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THE ANVIK-ANDREAFSKI REGION ALASKA

(INCLUDING THE MARSHALL DISTRICT)

BY

GEORGE L. HARRINGTON

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THE ANVIK-ANDREAFSKI REGION, ALASKA.

By George L. Harrington.

FIELD WORK AND ACKNOWLEDGMENTS.

This report is intended to cover the results of the explorations of a United States Geological Survey party during the summer of 1916, in charge of R. H. Sargent, topographic engineer. The writer was attached to the expedition as geologist, C. F. Bailey acted as recorder, and C. E. Anderson as cook.

The party was landed from the steamer at Anvik on June 15, and carried on work from that time until a steamer was boarded at Andreafski on September 13. A 30-foot poling boat equipped with a 2-horsepower engine of the detachable hang-over type was the principal means of transportation throughout the summer. A topographic and geologic traverse was made on the Yukon from Anvik to Andreafski and up Anvik, Bonasila, Stuyahok, and Andreafski rivers as far as was considered practicable under the limitations of the short season. The intervening stretches of country inaccessible from the boat were not visited. In addition to making these traverses along the streams, the party spent 16 days in the vicinity of Marshall in studying the mineral resources and in topographic and geologic mapping.

The writer wishes to express to Mr. Sargent and to each of the members of the party his appreciation of their cordial aid in the furtherance of the geologic work on every possible occasion. To Rev. J. W. Chapman and others at Anvik who assisted in the preparation and equipment for field work the members of the party feel their indebtedness, and to every miner, prospector, and merchant met during the summer thanks are due for the unfailing hospitality, the spirit of ready cooperation, and the unflagging interest in the carrying on of the Survey work. Such assistance made doubly efficient the efforts of the members of the party where reliance had to be placed on other than their own efforts or equipment for the prosecution of the work.

In the office the members of the division of Alaskan mineral resources have rendered assistance in many ways, and the writer is

especially indebted to H. M. Eakin and A. G. Maddren, whose work in near-by provinces has elucidated obscure physiographic and geologic problems in this region. Grateful acknowledgments are made to J. B. Mertie, jr., for assistance in making petrographic determinations. F. H. Knowlton and J. B. Reeside, jr., determined the fossil collections obtained during the summer.

EARLY HISTORY AND PREVIOUS WORK.

Although the coast of Alaska had been early explored by the Russian and English navigators, the interior country was wholly unknown, even after a considerable trade in furs had been established along the coast. Of the many who explored the Yukon, Glazanof[1] appears to have been the first. He reached Anvik from St. Michael early in 1834, crossing the portage with dogs. After crossing to the Kuskokwim, he returned to the Yukon and apparently reached St. Michael by way of the mouth of the river. He was followed in 1838 by Malakof, who crossed by the Unalaklik portage and ascended the Yukon as far as the mouth of the Koyukuk. The next summer he reached the mouth of the river by boat. In 1842 Lieut. Zagoskin, of the Imperial Russian Navy, traversed the river from its mouth to the vicinity of Nulato, and in 1844 he reached the mouth of the Nowitna. He prepared a map, which accompanies the report of his explorations.[2]

The earliest geologic work in this portion of Alaska was done by W. H. Dall in 1866 to 1868, while he was in charge of the scientific corps of the Western Union Telegraph Co.'s expedition. He made a traverse from Fort Yukon to the mouth of the river in 1867, and again went down the river from Nulato to St. Michael the following summer collecting geologic and other scientific data. His narrative[3] contains a map and some geologic notes, but more detailed information is to be found in other reports[4] of a more technical character.

Whymper was an associate of Dall and the artist of the telegraph expedition. He assisted in gathering data which were doubtless used in the preparation of his own book[5] and that of Dall. A map of the Yukon and a small-scale map of Alaska are included in his account of his travels with Dall.

[1] Brooks, A. H., unpublished manuscript.

[2] Zagoskin, L., Travels on foot and description of the Russian possessions in America, from 1842 to 1844, St. Petersburg, 1847 (in Russian); also in German in Erman's Archiv fur wissenschaftliche Kunde von Russland, vols. 6 and 7.

[3] Dall, W. H., Alaska and its resources, 1870.

[4] Dall, W. H., and Harris, G. D., Correlation papers, Neocene: U. S. Geol, Survey Bull. 84, pp. 232–268 and map, 1892. Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, pp. 763–908, 1896; Boston Soc. Nat. Hist. Proc., vol. 12, p. 138, 1869; Exploration in Russian America: Am. Jour. Sci., 2d ser., vol. 45, pp. 97–99, 1868.

[5] Whymper, Frederick, Travel and adventure in the Territory of Alaska, 1869.

Upon the acquisition of the territory by the United States, one of the questions to be settled was whether the Fort Yukon post of the Hudson Bay Co. was on American or Canadian soil. To determine this point the first of the expeditions under the auspices of the United States Army into interior Alaska was undertaken in 1869 by Capt. Raymond.[1] His party, consisting of himself, John J. Major, and Pvt. Michael Foley, obtained passage on the small steamer *Yukon* on its first trip up the river. Observations were taken at St. Michael, Anvik, Nulato, and Fort Yukon to determine their position. Assisted by Major, he made a traverse of the river while ascending it, using the time and compass method. After observations had been made at Fort Yukon, the party descended the river in a small boat and crossed to St. Michael by the Anvik portage. The results of Raymond's surveys appear on the map compiled by him and included in his report.

The party of Lieut. Schwatka[2] made a military reconnaissance of the Yukon in 1883, and Charles Homan, attached to the party as topographer, made a topographic sketch map of the region.

Russell[3] was the first geologist detailed by the United States Geological Survey to make studies in the Yukon Valley. In 1889 he accompanied the Coast and Geodetic Survey parties that determined the location of the international boundary where it crosses Yukon and Porcupine rivers. From the nature of his trip he was afforded but scanty opportunity for making geologic studies on the lower Yukon, but his report contains many significant facts regarding physiographic features.

With the development of gold mining in Alaska parties were sent by the Geological Survey to investigate the mineral resources and to make surveys in the producing regions. In 1896 such a party, in charge of J. E. Spurr, with H. B. Goodrich and F. C. Schrader as geologic assistants, undertook the study of the mining camps in the interior. They descended the Yukon from its source to its mouth, investigating on the way the Fortymile and Birch Creek districts and making extensive studies[4] along the river as far down as Nulato. A small-scale map[5] of the lower Yukon accompanies the report of this investigation. From information obtained on this trip and on a trip made in 1898 a geologic reconnaissance map of south-

[1] Raymond, C. W., Report of a reconnaissance of the Yukon River, Alaska Territory, 42d Cong., 1st sess., S. Ex. Doc. 12, 1871.

[2] Schwatka, Frederick, Report of a military reconnaissance in Alaska made in 1883, 48th Cong., 2d sess., S. Ex. Doc. 2, 1885.

[3] Russell, I. C., Notes on the surface geology of Alaska: Geol. Soc. America Bull., vol. 1, pp. 99–162, 1890.

[4] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, pp. 87–392, 1898.

[5] Idem, p. 190.

western Alaska was prepared.[1] A map of the Kuskokwim-Yukon portage[2] was compiled from notes taken by F. C. Hinckley, one of Spurr's assistants, who crossed to the Yukon by way of the portage and thence down the Yukon to St. Michael.

In 1902 Collier[3] spent the season in an investigation of the coal resources of the interior of Alaska. Sidney Paige assisted him and made a canoe traverse from Eagle to Paimiut. Collier's report contains a map[4] showing the distribution of the coal-bearing terranes in the Yukon Valley. The base map is a compilation of previous surveys but includes also the results of Collier and Paige. In addition to gathering data regarding coal, Collier made extensive geologic notes which have been available to the writer in the preparation of this report. In order to make stratigraphic and paleontologic studies Arthur Hollick, with Sidney Paige as his assistant, revisited in 1903 the localities from which fossils had been obtained by earlier geologists. The results of their collecting have been available to later investigators and are being utilized in the preparation of the monographs by Hollick on Alaskan Cretaceous and Tertiary floras.

In 1907 W. W. Atwood, with H. M. Eakin as his assistant, undertook further studies and descended the Yukon as far as Holy Cross, where the season's work was closed. The following year Maddren[5] spent a portion of the field season in a study of the Innoko placers and made material contributions to the existing knowledge of the geology of the lower Yukon region. Maddren's explorations were followed in 1909 by the expedition of Smith and Eakin[6] between Nulato and Norton Bay and in southeastern Seward Peninsula. The results of these expeditions are of great value in the interpretation of the geology of the areas lying south and southwest of the regions traversed by them, but large areas that are geologically unexplored lie between the areas previously surveyed and that mapped in 1916.

The Marshall district had not previously been visited by any member of the Geological Survey, but notes on the mining operations on Wilson Creek and on the general conditions in that vicinity were obtained by H. M. Eakin in 1914[7] and by A. H. Brooks in 1915.[8]

Besides the investigations by the parties of the Geological Survey work has been done by members of the Coast and Geodetic Survey

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[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol Survey Twentieth Ann. Rept., pt. 7, p. 234, 1900.

[2] Idem, p. 98.

[3] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, 1903.

[4] Idem, p. 10.

[5] Maddren, A. G., Thes Innoko gold palcer district, Alaska: U. S. Geol. Survey Bull. 410, 1910.

[6] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, 1911.

[7] U. S. Geol. Survey Bull. 622, pp. 65-66, 1915.

[8] U. S. Geol. Survey Bull. 642, pp. 67-68, 1916.

in this and adjoining regions. Commencing in 1898 and extending over the following season, several parties were engaged in charting the shores off the Yukon delta, the mouths of the river, and the main river as far us as Andreafski.[1] The work along the river and the shores of Norton Sound was controlled by triangulation and includes some topographic as well as hydrographic mapping. The work of the Geological Survey party in 1916 was done in an area adjoining that covered by the earlier work of the Coast and Geodetic Survey parties, of which a portion has been used in the preparation of the accompanying topographic map (Pl. I).

In 1908 a series of magnetic stations along the Yukon were occupied by J. W. Green, of the Coast and Geodetic Survey, and magnetic and astronomic observations for latitude and longitude were made in the region covered by this report at Anvik, Holy Cross, Russian Mission, and Andreafski.

GEOGRAPHY.

LOCATION.

The Anvik-Andreafski region as described in this report embraces the territory west and north of the lower Yukon River between Anvik and Andreafski rivers and an extensive area of low-lying country immediately contiguous to the Yukon on its east and south sides. Extending from longitude 159° 40′ to 163° 20′ W. and from latitude 61° 30′ to 63° 40′ N., the area covered by the surveys in 1916 is approximately 2,000 square miles. The map of the Marshall mining district (Pl. II, in pocket) covers the area in which mining is being done.

NOMENCLATURE.

The history of the Anvik-Andreafski region throws light on the source of the names of the towns and topographic features. These names are in part in the tongue of the two native races that first inhabited the region. Later the Russian language furnished some names, and the advent of men of English-speaking races brought about other changes, modifying some of the earlier names and substituting new names for others.

So far as possible the names in most common use have been employed on the topographic maps (Pls. I and II, in pocket) and in this text. If both native and English names are known and both appear to be used to about the same extent, the native name is given preference. For a list of the names of the natural features in the vicinity of Marshall, many of them applied by the natives, the survey is indebted to Mr. Frank Waskey.

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[1] Coast and Geodetic Survey chart 9370, Cape Romanzof to St. Michael, Alaska.

In naming some of the creeks the English-speaking miners have exhibited the same poverty of vocabulary or lack of originality that is to be found in many other mining districts. The repetition of the commoner names for creeks, such as Spruce, Willow, Bear, and Flat, in almost every district in Alaska leads to such confusion that in order to be clearly understood it is frequently necessary to refer not only to the district in which the creek is found but to the larger stream to which the particular creek is tributary. It may even be necessary to name a third or a fourth stream into which the smaller one flows in order to make identification positive. It would seem to be false modesty which inhibits the discoverer of a creek from naming it after himself. His name applied to it usually has the double advantage of giving it individuality and of having historic value.

RELIEF.

GENERAL CHARACTER.

In general, the relief of the region is slight. The highest point attains an altitude of about 2,700 feet, and there are comparatively few small isolated areas lying above 2,000 feet. Along the west and north bank of the Yukon the surface is in places sharply dissected, but as a whole the forms are those of a mature topography, so that the country presents a rolling aspect. Wide, poorly drained lowlands occupy the intermontane areas.

UPLANDS.

The uplands are scarcely high enough to merit the term mountains, although here and there a point rises well above the general level and furnishes a conspicuous and easily identified landmark. Of this character are Bonasila Dome, Chiniklik, and Pilcher Mountain.

Bonasila Dome lies east of Stuyahok River and south of Bonasila River, and its isolation, together with its peculiar form (a cone on the crest of a gently crowning dome), gives it prominence from whatever point it is seen. It is sometimes called Simel Mountain.

The highest and most conspicuous peak in the region is that known by the guttural native name of Chiniklik, frequently corrupted by the whites to Cheneegly. It appears remarkable that so high a peak should be only 4 miles from the Yukon. It lies 8 miles above Russian Mission and 12½ miles below Tuckers Point. This mountain was seen from points along Anvik River, from Andreafski, and from practically all the intermediate stations except those at the water's edge on the banks of the Yukon. Its conical outline, with shoulders a few hundred feet below the apex, readily identifies it. This peak is visible from many points along the crest of the divide between the Yukon and Andreafski drainage basin and from points far south of the Kuskokwim.

Pilcher Mountain lies about 5 miles east of Marshall. It rises well above the immediately adjacent hills, and is topographically prominent because of the exceptionally well-developed altiplanation terraces on all sides but the southeast.

The areas occupied by the softer sedimentary rocks of Mesozoic age are everywhere, except near the Yukon, marked by the gentle slopes and rounded crests that are characteristic of a mature topography. Elsewhere the drainage is that of an area past maturity in the cycle of erosion, but the crests of the hills present a terraced appearance (Pl. *V*, *B*, p. 22). The origin of these forms has been described by Eakin,[1] who termed the process altiplanation. This feature is discussed further in connection with the Quaternary history (p. 55). The terraces are best developed in the areas of igneous rocks at the higher elevations. To a minor degree altiplanation has taken place in some areas of the more indurated sedimentary rocks, especially in the vicinity of intrusives.

LOWLANDS.

The lowlands may be subdivided into two classes—those that lie above the flood level of the Yukon and those that are reached by its highest stages of water. The lowlands of the first class occupy the broad erosional depressions that are characteristic of the region. Bedrock crops out along the streams only here and there—not at all for several miles above their mouths. Alluviation has proceeded so far that, except in their headward portions, the streams flow in meandering courses along which are many oxbow sloughs formed by abandoned meanders. In the lowlands that lie within the influence of the Yukon are to be placed the wide stretches which extend to the Kuskokwim east and south of the Yukon. On the larger tributary streams alluviation has lowered stream gradients to such an extent that they are controlled by the Yukon at all but the lowest stages. Five miles up the Bonasila the writer saw débris which undoubtedly came from the Yukon. It is therefore conceivable and even probable that the alluvial material that is now being laid down over the bottom lands along the lower reaches of this and other tributaries is derived in large part from the overloaded flood waters of the Yukon, which deposit a considerable portion of their burden in the slack waters of the embayments furnished by these stream mouths.

[1] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, p. 78, 1916.

DRAINAGE.

To the geologic structure was due the original position and direction of many of the streams, but other factors have affected their later history, and the former courses have been somewhat modified by alluviation and lateral erosion. The valley occupied by Stuyahok, Bonasila, and Anvik rivers affords an excellent example of stream trend initially controlled by the underlying bedrock structure, and the Yukon above Holy Cross trends in the same general direction. Structural control is also evident in the vicinity of Marshall and, at least in part, along the north fork of Andreafski River.

The region considered in this report lies wholly within the Yukon drainage basin, but the wide, flat, lake-dotted delta between the Kuskokwim and the Yukon, opposite and below Russian Mission, has so little relief that the watershed between the two rivers is difficult of location. So far as could be ascertained, there are few places, except near the coast, that rise even so high as 100 feet above either of the rivers. At high stages of water much of this lowland is inundated. During the spring of 1916 the small steamer *Tana* left the Yukon through a slough near Pilot station and, entering Kashunuk River, reached Bering Sea through Hazen Bay. Essentially similar conditions are to be found in the delta of the Innoko. At high water this river may be reached through any one of several mouths, from a point several miles above Anvik to the last slough, about 11 miles below Paimiut. Other tributaries of the Yukon enter from the west and north after passing through considerable delta areas, which are modified by overflow from the Yukon and truncation of their fronts by that river. Bonasila, Koserefski, Kuyukutuk, and Chvilnuk rivers and many of the smaller creeks enter the Yukon through sloughs. Lakes are characteristic of the flood plains of some of these streams throughout their lower reaches and were especially noted in the broad depression occupied by Kuyukutuk and Chvilnuk rivers, which resembles in this regard the region between the Yukon and the Kuskokwim.

CLIMATE.

The climate of the Anvik-Andreafski region is intermediate in character between that of the upper Yukon and the coastal region from Norton Sound to Bristol Bay. The proximity of Bering Sea has a stabilizing influence, so that the summer temperatures are not so high nor, as a rule, the winter temperatures so low as those of the upper Yukon, although north winds may occasionally bring about similar conditions in the two areas. From the records the precipitation appears to be greater in this region than at coast points and almost double that of points in the upper Yukon Valley. In any two consecutive seasons there is likely to be considerable difference in the amount of rainfall and in the times when precipitation takes place, but normally the greatest precipitation occurs after the middle of July. In 1916 records were kept from June 15 to September 10, inclusive. In the 40 days from June 15 to July 25 there was some precipitation on 21 days, or 52 per cent. In the 48 days from July 25 to September 10 there was some precipitation on 35 days, or 73 per cent.

Meteorologic observations are available for Holy Cross, the only station within the region at which records have been kept for any great length of time, but for comparison records are given for Tanana and Nome also in the following tables, compiled from data obtained from the United States Weather Bureau. Figures in the first three columns are for 1915 only. The other columns are a summary of observations extending over several years.

