DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 687

THE KANTISHNA REGION ALASKA

BY

STEPHEN R. CAPPS

WASHINGTON
GOVERNMENT PRINTING OFFICE
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THE KANTISHNA REGION, ALASKA.

By Stephen R. Capps.

INTRODUCTION.

LOCATION AND AREA.

The Kantishna region as here defined is bordered on the south by the crest of the Alaska Range, on the north by Tanana River, on the east by Nenana River, and on the west by lower Kantishna River

Figure 1.—Index map showing location of the Kantishna region.

and one of its main headward tributaries, McKinley Fork. (See fig. 1.) In a broader sense, the Kantishna region should include the entire Kantishna basin and part of the Nenana basin, but the present paper does not describe the part of the Nenana basin that lies east of the main river between Broad Pass and the Tanana, the part of the Alaska Range that lies south of a line drawn from the mouth of Hines Creek to the terminus of Muldrow Glacier, and the part of the Kantishna basin that lies west of McKinley Fork and west of the main river below the mouth of McKinley Fork. Furthermore, the lowland of Tanana River north of the outermost range of foothills was visited only along the courses of Kantishna and Nenana rivers. The area here considered lies between parallels 63° 25′ and 65° north latitude and meridians 149° and 151° 10′ west longitude. It includes about 4,500 square miles and comprises a part of the Alaska Range and its foothills and a part of the Tanana lowland.

PREVIOUS SURVEYS.

Historically this country is new. During the Russian occupation of Alaska the Russian traders established themselves on lower Yukon and Kuskokwim rivers and on Cook Inlet and made some journeys inland beyond their most advanced trading posts, but apparently they never penetrated as far as this region. In 1872, after the territory was ceded to the United States, several prospectors came into the Yukon basin from the east, and in 1878 two of them, Arthur Harper and A. Mayo, ascended the Tanana to about the present site of Fairbanks. In 1889 a number of prospectors crossed from the lower Tanana basin to the head of Kuskokwim River, thus skirting the northwest edge of this area.

In 1897 and 1898, after gold had been discovered in the Canadian Klondike and a horde of gold seekers had rushed to that region, a great demand arose for authentic and more detailed information about Alaska. In response to that demand a number of expeditions were sent out in 1898 by the United States Geological Survey and by the War Department. Among those that carried explorations toward this region were two United States Geological Survey parties, one conducted by G. H. Eldridge[1] and Robert Muldrow, who ascended Susitna River and crossed to the head of the Nenana, and another in charge of J. E. Spurr[2] and W. S. Post, who ascended to the head of Skwentna River, crossed the Alaska Range to the Kuskokwim, and descended that stream to its mouth. In 1898 also Sergt. William Yanert, a member of the War Department expedition in charge of Capt. E. F. Glenn, made a traverse up Susitna River to the

[1] A reconnaissance in the Susitna basin and adjacent territory, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 1-29, 1900.

[2] A reconnaissance in southwestern Alaska in 1898: Idem, pp. 31-264.

headwaters of Nenana River. In 1899 a party commanded by Lieut. J. S. Herron[1] journeyed from Cook Inlet to the head of Kichatna River, a tributary of the Yentna, crossed the range through Simpson Pass, and proceeded northward through the lowlands of Kuskokwim and Kantishna rivers to the mouth of Tanana River. All these parties extended the geographic knowledge of surrounding areas, but none of them actually reached the region here described. The first accurate survey to be carried to the Kantishna region was made in 1902, when a Geological Survey party including A. H. Brooks,[2] D. L. Reaburn, and L. M. Prindle left Cook Inlet by pack train, ascended to the head of Skwentna River, and there crossed the Alaska Range into the Kuskokwim basin. Proceeding northeastward they traversed the northwest slope of the Alaska Range to Nenana River and followed that stream to its mouth. This expedition obtained the first authentic information concerning the geography and geology of the area here discussed. In 1906 Prindle made a hasty visit to the Kantishna placer district, then recently discovered, and published a brief account of its geology and gold placer deposits.[3] Between 1903 and 1913 several mountaineering expeditions were organized to scale Mount McKinley from the north side, and a number of accounts of these expeditions[4] have been published. All these accounts contain valuable geographic material, although none of the mountaineering parties attempted to make accurate surveys. Charles Sheldon, a naturalist, spent some time in the headward basin of Toklat River but has not yet published the results of his studies.

In 1910 both topographic and geologic surveys were made in the region between Nenana and Delta rivers,[5] which borders the east side of the area here discussed. In 1915 construction work was begun on a Government railroad to extend from Seward, on the Pacific coast, to Fairbanks, in interior Alaska, by way of Susitna, Nenana, and Tanana valleys. The railroad surveys made before and since the choice of that route have given precise geographic information concerning a narrow strip along the line of the railroad but have added little to the knowledge of the country west of the line.

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[1] Explorations in Alaska, 1899, for an all-American overland route from Cook Inlet, Pacific Ocean, to the Yukon: Adjutant General's Office, No. 31, pp. 1–77, 1901.

[2] Brooks, A. H., The Mount McKinley region, Alaska, with descriptions of the igneous rocks and of the Bonnifield and Kantishna districts, by L. M. Prindle: U. S. Geol. Survey Prof. Paper 70, 1911.

[3] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, pp. 205–226, 1907.

[4] Dunn, Robert, The shameless diary of an explorer, Outing Publishing Co., 1907: Cook, F. A., The top of the continent, Doubleday, Page & Co., 1908; Browne, Belmore, The conquest of Mount McKinley, G. P. Putnam's Sons, 1913; Stuck, Hudson, The ascent of Denali, Charles Scribners Sons, 1914.

[5] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, 1912.

PRESENT INVESTIGATION.

Fully realizing that interest in the Kantishna area would increase greatly with the better transportation that the railroad is soon to afford, the United States Geological Survey considered it desirable to extend the geologic and topographic mapping westward from the line of the railroad into an area that would be directly benefited by it and to make a study of the mineral resources of the region. Two field parties were therefore organized, one in charge of C. E. Giffin, to extend the topographic mapping, and one in charge of the writer, to map the geology and to study the mineral deposits. The topographic party consisted of Mr. Giffin, his assistant, and three camp hands, with eight pack horses. The geologic party included the writer, two camp hands, and five horses. Both parties sailed from Seattle for Skagway on June 2, and, traveling down the Yukon and up the Tanana, arrived at Nenana on June 16. From Nenana a trail up Nenana River was followed to the foothills, where field work was begun on June 22 and was continued until August 29, on which date the parties reached the Tanana by small boat down Kantishna River. A topographic map of an area of about 4,500 square miles on a scale of 1:180,000 was completed (see Pl. I, in pocket), and the geologic mapping was carried over an area of about 3,200 square miles (see Pl. II, in pocket). In addition a special study of the geologic conditions in the vicinity of the placer mines was made and all the placer mines and most of the prospects, including placer gold deposits, and gold, silver, and antimony lodes, were examined.

At the same time that the work here described was in progress a geologic party in charge of G. C. Martin was engaged in a special study of the Nenana coal field, just east of Nenana River, a report on which is now in press as Bulletin 664.

GEOGRAPHY.

DRAINAGE.

GENERAL FEATURES.

The principal streams of the region here described are all tributaries of Tanana River and include Nenana River, on the eastern border of the area, and Kantishna River, with its tributaries Toklat and Bearpaw rivers and McKinley Fork. All these streams except Bearpaw River drain from the main Alaska Range and from the glaciers that lie in the valley heads and therefore are supplied in large part by waters that flow from melting ice fields. The glacial streams receive abundant rock detritus from the glaciers during the summer period of melting and are heavily charged with gravel, sand, and silt. As the stream gradients are steepest toward the valley heads but diminish downstream the glacial streams display a marked tendency to build up extensive valley-floor deposits of gravel and sand and in general flow through many branching channels over deposits of their own making. (See Pl. II.) These characteristic valley-floor gravel deposits are coarsest upstream nearest the glaciers but become progressively finer downstream. Below the point at which most of the coarse material has been dropped each stream loses much of its tendency to split up and tends to flow in a single channel between banks of sand or silt. The glacial streams are subject to rapid changes of volume during the summer and are likely to become swollen after each day of warm sunshine and to diminish at night or on cold, cloudy days. The period of greatest run-off usually occurs early in summer, when the winter accumulation of snow is melting on the mountain slopes, but warm rains or a succession of bright, warm days quickly bring floods at any time during the summer. In winter, when melting ceases, the glaciers become inactive and the streams run clear or cease to flow. Within the higher mountains the northward-flowing streams occupy rather closely spaced, parallel valleys and, with the exception of Nenana River and McKinley Fork of Kantishna River, do not offer serious obstacles to the man on foot who wishes to cross them. At a greater distance from the crest of the range, where many smaller streams have united in a single valley, the rivers in summer become large enough to make fording difficult or impossible.

NENANA RIVER.

Nenana River receives most of its water from two large ice streams, Nenana and Yanert glaciers, that lie east of the area here described. These two glaciers are on the south flank of the Alaska Range, but their drainage, joining, flows northward directly across the range and borders this region on its eastern edge. In summer, when the ice is melting, Nenana River is a powerful stream. Its waters are turbid and swift, and in much of its course it flows between steep banks from which trees, undermined by the current, lean into the water and form "sweepers," which are so dangerous to boatmen. In even the ordinary stages of summer flow the river is too deep for horses to wade, and places at which they are able to swim the entire river in a single channel, with a shelving bank to land upon, are far apart. In its course through the mountains Nenana River receives no large tributaries from the west.

Teklanika River, the only large tributary of the Nenana from the west, joins that stream in the Tanana lowland at a point said to be near the mouth of the Nenana. Within the mountains the Teklanika has three main branches, of which Savage River, the easternmost, is a clear stream, without large glaciers in its basin, which lies in the foothills. Sanctuary River, the central branch, and the main Teklanika both head among glaciers that lie along the crest of the range, and both carry muddy waters from the melting ice. The main Teklanika and its two principal branches are antecedent streams whose courses were established in earlier geologic time, before the present mountains were formed, for they leave the high mountains and flow northward across three distinct mountain ridges and the intervening basins, plunging into deep rock canyons cut through the ridges, although courses taken in an easterly direction would have avoided these ridges and given easier outlets to the Tanana basin.

KANTISHNA BASIN.

The streams within the region here discussed that lie west of Teklanika River are within the basin of Kantishna River, which includes all the northwest front of the Alaska Range to the basin of Kuskokwim River. Between the Teklanika and the crest of the Kantishna Hills several streams, among which are Sushana, East Fork of Toklat, and Toklat rivers, and Stony Creek, flow northward from the mountains and their waters, combined in the Toklat, reach the Kantishna 52 miles above its mouth. Sushana River heads in one of the outer ranges of mountains, has no glaciers within its basin, and carries clear water. East Fork of Toklat River and the main Toklat both drain from the summit of the Alaska Range and are fed by numerous glaciers. Their waters are therefore heavily charged with débris during the summer, and they are subject to the rapid fluctuations of volume that characterize glacial streams. Stony Creek receives only a small amount of glacial drainage and is only moderately turbid. Its tributaries from the west are all clear streams. Bearpaw River, which joins the Kantishna 103 miles above its mouth, is fed by the numerous creeks that drain the south and east slopes of the Kantishna Hills. Below the town of Diamond it is a sluggish, clear stream that follows a meandering course to its mouth. Kantishna River below the mouth of the Bearpaw is a large, muddy stream of moderate current. Its muddy waters come from McKinley Fork, which drains Muldrow and Peters glaciers, but it is fed also by the clear waters of Bearpaw River and Lake Minchumina. At high stages of water shallow-draft launches can ascend the Kantishna to Lake Minchumina and the Bearpaw to Diamond.

VIEW NORTHWESTWARD FROM THE CREST OF THE KANTISHNA HILLS ACROSS THE LOWLANDS OF KANTISHNA RIVER.

VIEW SOUTHWARD FROM VILLAGE OF GLACIER ACROSS THE KANTISHNA HILLS TO MOUNT McKINLEY.

RELIEF.

TANANA LOWLAND.

In approaching this region from the north one must cross the broad Tanana lowland, which extends from Tanana River southward to the foothills. This lowland is of irregular width from north to south, for Tanana River flows in a winding course. Along Nenana River it is 25 miles wide, but from the mouth of the Kantishna southward to the foothills it is over 60 miles wide in a straight line. East of the Nenana it extends continuously along the north foot of the range, but west of the river it swings to the southwest, lying parallel to the range, and is continuous with the broad lowland at the head of the Kuskokwim. Within this great lowland, an area of many thousand square miles, the relief is very slight; the surface slopes gently northward from the base of the foothills to the Tanana, and is broken only by a few low hills. (See Pl. III.) The lowland is dotted with lakes and marshes and contains scattered groves of timber. In recent years beaver have so increased in number under protection of the game laws that they have further imponded the sluggish streams, making summer travel over much of the lowland impossible. The larger streams from the mountains maintain permanent and definite courses across the lowland, but many smaller streams sink out of sight in the gravels after they leave the hills. Even so large a stream as Toklat River is said to diminish noticeably in volume a short distance north of Chitsia Mountain, and Moose Creek is reported to disappear entirely for a stretch above Fish camp at times when the stream is flowing a large volume both above and below the dry area. The lowlands will probably be most useful for agriculture; no valuable mineral deposits have so far been found in them. They may contain coal, however, though none has yet been discovered.

FOOTHILLS.

The Tenana lowland gives way, along its southern edge, to a range of foothills that runs westward from the Nenana to the Toklat, beyond which it increases in width toward the south to include the Kantishna Hills. A second foothill range lies south of this, and reaches from the vicinity of Nenana River to the East Fork of Toklat River, where it merges into the main Alaska Range. The foothills east of the Toklat have rounded and smooth slopes and summits that reach a maximum elevation of about 4,000 feet. The Kantishna Hills west of Toklat River and north of Bearpaw River and Crooked Creek are also rounded, but farther southwest they become more rugged and reach elevations of 4,000 to 5,000 feet. (See Pl. IV.) If this range were elsewhere, it would be called a mountain range, but lying as it does within sight of the loftiest peaks of the Alaska Range it appears less bold than it actually is.

Lying between the foothill ranges and separating them from one another and from the higher mountains to the south are broad, eastward-trending structural basins of low relief. These basins have little relation to the present drainage, for they are crossed at right angles by many streams that enter and leave them through deep rock canyons, and they contain no large streams that flow through them longitudinally. The basins are floored by Tertiary unconsolidated deposits and by later gravels. (See Pl. XIII, p. 41.)

ALASKA RANGE.

The Alaska Range proper succeeds the foothills on the south. Between Nenana River and Muldrow Glacier the range is about 20 miles wide from its north front to its crest and consists of a number of rugged ridges, which extend from north to south and are separated by the valleys of closely spaced, northward-flowing streams. These ridges gradually become higher toward the crest of the range, and many peaks rise to elevations between 6,700 and 8,000 feet and are the gathering ground for glaciers. West of the big bend of Muldrow Glacier and south of the Kantishna mining district the range increases in height and scenic beauty and culminates in Mount McKinley and Mount Foraker at elevations of 20,300 and 17,000 feet, respectively. (See Pls. V, VI, and VII.) From this lofty part of the range glaciers push down the valleys to the mountain front and may be seen from the lowland, which there gives way abruptly to the snow-capped peaks of the mountains.

CLIMATE.

No accurate data concerning the precipitation and temperature of this region are available, but the climate here is much like that of the interior slope of the Alaska Range in general. In the interior of Alaska along Yukon and Tanana rivers, where records have been kept, the winters are cold and the summers are moderate. The annual precipitation is light, at Fairbanks ranging from 7.76 to 18.71 inches in the period from 1904 to 1910, but within the mountains and foothills of the Alaska Range it is probably higher. The winter snowfall is moderate, seldom sufficient to cover the surface irregularities and vegetation so as to afford good sledding until November. The mean annual temperature at Fairbanks for a seven-year period was 24.72° F., and during the same period the maximum recorded temperature was 86° and the minimum −65° F.

THE ALASKA RANGE AS SEEN FROM THE FORKS OF MOOSE CREEK.

MOUNT McKINLEY AS SEEN ALONG THE CREST OF THE RANGE, LOOKING SOUTHWESTWARD FROM THE HEAD OF STONY CREEK.

VEGETATION.

