.

PRODUCTION.

No statistics of production during the earlier years of mining in the Tidal Wave district are available, but it is probable that the production during the latter part of the nineteenth century was frequently greater than the average annual production during the period (1904–1912) for which records are available. The records of the United States Geological Survey show the production from 1904 to 1912.

Production of metals in the Tidal Wave district.

Year.	Ore.	Gold.		Silver.		Copper.		Lead.		Total.
	Tons.	*Fine oz.*		*Fine oz.*		*Pounds.*		*Pounds.*		
1904	21	39.67	$820	140	$80	....	....	8,000	$160	$1,060
1905	114	752.92	15,564	17,742	10,823	309	$48	59,485	2,691	29,126
1906	178	234.34	4,844	4,775	3,199	3,766	727	68,066	3,879	12,649
1907	184	370.17	7,652	2,026	1,337	....	....	55,636	2,949	11,938
1908	1,454	577.35	11,935	6,866	3,639	3,935	520	144,689	6,077	22,171
1909	468	754.44	15,596	10,056	5,229	882	115	155,942	6,705	27,645
1910	677	746.09	15,423	7,459	4,028	2,307	293	118,551	5,216	24,960
1911	400	596.70	12,335	6,415	3,400	2,205	275	146,802	6,606	22,616
1912	242	379.26	7,840	2,600	1,599	3,673	606	42,573	1,916	11,961
	3,738	4,450.94	92,009	58,179	33,334	17,077	2,594	799,744	36,199	164,126

The ore deposits and geologic features of the Tidal Wave district are not sufficiently uniform to render further general description useful. Numerous facts of interest, however, are brought out in the following descriptions of the several gulches:

DRY BOULDER CREEK.

Dry Boulder Creek occupies the northern part of the Tidal Wave district, its mouth being about 8 miles northeast of Twin Bridges and about 5 miles nearly due east of Iron Rod. Its waters maintain their identity in a surface channel for about three-fourths of the distance across the sands and gravels of the bench lands on their way from the Tobacco Root Mountains to Jefferson River.

The western slope of the Tobacco Root Mountains at Dry Boulder Creek is occupied by upturned Paleozoic limestones and some interbedded shales, and the central portion of the mountains is occupied by "granite" and gneiss. In general the line of contact between "granite" and limestone runs north and south, but in detail it is very irregular, and may be complicated by the presence of minor igneous intrusions.

Numerous deposits of ore lie along this contact. Some fill fissures in the "granite," but most of them are irregular bunches and chimneys in the limestone adjoining the "granite." Some ore bodies are associated with faults, but there is no evidence of extensive movement either in or across the ore deposits.

The writer did not visit the Copper Queen group of claims, but according to R. H. Sales, chief geologist for the Anaconda Copper Mining Co., copper ores occur there in irregular contact deposits in limestone, the chief ore minerals being malachite and azurite, with possibly some black oxide of copper. The ore is evidently a replacement of limestone along the contact and increases in quantity from the bottom to the top of the raise from the middle tunnel. A vein in "granite" is filled with iron oxides and some quartz and a few specks of iron pyrites. The veins and contact deposits have been extensively leached, but the existence of commercially important enriched ore deposits, due to precipitation below the zone of leaching, has not yet been established.

BEAR GULCH.

LOCATION.

Bear Gulch is in the northern part of the Tidal Wave district, the mouth of the gulch being about 7 miles northeast of Twin Bridges, and about 5 miles east-southeast of Iron Rod. Its waters flow rapidly, but within less than 2 miles from the mouth of the gulch they lose themselves in the sand and gravel of the Jefferson Valley.

GEOLOGY.

An interesting succession of rocks is to be found in Bear Gulch. At its mouth Paleozoic limestone striking north and dipping steeply west is cut by the westward-flowing creek. Less than half a mile up the canyon the limestone gives place to an intrusive granitic rock, which has invaded the limestone partly as sills and partly by breaking across the bedding. The ores are in close association with this intrusive, both as typical contact deposits and as fissure veins, which are usually farther from the contacts but which presumably extend downward to the granitic mass, whence their filling was probably at least in part derived. At the contact with the igneous rock the limestone is converted into lime-silicate rock containing garnet, epidote, zoisite, titanite, and diopside. A pale-green resistant rock lying along one contact consists chiefly of fine-grained granular diopside. The corundum which occurs on the Atlantic claim on the ridge between Bear Gulch and Coal Creek must have been produced by the contact metamorphism of a highly aluminous bed in the limestone, for it forms a band about a foot wide with garnet-epidote rock above and below it. A short distance farther up the gulch wholly or nearly isolated beds of limestone, approximately parallel and showing contact zones on their upper and lower surfaces, occur in the "granite." The approximately vertical walls of the canyon expose these relations to a depth of more than 1,000 feet, and show that some of the beds of limestone are cut off by "granite" on the dip, and that others extend below the creek level. The section as followed upstream shows repeated alternations of "granite" and limestone to a point where a bed of limestone rests on shaly sandstone grading downward into pure sandstone. Below this the "granite" occurs again, metamorphosing the sandstone much less than it does the limestone, though indurating it along the contact into a compact quartzite, which usually contains more or less orthoclase and muscovite. Farther east, up the gulch, limestone occurs again, underlain by quartzite which overlies gneiss, irregularly cut by "granite" masses. (See figs. 11 and 12.) The granitic intrusive here penetrates gneiss, quartzite, and limestone. Associated with the granite are some dikes of aplite and pegmatite.

PETROGRAPHY.

The "granite" is not uniform in composition but is spotted by patches of darker color, which are sometimes explained as due to segregation or differentiation in the magma before or during crystallization. In Bear Gulch no evidence of any such differentiation could be found. On the contrary, the patches themselves furnish evidence of a different origin. They consist largely of hornblende and plagioclase with subordinate titanite, apatite, and calcite.

Some of them have on their borders epidote and zoisite, and in places the epidote seems to have formed at the expense of biotite.

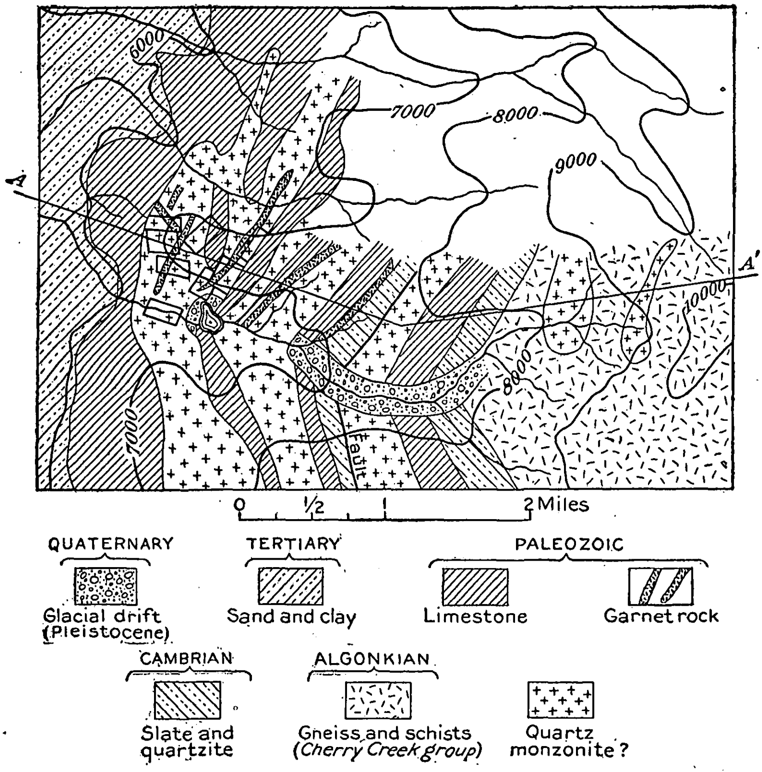


FIGURE 11.—Geologic sketch map of Bear Gulch in the Tidal Wave mining district, Mont.

Calcareous minerals are thus especially abundant. In other spots quartz and feldspar are unusually plentiful. Finally, some spots

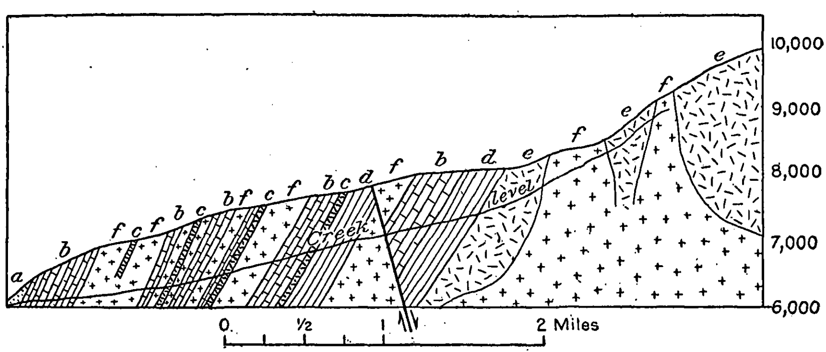
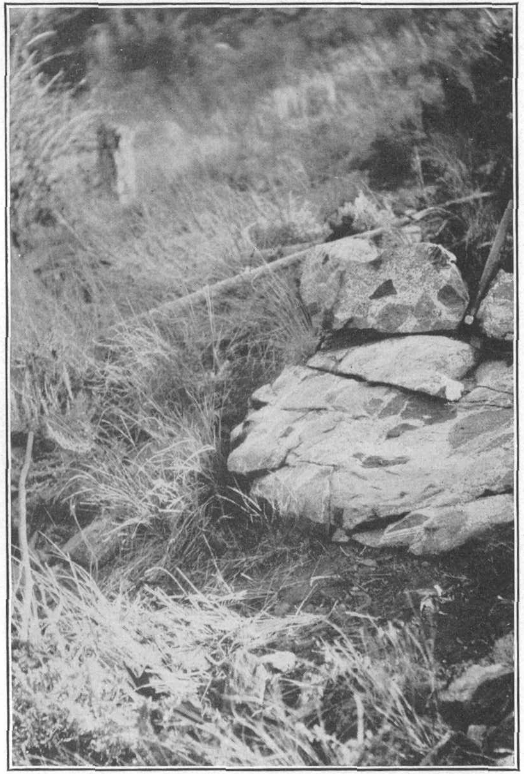


FIGURE 12.—Geologic vertical section of Bear Gulch in the Tidal Wave mining district. *a*, Sand and clay (Tertiary); *b*, limestones (Paleozoic); *c*, garnet rock (Paleozoic); *d*, slate and quartzite (Cambrian); *e*, gneiss and schist (Cherry Creek group, Algonkian); *f*, quartz monzonite (?).

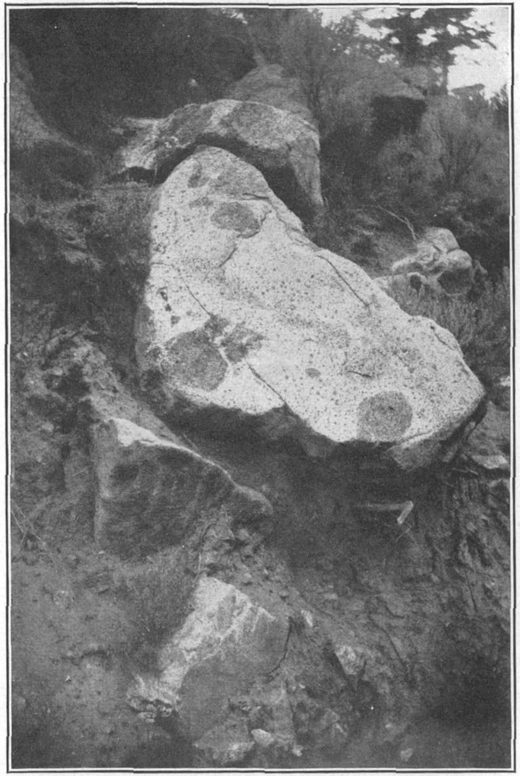
are clearly banded. Spots of the first type are found most abundantly near the limestone contacts, those of the second type near the quartzite contact, and those of the third type near the "granite" and gneiss contact. The first and second types occur in the lower (western) end of the gulch and the third type is confined chiefly to the upper (eastern) end. In a few places the various types are mingled in a single mass of "granite." Both from their composition and mode of occurrence, it seems probable that these spots in the "granite" are not differentiation products, but represent the incompletely absorbed fragments of the country rock. All stages in the process of assimilation are visible; in some spots the fragments or xenoliths are sharply angular (Pl. VI, *A*), in others the gneissoid or schistose structure of the included rock is still visible (Pl. VII, *B*), and in still others the angular outlines and the structure are more obscured or are obliterated entirely (Pls. VI, *B*, and VII, *A*) and the difference in composition between the xenolith and the inclosing "granite" is slight.