Records of temperature at Holy Cross compared with those at Nome and Tanana in degrees Fahrenheit.

	Highest in 1915.	Lowest in 1915.	Annual mean 1915.	Highest recorded.	Lowest recorded.	Mean of three summer months.	Mean of three winter months.
Nome	72	−36	....	78	−36	40 to 50	10 to 0
Holy Cross	81	−43	29.4	84	−57	50 to 55	0 to −10
Tanana	89	−48	25.2	90	−76	Over 55	−10 to −15

Dates of last freezing temperature in spring and first freezing temperature in autumn at Nome, Holy Cross, and Tanana, 1915.

	Last in spring.	First in autumn.
Nome	June 9	Aug. 21
Holy Cross	May 12	Sept. 9
Tanana	June 5	Aug. 29

Precipitation at Nome, Holy Cross, and Tanana.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Nome	0.87	0.69	1.13	0.43	0.70	0.85	1.21	2.83	2.10	1.27	0.67	1.07	14.82
Holy Cross	1.63	1.07	1.54	.56	.31	1.45	2.15	3.54	2.68	1.54	1.32	1.78	19.57
Tanana	.77	.62	.61	.20	.95	.73	2.01	2.42	1.18	1.04	.79	.65	11.97

Records of the time of opening and closing of the Yukon at Holy Cross have been kept for a considerable number of years, and there is probably normally very little difference between the dates at this point and others as far down the Yukon as Andreafski. These dates may be summarized as follows:

Ice began to run in spring between April 29 and June 1.
River clear of ice between May 21 and June 3.
Ice began to form in autumn between October 5 and October 16.
River closed between October 19 and November 3.

The rains are usually brought by southerly winds, and northerly winds prevail during periods of fair weather. The southerly winds are frequently of such force as to impede navigation seriously, as the steamboats are likely to be driven aground on some of the numerous bars of the river, and the seas caused by the wind make navigation dangerous for any small boat except a dory or one of the skin boats of the natives. The activity of the wind as an erosive agent was observed many times on the sand bars in the river, for as soon as the surface became dry the sand would drift before the wind and pile up in small irregular hummocks or dunes. Cross sections of dunes thus formed are exposed here and there in the cut banks of the Yukon.

VEGETATION.

Within the area crossed by the expedition of 1916 the conditions affecting vegetal growth are so diverse that a corresponding diversity of plant types is reasonably to be expected. In the vicinity of Anvik the lowlands are well timbered, although an approach to the tundra conditions found below Andreafski is presaged by the lowering of timber line compared with upper-river points. In the vicinity of Anvik, timber line is about 600 to 800 feet above the river, though in favorable localities, such as sheltered, well-drained valleys, it extends somewhat higher. No spruce was seen growing on the Yukon below Andreafski, but scattered stumps of spruce and an occasional straggling birch indicate a former scanty growth of these trees to elevations from 100 to 200 feet above Andreafski River. From the hills back of Andreafski small patches of spruce may be seen scattered through the cottonwood and willow thickets that extend along the Yukon above this point. The best growths of spruce are found along gullies, on slight eminences in the lowlands, or near the banks of streams. Farther back from the smaller streams in the lowlands, where drainage is poor, the growth is usually scattered and stunted. Wherever spruce is found on well-drained hill slopes, birch generally occurs also, together with small-leaved poplar or quaking aspen. Extensive growths of these trees are apparently less common than in the Tanana basin. On Anvik and Bonasila rivers the birch bark is used by the natives in making their canoes. Tamarack grows in very open groves in the more boggy places along the Anvik and Bonasila and was seen here and there along the Yukon.

Throughout the lower-lying portions of the area, cottonwood and several species of willow constitute the most common element of the forests. Some of the bars that have barely emerged from the river are covered with a dense growth of willows a few inches high.

In the driftwood along the river there appears to be less willow and cottonwood than spruce. From this it would seem that a considerable amount of the drift has come from points farther up the river, where the proportion of spruce is greater than it is within the Anvik-Andreafski region. It is probable, however, that the preponderance of spruce in the driftwood may be due partly to the fact that it rots less easily and is not so quickly waterlogged.

Alders are found throughout the region at considerably higher elevations than any timber trees. They cover the slopes, in places occurring almost at the crests of the hills or ridges, where some protection is afforded by the depressions in the headward portions of the streams.

Berries of some variety can be found in almost any part of the region. Blueberries are common on the fairly open slopes. Low-bush cranberries are found with them or at somewhat higher elevations and where there is little or no brush. The soft yellow salmonberry appears to grow at almost any elevation but seems to be most abundant in situations less well drained than those occupied by the other berries. The bitter high-bush cranberry was found in shady places along the river bank associated with red and black currants, which were also found on the drier, sunny slopes, together with red raspberries. Neither currants nor raspberries were seen in abundance anywhere.

Grasses are surprisingly plentiful in variety and amount everywhere in the region, so that horse feed could easily be obtained for outfits traveling by pack train, especially along the tributaries of the Yukon. On the Stuyahok there are many beautiful open parks containing luxuriant growths of grass, and at almost every point where a stop was made there was an abundance of forage. On the hilltops and most of the slopes a large part of the vegetal covering consists of mosses and lichens, but considerable horse feed is still to be found even here. On the river bars there is usually an abundance of the variety of *Equisetum* called mare's-tail, and occasionally the pea vine is found.

When the party left the field (September 13) there had been no frosts of sufficient severity to destroy the nourishing qualities of the grasses, but the season of 1916 was probably exceptional in this respect, and killing frosts may ordinarily be expected early in September.

Fairly extensive agricultural operations have been carried on for a number of years by the mission at Holy Cross. The native grasses in natural meadows on the flood plain of the Yukon below the mission are cut and cured for forage or are utilized as pasture. A considerable variety of vegetables are grown for private use. Any surplus is sold and finds a ready market along the river. At Anvik some gardening is done, and several varieties of vegetables mature. The season without frost appears to be slightly longer here than farther up the Yukon. Along the lower course of Anvik River are grass-covered areas almost wholly free from brush or timber. These natural meadows could doubtless be used for pasture or the grass cut for hay. Similar areas were seen on some other streams, but there appear to be few along the Yukon.

An attempt was made to procure a representative collection of flowers and grasses, so far as other work permitted, but no large shrubs or trees were obtained. The collection was submitted to the United States National Museum, and the following species were identified, the grasses by Mrs. Agnes Chase, the Pteridophyta by William R. Maxon, and most of the other specimens by Paul C. Standley:

FUNGUS.

Sphacelotheca hydropiperis borealis Clinton (on Bistorta plumosa (Small) Greene).

LICHENS.

Cladonia uncialis adunca (Acharius Flotow.
Cladonia deformis extensa (Hoffmann) Wainio.

MOSSES.

Drepanocladus uncinatus plumosus (Bruch and Schimper) Roth.
Polytrichum commune Linné (near var. uliginosum Hübener).
Polytrichum commune Linné.
Polytrichum strictum Banks.
Sphagnum fimbriatum Wilson.

POLYPODIACEAE.

Dryopteris dilatata (Hoffmann) Gray.
Dryopteris dryopteris (Linné) Britton.
Dryopteris fragrans (Linné) Schott.

EQUISETACEAE.

Equisetum arvense Linné.
Equisetum sylvaticum Linné.

LYCOPODIACEAE.

Lycopodium annotinum Linné.
Lycopodium complanatum Linné.

POACEAE.

Alopecurus alpinus J. E. Smith.
Calamagrostis canadensis (Michaux) Beauvois.
Festuca altaica Trinius.
Poa compressa Linné.

CYPERACEAE.

Carex canescens Linné.
Eriophorum angustifolium Roth.

MELANTHACEAE.

Tofieldia coccinea Richardson.
Tofieldia palustris Hudson.

JUNCACEAE.

Juncoides sp.

IRIDACEAE.

Iris setosa Pallas.

SALICACEAE.

Salix phlebophylla Andersson.

BETULACEAE.

Betula rotundifolia Spach.

POLYGONACEAE.

Bistorta plumosa (Small) Greene.
Bistorta vivipara (Linné) S. F. Gray.

Polygonum alaskanum (Small) Wight.
Rumex occidentalis S. Watson, form.

PORTULACACEAE.

Claytonia sarmentosa C. A. Meyer.

ALSINACEAE.

Arenaria arctica Steven.
Cerastium alpinum Linné.
Merckia physodes Fischer.
Moehringia lateriflora (Linné) Fenzl.

RANUNCULACEAE.

Aconitum delphinifolium De Candolle.
Anemone narcissiflora Linné.
Anemone richardsoni Hooker.
Batrachium aquatile (Linné) Wimmer.
Caltha palustris arctica (R. Brown) Huth.
Ranunculus reptans Linné.
Ranunculus sp., perhaps a new species.
Thalictrum sparsiflorum Turczaninow.

PAPAVERACEAE.

Papaver nudicaule Linné.

BRASSICACEAE.

Arabis lyrata intermedia (De Candolle) Wight.
Barbarea barbarea (Linné) MacMillan.
Cardamine pratensis Linné.
Draba borealis De Candolle.
Radicula palustris (Linné) Moench.

CRASSULACEAE.

Rhodiola alaskana Rose.

PARNASSIACEAE.

Parnassia kotzebuei Chamisso.
Parnassia palustris Linné.

SAXIFRAGACEAE.

Saxifraga hirculus Linné.
Saxifraga nelsoniana Don.
Saxifraga serpyllifolia Pursh.
Saxifraga spicata Don.

GROSSULARIACEAE.

Ribes hudsonianum Richardson.
Ribes laxiflorum Fischer.

ROSACEAE.

Argentina anserina (Linné) Rydberg.
Comarum palustre Linné.
Dryas octopetala Linné.
Potentilla nivea Linné.
Potentilla villosa Pallas.
Rosa acicularis Lindley.
Rubus arcticus Linné.
Rubus chamaemorus Linné.
Sanguisorba sitchensis C. A. Meyer.
Spiraea steveni (Schneider) Rydberg.

FABACEAE.

Lathyrus palustris Linné.
Lupinus arcticus S. Watson.
Oxytropis nigrescens (Pallas) Fischer.

GERANIACEAE.

Geranium erianthum De Candolle.

VIOLACEAE.

Viola biflora Linné.
Viola langsdorfii Fischer.
Viola palustris Linné.

ONAGRACEAE.

Chamaenerion angustifolium (Linné) Scopoli.
Chamaenerion latifolium (Linné) Sweet.
Epilobium davuricum Fischer.

APIACEAE.

Bupleurum americanum Linné.
Cicuta douglasii (De Candolle) Coulter and Rose.

CORNACEAE.

Cornus canadensis Linné.
Cornus stolonifera Michaux.
Cornus suecica Linné.

PYROLACEAE.

Moneses uniflora (Linné) Gray.

ERICACEAE.

Ledum decumbens (Aiton) Loddiges.
Loiseluria procumbens (Linné) Desvaux.
Phyllodoce caerulea (Linné) Grenier and Godron.
Therorhodion glandulosum Standley.

VACCINIACEAE.

Oxycoccus oxycoccus (Linné) MacMillan.
Vaccinium caespitosum Michaux.
Vaccinium vitis-idaea Linné.

DIAPENSIACEAE.

Diapensia lapponica Linné.

PRIMULACEAE.

Trientalis europaea arctica (Fischer) Ledebour.

GENTIANACEAE.

Gentiana glauca Pallas.

POLEMONIACEAE.

Polemonium acutiflorum Willdenow.
Polemonium humile Willdenow.

BORAGINACEAE.

Mertensia paniculata (Aiton) Don.

MENTHACEAE.

Mentha canadensis borealis (Michaux) Piper.

SCROPHULARIACEAE.

Castilleja pallida (Linné) Kunth.
Castilleja tristis Wight.
Pedicularis arctica R. Brown.
Pedicularis capitata Adams.
Pedicularis labradorica Panzer.
Pedicularis langsdorfii Fischer.

LENTIBULARIACEAE.

Pinguicula villosa Linné.
Utricularia vulgaris Linné.

RUBIACEAE.

Galium boreale Linné.

CAPRIFOLIACEAE.

Linnaea borealis Linné.
Viburnum pauciflorum Pylaie.

VALERIANACEAE.

Valeriana capitata Pallas.

CAMPANULACEAE.

Campanula lasiocarpa Chamisso.

CICHORIACEAE.

Hieracium triste Willdenow.
Taraxacum ceratophorum (Ledebour) De Candolle.

ASTERACEAE.

Achillea borealis Bongard.
Arnica lessingii (Torrey and Gray) Greene.
Artemisia arctica Lessing.
Artemisia tilesii Ledebour.
Aster sibiricus Linné.
Senecio resedifolius Lessing.
Solidago lepida De Candolle.
Solidago multiradiata Aiton.

ANIMAL LIFE.

Animal life is abundant, but there is little large game. Only one small black bear was seen, but the tracks of black bear were fairly common along the sand bars, and brown bear were reported. Neither caribou nor moose were seen, and it is said that there are none in this part of Alaska. Their former presence in great numbers is recorded by the earlier explorers, and on some of the ridges their trails are still visible. Domesticated reindeer are herded in the southern part of the region and small bands are pastured near Marshall and Andreafski.

Of smaller animals a few rabbits and foxes were seen. The tracks of the foxes were frequently observed along the river bars, where they had been stalking the aquatic birds. Beaver dams and houses were seen on the Stuyahok, and there was also evidence of the presence of ermine, mink, marten, and muskrats on this and other streams. To judge from their tracks, porcupines are fairly common: The red-backed mouse was frequently observed.

Ducks were seen almost constantly on the streams tributary to the Yukon. Geese were abundant on the Stuyahok and lower Bonasila, and in the fall they were seen in flocks of hundreds on Yukon and Andreafski rivers. Large flocks of ducks were also seen on the Andreafski, as well as smaller flocks of swans and cranes. Near the banks of the rivers some individuals of the several species of sandpipers, snipe, and plover were almost always in sight, busily engaged at the water's edge in search for food.

The land game-birds were exceptionally scarce. Ptarmigan were seen but twice, and only one grouse was seen during the summer. Other birds noted include loon, tern, gulls of several species, horned owl, hawks of several species, kingfisher, raven, three species of swallows, junco, three species of sparrows, varied thrush, hermit thrush, robin, warblers, waxwing, Canada jay, and shrike.

On clear-water streams that had a good current grayling were taken with a fly, and no difficulty was experienced in getting as many as were desired. Occasionally a trout was caught, but the trout seemed less numerous than the grayling. Fish wheels and fishtraps are used on the Yukon for catching salmon and whitefish. The salmon are smoked and dried or salted down to be eaten during the winter, by dogs as well as men. The whitefish are used largely as summer feed for the dogs. Trout, pike, and pickerel are also said to be taken by fish wheels or in nets. Considerable quantities of fish of various kinds are caught in large dip nets, which are handled with consummate skill by the natives. In winter whitefish are caught through holes in the ice by the natives, who use for bait an artificial minnow made of bone or ivory.

On Bonasila River large areas were noted where the willows and alders along the banks had been almost entirely stripped of their foliage by small worms, probably the larvae of a small black and white butterfly which was especially common. In places also the willows were infested with small black weevils, which were doing considerable damage.

SETTLEMENTS AND POPULATION.

A certain proportion of Alaska's inhabitants may be termed literally a "floating" population, and for many of them, both whites and natives, the act of changing their abodes in summer consists in loading their few necessities into boats of some description and traveling by water to places where employment may be had or where there exist more favorable conditions for obtaining food by hunting or fishing. A great number of the natives live in temporary fishing camps during the summer but assemble into villages in the winter. The population of many a mining camp is evanescent, and winter finds the workers greatly diminished in numbers, the quondam miner having become a prospector or trapper and sought other scenes for his activities, or he may have left Alaska for the winter, to return in the spring. The following statements as to the population of the Anvik-Andreafski region should be considered with these general conditions in mind.

There are permanent white residents at Anvik, Holy Cross, Marshall, and Andreafski, and a few others have trading posts or fishing stations at other points on the Yukon. There are also white teachers at Pilot station and Russian Mission. On Anvik, Bonasila, and Stuyahok rivers are cabins which are used in winter by prospectors and trappers. It is said that cabins have also been built for winter use on the Kuyukutuk, Chvilnuk, and Andreafski. Marshall is the point of transfer for the supplies for the mining camp on Willow Creek, about 7½ miles away, which is the largest center of population in the region. In August, 1916, none of the cabins on Wilson Creek, which lies between Willow Creek and Marshall, were occupied, although considerable mining had been done on its tributaries earlier in the season. The white population at Marshall and on Willow Creek in 1916 was about 225 and at all other points from Anvik to Andreafski, including these villages, about 35, a total of 260.

The natives are of two stocks. Those above Paimiut are affiliated with the Athapascans of the upper Yukon. Those at and below Paimiut are affiliated with the natives of the coast but show slight differences in dialect. At each of the towns in the region except Marshall the natives are more numerous than the whites. Many native villages are scattered along the Yukon, some of which are temporary and some permanent, having solidly constructed log houses, caches, and drying houses for the summer catch of salmon. There are no permanent native villages in the mountainous country on the west and north bank of the Yukon. Ruins of old deserted villages were seen on the Anvik, and early in the spring the natives make a trip up this river to fish and to build boats, but nothing like a permanent camp was seen. It is said that the natives also frequently make portages from the head of Mountain Creek to the headwaters of the Stuyahok to fish and trap on that stream, and they then drift down to the Bonasila and the Yukon to avoid the return portage. The native population includes about 200 at Anvik and along the Yukon between Anvik and Holy Cross, 200 at Holy Cross, and 300 in the Innoko delta. Between Holy Cross and Russian Mission there are about 70 natives, mostly at Paimiut. There are 150 at Russian Mission and in the villages between Russian Mission and Marshall. About 750 make their homes in the area between Marshall and St. Michael, and of these perhaps 120 are at Marshall and Andreafski and between these two villages. The total native population in the Anvik-Andreafski region is nearly 1,000, of which about 700 are of the upper river race and the others belong to the lower river or coast stock.