The Tanana lowland contains fair stands of spruce and cottonwood, especially along the courses of the larger streams and on the lower, well-drained slopes of the foothills, as well as some birch on the drier hillsides, and tamarack and scrubby spruce in the marshes. Spruce trees furnish the only logs from which merchantable lumber can be cut, and few of these exceed 24 inches in diameter at the base, so that the forests will probably never furnish lumber for other than local uses. (See Pl. VIII.) Tongues of timber extend from the lowland southward along the valleys of the main streams. (See

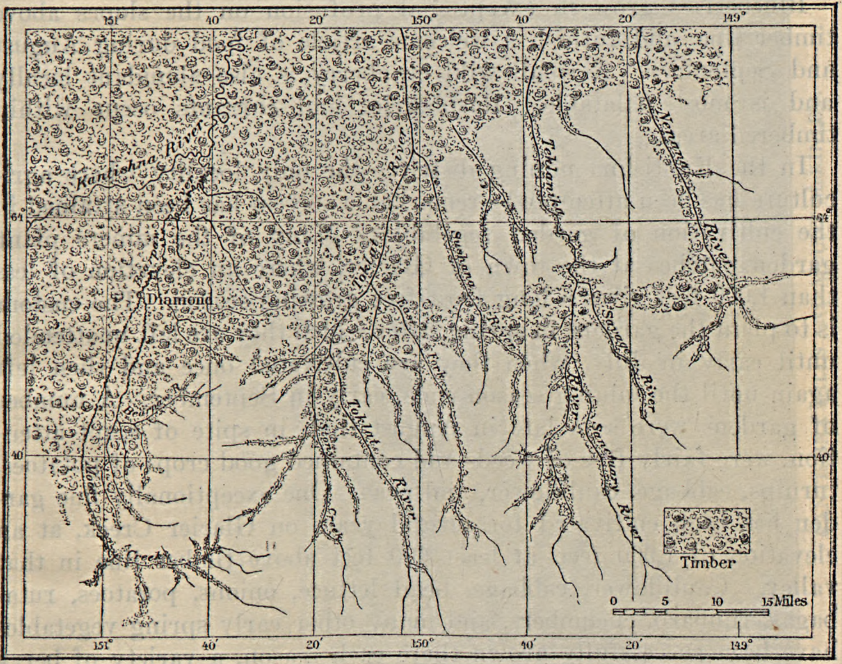

FIGURE 2.—Sketch map of the Kantishna region, showing areas in which timber occurs.

fig. 2.) Timber is limited to areas below 3,000 feet, though a few trees were seen as high as 3,700 feet, but not all the surface below 3,000 feet is forested. Even in the lowlands there are large swampy areas in which trees are sparse, or altogether lacking. In the Kantishna mining district there is little timber above 2,000 feet, and on Glacier and Caribou creeks it is not found above 1,400 feet. Lumber and fuel for firewood must be hauled to practically all the placer claims on which mining is in progress. In most valleys, however, willow bushes large enough to furnish tent poles and fuel for the camper may be found at elevations several hundred feet above timber line, and it is upon such brush that the prospector and explorer

must rely in most of the valleys within the main Alaska Range. The upper 10 to 15 miles of each of the larger valleys is devoid even of brush.

Grass for horses may be found at almost any place where fuel can be had for the camp fire, and during the summer pack horses will do well if they have sufficient opportunity to graze. The principal herbage on which the horses feed are red-top grass, bunch grass, and a vetch locally called "pea vine." In autumn, however, heavy frosts cause most of the grasses to lose their nutritive value, and horses must be fed on hay and grain if they are expected to do heavy work.

Blueberries grow in exceptional profusion on the slopes above timber line, and furnish a welcome article of food during August and September. A small wild cranberry is also abundant locally and is most palatable. Raspberries and currants occur within timbered areas.

In the Kantishna mining district—the only locality where agriculture has been attempted—remarkable success has been attained in the cultivation of garden vegetables. Many of the miners plant garden patches at the town of Glacier, where an elevation of less than 1,000 feet gives a long frost-free growing season. The custom is to plant the gardens in spring, after which they are left unattended until early in July, when they are cultivated once and then left again until the mining season ends, early in September. A number of gardens were seen late in August that, in spite of scant attention, were fairly free of weeds and contained good crops of potatoes, turnips, cabbage, cauliflower, and peas. One exceptionally fine garden has been cultivated for several years on Glacier Creek, at an elevation of 1,900 feet, at least 600 feet above timber line in that valley. Cauliflower, cabbage, head lettuce, onions, potatoes, rutabagas, rhubarb, cucumbers, and many other early spring vegetables have been successfully grown there each season, a variety of berry tomato matures, and timothy and oats ripen. Garden flowers, including several varieties of poppies, pansies, and many native wild flowers bloom in profusion. The uniform success of vegetable and flower gardens through many successive seasons gives assurance for the future of agriculture in the favorably situated parts of this region.

GAME.

Probably no other part of North America is so well supplied with wild game, unprotected by game reserves, as the area on the north slope of the Alaska range west of Nenana River. This region has been so seldom visited by white men that the game herds have until recent years been little molested by hunters. White mountain

KANTISHNA HILLS AND MOUNT McKINLEY.

SPRUCE TIMBER ON UPPER TEKLANIKA RIVER.

sheep are particularly abundant in the main Alaska Range and in the more rugged foothills. Caribou are plentiful throughout the entire area and were seen in bands numbering hundreds. Moose are numerous in the lowlands and range over all the area in which timber occurs. Black bears may be seen in or near timbered lands, and grizzly bears range from the rugged mountains to the lowlands. Rabbits and ptarmigan are at times remarkably numerous, but they vary in abundance from year to year. In 1916 both rabbits and ptarmigan were scarce. Fur-bearing animals are taken each winter, notably fox, lynx, mink, and marten, and beaver are exceptionally abundant in the lowlands but are now protected by law.

During the last few years market hunters have visited the basins of Teklanika and Toklat rivers and have killed large numbers of mountain sheep for the Fairbanks market. With the establishment of a town at Nenana a market for wild meat is brought closer to the game ranges, and the completion of the railroad will make accessible to visitors a famous game country which has so far been preserved only by its inaccessible location. It was therefore imperative, if the great game herds were to be preserved, that some provision should be made by law to prohibit hunting in this region. With this end in view, a bill was passed by Congress in February, 1917, establishing a great reserve and game refuge—the Mount McKinley National Park. The enactment of this law insures the future safety of the game within the park boundaries.

POPULATION.

The natives have no permanent settlements in this area. As the Indians of interior Alaska depend principally on fish for their subsistence, their villages are all on fish streams, and they spend the summer season in catching and drying fish. The largest Indian villages in this general region are on Tanana and Yukon rivers, one just above the new railroad town of Nenana and the other at the junction of the Tanana with the Yukon. Smaller settlements are on Lake Minchumina and at Telida, in the upper Kuskokwim basin. From all of these settlements hunters and trappers sometimes make trips to the foothills and mountains of the area here considered, but moose, killed in the lowlands, furnish these men most of their fresh meat, as moose may be obtained nearer the settlements than either sheep or caribou. In the summer of 1916 the Geological Survey parties saw no Indians in the mountains and found evidence only of scattered temporary camping grounds.

The only permanent habitations in the region are those of the miners in the Kantishna district. The original discovery of gold placer deposits in 1905 brought about an influx of gold seekers and in the fall of that year several thousand persons rushed in to share in the prosperity of the new camp. Many new log-cabin towns were built, among which the most important were Diamond, at the head of navigation on Bearpaw River; Glacier, on the same stream, at the mouth of Glacier Creek; and Roosevelt, on Kantishna River, 10 miles below the mouth of McKinley Fork. Each of these towns had at one time a population of several hundred, and from them the miners and prospectors traveled to the numerous creeks. During the winter of 1905 and the spring of 1906 it became apparent that the deposits of gold-bearing gravel were neither so widespread nor so rich as the prospectors had hoped, and most of them left the district. Some 40 or 50 men, however, including those who had obtained promising claims and those who believed that further prospecting was warranted, stayed in the district, and the population has remained rather constant ever since. Of the 36 people in the district during the summer of 1916 over half came to this camp during the first two years after its discovery.

The town of Roosevelt is now completely deserted and is seldom visited. Diamond is also deserted, though it is on the route of summer travel to the mines and is used as a storage place for such provisions as are brought in by boat and await freezing weather to be sledded to the mines. Glacier is also deserted in summer, though a number of cabins are kept in repair as winter quarters for miners who prefer to spend the cold months in the shelter of the timber, near their fuel supply.

ROUTES OF TRAVEL.

The Kantishna region lies well away from any commonly used route of travel in Alaska and is therefore visited only by persons whose business takes them to it. The headwater areas of Teklanika and Toklat rivers have no permanent habitations, and are seldom visited except by a few trappers and hunters. Travel in this region is confined almost entirely to routes leading to the mines in the Kantishna Hills. Until the summer of 1916 Fairbanks was the large settlement nearest the mines and was the point from which most of the provisions and equipment for the Kantishna region were obtained.

Two routes of travel from Fairbanks to the Kantishna basin are commonly followed. In summer, when the streams are open to navigation, Tanana River is followed to the mouth of the Kantishna, and small launches are taken up that stream to the mouth of Bearpaw River, and up the Bearpaw to the deserted village of Diamond, at the head of launch navigation, a total distance of 143 miles from Tanana River to Diamond. From Diamond an old trail led overland to the abandoned town of Glacier, but this trail has now become so much obstructed by beaver ponds that it is almost impassable even to a man on foot, and is entirely impracticable for horses. A better route follows Moose Creek up to Fish camp, a distance of 7 miles, and thence across dry gravel benches to Glacier. From Glacier indistinct trails lead up Glacier Creek and thence to the small mining communities.

For travel in winter, when much of the freighting to the placer camps is done, a different route is chosen. Tanana River is followed to Nenana, and Nenana River is ascended for 30 miles to the base of the foothills. From that point a trail leads westward along the south edge of the lowland to Knight's roadhouse on Toklat River, northwest of Mount Chitsia. Thence Toklat River and its tributary Clearwater Fork are followed to Myrtle Creek. The trail follows Myrtle Creek up to a point near its head, crosses a low pass into the head of Spruce Creek, and descends that stream and Moose Creek to the vicinity of the mines on Moose, Eldorado, and Friday creeks. The total distance along this route by sled from Fairbanks to Eureka Creek is about 165 miles.

No definite schedule of charges for winter freighting from Fairbanks to the mines has been established, for most of the supplies have been brought in by the miners themselves, and no large amount of contract freighting has been done. Small lots of freight have been carried for 15 cents a pound but by men who were making the journey for other purposes. Contracts for freighting larger amounts of supplies by dog sled from Fairbanks to the mouth of Eureka Creek could probably be let at 15 to 20 cents a pound. Perishable supplies that must not be frozen have been brought from Fairbanks to Diamond by way of Tanana, Kantishna, and Bearpaw rivers in small launches, at a charge of 4 to 6 cents a pound.

On the completion of the Government railway, which will traverse the valley of Nenana River, travel to the Kantishna region will be greatly facilitated. It will be possible to reach the eastern edge of the region in one day's journey from the coast at all seasons of the year. From Nenana River a splendid route, along which travel by pack train is now easy, extends from the mouth of Hines Creek, opposite the mouth of the Yanert Fork, westward across Teklanika and Toklat basins through a series of low divides that lead in a direct course to the head of McKinley River, at the base of Mount McKinley. In this region is the Mount McKinley National Park, which includes an area of about 2,200 square miles of the Alaska Range. To make this park accessible to visitors a road should be constructed from the railroad along the route just described, and such a road would be of great benefit to the miners of the Kantishna district.

In 1916 the town of Nenana was established at the mouth of Nenana River, and there construction work on the new Government railroad from Seward to the interior was begun. It seems likely that in the future Nenana, which is 55 miles nearer than Fairbanks, will furnish much of the supplies used in the Kantishna region.

MOUNT McKINLEY NATIONAL PARK.

The northeastern portion of the Mount McKinley National Park lies within the area here discussed. The act establishing this park is as follows:

[Public, No. 353, Sixty-fourth Congress.]

An act to establish the Mount McKinley National Park, in the Territory of Alaska.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the tract of land in the Territory of Alaska particularly dscribed by and included within the metes and bounds, to wit: Beginning at a point as shown on Plate III, reconnaissance map of the Mount McKinley region, Alaska, prepared in the Geological Survey, edition of nineteen hundred and eleven, said point being at the summit of a hill between two forks of the headwaters of the Toklat River, approximate latitude sixty-three degrees forty-seven minutes, longitude one hundred and fifty degrees twenty minutes; thence south six degrees twenty minutes west nineteen miles; thence south sixty-eight degrees west sixty miles; thence in a southeasterly direction approximately twenty-eight miles to the summit of Mount Russell; thence in a northeasterly direction approximately eighty-nine miles to a point twenty-five miles due south of a point due east of the point of beginning; thence due north twenty-five miles to said point; thence due west twenty-eight and one-half miles to the point of beginning, is hereby reserved and withdrawn from settlement, occupancy, or disposal under the laws of the United States, and said tract is dedicated and set apart as a public park for the benefit and enjoyment of the people, under the name of the Mount McKinley National Park.

SEC. 2. That nothing herein contained shall affect any valid existing claim, location, or entry under the land laws of the United States, whether for homestead, mineral, right of way, or any other purpose whatsoever, or shall affect the rights of any such claimant, locator, or entryman to the full use and enjoyment of his land.

SEC. 3. That whenever consistent with the primary purposes of the park, the act of February fifteenth, nineteen hundred and one, applicable to the location of rights of way in certain national parks and national forests for irrigation and other purposes, shall be and remain applicable to the lands included within the park.

SEC. 4. Nothing in this act shall in any way modify or effect the mineral land laws now applicable to the lands in the said park.

SEC. 5. That the said park shall be under the executive control of the Secretary of the Interior, and it shall be the duty of the said executive authority, as soon as practicable, to make and publish such rules and regulations not inconsistent with the laws of the United States as the said authority may deem necessary or proper for the care, protection, management, and improvement of the same, the said regulations being primarily aimed at the freest use of the said park for recreation purposes by the public and for the preservation of animals, birds, and fish, and for the preservation of the natural curiosities and scenic beauties thereof.

SEC. 6. That the said park shall be, and is hereby, established as a game refuge, and no person shall kill any game in said park except under an order from the Secretary of the Interior for the protection of persons or to protect or prevent the extermination of other animals or birds: *Provided*, That prospectors and miners engaged in prospecting or mining in said park may take and kill therein so much game or birds as may be needed for their actual necessities when short of food; but in no case shall animals or birds be killed in said park for sale or removal therefrom, or wantonly.

SEC. 7. That the said Secretary of the Interior may, in his discretion, execute leases to parcels of ground not exceeding twenty acres in extent for periods not to exceed twenty years whenever such ground is necessary for the erection of establishments for the accommodation of visitors; may grant such other necessary privileges and concessions as he deems wise for the accommodation of visitors; and may likewise arrange for the removal of such mature or dead or down timber as he may deem necessary and advisable for the protection and improvement of the park: *Provided*, That no appropriation for the maintenance of said park in excess of $10,000 annually shall be made unless the same shall have first been expressly authorized by law.

SEC. 8. That any person found guilty of violating any of the provisions of this act shall be deemed guilty of a misdemeanor, and shall be subjected to a fine of not more than $500 or imprisonment not exceeding six months, or both, and be adjudged to pay all costs of the proceedings.

Approved, February 26, 1917.

GEOLOGY.

PRINCIPAL FEATURES.

The areas of outcrop of the rock formations that have been differentiated in this region are shown on the accompanying geologic map (Pl. I, in pocket). The distribution of the formations as shown on this map has been determined only by reconnaissance field work, in which a large area was visited in a short summer field season, so that it was possible to make only an approximate outline of the geologic units. There was not time to trace out all the formational boundaries, and when the geologic field work was done the only topographic map available was that prepared by Brooks and Reaburn in 1902, on which merely a narrow strip of country was shown, on a scale of 10 miles to the inch. The geologic notes made in the field were therefore adjusted to the finished topographic map given here (Pl. II, in pocket) several months after the field work had been completed. An additional difficulty in fixing the age and stratigraphic position of most of the formations arises from the fact that in this region fossils are scarce and unsatisfactory, so that the determination of the age of many of the geologic units depends upon their correlation with similar beds in other localities or upon their stratigraphic relations to other formations whose age has been established. The ages to which some of these formations are assigned may therefore be changed in the future when diagnostic fossils are discovered or when the stratigraphic succession is more fully worked out. Under these circumstances it is inevitable that the outlines of the formations as shown will be found to be somewhat in error in places when critical and detailed examination is made in the field. Nevertheless, the map is believed to represent with a fair degree of accuracy the general outlines of the formations shown and to furnish at least a guide for the future worker who has time and facilities for more refined mapping. The formational boundaries shown by Brooks and Prindle have been accepted for a few places within the region that the writer had no opportunity to revisit.

As will be seen from the geologic map (Pl. II, in pocket) the pre-Tertiary rocks have been divided into four units—the Birch Creek schist, the Tatina and Tonzona groups, and the Totatlanika schist. In none of these rocks have fossils been found in this area, and they have been differentiated largely on lithologic and stratigraphic grounds. Any one of these divisions may contain some rocks that should properly be placed in another division, for each division contains a variety of materials. Any of these divisions may also comprise several formational units, and if so they should be subdivided. This is particularly applicable to the Totatlanika schist, which includes schists and gneisses of sedimentary and igneous origin. Such a subdivision, however, must await the careful and painstaking work of the detail geologist, for it is not possible in reconnaissance mapping. The geologic formations of the Kantishna region range in age from the pre-Ordovician schists to the present stream gravels, and comprise a great variety of materials, including sediments of all the common types and both intrusive and extrusive igneous rocks of many kinds. They also vary in degree of metamorphism from highly altered mica schists to unconsolidated and flat-lying recent deposits. Although the outermost range of foothills is composed dominantly of altered igneous rocks, the other foothill ranges and the main Alaska Range south of this region may be said to be composed primarily of material of sedimentary origin, with which are associated minor amounts of igneous material. The range is therefore the result of the folding and uplift of old sediments rather than a mountain mass formed by the injection of large quantities of molten intrusive rocks or by the upbuilding of a great mass of volcanic flows. Farther southwest, especially beyond Muldrow Glacier, large areas of granitic rocks make up an important element of the Alaska Range, but east of that glacier deep-seated igneous rocks are of minor importance.

The axis of folding in the region has a pronounced east-northeast trend (see Pl. II) parallel to the axis of the Alaska Range, and is the result of crustal movements brought about by stresses applied in the same direction as those that caused the elevation of the range. The uplift of the present mountain mass, however, did not produce all the metamorphism that some of the rocks have undergone, for that uplift took place in post-Mesozoic time, and before it began some of the rocks of the range, notably the Birch Creek schist and the Totatlanika schists and gneisses, had been greatly metamorphosed by crustal movements acting in the same direction as those that forced up the mountains. The present range, therefore, was formed along a zone of weakness that had previously yielded to stress. It is not yet possible to state whether or not the crest line of the present range coincides with the axis of an older range. The geology of the higher part of the mountains in this region and of the Susitna slope of the range to the south have not yet been studied, but it appears that the older rocks, including the schists and gneisses, do not outcrop there. It may be that the schists and gneisses of the north flank of the range represent the core of an older range, but if so that range was reduced by erosion to a series of hills of low relief before the deposition of the Tertiary beds that were involved in the last stage of mountain uplift.