In the upper canyon of Bighole River, between Divide and Dewey, in Beaverhead County, similar xenoliths occur in an igneous rock, which is probably the quartz monzonite of the Boulder batholith. In this locality the xenoliths are wonderfully abundant; within 3 miles east of Dewey there are thousands of them of all sizes, some being as large as a small house. (See Pls. VI to VIII.)

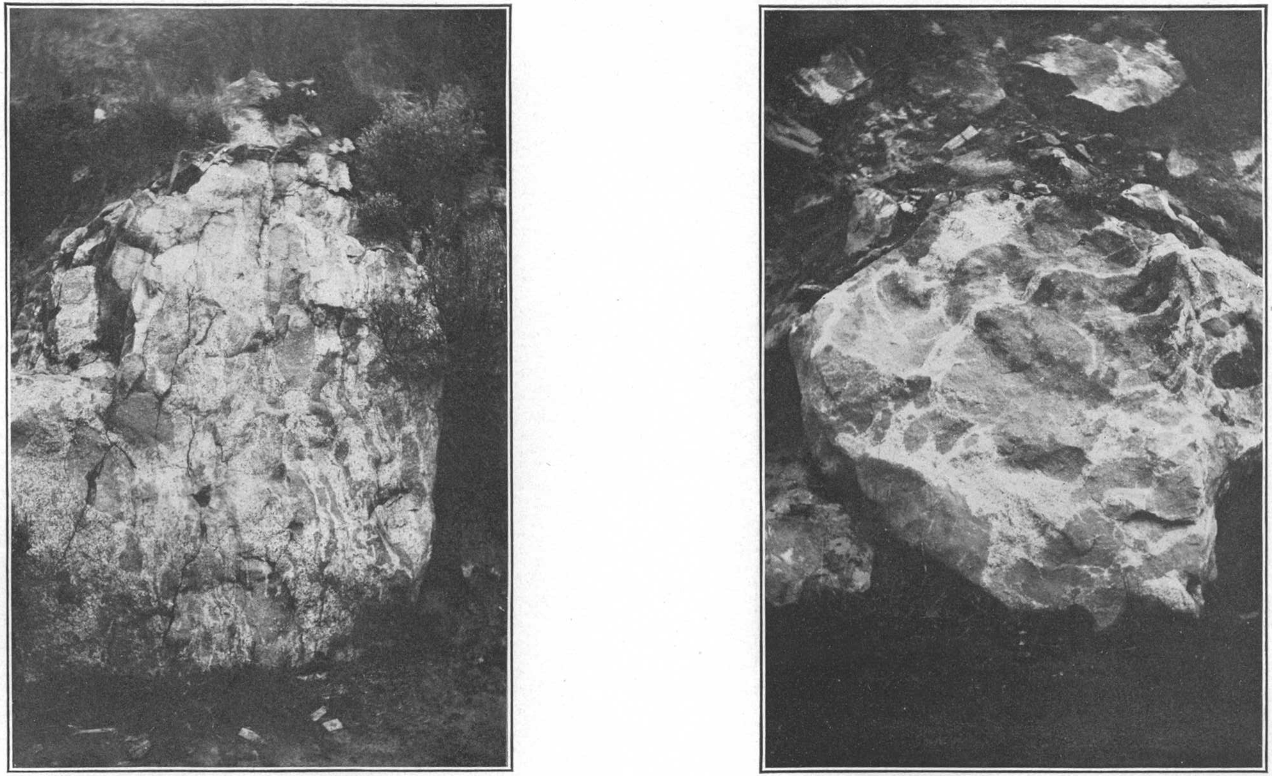
It is believed that the facts stated indicate that these spots are not differentiation products, but are the remains of foreign rocks incompletely assimilated by the intruding "granite." It seems that the fragments of adjoining rocks which become inclosed in the "granite" are gradually absorbed by it. If heat and time are insufficient the fragment may be very little modified, especially if it was originally siliceous. Such a fragment is easily recognized as a xenolith, especially if the schistose structure is present. If the fragment was originally limestone and was small, heat and time appear to have been invariably sufficient to expel the carbonic acid completely and to produce silicates of lime. With more heat and longer time the fragments lose their original outlines, and doubtless the constituents of the magma become diffused into the xenolith, and those of the xenolith into the magma. Thus the chemical composition of the two tends to become the same. But as the chemical composition becomes more alike the process of diffusion becomes less active. If the xenolith is completely dissolved diffusion appears to be able so to equalize the composition that the absorption of foreign material produces no perceptible effect on the color or texture. If the xenolith is only partly dissolved diffusion may considerably reduce the differences in composition between the xenolith and the inclosing magma. At any particular place diffusion begins to modify the composition before solution occurs, but uniformity of composition is rarely, if ever, attained through the operation of diffusion



A. XENOLITHS OF GNEISS, SLATE, ETC., IN "GRANITE," BEAR GULCH, MADISON COUNTY, MONT.



B. XENOLITHS IN "GRANITE," BIGHOLE CANYON ABOUT 3 MILES EAST OF DEWEY, BEAVERHEAD COUNTY, MONT.



A. *B.*

XENOLITHS IN "GRANITE," BIGHOLE CANYON ABOUT 3 MILES EAST OF DEWEY, BEAVERHEAD COUNTY, MONT.

A shows plasticity (?).

alone. On the other hand, approximate uniformity of composition through small volumes is reached rather easily by diffusion when solution-fusion also occurs.

Benedicks and Tenow[1] have recently published an interesting description, with photographic illustrations, of assimilation textures, some of them orbicular, produced by partial fusion of suitably prepared mixtures of graphite or other material in paraffin.

GLACIATION.

A glacier extended down Bear Gulch to a point about a mile above the mouth, where a small terminal moraine crosses the gulch and produces a small lake. This lake has the peculiarity of filling in the spring to a certain height, at which it begins rather suddenly to discharge through the moraine. By autumn the lake is small, or wholly dry.

Instead of the ordinary rounded and considerably mixed bowlders and sand the morainic material in Bear Gulch consists of bowlders practically free from sand, in places very uniform in composition, and remarkably angular in shape. That the bowlders are morainic and were not deposited by a landslide is indicated by the surroundings, there being no probable local source for the material, and also by the occurrence of similar and more typical morainic bowlders for a distance of 3 to 4 miles up the gulch, which heads in several small glacial cirques of normal type.

The peculiar characteristics of the terminal moraine are probably due to special conditions existing in the gulch during the period of glaciation. It seems probable that the terminal moraine consists of material that was carried by the glacial ice exclusively on its upper surface, probably for the most part from the walls of cirques about 3 miles east of the moraine, which are composed largely of the same materials. Detritus which sank to the base of the glacier or far enough into it to undergo considerable wear and rounding probably did not reach the terminal moraine but was deposited farther up the gulch.

It is believed that conditions which would favor the transportation of material on the upper surface of the glacier existed in this region during glaciation. It is evident that these conditions are (1) an abundant supply of material falling upon the glacier from inclosing rock walls, (2) a snowfall so deficient that such superglacial material would not be covered with névé or ice, and (3) a valley steep enough to cause rather rapid glacial movement in spite of the deficiency in the supply of ice.

The present state of the walls of the small glacial cirques at the head of Bear Gulch shows that an abundant supply of material

[1] Benedicks, C., and Tenow, O., Geol. Fören. Förhandl., vol. 33, p. 105, 1911.

must have fallen upon the glacier from the inclosing rock walls. A similar cirque at the head of Mill Creek about 10 miles southeast of the head of Bear Gulch (see Pl. V, p. 136) contains abundant talus accumulated since glacial time.

That the snowfall was light in this region during glacial time is indicated, first, by the fact that rainfall is deficient in the region and there is no evidence of a change in precipitation, and, second, by the fact that although local glaciers were abundant throughout southwestern Montana, none of them extended far from the mountainous centers of accumulation. Many of them, in fact, like the one in Bear Gulch, did not even emerge from the mountainous region into the valleys.

The Bear Gulch valley has a total fall of 2,000 feet in 3 miles—nearly 700 feet to the mile, or about 12 per cent—a fall sufficient to facilitate rapid movement of the glacier in spite of deficient snowfall.

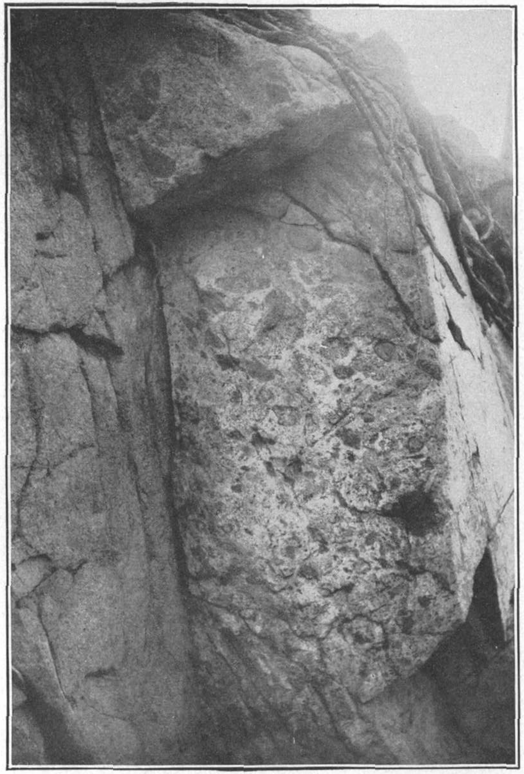
ORE DEPOSITS.

In the lower (western) end of Bear Gulch the ore deposits are chiefly of the contact type and occur in limestone near "granite" intrusions. They are characterized by the presence of epidote, garnet, diopside, zoisite, titanite, and hornblende in the metamorphosed zone, and by magnetite, hematite, cuprite, melaconite, native copper, malachite, azurite, chrysocolla, chalcopyrite, bornite, pyrite, and, rarely, films of chalcocite in the ores. Aside from minerals that are the result of weathering the others contained in the primary ore show the characteristic association of oxides and sulphides illustrated by the presence of magnetite with pyrite.

Along the same contact in the next gulch to the north, locally known as Coal Creek, the ores are chiefly argentiferous galena with practically no copper.

The most development work in this part of Bear Gulch has been done on the Johnston-Moffet group of claims, about 8 miles from Twin Bridges. These claims are from 6,000 to 7,000 feet above sea level and extend from the gulch over the ridge to the north. The limestone has been changed to garnet, epidote, and other calcium and magnesium-aluminum silicates for a distance of 300 or 400 feet from the "granite." Since the first deposition of these ores surface waters have produced oxides and carbonates. The most important ores of this type include some bodies of malachite, with subordinate azurite, cuprite, melaconite, chrysocolla, and native copper. But, probably owing to the small rainfall, oxidation has not penetrated deeply and below 100 feet from the surface the rocks become rapidly harder.

The principal shaft, an incline on the contact, is in the northeast corner of the Mountain View claim. For the first 100 feet the ore



A.

B.

XENOLITHS IN "GRANITE," BIGHOLE CANYON ABOUT 3 MILES EAST OF DEWEY, BEAVERHEAD COUNTY, MONT.

body resembles a vein in shape and continuity. Below this for 25 feet or more is black shaly material formed from altered limestone. At a depth of 125 to 150 feet chalcopyrite and pyrite appear in small particles and streaks and in some solid lenses. The 200-foot level about 150 or 160 feet vertically below the surface, is developed by crosscut with east-west drifts on ore streaks. No large bodies of sulphide ore have yet been found. The principal mine opening in this part of Bear Gulch is an adit about 2,400 feet long, which enters the south side of the ridge north of Bear Gulch not far above the creek and extends to a point below another tunnel (called the Moffet tunnel) on the north side of the ridge. The long tunnel penetrates "granite" for about 1,400 feet and then passes into limestone. There is no ore at the contact, but some chalcopyrite and bornite, with a little chalcocite, which may represent the beginning of enrichment, was found below the Moffet tunnel. This ore occurs from 160 to 170 feet south of the face of the tunnel, which appears to be approaching another contact, the limestone probably being inclosed by "granite."

The rocks in this tunnel are hard and unoxidized except near the face, where there is a little oxidized ore containing malachite and native copper associated with pyrite and magnetite in garnet rock.

The Moffet adit starts in "granite" on the Quincy claim and runs southward for about 230 feet to the north contact of the limestone with "granite." At the contact a drift has been run about 100 feet to hard limestone and garnet rock through copper ore, consisting of a mixture of oxides and sulphides, which seems to have been rearranged and rudely banded by the action of surface waters. At other points near the surface on this group of claims small bodies of high-grade oxidized copper ores have been found, but so far as known no large bodies of profitable ore have been uncovered.