Schools have been established at many of the villages. Those at Anvik and Holy Cross are sectarian, and most of their students live in the school dormitories. Government schools are maintained at Russian Mission, at Pilot station, and in the Innoko delta at Shageluk. Two Government teachers are also attached to the mission school at Holy Cross.

COMMUNICATION.

In summer practically the entire region is accessible by boat. Steamboats afford a ready means of transportation on the Yukon and are run at intervals of a week to 10 days. On the Bonasila there is sufficient depth of water for steamboat navigation to the mouth of the Stuyahok, where soundings gave a depth of 13 feet. All the larger streams are navigable by poling boats or small launches for considerable distances from the Yukon. The Survey party in 1916 used a 30-foot poling boat equipped with a 2-horsepower engine of the detachable type. The boat usually carried a load of nearly a ton but experienced little difficulty in ascending the streams that were traversed and made good progress up the Yukon. An engine of higher power, however, is to be recommended for a boat and load of this size. A boat with greater freeboard than a poling boat is also desirable for use on the Yukon.

During the summer of 1916 a wireless station was erected at Holy Cross by the Signal Corps of the United States Army. This is the only telegraph station within the region, but there are stations at Nulato, Kotlik, and St. Michael.

During the summer there is a weekly mail service on the Yukon and throughout the year a monthly service between points on Kuskokwim River and on the Yukon to and above Russian Mission. During the period when navigation is closed there are five mails from St. Michael to Marshall (Fortuna Ledge post office) and intermediate points.

DESCRIPTIVE GEOLOGY.

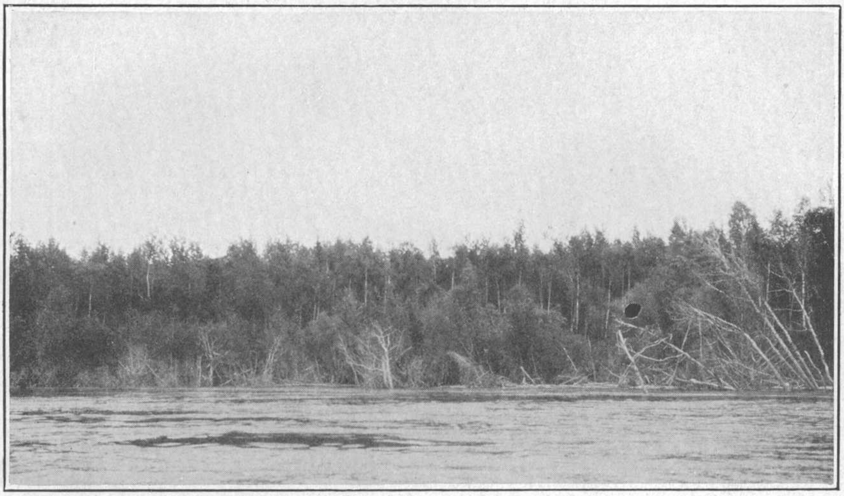
GENERAL FEATURES.

The principal rocks of the Anvik-Andreafski region are distributed essentially as indicated on the geologic maps (Pls. III and IV, in pocket). Much the same conditions prevail in this region as in many other parts of the Yukon basin, so that, although the general distribution of the several units is ascertainable, their exact boundaries are not readily determined. Contacts are almost universally obscured by Quaternary alluvium or by a mantle of residual material, produced by mechanical and chemical disintegration, which migrates down the slopes and effectually conceals the distribution of the underlying rocks. Comminuted rock débris derived in this manner covers the lower slopes (Pl. *V*, *B*) and merges into material of alluvial origin without perceptible break. It is obvious that in such places the boundaries of the alluvium must be generalized.

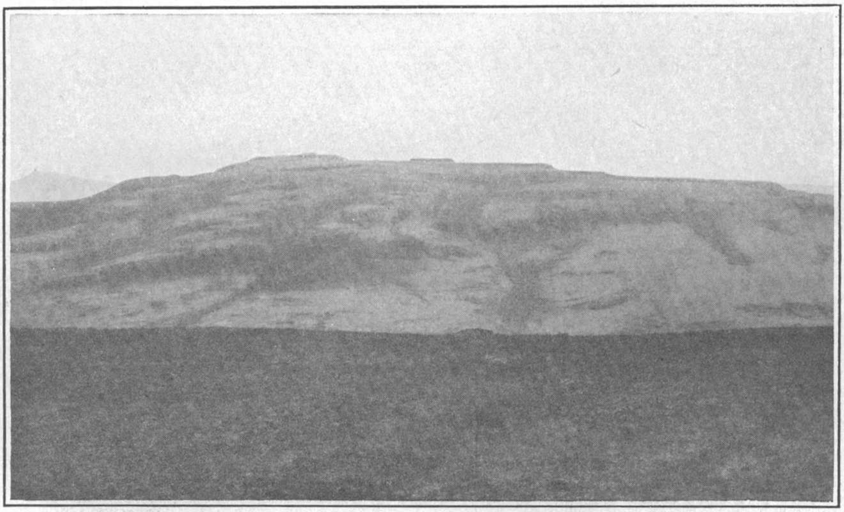
In reconnaissance work like that done in 1916 it is not possible to trace out formation boundaries so accurately that no assumptions need be made. Topographic form, color of rocks as seen from a distance, indications afforded by changes in type of vegetation, and other forms of evidence are considered, but inevitably there will be some error in detail, although the working out of the major relations may prove to be essentially correct.

In the vicinity of Marshall there is an area of metamorphic rocks which extend eastward to the Kuyukutuk and reappear along the Yukon below Russian Mission and still farther east between Mountain Creek and Koserefski River. Greenstones of a rather wide range in composition and origin, probably embracing intrusive rocks as well as flows and tuffs, make up a large proportion of these metamorphic rocks. Closely associated with the greenstones are slates, quartzites, and conglomerates and many intermediate rock types. The greenstones appear to have suffered the most intense changes, but secondary structure has developed in the sediments also. Undeformed acidic dikes cut both the greenstones and the sediments. Although the complete solution of the questions involved in the stratigraphic sequence of these rocks and their mutual relations must await more detailed study, it is now tentatively assumed that the greenstones, including the tuffs and some conglomerates which occur with them, are of late Paleozoic age and that the sedimentary rocks are the metamorphosed equivalents of the Cretaceous beds found elsewhere in this region.

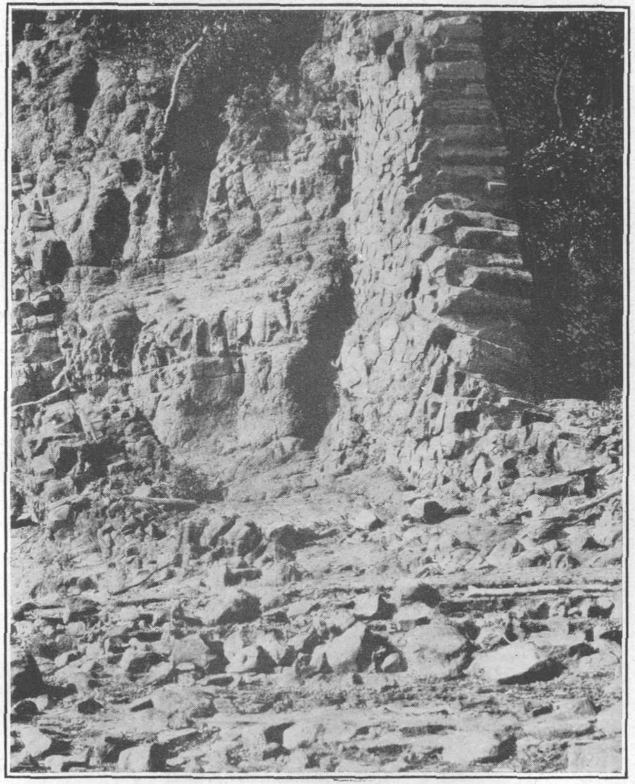
Cretaceous rocks were found on Anvik and Andreafski rivers and probably occupy much of the intervening area. The principal rock types found are conglomerates, sandstones, and shales, which have



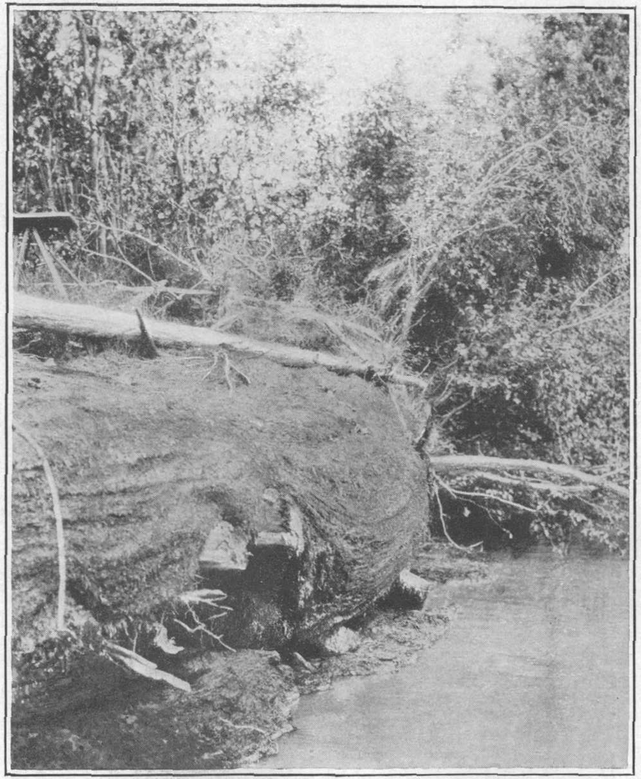
A. EROSIONAL EMBAYMENT IN THE BANK OF THE YUKON BELOW HOLY CROSS.



B. ALTIPLANATION TERRACES AND SOLIFLUCTION SLOPES EAST OF FAITH CREEK.



A. BASALT DIKE CUTTING HORIZONTAL BASALT FLOWS, 2½ MILES ABOVE INGRUMHART.



B. LOGS IN PEAT IN THE WEST BANK OF THE YUKON, 5 MILES BELOW ANVIK.

locally been metamorphosed into quartzites and slates. Though these rocks are generally thin bedded, with an extreme phase of alternating sandstone and shale layers less than half an inch thick, massive phases also occur in which the individual beds may be several feet in thickness. More or less closely associated with the Cretaceous rocks in the northern and eastern parts of the region are a series of tuffs and flows of intermediate basic types. Some of the flows appear to be intercalated with the Cretaceous sediments. In the southern part of the region are a number of dacitic porphyry dikes of late Cretaceous or post-Cretaceous age. It is probable that some of the intrusions in the vicinity of Marshall took place at the time these dikes were formed.

No sediments of known Tertiary age were found in the area, but at somewhat widely separated points vesicular lavas occur as undeformed horizontal flows (Pl. VI, *A*), which are either late Tertiary or early Quaternary. Quaternary deposits are found throughout the region. They include the residual mantle or rock and soil on the higher hills and slopes, the gravels, sands, and silts of the terraces and lower hills, and the alluvium that occurs along the stream courses almost to their heads but is most extensive in the lowlands of the Yukon and its larger tributaries.

CARBONIFEROUS GREENSTONES AND ASSOCIATED SEDIMENTS.

AREAL DISTRIBUTION.

Metamorphosed tuffs, flows, and intercalated sedimentary rocks, together with some rocks that may represent altered basic intrusives, occur at a number of places in the Anvik-Andreafski region. In the vicinity of Marshall they form a considerable portion of the bedrock along the divide between Spruce and Wilson creeks, on the south and west slopes of Pilcher Mountain, and on the south slope of the range of hills to the east of this mountain. This series of rocks also appears at four other localities between the mouth of Koserefski River and Marshall, outcrops being found below Russian Mission, in the vicinity of Bareface Bluff, above Tuckers Slough, and for a short distance along the Yukon at the mouth of Koserefski River.

LITHOLOGY.

A large proportion of these rocks are igneous, but rocks of sedimentary origin make up a minor part of the series. Only in the vicinity of Bareface Bluff are the sediments notably abundant. In the area between Paimiut and Tuckers Slough a few thin beds of conglomerate are intercalated with the flows. The conglomerate pebbles consist mainly of igneous material, with lesser amounts of chert. Green tuffaceous grits and sandstones also occur at this locality in similar relations to the flows. Small chert grains are fairly numerous in some of the coarser-grained beds. Here and there thin beds of argillitic sand separate the flows. Below Russian Mission occur some grits, the grains of which are almost wholly gray and black chert. In the rocks near Bareface Bluff greenish tuffs and tuffaceous sandstones are associated with red cherts and argillites as well as with greenstone flows.

Near Marshall this series is represented, so far as observed, only by greenstone flows and intrusive rocks, and the associated sedimentary rocks are presumably younger. Several rather widely different types, ranging from schists to massive rocks, are included under the term of greenstones. At the bluff below Marshall the greenstones are extremely schistose, much contorted, and netted with quartz veins, which have also been subjected to deformation. One of the quartz veins noted is 6 inches or more in thickness. At Marshall the deformation appears to have been less intense, although a schistosity which gives the impression of bedding has been developed. Elsewhere on the slopes of Pilcher Mountain and along the ridge east and west from Mount Okumiak the rocks appear gneissoid rather than schistose, with some massive phases in which but little secondary structure has been developed. These various phases appear very different in the hand specimens, but under the microscope nearly all prove to be epidote-amphibole rocks, practically the entire rock being made up of these minerals, with a moderate amount of magnetite and here and there small amounts of quartz or chloritic minerals. Less frequently pyroxene and plagioclase feldspars may be determined.

These rocks are all recrystallized, and there is some doubt as to their original nature, but they probably represent a metamorphosed series of andesite or basalt tuffs and flows which have included some gabbroic intrusives. This conclusion as to the origin of the greenstones is confirmed by their composition at the localities below and above Russian Mission, where they have not been subjected to such intense metamorphic processes and their original nature is more readily determinable. The tuffs and flows are largely basaltic, with augite and labradorite as their principal constituents and magnetite as the chief accessory mineral. Some of the flows are a little more siliceous, the feldspars having the average composition of andesine, and the rock is an andesite. Secondary minerals have been developed to some extent, mainly by the alteration of minerals containing iron, forming hornblende, chlorite, or serpentine. Glass is found in some of the tuffs.

Intrusives in the greenstone series occur at a number of places in the vicinity of Marshall, where they cut the Cretaceous rocks also. (See Pl. IV, in pocket.) Soda granites and quartz diorites make up the larger stocks, and the numerous dikes are dacites. They are discussed under the heading of "Igneous rocks" (pp. 44–47).

STRUCTURE.

The structure in the greenstone areas is rather complex. To some extent it has been induced by the intrusives which have cut the series, but for the most part it is related to broader orogenic features. The intrusion of the soda granite that forms the core of Pilcher Mountain probably produced the complex structure in the area north of Wilson Creek and caused a general doming effect in that area. The structure south of Wilson Creek is open to two interpretations and may have been produced either by close folding or more probably by faulting. The outcrops in this area are massive and afford few structural data. It is notable that the drainage of this area is controlled by bedrock structure. Between Russian Mission and Grand Island the structure can not be determined, mainly on account of the massive nature of the rocks, both the flows and the associated sediments showing no deposition planes. They are, however, much jointed, and along the joint planes considerable movement has taken place.

The sedimentary rocks above and below the mouth of Kako Creek contain prominent joints and are in many places broken by conspicuous faults. Locally the stresses are adjusted by movements along bedding planes, but the effects of such movements are not pronounced. For the most part these rocks have a northeasterly strike and a northwesterly dip, conforming to the regional trends. Both the topography and the rock attitude suggest that they are separated by faults from the sedimentary series in the vicinity of Dogfish Village.

Where their attitude is determinable the greenstones above the entrance to Tuckers Slough strike northeast and dip steeply to the northwest. It appears likely that this dip is reverse, and that the flows represent an overthrust upon the younger sediments. Faulting has been extensive, across as well as along the flow planes and bedding planes of intercalated sediments. The contact with the sediments lying to the southeast and up the Yukon is complicated by faulting, apparently with some intershearing, so that no sharp line between the two series can be drawn. At the mouth of Koserefski River these rocks are massive and the outcrops afford no evidence of their attitude, but, as in other localities, they have been faulted. The general arrangement and distribution of the greenstone areas, flanked on either side by younger sediments derived from the greenstones, suggests an earlier easterly folding upon which has been superposed a northerly or northeasterly structural trend, which now predominates. Between Marshall and Russian Mission cross faulting has been sufficient to produce great offsets. (See Pl. IV, in pocket.)

AGE AND CORRELATION.

The greenstones and intercalated sediments are the oldest rocks in the region and represent the source of a considerable amount of the material which makes up the Cretaceous beds. No additional evidence from this region as to their position in the geologic column is at hand, and correlations must therefore be made with other near-by regions where more information is available. Maddren[1] describes similar rocks, here correlated with the greenstones, on the north side of the Kuskokwim, 6 miles above Ohagamut, where there is a gradation downward from tuffs through tuffaceous limestones to pure crystalline limestones. Fossils of Artinskian or late Carboniferous age were obtained in the tuffaceous limestones, and it is therefore evident that this period of geologic time was marked by the inception of the volcanic activity which resulted in the formation of the greenstone series.

CRETACEOUS SEDIMENTS.

AREAL DISTRIBUTION.

Sediments of Cretaceous age are widely distributed throughout the lower Yukon Valley. In the Anvik-Andreafski region they appear about the margins of areas of uplifted older rocks and doubtless occupy much more territory than is indicated on the geologic map (Pl. III, in pocket). They probably underlie considerable portions of the drainage basins of Anvik, Hawk, Chvilnuk, and Andreafski rivers and possibly that of the Golsova also. The rocks on the headwaters of Bonasila River are probably Cretaceous, and the sediments associated with the flows and tuffs on the Stuyahok are believed to be of the same age. Tuffs and flows which may be late Upper Cretaceous or early Tertiary occupy considerable areas in the Anvik, Bonasila, and Stuyahok basins and appear also along the Yukon, forming the hills along its west bank immediately below Anvik and below the mouth of the Bonasila.