The following table gives the stratigraphic sequence for this district as determined by the geologic studies that have so far been made:

Quaternary:
- Gravels, sands, and silts of the present streams; talus accumulations; peat and impure organic deposits, or muck; soils and rock disintegration products in place; deposits of existing glaciers.
- Terrace and bench gravels, some of glaciofluvial origin.
- Glacial deposits of at least two stages of Pleistocene glaciers.

Tertiary:
- Nenana gravel (loosely consolidated elevated gravels and sands, of yellow or buff color, locally tilted). Possibly in part Pleistocene.
- Coal-bearing formation (generally light-colored soft sandstones, clays, and gravels, little indurated, locally containing lignite). Probably Eocene. Associated with these sediments are lava flows and tuffs.
- Cantwell formation (dark-colored indurated conglomerates, grits, sandstones, and shales, with some carbonaceous material). Of Eocene age. Associated with these sediments are dikes, lavas, and tuffs.

Mesozoic (?) limestones at head of Sushana River.

Pre-Tertiary amygdaloidal greenstones, locally ellipsoidal.

Devonian or Silurian:
- Totatlanika schist (quartz-feldspar schists and gneisses, with some metamorphosed black carbonaceous slates and limestone).
- Tonzona group (black slates, argillites, and phyllites, with some schists, graywacke, and chert).

Ordovician (?):
- Tatina group (black slates and argillites, with some graywacke, thin-bedded limestone, shale, sandstone, and chert).

Pre-Ordovician:
- Birch Creek schist (micaceous and quartzitic schists and phyllites, with some metamorphosed igneous material).

The geologic history of this part of Alaska can be only outlined. Fossils that would enable the geologist to determine the age of the formations are scarce, and in many important rock units no fossils have been found. The intense metamorphism of the older rocks and their complex structure also make difficult the determination of the stratigraphic relations of the units. Furthermore, there are many breaks in the stratigraphic record, representing long periods of time during which either this area was a land mass and no sediments were deposited, or such sediments as once existed were removed by erosion or covered from view by younger overlying materials.

Our present knowledge of the geologic history may be summarized briefly, as follows:

The oldest rocks recognized are the Birch Creek schist, which as originally deposited consisted of shales, sandstones, and a little limestone. Into these rocks were intruded various kinds of igneous materials, chief of which was a basic rock, perhaps a diabase. These materials were all still later buried to a considerable depth and subjected to intense crustal movements which deformed them, caused the formation of such secondary materials as mica and garnet, and gave the rocks a schistose cleavage. The deformation and metamorphism that the schists have undergone were not accomplished, however, during a single period of crustal movement but are the result of the successive periods of deformation that have affected the region at different times. The Birch Creek schist is believed to be of pre-Ordovician age.

Succeeding the Birch Creek schist is the Tatina group, which includes black slates and argillites, massive graywacke, and thin limestone and chert beds, all more or less intricately folded and metamorphosed. These rocks were included by Brooks in his Tatina group, because they resembled similar rocks found farther southwest, along Tatina River. As will be shown later, there is some reason to suspect that the rocks so classified in this area may be younger than those at the type locality on Tatina River. They are, however, here called the Tatina group. The Tatina is regarded as at least partly Ordovician but possibly in part Silurian.

On the south border of the Birch Creek schist, between Teklanika and Stony rivers, there is a narrow belt of rocks comprising black slates and argillites, with some phyllites and schists. In many ways these beds resemble some of the metamorphosed sediments included in the Totatlanika schist. They have been included by Brooks in his Tonzona group, of Devonian or Silurian age.

In the northern part of the Kantishna region there is a group of rocks composed predominantly of quartz-feldspar schists and gneisses that form the northernmost range of foothills from Nenana River to Mount Chitsia. These rocks, called the Totatlanika schist, consist primarily of metamorphosed intrusive rocks but include also some metamorphic sedimentary materials, chiefly black carbonaceous slates and minor amounts of sand and limestone. They are believed to be of Devonian or Silurian age, and the sediments to correspond to the Tonzona group of the southern part of the region.

All the rocks listed above are considerably metamorphosed, and have been affected by more than one period of deformation. A large part of their folding and metamorphism, including the development of schistose structure, was accomplished in pre-Tertiary time.

There is a long gap in the stratigraphic column, extending from mid-Paleozoic to the beginning of Tertiary time, during which no sediments, so far as known, were laid down in the Kantishna region, except some limestones in Sushana Valley that may be of Mesozoic age. The Cantwell formation, a thick series of sandstones, conglomerates, and shales, succeeds the Tonzona group and forms an important element on the north flank of the Alaska Range. These beds are generally dark and firmly indurated, and are tilted, folded, and faulted. Although the Cantwell beds have been subjected to considerable deformation, they are little metamorphosed as compared with the older formations already described, and their present attitude can be ascribed to the movements of the crust that brought the Alaska Range into existence. The Cantwell formation is cut by many dikes, and a large amount of lava and volcanic tuff is locally interbedded with the sediments. The Cantwell is of early Tertiary age and has been assigned to the Eocene.

In certain parts of this region there are shales, sands, and gravels with which lignitic coal is locally interbedded. The outcrops of the coal-bearing formation are small, for the deposits are generally concealed beneath a covering of later gravels. The sands, gravels, and shales associated with the coal are prevailingly of light colors and are little indurated. At some places they include fragmental volcanic material and lava flows. They are of early Tertiary (probably Eocene) age.

A heavy deposit of bedded, unconsolidated gravels succeeds the coal-bearing beds in the eastern half of this region. These gravels, called Nenana gravel, have been tilted and faulted and now form a prominent range of hills. They are younger than the coal-bearing formation but are believed to be of Tertiary age.

Quaternary deposits are represented in this region in great abundance and in considerable variety. They include the morainal materials laid down during an ancient glacial advance and certain elevated terrace and bench gravels that are in part formed of the outwash materials from the old glaciers and in part of the reworked materials derived from the easily eroded Tertiary beds. The present streams are also actively engaged in the transportation of detritus, and such of them as head in glaciers have developed extensive flood-plain deposits of gravel, sand, and silt. Accumulations of muck, peat, soil, and talus represent the deposits now in process of formation in the interstream areas.

STRATIGRAPHY.

BIRCH CREEK SCHIST.

CHARACTER AND DISTRIBUTION.

The Birch Creek schist occupies a narrow belt extending from Nenana River, south of Dry Creek, westward to Stony Creek, beyond which the schist area expands northward to include practically all of the Kantishna Hills southwest of Chitsia Mountain. (See Pl. II, in pocket.) Southwest of the area here discussed its limits are not known, but east of Nenana River the schist extends continuously to and beyond Delta River, and there forms a large part of the north slope of the Alaska Range. Within the Kantishna region, however, the schist occupies only the extreme northern front of the range westward to Stony Creek, and beyond that stream has not been observed in the main range.

The Birch Creek schist of this general region has been described by Brooks,[1] Prindle,[2] and Capps,[3] and it is apparent that the formation as a whole is of remarkably uniform composition and distinctive appearance throughout a wide area and can be readily identified in the field, though it includes a number of rock types. As the schists generally occur in mountains and hills of high relief, excellent exposures are numerous. The prevailing rocks include highly contorted fissile mica schists, quartzite schists, and phyllites in shades of green, red, brown, and gray. In exposures where the rocks are little weathered the beds appear rather massive, the rocks cleave into thick slabs, and the prevailing color is green. In weathered outcrops, on the other hand, the schists break down into thinly foliated sheets, the mica is conspicuous, and in places the material has oxidized to red and brown colors. (See Pl. IX.) A characteristic phase is a greenish rock in which the mica is so abundant that it gives the rock surface a glistening, silvery appearance. Locally garnets are scattered through the schist, and some stream gravels contain large quan-

[1] Brooks, A. H., The Mount McKinley region, Alaska, with descriptions of the igneous rocks and the Bonnifield and Kantishna districts by L. M. Prindle: U. S. Geol. Survey Prof. Paper 70, pp. 56–60, 1911.

[2] Prindle L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, p. 206, 1907.

[3] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 20–22, 1912.

VIEW EASTWARD ACROSS CANYON OF SAVAGE RIVER ALONG MOUNTAINS OF BIRCH CREEK SCHIST.

tities of them. The finer silts are composed in great part of mica scales. The degree of schistosity varies from place to place; in some localities it is developed to an extreme degree, where the mica is most abundant, but in other places the rocks are rather massive and the cleavage is not well developed. Included quartzitic beds have in general been most resistant to the development of schistose structures, and some of them are quite massive. They grade from nearly pure mica-free quartzites to siliceous mica schists in which secondary mica has developed in sufficient abundance to give a marked schistose cleavage. As in all schists, the secondary mica scales are oriented in parallel planes, and the cleavage is in large measure due to the facility with which the mica crystals split.

Quartz veins are found abundantly throughout the schist and show a tendency to follow their foliation. Small gash veins and thin stringers of quartz are the common type, though lenses and bunches of quartz several feet thick were seen, many of which have been twisted and contorted during the metamorphism of the schist and thus bear witness to the fact that they were formed in the distant past before the folding of the schists was completed. The numerous quartz gash veins and lenses are commonly little mineralized and are prevailingly of milky white, massive quartz, entirely free from discoloration by the oxidation of metallic sulphides. At a few places some scattered pyrite was observed in them. In addition to the twisted gash veins that follow the lines of schistosity quartz veins of a different kind have been found in the Kantishna mining district, where such veins, some of them many feet thick, cut across the foliation of the schist, and show no evidence of having been folded with the inclosing country rock. Some of these veins have been traced along the surface for several hundred feet, and throughout their exposed length they maintain rather constant attitudes both of strike and dip. Furthermore, they are commonly mineralized and in places show abundant sulphides, including pyrite, arsenopyrite, sphalerite, galena, stibnite, and native gold. Without doubt veins of this group have supplied most of the gold to the stream placers of the Kantishna district. They may be termed fissure veins, to distinguish them from the gash veins, and were deposited much later than the gash veins, after the metamorphism of the inclosing schists was completed, and probably in connection with the intrusion of igneous rocks.

Some pyrite is scattered through the schist itself, and the red and brown colors of the weathered schists are probably due to the oxidation of finely disseminated pyrite.

The area of Birch Creek schist as shown on the geologic map (Pl. II, in pocket) includes also intrusive rocks of a wide range of composition and texture, and possibly also some lava flows that were interbedded with the sediments from which the schists were derived at the time they were originally deposited. The igneous rocks range in composition from basic greenstones and hornblende schists to acidic intrusives and in texture from fine-grained materials to coarse porphyries. The degree of metamorphism which the igneous rocks have undergone also shows a wide range. Some have been so thoroughly deformed and altered that it is difficult to determine their original character. They appear to be as thoroughly metamorphosed as the inclosing schist and to be of almost equal age. Other intrusive masses are fresh and unaltered, and certainly were intruded after the schists had reached almost their present state of alteration. The schists have evidently been cut by intrusions of different kinds and at many periods throughout their history, and igneous rocks are now so intimately intermingled with the materials of sedimentary origin that their complete separation on a geologic map is almost impossible. Only those igneous masses that have been little deformed and have considerable areal extent have been shown on the accompanying geologic map. (See Pl. II, in pocket.)

In the Cosna-Nowitna region, lying northwest of this area and separated from it by the broad lowland drained by Kantishna River, Eakin[1] found two groups of pre-Ordovician rocks, the lower group composed of limestone and altered greenstone, and the upper consisting of quartz-mica schists, quartzite, and black slates. On lithologic grounds there seems to be some justification for correlating the Birch Creek schist with Eakin's upper group of pre-Ordovician rocks.

STRUCTURE AND THICKNESS.

As a result of the very nature of the processes that have developed mica schists from previously unaltered sediments, the structure of the schist as a whole is extremely complex, and can be deciphered only by elaborate and detailed field studies. Metamorphism has destroyed in large measure the original character of the beds; bedding planes are generally difficult to distinguish, and the only obvious structure is that of the planes of schistosity, which may depart widely from the planes of bedding. Furthermore, extensive faulting has taken place, and intricate and close folding tends to reduplicate the same bed many times in a single exposure. Thus structural studies of a limited area may give a false idea of the structure of the schist series as a whole. In a general way, however, the prevailing strike of the schist lies east-northeast, parallel to the trend of the Alaska Range, and the average dips of the beds are steep.

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[1] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, pp. 20-22, 1918.

ORIGIN.

Most of the materials that now make up the Birch Creek schist were no doubt originally clastic sediments, including shales, sandstones, and a little limestone. The quartzite beds represent original sandstones, certain carbonaceous slates are the altered equivalent of shales, and the limestones are certainly water-laid. All these rocks contain secondary mica, and the highly micaceous schists probably represent only a more completely metamorphosed phase of the sediments. On the other hand, they contain certain constituents that without doubt are of igneous origin, such as greenstone schists and gneisses, which grade into little-altered igneous rocks. The schist, as a whole, therefore, consists mostly of altered sediments with which are associated igneous rocks in various stages of metamorphism.

AGE AND CORRELATION.

Although the Birch Creek schist has been studied over a wide area and by many observers positive evidence of its age is still lacking. No fossils have been found in it. Furthermore, these schists are the oldest rocks seen in the region, so that nothing is known of the materials upon which they lie. The next succeeding rocks, the Tatina group, lie unconformably upon the schists, and although they have been tentatively regarded as Ordovician and possibly in part Silurian, their age is still uncertain. If the age suggested is correct, however, the Birch Creek schist is much older, for it is much more completely metamorphosed than the rocks of the Tatina group. No definite evidence of the age of the schists has been obtained in the region here considered, but their general appearance suggested their correlation with the Birch Creek schist between Yukon and Tanana rivers, and there seems to be no sufficient reason for questioning that correlation. The rocks first described by Spurr[1] from the type locality have been correlated with a series of black slates and quartzites on Porcupine River, which, according to Kindle,[2] underlie beds that carry Ordovician fossils, and which he therefore considers pre-Ordovician. All that can now be said concerning the age of the Birch Creek schist is that it is probably pre-Ordovician.

TATINA GROUP.

CHARACTER AND DISTRIBUTION.

The Tatina group as originally described by Brooks[3] includes a series of sediments that are dominantly calcareous but that contain also

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[1] Spurr, J. E., Geology of the Yukon gold district, Alaska; U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 140, 1898.
[2] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, pp. 320–322, 1908.
[3] Brooks, A. H., op. cit., pp. 69–73.

shales and sandstones. The typical exposures occur in the upper Kuskokwim basin, in the valleys of Tatina and Jones rivers, where several thousand feet of beds are exposed. In the Kantishna region beds that were classified by Brooks with his Tatina group occur in a narrow belt extending from Stony Creek eastward into Teklanika basin. (See Pl. II, in pocket.) As studied on Big Creek, a tributary of Teklanika River, this group includes black slates, argillites, cherts, and black limestone, cut by many quartz and calcite veins and much contorted and folded. These beds lie unconformably beneath the Cantwell beds on the south and are intruded by considerable masses of gabbro. On the north the only contact observed was with a similar intrusive mass. Similarly, on the East Fork of the Toklat, just above the canyon, contorted black slate, argillite, and limestone outcrop. Here again the beds are in unconformable contact on the south with Cantwell sediments, and on the north lie against a mass of igneous material. On Toklat River there are extensive exposures of highly contorted and folded carbonaceous slate schists and some interbedded coarser materials. The folding of the beds is locally so close that opposite limbs of the same fold lie parallel. The closely folded Tatina beds at this place are overlain both on the north and south by little metamorphosed Cantwell sediments. On Stony Creek black slates of this group are bordered both on north and south by Cantwell beds.

STRUCTURE AND THICKNESS.

At all localities where they were studied the sediments of the Tatina group are intensely deformed. This deformation is displayed by great structural folds and by intricate close folding and crumpling superposed on the larger structures and parallel to them. The development of slate schists and slates is the result of this deformation. Faults are common within these rocks, and some of them appear to be of great displacement. The areal distribution of the Tatina rocks in this region in a long, narrow band, bordered for the most part by Cantwell sediments, is explained by their anticlinal structure. Brooks[1] has mapped the west end of this anticline, and the same conditions exist farther east, the Cantwell beds flanking the anticline on both limbs but lying unconformably upon the Tatina. Subsidiary to this great anticlinal fold there has been intense crumpling and the development of multitudes of small, close folds parallel to the major structure. Farther southwest, beyond the borders of the region here described, Brooks noted another set of small folds superposed upon the major folds but at right angles to them.

It is impossible to make a reliable estimate of the thickness of the beds of this group as exposed in Toklat and Teklanika basins. The

[1] Brooks, A. H., op. cit., fig. 12.

belt in which they occur measures from half a mile to 2 miles in width at right angles to the strike, and in general the beds have steep dips. Faulting and close folding have so complicated the structure, however, that no reliable estimate can now be made. Moreover, only the crest of the anticline is exposed, and the base of the beds was nowhere seen. It seems safe only to say that the measure of their thickness must be expressed in thousands rather than in hundreds of feet.

AGE AND CORRELATION.