North of Bear Gulch, about 2 miles east of the Johnston-Moffet property, limestone occupies the summit of Smelter Hill, so called from an old smelter near its base. This limestone is partly inclosed and apparently underlain by "granite." Along the contact occur lead ores, consisting chiefly of argentiferous galena. The mines and smelter are abandoned.

A cyanide plant which was built at the mouth of Little Bear Gulch (the main tributary of Bear Gulch from the south) for the purpose of treating gold ores occurring on that gulch was closed in the fall of 1909 after running about six months.

At the head of Bear Gulch the "granite" is in contact with gneiss, schists, and black slate. In this region the ores occur in well-defined veins, and, like the contact deposits, are with little doubt genetically connected with the granitic intrusion. Their different character is probably due to the difference in the country rock. When "granite" intrudes limestone the escaping ore-bearing solutions penetrate the limestone irregularly and produce ore bodies of correspondingly irregular form. On the other hand, when "granite" invades quartzite, gneiss, schists, or similar rocks, the escaping solutions are forced to follow fissures, fault planes, or similar openings. Limestone may be more porous before the intrusion than the other intruded rocks, and, whether it is or not, the heat of intrusion may drive off its carbon dioxide, rendering it more porous and giving it an affinity for silica and water. The effect of heat upon other intruded rocks is commonly to make them less porous. Furthermore, limestone is much more soluble than most rocks. Thus, ores from a common source may form contact deposits in limestone and vein deposits in siliceous rocks.

Near the surface the veins at the head of Bear Gulch have undergone some oxidation and concentration, but some unaltered sulphide ore usually remains, and this may even extend to the surface. The veins occur in "granite," in gneiss, or along the contact between the two. Thus, in the Pritchett mine, at an elevation of about 9,000 feet, a crosscut penetrates "granite" for about 200 feet southward to dikes of aplite and fault veins, which strike northeast and dip steeply southeast. The ore shoot, which is near a contact of "granite" with slate or fine-grained black gneiss, pitches about 75°. One shoot, which carries pyrite and galena, considerable gold, and some silver, has been mined from the tunnel level to the surface. Extremely little oxidation is apparent, though water is now going through rather abundantly. The mine has a 5-stamp mill with a plate and a Wilfley table. The high-grade ore and concentrates are sacked and hauled by wagon to Twin Bridges, whence they go by rail to one of the smelters of the region.

The Royal Bear, Aurora, and Peter claims adjoin the Pritchett property on the south, on the other side of a spur between two glacial cirques. Several tunnels, which run very irregularly northward along stringers of pyrite and galena in "granite" near the contact with gneiss, have found pockets of high-grade gold ore but no large ore bodies. These workings reach an important fault, striking about east and dipping about 80° S., which shows 5 to 8 feet of gouge but no ore. In this mine the pyrite is said to carry \$300 to \$400 and the galena about \$20 in gold to the ton, with very little silver. Sulphide ores extend to the surface, where they are mixed with a little cerusite. They include a little chalcopyrite and sphalerite, but the important constituent is the auriferous pyrite.

On the Blue Jay and Jay Gould claims, to the west, two kinds of ore occur. One consists of chalcopyrite, tetrahedrite, and bornite, with auriferous pyrite in a gangue of quartz, barite, siderite, and calcite. The other consists of auriferous pyrite without copper minerals. The first kind of ore has been enriched in both gold and copper to a depth of about 75 feet. The second kind has not been much modified by weathering, though it contains a little free gold in the shallow oxidized zone. The vein strikes about east and west and dips about 20° N. It varies from 1 to 2 feet in thickness.

GOODRICH GULCH.

GEOLOGY.

Goodrich Gulch opens into the Jefferson Valley about 5 miles east-northeast of Twin Bridges. Near its mouth the creek has taken advantage of faults in cutting across the Paleozoic limestone flank of the Tobacco Root Mountains. To the north a hard dark-blue limestone dips about 20° W., and to the south yellow to gray limestones dip 35° S. to SW. A short distance above its mouth the course of the gulch is offset nearly a mile to the north, probably by another fault. In going up the gulch one crosses the geologic formations in descending order. Beneath the limestones lie shales, quartzite, and gneiss. Near the head of the gulch these formations are underlain and cut by intrusive "granite" of the same type as that so abundant along Bear Gulch. Associated with the "granite" are broad aplitic dikes, consisting of a fine-grained matrix of quartz and orthoclase containing a few phenocrysts of orthoclase, which are commonly altered to sericite, kaolinite, quartz, hematite, chlorite, and titanite. The matrix in places shows a eutectic intergrowth of quartz and orthoclase. These dikes occur on the divides between Goodrich Gulch, Little Bear Gulch, and a tributary of Wisconsin Creek. One dike, running northwest and southeast, is 600 to 800 feet wide; another, extending northeast and southwest, is about 1,000 feet wide.

ORE DEPOSITS.

The Schmidt property is located at the extreme head of Goodrich Gulch, some of the workings being about 1,000 feet above running water. About 800 feet below the divide at the head of the gulch a vein, opened by a tunnel cutting shale for about 120 feet, dips about 70° E., increasing to 80° at the face of the tunnel. The ores are oxidized and are rich in gold, but the underlying sulphides are of low grade.

Although the important constituent is gold, cerusite, malachite, cuprite, chrysocolla, bornite, chalcopyrite, pyrite, and sphalerite are also present.

On the Red Bell claim, about half a mile below Schmidt's camp, is a tunnel penetrating gneiss for about 350 feet. About 150 feet from the mouth it cuts ore in a zone of crushed ground, with much talc running in all directions. The ore here is auriferous pyrite and argentiferous galena with a little sphalerite.

About 2 miles below the head of Goodrich Gulch is a group of claims, the Carolina, Topeka, Little Goldie, and Nettie, which are being worked more or less regularly by lessees. They are on the south side of the creek well up on the ridge between Goodrich and Georgia gulches. The Carolina, which is about 800 feet above the creek and 7,700 feet above sea level, has a vein striking N. 30° W. and dipping 32° SW. The ore is chiefly auriferous pyrite. The mine is opened by an inclined shaft 125 feet deep and a tunnel about 760 feet long. The tunnel cuts at least two veins, one striking N. 25° E. and dipping about 30° NW. and the other striking about north and dipping about 60° E. The latter is cut about 400 feet and the former about 700 feet from the mouth of the tunnel. These veins cut slate and quartzite underlying Paleozoic limestone of either Cambrian or pre-Cambrian age. At this place the apparent thickness of the slate and quartzite is about 200 feet. It is underlain by gneiss, apparently belonging to the Cherry Creek group. The ore deposits are in the upper part of the slate and quartzite series near the base of the overlying limestone.

DRY AND WET GEORGIA GULCHES.

LOCATION.

Two gulches 4 and 5 miles nearly due east of Twin Bridges are known as Dry Georgia and Wet Georgia, respectively. Their waters flow southwestward from the westernmost part of the Tobacco Root Mountains. Even in the wet season the water in Dry Georgia Gulch is so scanty that it sinks into the sands and disappears completely within a mile or two of the mountains.

Mining has been carried on in the vicinity from the early days of quartz mining in the territory. The Tidal Wave mine, on the ridge between Dry Georgia and Goodrich gulches, was known in the sixties. The High Ridge mine, on the southwestward face of the mountains between Dry Georgia and Wet Georgia gulches, was operated by Dahler & Elling early in the eighties, and for the last 20 years has been worked more or less continuously by lessees.

GEOLOGY.

The westward-dipping Paleozoic limestones forming the western flank of the Tobacco Root Mountains may be followed southward along their strike from the steep cliff near Renova to Dry Georgia Gulch, where they disappear. The same Paleozoic limestones form the western flank of the Ruby Range, and it is possible that the two areas of limestone are continuous beneath the gravels of the Passamari Valley. But the surface distribution indicates the probability of faulting in this valley, and the continuity of the limestones is uncertain. In the region of the Georgia gulches the limestone rests in general upon schists and gneiss, which contain some beds of limestone and quartzite and which probably belong to the Cherry Creek group. These underlying beds are considerably metamorphosed and are cut by dikes of andesite and aplite. On the Buckeye group of claims in Dry Georgia Gulch the surface of the schists and gneiss immediately below the limestone seems to be considerably weathered, and the great difference in the degree of metamorphism exhibited by the underlying schists and gneiss and the overlying limestones is further evidence of an unconformity at this point. The meager evidence obtained concerning the strike and dip of the schists points to the same conclusion.

ORE DEPOSITS.

The ore deposits of the two Georgia gulches are chiefly in veins cutting the schists and gneiss of the Cherry Creek group. They are in general closely associated with dikes or sills of various types of intrusive rocks, chiefly aplite and andesite. There seem to be at least two sets of veins in this region. One set carries gold as its most important constituent with important amounts of silver and some lead. The other set carries silver and lead as the chief metals, with minor quantities of gold.

In the region of the Georgia gulches enrichment extends to a much greater depth than it does in the Bear Gulch area (p. 152), and it seems possible that this is due to the greater age of the ore deposits of the Georgia gulches. If these deposits existed in the schists and gneisses of the Cherry Creek group before the deposition of the Paleozoic limestones, enrichment may have occurred chiefly during the erosion interval represented by the unconformity above the Cherry Creek group. It is entirely in harmony with this view that the veins of the Georgia gulches nowhere extend upward into the Paleozoic limestone, although in places they extend practically to the base of the limestone.

In the Buckeye group of claims on Dry Georgia Gulch gold ore occurs in gneiss just below the contact with the overlying limestone. The ore, so far as opened by a shaft 200 feet deep and an incline 600 feet long, reaching a depth of about 300 feet, is all oxidized. The gneiss is much folded and faulted.

The High Ridge mine, on the mountain side between Dry and Wet Georgia gulches, is in gneiss about 400 feet below the limestone. The ore carries chiefly silver and lead, with some gold. The vein dips about 20° NE.

The Democrat mine, which adjoins the High Ridge on the southwest down the slope, shows oxidized gold ore in a quartz vein in gneiss. Tunnels run in 200 to 400 feet without reaching sulphide ore.

The Empire and Bay State properties on Wet Georgia Gulch are in gneiss about 500 feet below the limestone.

The Keynote mine is in gneiss 1,000 to 1,200 feet below the limestone. One vein which strikes about east and dips about 75° S. is closely associated with a pegmatite dike rich in orthoclase. It carries chiefly gold and silver. Another vein which strikes about north and has a flat dip, first to the west and then to the east, carries chiefly lead and silver, with some gold.

The Ella mine, on Wet Georgia Gulch, is in gneiss about 500 feet below the limestone. An andesite dike about 100 feet wide strikes northeast and dips about 30° NW. The quartz vein dips about 10° N. and carries chiefly lead and silver, with some gold. Oxidation on this vein is less advanced than elsewhere, and some sulphides (galena and pyrite) occur even to the surface, but they are mixed with oxidized ores (cerusite and iron-stained quartz) at all depths opened.

The Argenta mine, which is nearly on the divide between the head of Wet Georgia and Goodrich gulches, is in gneiss just below the limestone. The ore is auriferous pyrite and galena in a quartz vein along the footwall of an aplite dike, as seen in the main tunnel. The dike strikes about north and dips about 15° W. The limestone on the ridge at the head of the gulch strikes nearly east and dips north.

On the Buckeye group, in Dry Georgia Gulch, a vein of oxidized manganese ore (pyrolusite) lies parallel with the banding in gneiss and locally attains a thickness of 10 feet. This manganese ore, so far as exposed, is not in the same veins as the gold ore, but is so closely associated with them that it may have played an important part in the process of concentration. It has been shown by Emmons [1] that manganese is important in the concentration of gold, not only in causing the solution of gold by producing nascent chlorine, but also in preventing the reprecipitation of gold by keeping sulphated iron in the ferrous state. In harmony with this view is the fact that placers have never been commercially important in Dry Georgia Gulch, though they have been actively worked in many other gulches of the southwestern slope of the Tobacco Root Mountains. The veins have not yet been opened to sufficient depth to determine whether the gold is notably concentrated, but the conditions seem to be favorable for concentration.

VIRGINIA CITY DISTRICT.

LOCATION.

Virginia City is situated near the upper end of Alder Gulch, in the central part of Madison County, at an altitude of about 6,000 feet, in a gulch which cuts deep into the heart of the Tobacco Root Mountains. The nearest railroad station is about 9 miles west, at Alder, the terminus of the Ruby branch of the Northern Pacific Railway. Alder Creek rises along the northern base of Old Baldy Mountain, flows north about

[1] Emmons, W. H., Am. Inst. Min. Eng. Bull. 46, pp. 768-831, 1910; Jour. Geology, vol. 19, pp. 15-46, 1911.