The sedimentary rocks associated with the greenstones near Marshall have been considerably metamorphosed but, aside from the secondary metamorphic features developed in them, are not essentially

[1] Maddren, A. G., The mineral resources of the middle Kuskokwim region, Alaska: U. S. Geol. Survey Bull. — (in preparation).

different from the Cretaceous beds, of which they are believed to be the metamorphosed equivalents, and with which they are mapped. (See Pls. III and IV, in pocket.)

LITHOLOGY AND STRATIGRAPHY.

The sediments of this period exhibit a great diversity in lithology. Conglomerates and fine-grained argillites represent the extremes in texture, but sandstone and argillites are the most common rock types. Grits are fairly common in some parts of the area, and in places are of considerable thickness.

Some of the conglomerate appears to be basal and made up of pebbles of the older metamorphic rocks, greenstones, and chert predominating. Quartz pebbles and cobbles are found in these conglomerates but only in small amount. Here and there are intraformational conglomerates a few inches in thickness in which rounded white quartz pebbles form almost all the larger rock fragments. On account of the light color of the material forming these beds, débris from them is much more conspicuous than that from other rocks, and they appear to be more widely distributed than is indicated by the number and width of the conglomerate beds seen in outcrops.

In the basal portion of the Cretaceous sediments sandstones appear to constitute the dominant lithologic type. There is, however, every gradation between the conglomerates and the sandstones, both in size and in character of grain, and locally the grits attain considerable prominence. The individual grains of the grits are fragments of greenstone, chert, or other rocks, as well as quartz and feldspar in greater or less amount. Feldspar is found in varying amounts in almost all the sandstones. In some rock phases the feldspar grains appear to be as numerous as those of quartz. The ferromagnesian minerals appear in a few places, but they are as a rule largely, if not completely, altered to secondary minerals. Small grains of chert or slate are discernible in thin sections of some of the sandstones. Calcite is apparent in most sections in amounts ranging from a few small grains, which may represent replacement near fissures, to fairly large areas in which some of the calcite was probably deposited as grains with other rock constituents, although much of it may represent later replacement or deposition from solution.

The finer-grained rocks comprise both siliceous and argillaceous types, as well as gradational phases between the two. Some of the siliceous rocks are so fine grained and so badly altered that only a small proportion of the grains, mostly quartz with some plagioclase feldspars, can be readily determined. The argillaceous beds show several phases, of which some are due to differences of induration and some to differences in composition. The least indurated beds were called mudstone in the field. They range in thickness from a few inches to several feet, and one of their most common characteristics is the occurrence of numerous ellipsoidal nodules, from some of which successive layers may be removed. These nodules are presumably of concretionary origin, although possibly due to processes of weathering. The more strongly indurated argillites have closely spaced cleavage planes and break up into angular faceted blocks, in places forming the so-called pencil slates. True slates, which break up into thin plates with parallel surfaces, are only occasionally found.

It is not possible to make an approximation of the thickness of the Cretaceous rocks within this region, as no continuous section from the base to the top of the series is exposed. Faulting, largely of the normal type, is common, and there is probably much repetition of beds in outcrops on this account. Nevertheless there are several localities in which the section exposed is from 300 to 700 feet thick, and lithologic differences in these sections are sufficiently great to warrant the belief that they represent different portions of the series. If this belief is correct, the minimum thickness for the Cretaceous is at least 2,000 or 3,000 feet, and the maximum may be 10,000 feet or more.

LOCAL FEATURES.

ANVIK RIVER.

Mudstones or consolidated shales are the most characteristic deposits along Anvik River. Some of these shales display in a very pronounced manner the ellipsoidal nodules already mentioned. The rocks are characteristically gray to very dark gray, and in many places they have a greenish tinge. On weathered surfaces red, yellow, and brown tones are pronounced. Fine-grained siliceous rocks, locally cherty, occur with the mudstones.

The sandstones are not so massive as those farther south, 6 to 8 inch beds between shaly layers being the most common, although sandstones 5 feet or more in thickness are occasionally found. These are almost universally gray with a greenish tinge, which may be lacking, however, on some leached beds that appear cream-colored on the surface.

Thin sections examined show a considerable amount of plagioclase feldspars, of which albite is the least altered. In many sections the more basic feldspars are not readily recognizable on account of the amount of decomposition they have undergone. Many of the beds are calcareous. In some a large amount of the matrix is calcite, and apparently some of the basic plagioclase feldspars also have been replaced by calcite, of which the lime radicle has been chiefly derived from the decomposition of the feldspars.

KOSEREFSKI RIVER TO MOUNTAIN CREEK.

Above Holy Cross, and on the west and north bank of the Yukon opposite Paimiut, coarse-grained clastic rocks predominate. Conglomerates, grits, and sandstones alternate locally in beds 100 feet or more in thickness or in massive beds whose attitude and thickness are not determinable from the outcrops. Argillites of considerable thickness are present here and there, but more commonly the argillite occurs as thin beds or partings in the other rocks, especially near Paimiut. Most of the pebbles in the conglomerate consist of green, black, or gray chert, but pebbles of gabbroic or basaltic rocks are rather common. The grits are essentially the same in composition as the conglomerates, representing a greater comminution of material from the same source. Similar material is found in the sandstone, of which quartz, feldspar, and chert grains are the principal constituents. All these coarser-textured rocks show on exposed surfaces a predominance of rounded forms, which have probably been produced by exfoliation. The rocks are all indurated, and some of the more quartzose sandstones might better be termed quartzites and others graywackes.

The argillitic rocks are gray to nearly black indurated shales, some of which contain small amounts of carbonized material. The argillites contain many closely spaced partings at various angles, so that the débris resulting from their breaking down is mainly in angular fragments. Some of the rock that breaks down into elongated fragments is called pencil slate. True slates are not common in this area.

DOGFISH VILLAGE.

Fine-grained rocks predominate along the Yukon from the mouth of Mountain Creek to a point below Dogfish Village. They are largely siliceous and include cherts and quartzites as well as some fine-grained quartzites containing a considerable amount of argillaceous or possibly tuffaceous material. Associated with the finer-grained rocks are a few beds of grits and conglomerates, but the pebbles of the conglomerates are mostly not over an inch in diameter. A large proportion of the pebbles are of green and horn-colored chert.

In the range of hills north of Dogfish Village a great many dacite porphyry dikes intrude the sedimentary rocks. These dikes have probably increased the induration in the siliceous beds, rendering them more resistant to erosion than rocks in adjacent areas, so that the highest peaks in the region are found within these rocks at a comparatively short distance from the river.

DEVILS ELBOW.

A rather wide lithologic range appears in the outcrops along the north bank of the Yukon between Grand Island and Round Point. Sandstones and argillite, comparable to those of the Cretaceous areas above discussed, are included in the series, which contains, in addition, however, many fine-grained siliceous and argillaceous sediments of somewhat different character. These sediments are thin bedded for the most part, and in places show numerous alterations of the two principal phases. Some of these beds are light colored, in places nearly white on the weathered surfaces; other beds are green or brown or darker gray. Where these differently colored beds occur together, as opposite the island about 2 miles below Toklik, the appearance of ribbon banding is pronounced. It is probable that some of the green bands may represent altered ash beds or tuffs. The sequence of the beds is not wholly clear, but there seem to be fairly good structural grounds for considering these rocks younger than the sandstones and argillites.

It was noted in this small area of Cretaceous rocks more conspicuously than elsewhere that the exposed sections of small ridges that are truncated by the river commonly show the effects of weathering on both the upstream and downstream sides near their bases. This weathering is made conspicuous by the rusty red color of the residual material formed by the decomposition of the hard rocks. Decomposition has progressed so far that it is not always possible to determine the contact of the rocks with the overlying silts where the entire section is exposed. In the centers of the truncated sections the rocks are weathered comparatively little, erosion proceeding so rapidly that it almost keeps pace with weathering.

MARSHALL.

In the area where mining operations are being carried on near Marshall greenstones of various types predominate, but there are some sedimentary rocks that are considered Cretaceous. Their distribution is shown approximately on the geologic map (Pl. III, in pocket). In this area sandstones and argillites have been altered to quartzite and slates, and conglomerates carrying quartz pebbles have been subjected to pressures so great that the pebbles have been sheared and distorted. Cherts are interbedded with the other sediments, both light and dark gray varieties being seen either in outcrop or in the gravels on Disappointment Creek.

The sediments are cut by a number of dikes and larger intrusive bodies of acidic rock, which are discussed under the heading "Igneous rocks" (pp. 44–47.)

CHVILNUK AND ANDREAFSKI RIVER BASINS.

In the basins of the lower Kuyukutuk, Chvilnuk, and Andreafski rivers the carving of the stream valleys has been greatly facilitated by the occurrence of an easily eroded bedrock. Both the Kuyukutuk and the Chvilnuk flow into a slough of the Yukon after passing for a considerable distance through the Yukon flood plain. Similarly, Andreafski River and its east fork flow in rather wide valleys and join after reaching the flood plain of the Yukon. It is probable that the wide valleys of these streams are also due partly to the fact that they were formed when the base level of erosion was much lower than it is now.

Along the route traversed the Cretaceous rocks appear for nearly 2 miles below the mouth of the Chvilnuk, and are succeeded on both sides of the river by Quaternary river-laid sands and flood-plain deposits, which extend to the mouth of Andreafski River. Here the Cretaceous beds reappear and extend up the main Andreafski as far as the traverse was carried, and it is known that they form the hills along the north bank of the Yukon for several miles below the mouth of the Andreafski.

The rocks near Pilot station are slightly different in some phases from those seen elsewhere. Some of the beds show striking alternations of sandstone and argillite laminae. Lenticular sandstone layers appear in the argillites. The argillitic material is usually so nearly black that in the talus it resembles " bloom " from a coal seam. Some of the sandstones are highly calcareous.

Movement along bedding planes has been common in this area, and in certain localities slickensides appear on practically all the bedding surfaces. In the black argillites graphite and sericite occur along the slickensides.

Along the Andreafski conglomeratic phases are more common than near Pilot station. They appear generally in sandstones several feet thick, and the pebbles have a maximum diameter of about 2 inches. Some of the pebbles are white vein quartz, but more of them consist of argillitic material. The argillite pebbles have a poor cleavage, which has been developed since the formation of the conglomerates.

The argillitic rocks are mainly slaty, but they include some fossil leaf-bearing beds that have suffered comparatively little metamorphism, being scarcely more indurated than well-compacted shales. Closely spaced joint cracks, however, cause the rock to break up into angular fragments and make it difficult to obtain determinable leaf imprints. In the sandstones the leaves are represented only by a very faint smear of graphite and the stems by indeterminable compressed carbonized rods. Besides the leaves, some of the argillitic beds also contain distorted casts of invertebrates, and in a few places the two fossil types occur together. This association, together with the alternation of rock types and the presence of well-preserved fossil ripple marks, is indicative of near-shore or shallow-water deposition.

STRUCTURE.

Massive bedding is the general rule for the sandstones, grits, and conglomerates and is found in some of the argillitic rocks as well. In some of the coarser rocks the bedding planes are not determinable, but in the finer-grained clastic rocks slight textural or color differences make them apparent. In places a thin band of argillite appears between heavy beds of sandstone or grit.

In consequence of the deformation to which the entire series has been subjected, jointing is practically universal, but naturally the joint planes are more closely spaced in the argillites than in the sandstones and grits, so that talus from the argillites is composed of small angular, faceted pebbles, whereas that from the sandstones and grits is made up of large boulders. Locally metamorphism has been so intense as to convert the argillites to slates that have a typical platy cleavage, mostly parallel to the bedding.

The sandstones show in many places a slight tendency to assume rounded forms, between joint cracks, which is attributed to exfoliation through weathering. In the argillites a somewhat similar feature may be due in part to weathering, but the exceptionally well-developed ellipsoids sometimes formed are probably concretionary.

Deformation has been most severe in the vicinity of Marshall, but exposures there are not sufficient to indicate the attitude of the beds. Elsewhere sections along the Yukon and its larger tributaries afford opportunity for studies of the structure. The dips for the most part are less than 45°, but on the Anvik and on the Yukon below Toklik beds standing vertical or having reverse dips were seen. The beds strike mainly in a northerly or northeasterly direction, but near the Devils Elbow some northwesterly strikes were measured. The older greenstones are in general flanked on both sides by Cretaceous sediments dipping away from the greenstones or by possibly Cretaceous tuffs and flows, a distribution of outcrops that suggests an anticline whose crest has been truncated by erosion. Accompanying minor open folds are seen in outcrops between Akahamut and Ohogamut. In the group of hills north of Dogfish village there are cross folds in which the nearly vertical beds strike almost at right angles to the river and to the general trend of the formations. Near Marshall either close folding or faulting is indicated by the distribution of lithologic units and the arrangement of drainage lines. It is probable that both folding and faulting have taken place, for the rocks in the few exposures at Marshall and at the bluff below appear much faulted and exhibit crumpled and crenulated surfaces.

In no part of the region do the Cretaceous rocks appear undeformed, but except as noted above the stresses have been relieved by the formation of open folds and by faulting, mostly of the normal type. In nearly all outcrops faults along planes nearly perpendicular to the bedding were observed, and although many of these are of comparatively small throw, the occurrence of others having throws ranging from several feet to possibly several hundred feet and of numerous faults along bedding planes, which are not so readily apparent, is indicative of the magnitude of the stresses to which the region has been subjected.

AGE AND CORRELATION.

Fossil plants were collected at several localities within the Anvik-Andreafski region, on Anvik River, on the Yukon between Holy Cross and Paimiut, and on the Andreafski about 11 miles above its mouth. Invertebrate fossils were found in the same bed as plant fragments on Andreafski River about half a mile above its mouth and were also obtained near the fossil-plant locality farther upstream. The fossil plants were examined by F. H. Knowlton. Those from the Anvik and Yukon river localities are indeterminable. Concerning the collection from the east bank of Andreafski River 9.2 miles northeast of Andreafski he reports as follows:

7250. Fragments of bark and wood. Also fragments of dicotyledons of two kinds, with little or no margins preserved. I also note *Podozamites lanceolatus* and *Taxodium* sp. I am free to confess that I am not able to place this lot satisfactorily, though there would seem to be no doubt of its being Cretaceous. If it depended on the *Podozamites* I should incline to put it well down in the Cretaceous, but the dicotyledons indicate that it can hardly be older than middle Cretaceous.

Determinations of the invertebrate fossils were made by J. B. Reeside, jr., as follows:

9774. 16 A Ha 134. East bank of Andreafski River 9 miles northeast of Andreafski:
   Small unios of three or four probably undescribed species.
   Fragment of gastropod.

9775. 16 A Ha 135. East bank of Andreafski River 9.2 miles northeast of Andreafski:
   Sphaerium sp.?
   Unio sp., small forms like those in lot 9774.
   Goniobasis sp., fragments of a sharp-keeled form and of a multilineate form.
   Viviparus sp., fragments of a high-spired form and of a stout low-spired form.

9776. 16 A Ha 140. West bank of Andreafski River 1.5 miles below Andreafski:
   Ostrea sp., small unsculptured form.
   Fragment, apparently of a large pelecypod with a sculpture like that of some species of Inoceramus.

Collections 9774 and 9775 contain the same fauna of fresh-water pelecypods and gastropods. The unios do not differ essentially from forms collected by Collier, Atwood, and Hollick along the Yukon at and below Nulato. All are probably undescribed. The same is true of the gastropods, specimens collected by Collier, showing no appreciable differences. The fauna is supposed, on physical grounds, to be Cretaceous, though in itself it does not afford conclusive evidence of its age, for the types represented are of long range.

Collection 9776 contains a form of *Ostrea* inseparable from material collected by Hollick near Nulato and represents a brackish-water fauna. No such forms are known in the Tertiary of the entire region, and this lot also is probably Cretaceous, though the fossils alone are not sufficient proof.

Other collections made in 1902 by A. J. Collier, in 1903 by Arthur Hollick, and in 1907 by W. W. Atwood and H. M. Eakin include specimens obtained along the Yukon from a point near the mouth of Melozitna River to a point about 10 miles above Anvik and probably represent the same series of rocks as those found in the Anvik-Andreafski region. The plants from these collections were studied by Hollick, who summarizes them as follows:

There is a complex mixture of floras, not only from locality to locality, but also in many of the individual collections. Localities of lower or middle Cretaceous strata alternate with localities where the beds are of Upper Cretaceous or possibly of Tertiary age, some of them only a few miles distant from each other, and some of the collections contain floral elements so diverse that it is impossible at present to correlate them satisfactorily with any known or described flora. There can be no doubt that the collections in at least two of the localities indicate strata as old as lower-middle Cretaceous; the others indicate strata which are either Cretaceous or questionably as young as basal Eocene.

Marine and fresh-water invertebrates from the same region have been determined by Stanton to be mainly of Upper Cretaceous age. The wide distribution in near-by regions of known Cretaceous rocks that are lithologically similar to those in this region, together with the corroborative evidence of the fossils found, even though they were obtained at rather widely separated localities, and only those collected on Andreafski River are of stratigraphic value, affords grounds for the belief that the consolidated sedimentary series as a whole is of Cretaceous age. So far as has been determined, however, the entire Cretaceous section may be present, together with basal Tertiary deposits. It is not impossible that Triassic or Jurassic rocks occur in the areas mapped as Cretaceous, but no evidence of such age for any of the rocks was found.

Some of the effusive rocks on Anvik River appear as intercalated flows, presumably near the top of the series, and are therefore late Upper Cretaceous or early Tertiary. These flows are believed to belong to essentially the same period of igneous activity as the extravasation of the flows, the deposition of the tuffs in the Bonasila basin, and possibly the intrusion of the earlier Cretaceous sediments by dikes of acidic rocks.