The beds here classified as the Tatina group have in this region failed to yield fossils. They have been identified by Brooks with the Tatina farther southwest by their structural and lithologic similarity, and, as shown on his map (Pl. IX), crop out almost continuously from the upper Kuskokwim basin to the basin of Teklanika River. This areal continuity and the similarity of the appearance of the rocks over a wide area give a strong support to the idea that they belong to a single group which extends throughout this region. From fossils collected near the type locality the age of at least the basal part of the Tatina was identified as Ordovician. In the absence of definite evidence from the rocks in this region, the age is therefore tentatively accepted as Ordovician. The structural relations alone, however, seem to give some evidence that these beds may be younger than Ordovician. In Toklat basin the oldest rocks, without much doubt, are those of the Birch Creek schist. These are immediately succeeded on the south by beds that have been assigned to the Tonzona group, of probable Silurian or Devonian age. The next younger formation is the Cantwell, of early Tertiary age. As already shown, the Tertiary Cantwell beds appear on both limbs of an anticline whose crest is composed of Tatina rocks, whereas the presumably younger Tonzona beds do not appear in that anticline although they outcrop near by upon the Birch Creek schist. If the rocks here grouped with the Tonzona are younger than the rocks classified as Tatina and occur beneath the Cantwell they should outcrop along the anticline. It would further be expected that if these Tatina rocks are older than the near-by Tonzona beds they should occur nearest the Birch Creek schist instead of the Tonzona, which forms a narrow border along the south flank of the schists. These anomalies are suggestive rather than conclusive, for faulting and folding have greatly complicated the stratigraphic relations. The more conclusive evidence of stratigraphic continuity and lithologic similarity is therefore accepted.

In the Cosna-Nowitna region, northwest of this area, Eakin[1] has found a series of massive limestones, several thousand feet in thick-

[1] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, pp. 23-25, 1918.

ness and carrying Upper Ordovician fossils. No such massive limestones occur in the region here considered. The Tatina beds, described above, though calcareous, were nowhere observed to carry massive and prominent limestone beds, and a correlation with the Ordovician limestone of the Cosna-Nowitna region can have little value.

TONZONA GROUP.

CHARACTER AND DISTRIBUTION.

The Tonzona group comprises a series of argillites, slates, and phyllites, with some graywacke and chert that outcrop almost continuously along the north flank of the Alaska Range from Kuskokwim River to the Nenana. The name was first used by Brooks[1] to designate a subdivision of Spurr's Terra Cotta series,[2] on Tonzona River west of Mount Dall. In the northern part of the Kantishna region the sediments of the Tonzona group are intimately associated with gneissic rocks of igneous origin, and no attempt has been made to separate them on the geologic map, the whole being there shown with a single pattern and called the Totatlanika schist. This name was proposed by the writer [3] for these rocks in the Bonnifield region, where the same conditions prevail, the sediments and gneisses being completely intermingled. In the southern part of the Kantishna region, occupying a long, narrow belt between the Teklanika basin and the valley of Stony Creek, there is a group of rocks, largely of sedimentary origin, that were classed by Brooks with his Tonzona group, and that name is therefore applied to them in this report. It is to be understood that in this area the rocks designated the Tonzona group are represented by the sedimentary materials of the Totatlanika schist, to be described later, which includes both the Tonzona and a large quantity of metamorphosed intrusive rocks as well. Thus defined, the sediments of the Totatlanika schist should be classed as Tonzona as soon as their areas are outlined.

The Tonzona beds in this area are characteristically black slates and argillites, much metamorphosed and cut by multitudes of small quartz and calcite veinlets. In the mountain just north of the head of Sushana River the slates and argillites are associated with some altered intrusive rocks, and infolded with the slates and gneisses there is considerable black siliceous limestone, which becomes gray on weathering. As a fossil coral found in the limestone appears to be of Mesozoic age we must assume either that some Mesozoic limestone has been folded or faulted down into these Paleozoic rocks,

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1 Brooks, A. H., op. cit., p. 73.

2 Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 156-157, 1900.

3 Capps, S. R., op. cit., pp. 22-26.

or that some of the supposedly mid-Paleozoic rocks are in reality Mesozoic. The best exposures of the Tonzona rocks are in or near the canyons cut through them by East Fork of Toklat and Toklat rivers, where the rocks are prevailingly black slates, blocky argillites, and graywacke, much folded and contorted and dipping at high angles.

STRUCTURE AND THICKNESS.

The Tonzona rocks everywhere show the effects of strong regional metamorphism, and are folded, faulted, and in places closely crumpled. Nevertheless, compared with the Tatina sediments in near-by localities—for example, on the East Fork of Toklat River—the Tonzona rocks are less intricately crumpled than the Tatina. The major structure consists of great folds parallel with the axis of the Alaska Range, and the faults that cut the folds have the same general trend. Numerous minor faults and small overturned and closely compressed folds were observed. Faulting has taken place locally along the contacts of the Tonzona beds with both the Birch Creek schist and the Cantwell formation, and it is not known how far this faulting has affected the stratigraphic relations, although it seems certain that the Cantwell lies with unconformable overlap upon the Tonzona.

Obviously the complex structure of the beds has made any estimate of their thickness unreliable, but the high dips and areal extent of this group indicate a thickness of several thousand feet. Brooks[1] suggests that the group as a whole consists of two divisions, a lower division, made up largely of phyllites and black slates with some graywacke, to which the beds in this district probably belong, and an upper division, composed of black, red, and green slates, and locally of shales and cherts. He estimates that the lower division is 2,000 to 3,000 feet thick and that the thickness of the whole group is 4,000 to 5,000 feet.

AGE AND CORRELATION.

The age of the Tonzona group is uncertain, as no fossils have been obtained from characteristic Tonzona rocks. Fossils obtained from a limestone bed associated with Tonzona rocks in upper Sushana basin were reported upon by T. W. Stanton, as follows:

> 10031. No. 2. This lot contains a few imperfectly preserved corals which seem to be of Mesozoic types, though it has not been possible to identify them even generically. They are similar to corals obtained in Triassic limestones in other Alaskan areas and are probably of that age.

As these fossils came from a limestone bed, and as limestones are rare or lacking elsewhere in the Tonzona group, their stratigraphic

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[1] Brooks, A. H., op. cit., p. 73.

value is small, for the limestone bed in which they were found may have been merely infolded or faulted into the Tonzona at this place and may not be of the same age as the inclosing material. Brooks referred the Tonzona rocks provisionally to the lower Devonian or to the Silurian because they appear to be younger than the Tatina and are overlain, probably unconformably, by a Middle Devonian limestone. The validity of this determination therefore depends on the uncertain stratigraphic relation between the Tonzona and the Middle Devonian limestone. When Brooks made his correlation the Cantwell, which also overlies the Tonzona, was regarded as Carboniferous, but it is now known to be Tertiary. This fact must make us realize that late geologic formations may exhibit great deformation and metamorphism, for the Cantwell is in places highly metamorphosed and schistose. The degree of metamorphism of the Tonzona, as compared with that of the Tatina and the Cantwell, may justify its assignment to a position somewhere between the two, but this group can not be finally placed in the stratigraphic column until more definite evidence is obtained. Brooks's assignment of it to the Lower Devonian or to the Silurian must be accepted for the present.

Limestones and associated calcareous and slaty carbonaceous shales of Middle Devonian age have been recognized in the Cosna-Nowitna region.[1] These beds should probably be correlated with the Middle Devonian limestone, which according to Brooks[2] overlies the Tonzona beds unconformably, rather than with those of the Tonzona group.

TOTATLANIKA SCHIST.

CHARACTER AND DISTRIBUTION.

The name Totatlanika schist was first applied by Capps[3] to a series of quartz-feldspar schists and gneisses, with some metamorphosed sedimentary rocks, which occupy an extensive area in the foothills and higher mountains between Nenana and Delta rivers. These rocks have now been found to continue westward to the vicinity of Chitsia Mountain and form the outermost range of foothills in the area here discussed. Their northern extension, as shown on the geologic map (Pl. II, in pocket), is at the north base of a prominent eastward-trending range of foothills, but the rocks doubtless extend northward beneath a covering of later gravels and may crop out north of the area in which they have been mapped. The lowland area north of latitude 64° was not visited except along Nenana and Kantishna rivers, and the lowlands were seen only at a distance. On their south border the rocks of this series are also

[1] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, pp. 25–27, 1918.

[2] Brooks, A. H., op. cit., p. 76.

[3] Capps, S. R., op. cit., pp. 22–26.

covered by younger deposits except at the northeast end of the Kantishna Hills. It should be noted that the rocks here classed as the Tonzona group, in the southern part of the Kantishna region, represent sediments which in the northern part of the region are associated and have been mapped with the Totatlanika schists and gneisses because sufficient work has not yet been done to differentiate them.

The rocks here called the Totatlanika schist have already been described, although not under that name, by Prindle[1] and by Brooks and Prindle.[2] They include materials of great variety and contain rocks of both igneous and sedimentary origin and of wide range in degree of metamorphism. One striking and characteristic phase is a porphyritic schist or augen gneiss, in which quartz and feldspar crystals, in a groundmass composed chiefly of fine-grained quartz and mica, form phenocrysts or augen that reach maximum diameters of half an inch to 2 inches. This phase of the rock is decidedly schistose, the phenocrysts are commonly oriented parallel to the schistosity, and the foliation of the matrix lies in curved lines around the augen. The gneiss or schist containing large feldspar phenocrysts reaches its most striking development in the Bonnifield region, in the basin of Totatlanika River, from which stream the rocks received their name. In the area west of Nenana River the characteristic augen gneisses are less abundant and the phenocrysts are less perfectly developed, yet there can be little doubt as to the identity of the rocks. Their best exposures are in the lower canyon of Teklanika River. Associated with the augen gneisses are various phases of material, grading into fine white to cream-colored sericitic schists and including finer-grained schists in which large phenocrysts are lacking.

Prindle's[3] studies have shown that the quartz-feldspar rocks are of igneous origin and were originally rhyolites or rhyolite porphyries and perhaps some tuffs. From these materials the present rocks have been produced by metamorphism. Prindle's description of them is quoted as follows:

> The rock is composed essentially of angular quartz and perthitic orthoclase grains in a finely granular mass of quartz, feldspar, and sericite. It contains a few small grains of plagioclase (albite), apatite, zircon, magnetite, limonite, chloritic material, and some specimens show considerable carbonaceous matter. There are in general three varieties—a coarse-grained variety with feldspars up to 4 centimeters in diameter, a medium-grained variety (the most common) with feldspars 2 to 5 millimeters or more in diameter, and a fine-grained variety, which is a glistening sericite schist containing only a few isolated grains of

[1] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, pp. 206-207, 1907.

[2] The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 149-150, 1911.

[3] U. S. Geol. Survey Prof. Paper 70, pp. 149-150, 1911.

quartz and feldspar. At all localities the rock exhibits a greater or less degree of schistosity, but this is due rather to the arrangement of the fine material than to that of the quartz and feldspar phenocrysts, some of which are conspicuously oriented with their longer diameters nearly at right angles to the general structure. The sinuous lines of fine material wind irregularly among the grains in directions governed by their presence. At some localities the coarse feldspars have, through weathering, been released from the groundmass, and their crystal forms and edges are well preserved. Under the microscope the same is found to be true of much of the quartz, and both quartz and feldspar exhibit many cases of embayment. In the least altered rocks the phenocrysts are still in the original relation to the groundmass, and the structure of the groundmass is preserved; it is micrographitic, granophyric, or flow structure. In the rocks showing flow structure protoclastic phenomena are common.

In the process of metamorphism the quartz and orthoclase have been fractured, and in every specimen observed where this had happened with the two in contact the quartz had yielded to the feldspar. Both quartz and feldspar have in many places been converted into augen by the physical and chemical shifting and deposition of material about their margins.

A striking characteristic of these rocks is the universal presence of quartz-feldspar and feldspathic veins. Some of these are a foot or more thick, but most commonly they are but a few inches thick and of small extent. The minutest gash veins cutting the rock in various directions are of the same character. One such vein in thin section proved to be composed for the greater part of its length of feldspar alone. Toward the termination of the vein, however, the feldspar is limited to the margins of the vein, from which automorphic forms extend toward the middle of the vein, where they become embedded in granular quartz. The feldspar is perfectly fresh, has a lower index of refraction than balsam, and on sections cut at right angles to the positive bisectrix gave angles of 5 to 7 degrees to the basal cleavage. No evidence of twinning was observed, and in composition it is probably a nearly pure potash feldspar. So far as noted there is no indication that these feldspathic veins are connected with intrusion, and their material has apparently been derived from the rocks in which they occur. They are unmetamorphosed. In the lack of detailed observations and studies of these veins any explanation can have but a tentative value, but it would seem that the inciting cause is to be found in the process of metamorphism to which these rocks have been subjected.

So far as the evidence is available, this assemblage of gneisses and feldspathic schists comprises highly metamorphosed rhyolitic rocks, presumably flows, with possibly some associated tuffs and quartz-feldspar sediments.

Considerable material of sedimentary origin is associated with the altered igneous rocks throughout the Totatlanika schist, especially near the base of the series. (See p. 32.) This material consists principally of black slates, carbonaceous slate schists, limestone, and quartz conglomerate, so closely infolded and involved with the quartz-feldspar schists that they have not been differentiated and are included in the Totatlanika schist.

STRUCTURE AND THICKNESS.

The gneisses, schists, and associated sediments, as has already been stated, are complexly folded, faulted, and metamorphosed. In certain localities the crumpling seems to have no definite trend, but throughout the region the principal thrusts that have produced the contortion seem to have been applied from the north and south, at right angles to the axis of the range, and the resulting folds and the strike of the schistosity trend east and west. Faulting is common, and faults parallel to the planes of schistosity as well as faults that cut the foliation were observed. During the summer of 1916 a geologic party in charge of G. C. Martin, while studying the Nenana coal fields, noted eastward-trending faults that cut both the Totatlanika schist and the Tertiary deposits.

AGE AND CORRELATION.

The discussion of the age of the Tonzona group (see pp. 33–34) serves equally well for the Totatlanika, which represents both the Tonzona beds and the associated metamorphosed igneous rocks in areas where the two classes of materials have not been differentiated. The Tonzona is dominantly sedimentary but contains some metamorphic rocks of igneous origin. The Totatlanika is dominantly igneous but includes some sediments. Though the age of this series, as well as that of the Tonzona, has been determined on somewhat uncertain evidence, both are here grouped as Lower Devonian or Silurian.

MESOZOIC (?) ROCKS.

The only rocks of probable Mesozoic age in this area are the limestone beds associated with Tonzona slates and gneisses near the head of Sushana River, already mentioned (p. —). The limestone appears on the surface as two parallel beds separated by several hundred feet of slate and gneiss. Along the outcrops the beds are interrupted, possibly by faults, and the two apparently distinct beds may be merely the outcrop of the same bed, repeated by folding or faulting. The limestone is highly siliceous and weathers gray, but on freshly fractured surfaces is black. Its surface distribution is so small and its stratigraphic relations are so obscure that it has not been shown on the accompanying geologic map (Pl. II, in pocket). All that is known of its age is stated in the discussion of the age of the Tonzona group. (See pp. 32–33.)

CANTWELL FORMATION.

DISTRIBUTION AND CHARACTER.

The Cantwell formation, which occupies an extensive area in the higher parts of the Alaska Range and which has been mapped from the vicinity of Muldrow Glacier on the west to Sanctuary River on the east, comprises the oldest Tertiary sediments that have been recognized in the Kantishna region. Along its northern border this formation gives place to metamorphosed Paleozoic sediments, but on the south it extends into the heart of the range beyond the area discussed in this report.

The Cantwell formation was named by Eldridge,[1] who applied that designation to a series of conglomerates and coarse sandstones that outcrop along Nenana River 10 or 15 miles above the mouth of Yanert Fork of Cantwell River. Eldridge made no suggestion as to the age of the formation. In 1902 Brooks traced these rocks to the north and west and expanded the definition of the formation to include not only the conglomerates and sandstones seen by Eldridge but also a thick series of associated sandstones and shales. As will be shown later, Brooks regarded the Cantwell as Carboniferous. In 1910 the writer[2] observed certain firmly cemented sandstones, shales, and conglomerates on upper Wood River, in the Bonnifield region, east of the area here described. He recognized the probable Tertiary age of the materials but correlated them with the coal-bearing formation, for the Cantwell was then still considered Carboniferous. In 1913 Moffit[3] extended the known area of Cantwell rocks eastward into the upper Nenana basin, demonstrated their Tertiary age, and showed that the beds in upper Wood River basin, which the writer earlier thought were a part of the Tertiary coal-bearing formation, really belonged in the Cantwell formation. By the investigation on which this report is based the known area in which rocks of the Cantwell formation occur was extended still farther. The general northern boundary of the formation as already determined by Brooks[4] was confirmed, though some minor corrections were made possible by more detailed work and by a larger-scale topographic map. The southern boundary was not everywhere determined, but the formation is now known to extend southward to include the area shown on the accompanying geologic map (Pl. II, in pocket), and on a number of trips made southward into unmapped areas the Cantwell sediments were seen to continue far into the Alaska Range, almost to its summit.