7 miles to Virginia City, and thence northwest and west about 10 miles to Passamari River at Laurin. The lower portion of Alder Gulch is in the Dillon quadrangle, and the extensive dredging now (1910) in progress there is described in connection with the Alder Gulch district. (See pp. 59–61.) The portion west and south of Junction, at the mouth of Granite Creek, is in the Threeforks quadrangle and is described below, attention being directed to the quartz mines rather than to placers.

The Virginia City district, as the name is here used, includes six mining districts on Alder Gulch, once fully organized, and two districts, Browns Gulch and Granite Creek, on tributaries of Alder Creek. The Fairweather district is at Virginia City, the Highland district is about 2 miles farther up the gulch, the Pinegrove district is next above, and the Summit district includes the small settlement of the same name about 6 miles south of Virginia City. West of the city and down the gulch the Nevada and Junction districts are located about former towns of the same names. All these districts were originally organized by placer miners, but all include within their limits numerous quartz mines.

HISTORY.

Gold was discovered in Alder Gulch in 1863, and within a year auriferous quartz veins were discovered and their development begun. As early as 1866 mills were erected at Summit to treat quartzose ores from the deep mines, and by 1871 there were at least eight mills in different parts of the Virginia City district. In 1870 the Oro Cache mine was the most important producer in the Summit district, and the Kearsarge, Keystone, Nelson, Polar Star, and Excelsior were known. In Browns Gulch the Pacific mine was found to contain antimonial sulphide silver ores and some gold. The Easton mine, in the same gulch, was reported in 1873 to contain silver ore with about 1 ounce of gold to 30 or 40 ounces of silver. In 1876 the Oro Cache was the only mine in operation in the Summit district. In 1881 the past production of the Oro Cache and the Kearsarge in the Summit district was estimated at $500,000 and $150,000, respectively, by the Director of the Mint. In 1897 the Kennett mine was in active operation, and a 60-stamp mill was installed. During 1902–1904 there was renewed activity at the Kearsarge. During recent years most of the mining of quartz veins in the Virginia City district except at the Easton-Pacific mine has been confined to work above water level and has been carried on by lessees and others operating on a small scale.

GEOLOGY.

The Virginia City district is occupied by pre-Cambrian schists and gneisses, some recent volcanic flows, and small areas of Tertiary "lake beds," stream gravels, and aplitic intrusions. The gneisses and schists have been described as Archean by Peale,[1] but they contain interbedded crystalline limestones and marbles in this region and in the Sheridan district (p. 132). It is, therefore, not desirable to consider them Archean, and they may be correlated provisionally with the Cherry Creek formation of Peale. On Browns Gulch these schists are cut by an important intrusion of quartz monzonite aplite, which is the country rock of the Easton and Pacific mines. All along Alder Gulch and to some extent on Browns Gulch stream gravels are distributed. North of Virginia City is a small area of Tertiary deposits, called Bozeman lake beds by Peale, consisting of terrestrial deposits formed partly by lakes but more largely by streams and winds. Near the city are small exposures of biotite andesite porphyry. West of Virginia City Tertiary basalt flows extend several miles beyond the area shown in figure 13 and occupy the summit of the Tobacco Root Mountains for about 12 miles from north to south. Most of the basalt flows are nearly horizontal, but one near Gravelly Range about 7 miles south of Old Baldy Mountain dips west. Gravelly Range itself, which extends for about 2 miles along the west slope of the mountains near the summit, consists of conglomerate and gravel and bowlders of sandstone, quartzite, gneiss, granite, and limestone. The bowlders are well rounded and some of them are flattened. The whole mass suggests an old stream deposit.

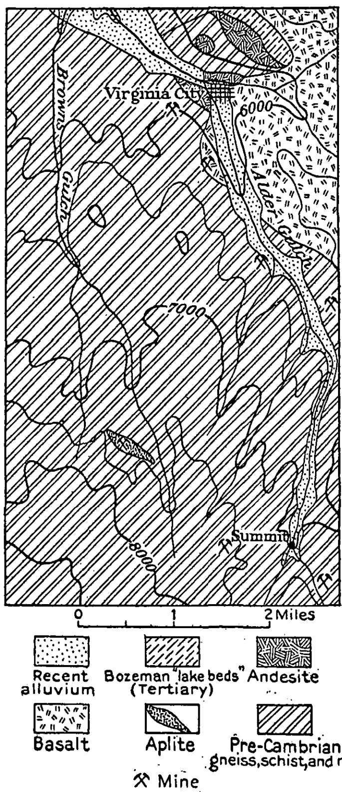


FIGURE 13.—Geologic map of the Virginia City mining district, Mont. Based on maps in the Threeforks folio.

The aplite of Browns Gulch contains abundant quartz, microcline, some orthoclase, sericitized plagioclase, and rare muscovite with imperfect aplitic texture. The andesite porphyry contains phenocrysts of sodic andesine (about Ab_2An_1) and biotite in a groundmass of plagioclase, biotite, magnetite, and apatite. A remarkable feature of the rock is the fact that some of the plagioclase phenocrysts contain cores of calcite. The carbonate is completely surrounded by unaltered feldspar, and calcite is not generally dissemi-

[1] Peale, A. C., op. cit.

nated through the rock nor present in the groundmass; it seems probable that the carbonate was formed before the plagioclase and is therefore of magmatic origin. The relations of the minerals are shown in photomicrographs in Plate IV, *B*, *C* (p. 128). Magmatic calcite in nepheline syenite has been described by Adams,[1] Törnebohm,[2] Holland,[3] and Workman.[4] A primary origin has been suggested for the calcite in certain alkali-granites associated with nepheline syenite by Chrustschoff,[5] Törnebohm,[2] and Walker.[6] It is easy to believe that in these plutonic rocks crystallization occurred under sufficient pressure to prevent the escape of carbon dioxide and thus lead to the formation of carbonates. Emerson[7] has claimed a primary origin for calcite and ankerite in rock glass of diabase aplite of Holyoke, Mass., but in such a dike rock, evidently moving quickly into a fissure where it is chilled, it is more difficult to explain the presence of carbonates as due to great pressures. In effusive rocks like the andesite from Virginia City it is impossible to believe that crystallization occurred under enormous pressure, and it is necessary to choose between the following conclusions:

1. The calcite in andesite from Virginia City is not magmatic but secondary in origin in spite of the fact that it is inclosed by unaltered plagioclase.

2. Pressure is unnecessary to enable carbonates to crystallize from solution in magmas. Calcium carbonate dissociates[8] completely under atmospheric pressure at a temperature of about 900° C., and under a pressure of four atmospheres at about 1,000° C., but in the presence of silica may dissociate at temperatures as low as 260° C.[9] or even 100° C.[10] with free silicic acid. Increase of pressure retards this dissociation,[11] but increase of temperature assists it. Therefore, in the absence of great pressure silica expels carbon dioxide from carbonates at magmatic temperatures.

3. The calcite and its inclosing plagioclase is of intratelluric origin; that is, they crystallized in the magma before its escape to the surface and therefore at some depth within the earth and under considerable pressure. Once crystallized and surrounded by andesine, the calcite was protected from the action of the magma after extrusion.

[1] Adams, F. D., Am. Jour. Sci., 3d ser., vol. 48, p. 14, 1894.
[2] Törnebohm, A. E., Geol. Fören., Stockholm Förhandl., vol. 17, pp. 100, 214, 1895.
[3] Holland, T. H., Geol. Survey India Mem., vol. 30, p. 197, 1901.
[4] Workman, Rachel, Geol. Mag., vol. 8, p. 193, 1911.
[5] Chrustschoff, St.-Petersbourg Acad. Imp. Sci. Mém., 42d ser., No. 3, vol. 7, 1894.
[6] Walker, T. L., Geol. Soc. London Quart. Jour., vol. 53, p. 55, 1897.
[7] Emerson, B. K., Geol. Soc. America Bull., vol. 16, p. 105, 1895.
[8] Johnston, J., Am. Chem. Soc. Jour., vol. 32, p. 938, 1910. Also Königsberger, J., Neues Jahrb., Beil. Bd., vol. 32, pp. 101-133, 1911.
[9] Königsberger, J., loc. cit.
[10] Bischof, G., Chemical and physical geology, vol. 1, pp. 6, 237-241, 1856.
[11] Struve, F. A. A., and Müller, R., Min. pet. Mitt., vol. 7, p. 47, 1877.

Though recognizing that the evidence is not conclusive, the writer prefers the last explanation.

The basalt near Virginia City contains numerous small phenocrysts of partly serpentinized olivine and others, locally in groups, of colorless augite in a fine trachytic groundmass of plagioclase, augite, and magnetite.

ORE DEPOSITS.

BROWNS GULCH.

In the early days of mining in Montana the important mines on Browns Gulch included the Easton and the Pacific. These two claims contained two ore shoots on the same vein, and during the past 20 years the two have been under single ownership and management. The Easton-Pacific mine is about 8 miles southwest of Virginia City and about the same distance from Alder Gulch, at an elevation of about 7,000 feet above sea level. The vein is in a large somewhat irregularly lenticular mass of quartz monzonite aplite, rich in feldspar, which cuts the gneiss and schists of the region. The vein on the Pacific claim is opened by tunnels and a winze to a total depth of about 500 feet; but it was not productive below a depth of about 300 feet. It strikes N. 57° W. and dips about 70° NE. It contained antimonial silver sulphides carrying gold with free silver in quartz and iron oxides. On the Easton claim the mine is opened to a maximum depth of about 725 feet by long tunnels and a 400-foot vertical shaft. In this part of the ground there are two veins, uniting to the east. The Easton vein strikes N. 48° W. and dips about 78° NE.; the "south" vein strikes N. 55° W. and dips about 68° NE. on the 100-foot level. The ore minerals include argentite, auriferous pyrite, native silver, tetrahedrite, native gold, sphalerite, and stibnite. The gangue materials are chiefly quartz with orthoclase, hematite, and limonite. The ore shoot on the Easton vein decreases in width from 600 feet on the highest level to 150 feet on the lowest level now open. The vein varies in thickness from about 18 inches to 6 or 8 feet. The footwall is clearly defined by a strong fault; the hanging wall is indistinct, ore grading into "feldspar" in many places. The mine has a 10-stamp mill, with amalgamating plates, a concentrator, and a 25-ton cyanide plant. Only about one-third of the values are recovered on the plates.

SUMMIT DISTRICT.

In the Summit district the mines with the largest past production are the Oro Cache and Kearsarge. The Oro Cache, discovered in 1864, is about half a mile from Summit, on Spring Gulch. Its vein, which is about 4 feet wide, strikes N. 10° E. and dips about 65°–70° W.

Sulphide ore was found at a depth of about 100 feet. The mine is reported to have produced about $500,000 worth of gold between 1864 and 1880, but for about 20 years it has been inactive or nearly so. The Kearsarge mine is at Summit, at an elevation of about 7,300 feet, about 6 miles south of Virginia City and 16 miles from the railroad at Alder. It had large bodies of low-grade ore in two veins, or in one vein and a parallel system of lenses. The country rock of the Kearsarge is gneiss and schist, the former being largely a biotite-quartz-feldspar rock, and the latter either of the same mineral composition or containing garnet or chlorite. The general strike of the schists is about N. 30° E. and the dip about 60° NW. The vein and lenticular ore bodies are composed largely of crushed feldspar or "clay," abundant quartz, and some chlorite, calcite, and auriferous pyrite. They have been developed by about 8,000 feet of tunnels and drifts and opened to a maximum depth of 400 feet, measured on the dip of the vein. Oxidized ore extends to a depth of about 130 feet, yielding gold with very little silver and practically no base metals. The precious metal occurs in finely divided particles in the pyrite, as coarse native gold, and less commonly as telluride of gold. Nagyagite is reported from this mine. The "Kearsarge vein" strikes N. 23° E. and dips about 65° NW. It is 2 to 20 feet wide, but the ore is confined chiefly to a layer about a foot thick on the footwall. The "big vein" on the same claim, which runs nearly parallel with the Kearsarge vein, consists of a series of lenses which attain a thickness of 40 feet or more. On the same group of claims the Rough Rider vein has about 6 feet of ore. A 60-stamp mill, equipped for amalgamation, concentration, and cyanidation of the ore, was erected at the Kennett mine, about 4 miles from Virginia City, in 1897, but was transferred to the Kearsarge mine, at Summit, in 1903.