Cretaceous rocks are widely distributed elsewhere in western Alaska, and probably have a greater areal extent than all other consolidated deposits in this general region. From the Kobuk southeastward to the Melozitna and southward to Nulato and Norton Sound, as well as along the west bank of the Yukon still farther south, both Lower and Upper Cretaceous rocks are found. South of the Yukon they crop out in an area extending from the headwaters of the Nowitna and its tributaries to and far south of the Kuskokwim, including the Innoko and Iditarod districts. South of the Kuskokwim volcanic rocks appear in the series. Cretaceous strata occupy considerable areas on the Alaska Peninsula, where sedimentation was apparently uninterrupted during the transition period from Upper Cretaceous to early Tertiary time. Evidence of the wide distribution of the Cretaceous rocks elsewhere in Alaska is afforded by their presence along the north front of the Endicott Range, in the Yukon-Tanana region, in the Chitina Valley, and in southeastern Alaska. Close correlation of the Cretaceous of the Anvik-Andreafski region with that of other regions should not yet be attempted. It is, however, safe to make broad correlations and to state that the deposits of the entire lower Yukon Valley were laid down in the same or adjacent basins during Cretaceous and Eocene time. A concept of the conditions of sedimentation in great embayments, with alternations of periods of quiescence, subsidence, and occasional elevation of the land surface, affords a means of understanding how such a series of rocks might have been formed.

TERTIARY SEDIMENTS.

As suggested above, a portion of the sediments mapped as Cretaceous may be early Tertiary. If this is true, however, the Cretaceous and Tertiary localities can be separated only through the finding of determinative fossils, as the rocks of the two systems, if both are represented, are lithologically similar.

It is likewise possible that the series of tuffs and flows intercalated with the sediments at one locality on Anvik River may be Tertiary. Together with the intrusives below Holy Cross, these rocks are considered in the foregoing description of the Cretaceous rocks, for they are of the same age as rocks supposed to be Cretaceous. The effusive and intrusive rocks are considered as belonging to the same period of igneous activity, although no direct evidence to support this inference was seen. No sediments known to be of Tertiary age were found. It is likely that during Tertiary time, especially during the later part, the present topography was outlined, although the base level was considerably lower than at present and the relief was greater. Only terrestrial deposits were formed, and these have been almost, if not entirely, removed by Quaternary erosion or covered with the products of erosion.

At two localities sediments occur which may be of Tertiary age. Near the mouth of the small creek entering Andreafski River about 200 yards below the post office at Andreafski is a very small exposure of blue clay which differs from any Quaternary deposits seen. On the Yukon 2½ miles above Ingrumhart gravel beds are overlain by basaltic flows, but as the pebbles of the gravel are similar in composition to the overlying flows, the presumption is that they belong to the same period as the lavas. No direct evidence is at hand as to the possible Tertiary age of either the clay or the gravels. No fossils were found in either place, and the relations of these beds to other rocks are such that they might be either Tertiary or Quaternary. They are described in connection with the Quaternary deposits.

QUATERNARY SEDIMENTS.

AGENCIES AND PROCESSES.

The unconsolidated deposits found in this region are of many types and owe their presence to different agencies and processes. Silts and gravels that lie at elevations well above the present stream courses undoubtedly were laid down in part as deltas in embayments at a time when much of the region was inundated. On reelevation of the land surface drainage lines were again established. It appears likely that for the most part the courses of present streams are those of the period following the reelevation. These streams have laid down alluvial deposits of gravel, sand, and silt, the extent of which is generally limited by the flood plains, so that along the smaller streams the deposits are but a few feet in width, whereas along the Yukon and its larger tributaries they extend for many miles.

On the higher hills and ridges the products of comminution by mechanical and chemical forces form a mantle over much of the surface, either as soil, as talus, or as broken residual rock débris. So completely do these deposits conceal the underlying rock that the nature of contacts and the attitude of individual beds are obscured.

Vegetation serves to hide still further the nature of the material upon which it grows, especially on all but the steepest slopes in the untimbered areas, where lichens, mosses, and grasses make up a protective mat and in some places form peat beds that may be several inches thick.

Practically the entire region is thus mantled with Quaternary deposits which mask what lies beneath. Bedrock is as a rule seen only along the streams and at or near the crests of hills or ridges.

Many of the outcrops on hills or ridges cover only small areas and are so much affected by creep or jointed by frost as to be of little service in the interpretation of structure.

The Quaternary deposits as mapped include only the older silts and recent alluvium, not the residual mantle of soil, talus, and rock débris or the covering of peat, which are not mapped. Although the older silts and recent alluvium are described separately, they are mapped together, as sufficient data were not obtained to map them individually. There is not everywhere a topographic break between the older and younger sediments, and contacts that are not exposed in cuts along the banks of streams are masked by vegetation.

Between the higher-lying residual soil or talus on slopes and the silts or alluvium there is generally no sharp line of demarcation and apparently every stage of gradation in topographic form exists. As a consequence the boundary lines as drawn between the areas of water-laid deposits and of bedrock are of necessity approximations.

OLDER SILTS AND GRAVELS.

In the valleys of Bonasila and Anvik rivers and at numerous places on the Yukon and one locality on the Andreafski are silt and gravel beds which lie at considerable elevations above the present stream courses. These deposits were noted in sections along streams almost 300 feet above sea level. The exposure usually has the appearance of a dissected terrace, sloping back from the top of the section at a very low angle. Above such terraces and farther back from the drainage courses rise still other terraces to elevations of about 600 feet, in which no sections were seen. It is significant, however, that rocks crop out but rarely below 600 feet, except along stream cuts, and that outcrops are considerably more common above this elevation. Sections of the older gravels and silts are not especially common, even along streams, but exposures were seen in many parts of the area and afford evidence of the widespread distribution of such sediments.

At Anvik silts cover the underlying bedrock, which is exposed only along the river beach. Two miles up Anvik River sand and silt make up the bluff that rises steeply about 100 feet above the river. Farther upstream they appear to merge with the present flood-plain deposits of the Anvik. About 4 or 5 miles below the mouth of the Beaver a small stream enters the Anvik from the east. For a quarter or half a mile above its mouth the silts form a bluff 20 to 30 feet high, into which the river is cutting. At the upper end of the bluff bedrock is exposed in a much weathered outcrop, which is overlain by weathered gravels, and these grade within a short distance into the conformably overlying silts. On the Stuyahok a bluff was noted in which the gravels occurring at the upper end grade downstream into finer material. At the upper end of the outcrop practically the entire section consists of gravel; a few hundred feet downstream gravels and sands are interbedded; still farther downstream practically the entire section is fine sand or silt. On the lower Bonasila the river cuts against the low hills between Bonasila and Anvik rivers, giving exposures of 30 feet or more of fine sands and silts. On the Anvik side, hills of similar material rise sharply 150 feet or more directly from sloughs of the Anvik.

Between Anvik and Russian Mission the older unconsolidated deposits are seen in few exposures, but well-developed terraces such as are associated with these deposits elsewhere appear at several levels. Of these terraces the one at 600 feet seems to be the most persistent. Along the hill facing the river erosion has removed not only the unconsolidated sediments but considerable of the underlying bedrock, and it is only in the small lateral valleys that the sediments remain and appear as terraces. Much the same conditions are found below Russian Mission, but the exposures are somewhat better. In the small slough about 2 miles below Russian Mission at least 200 feet of silts are exposed in what appears to be an old bedrock depression. On either side of this exposure silts to a depth of several feet overlie the bedrock, as if the old depression has been filled to the level of its banks, and sedimentation had then continued over both the filled depression and the adjacent low hills.

At several places farther down the river essentially similar features may be seen, the gravels and silts that fill the lateral tributary valleys still persisting. Such deposits are especially noticeable 2 miles below Toklik, where 15 to 20 feet of silt and fine sand appear above 50-foot exposures of the Cretaceous rocks. From the upper edge of the silt exposure to the crests of the flat-topped hills 150 to 200 feet above the river the slopes are less steep and are covered with vegetation. It seems likely that these hills represent silt terraces on the fronts of the hills farther back from the river. Similar terraces are seen near the Cross Slough but are less distinct elsewhere, as at Marshall, on account of the much gentler slope of the bedrock.

On Andreafski River terraces are only faintly indicated. The dark-gray or blue-gray mud and clay banks of the stream are in places 15 to 20 feet high and possibly represent the products of flood-plain deposition, though they may be older. The gravels seen at the end of the Survey traverse, 8 or 10 feet thick where exposed, may also be river borne or they may be the basal beds of the older gravels, sands, and silts, but no sections were observed here or elsewhere on the Andreafski of a nature to confirm the suggestion as to this occurrence which the terrace forms present.

Near the mouth of the small stream below the warehouses of the Northern Commercial Co. at Andreafski is a small outcrop of light blue-gray clay. Its age and origin are wholly in doubt. It may represent a remnant of late Tertiary sediments but appears more likely to be Quaternary and equivalent to the older gravels and silts or to more recent river-laid sediments.

The exposure of gravels under the flows above Ingrumhart is discussed in connection with the Quaternary igneous rocks. (See p. 49.)

The most satisfactory explanation of the origin of these high-lying unconsolidated sediments is afforded by the hypothesis that an inundation of the region covered points now 600 feet or more above sea level and that the gravel, sand, and silt represent the deposits laid down by the advancing sea and reworked by the retreating sea during the period of emergence. From the occurrence of deeply buried valleys such as those on the lower courses of Anvik, Bonasila, Koserefski, Kuyükutuk, and Chvilnuk rivers and some of the smaller streams it is evident that at the beginning of the period of inundation the base-level of erosion was lower and the land stood considerably higher above the sea than at the present time. The record of the inundation and filling in of depressions below the present land surface is concealed by the sediments laid down at that time and by the later alluvial deposits. If elevation and subsidence took place fairly uniformly over the entire region, as is indicated by the presence of terraces at the same elevation at widely separated localities, the outlines of the sea at successive stages may be closely approximated from the topographic map (Pl. I, in pocket). From Russian Mission to the Kuskokwim as well as west to Bering Sea the deltas of the Kuskokwim and Yukon were inundated, and embayments reached far up these streams and their tributaries. At successive stages of the inundation deltas were formed in the embayments at the mouths of the streams, and the delta deposits are now represented by gravel beds such as those on the Stuyahok or on the Anvik above the mouth of Yellow River. Beach deposits were formed along shore lines at about the same levels, and these may be represented by the gravels near Anvik. Fine sands and silts were laid down in the deeper water of the embayments. Deposits of this type form the plain through which the lower Stuyahok, Bonasila, and Anvik rivers now flow. The fine and unconsolidated nature of the material facilitated the rapid cutting of the stream courses in adjustment to new grades, and later erosion by lateral cutting has produced wide valleys and flood plains intrenched in these older sediments. None of the other large streams were traversed by the Survey party, but it seems likely from the evidence afforded by the low terraces along the Yukon as far down as Marshall that inundation occurred there under the same conditions as elsewhere, and that similar deposits will be found in the valleys of Kuyukutuk and Chvilnuk rivers.

No direct evidence was found in the region as to the age of these deposits, except that there is generally no sharp line of demarcation between them and the products now being formed by residual decomposition, solifluction, alluviation, and other processes.

Silts and gravels essentially similar in character to those in the Anvik-Andreafski region are said to be widespread throughout the lower Yukon and Koyukuk valleys.[1] The best exposures of these deposits along the Yukon are in the Palisades below Tanana and the high silt bluffs about 8 miles below Louden telegraph station. No such sections have been noted in the Innoko and Iditarod valleys, although Maddren[2] mentions silt banks 30 feet high on the lower Innoko, but the occurrence of 50 to 70 feet of muck above 5 to 20 feet of gravel on Poorman and Flat creeks, in the Ruby district,[3] and of 70 feet of muck above 30 feet of gravel on Boob Creek, in the Innoko district, indicates that processes other than alluviation were active in those areas. These deposits and those on the Yukon are attributed by the writer to inundation, the agency that caused the formation of the silt and gravel beds in the Anvik-Andreafski region.

The fresh-water Pleistocene invertebrate fossils found in the silt at the Palisades are presumed to have lived in a fresh-water estuary at an early stage of the inundation. In the silts above Anvik Gilmore[4] collected remains of Pleistocene mammals, finding bones of mammoth and bison about 5 miles above Hall Rapids, and W. C. Chase, of Anvik, found the lower jaw of *Elephas* near Grayling. Gilmore also mentions a reported Pleistocene fossil locality on the Yukon-Kuskokwim portage. Other such localities in the vicinity of a lake south of Andreafski and a lake near Fort Hamilton were reported to the writer. A large bone fragment seen at Andreafski was said to have come from the locality near old Fort Hamilton. The Pleistocene mammal bones found by Gilmore near Hall Rapids were similar to others[5] found by him at the Palisades, on the Nowitna, and at other places in the Yukon basin. Similar fossils were seen by the writer

[1] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, pp. 53–63, 1916; The Cosna-Nowitna region: U. S. Geol. Survey Bull. 667, pp. 35–36, 1918. Mertie, J. B., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. — (in preparation). Gilmore, C. W., Smithsonian Misc. Coll., vol. 51, No. 1807, 1908.

[2] Maddren, A. G., The Innoko gold placer district, Alaska: U. S. Geol. Survey Bull. 410, p. 58, 1910.

[3] Mertie, J. B., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. — (in preparation).

[4] Gilmore, C. W., op. cit., p. 12.

[5] Gilmore, C. W., op. cit.

on many of the creeks in the Ruby district. This fauna serves to correlate the silt in the localities where evidence of it is found and to furnish evidence of its Pleistocene age.

Shell fragments were also reported as having been found in test pits during the course of prospecting on the flats near Willow Creek. These were not seen by the writer, but from the description given they appear to have been marine.

MODERN STREAM DEPOSITS.

Throughout the region the streams are transporting and laying down gravels, sands, and silts, representing reworked older material of similar texture, either of alluvial or marine origin, as well as soil and other comminuted products of chemical and mechanical disintegration. In all the streams except the Yukon the water is clear, except as it is discolored by vegetable matter or, during flood stages, by silt and sands. It appears likely that part of the deeper-lying gravels found in prospecting on some of the streams were formed at an earlier time and possibly by other agencies, but further study will be required to determine these points. The creek gravels along some of the streams near Marshall are discussed under "Mineral resources" (pp. 59–63).

In the lower reaches of the rivers tributary to the Yukon gradients are low and stream velocities appear to be controlled largely by the stage of water in the master stream. This feature is well displayed by Bonasila River. On July 6, 1916, the current in this stream was barely perceptible even at 20 miles above the Yukon; two weeks later, when the Yukon had fallen 6 feet or more, the current in the Bonasila was noticeable almost to its mouth. During stages of high water the silt-laden Yukon overflows its own lowlands and those of many of its tributaries and deposits most of the fine sands and silts. As a result the banks of the lower reaches of these streams are made up wholly of silt, largely deposited by the Yukon. Farther up the tributaries the silts are the result of flood-plain deposition by the streams themselves, and although the banks may be 6 to 12 feet high, they usually contain sand and gravel layers near the base, and gravel bars are normally found at bends in the streams. Oxbow sloughs and lakes, resulting from the cutting through of meander loops, are of common occurrence in the flood plains. Nearer their heads the stream gradients increase, the flood plains become narrower, and the alluvial deposits include more and more gravels and sand.

The sediments laid down by the Yukon are more striking than those of the smaller streams. Stages of water 30 or 40 feet above the normal are reported, and for many miles along the river the banks are not over 20 feet high. On the left bank flood-plain deposition reaches back several miles from the river, but on the right bank the river cuts bedrock at many places, so that flood-plain deposits on this side are usually of small extent. The rate of deposition by the Yukon was very well shown in a cut bank at the edge of a marsh near the mouth of the Bonasila. In this bank thin bands of vegetal material alternate with beds of fine sand and silt from a quarter of an inch to 3 inches in thickness. In a section of 3 feet about 50 such silt beds appear; and as each layer of vegetal material probably represents the growth of one season, or possibly two, and each layer of sediments represents the deposition during the period of overflow, mainly in the spring, it seems reasonable to presume that the time required for the accumulation was approximately 50 years, or 250 years for the accumulation of the sediments represented in the 15 feet exposed in the cut bank. Conditions appear to have been exceptionally favorable for sedimentation and preservation from erosion at this place, and it does not follow that sedimentation is proceeding at this rate everywhere in the region. At several places, however, the steamboat channels have changed considerably in the last 15 or 20 years, the old channels having filled up so as to be impassable to the larger boats, and sloughs have been cut through to form new channels. Thus Poltes Slough at Marshall is now used by the steamboats and is rapidly cutting a larger channel, while the much larger old channel is being so rapidly filled that none of the steamers now follow it. Above Paimiut the main stream formerly flowed to the north of Horse Island, but it now flows south of the island, and the old channel is filling. At the Devils Elbow similar filling has taken place; the middle slough, formerly used by steamers, is no longer passable, and the large loop of the elbow is the principal channel, although some of the largest boats pass through Cross Slough.

The sediments of the Yukon are mainly fine sands and silts, and little gravel is to be found except at the mouths of small streams entering the river from the right. Ice-rafted pebbles from these gravels may be seen here and there on bars or on the left bank of the river. Below Dogfish village some of the streams have built gravel deltas out into the Yukon. The sediments that were laid down from waters flowing with considerable velocity consist mainly of sand, as in the numerous bars covered at high water and the flood-plain sands near the banks of the streams. Quartz and feldspar grains are the principal minerals, but a few deposits contain some mica. The sand was tested wherever the banks were sufficiently dry and was found to contain some magnetite. Below Russian Mission a considerable amount of magnetite was seen in the sand, and this is thought to have caused the local magnetic disturbance that affected the needle of the alidade compass.

The finer silty material is laid down in slack water and forms most of the deposits in depressions away from the river, or in the shallow dead water found in places along one bank, as on the south side below Paimiut, where mud 2 or 3 feet deep forms the wide beach between the steep banks cut at high water and the water's edge at normal and low stages.

ORGANIC DEPOSITS.