The Cantwell formation consists predominantly of coarse clastic sediments. These grade from beds of coarse, massive conglomerate containing pebbles as large as 6 inches in diameter through finer conglomerates to coarse gritty sandstones, and from those into shales. The northern border of the Cantwell is not everywhere a normal contact of sedimentation but is at some places formed by faults, and at such places the base of the formation is not exposed. Where the

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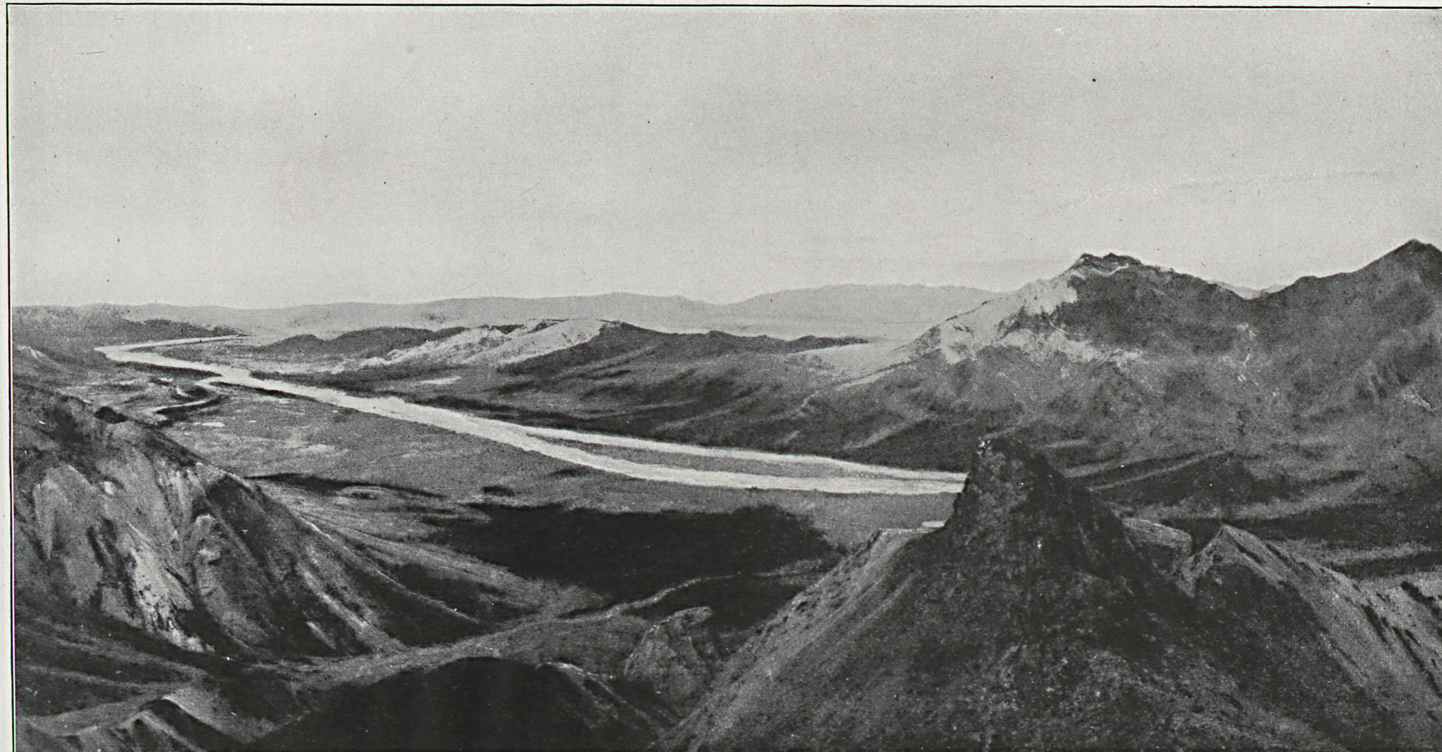
[1] Eldridge, G. H., A reconnaissance in the Susitna basin and adjacent territory, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 16, 1900.

[2] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, p. 28, 1912.

[3] Moffit, F. H., The Broad Pass region, Alaska, with sections on Quaternary deposits, igneous rocks, and glaciation, by J. E. Pogue: U. S. Geol. Survey Bull. 608, pp. 40-49, 1915.

[4] Brooks, A. H., op. cit., pl. 9.

VIEW SOUTHWARD INTO THE VALLEY OF SANCTUARY AND TEKLANIKA RIVERS.



VIEW NORTHEASTWARD ACROSS THE VALLEY OF TEKLANIKA RIVER.

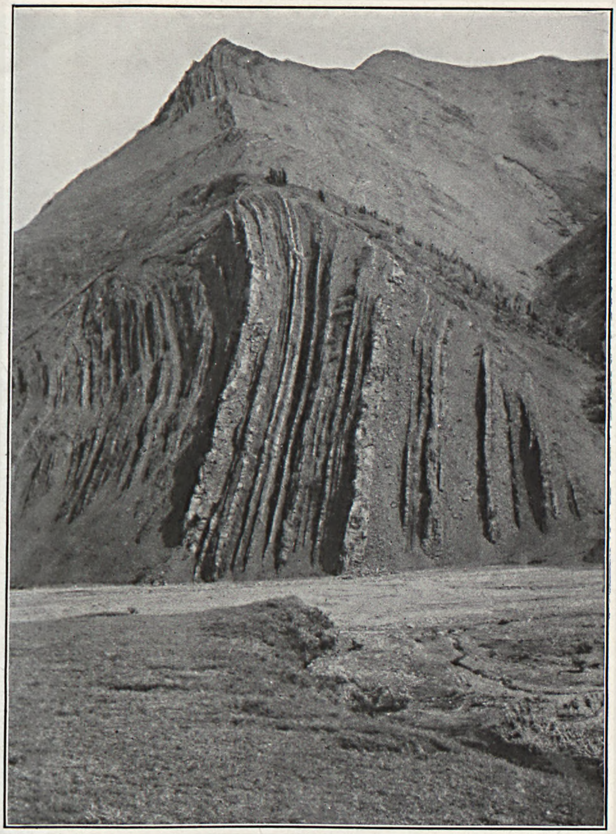
stratigraphic relations are normal, however, the lowest part of the Cantwell is composed of coarse, massive conglomerate, locally 200 feet or more thick, including well-rounded pebbles composed of white and bluish quartz, chert, slate, and granular intrusive rocks. The pebbles are commonly less than 1 inch in diameter and are inclosed in a matrix of coarse sand or grit. The basal conglomerate is succeeded above by interbedded sandstones, grits, shales, and conglomerates, the individual beds ranging in thickness from a few inches to many feet. The succession is probably not the same at any two places, for a single bed may vary in character along the strike, being fine grained in one place and coarse grained in another. In a general way it may be stated that the proportion of conglomerate decreases and that of shale sandstone increases upward in the section, which, however, includes conglomerate beds throughout. In color the Cantwell sediments range from light gray in some sandstones and conglomerates to dark gray and black in the shales. They include some reddish sandstones, but their colors are prevailingly somber. These dark beds contrast sharply with the brilliant colors of the associated lavas.

The conglomerates, sandstones, and shales of this formation are well indurated throughout, and weather into bold, rugged forms. (See Pls. X, XI, and XII, *B*.) The peaks of many high mountains are composed of these materials, and the coarsest beds, particularly the conglomerates, produce many fantastic and picturesque forms. The shales and argillites are generally less resistant to erosion than the sandstones and conglomerates, and where the formation is largely composed of the finer beds the relief is less bold and the slopes are smoother than where the coarser materials prevail. In many exposures the harder, coarse-grained beds stand out as parallel plates of high relief, the shales having weathered into deep troughs between them. (See Pl. XII, *A*.)

Moffit has shown that east of Nenana River the Cantwell sediments exhibit a progressive change from little-altered sediments, through materials that show increasingly the effects of metamorphism, to highly metamorphic rocks that include mashed conglomerates, black slates, and mica schist. He traced the formation throughout these various stages and entertained no doubt that the slates and mica schists of one locality were contemporaneous with the little-altered sediments seen elsewhere. Within the Kantishna region the Cantwell beds have locally been much deformed, but nowhere were they observed to have been so greatly altered as to approach slates and schists in appearance. Blocks of conglomerate seen on the surface of Muldrow Glacier that were similar to some of the Cantwell beds showed signs of incipient crushing and stretching, but no outcrops of that material in place were found. The Cantwell formation throughout contains carbonaceous material, commonly in thin, scattered leaf-like lenses, which represent former vegetable material now turned to lignite. Although this carbonaceous matter can be recognized from its shape as having originally been leaves, twigs, or sticks, its structure and surface markings are generally too poorly preserved for identification by the paleobotanist. At a few places thin seams of sheared lignite less than an inch thick were seen. No workable coal beds have yet been discovered in the Cantwell formation, and at only a few places have fossil leaves sufficiently well preserved for identification been found.

Associated with the sedimentary Cantwell beds there are in places large quantities of volcanic rocks, which occur both as intrusive dikes and sills and as lava flows interbedded with the sediments. (See Pl. XIII.) These materials are particularly abundant in Teklanika and Toklat basins a short distance south of the area mapped in Plate II. They include rocks of considerable range in texture and composition, among them rhyolite, porphyry, rhyolite flows and tuffs, andesite, diabase, and amygdular greenstone. In color the andesites and rhyolites range from white and cream, and light shades of pink, red, green, and purple to darker shades of brown, red, and green; the diabase from dark green and purple to black. Wherever these rocks are well exposed in the high rugged mountains their bright colors, which contrast sharply with the somber associated Cantwell sediments, produce unusually vivid and beautiful scenery. This is particularly true of the mountains on the main East Fork of Teklanika River and East Fork of Upper Toklat River.

Though the Cantwell sediments contain the remains of land plants, they have failed to yield any trace of the marine fossils. It is believed that the beds were laid down as continental land deposits, largely by streams but perhaps locally in small, shallow lakes. They were therefore accumulations of mud, sand, and gravel in stream valleys or on a piedmont plain near some land mass from which the materials were derived. The coarseness of the material shows that this land mass stood rather high, for the streams must have had fairly steep gradients to carry the gravels and coarse sands that make up so large a part of the formation. Furthermore, the great quantity of material necessary to furnish the existing Cantwell sediments, extending as they do from east to west for 100 miles, with a width from north to south reaching 20 miles, and a thickness of several thousand feet, requires the erosion of a land mass of at least as great a volume as that of the remaining sediments derived from it. Neither the location of this land mass nor the rock formations of which it was composed have been definitely ascertained.



A. STEEPLY TILTED SHALES AND GRITS OF CANTWELL FORMATION IN THE BASIN OF EAST FORK OF TOKLAT RIVER.

B. SOUTHWARD-DIPPING ROCKS OF CANTWELL FORMATION IN UPPER TEKLANIKA BASIN.

UPPER FORKS OF TEKLANIKA RIVER.

STRUCTURE AND THICKNESS.

As has been stated, the general structure of the Cantwell formation as a whole is that of a broad synclinal basin whose axis extends from east to west, parallel to the main mountain range. Both the north and south limbs rest unconformably on older rocks, including the early Paleozoic sediments and certain pre-Tertiary igneous materials. Studies were confined for the most part to the northern border of the Cantwell beds, where the Tertiary sediments lie unconformably upon both Tatina and Tonzona beds and terminate against masses of intrusive rock. To the south, in the Toklat basin, the Cantwell beds at several places lie upon a floor of basic lava flows. Moffit[1] has shown that the Cantwell sediments on their southern border, in the Broad Pass region, are faulted into contact with Devonian limestones, are cut off by intrusive rocks, or are covered with Quaternary deposits.

The synclinal structure of the Cantwell formation is only general, for between the north and south borders of the formation there are

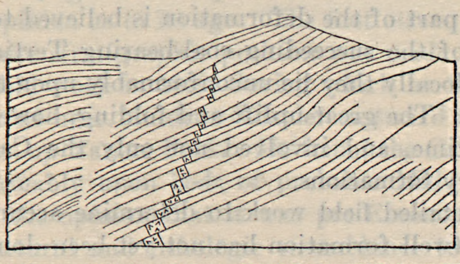


FIGURE 3.—Sketch of Cantwell formation on East Fork of Toklat River, showing bedding faults. As originally intruded the dike cut the formation at right angles to the bedding. Many parallel faults along the bedding planes have offset the dike.

evidences of numerous folds, both anticlines and synclines, and over considerable areas monoclinal dips prevail. The minor folds and the strike of the monoclinal beds are commonly parallel to the folding of the main range. Numerous faults running parallel to the folds were also observed. Some faults cut the bedding with unknown displacement, others lie parallel to the bedding and are distributive faults, confined to numerous parallel beds of the less resistant shales. Such bedding faults are inconspicuous and may readily escape notice unless revealed by the presence of dikes that are offset by the faults. A particularly good illustration of parallel bedding faults is seen in the finely exposed bluffs along upper East Fork of Toklat River. (See fig. 3.)

The folding in the formation on East Fork of Toklat River is broad, open, and apparently of simple structure, and is followed by areas of monoclinal dips. Close study, however, reveals the presence

[1] Moffit, F. H., op. cit., pl. 2.

of large, closely compressed folds with parallel limbs, bringing about a reduplication of beds that would not be suspected unless the folds were seen. (See fig. 4.) At other localities the folding has been intense, and has resulted in intricate contortion, sharp overturned and broken folds, and faulting. (See fig. 5.)

The folding, faulting, and deformation that are now observed in the Cantwell were brought about by the mountain-building processes that created the present Alaska Range. Certainly no mountains ex-

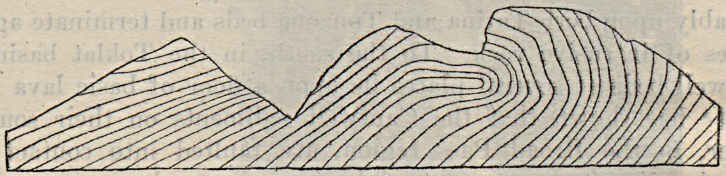


FIGURE 4.—Sketch showing overturned fold in Cantwell formation on East Fork of Toklat River. River bluff is 400 feet high.

isted in early Tertiary time in the area now occupied by the Cantwell formation, for its materials were of necessity deposited in low-lying areas. A part of the deformation is believed to have preceded the deposition of the succeeding coal-bearing Tertiary beds, for it is thought that locally they lie unconformably upon the eroded edges of the Cantwell. The great uplift and folding, however, occurred in later Tertiary time, and involved not only the Cantwell but also younger Tertiary formations.

Sufficiently detailed field work to determine accurately the thickness of the Cantwell formation has not yet been done. The base of

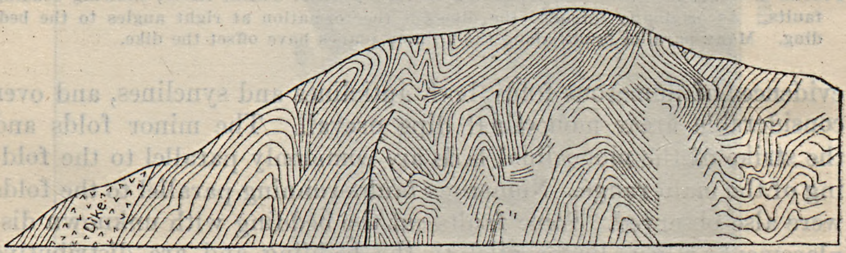


FIGURE 5.—Sketch showing structure of shales and grits of Cantwell formation in the basin of East Fork of Toklat River.

the formation has been observed at several places; but as the beds form a great folded syncline and are generally uncovered by younger deposits, the rugged mountains formed of this material represent only the portion of the beds that have remained, an unknown amount of the formation having been removed by erosion. Its top has not been recognized. Many peaks composed entirely of Cantwell sediments stand from 2,000 to 2,500 feet above adjacent stream beds, and Sable Mountain, between Teklanika and East Fork of Toklat rivers, rises

3,000 feet above the valley to the west, although the beds there are not flat lying. The area occupied by the Cantwell in this region has a maximum known width of at least 12 miles, but in that area the beds have been folded, faulted, and tilted, and the same bed may be crossed many times by one journeying from the north to the south edge of the area. It is difficult to conceive that so wide a belt of rugged mountains could be composed of a single formation unless its normal thickness is to be measured in thousands of feet. Moffit[1] calculated a thickness of approximately 2,700 feet in a single mountain in the Broad Pass region near the mouth of Jack Creek and believed that that measurement represented only a part of the section. Brooks[2] estimated a thickness of at least 2,000 feet in Toklat basin. From the incomplete evidence now at hand it appears to the writer that both these estimates are too low, and that the thickness of the Cantwell beds in the Toklat basin is at least 3,000 feet, and may be much more.

AGE AND CORRELATION.

In Eldridge's original description of the Cantwell formation he expressed no opinion as to its age. The first attempt to assign these beds to a definite stratigraphic position was made by Brooks[3] as a result of his field work in 1902, during which he traced the formation from a point near Muldrow Glacier eastward to Nenana River and for 25 miles up Yanert Fork. He found the Cantwell formation lying unconformably upon beds of probable Middle Devonian age and expressed the opinion that it was pre-Eocene, although recognizing its structural and lithologic resemblance to Eocene beds in other parts of Alaska. Brooks even found Eocene plant remains in shales resembling the Cantwell shales, but they were associated with faults, and from other considerations he concluded that the Cantwell formation was pre-Mesozoic; and that if so, it would most likely be Carboniferous. Moffit,[4] however, as a result of his work in the Broad Pass region in 1913, unqualifiedly assigned the Cantwell to the early Tertiary (Eocene). He collected fossil plants from several localities on the West Fork of Wells Creek, and the following forms in his collection were identified by F. H. Knowlton and Arthur Hollick:

Locality 6565. Ten miles east of mouth of Jack River.
- Taxodium tinajorum Heer.
- Taxodium dubium (Sternberg) Heer?
- Sequoia langsdorfii (Brongniart) Heer?
- Populus arctica Heer?
- Daphnogene kanii Heer.

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[1] Moffit, F. H., op. cit., p. 47.
[2] Brooks, A. H., op. cit., p. 81.
[3] Op. cit., p. 82.
[4] Moffit, F. H., op. cit., pp. 48-49.