Other mines at Summit, including the Keystone, Lucas, Polar Star, Excelsior, and Nelson, carry gold ore exclusively. The Nelson claim is in gneiss country rock at an elevation of about 7,800 feet. Unlike most of the veins in the district the Nelson vein strikes east and dips about 35° S.

FAIRWEATHER AND HIGHLAND DISTRICTS.

In former years some of the more important mines in the Fairweather and Highland districts at or very near Virginia City were the Alameda, U. S. Grant, Eagle, Bell, and Sonoma. More recently the U. S. Grant, St. John, Valley View, and Winnetka have been in operation. At the U. S. Grant, about half a mile above Virginia City, the tunnel on the mill level runs through about 200 feet of decomposed basaltic rock, more or less brecciated, and then enters the underlying gneiss, which contains stringers and quartz veins carrying pyrite, chalcopyrite, and galena. One 2-foot vein strikes N. 45° E. and dips about 45° NW. The ore is chiefly in narrow stringers, and much of that which has been opened is oxidized and enriched by surface waters. The mine has a 15-stamp mill, with plate amalgamation, concentrating tables, and cyanide tanks. It has been idle for the last seven years.

About a mile above Virginia City open-pit mining is now in progress on the Valley View claim, at an elevation of about 6,200 feet, where decomposed gneiss contains numerous small quartz veins carrying gold and silver. These veins have been considerably enriched near the surface by the action of meteoric waters. The ore contains quartz, hematite, limonite, pyrite, pyrolusite, and a little copper stain. The metals recovered are gold and silver.

The ore at the St. John mine is reported to contain quartz, pyrite, hematite, free gold, and sylvanite.

A fissure vein on the Winnetka mine, in the Highland district, about 3 miles above Virginia City, carries about equal quantities by weight of gold and silver. The ore contains quartz, pyrite, a telluride (sylvanite?), hematite, limonite, and a little chalcopyrite, malachite, pyrargyrite, sphalerite, and galena. The vein strikes about east and dips about 45° S. In the upper tunnel it is cut off, about 250 feet from the portal, by a fault which strikes about S. 70° E. and dips about 50° NE. The vein is said to be traceable eastward on the surface for about 600 feet.

ORIGIN OF ORE DEPOSITS.

The source of the ore deposits in the Virginia City district is not easily determined. In Browns Gulch the ores are found only in an intrusion of quartz monzonite aplite, and it is reasonable to consider that their position is the result not of chance but of genetic relationship. Elsewhere in the region, however, ores are found in old gneisses not closely associated with known igneous intrusions. It is clear that they have no genetic connection with the Tertiary basic flows, which are much younger. The presence in these ores of such minerals as pyrargyrite, sylvanite or calaverite, nagyagite, stibnite, and tetrahedrite indicates that they belong in Spurr's[1] highly mobile zone and that they may have traveled a considerable distance from some parent igneous mass. On the other hand, the country rock of these ores is much broken and much altered, and such conditions facilitate and bear witness to active circulation of meteoric waters. If such waters penetrated to sufficient depth and lost their acidic and oxidizing qualities they might dissolve the materials of the ore deposits from the country rock on their downward and lateral journey and redeposit them in the fissures through which they moved upward to the surface.

[1] Spurr, J. E., Econ. Geology, vol. 7, p. 489, 1912.

PRODUCTION.

The following table gives the estimated production of gold and silver in the Browns Gulch district from 1891 to 1900 and the combined production of the Browns Gulch and Fairweather districts, as recorded by the United States Geological Survey, from 1902 to 1912:

Production of the Browns Gulch and Fairweather districts.

Year.	Ore.	Gold.		Silver.		Total.
	Tons.	*Fine oz.*		*Fine oz.*		
1891-1895	6,400	3,700.00	$76,486	242,000	$181,500	$257,986
1896	4,000	1,000.00	20,672	32,000	21,760	42,432
1897	5,000	1,200.00	24,806	40,000	24,000	48,806
1898	5,000	1,200.00	24,806	40,000	23,600	48,406
1899	5,000	1,200.00	24,806	40,000	24,000	48,806
1900	5,000	1,000.00	20,672	35,000	21,700	42,372
1902	2,591	2,625.26	54,269	43,631	23,124	77,393
1903	5,200	1,100.00	22,739	45,000	24,300	47,039
1904	8,475	4,212.88	87,088	98,749	57,274	144,362
1905	6,814	3,314.03	68,507	65,807	39,748	108,255
1906	4,961	2,507.00	51,824	77,309	51,697	103,521
1907	994	1,774.39	36,679	49,889	32,927	69,606
1908	586	550.12	11,372	1,980	1,049	12,421
1909	7,283	2,838.40	58,675	56,519	28,390	87,065
1910	8,654	3,444.54	71,205	84,730	45,754	116,959
1911	7,903	3,635.62	75,154	69,210	36,681	111,835
1912	2,219	1,314.60	27,175	12,051	7,412	34,587
	86,080	36,616.04	756,935	993,875	644,916	1,401,851

In addition to the precious-metal output small amounts of copper from Browns Gulch and of copper and lead from Fairweather district were obtained during the years 1906–1911. The total copper was 30,553 pounds, valued at $5,155, and the total lead was 23,363 pounds, valued at $1,105.

DIVIDE CREEK DISTRICT.

LOCATION.

Divide Creek drains the northern and eastern slopes of Fleecer Mountain. It flows eastward, approximately parallel with the main Continental Divide and not more than a mile or two south of it, for about 5 miles, and then turns abruptly southward into the abandoned valley of a large river that once probably flowed across the site of the present divide at Feely. After flowing southward about 10 miles it empties into Bighole River near the town of Divide. The Divide Creek district lies south of the divide on both sides of Divide Creek.

GEOLOGY.

For a few miles on both sides of the Continental Divide the Tertiary deposits of the old waterway apparently rest upon a bedrock of quartz monzonite that is part of the Boulder batholith. In the region 3 to 5 miles east and southeast of Feely this batholith is cut by dikes of aplite, some of which vary in texture toward a quartz porphyry. Closely associated with these dikes are fissures which have been mineralized by solutions bringing in gold and silver.

ORE DEPOSITS.

At the Clipper group, about 3½ miles east-southeast of Feely, at an elevation of about 7,250 feet above sea level, the ore deposit is in a vein striking N. 80° E. and dipping from vertical to 85° S. Shoots in the vein pitch either east or west. The vein is cut by faults striking N. 40° E. and dipping about 75° NW. Another set of earlier faults are nearly horizontal and seem to offset the vein to the south (going down), while the later faults offset the vein to the south (going west). The earlier faults are mineralized; the later ones are not. Ore minerals noted here include native gold, native silver, cerargyrite, bromyrite, pyrargyrite, stephanite, argentite, and a telluride of gold.

About a mile south of the Clipper group other claims are located on ore of the same type. On the Original claim the vein strikes S. 55° E. and dips about 75° NE. The ore, which occurs in shoots, pitching southeast, consists chiefly of cerargyrite carrying a little gold in a gangue of quartz and talc (or sericite?). It is accompanied by an aplite dike.

On the western slope of Fleecer Mountain, at an elevation of about 8,500 feet above sea level, several claims have been located and more or less developed. On the Bonanza claim an adit 350 feet long penetrates quartzite, striking N. 20° W. and dipping about 50° NE. The strike turns to north or a little east of north within 100 feet from the mouth of the tunnel. Below the quartzite the tunnel enters limestone. At 150 feet from the mouth a fault reverses the dip, but another fault about 20 feet farther in restores it to its former direction. Still other faults follow the bedding planes, one of them producing a black talc from a shaly bituminous limestone. The vein, as shown by an inclined shaft above the tunnel, strikes north and dips about 55° E. The principal metals in the ore are gold and silver. Other claims in the vicinity have produced some copper ore, chiefly malachite.

A little more than 2 miles northwest of Divide, on the southeast slope of Fleecer Mountain, the Cayuga Development Co. is prospecting for copper ore near a contact of quartz monzonite with sedimentary rocks that are apparently of Mesozoic age. The veins strike east or southeast and dip commonly about 60° N. The copper ore consists of malachite, cuprite, melaconite, chrysocolla, and a little azurite in a granitic and quartzose gangue. The sulphide zone has not been penetrated, but sulphides remaining in the oxidized ore include chalcopyrite, bornite, and a little chalcocite.

J. T. Pardee, of the United States Geological Survey, visited this deposit during 1911, and the following description is quoted from his report:

A group of unpatented mining claims surrounds the quarter corner on the west line of sec. 6, T. 1 S., R. 9 W. At the time this property was visited development work was being done on the Cayuga claim at a shaft 230 feet east of the west line of the section. This is a double-compartment timbered shaft 125 feet deep and is equipped with a horse whim. It is sunk in the hornstone and granite that forms the footwall of a lode which outcrops a few feet to the north. Crosscuts from the shaft to the lode had not yet been run. Open cuts along the outcrop of the lode show that its course is west and that it extends into T. 1 S., R. 10 W., in a southward-bending curve for a quarter of a mile or more. The outcrop lies near the granite contact, within the hornstone area, and consists of massive to earthy limonite. An open cut and short incline a few feet north of the shaft show the dip there to be 60° NE., the width to be 15 feet or more, and the vein filling to be limonite and shattered quartz carrying bornite, chalcopyrite, and copper carbonates and oxides. Partly oxidized sulphide ore occurs in bunches as much as a foot or more in diameter. On the dump was about 2 tons of sorted ore. An average sample of this material was analyzed by R. C. Wells, of the Geological Survey, who reported 14.84 per cent of copper. The dump of a caved shaft near the contact on the Shannon claim shows considerable partly decomposed garnet rock, also massive limonite and vein quartz stained with copper.

ORIGIN OF ORE DEPOSITS.

The ore deposits are so closely associated with the aplitic dikes as to strongly suggest that both were derived from the batholithic magma by a process of residual concentration. That is, it may be supposed that as the ordinary products of crystallization of the monzonitic magma include no water and none of the rare magmatic constituents like boron, gold, silver, and copper, these were gradually concentrated in the residual liquid magma during crystallization. As water under pressure at high temperatures probably has strong affinities for silica, the latter accumulates with the water and brings with it acidic feldspar in eutectic proportions. When the cooling of the batholith has continued so far as to produce cracks from shrinkage the highly siliceous and richly aqueous residual magma tends to escape from the pressure of superincumbent rock by filling these cracks. At this stage the light siliceous portion of the residual magma escapes and forms aplites and pegmatites. It is commonly not until after these are formed that the heavier sulphides and native metals escape into fissures of later formation and produce ore deposits.

It is probable that the ore deposits of the Divide Creek district have been derived from the monzonitic magma in the way outlined. They fill fissures which are practically the same as those containing the aplite dikes, and yet they are later than the solidification of the aplite, for they lie in places on one wall and in places on the other and in places they cut across from wall to wall.

On the west side of Divide Creek, southwest of Feely, conditions are different. This region is sometimes known as the Fleecer district from the name of the mountain that occupies the whole area between Divide Creek, Jerry Creek, and Bighole River. Here Paleozoic quartzites and limestone are intruded by a "granite" very similar to that of the Boulder batholith, and contact ores have been developed in the sedimentary rocks.

INDEPENDENCE DISTRICT.

The Independence district lies north of and across the Continental Divide from the Divide Creek district. It includes the part of what is now known as the Butte district, that lies west of Missoula Gulch and south of Silver Bow Creek, and it extends southward and southwestward to the divide. As the largest mines in this district are not within the limits of the Dillon quadrangle and have been described in the Butte special folio, it is unnecessary to describe the Independence district in this place. It may be noted, however, that the country rock of the district is quartz monzonite of the Boulder batholith, cut by aplite dikes. The ores are in fissure veins and are chiefly valuable for silver, but carry also some copper, gold, and lead. The uncommon silver mineral, polybasite, has been found in well-formed crystals at the West Olive Branch mine, which is on the border of the Dillon quadrangle just south of Silver Bow Creek and northwest of Williamsburg.

ELKHORN DISTRICT (BEAVERHEAD COUNTY).

LOCATION.

The Elkhorn mining district in Beaverhead County unfortunately bears the same name as a better-known district lying about 80 miles to the northeast in Jefferson County, which has been described by Weed and Barrell.[1] The district in Beaverhead County is only about 10 miles from Hecla but is rarely approached from that direction on account of the rugged intervening mountains. It may be reached from the north by road up Wise River from Bighole River above Dewey or, more easily, from the south by road from Dillon by Bannock or Argenta to Gray, and thence north along Grasshopper Creek to its northeastern sources. By road up Wise River the Elkhorn district is about 40 miles from the Oregon Short Line Railroad at Divide; by road from the south it is about 50 miles from the railroad at Dillon. The district is northwest of Comet Mountain in a timbered region lying 7,000 to 8,000 feet above sea level and having rather gentle slopes to the west. No map is available, but the sketch given in figure 14 is based on mine surveys. The central group of claims is about 4 miles northeast of Elkhorn Hot Springs on the west

[1] Weed, W. H., and Barrell, J., U. S. Geol. Survey Twenty-second Ann. Rept., pt. 2, pp. 399-549, 1910.

side of East Fork of Wise River on unsurveyed land in the Beaverhead National Forest.