On all but the steepest slopes in this region the underlying rock or soil is covered by vegetation, for the most part moss or lichens, although in some places grasses and other plants predominate. At high elevations, where there is usually fair drainage, vegetal accumulations are slight in amount. On gentle slopes or on the crests of rounded ridges mosses and lichens, together with leaves and grasses, form a practically continuous mantle, which is, however, generally not more than a foot in thickness over any extensive area. On flat-topped hills, under favorable conditions, these accumulations may reach slightly greater thicknesses. The most extensive deposits, however, are formed along the poorly drained areas within or slightly above flood plains. In such situations the conditions for growth seem to be most favorable and accumulations of peaty material are common. For the most part these deposits are formed from the same plants as those at higher elevations, but grasses and sedges and some aquatic plants occur in greater amount, and trees that float in during high water or, growing on the deposit, fall and form a part of it are of common occurrence. Many sections of these deposits are exposed. One of the best exposures seen appears in the bank of the Yukon above the Bonasila. Here the brown peat is at least 5 feet thick and contains many spruce logs, which have been broken off flush with the surface of the bank by floating ice. (See Pl. VI, *B*, p. 23.) The logs appear but little rotted. The peat is layered, and some partings of silt or fine sand appear in it, the result of deposition at flood stages of the river when the peat was being formed. No such deposits were seen on any of the tributary streams, although well-consolidated beds of peat over a foot thick are fairly abundant.

In the eddies of the Yukon at high water driftwood often forms piles on the banks which are several feet high, and in 1916 the banks of one or two sloughs were covered with logs two or three deep. Here and there a log was embedded in the bank, but no suggestion was seen of any such piles becoming thick enough to form on alteration beds of lignite. It appears likely that for the most part these logs are picked up during periods of rising water of successive high-water stages, carried along for a time, and then dropped when the water falls.

None of the deposits of peat appear to have any present value, in view of the abundance of timber in the areas where the peat is found.

IGNEOUS ROCKS.

GREENSTONES.

Carboniferous greenstones occupy large areas in this region, but the rocks are intermingled with sedimentary deposits and are described in connection with the sediments on pages 23–26.

SODA GRANITES, QUARTZ DIORITES, AND DIORITES.

At a number of places below Russian Mission large dikes or sills and still larger bodies of stocklike form have intruded the greenstones and the younger sediments. Such intrusions occur just above the native villages of Kaka and Ohogamut. Between Spruce Creek and the Kuyukutuk there are several larger areas of soda granites, the largest of which forms the core of Pilcher Mountain. The next largest area is at the head of Willow Creek and extends from a point near the forks at claim No. 5 above Discovery almost to the crest of the ridge. Owing to the covering of soil, rock débris, and vegetation it was not determined whether this body is continuous with those to the west at the heads of Owl and Slope creeks and to the east at the head of McNeill Creek. Some of these areas are believed to represent separate intrusive masses and have been so mapped.

Along the bank of Poltes Slough, both at Marshall and a short distance below the mouth of Wilson Creek, there are some sheared gneissoid dikelike bodies that approach quartz diorites in composition, but their original texture has been destroyed and it can not be positively stated whether they are of igneous or sedimentary origin. Similar gneissoid material was seen in the talus southwest of Pilcher Mountain and on the north slope of Mount Okumiak. Along the edges of the intrusive masses at the heads of Slope and Owl creeks evidence of shearing is found in the secondary structure which has been developed. Except as stated above, the texture and appearance of these rocks is essentially granitic, with only an occasional suggestion of gneissoid structure.

At the end of the Survey traverse on Anvik River a small cropping of diorite was seen, but its relation to adjacent rocks was not determined. Similar rocks were seen in small areas east of Mount Okumiak, and on account of their lithologic similarity to the quartz diorites and the small size of the exposures, they are mapped with the quartz diorites and soda granite.

Considerable variations in mineral composition are found from place to place, but these are believed to be only such as are normally to be expected. Quartz is not abundant, being usually less in quantity than the feldspars, though everywhere present in moderate amount except in the diorites. The feldspars are all plagioclase, of which oligoclase-albite appears to be the most abundant, but it is almost invariably associated with albite or with andesine. Other members of the plagioclase series which may be as basic as labradorite are occasionally seen. Magnetite is usually found in small amounts. Apatite occurs in some of these rocks, especially in those in which there are graphic intergrowths of quartz and feldspar. Biotite is less common than hornblende or pyroxene. Secondary minerals have developed at the expense of the feldspars and ferromagnesian minerals and include epidote, chlorite, calcite, and green hornblende, which have given most of the rocks a greenish tinge.

These intrusives are all younger than the greenstones, and some if not all of them are younger than the members of the sedimentary series between Windy Point and Marshall, which have been provisionally mapped as Cretaceous. There may thus be two series of igneous rocks of very similar chemical composition; on the other hand, there is a possibility that the sediments mentioned are early Mesozoic and that but one period of igneous activity is represented. It is believed, however, that intrusion occurred during two periods, to the earlier of which belong the gneissoid dikelike bodies near Marshall and the intrusive mass forming Pilcher Mountain, as well as some of the intrusives eastward from Mount Okumiak, and to the later of which are to be assigned the bodies of soda granite near Kaka and Ohagamut, together with some of those near Willow Creek, which are believed to be contemporaneous with the dacite dikes in the Marshall district and in the vicinity of Dogfish village, as well as with the andesite and dacite tuffs and flows farther north. As is stated below these andesites and dacites are probably of early Tertiary age. They show little or no deformation. The fact that some of the soda granites are undeformed, though other rocks resembling them closely in composition and occurring in the same area are much deformed, is taken as evidence of two periods of intrusion, the earlier of which is pre-Cretaceous. This conclusion is supported by the occurrence of grains of oligoclase-andesine and pebbles of vein quartz in the Cretaceous sandstones and conglomerates on the Andreafski. The feldspar must have been derived from a pre-Cretaceous medium-silicic rock, such as a diorite or quartz diorite, and the vein quartz was derived from veins accompanying the intrusive. Such quartz veins appear at the bluff below Marshall. They have suffered deformation comparable in amount with that suffered by some of the diorites and granites, and it may reasonably be inferred that the veins accompanied these intrusives.

The degree of metamorphism and the fact that some of the Cretaceous sediments were derived from rocks of similar composition therefore appear to justify the assumption that some of the soda granites and the quartz diorites are pre-Cretaceous in age and may be correlated with the late Middle Jurassic quartz diorites in the Talkeetna Mountains described by Paige and Knopf [1] and may represent the great granodiorite intrusion which occurred along the Pacific coast and along the axis of the Alaska Range at about that time.[2]

DACITES AND ANDESITES.

The later igneous rocks north of Anvik are basalt, but those south and west of this point appear to be more siliceous, dacite and andesite dikes, flows, and tuffs being found along Yukon, Stuyahok, and Bonasila rivers. The andesites occur mainly as tuffs and flows near the Yukon between Anvik and the mouth of the Koserefski and as flows on the Bonasila and Stuyahok. In the Stuyahok basin dacites were found as glassy flows in undetermined associations with andesite. In the sedimentary area north of Dogfish village and in the vicinity of Marshall numerous dikes of dacite cut the older rocks. Dacite pebbles found on the bars on Andreafski River about 12 miles above its mouth indicate that intrusives of this type occur also west of the Marshall district.

On account of their close associations the dacites and andesites in the Stuyahok basin could not be separately mapped, although it is recognized that many essential differences exist between these rock types. Both are porphyritic, but there is a wide range in groundmass texture, that of some of the dacite flows being glassy and that of the dikes being distinctly granular. Between these two are gradational textural phases. For the most part the andesites are porphyritic, with microgranular groundmass.

The andesites are dark gray, some of them with a green tinge, and many of them can not readily be distinguished from basalts. It is believed, however, that as a rule they weather in lighter colors than the basalts. A lighter gray, in places tinged with light green,

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, p. 20, 1907.

[2] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 250, 1906.

is characteristic of the dacite dikes, and this coloring, with their porphyritic habit, exhibiting numerous quartz phenocrysts, serves to distinguish them from other igneous rocks found in this region. In the dacite flows the colors are also light, ranging from very pale yellow to a light rusty brown. Fresh surfaces appear gray, locally with a greenish tinge. Quartz phenocrysts are more prominent in the flows than in the dikes, especially on weathered surfaces.

In mineral composition the dacites appear to be the porphyritic equivalents of the soda granites. The most common feldspar is oligoclase, but there is a range from albite-oligoclase to andesine. Pyroxene phenocrysts are prominent on freshly broken surfaces. Under the microscope magnetite is usually found in small grains. Biotite appears in a few places. Secondary alteration products include epidote, chlorite, green hornblende, and calcite, together with sericite from the alteration of feldspars. Andesine, augite, and magnetite are the chief constituents of the andesites except that some contain also numerous grains of olivine, which show a strong tendency to weather to serpentine. Otherwise the secondary minerals are the same as those produced by the weathering of the dacites.

It is not possible to make definite statements as to the age of the dacites and andesites, which are held to be of the same age as the soda granites. There are, however, two points of reference. The dacites have cut the Cretaceous rocks, and the andesites are cut by the basalt dikes, so that if, as has been assumed, the dacites and andesites are of the same age, they were formed sometime between the end of Cretaceous sedimentation and the extravasation of the basalts, which probably occurred in late Tertiary or early Quaternary time.

Similar rocks, to which a Tertiary age has been assigned, occur in the Ruby-Kuskokwim region,[1] and it is believed that they represent a phase of the Tertiary igneous activity which prevailed over western and southwestern Alaska and are to be correlated with the andesites and dacites of the Anvik-Andreafski region.

BASALTS.

DISTRIBUTION.

Basaltic flows appear in the low bluffs near Russian Mission and overlie basaltic gravels in the still lower banks at and above Ingrumhart. The hills between Ingrumhart and Engineer Creek consist of lava, and it is probable that other low hills between Engineer Creek and Russian Mission are made up of a continuation of these same

[1] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region: U. S. Geol. Survey Bull. — (in preparation).

flows. Basalt flows occupy the small area mapped on the west bank of Bonasila River, and basalt dikes and sills cut the andesitic tuffs along the Yukon below the mouth of the Bonasila. On Anvik River some basalt dikes, flows, and tuffs are associated with the sedimentary rocks. In one exposure an argillite bed lies between two flows. The most extensive areas of these rocks are found below the mouth of Goblet Creek and above the mouth of Yellow River, and in these areas the basalts appear to consist of a series of successive flows, with which some sedimentary rocks occur in unknown association. Basalt dikes, sills, and tuffs occupy some smaller areas, most of which are indicated on the geologic map.

LITHOLOGY.

A large proportion of the basalt flows are vesicular, but they show a wide variation in the amount of cell space. Some are fairly dense, with vesicles few and small; others are extremely porous. Some of the flows are amygdaloidal. A number of the dikes seen above Ingrumhart are vesicular; others 4 or 5 feet thick are more dense and display columnar structure. These dikes probably represent the vents through which the latest extravasations took place. At the lower end of this exposure the flows rest upon gravels which range from cream-colored to rusty red. The pebbles are basalt and represent the products of an interflow period of erosion.

The feldspars are mostly labradorite, although in some specimens that contain large phenocrysts and smaller laths some of these laths are andesine or andesine-labradorite, and these appear to represent rocks intermediate in composition between the typical basalts and the pyroxene andesites. Augite is the most common of the mafic minerals, but in places olivine is conspicuous and here and there it alters to serpentinous aggregates. In weathered rock chlorite is developed. Magnetite is universally present. Some flows are amygdaloidal and the cavity filling consists largely of calcite, but some opaline quartz was also noted.

AGE AND CORRELATION.

It is not impossible that more than one period of volcanic activity is represented by these rocks. Only along the Yukon do the exposures afford an indication of their relative age. Elsewhere the relations are obscure and give little additional data bearing on this point.

There appears to be an intercalation of flows and sediments on Anvik River, where the sediments are presumably of late Cretaceous or early Tertiary age. Above Holy Cross the undeformed basalt dikes and sills are intrusive in andesitic tuffs that are believed to be of Tertiary age. From these relations the maximum age of the basalts appears to be late Cretaceous or early Tertiary. At and below Russian Mission the flows are nearly horizontal (Pl. VI, *A*, p. 23) and undeformed, and their attitude indicates that they, as well as the dikes above Holy Cross, have not been influenced by the deformation that probably marked the end of the Eocene epoch. They have not been subjected to any local warping and show no faulting or folding.

Although it is recognized that other explanations are possible, the gravels between the flows above Ingrumhart seem best accounted for by the hypothesis that they represent beach gravels laid down at a stage of the Quaternary inundation and subsequently covered by flows that were poured out during this stage. Some evidence as to the character of the flows is afforded by irregularly rounded weathered lava surfaces at the level of the present river beach a few hundred yards upstream, suggesting the ellipsoids produced by submarine flows. These rounded surfaces may have been produced by other agencies, however, so they afford no positive proof of the littoral origin of the flows.

More definite evidence is at hand regarding the minimum age of the basalts, which in a few localities are overlain by a mantle of Quaternary silts and are therefore older than the silts.

Elsewhere in western Alaska similar rocks are rather widely distributed. Collier's unpublished notes on the geology along the Yukon contain many references to basaltic tuffs, dikes, and flows between Kaltag and Holy Cross. Smith and Eakin[1] state that the vesicular lavas of the Reindeer Hills and Besboro Island "probably mark a connecting link between the well-known volcanic flows of St. Michael on the south and of the Koyuk Valley on the north." Moffit[2] describes considerable areas of basalts on Seward Peninsula in the valleys of Kuzitrin, Noxapaga, and Koyuk rivers. Some of these flows show very fresh ropy surfaces, which have been only slightly affected by weathering. The age of the youngest effusives is considered to be Pleistocene or late Pliocene, but that of the older flows is more doubtful, because the age of the youngest sedimentary rocks, upon which they rest, has not been determined.

It thus appears that volcanic activity extending over a considerable period of time has occurred not only in the Anvik-Andreafski region but in other regions farther north. The evidence at hand shows that some of the eruptions were separated by considerable intervals of erosion, yet it seems unlikely that in any one locality

[1] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, p. 72, 1911.

[2] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 247, pp. 31-35, 1905.

volcanic activity occurred even spasmodically throughout the period between the times of extravasation of the oldest and youngest lavas. More probably in each locality volcanic activity was confined to a relatively short period and therefore was not exactly synchronous with the activity at other centers.

Criteria are lacking at most of the localities to determine the time at which the lavas were extruded, and it is only possible to say that although they may have been extruded in late Cretaceous, Tertiary, or Quaternary time it appears probable that most of them are late Tertiary or early Quaternary.

GEOLOGIC HISTORY.

Too many facts are missing to permit the writing of the complete geologic history of this region. Fossils give only a single point of reference upon which an outline may be drawn, and all other historical data must be obtained from lithologic relations, from the structure, and from the amount of metamorphism of the rocks within the region, or, if these facts are lacking, by correlation with formations outside the region. Nevertheless, an attempt is here made to summarize such points as are known or may be surmised from the studies that have been made in this and near-by parts of Alaska.

PALEOZOIC TIME.

Nothing is known of the history of this region prior to late Carboniferous time. At that time at least a portion of the region was a land surface upon which flows were poured out, while in the near-by marine basins were laid down deposits consisting largely of tuffs, which in places alternate with conglomerates, sandstones, and even argillitic rocks. These deposits afford an indication of the changing relations of land and sea areas while sedimentation was going on.

In other portions of Alaska[1] a crustal movement took place at the beginning of the Permian epoch, and the pre-Cretaceous movement in this region may well have occurred at the same time. The result of this movement was a general east-west structural trend which is indicated by the general trend of the greenstone areas.

MESOZOIC AND EARLY CENOZOIC TIME.

The extent of the Permian orogenic movements is in doubt, but in the absence of known Triassic or Jurassic sediments it seems likely that they produced ranges of considerable elevation.

Through early Mesozoic time destructional processes were active. Periods during which there were extensive movements, accompanied by granitic intrusions, alternated with periods of quiescence in which erosional agencies were active in reducing the land surface to base-

[1] Brooks, A. H., op. cit., p. 265.

level. Neither marine nor terrestrial deposits of early Mesozoic age are known, so that if such deposits were formed they have been destroyed by erosion. At the beginning of the Lower Cretaceous epoch this part of Alaska was a land surface of moderate relief, across which many broad valleys extended in a general easterly or northeasterly direction. In some of these valleys in adjacent regions subsidence had occurred and marine sediments were being laid down. Between the Lower and Upper Cretaceous epoch extensive diastrophism occurred, resulting in some folding of the earlier sediments and in the Anvik-Andreafski region in the formation of depressions or embayments in which sedimentation took place. It is inconceivable that the submergence of the lowlands was catastrophic, for the amount and texture of the material contained in the Upper Cretaceous sediments preclude anything but a near-by source for much of it, and the occurrence of ripple marks, cross-bedded sandstones, and fresh and brackish water fauna, locally in close association with a fossil flora, indicate littoral and estuarine conditions of deposition over much of the region. The almost universal occurrence of conglomerates along the contact with older rocks is similarly indicative of a sea that slowly encroached upon the land area. Periods of quiescence or even of slight emergence alternated with the periods of subsidence, and thus were formed the basins in which a rank vegetation flourished and was preserved to be converted into beds of coal. These conditions persisted until late Cretaceous or early Eocene time. Sedimentation was then interrupted by igneous activity, but the sediments of normal types that are in places intercalated with the basaltic flows and breccias indicate that the volcanism was not everywhere continuous. In other places there were mountain-forming movements which resulted in great deformation of the Cretaceous beds and superposed a second deformation and cross folding upon the older rocks. With this great diastrophic movement was associated the intrusion of many dikes and larger masses of soda granite along lines of weakness. Auriferous mineralization attended the intrusion. Before the movements ceased, probably in Eocene[1] or early Miocene time, the earlier flows had also been subjected to some deformation.

QUATERNARY PERIOD.

A rather complex series of events marks the history of the region during Quaternary time. At the beginning of this period the surface stood at a somewhat higher elevation than now, and the base-level of erosion was lower, so that many of the streams were able to carve deeper valleys in bedrock than those they now occupy. It

[1] Brooks, A. H., op. cit., p. 266.

appears likely that the stream systems had become well established and a fairly mature topography had been developed.

At some time in this stage of erosion there was an extravasation of basaltic lava which materially altered the courses of some of the larger streams, possibly including the Yukon itself or its predecessor. Such is the interpretation of the occurrence of flows between Russian Mission and Ingrumhart.