Locality 6567. Ten miles east of mouth of Jack River (near 6565).
Aspidium heerii Ettingshausen?
Taxodium dubium (Sternberg) Heer?
Ginkgo adiantoides (Unger) Heer?

The leaves collected by Brooks from Toklat basin included forms like three of the species in lot 6565.

Another fragmentary collection obtained by the writer on Big Creek, a tributary of Teklanika River, at a point about 4 miles above the mouth of Big Creek, was examined by F. H. Knowlton, who reports as follows:

Locality 7278.

There are two types of conifers present—isolated leaves of *Pinus?* sp. and what appear to be branchlets of *Sequoia langsdorfii*—but the shape and attachment of the leaves are not clear. The dicotyledons represent at least three species, but no specimen is well enough preserved to permit certain identification. One strongly suggests *Corylus macquarrii*, but it is without margin; another might be a *Platanus*, but this is uncertain.

From the data available I am not in position to make a very positive age determination, but in my opinion it is probably Tertiary and Kenai in age. It may be as old as uppermost Cretaceous, but I do not think so.

From the facts already stated the Cantwell formation as shown on the geologic map (Pl. II, in pocket) is assigned definitely to the early Tertiary (Eocene), for although the fossil plants collected from this area are alone too few and too imperfect to establish the age of the formation, the stratigraphic continuity of the formation eastward to the fossil localities found by Moffit is believed to be proved, and the lithology of the formation is characteristic and uniform in both areas.

TERTIARY COAL-BEARING FORMATION.

CHARACTER AND DISTRIBUTION.

Coal-bearing Tertiary sediments, supposed to be of Eocene age, have for many years been known in the basin of Nenana River, in the Nenana coal field. Their distribution was first shown by Brooks[1] and Prindle, as the result of field studies made in 1902 and 1906. In 1910 Capps[2] again examined the area between Nenana and Delta rivers and mapped the coal-bearing rocks there. In 1916 G. C. Martin and his assistants made a detailed study of a part of the Nenana coal field. Martin's report on the areas is now in press. These and other investigations have shown that coal-bearing Tertiary deposits occur on the north slope of the Alaska Range and on its eastward continuation, the Nutzotin Mountains, from the head of Kuskokwim

[1] Brooks, A. H., op. cit., pl. 9.
[2] Capps, S. R., op. cit., pp. 26–30 and pl. 2.

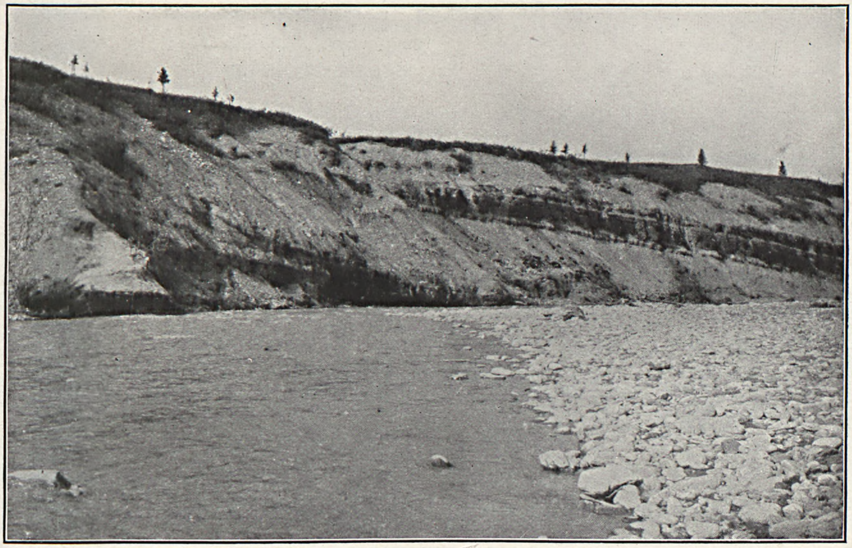
River northeastward and eastward to the international boundary between Alaska and the Canadian Yukon. Throughout most of this distance the beds as known occupy only small areas, and occur either as small warped basins surrounded by older rocks or as beds that dip beneath a cover of later materials. Only in the area between Little Delta River on the east and Teklanika River on the west have any considerable areas of the coal-bearing sediments been noted. By far the largest area of the coal-bearing formation, and that containing the most abundant coal, lies just east of Nenana River, in the basins of Hoseanna, Healy, and Totatlanika creeks, adjoining the region here described. Within the Kantishna region some beds of the coal-bearing formation occur in the basin of Dry Creek, and it is reported that coal beds crop out on the west bank of Nenana River, opposite the mouth of Healy Creek. The formation may be of considerable extent at that place, but, if so, it is covered for the most part by younger materials. Remnants of the basal portion of the coal-bearing formation occur on the divide between Dry Creek and Savage River, and in the Teklanika basin the beds outcrop in such a way as to show the presence there of a considerable area of coal-bearing materials in warped and faulted basins. This area may be considered a western extension of the Nenana coal field, though in places the coal-bearing formation has been removed by erosion. The broad basin extending from Nenana River opposite Hoseanna Creek westward to the Kantishna Hills may contain a large area of the coal-bearing Tertiary beds. On Savage and Teklanika rivers, near their junction, and on Crooked Creek, at the base of the Kantishna Hills, outcrops of this formation occur, and the lack of other areas between Teklanika and Toklat rivers, as shown on the geologic map (Pl. II, in pocket), is more likely to be due to the fact that the basin has been little studied than to the actual absence of the formation between the outcrops shown. Two small basins of the coal-bearing formation were seen in the higher mountains, one at Highway Pass between Toklat River and Stony Creek, and the other between Stony Creek and the extreme southeast head of Moose Creek. Other small areas were mapped on Glacier Creek, a tributary of Bearpaw River from the west slope of the Kantishna Hills.

Any complete description of the coal-bearing Tertiary beds on the north side of the Alaska Range must refer to the basins of Hoseanna (Lignite) and Healy creeks, just east of Nenana River, for it is there that the formation is best exposed and contains the greatest thickness of coal. Furthermore, as that coal field lies on the route of the Government railroad, now under construction, the commercial development of coal mines is certain to be first undertaken there. On Healy

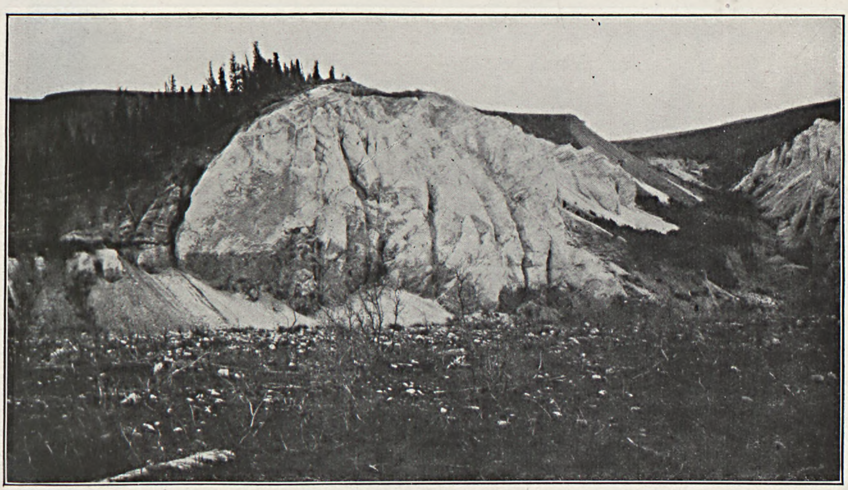
Creek a section measured by Prindle showed a total thickness of 1,900 feet of coal-bearing beds, consisting of gravel, shale, sands, and lignite, of which 220 feet was lignite in 23 separate beds. The stratigraphic relations at that locality are typical of the formation at many other places. The basal beds consist of about 100 feet of smoothly rounded chert and white quartz pebbles in a matrix of white sand and kaolinic material, lying unconformably upon the Birch Creek schist. This basal member, with its conspicuous white color, is characteristic over wide areas, and is of great value in recognizing the base of the formation. Above the white basal gravels are alternating beds of shale, clay, sand, and lignite, with some fine gravels. The lignite beds are thickest and most numerous in the lower half of the formation, where there are seven beds aggregating 174 feet of coal. In the upper half of the section the coal occurs in thinner beds, and fine gravels are more abundant. The formation is succeeded above, in apparent conformity, by a thick deposit of gravel.

In the basin of Dry Creek only the basal white gravels were observed, dipping beneath a covering of younger materials. The white gravels also occur as a thin layer upon the schist in the Dry Creek-Savage River divide and are there scattered remnants of the formation, most of which has been removed by erosion.

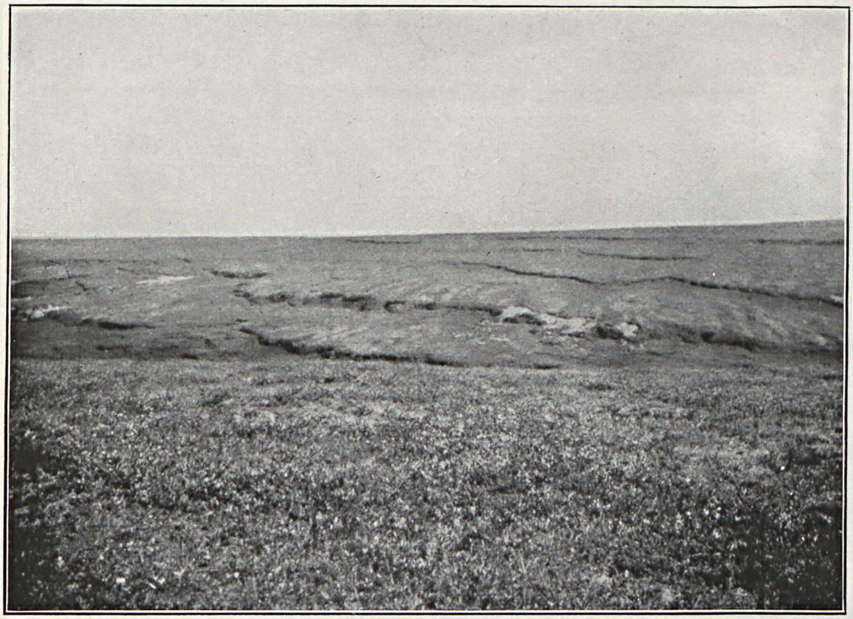
In the basins of Savage and Teklanika rivers west of the head of Dry Creek there is a coal field including several square miles, in which the presence of worakble coal beds of good quality is indicated by the outcrops of lignite along the streams, though later gravels cover most of the probable coal-bearing area. The base of the formation, consisting of white quartz gravels and sands, lies unconformably upon the Birch Creek schist to the south, and the beds dip northward beneath the terrace gravels. (See Pl. XIV, *B*.) The structure of the beds apparently carries them beneath the hills of Nenana gravel, but faulting may cut them off. Coal beds were examined at a number of localities. On the south side of Ewe Creek, 1½ miles above its mouth, one lignite bed, 10 feet thick, apparently of small area, crops out in a small tributary gulch, and another bed 2 feet thick shows near the main stream. On the north bank of Ewe Creek a lignite bed 9 feet thick crops out at intervals for a mile above the mouth of the stream and dips northward. On Savage River north of Ewe Creek a bluff on the west side of the valley shows a short exposure of a lignite bed 14 feet thick dipping northward and overlain conformably by cross-bedded sands. The coal formation is there capped by horizontal terrace gravels. Farther downstream the same bluff shows five coal beds, aggregating 25 feet 8 inches in thickness, interbedded with clays, shales, and sands, dipping northwestward. (See Pl. XIV, *A*.)



A. BEDS OF LIGNITE ON SAVAGE RIVER.



B. BASAL BEDS OF THE TERTIARY COAL-BEARING FORMATION ON SANCTUARY RIVER.



A. SOIL FLOWS IN BASIN OF MOOSE CREEK.

B. SANDS, CLAYS, AND GRAVELS OF THE TERTIARY COAL-BEARING FORMATION ON CLEARWATER FORK OF TOKLAT RIVER.

The section as roughly measured was as follows:

Section of coal-bearing formation on west side of Savage Fork, 2 miles below the mouth of Ewe Creek.

[See Pl. XIV, *A*.]

	Ft.	in.
Gravels of horizontal terrace	15	
Unconformity.		
Clay	24	
Lignite	6	
Clay	18	
Lignite	3	6
Clay	2	
Lignite	1	2
Clays and sands (poorly exposed)	32	
Shale, dark gray	3	
Sandstone, fine gray	3	
Lignite	3	6
Shale, dark gray	2	
Shale, light gray	3	
Shale, dark gray	2	
Sands, gray	4	
Shale, dark gray	3	
Gray sands		
Lignite	6	
Bottom not exposed.		

On the east side of Savage Fork, a quarter of a mile above the section just described, a lignite bed about 8 feet thick is exposed. Too little work has been done to determine whether or not all the lignite beds on Ewe Creek and Savage River are separate beds, or whether the same bed shows at more than one locality.

A small, imperfect exposure of the coal-bearing formation, with a little impure lignite, was seen 1½ miles above the mouth of Savage River.

Sediments of the coal-bearing formation occur along both Sanctuary and Teklanika rivers for 3 miles above their junction. In most of the exposures no lignite beds were seen, but on the Teklanika, half a mile north of the mountains of Birch Creek schist, a lignite bed 3 feet thick shows in the east stream bluff.

In the eastern half of Highway Pass, between Toklat River and Stony Creek, on the north valley wall, there is a small area of the coal-bearing formation, consisting of shales, sandstone, and fine gravels, and a little impure lignite. In the same area, on the south side of the valley, three lignite beds from 1 to 3 feet thick, are reported to crop out.

A pass between Stony Creek and the extreme southeast branch of Moose Creek contains a narrow basin of the coal-bearing formation. Exposures in the valley bottom show an alternating series of clays, sands, gravels, and some streaks of impure carbonaceous material a few inches thick. Scattered through the formation there are lignitized streaks and logs that still show knots and branches and annual rings of growth. On the north edge of this basin the beds of the coal formation dip steeply to the south. Near their margin a bed of weathered lignite, 12 feet thick, associated with purple shale, lies close to a mass of intrusive andesite porphyry, and the discoloration of the shale is believed to be the result of contact metamorphism. Near Stony Creek the beds of this formation contain abundant blocks of extrusive rock and are interbedded with columnar lava.

In the basin of Glacier Creek, in the Kantishna mining district, the white basal gravels of the coal-bearing formation have been disclosed by prospect holes dug near the line of contact between the Birch Creek schist and the southeast edge of the terrace gravels. Farther down the same stream the white gravels crop out in the stream bluffs, again in a position that indicates that they lie upon the schist. Obscure exposures and scattered fragments of lignite on the stream bars of lower Glacier Creek suggest that the formation is present over a considerable area but beneath a cover of younger gravels.

High bluffs of unconsolidated sands, clays, and gravels that are believed to belong to the coal formation occur at several localities in the valley of Clearwater Fork of Toklat River. (Pl. XV, *B*.)

STRUCTURE AND THICKNESS.

The principal features of the structure of the coal-bearing formation in the areas in which it was studied and mapped have already been described, but the facts may again be briefly summarized. The sediments that make up this formation were deposited by streams in low, basin-like areas at a time when the site of the present Alaska Range was yet a region of low relief, a fact indicated by the character of the sediments themselves, for they are dominantly fine shales, clays, and sands. The deposition of the lignite beds must have taken a long period of time, during which little detrital rock material was laid down, for the coal beds were formed by the slow growth and accumulation of vegetation, and while they were being built little stream-borne débris was brought in. The detrital materials are much finer than the sediments now being handled by the streams, and point to low gradients and comparatively sluggish streams. The drainage lines then followed a general easterly direction, in contrast to the present drainage lines, which run north and south.

Much of the deformation and uplift of the Alaska Range has been accomplished since the coal-bearing formation was laid down, and the mountain-building processes of folding and faulting have affected these deposits as well as the older rocks of the region. The compression with the consequent warping of the crust during the growth of the range was comparatively slight in the foothills area, in which the coal-bearing sediments are most abundant, but in the higher mountains was severe, and the small areas of this formation that occur there are more highly deformed than those farther north. Thus each of the areas in the Upper Toklat basin is a syncline, with both limbs lying upon older rocks and dipping steeply toward the axis of the basin. The Teklanika coal-bearing area, lying as it does in a broad basin in the foothills belt, is only moderately compressed, and the observed dips show a monoclinal structure with the beds dipping northward. Similarly, the imperfect exposures on Glacier Creek, west of the Kantishna Hills, indicate moderate northward monoclinal dips. East of Nenana River the same generalizations with regard to the structure hold true. In upper Healy Creek, in a mountainous area, the coal-bearing formation is compressed into a syncline with steep dips on the limbs. In the basins of Hoseanna and Totatlanika creeks, within the foothills belt, the dips are more gentle and the deformation is less severe.

Little information concerning the thickness of this formation was obtained from the Kantishna region, for the exposures there are small and discontinuous. The nearest locality at which anything like a complete section is exposed is on lower Healy Creek, where the formation is about 1,900 feet thick. Farther west, in the region here considered, the formation probably does not reach so great a thickness. The beds were laid down in shallow basins in which deposition took place first in the lowest parts; later, as the beds increased in thickness, their area also increased. Thus the formation continued to expand in area, the higher beds overlapping the older rocks of the river basin. Only over the deepest part of the basins was the full thickness of beds developed, and measurements taken elsewhere will show an incomplete section, even though the formation is exposed from the underlying older rocks to the cover of Nenana gravel.

AGE AND CORRELATION.