Perhaps largely because of its rather remote situation the Elkhorn district has never been productive except in a very small way. The veins have not yet been opened to such depth as to permit a large output, but near the surface some of them yielded some ore rich in silver and copper. The district was discovered in 1874.

GEOLOGY.

The country rock of the Elkhorn district is a porphyritic biotite-hornblende-quartz monzonite. In general, its porphyritic character is not noticeable in the field but becomes apparent in microscopic study. Large orthoclase crystals poikilitically inclose so much foreign material that the rock is given a granitic aspect megascopically. The included minerals are euhedral plagioclase, quartz, biotite, hornblende, magnetite, apatite, and rarely pyrite. The monzonite of the southwestern part of the district is dark greenish gray, but that near Wise River is light gray and similar to the Butte quartz monzonite. The quartz monzonite of the Elkhorn district extends south about 8 miles to the Polaris mine, southwest about 4 miles to Dory's ranch on Grasshopper Creek, and apparently occupies the mountains to the north and east to Hecla and at least as far as Mount Torrey. Within the district the quartz monzonite is penetrated by dikes of aplite and pegmatite and also by fissure veins containing copper ores in a quartzose gangue.

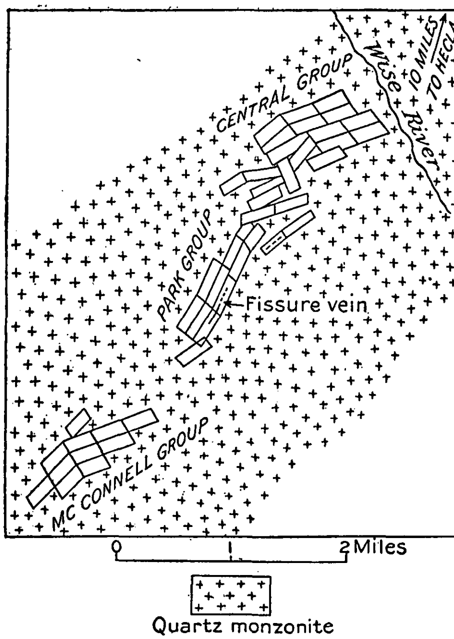


FIGURE 14.—Geologic sketch map of the Elkhorn mining district, Mont.

Much of the region has been glaciated, but drift is not abundant. There is a moraine in the mouth of the gulch east of Dory's, about 4 miles north of Polaris.

ORE DEPOSITS.

In the southwestern part of the district on the McConnell group of claims the quartz monzonite is intersected by narrow seams of quartz with pyrite carrying a little silver and copper. The veins contain chalcopyrite, galena, sphalerite, and chalcocite films on pyrite; in the oxide zone the copper minerals are especially conspicuous; they include malachite, azurite, and native copper. The ores are in planes of movement and are crossed by later faults containing quartz, fault gouge, and pyrite with some copper minerals. Some of the fault seams are nearly flat and dip gently to the west; others are nearly vertical and strike about east.

On the Park group a fissure vein strikes northeast and as seen near the surface dips about 75° NW. It has a maximum thickness of 20 to 30 feet and contains ores similar to those of the McConnell group. The veins are associated with aplite dikes in quartz monzonite.

Fissure veins on the Central group contain pyrite and chalcopyrite and quartz at a depth of 250 feet. Sooty copper glance is formed at water level at a depth of 150 to 250 feet. A vein on the Central claim, opened by an adit, strikes nearly east and dips about 65° S. and contains argentiferous galena and tetrahedrite with bornite. It is cut by faults without mineralization which strike nearly north. The veins in this group of claims are associated, in some places at least, with aplitic intrusions.

The exploratory mining work done in the Elkhorn district has yielded encouraging results. The ores in general are of low grade, but the veins are large. With adequate transportation facilities the district may become productive.

It is probable that the ores of the Elkhorn district are of the same origin as those found elsewhere (as in the Independence and Norris districts) in fissures cutting quartz monzonite. The association with aplitic dikes is probably due to relationship in origin, the ores being deposited by solutions derived from the monzonite magma in the final stages of its solidification. It is believed that the ores received their chief concentration at the time of primary deposition from hot ascending solutions, but it is probable that solution and redeposition by descending surface waters have also occurred and have caused the formation of sooty chalcocite near the ground-water level.

MAMMOTH DISTRICT.

LOCATION AND HISTORY.

The Mammoth district is in the heart of the Tobacco Root Mountains, about 16 to 20 miles south-southwest of Cardwell, a station on the Northern Pacific Railway, about 7 miles east of Whitehall. A good mountain road extends from the Jefferson Valley up South Boulder Creek to Mammoth. The district is only about 7 miles west of Pony, but the road to that town crosses a divide about 1,300 feet higher than Mammoth. On the west the region is separated from the headwaters of Bell Creek by the main ridge of the Tobacco Root Mountains. Jefferson Peak, locally called Old Hollowtop, which reaches an altitude of almost 11,000 feet, the highest point in these mountains, lies about 4 miles to the south-southeast.

The old town of Mammoth is on South Boulder Creek, about 17 miles from Cardwell and the same distance from Jefferson Island, a station on the Chicago, Milwaukee & St. Paul Railway. About this old town are grouped the Leviathan, Mammoth, Grand Central, Monitor, Ready Cash, Boulder, Willow Creek, and Mount Vernon mines. About 4 miles farther south, at the forks of South Boulder Creek, another group of mines includes the Sultana, Bismark, and Mogullian.

The Mammoth district was discovered about 1870. For several years it yielded free-milling gold ores. About 1880 the Grand Central, as reported, had a 6-foot vein of high-grade gold ore, and the Leviathan and Mammoth were also in active operation. When the oxidized ores were exhausted, attempts were made to treat the sulphide ores, but they met with little success, and the district became unproductive. During recent years little has been done toward reopening the gold mines, but work has been prosecuted steadily on certain veins carrying copper. At the Bismark mine copper ores of fair grade have been opened.

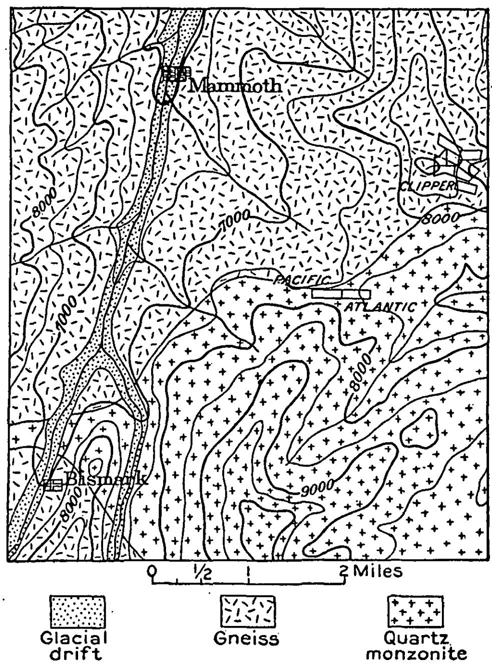


FIGURE 15.—Geologic sketch map of the Mammoth mining district, Mont.

GEOLOGY.

The geology of the Mammoth district is relatively simple. Near the old town of Mammoth the country rock is gneiss. A porphyritic dike is reported near the old Leviathan mine, but is not shown on the map (fig. 15), because lack of time prevented its detailed location. The map shows the approximate position of the contact between gneiss and quartz monzonite from the vicinity of the Clipper mine (Pony or Mineral Hill district) to the Bismark mine in the Mammoth district.

About 2 miles north of Mammoth an intrusion of tonalite porphyry lies between the gneiss and the Paleozoic formations to the north. It contains phenocrysts of oligoclase, quartz, and hornblende in a fine-grained granular groundmass of dominant quartz, some plagioclase, magnetite, apatite, epidote, and titanite.

Near the Sultana mine, about 4 miles south of Mammoth, the country rock is a porphyritic biotite-quartz monzonite; it contains large phenocrysts of orthoclase in a granitic groundmass. The phenocrysts contain inclusions of plagioclase, quartz, biotite, titanite, magnetite, epidote, chlorite, and calcite.

The Bismark mine is near the quartz monzonite gneiss contact. Here the igneous rock is cut by dikes of very coarse grained aplite containing abundant quartz, some orthoclase, rare plagioclase, a little muscovite and rutile, and a mineral resembling basaltic hornblende. Some of the feldspar is altered to sericite, epidote, and other minerals.

ORE DEPOSITS.

At Mammoth the gold ore is in fissure veins associated with igneous intrusions in gneiss. Three or four miles east of Mammoth, in the Clipper and Boss Tweed mines of the Pony district, gold ore occurs in rather flat shoots in wide veins in gneiss near its contact with quartz monzonite. About 3 miles southeast of Mammoth, at the Atlantic and Pacific mines, gold ore is disseminated in a much altered aplitic or porphyritic rock associated with quartz monzonite. Four miles south of Mammoth at the Bismark mine copper ore occurs in fissures in quartz monzonite very near its contact with gneiss. Here the vein strikes N. 57° W. and dips 72° SW. The ore minerals include chalcopyrite, bornite, galena, pyrite, and sphalerite in the sulphide zone and malachite, azurite, and chrysocolla in the oxide zone. The other vein minerals are quartz, molybdenite, hematite, and limonite. The vein is displaced about 10 feet by a fault which strikes N. 30° W. and dips about 60° NE. Another wide fault zone, cut by the main tunnel near its portal, strikes N. 35° E. and dips nearly vertically. Another fault, intersected by the main tunnel about 850 feet from the portal, strikes N. 75° W. and dips about 70° SW.

About a mile east of the Bismark on the east fork of South Boulder Creek the Mogullian claim has a vein of quartz and argentiferous galena in quartz monzonite near its contact with gneiss.

RADERSBURG (CEDAR PLAINS) DISTRICT.

LOCATION.

Aside from a few outlying mines in Beaverhead County, the Radersburg district (see fig. 16) is the only region described in this report which lies outside of the area shown on the key map (fig. 2, p. 13). It is in Broadwater County, in the Fort Logan quadrangle, about 10 miles west of Toston, a station on the Northern Pacific Railway, 45 miles southeast of Helena. Radersburg is about 20 miles north of Threeforks and 25 miles east of Boulder. Compared with other mining districts in southwestern Montana it is in a region of low elevation, its chief mines being about 4,600 feet above sea level. The placer mines of the district extend from about a mile west of Radersburg eastward down Crow Creek for several miles. The "deep" mines are 1 to 8 miles west and southwest of the town, the larger ones being about 2 miles west-southwest.

HISTORY.

The Keating mine in the Radersburg district was discovered in 1866 and was worked continuously until 1877. A 15-stamp mill, with amalgamating plates, was erected on the Keating in 1870. From the beginning of work to the present time the Keating has been the most important mine in the district, though several others, including the Ohio, Diamond, Iron Clad, and Leviathan, were discovered and worked during the sixties and seventies. During this period the ores taken out were thoroughly oxidized, and the gold was easily recovered by amalgamation after crushing in small stamp mills or arrastres. On the Keating the zone of oxidation extends to a depth of about 175 feet and is succeeded by a 59-foot zone of partial oxidation.

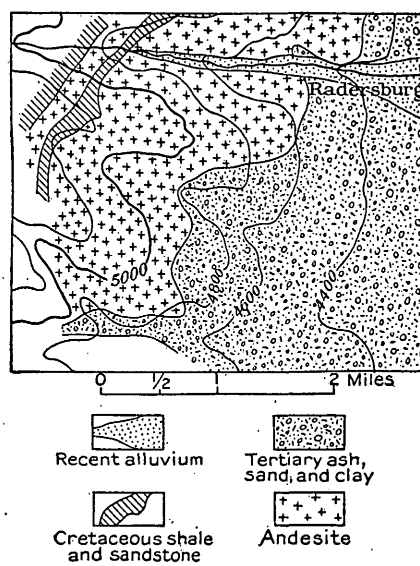


FIGURE 16.—Geologic sketch map of the Radersburg mining district, Mont.

When these ores were exhausted in 1878 the mine shut down and remained idle until the Northern Pacific Railroad was built. Then a small blast furnace was constructed at Toston to treat the sulphide ores but was soon abandoned. After the installation of large smelters at Helena and Butte, ores rich in sulphides were in demand and the treatment charges on such ores were made so low as to stimulate activity in districts like Radersburg, where the ores are almost exclusively sulphides.