That the period of extrusion of the lavas was long is made manifest by the occurrence above Ingrumhart of an alternation of flows and of gravel beds in which the pebbles consist of basalt derived from the flows. The gravels may be either river borne or of marine origin. If the former, mature topographic forms may have been developed at this stage; if the latter, they mark the beginning of the succeeding stage in the cycle of events, when there was a subsidence of the land surface of at least 600 feet and possibly much more. It is impossible to state how much higher than its present elevation the land stood at the beginning of the period of subsidence, but that at the end of this period the sea occupied a position 600 feet or more above its present level is clearly indicated by the wave-cut terraces occurring at this elevation, and the unconsolidated deposits below it.

It is believed that this inundation progressed rather steadily and that emergence from the sea was almost equally continuous. As to the duration of this period of inundation little field evidence was found, except in so far as the extent of the terraces then developed is a marker of the length of time taken to form them. These terraces are not extensive anywhere along the Yukon, although traces of them at 600 feet appear more or less clearly on almost every ridge that rises above this elevation, and lower benches of less extent are occasionally seen. On the Anvik below the mouth of Yellow River their best development appears to be between 400 and 500 feet. On the lower half of the Stuyahok the most conspicuous bench appears between 300 and 400 feet. On both the Anvik and the Stuyahok the 600-foot terrace is not so pronounced, although it may be noted on some ridges. (See Pl. I, in pocket.)

To this submergence are due the drowning of the lower portions of practically all the valleys and the formation of the delta deposits which are found throughout the region.

The lack of corroborative fossil evidence as to marine inundation is to be accounted for mainly by two facts. Brackish-water invertebrates whose structure favors fossilization are few in number and, like marine species, might find difficulty in migrating to keep pace with the inundation. The conditions which have prevailed throughout most of the deposits since emergence have tended to destroy rather than to preserve evidence of animal life. Confirmation of the hypothesis of marine inundation during Quaternary time is therefore to be sought from physiographic details, rather than from fossil evidence.

Emergence after this inundation probably took place very slowly, although it went on at a fairly uniform rate, for few terraces remain to mark stages at which there may have been a long-continued cessation of movement. During the period of emergence there was more or less reworking of the unconsolidated sediments above and along the strand line, and the finer material was carried to successively lower levels. The depressions formerly occupied by the streams were thus gradually filled with silts and fine sands, while the higher portions of the former land surface were again exposed.

During the later part of the Quaternary period there has been little if any relative change of level. The most important geologic event of which evidence is afforded by the present topographic forms is stream adjustment to the new base-level of erosion, through the removal and redeposition of the earlier Quaternary sediments.

Some of the details of adjustment are worthy of note, as they may throw light on the form of possible placers in the larger streams. Keeping pace with the reelevation of the land surface to approximately its present position, the larger streams rapidly cut channels in the unconsolidated silts and fine sand in adjustment to the new base-level of erosion. This base-level was then probably considerably lower than at present, for the Yukon, like other large rivers, tends to aggrade in its lower course and has raised its own base-level of erosion and that of its tributaries. The tributaries in turn have filled in their channels in adjustment to the gradually rising base-level.

Where the streams flowed through unconsolidated material the gradients were low, but in their headward portions, above the level of inundation, gradients had been established in bedrock in adjustment to a lower base-level before inundation and were accordingly much steeper. In consequence there was a distinct change in grade where the streams left their bedrock courses and flowed across the silts. Erosion has tended and is tending to restore normal grades throughout their courses, but there still appear to be some streams in which complete adjustment has not yet been reached. In their lower courses erosion consists of a minor amount of lateral cutting of the high silt banks and the migration of meanders. In their upper reaches, where erosion is most active, the elevation of base-level has probably caused no difference in the type of cutting going on, although the amount has been decreased.

A great change, however, has taken place at the points where the streams left bedrock to flow in channels in the silts. Because of the change of grade at these points gravels were deposited there, decreasing the grade above but increasing it below and permitting the transfer of gravels farther and farther downstream. In this way there have been built up within the silts gravel-bottomed channels over which the streams now flow.

Many factors have entered into the location of the present course of the Yukon. A striking feature is the lack of hills on the left bank, and their presence, except where tributaries enter, on the right bank. This feature has been noticed on many northern rivers and is explained by Eakin[1] as being due to deflection to the right caused by the earth's rotation. As the Yukon is an aggrading stream, its channel is constantly changing, and it swings back and forth across its flood plain, but nevertheless the erosion on the right bank is distinctly apparent and appears to control the course of the river. Many channel changes have occurred in the last 20 years. Poltes Slough has been used as the steamboat channel for only a few years, and only in the last year or two have some of the large boats used Cross Slough instead of the channel around the Devils Elbow. Other changes have occurred near Holy Cross and elsewhere. At the site of old Anvik, 1½ miles above Anvik, there is a distance of about 125 feet between Yukon and Anvik rivers, and this distance is constantly decreasing, as both rivers are now cutting at this point. In 1916 the cutting amounted to nearly 20 feet, so that apparently the remaining narrow neck will be cut through in a comparatively short time and the mouth of the Anvik will be at this point rather than at Anvik. At Holy Cross also the amount of cutting may be directly measured. In 1916 it is said to have been 30 feet, and in previous years it had been as much or more, necessitating the moving of many of the buildings that were near the water front. On the other hand, deposition appears to be going on at Russian Mission, although it lies just below one of the narrowest stretches of the river.

One of the peculiar erosion features seen along the Yukon is the occurrence of numerous small semicircular embayments in the shore lines, in which trees still stand but are partly submerged. This is well illustrated in Plate V, *A* (p. 22); only the tops of the trees in the center are visible, and those on either side are toppling into the water. Below Holy Cross these embayments are especially numerous. They range in radius from a few feet up to about 100 feet. They have probably been formed by the undercutting of eddies at stages of high

[1] Eakin, H. M., The influence of the earth's rotation upon the lateral erosion of streams: Jour. Geology, vol. 18, pp. 435–447, 1910.

water in the spring. Roots and frost prevent erosion at the surface but do not prevent undermining, and as the water subsides the entire undermined area drops and is partly submerged. Each of these areas is comparatively small, but in the aggregate the amount must be large and represents a mode of stream erosion which must be considered.

At elevations above the direct influence of stream erosion other processes have been active. Weathering is hastened by the comminution produced by great variations in temperature and by the extremely effective work of frost. The transporting agent that carries most of the material produced in this way to the lower levels, where it is reworked by the streams, is solifluction rather than running water, as in warmer climates. Solifluction on sloping surfaces is accomplished by the heave and thrust of frost and by gravity, resulting in the characteristic hillside forms that show lobate waves and from a distance have the appearance of flows of some extremely viscous substance. For the most part these lobate forms are characteristic where the rock detritus is fairly fine. Where the frost-riven rock breaks into large angular boulders, solifluction produces distinct topographic forms called altiplanation terraces by Eakin,[1] who has described the processes by which they originate. They resemble wave-cut terraces in outline (see Pl. V, *B*), and may not be readily distinguished from such terraces at a distance, but careful mapping (Pl. I) reveals the fact that terraces on adjacent ridges are not at the same elevations and are separated by different intervals. Furthermore, many of them have the appearance of having been tilted, and a terrace may be tilted in the opposite direction to one below it, thus precluding the hypothesis that they are wave cut. A lack of water-worn pebbles on the terraces also supports the inference that they originated in some way other than by water action.

These terraces are very conspicuous in most of the areas of igneous rocks and in some areas of the sedimentary rocks. Their formation appears to be favored by certain conditions of vegetal growth, for so far as known they do not appear below timber line, although, as in the vicinity of Marshall, they extend down very close to it. Solifluction processes may have acted upon land forms resulting from inundation, which, it has been assumed, extended to an elevation of about 600 feet above present sea level, but no clear evidence of this is at hand.

The present topographic forms are the resultant of all the forces which have been at work to carve them, and it is largely through these forms that the Quaternary history of the region has been interpreted. Each force has acted and is acting to produce definite forms, but such forms have been modified by many other forces, and the

[1] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, pp. 78–82, 1916.

present configuration of the land surface has been produced by the agencies which have been described. Erosion has been the dominant factor, and the effects of sedimentation are only local.

MINERAL RESOURCES.

HISTORY OF MINING DEVELOPMENT.

On the discovery of gold at Dawson and at Nome there was an influx of prospectors, who left few of the readily accessible creeks anywhere in Alaska unprospected. Yukon River was the main highway for these men from one camp to another and from the upper river points to St. Michael and Nome. The Anvik portage gave a shorter route to St. Michael than the Yukon and was followed by some. Naturally enough, too, the bars on the Anvik were panned. Colors of gold were found but apparently never in sufficient quantity to warrant mining, and the prospectors sought other localities to work. Almost every year, however, there has been some one prospecting on the Anvik, the Andreafski, and streams between these rivers. In part the prospectors were men who devoted most of their time to trapping, but others had a grubstake sufficient to permit them to devote their entire attention to the search for gold. As a result of their work gold has been found in several places. On the Anvik there are said to be deposits along bars containing gold in paying quantities, but up to 1916 no effort has been made to mine it. Gold colors are said to be obtainable in panning on Stuyahok, Kako, Kuyukutuk, and Andreafski rivers and Mountain Creek, as well as on some of the small creeks emptying into the Yukon near Tuckers Point. No mining has been done on these streams.

The outcrop of metamorphic rock on Peltes Slough, at the present town of Marshall, was noticed by some of the early traders and prospectors on the Yukon, and some desultory prospecting was done on Wilson Creek and on streams flowing into the Kuyukutuk. It was not until July 15, 1913, however, that gold was discovered on Wilson Creek by E. L. Mack and Joe Mills. Claims were staked by these men, and a few days later others were located by Andrew Edgar and A. C. Rohde. A stampede followed, and Wilson Creek and its tributaries were quickly covered with claim locations. Late comers were forced to cross the divide and located claims on Willow Creek and other tributaries of Spruce Creek.

The claims had to be recorded at St. Michael, so that many of them were unrecorded and title to them was lost. On October 25, 1913, a miners' meeting was held and G. M. Pilcher was elected local recorder, but until the Wade Hampton mining precinct was established, with the recorder's office at Marshall, it appeared advisable to many to make their titles secure by recording both with the local recorder and at St. Michael.

Assessment work for 1913 was not done on many of the claims lying outside of the Wilson Creek valley, and title to them was lost. Prospecting during the winter of 1913 and mining operations early in 1914 gave proof of the presence of gold in paying amounts on Wilson Creek. This stimulated prospecting on other streams near by and led to the discovery of gold on Willow Creek by W. C. Blanker, Ben Blanker, and Robert Barr. Discovery claim, the Bumblebee (corresponding to "No. 1 below"), and "No. 2 below" were staked June 17, 1914. Assessment work and some prospecting was done on these and other claims on Willow Creek, but no gold was obtained from them in 1914.

The shortness of Willow Creek made it at once apparent that the source of gold in the placers was not far distant. Vein quartz carrying free gold was found in the talus on the east slope of the valley about even with claims Nos. 5 and 6 above Discovery, and the veins from which this talus came were staked as lode claims by Thomas Plunkett August 8, 1914.

The first production of placer gold was made in 1914, when about $15,000 was obtained from two properties on Wilson and Disappointment creeks. In 1915 the output was about $25,000, mostly from two claims on these creeks, but the list of producers also includes four claims on Willow. A small sample shipment of ore was also made from the lode claims on Willow Creek. In 1916 the gold production was $270,000 from two claims in the Wilson Creek basin and from seven claims on Willow Creek. Preliminary estimates give the production in 1917 as $425,000, practically all from six claims on Willow Creek.

The boundaries of the Wade Hampton mining precinct are defined as beginning at a point on Bering Sea between Pastol Bay and Yukon River and following the height of land, which separates Yukon River and Bering Sea drainage, to the one hundred and sixty-first meridian, thence south to a point within 5 miles of the Kuskokwim, thence paralleling the Kuskokwim at a distance of 5 miles from it to the sixtieth degree of north latitude, thence following this parallel to Bering Sea, thence along the coast of Bering Sea, including the adjacent islands, back to the point of beginning.

ECONOMIC FACTORS AFFECTING MINING.

Timber is fairly plentiful for such mining operations as have been conducted. On Elephant and Disappointment creeks fuel could be procured for a time from the bottoms of the valleys along these streams. Extensive operations, using steam power, would necessitate hauling wood from the valley of Wilson Creek. Alders are the only trees found on Willow Creek above claim No. 2 below Discovery, and consequently all the fuel used for producing power is obtained from the gentle foot slope between Spruce Creek and the hills. This wood costs $5 a cord to cut, and by the time it is laid down at the mine plant ready to use there is an additional charge of $5 to $7 for labor and hauling.

Wages are about the same in this region as at other interior Alaska points. Miners were paid $5 a day and board in 1916, but in 1917 this was increased to $6 and board; hoistmen, blacksmiths, and cooks receive $7 and board. Two shifts of eight hours are employed by the larger plants, but the smaller plants work only one shift. In 1916 employment was given to everyone who wished to work when there was a full sluicehead of water. Natives are employed around the camp but do no mining. They are paid $2 to $3 a day.

The camp on Willow Creek is very accessible. About 3 miles from the camp, Spruce Creek flows into a small lake, which empties through a slough into the Yukon and rises and falls with that stream. Supplies may be brought to the landing on the lake by gasoline boats or in scows, and one of the smaller steamboats also brought a barge load of lumber up to the lake. The freight rate from Marshall to the landing, about 8 miles by boat, is $15 a ton. From the landing the rate in 1916 was $30 a ton to the lower claims on the creek and $40 a ton to points as far up as "No. 5 above." The winter rate is probably much lower. The rate on general merchandise from Seattle to Marshall, by way of St. Michael, was $45.50 a ton.

In 1916, on account of traffic conditions, there was a scarcity of some commodities at Marshall. The following prices were paid for staples on the creek:

Flour	per hundredweight	$10.00
Bacon	per pound	.37
Coffee	do	.75
Tea	do	1.00
Beans	do	.12
Rice	do	.12½
Sugar	do	.13½
Butter	do	.67½
Reindeer meat	do	.25-.30
Beef	do	.45-.50
Potatoes	do	.07½

Lumber was difficult to obtain until a barge load was brought down from Ruby. This sold at $80 a thousand at the lake.

GOLD PLACERS.

WILSON CREEK.

Until the summer of 1916 most of the mining in the vicinity of Marshall had been done on Wilson Creek and its tributaries. In the spring of 1916 a small dump was taken out on Elephant Creek, and early in the summer considerable ground was worked at the mouth of Disappointment Creek. At the time of the writer's visit, about the middle of August, there was no one working in the Wilson Creek basin.

Mining had been done by underground methods on claim "No. 5 above" on Elephant Creek, although the ground is comparatively shallow. It is understood that a hydraulic plant is to be installed, the water to be obtained from the headwaters of this stream. The ground on claims above and below No. 5 will be stripped and mined by hydraulic methods.

The workings on Wilson and Disappointment creeks have been confined to about two claims at the mouth of the latter, over a maximum width of about 300 feet. The gravels containing gold in quantities sufficient to justify mining appear to have been irregularly distributed, as work was done at several spots separated by unworked ground. Open-cut methods were employed. These deposits are apparently not over 10 or 12 feet deep to bedrock. The upper portion is composed of 2 to 3 feet of soil and vegetable matter, and this with some of the underlying gravel was stripped off by groundsluicing. The lower stratum of gravel containing the gold was shoveled into sluice boxes. It is said that holes sunk at the mouth of Disappointment Creek failed to reach bedrock at a depth of 35 feet. They were then abandoned on account of water coming in. No mining has been done in the deeper gravels of Wilson Creek itself.

The principal mineral found in the concentrates is hematite, probably coming from a band farther up the creek, which is believed to be the weathered outcrop of a pyritized sedimentary bed. In addition a small amount of magnetite occurs in the octahedral form characteristic of this mineral. A specimen of a few grains of a white metal from the creek sent to the Survey for determination was found to be platinum.

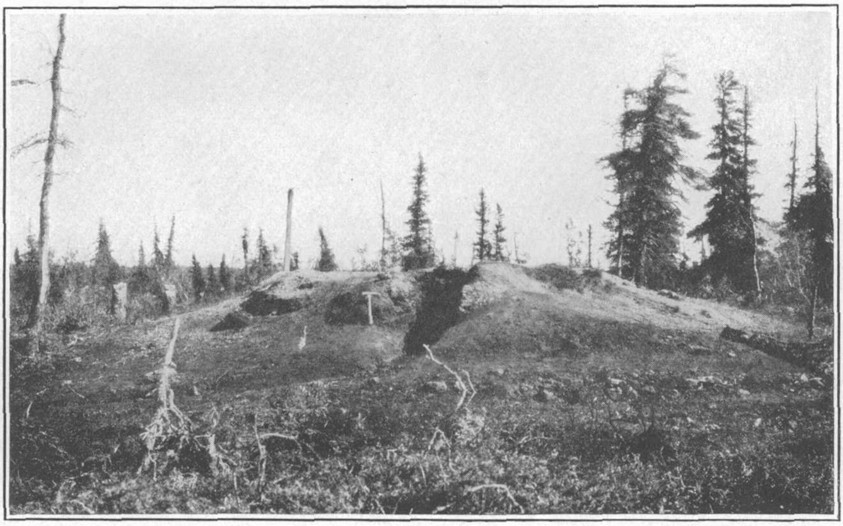
The bedrock is of sedimentary origin. It was not seen in the creek bed, but slates and conglomerates, together with fine grits, appear along the south bank of Wilson Creek just above Disappointment Creek, and these rocks, together with some dark-gray cherts, make up most of the gravels. Some pebbles are derived from dikes that cut the sedimentary rocks and form the igneous rocks at the head of the creek. The gravels are mostly small and well-rounded pebbles, 8 inches being about the average diameter of the largest cobbles seen. The finer material of the gravels is partly ferruginous, and, although it disintegrates readily in the sluice boxes, on exposure to the air it hardens and cements the larger pebbles into a conglomerate.

WILLOW CREEK.