The age of this formation has been determined largely from the fossil plants that have been found in it, and from its lithologic resemblance to similar beds in other parts of Alaska that have also yielded fossil plants. Although plant remains in the form of lignite and of carbonaceous imprints of leaves and twigs are common, they have in general been so completely lignitized that the plant forms can no longer be determined. Furthermore, the inclosing sediments are little consolidated, and the plant imprints will not stand the handling necessary to bring them out for identification. In the Nenana coal field the best fossil leaves have been collected from beds that have been hardened by the burning out of adjacent coal beds, and from such materials a number of forms have been identified. No collections have been made in this region.

The fossil leaves found in the coal-bearing formation just east of Nenana River indicate that it is early Tertiary, and the Eocene coal-bearing formation of Alaska has often been referred to under the name of Kenai formation. This is the age assigned to the plants taken from the Cantwell formation, already described. The studies of the Cantwell and the coal-bearing sediments in this area, however, show that there is a decided difference in both lithology and structure between these two sedimentary series, a greater difference than can be accounted for by the more severe alteration of the Cantwell due to its position along the line of greatest metamorphism of the Alaska Range. The chief differences between the two formations may be briefly summarized as follows: The Cantwell beds are everywhere well indurated, and comprise hard rocks, including shales, sandstones, and hard conglomerates, whereas the beds of the coal-bearing formation are almost everywhere little consolidated, and include sands, clays, and fine gravels. The Cantwell is prevailingly of dark, somber colors, being composed for the most part of dark-gray to black beds, whereas the coal-bearing formation is conspicuously light colored, its prevailing shades being white, cream, and buff. The Cantwell formation, although presenting large, clean exposures, has nowhere been found to contain thick coal beds, whereas the coal-bearing beds, even those in the midst of areas of highly deformed Cantwell sediments, are less steeply folded, and preserve their light colors and incoherent character.

As the coal-bearing beds and the Cantwell beds were not found anywhere in direct contact their relative ages have not been proved, but the coal-bearing formation seems clearly the younger. Its general lack of induration and its lesser deformation indicate this, as does also the stratigraphic position of the beds at the localities in Toklat River and Stony Creek. The coal-bearing beds in Highway Pass form a simple syncline, whereas the Cantwell beds in Divide Mountain, just to the east, are highly deformed. The coal-bearing beds were there deposited in a valley that had previously been eroded into a group of hard rocks of which the Cantwell is one formation. Farther west, in the pass between Stony Creek and the southeast head of Moose Creek, the same situation exists. The Cantwell in the area just north of the pass, where it is separated from the coal-bearing beds only by a narrow belt of igneous material, is standing on edge and is composed of thoroughly indurated black materials. The coal-bearing beds, apparently here also deposited in a valley eroded into the lavas and Cantwell sediments, are unconsolidated, of light colors, and much less deformed than the Cantwell. They contain pebbles of a conglomerate that is identical in general appearance with much of the Cantwell conglomerate. If the conglomerate pebbles were derived from the Cantwell the younger age of the coal-bearing beds at this place is proved, for the Cantwell conglomerate, to have yielded the pebbles, must first have been indurated to a hard rock and then subjected to erosion.

The facts above cited have convinced the writer that the coal-bearing formation is younger than the Cantwell, although the case can not be considered as conclusively proved until the two formations are found in direct contact or until a distinction is recognized between the floras which they contain. If his conclusions, based on structural, stratigraphic, and lithologic grounds, prove to be correct, then the assemblage of fossil plants that have hitherto been referred to the Kenai must have a wider stratigraphic range than has been supposed, and the rocks containing them must vary widely in lithology, deformation, and age.

NENANA GRAVEL.

CHARACTER AND DISTRIBUTION.

The term Nenana gravel was first used by Capps[1] to designate a series of elevated gravels that reaches a widespread development on the north flank of the Alaska Range and is well exposed on both sides of Nenana River near the mouths of Hoseanna (Lignite), Healy, and Dry creeks. These gravels were first studied by Brooks and Prindle in 1902, were regarded as of glacial origin, and were grouped with the other Pleistocene deposits on the geologic map.[2] Prindle again visited the Bonnifield and Kantishna regions in 1906, and although he published no geologic map he added much to our knowledge of the distribution and stratigraphy of the various geologic formations. His study of the elevated gravels there, which led him to a different conclusion as to their age, is discussed on page 54. In 1910 Capps studied the gravels in the Bonnifield region, outlined the areas in which they occur, and arrived at the conclusion that they are of Tertiary age. In the progress of the present investigation the Nenana gravel was encountered and more information was gained in regard to its extent and stratigraphic relations. The study of the Nenana coal field by G. C. Martin[3] and his associates, also made in 1916, should give much detailed information concerning the relations of the Nenana gravel to the coal-bearing Tertiary in that locality.

[1] Capps, S. R., op. cit., pp. 30–34.
[2] Brooks, A. H., op. cit., pl. 9.
[3] U. S. Geol. Survey Bull. 664 (in press).

The field work done by the geologists cited above has furnished outlines of the areas occupied by these high-level gravels between the Kantishna Hills on the west and Delta River on the east. East of Nenana River they occur as irregular patches bordered by older rocks, as scattered gravel capping ridges from which most of the deposit has been removed by erosion, and as extensive areas forming prominent ridges and ranges of hills. West of the Nenana they reach their greatest extent between that stream and the East Fork of Toklat River, where they form a conspicuous range of foothills. (See Pl. XVI.) Less extensive areas were mapped on Sanctuary River above its lower canyon, near the mouth of Savage Fork, and on Glacier Creek in the Kantishna mining district. On the geologic map (Pl. II, in pocket) they have been shown only where their character is evident and where they are not covered by later materials. In the area of their greatest extent, west of Dry Creek, they dip northward beneath the younger gravels and may be continuous beneath the surface with the gravels shown near the mouth of Savage Fork, and possibly occur in large areas along the whole depression extending from Nenana River to the Kantishna Hills. They probably also occur in the area north of the northernmost range of foothills and may even occupy the surface in parts of that area. No opportunity was available for a careful study of that part of the field. Furthermore, these gravels may be present in the lowland of upper Kantishna River, although they have not been differentiated there.

The Nenana gravel comprises a thick series of unconsolidated or only loosely cemented material consisting in large part of beds of rather coarse, well-rounded gravel, with only a minor amount of sand. Most of the pebbles are small, ranging from 1 inch to 3 inches in diameter, but cobbles a foot in diameter were seen. In one well-exposed section on Dry Creek about 5 per cent of the bluff was composed of thin beds of sand. The pebbles include many kinds of rock, among which the commonest are quartz, quartzite, schist, and conglomerate, as well as many kinds of igneous material. All these rocks occur in the Alaska Range, to the south, and the gravels were no doubt derived from the main range. At some places the gravels are sufficiently indurated to stand in steep cliffs, but on weathering the sand matrix crumbles and frees the pebbles. A characteristic feature of the Nenana gravel is its yellow or buff color, which distinguishes it sharply from most of the more recent gravels. This color is due to the oxidation of iron-bearing minerals in the sandy matrix and in the pebbles and indicates that the deposit is older than the blue and gray unoxidized gravels of the present stream valleys.

The topographic features formed by erosion on the gravel deposits are generally smoothly rounded, and throughout most of the area

VIEW EASTWARD ALONG NENANA GRAVEL RIDGE OF TEKLANIKA BASIN.

in which they occur the gravels are so deeply covered by loose surface material and by vegetation that their structure can not be made out. Only where vigorous streams have cut into the gravel hills and formed bare bluffs can sections showing the character and structure of the beds be found. The present topography is due in part to the structure of the material, but the readiness with which the gravels break down and the absence of any hard, resistant beds have given the hills their smooth outlines.

STRUCTURE.

The character and composition of the gravel beds indicate that they were laid down by streams. They show the same arrangement of material, lack of complete assortment, and lenses and thin beds of sand that are seen in the stream gravels now being deposited along the larger streams, and they include no well-stratified and assorted silts and sands such as are commonly formed in bodies of standing water. This gravel series was probably laid down by streams flowing northward from the mountains, after they had been rejuvenated and steepened by the uplift of the mountain mass. The steepened streams, able to carry more and coarser material than formerly, removed large quantities of rock from the mountains, rounded and shaped that material as it was carried northward, and deposited it at the edge of the lowland as a great, compound alluvial fan, the deposits of each stream spreading laterally along the slopes to join those of its neighbors to the east and west.

Since the gravels were laid down the mountain-building processes have continued, and the gravels themselves are locally tilted, uplifted, and faulted. The hills extending from lower Dry Creek to Sushana River exhibit monoclinal dips to the north as great as 12°. On their south edge the gravels are cut off, apparently, by a fault; to the north they dip beneath the younger deposits. In the valley of Glacier Creek the beds at the single exposure where they were studied also dip northward, and this is the prevailing dip in the Nenana coal field where the gravels, which apparently lie conformably upon the Tertiary coal-bearing formation, dip 10° to 15° N. Similar structural relations have been found east of Nenana River, where the Nenana gravel in general shows deformation in about equal degree with the associated coal-bearing sediments.

THICKNESS.

The most complete section of the gravel that has been measured is that on lower Healy Creek, where Prindle[1] found it about 2,000 feet thick, lying in apparent conformity upon the coal-bearing for-

[1] U. S. Geol. Survey Bull. 501, fig. 3, p. 58, 1912.

mation. The writer[1] estimated that its thickness was even greater on Gold King Creek, though the exposures there were too poor to permit exact measurements. On lower Dry Creek a steep, bare bluff shows above 700 feet of uniform oxidized gravels. An estimate of the thickness of the formation at the high ridge north of the Dry Creek-Ewe Creek divide, in which the vertical thickness and the dip of the beds were taken into account, indicates a thickness perpendicular to the bedding of about 1,600 feet. The gravel reaches its greatest thickness on this ridge. At other places it is thinner, either because of erosion of part of it or because it did not accumulate there so abundantly as at the other places mentioned. If it was deposited in the way already described, it must originally have varied greatly in thickness from place to place, owing to the unevenness of the surface upon which it was laid down and to the natural thinning of the alluvial fans toward their borders. At present the gravel ranges from a deposit having the maximum thickness noted, 2,000 feet, to a thin layer or even to scattered pebbles on the ridges from which all but a remnant of the formation has been removed.

AGE AND CORRELATION.

The age of the Nenana gravel is still somewhat uncertain. No fossils, either plants or other organisms, have been found in it, and any conclusions as to its age must be based upon its stratigraphic relations to other formations and upon its physiographic position, general structure, and resemblance to other formations of less doubtful age. As first mapped by Brooks[2] it was grouped with the Quaternary deposits, and was considered Pleistocene. Prindle[3] and Capps,[4] both of whom studied the gravel in the Bonnifield region, observed that in many places it apparently lies conformably upon the coal-bearing formation, and that in those places the gravel has been deformed in equal degree with the coal-bearing formation. The imperfect exposures of the two formations west of Nenana River also indicate a general parallelism of bedding between the gravel and the coal-bearing sediments. On the other hand, near Wood River, in the Bonnifield region, the gravel is little deformed, and lies unconformably upon the steeply dipping coal measures, so that at least a part of the gravel is much younger than the coal-bearing formation. The apparent anomalies in different parts of the field are best explained by considering the physical conditions in the region when the gravel deposition began. The laying down of the

[1] Capps, S. R., op. cit., p. 32.
[2] Brooks, A. H., op. cit., pp. 108–109.
[3] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, p. 222, 1907.
[4] Capps, S. R., op cit., pp. 32–34.

coal-bearing series was terminated by an uplift of the Alaska Range, which caused the steepened streams to discharge coarse material over areas that had before received only silts, sands, and fine gravels. The uplift was probably not everywhere equal, so that in one place coarse gravels may have been laid down conformably upon the coal-bearing formation, while elsewhere that formation remained uncovered. As the coal-bearing formation also became involved in the uplift its beds may here and there have been tilted and eroded and later unconformably covered with gravel. Therefore conformity between the two formations might exist at one place, whereas they might be in unconformable contact at another place not far distant.

In studying the relations of the two formations it is necessary to bear in mind the fact that gravel beds composed of material derived from the Nenana gravel may so closely resemble it in color and composition that the two can be distinguished only with great difficulty. This difficulty was experienced at many places along the east side of Nenana River, below Hoseanna Creek, where the Nenana gravel forms an important element of the east valley wall. There reworked gravels, obviously derived from the Nenana gravel of the slope above, form terraces along the valley side and should be correlated with much younger terraces than those formed of the Nenana gravel which they so closely resemble. At some places the reworked materials lie upon the Nenana gravel, and their later age can be determined only in those rare exposures which exhibit the structure of both classes of material. Such reworked materials also lie unconformably upon the coal-bearing sediments, and unless their true character is recognized they give the impression that the section shows an unconformity between the Nenana gravel and the coal-bearing formation. The actual relations between the Nenana gravel and the coal-bearing formation can be determined only by careful study, in which a keen discrimination is made between undisturbed Nenana gravel and the closely similar but reworked and much younger terrace materials derived from them.

The determination of the time at which the deposition of the gravels ceased is also difficult. Brooks considered them Pleistocene, supposing that they were laid down by flood waters during the retreat of the Pleistocene glaciers. It now seems certain, however, that during the last great ice advance the glaciers moved down valleys that had already been deeply eroded in the Nenana gravel. The terminus of the Nenana Glacier at its maximum stand during the last glacial stage stood at the mouth of Dry Creek, where a distinct terminal moraine was deposited. No evidence of glaciation of that stage was observed below Dry Creek. As the Nenana gravel had been uplifted and deeply eroded before that ice advance it is certainly older than that stage. Our knowledge of the glacial history of Alaska before the last great ice advance is scanty, but locally there have been at least two glacial stages,[1] one much earlier than the other, and there may have been several. Thick deposits of glacial till and tillite are found in the valley of White River, near the international boundary, and the conditions that caused successive glacial stages there no doubt affected other parts of Alaska also. In 1910 the writer[2] noted large boulders on the top of the Nenana gravel, near Hoseanna Creek, and in the valley of Gold King Creek, and though he could not explain their presence he expressed doubt as to their glacial origin, for they lay high above the limits reached by ice during the last glacial advance. At that time an earlier stage of glaciation in Alaska had not been recognized. Similar boulders were observed in 1916 on the top of the Nenana gravel hills near Savage River. In that year G. C. Martin and his associates found many such boulders on the high ridge between Totatlanika basin and Nenana River, and they consider them as of glacial origin. If so they represent a glacial advance that antedated by a long period the last ice advance, and were placed in their present position by a glacier much larger than the last one, if the ridge on which they lie has not been uplifted since they were dropped there. Although the establishment of a glacial origin for these boulders will modify the previous conclusions as to the maximum extent of the glacial ice, it does not prove the glaciofluvial origin of the Nenana gravel. All the boulders observed lie on the top of the Nenana gravel, which must have been present before the ice advanced to it, in order to receive glacial boulders on its surface. The physiographic development of the gravel, which, after its uplift and tilting, was eroded into mature topographic forms, with deep intersecting valleys, indicates a considerable age for the gravel, as does also its thorough oxidation. The apparent stratigraphic conformity of the gravel with the coal-bearing formation, where both have been steeply tilted and deformed, also points to a similar age for both formations.

To summarize briefly, the Nenana gravel, as studied over a long belt along the north flank of the Alaska Range, appears to be generally conformable with the coal-bearing formation, though locally unconformities appear. Its deformation, advanced oxidation, and mature topographic forms indicate that it is of considerable age. It is certainly much older than the deposits of the last stage of glaciation which lie in valleys deeply eroded into the gravel. Boulders, apparently glacial, lie on its surface high above the limits

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[1] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pp. 63–67, 1916.

[2] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 33–34, 1912.

reached by the last great glaciers, but those boulders have been seen only on the surface of the gravel and not interbedded in it.

Any determination of the age of the Nenana gravel can be only tentative. It is younger than the Tertiary coal-bearing formation and much older than the last glacial deposits. The writer is inclined to classify it as Tertiary.

IGNEOUS ROCKS.

Igneous rocks are found in all the formations discussed in this report, from the Paleozoic Birch Creek schist to the Tertiary coal-bearing formation, and a microscopic study of them in thin section was made by R. M. Overbeck. They have almost as wide a range in age as the sedimentary rocks. Thus the Birch Creek schist contains basic greenstones that were apparently lava flows extruded upon and interbedded with the water-laid sediments of which the formation is largely composed. If the greenstones are actually interbedded with the sediments, they are of course of the same age. The Tatina group, although cut by intrusive rocks, is comparatively free from igneous material. The Tonzona group, though dominantly sedimentary, contains some metamorphic rocks of igneous origin, and the Totatlanika rocks are composed predominantly of metamorphosed igneous materials.

A series of greenstone flows, apparently at least 2,000 feet thick, appears beneath the Cantwell sediment in the upper Toklat basin. The beds are prevailingly dark-green, brown, or deep purple, are commonly amygdular, and in some flows show ellipsoidal structure. These characteristics indicate that the greenstones were poured out as lava flows on the surface, or perhaps in part beneath water. The section studied contained little interbedded sedimentary material and no fossils. The only stratigraphic relation that could be made out was that the greenstones appear to lie unconformably beneath the Cantwell and are therefore pre-Tertiary. Although conclusive evidence of their age has not been found in this region, the suggestion is made that they may be late Paleozoic or early Mesozoic. In the Broad Pass region Moffit[1] found similar greenstones that he tentatively classified as Triassic. At the headwaters of White River a similar group of lavas seems to be transitional between the Paleozoic and Mesozoic.[2] Lavas that seem to be a continuation of those in the Chisana-White River district have been mapped in the Nizina district[3] as the Nikolai greenstone, where they lie conform-

[1] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 26–28, 1915.