GEOLOGY.

The mines of the Radersburg district are in porphyritic igneous rocks which are intrusive in Cretaceous sediments and are partly covered by Tertiary deposits. To the west of the district some outlying mines are in the thick pre-Cretaceous sedimentary series, which here strikes about north and dips about 30° E. The oldest sedimentary formations in this region observed by the writer are Paleozoic limestones, but still older (Cambrian and pre-Cambrian) quartzites and slates are reported to occur farther west. A quartzite at least 400 feet thick which is found east of the Paleozoic (Madison) limestone and above it stratigraphically is probably to be correlated with the Quadrant formation. This quartzite is capped by shaly sandstone and other sediments (probably shaly limestone) of unknown thickness, and these are succeeded by about 600 feet of shales and slates, which underlie about 100 feet of sandstone having a well-defined conglomerate 2 to 5 feet thick at its base. The igneous intrusions near Radersburg penetrate especially these later sandstones and shales. It seems probable that the conglomerate and overlying sandstones belong to the Kootenai formation of the Lower Cretaceous. In the western part of the Radersburg district these sediments form a synclinal trough, pitching south at the north end. At the south end they are faulted so as to outcrop twice, and have been overturned to the west and now dip eastward. The Tertiary deposits lie in very evident unconformity above the Cretaceous sediments.

No fossils were obtained by the writer from the Radersburg district, but they are reported to occur in shales on the Mammoth claim in the western part of the area.

The igneous rocks of Radersburg are chiefly andesites formed at two or more periods. Lone Mountain, which is apparently an eroded remnant of an old andesitic volcano about 5 miles south of the town, is bordered on the west by an area of hornblende granite, and a small outcrop about 2 miles west of Lone Mountain is hornblende-quartz monzonite, but the igneous rocks in which the ores occur are extrusive andesites. No auganite has been found in this region.

The relative age of the various andesite flows and intrusions has not been determined, but field study indicates that andesite dikes cut older andesite. All the andesites are older than the Tertiary deposits, which lie upon weathered and eroded andesite surfaces, and are younger than the Cretaceous rocks, for they penetrate Cretaceous sandstones and conglomerates. Along a contact between andesite and hornblende granite on Lone Mountain the texture of the granite is the same, as it is well within the mass, but that of the andesite is denser. Microscopic study shows that the denser texture is due not to fineness of grain but to a change from ordinary porphyritic texture with felsitic groundmass to a porphyritic texture with globulitic groundmass. It is probable, therefore, that the andesite is later than the granite.

The hornblende granite near its contact with andesite contains about 23 per cent of oligoclase, 47 per cent of orthoclase, abundant quartz, and some hornblende, magnetite, biotite, titanite, and apatite. It is probably a variation of the great quartz monzonite batholith of the region, from which it differs only slightly. A decrease of 5 per cent in the orthoclase would change the rock into a quartz monzonite. The small outcrop 2 miles west of Lone Mountain is perhaps connected with the same igneous mass; it is typical hornblende-quartz monzonite containing abundant plagioclase, orthoclase, and quartz, and some hornblende, magnetite, titanite, biotite, and apatite.

Most of the andesites are distinctly porphyritic and contain large phenocrysts of oligoclase; many of them contain other phenocrysts of hornblende or even of magnetite. Some samples, especially andesites from Lone Mountain, contain large augite crystals with calcic oligoclase and some biotite and magnetite, and are therefore augite andesites, as that name is used in this report. Some samples contain andesine, and zonal growth of the plagioclase is very common. Even the magnetite in some of these andesites shows clearly two periods of growth. A cellular texture is found in some samples. These rocks have undergone alteration in two different ways and to varying extent. They have been subjected in places to the modifying influences of hot vein-forming solutions, and they have been altered near the surface by cold meteoric waters. In some samples the processes of alteration have produced abundant chlorite with some calcite; in others the new material is chiefly calcite, and in others it is a mixture of epidote, chlorite, quartz, and sericite. In one sample there is abundant secondary orthoclase with some sericite, chlorite, quartz, and epidote. In some samples calcite is pseudomorphous after oligoclase, and all stages of the change can be seen. In another sample the groundmass is altered to chlorite in one part and the feldspar is relatively fresh, and in another part of the same section the oligoclase phenocrysts are wholly replaced by chlorite and the groundmass is little changed.

The chemical composition of andesites from Radersburg has been determined by the following analyses, made for the writer by Chase Palmer in the laboratory of the United States Geological Survey. The specific gravity and porosity were measured by L. E. Dagenais at the University of Wisconsin.

Analyses of andesite.

	1	2	3	4	5
SiO_2	56.61	57.35	60.78	63.69	61.30
Al_2O_3	17.91	16.33	18.10	18.60	16.88
Fe_2O_3	4.22	3.13	3.15	.94	3.01
FeO	2.70		.97	.09	2.76
MgO	2.21	4.31	2.04	.18	2.49
CaO	6.88	6.12	4.61	.24	5.07
Na_2O	3.10	.70	2.81	.32	3.99
K_2O	2.71	3.82	2.75	12.81	1.89
H_2O-	.29	.62	.68	.51	....
H_2O+	1.16	3.05	2.62	1.14	1.33
TiO_2	.71	.65	.24	.32	.86
CO_2	.13	.70	.00	.00	....
P_2O_5	.46	.16	.62	.10	.25
SO_3	....	....	.16	.30	....
S	.03	....	....	....	....
FeS_2	....	1.82	....	....	....
MnO	.58	.30	.39	.34	.17
BaO	.14	.05	.18	.37	....
Sum	99.84	99.11	100.10	99.93	100.00
Specific gravity	2.76	2.84	2.73	2.57	....
Porosity	3.30	3.90	13.10	14.40	....

Analysis No. 1 represents a slightly altered augite andesite from the Rena mine. Under the microscope the phenocrysts of sodic andesine may be seen to have had two and even three periods of growth with slight alteration marking intervals of no growth. Large hornblende phenocrysts have been heated above their stability range and are now converted partly into chlorite with a fringe of magnetite. The augite phenocrysts are clear and unaltered.

Analysis No. 2 represents a considerably altered andesite from the Rena mine. Under the microscope the plagioclase phenocrysts are seen to be partly altered to calcite and chlorite with some secondary quartz. The rock contains considerable pyrite which is disseminated through the mass.

Analysis No. 3 represents a notably altered andesite from the Keating mine. It contains partly altered phenocrysts of andesine in a groundmass of chlorite, sericite, quartz, epidote, hematite, limonite, and kaolinite.

Analysis No. 4 represents a white rock from the Keating mine, which field study shows to be an extreme alteration product of andesite found only near veins and as the gangue of disseminated ores. It is very porous and is locally known as a rhyolite on account of its white color. Under the microscope its alteration is seen to be so intense that the phenocrysts are no longer distinct. It contains a secondary granular feldspar which is not easily identified optically, but which is apparently orthoclase, for it has low refringence. It contains also some chlorite, quartz, sericite, and epidote with a little limonite.

Column 5 gives the average composition of 57 andesites, including ordinary hornblende and mica andesites and pyroxene andesites containing acidic plagioclase. It has been calculated from data of Daly,[1] Clarke,[2] Rosenbusch,[3] and Osann.[4]

By converting these analyses, by aid of the geologist's slide rule,[5] into percentages of mineral molecules according to the rules of the quantitative classification of igneous rocks, the following results are obtained:

Mineral composition (norm) of andesite.

	1	2	3	4	5
Quartz	11.7	16.8	22.2	11.5	16.4
Corundum	....	....	3.1	3.2	....
Orthoclase	16.0	22.6	16.2	75.8	11.2
Albite	26.2	5.9	23.8	2.7	33.8
Anorthite	26.8	30.0	19.9	2.4	22.4
Diopside	4.0	....	....	....	.9
Hypersthene	5.1	16.0	5.1	.5	7.3
Magnetite	6.1	....	3.7	.5	4.4
Hematite	....	....	.6	.6	....
Ilmenite	1.4	1.2	.5	.6	1.6
Apatite	1.0	.4	1.5	.2	.6
Pyrite	....	1.8	....	....	....
(Water, etc.)	1.6	4.5	3.5	1.9	1.3
	99.9	99.2	100.1	99.9	99.9

The fresh augite andesite of the Rena mine at Radersburg contains less silica and soda and more lime and potassa (K_2O) than the average andesite; correspondingly, its norm contains less quartz and albite and more anorthite and orthoclase than the average rock; it also contains more diopside and magnetite and less hypersthene. In the quantitative classification this rock is called harzose-tonalose, having three molecules of potassa to five of soda, whereas the average andesite is called tonalose, being dosodic.

The altered andesite (No. 2) of the Rena mine shows the effects of hydration, pyritization, and some carbonation with decrease in iron and soda and increase in potassa and magnesia. The norm of the altered andesite shows the introduction of pyrite and the increase in quartz, orthoclase, anorthite, and hypersthene with a radical decrease in albite.

The andesite (No. 3) from the Keating mine has been hydrated and oxidized, but shows little evidence of other alteration. Aside from the alteration, it contains less lime and soda and more potassa than the average andesite but is more closely related to the latter than the augite andesite of the Rena mine. The norm of this rock has a little corundum and hematite with abundant quartz and orthoclase and

[1] Daly, R. A., Am. Acad. Sci. Proc., vol. 45, p. 223, 1910.
[2] Clarke, F. W., U. S. Geol. Survey Bull. 419, 1910.
[3] Rosenbusch, H., Elemente der Gesteinslehre, pp. 374, 378, 382, 1910.
[4] Osann, A., Chemischen Petrographie, vol. 2, 1905.
[5] Mead, W. J., Econ. Geology, vol. 7, p. 136, 1912.

less plagioclase and hypersthene than in the average andesite. In the quantitative classification this rock is harzose, related to amiatose.

The highly altered andesite (No. 4) from the Keating mine is extraordinary in its tenor of potassa, containing only trifling amounts of all other bases except alumina. The norm contains 75 per cent of orthoclase, 11 per cent of quartz, and small amounts of corundum and plagioclase. Such rocks are almost unknown, but a "quartz porphyry" described by Loretz [1] is similar, containing 12.33 per cent of potassa, 14.41 of alumina, and 69.06 of silica. In the quantitative classification this rock would belong in the division I.5.1.1, but it is too much altered to be amenable to the standards of that system. As there has been no slumping as a result of alteration of this rock and as the porosity is less than 15 per cent this rock must have been formed not by processes of leaching alone but by actual introduction of potassa and by its combination with alumina and silica set free by removal of other bases.

This rock occurs in zones and irregular areas which have been sometimes regarded as independent intrusions. Its contact with the unmodified andesite is remarkably sharp in some places, but elsewhere it may be found grading gradually into the latter. It is apparently more abundant near the surface than at greater depth, and is closely associated in distribution with the ores.

ORE DEPOSITS.

The ores of Radersburg are chiefly productive of gold, but yield also some silver and small amounts of other metals. They are found in narrow veins, in porphyritic igneous rocks of post-Cretaceous age, probably later than the quartz monzonite of the Boulder batholith. The most important deposits consist of gold-bearing pyrite veins which contain very little quartz or other gangue material. On account of their high pyrite and very low silica these ores have been treated very cheaply at the copper and lead smelters at Butte and East Helena.

The Delome Gold Mining Co. has a vertical shaft 65 feet deep on a vein striking N. 55° W. and dipping about 75° SW. The ore is quartzose and contains pyrolusite and limonite. The coarse andesite country rock is in contact with remnants of conglomerates which are cemented by the intrusive. Epidote is another result of the contact.

At the Rena mine the shaft is 300 feet deep on the incline. On the surface the vein strikes N. 17° W. and dips about 75° W., but the shaft shows that there are notable variations in dip underground. The vein is cut by two faults which strike about north and offset the

[1] K. preuss. Landesanstalt Jahrb., 1888.

vein 5 to 10 feet toward the west (going north). The vein is 1 to 3 feet wide and contains auriferous pyrite and quartz in shoots. The ore contains small amounts of sphalerite, arsenopyrite, chalcopyrite, and galena. The country rock, which varies from very fine to medium coarse in grain, is silicified and mineralized near the vein. The fresh rock weathers to a dark greenish gray, and the altered rock to a light gray.

About a quarter of a mile north-northwest of the Rena shaft a contact deposit of magnetite and hematite replaces shales and slates. The bedding of the sediments strikes west and dips about 60° S., but farther east the strike curves to the south. The whole deposit and the unaltered shale occupy only a small area extending irregularly some 500 feet.