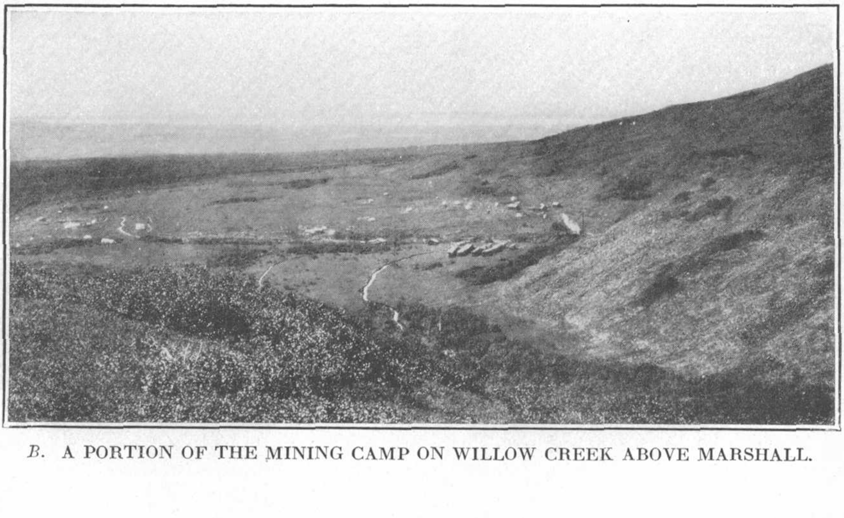
Willow Creek heads against Disappointment Creek, and the divide is about 700 or 800 feet in elevation above the claims on which most of the mining has been done. Mining has been confined to the west fork of the creek and to the claims from No. 2 below to No. 5 above Discovery; the latter claim covers some ground on the western branch of the small forks near the head of this stream. Some prospecting has been done on "No. 6 above" and on other claims below "No. 2 below," but in 1916 development had not progressed sufficiently to warrant the undertaking of mining operations. Prospecting on claims below "No. 2 below" during the spring and summer of 1917 is said to have resulted in the discovery of deposits rich enough to work.

Two small plants were operating on "No. 5 above," the material being shoveled into sluice boxes. Prospecting was being done on Nos. 3 and 4 above Discovery, and some mining was done on these claims in 1917. Power plants were working on "No. 2 above," the upper half of "No. 1 above," and the upper half of Discovery. On Nos. 1 and 2 above Discovery the auriferous gravel is wheeled in barrows to a bucket and then hoisted to lines of sluice boxes on the hillside. A portion of the stripping is done in the same way, but some of the overburden is removed by sluicing.

The plant operating on the upper half of Discovery in 1916 worked the lower half of "No. 1 above" in 1917. As these claims lie below that portion of the valley that has steep walls (Pl. VII, *B*), the line of sluice boxes was mounted on trestles to provide the necessary grade and dump room for tailings. A novel feature at this property is that both stripping and hoisting are done by a slack-line scraper, which is a modification of the drag-line scraper used in other Alaskan mining districts. The bucket has a capacity of a yard and a half. On account of the large size and angularity of the boulders and the extremely uneven and blocky character of the bedrock, some difficulties have been experienced with this equipment. It appears likely that the bedrock will have to be cleaned by hand, as it is on other properties. The conditions of operation on Willow Creek for a scraper of this type are probably as difficult as will be found anywhere else, and its successful operation here would warrant an investigation into the possibilities of its economical use at other Alaskan



A. SINTER CONE OF ONE OF THE SODA SPRINGS NEAR MARSHALL.



B. A PORTION OF THE MINING CAMP ON WILLOW CREEK ABOVE MARSHALL.

camps. The rounded and smaller gravels on Disappointment Creek appear to offer more favorable conditions for such a scraper than is afforded by any of the placer ground on Willow Creek.

During 1915 the most extensive mining operations on Willow Creek were on the lower half of Discovery claim. Operations were continued in 1916, and one shift of men was employed shoveling into the sluice boxes. The sluice-box arrangement differs from that on other properties, and a greater effort is made to save the fine gold. The upper four boxes into which the gravel is shoveled have false bottoms, in which are 2-inch holes, spaced 4 to 6 inches on centers. Below this in the line is a box containing Hungarian riffles, with a 6-inch drop to a mud box. The mud box, like the three sluice-box lengths that follow it, has pole riffles of the usual type. At the other properties on the creek all the sluice boxes carry pole riffles, made either of local spruce poles or, when it is obtainable, of sawed 2 by 2 inch lumber. The lumber riffles are generally faced with 2-inch strap iron.

Mining was done on the upper end of the Bumblebee claim early in the summer of 1916, and a small area of ground was worked out. Operations were then shifted to the claim below, and preparations were made for more extensive mining. A sluiceway had been excavated 8 or 10 feet to bedrock, and boxes were being put in on August 27, when the writer left the creek. The contemplated operations included the sluicing of both the overburden and the auriferous gravels from "No. 2 below" through this line of boxes.

On account of the small drainage basin of the creek, the water supply for the claims lying above Discovery is likely to be somewhat scanty unless there are frequent rains. By the time it reaches Discovery claim even this scanty supply has been somewhat lessened. The operators on Discovery have diverted the water from the East Fork of Willow Creek, and so increased the amount available for this claim and those below it. A ditch from Slope Creek was constructed late in the summer to furnish an additional supply for the mining operations on "No. 2 below."

Discovery claim lies about opposite the front of the range of hills, which marks a distinct change in the topography. Below Discovery claim there is a wide, coalescing apron which slopes gently down to Spruce Creek and the Yukon, as illustrated in Plate VII, *B*. Above this topographic break Willow Creek has a V-shaped valley with walls of fairly steep slope; below it the stream has intrenched itself but little in the frontal apron, across which it flows at a gradient lower than where it is confined within the valley. There appears to be a suggestion of a beach line between elevations of 500 and 600 feet (see Pl. II, in pocket), and the change in the topography occurs at about 500 feet or somewhat lower. This topographic break may mark the position of a beach, and some evidence has been found near Marshall to confirm the suggestion of the topographic form. Fragments of shells are reported to have been found in 1917 in prospect holes at an elevation of about 450 feet on claims on lower Willow Creek. The widening and somewhat irregular distribution of the auriferous gravels below Discovery may be due in part to beach concentration and in part to changes in the channel of the stream before it had become intrenched in its present course.

The depth to bedrock ranges from about 6 to 16 feet. On "No. 1 above" it is from 12 to 16 feet. The upper half of the deposit consists of soil and angular rock fragments with comparatively little rounded gravel. This is stripped off before mining the lower layers. Gold is found both above and below a clay seam lying about 2 feet from bedrock, and some of the coarsest gold occurs above this seam. The bedrock is extremely rough and blocky, and just above it there are a considerable number of large angular boulders, part of which are talus boulders from the valley slopes and part represent frost-heaved material from the greenstone bedrock. On the lower claims there appear to be more rounded gravels, but the bedrock is similar in character to that on the upper portion of the creek.

The gold is somewhat rough, and some of it appears rather porous. Over half of it is coarser than will pass through an 8-mesh screen. Nuggets valued at $5 to $10 are not uncommon in the clean-ups, but few worth over $20 are found. The very fine gold saved constitutes only a very small percentage of the clean-ups. It is believed that the installation of devices for saving the fine gold would be warranted, as some of the fine gold already saved is flaky and light, and it is quite possible that a greater proportion of this light gold goes through the boxes than is saved in them. Few assays of the Willow Creek gold are available. One of these is said to have given a value of $18.30 an ounce. The gold passes current at $17 an ounce.

Magnetite is one of the most common minerals associated with the gold in the clean-ups. Ilmenite occurs in small amounts. Although pyrite may be seen here and there in the greenstone near the head of the creek, little or none is found in the concentrates, oxidation having converted it to hematite. Shot is frequently found in the heavy sands resulting from the clean-up. A few grains of platinum are also said to occur in the concentrates.

OTHER STREAMS.

Anvik River and its tributaries have been prospected ever since 1900, and possibly even before that time. Gold has been found on the bars at numerous localities, but never in sufficient amount to justify mining operations. It is reported, however, that in the winter of 1916–17 two men were prospecting on this stream and found workable placers, upon which work was being done in the summer of 1917. Platinum in considerable amount is said to occur in association with the gold and is mined with it.

Practically all the other large streams accessible by a poling boat or canoe have also been prospected, but up to the present time no commercial placers have been discovered on them.

GOLD LODES.

The hills in the vicinity of Marshall have been prospected to find the lodes from which the placer gold has been derived. A number of lode claims have been staked in the Kuyukutuk basin, on the north side of the ridge extending eastward from Pilcher Mountain. Little development work is reported as having been done on these claims, and they were not visited. Free-milling gold is reported from quartz veins near the head of Edgar Creek, and claims have been staked there. A number of quartz veins were seen along the crest of the divide between Wilson and Spruce creeks. Claims have been staked to cover most of these veins, but no evidence was seen of work having been done upon any of them except on the east side of Willow Creek near its head.

The group of claims on the east side of Willow Creek, known as the Arnold lode, was staked August 8, 1914, by Thomas Plunkett. The development work consists entirely of open cuts made with a view to determining the size and continuity of the veins, of which a number are exposed. One of the lower veins has been traced along its strike for over 100 feet by a series of trenches, 2 to 6 feet deep, through the talus and slide of the hillside. The vein is from 6 inches to a foot in width and shows free gold in places. Farther up on the slope a cut has been dug about 30 feet into the hill, so that there is exposed a face 12 or 15 feet in height and 3 to 6 feet wide. In this face appears a quartz vein ranging in width from 4 to 8 inches. The minerals in the vein include calcite, pyrite, galena, molybdenite, and free gold. In places the pyrite has oxidized, and the quartz is stained with iron oxides. The vein shows numerous cavities formed by the removal of pyrite and calcite. In some of these cavities small glassy quartz crystals may be seen, together with an occasional rosette of calcite crystals. Some of the dirt from the bottom of the open cut was panned. In addition to the vein minerals mentioned above, the concentrates from panning included small amounts of wulfenite, the yellow to orange-colored molybdate of lead, and anglesite, the white sulphate of lead. Magnetite and the oxides derived from the alteration of iron pyrite are also present in considerable amounts. The source of the latter minerals is the greenstone country rock, the hanging wall in places showing strong pyritization. Veins near by show a small amount of chalcopyrite, accompanied by the characteristic green stain produced by its oxidation. Similar mineralization has occurred in the quartz veins that appear in the bank of the river at Marshall.

ANTIMONY.

No veins carrying antimony are known within the areas visited, but at Paimiut it was reported that stibnite occurs in the group of hills south of the Yukon, near the Kuskokwim.

MINERALIZATION.

Data regarding the mineralization in this region are not sufficiently complete to justify positive statements regarding the source of the gold, but some inferences concerning it can be drawn. Wherever gold has been found there are also soda granites or porphyritic dacite dikes, many of them of considerable width, and it is believed that the mineralization was consequent upon the intrusion of both the sedimentary and igneous rocks by these granites and dacites. The dacites are similar in chemical composition to the soda granites and differ from them only in having a somewhat finer groundmass and a porphyritic texture. They represent offshoots from the larger igneous masses or were derived from the same sodic granite magma. Both the larger granite masses and the dacite dikes appear to have been concerned in the mineralization. The quartz veining that followed is also related to the intrusions, and much of the gold occurs in the vein quartz, but wall-rock impregnation has also taken place. Besides the gold the sulphides of iron, lead, molybdenum, and copper occur as pyrite, galena, molybdenite, and chalcopyrite, in the veins and mineralized wall rock. These minerals have not been found in the soda granites or dacites but doubtless were formed as a consequence of their intrusion.

SUGGESTIONS FOR GOLD PROSPECTING.

As the mineralization was attendant upon the soda granites and the porphyritic dacites, it follows that streams which drain areas where these rocks appear afford the most attractive field for prospecting. Exposures are few in most parts of the region but may usually be found along the crests of the ridges or here and there along minor streams. The nature of the gravel along bars, however, will afford quite as effectively an indication of the nature of the rocks farther upstream. Vein quartz or pebbles of light-colored granitic or porphyritic igneous rock should be noted. The rocks from which these pebbles are derived are of course not necessarily accompanied by gold, but, on the other hand, in this region the gold has always been found under conditions which indicate its derivation from these intrusives.

On the upper courses of most of the streams the valleys are comparatively narrow and the depth to bedrock slight, making crosscutting of the channel fairly easy. On the lower reaches, however, the width is greater, in some places being several miles, and the valley fill is of unknown depth. Prospecting under such conditions, taken in connection with the possibility of changes in the position of stream courses since the concentration of the gold in placers, appears uncertain to yield profitable results.

COAL.

The presence of coal on Anvik River has long been known and is mentioned by Collier.[1] It seems to have been used to a moderate extent by the natives, who formerly employed it in the manufacture of a black pigment. A small amount has also been used for blacksmith coal at Anvik, but so far as known no other utilization has been attempted. The following information regarding these deposits was obtained from Mr. F. H. Kruger, a merchant and prospector at Anvik.

The coal seams crop out about 45 miles above the mouth of Yellow River, or over 100 miles by water from the Yukon; the air-line distance to the nearest point on the Yukon is probably about 35 miles. Anvik River cuts diagonally across the sedimentary series, made up of sandstones, shales, and coal beds, which appear for a distance of about 5 miles along the course of the stream. Both up and down stream from the sedimentary series are rocks of igneous origin. Within the series coal seams appear for nearly a mile along the river, most of the outcrops on the east bank. One seam has a thickness of about 10 feet, and several have a thickness of 2 feet.

Transportation to the Yukon would entail a high expense, as only small poling boats could be used except at high-water stages, when small scows and power boats might be utilized. Transportation overland would prove feasible only if the local market were sufficiently great to warrant the construction of a road, after exploration and development work had proved the extent and quality of the coal.

Coal seams of varying thickness will doubtless be found elsewhere in the areas of Cretaceous rocks. Many fragments of weathered coal were found in the high gravel bank on the east side of Stuyahok River about 45 miles from its mouth. It is likely that these fragments have not been carried for any great distance and that careful

[1] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, p. 58, 1903.

prospecting would reveal the seams from which they were derived. Like those on the Anvik these beds when found would probably be of local value only, unless they were of considerable extent and the coal of such a quality as would permit it to compete with other fuels.

At Marshall it was learned that coal occurs on one of the creeks which flows into a slough of the Yukon about 20 miles above Marshall. No information concerning this deposit other than the fact of its occurrence was obtainable.

A narrow band of bituminous shale occurs in the vicinity of the old fort at Andreafski.[1] The Russians attempted to utilize this shale for fuel, but it was too impure to burn well, and the attempt was abandoned. This locality is a few miles down the Yukon from Andreafski, where field work was terminated in 1916, and was not visited by the writer.

MINERAL SPRINGS.

About 7 miles east of south of Marshall and half a mile from the Willow Creek landing are what are known locally as the Soda Springs. Analyses show the mineral content of the waters from these springs to be chiefly calcium and bicarbonate, with considerable iron. Free carbon dioxide is constantly being liberated and bubbles up intermittently in almost all the pools and springs of this group. Some have built up considerable cones, 4 to 6 feet high and 10 to 20 feet wide at the base. (See Pl. VII, *A*.) The material in these cones consists of lime carbonate and yellow and red iron oxides. At the northern edge of the group is an extensive area covered with granular precipitated oxides of iron, with some lime carbonate, which is rather loose and incoherent, much resembling gas-house cinders. It has built up a deposit thick enough to afford a solid footing, much in contrast with that of the soft, spongy moss-covered areas near by. That very little vegetation grows on the sinter is indicated by the photograph of the cone. (See Pl. VII, *A*, p. 60.)

Between the main group of springs and the landing are a number of pools of water which in part may represent the overflow from the springs above and in part may be the basins of other springs having a comparatively small flow. The deposits in the vicinity of these pools consist chiefly of lime carbonate and are conspicuous for their white color and scanty growth of vegetation.

The springs are situated at the base of the south frontal slope of the range of hills between Spruce and Wilson creeks. A mantle of vegetation and unconsolidated material so completely covers the surface that it is impossible to determine the nature of the underlying bedrock. It appears likely, however, that the springs occur

[1] Dall, W. H., and Harris, G. D., Correlation papers, Neocene: U. S. Geol. Survey Bull. 84, p. 247, 1892.

near the contact of the Quaternary lavas and the greenstones which make up the ridge to the north. Other springs of essentially similar character are reported as occurring about 12 miles to the east, where the topographic situation and geologic conditions are much the same as at this locality.

Little utilization has been made of these mineral waters. The spring shown in Plate VII, *A*, was dug down about 3 feet or more from the crest of the cone, and a small basin was dug below the rim of the outlet. This spring flows a few quarts to the minute. The water is carried up to the camp on Willow Creek and used to a small extent as a table water. A few hundred yards to the north another spring has been dug out, the cone leveled off, and a log building erected over it. This building was in use as a saloon, and the basin of the spring served both for cold storage and as a source of carbonated water.

An analysis[1] of this water by R. B. Dole and Alfred A. Chambers gave the following results:

Analysis of water from Soda Springs, near Marshall.

	Parts per million.
Silica (SiO_2)	40
Iron (Fe)	6.2
Aluminum (Al)	4.0
Calcium (Ca)	366
Magnesium (Mg)	58
Sodium (Na)	32
Potassium (K)	14
Carbonate radicle (CO_3)	.0
Bicarbonate radicle (HCO_3)	1,456
Sulphate radicle (SO_4)	18
Chloride radicle (Cl)	3.1
Nitrate radicle (NO_3)	Trace.
Total dissolved solids at 180° C	1,270
Free CO_2	1,340

Water for analysis was taken from the open spring and so had lost some free CO_2. It is possible that some of the iron may have been precipitated. In precipitating from solution the iron appears to have gone out first, so that even the small percentage shown by this analysis would account for the presence of the iron minerals near the vents of the springs. Iron oxides make up a considerable amount of the sinter but appear to constitute a much larger part of it than they really do, as both the yellow and brown sinter contain considerable lime carbonate, the presence of which is concealed by the color of the iron minerals.

[1] Waring, G. A., Mineral springs of Alaska: U. S. Geol. Survey Water-Supply Paper 418, p. 87, analysis No. 5, 1917.

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