The Keating mine is the most important in the district. It has an incline shaft 725 feet deep and several levels, the lowest, called No. 6, being 550 feet vertically below the surface. The vein strikes about north and dips about 65° W.; it has been opened for 1,000 to 2,000 feet north and south of the shaft on four different levels. Most of the ore is solid auriferous pyrite, but one shoot 600 to 900 feet north of the shaft contains some andesitic gangue. This shoot has rather indefinite walls, but the vein in general has sharply defined walls; its dip is about 80° W. The Keating vein is crossed by at least three faults not parallel in strike nor in dip, one of them striking about N. 52° W. and dipping about 75° SW., and another dipping about 50° N. The offset of each fault is to the west (going south) and is nowhere very great, being 5, 15, and 25 feet in different places. Most of the ore is very clean. The gangue, where found, consists of calcite and quartz. Where the quartz is abundant the ore is not mined. The removal of ore leaves remarkably definite walls which are strong enough to stand with very little timbering.

The mine is equipped with a 10-stamp mill having two Frue vanners and a Wilfley table, but concentration is of little use, for nearly all the ore is clean pyrite.

The Ohio mine is about 1,000 feet west of the Keating, on a nearly parallel vein which strikes about N. 15° W. and dips about 80° W. About 175 feet north of the shaft the vein is cut by a later well-defined fault fissure which produces no appreciable offset. Two hundred feet farther north a fault striking about east and dipping about 75° N. offsets the vein about 6 feet to the east. The mine is opened by an incline shaft 200 feet deep. The country rock is a much modified and silicified andesite. The vein, which is known for about 1,500 feet, has an average thickness of 1 or 2 feet, ranging from 1 to 5 feet. The ore is very similar to that in the Keating vein and consists of clean auriferous pyrite or its oxidized equivalents.

Where ore is lacking the vein contains fault gouge, quartz, and calcite, with lenses of country rock in places.

The Black Friday mine, about 3 miles southwest of Radersburg in andesitic country rock, has an inclined shaft 500 feet deep on a vein which strikes about north and dips steeply west. It was not open to inspection when the district was visited.

The Dewdrop group includes five claims from a quarter to half a mile west and northwest of the Keating. On the Hidden Treasure claim a vein has been opened by a tunnel about 700 feet long. It strikes N. 15° W. and dips about 55° W. The vein has been stoped from the surface to water level for about 400 feet, although it is only 4 to 8 inches wide. The andesitic country rock is altered and mineralized on parts of these claims.

In the western part of the Radersburg area some parts of the Cretaceous conglomerate are said to carry gold, but the tenor is rarely greater than $2.50 per ton.

The Congress claim is about 2,000 feet south of the Black Friday, on a vein about 2 feet wide, striking about N. 68° W. and dipping about 65° NE., and having andesite as the country rock. It contains galena, cerusite, wulfenite, pyrolusite, quartz, limonite, and probably vanadinite. Gold is unimportant.

On the Montezuma claim, in the western part of the district, a vein about 4 feet wide, striking N. 16° W. and dipping about 76° W., occurs along the contact between andesite and slate, andesite forming the hanging wall. The ore, which is argentiferous galena with some pyrite, is in narrow stringers 1 to 2 inches thick, in a gangue containing quartz, calcite, siderite or ankerite, limonite, and pyrolusite.

The Hard Cash vein, a short distance west of the Radersburg district, strikes about N. 43° W. and dips about 80° NE. It is opened along the strike for 500 feet by an adit which discloses a fault cutting off the vein about 600 feet from the portal. Beyond the fault another vein is encountered which strikes about N. 25° W. and dips about 70° WSW. The ore shoot on the Hard Cash vein is about 250 feet long and contains auriferous pyrite, a little sphalerite, bornite, chalcopyrite, and native copper, with quartzose gangue. The vein is in a fissure in andesite near its contact with slates.

The Rothfuss mine is about 6 miles west of Radersburg in Keating Gulch. The workings are shallow and confined to the oxidized zone. Some of the ore is high in gold, and much of it contains abundant films of secondary copper minerals, especially chrysocolla, malachite, and melaconite. The gangue contains some fragments of country rock, abundant quartz, and hematite and limonite. One ore shoot pitches about 60° NE. The ore occurs in irregular deposits along a contact between andesite and slates.

The Jo Jo group is in the Cedar Plains district, about 4½ miles southwest of Radersburg. The country rock is quartzite, probably of Quadrant age, and some limestone, both striking north and dipping about 30° E. About 400 feet east of the ore andesite occurs in sills. The ore is in veins, some of which follow the strike of the country rock, and others strike east and dip steeply south. The veins which are opened by an inclined shaft about 200 feet deep and by several shorter shafts and tunnels, vary in thickness from 1 to 6 feet and contain ore commonly 6 to 10 inches thick. The ore, which was originally mined for silver, contains cerusite, wulfenite, quartz, calcite, hematite, and limonite. The wulfenite seems to be of two varieties, one red in color and pyramidal in habit, and the other yellow in color and platy in habit; both are well crystallized in tetragonal forms.

The Parker group is about 8 miles west of Radersburg on Johnny Gulch in country rock of limestone and shale cut by andesite. These sedimentary rocks are stratigraphically above the Quadrant (?) quartzite and may be provisionally assigned to the Cretaceous. The ore is in pockets and shoots in somewhat irregular veins cutting the sediments near the igneous contact. It has been cut by several later faults. The ore is chiefly argentiferous galena in a gangue of siderite, quartz, hematite, limonite, and pyrolusite.

The Rowell group is about 4 miles south of Radersburg in a region of andesite partly bleached by leaching to a white porous rock locally called rhyolite. The veins in the volcanic rocks contain pyrite, chalcopyrite, arsenopyrite, malachite, and chrysocolla. They strike about east and dip about 80° N. Ore shoots 2 to 5 feet thick are found where stringers join the main vein.

ORIGIN OF ORE DEPOSITS.

The ores of the Radersburg district are closely associated geographically with intrusions and extrusions of andesite. The most valuable deposits are in fissure veins cutting the andesite, and less productive ores are found along contacts between the intrusive rock and earlier sedimentary formations or in the latter not far from such contacts. With rare exceptions the ore in veins cutting the andesite is valuable chiefly for gold, and that along or near the igneous contact for argentiferous galena, some copper, and a very little gold. This mode of occurrence is believed to indicate that the ores are genetically related to the andesite and that they were formed at two periods, the contact ores being probably the older.

Spurr[1] has recently attempted to define the principal ore zones and to state their relative age. He believes that in general the zone

[1] Spurr, J. E., Econ. Geology, vol. 7, p. 485, 1912.

of argentiferous galena is later than the gold-pyrite-quartz zone, and he does not recognize a zone of auriferous pyrite without quartz, although he describes three zones in which the ores are characteristically solid sulphides. At Radersburg the argentiferous galena deposits are probably older than the auriferous pyrite ores, and the latter are remarkably clean and free from quartz.

It has been suggested [1] that ore deposition at Radersburg continued to very recent times and that hot-spring deposits in and upon Tertiary beds of the region represent the last phase of activity of the ore-forming solutions. In support of this view it is pointed out that the principal ores are in veins which contain a little quartz and calcite as gangue material, and that the recent travertine and calcite contain traces of gold. Whether this view is correct or not it is probable that the period during which commercial ores were formed entirely preceded the Tertiary, for the Keating vein has been followed underground to the south (on the fourth level) to "broken ground," which is probably part of the Tertiary deposit. The "broken ground" shows no evidence of stratification and consists of partly rounded bowlders of all sizes, the largest 18 inches in diameter, which are highly altered, oxidized, and soft. The bowlders are partly if not wholly altered andesite of local derivation. The vein extends to these bowlders and no farther, though a little oxidized and probably secondary ore extends a few feet into the "broken ground."

PRODUCTION.

Estimates of the production of the "deep" mines of the Radersburg district prior to 1904 run above $3,000,000, but more conservative detailed estimates of the output of each mine in the district reduce this more than one-half and lead to the figures given below. Since 1904 the figures have been collected by the United States Geological Survey and are more reliable.

In addition to the output of gold and silver, small amounts of silver-lead and silver-copper ore have been shipped from the district, although the chief veins contain gold ore exclusively. From 1908 to 1911 the base ores contained 509,726 pounds of copper, worth $74,150, and 69,151 pounds of lead, worth $2,950. Old residents of the district estimate the gold won from gravels from 1866 to 1904 at $500,000 to $1,000,000.

[1] Bard, D. C., Assoc. Eng. Soc. Jour., vol. 45, p. 14, 1910.

Production of Cedar Plains or Radersburg district, Mont.

[From records of the division of mineral resources, U. S. Geological Survey.]

Year.	Crude ore.	Gold.	Silver.	Copper.	Lead.	Total value.	Placer gold.
	Tons.	*Fine oz.*	*Fine oz.*	*Pounds.*	*Pounds.*		*Value.*
1902	3,247	3,982.86	30,612	....	1,011,538	$123,633	$849
1903	827	147.50	11,632	800	8,000	10,560	476
1904	61	124.66	30	....	....	2,596	8,324
1905	918	828.71	1,335	....	40,645	22,386	....
1906	822	571.38	492	....	644	12,179	3,224
1907	72	83.98	39	....	....	1,762	789
1908	6,524	5,291.64	3,015	5,032	46,778	113,618	791
1909	13,257	10,072.59	2,423	21,601	....	212,287	1,146
1910	13,867	14,203.38	4,793	65,009	14,309	305,085	208
1911	24,627	23,556.88	664	135,674	8,064	504,638	510
1912	19,158	15,506.99	8,666	282,410	....	372,884	397

FUTURE OF MINING IN THE DILLON QUADRANGLE AND ADJACENT AREAS.

In considering probable future developments in the mining industry in the Dillon region, it is important to distinguish sharply between those ores which have received a second concentration either through mechanical sorting by stream action and final deposition in placer deposits or through the process of enrichment, and those which have not been modified but remain substantially as they were when first deposited. In general, the deposits of the first class which have been discovered have been mined out or are already largely depleted, and deposits of the second class must furnish the basis of future mining operations. In many regions secondary ores are far more valuable and lasting than primary deposits, but in the Dillon quadrangle, so far as known, they do not extend to sufficient depth to make enduring mines. The distinction between secondary ores due to enrichment and ores which are of primary origin is not always easily made. Some secondary ores are readily identified as such, and some deposits are plainly primary in origin, with only unimportant modifications due to enrichment, but most deposits demand careful and detailed study before their mode of formation can be determined.

Furthermore, nearly all deposits consist of two parts, the upper owing its metals chiefly to enrichment and the deeper resulting from primary deposition only. If the primary ores are sufficiently rich to be of value the profitable ore may be expected to extend to much greater depth than a deposit of similar grade produced by enrichment. This is especially true when the enrichment is confined largely to the zone of oxidation, as it usually is in gold deposits.

The placer deposits of the Dillon region, so far as known, are now (with few exceptions) of too low grade to permit profitable exploitation by ordinary methods of sluicing or hydraulicking. The deposits along Alder Gulch, however, are being worked very successfully by dredges, and there is reason to believe that this work will continue for 10 to 15 years. After the exhaustion of the placers near Virginia City and Ruby dredging methods may be applied to some of the smaller deposits of this type.

It is probable that placer deposits were formed by Alder Creek before the basaltic lava flows of the Tertiary period covered the region, and that these old placers were not destroyed but simply buried by the flows of andesite and basalt. If they are not too deeply covered by volcanic ash and lava flows it is possible that they may in the future supply the material for extensive mining operations.

As already suggested, mining districts in which the deposits owe their value chiefly to a shallow enrichment can not be expected to attain future prominence, though a few of the deposits heretofore worked only in their enriched upper portions may be underlain by primary unenriched ore that is of lower grade but is still capable of yielding profitable returns. Such deposits are worthy of careful search because they will be limited downward not by the depth of the oxidized zone, but rather by slow decrease in metallic contents or by the ending of the deposit itself.

Mining districts which contain valuable deposits of primary ore have good prospects for the future. It is for this reason that the gold deposits at Radersburg and at Pony may be expected to endure for years if not for decades. Other deposits in different parts of the Dillon quadrangle are of importance for the same reason. The tungsten deposits in the Potosi district are of primary origin, and it is probable that if they are of sufficiently high grade to be valuable near the surface they will continue to be profitable to considerable depths.

Contact ore deposits such as those in the Bryant, Highland, Utopia, and Bannock districts and some of those in the Tidal Wave, Sheridan, Blue Wing, Vipond, Radersburg, and Argenta districts are not so regular either in form or continuity as fissure-vein deposits, but some of them are of sufficient extent to be of great value.

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