[2] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, p. 47, 1916.

[3] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, p. 63, 1911.

ably beneath the Triassic Chitistone limestone and were considered Triassic or pre-Triassic. Similar amygdaloidal greenstones, either of upper Paleozoic or lower Mesozoic age, are found in other parts of Alaska, so that during one of those periods lavas of that type were poured out over wide areas in Alaska. In the absence of definite evidence from the Kantishna region the age of the greenstones of the upper Toklat basin must remain undetermined for the present and their correlation with the late Paleozoic or early Mesozoic greenstones of other parts of the territory must be considered as a suggestion only.

The occurrence of rhyolite, andesite, and diabase lavas in both the Cantwell and the coal-bearing Tertiary beds has already been mentioned, and those flows in the coal-bearing beds apparently represent the latest volcanic outbursts in this region.

Dikes and sills of granular intrusive rocks, including diabase and andesite and rhyolite porphyries, cut all the formations up to and including the coal-bearing Tertiary beds. In the vicinity of the Kantishna mines larger masses of granitic materials, including quartz porphyry containing abundant orthoclase, cut the Birch Creek schist, and in the vicinity of Muldrow Glacier, south of the area shown on the accompanying map (Pl. I), there are considerable areas of andesite, of dacite and rhyolite porphyry, and of granodiorite. These granitic materials are presumably related to the intrusion of large masses of granitic rocks within the Alaska Range—intrusions that have been generally considered to be of Jurassic age.

QUATERNARY DEPOSITS AND HISTORY.

PREGLACIAL CONDITIONS.

The uplift of the Alaska Range, which began in early Tertiary time, proceeded intermittently. After the first elevation the coarse, stream-laid materials that comprise the Cantwell formation were laid down. This elevation was followed by a period of quiescence, during which the finer coal-bearing sediments and the vegetation that later became lignite coal accumulated. Another uplift caused the steepened streams to bring down the Nenana gravel. The continued growth of the mountains then began to spread northward and involved the area now included in the foothills. Faulting and folding elevated the foothills belt, and the vigorous northward-flowing streams began to intrench themselves in the easily eroded Nenana gravel, in the coal formation, and in the ridges of hard rock that crossed their courses. As these soft materials yielded to stream cutting much more rapidly than the hard rocks the basin between the rock ridges were widened and deepened while the streams were engaged in their long task of cutting canyons through the rock ridges. The valleys lying within the Tertiary unconsolidated sediments thus reached a mature topography while the canyons in the schists and gneisses were still young.

GLACIAL CONDITIONS.

OLDER GLACIATION.

At the beginning of Pleistocene time a change of climate occurred, involving an increase in precipitation and perhaps also a colder mean annual temperature, so that areas in the high mountains received more snow each winter than melted during the succeeding summer. This continued year after year; the snow banks enlarged and joined, and valley glaciers were formed. At first glaciers could exist only at the heads of valleys in the high mountains, but as the process continued many ice tongues, converging from the headwaters of the streams, joined to form great valley glaciers that extended downward toward the flanks of the mountains.

Our knowledge of the events of early glacial time in Alaska is meager. In the northern part of the United States and in Canada there were a number of glacial advances, separated by long periods of time, during which the ice edge withdrew to the north; but the evidence for Alaska is not so complete. The last great stage of glaciation in Alaska was without much doubt contemporaneous with the last or late Wisconsin continental glaciation,[1] but the earlier stages of Alaska glaciation have not yet been correlated with those that occurred in the central part of the continent. Indeed, it is only within the last few years that positive evidence of more than one stage of glaciation in Alaska has been found. In 1891 Russell[2] observed on the southern slopes of Mount St. Elias some elevated marine deposits containing boulders that he believed to be of glacial origin. Maddrén[3] in 1913 studied the same deposits, and agreed with Russell in assigning to the boulders a glacial origin. In 1914 the writer[4] found a thick series of deformed beds of glacial till and tillite and associated outwash gravels in the upper basin of White River, the whole series being undoubtedly much older than the deposits laid down by the glaciers during their last great advance. The last glacial stage was correlated rather definitely with the late Wisconsin stage of continental glaciation. In 1910[5] the writer also observed many large boulders on the surface of the Nenana gravel

[1] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pp. 69–75, 1916.

[2] Russell, I. C., An expedition to Mount St. Elias: Nat. Geog. Mag., vol. 3, pp. 170–173, 1890; Second expedition to Mount St. Elias, in 1891: U. S. Geol. Survey Thirteenth Ann. Rept., pt. 2, pp. 24–26, 1893.

[3] Maddren, A. G., Mineral deposits of the Yakataga district: U. S. Geol. Survey Bull. 592, pp. 131–132, 1914.

[4] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pp. 63–75, 1916.

[5] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 33–34, 1912.

near Nenana River, and, although he considered the possibility of their glacial origin, he was at that time inclined to doubt that they had been brought to their present position by glacial ice, as they lay high above the elevation reached by the glaciers during their last great advance. In 1916 similar boulders were found on top of the Nenana gravel near Savage River, and G. C. Martin and his associates, while studying the Nenana coal field, reached the conclusion that the boulders there are certainly of glacial origin. Thus evidence is accumulating that there have been recurrent glacial stages in Alaska, separated by long intervals during which the ice retreated.

In the basin of Nenana River the evidence furnished by the large erratic boulders indicates that at one time an ice tongue pushed down that stream to the north edge of the foothills, and that at the mouth of Hoseanna Creek its surface stood at an elevation of at least 3,800 feet, or 2,600 feet above the present level of Nenana River, near by. An even greater elevation of the ice surface is indicated by boulders on the Nenana gravel ridge east of Savage River and north of the Ewe Creek-Dry Creek divide, where they were found at a height of 3,980 feet. These figures are based on the conclusion reached by Martin that the boulders are glacial, and on the assumption that no uplift of the gravel hills has occurred since the boulders were dropped, an assumption concerning which we have at present no evidence, either for or against. Farther west, in the upper basin of Moose Creek, erratic boulders occur in positions along Moose Creek itself and in the valleys of its tributaries, Eureka and Eldorado creeks, that show the former presence of ice to a considerable elevation. Those boulders, however, may have been laid down by the greatly expanded Muldrow Glacier at the time of the last ice extension. Elsewhere in the region no evidence of a glacial stage earlier than the last notable one has been obtained.

ADVANCE OF THE LAST GREAT GLACIERS.

No matter how many major glacial advances there have been in this region, it is known that before the last glacial stage began a long time elapsed during which there were no large glaciers in the main mountain valleys, and that the normal processes of weathering and stream erosion were in operation throughout this area. With a renewal of climatic conditions favorable for ice accumulation, however, the ice tongues began once more to grow and to push northward down the stream valleys. In advancing over a country long bared to the action of atmospheric agencies they encountered great quantities of soil, talus, and stream gravels which they picked up and carried northward. As the glaciers removed the surface materials, the rock-filled ice moved over fresh rock, which it ground down and from which it plucked out great blocks of rock. By these processes, which were in operation for a long time, the irregularities of the valley walls and bed were removed, and broad glacial troughs, now so characteristic of the mountain valleys, were formed.

EXTENT OF GLACIATION.

As already stated, glacial boulders and beds indicate that during an earlier glacial stage ice advanced down the valley of Nenana River as far as the north front of the foothills. Similarly, in the valley of upper Moose Creek and near the mouth of Clearwater Fork of Toklat River there are erratic boulders that suggest the former presence of ice, but in those places the outer limits reached by the last great glaciers have not been accurately determined, and the boulders may have been deposited during the final advance of the ice.

During their last advance the glaciers of the Alaska Range left moraines that show definitely the farthest northern position they reached. Thus in the valley of Nenana River a distinct terminal moraine extends to the mouth of Dry Creek, and below that point there is no definite evidence of glaciation of that stage. Similarly, in the valleys of Sanctuary and Teklanika rivers the outermost recognizable terminal moraines lie north of the prominent eastward-trending range of mountains composed of Birch Creek schist. (See Pl. II, in pocket.) In Toklat basin, likewise, the evidence indicates that the mountain glaciers terminated within the mountain valleys and failed to cross the high ridge of Birch Creek schist. In the vicinity of Muldrow Glacier, however, there is every indication that that ice tongue was formerly much expanded. It overrode the divide into upper Moose Creek, filled the upper basin of that stream to a considerable depth, and was flanked on the north by the Kantishna Hills. Some of the ice from this glacier moved northward into the basins of Stony River and Clearwater Fork of Toklat River, but the main outlet was westward along McKinley River. Some ice pushed a short distance northward through the upper canyon of McKinley River, but the main ice tongue is believed to have moved westward into the valley of Birch Creek, west of the area here described. Extensive morainal deposits were laid down in the upper basin of Moose Creek and over the McKinley River–Moose Creek divide. (See Pl. II, in pocket.) The exceptionally large size reached by Muldrow Glacier at that time, in comparison with the much smaller glaciers in the valleys to the east, is due to the altitude of the mountain slopes that drain to it and to the size of the upper Muldrow basin. That glacier once received the ice from the north slope of the range, in its highest part, for a distance extending eastward for more than 30 miles.

The limit reached by the glacial ice in the Kantishna region during the last great stage of glaciation corresponds well with the outermost moraines recognized in the Bonnifield region to the east.[1] Thus in the valleys of Wood River, Little Delta River, Delta Creek, and Delta River the ice tongues, as shown by their morainal deposits, reached almost to the northern front of the mountains, if not a short distance beyond. The glaciers that moved down Nabesna and Chisana River valleys, still farther east, terminated a short distance beyond the border of the mountains. On the south slope of the Alaska Range the situation was very different. The precipitation on that slope was apparently much heavier than on the north or inland slope, for the glaciers there were much larger than those in the Yukon basin. At the time of maximum glaciation the entire basins of both Copper and Susitna rivers were occupied by glaciers. The Susitna Glacier not only extended southward into the Cook Inlet depression but was of sufficient depth to send a northward-flowing tongue through Broad Pass into the valley of Nenana River. Similarly, the Copper River glacier overflowed northward through the range into the valley of Delta River and through other passes still further east. This dissimilarity in the abundance of glacial ice on opposite sides of the same range must have been due in large measure to the difference in precipitation on the two sides.

RETREAT OF THE ICE.

After the glaciers had reached their greatest extension another change in climate, perhaps a decrease in precipitation, came about, which was less favorable to the growth and support of the ice fields, so that they began to shrink both in thickness and in area. The withdrawal of the ice tongues, like their advance, was not constant but was marked by a number of oscillations; but as the supply of snow in the mountains, on the whole, diminished, the sum of the many minor advances, halts, and retreats was a corresponding diminution of the ice-covered area. This diminution continued until many valleys that had once contained large glaciers were free of ice and such other glaciers as still persisted were greatly shrunken. The present glaciers of the Alaska Range are remnants of Pleistocene glaciers, and the ice withdrawal that marked the end of Pleistocene time is believed to have brought about the retreat of the glaciers to approximately the positions they now occupy.

PRESENT GLACIERS.

No important glaciers appear on the accompanying map (Pl. I, in pocket), for the area here discussed comprises only the northern spurs

[1] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pl. 2, 1912.

and valleys of the Alaska Range; it does not include the crest of the main Susitna-Tanana divide. Few mountains in this area are high enough to maintain perpetual snows. Farther south, along the crest of the mountain range, glaciers are still found in the heads of nearly all the valleys. Between Nenana River and Muldrow Glacier the mountains are of only moderate height, and the northward-flowing glaciers are small, the largest being only a few miles long. Farther west, toward the higher peaks of the range, the glaciers are larger. Muldrow Glacier, which stands near the head of Moose Creek, at the southern border of the area mapped, is the largest glacier that drains the inland front of the Alaska Range. Heading near the very summit of Mount McKinley, it flows northeast, then north, and then west, and emerges from the mountains at the head of McKinley River, having a total length of 39 miles.

GLACIAL DEPOSITS.

Although deposits of morainal material are widely distributed throughout the area covered by the glaciers during their last great advance they are in most places hidden by vegetation and are inconspicuous. At a few places there are readily recognizable terminal moraines, which mark the outermost stand of the ice during its last period of expansion. One such moraine lies on the west side of Nenana River just above the mouth of Dry Creek. (See Pl. II, in pocket.) Its surface, like that of most other moraines, is hummocky and irregular, and the larger depressions in it are occupied by ponds and lakelets. It is so overgrown with moss and brush that it affords little opportunity for a study of the materials of which it is composed. Another terminal moraine, in the upper valley of Sanctuary River, is formed of two crescentic ridges that converge downstream and are separated from one another by the flat over which the present stream flows. A similar terminal moraine may be recognized on Teklanika River, where the ice advanced about as far as it did on Sanctuary River. A broad basin in the upper valley of East Fork of Toklat River is floored with morainal materials that show no distinctive glacial topography, but the northernmost stand of the ice in that basin and in the valley of Toklat River is not accurately known, for no terminal moraines were observed. Glacial materials and evidences of glacial erosion were seen in both valleys as far downstream as the canyons through the ridge of Birch Creek schist, but the canyons were apparently not glaciated, and the northward-moving ice in the valleys probably extended no farther than the canyons. A large area north and northwest of the terminus of Muldrow Glacier, occupying the upper basin of Moose Creek and extending into the basin of Stony Creek, is covered with glacial moraine and outwash gravels. The area is one of smooth slopes and flat-topped ridges, which are so well covered with vegetation that good exposures are rare. Outcrops of hard rock are lacking, but gravels and a few erratic boulders scattered over the surface indicate that at least the surficial deposits are glacial.

TERRACE GRAVELS.

Large areas in the Tanana lowland and in the basins between the foothill ranges are covered with stream-laid gravels that are related to the present topography but that lie above the level reached by the present streams, even when they are at flood stage. These gravels form terraces along the stream valleys and occupy the interstream areas in those basins that lie between the foothill ranges and in the great lowland north and northwest of the foothills. (See Pl. XVII.) The term "terrace gravels" has been applied to all material of this class, to distinguish it from the much older and generally deformed Nenana gravel and from the deposits of the present streams.

The terrace gravels are stream laid, and resemble the deposits of the present streams in composition, structure, and degree of assortment. They consist primarily of well-rounded gravels, varying considerably in coarseness from place to place, intermingled with which are considerable sand and silt, both as an interstitial filling between the pebbles and in irregular beds and lenses. In general the terrace gravels are undeformed, and their surface slopes are the slopes of deposition, somewhat modified by subsequent erosion. Their topographic position indicates that they were laid down by streams that followed in a general way the courses of the present drainage lines, but they have been left in their present elevated positions by the lowering of the adjacent stream valleys through normal stream erosion. The terrace gravels are commonly little oxidized; they maintain their original grayish color and thus contrast sharply with the thoroughly oxidized and yellow Tertiary gravels. In most exposures examined they are not very thick, though they range from 2 or 3 feet to 20 feet or more, but they cover wide areas to a depth sufficient to hide the underlying deposits. Their surface is commonly covered with vegetation. Locally the character of the terrace gravels is strongly influenced by the character of near-by materials from which they were originally derived. Thus, along the east bank of Nenana River many deposits were seen that, as shown by their physiographic position and form, obviously belong with the terrace gravels, but that were composed of oxidized and yellow materials closely resembling in appearance the Nenana gravel. In those places the distinction must be based on the physiographic evidence, for the

CANYON IN BIRCH CREEK SCHIST ON TEKLANIKA AND SANCTUARY RIVERS.

terrace gravels there have been derived wholly or in large part from near-by ridges of Nenana gravel and retain the oxidized character of the ancestral deposit but have taken on the physiographic form of the much younger terrace materials.

The general physical condition and form of the terrace gravels, their resemblance to similar materials in the Bonnifield region, and their relations to the glacial moraines indicate that in part at least they are composed of outwash materials laid down beyond the ice border at the time of the last great ice advance. At some places they consist of material brought from a distance by streams. At others they are composed largely of material of local derivation that has been rehandled and reshaped into new physiographic forms but moved no great distance from its source.

The fact that in a single stream valley there may be a series of terraces, one above the other, shows conclusively that the materials composing those terraces vary considerably in age, the lowest being the youngest and the highest the oldest. Such stream terraces have probably been continuously in process of formation from glacial time until the present, and the terrace gravels therefore range in age from Pleistocene to Recent. Placer gold has been found in encouraging amounts at several places in the terrace gravels, and at one place a considerable amount has been recovered by mining. The so-called "benches" on Moose, Glacier, and Caribou creeks are auriferous, and it is possible that the terrace gravels may at some time be extensively mined.

PRESENT STREAM GRAVELS.

The gravel deposits of the present streams have been laid down under conditions essentially like those that now exist in the region. In this class are included only gravels that occupy the flood plains of the present streams and that may be overflowed in periods of high water. As a result of their method of formation the stream gravels appear on the map (Pl. II, in pocket) as long, narrow bands following the windings of the stream valleys. These deposits are really continuous, but at places where there are narrow rock canyons the streams may entirely cover the valley floor, or the stream deposits may appear only as patches too small to be shown on a map of this scale.

The width of the belt of gravels along any stream depends in large measure upon the size of the stream, the shape of the valley floor, and the amount of material that the stream carries in suspension. Most of the streams that are fed mainly by water from melting glaciers are heavily loaded with detritus and flow in many branching channels over wide gravel flats. Nenana and Toklat rivers are of this type.

The streams of this area that are not glacier-fed and that flow clear water have in general only narrow flood plains. Bearpaw River and its tributaries are of this type, although, as shown on Plate II, the stream gravels have been mapped to include the meanders of the stream and are therefore wider than the actual flood plain.

Along any single stream the gravels are coarsest in the high mountains, where the stream is confined in a narrow valley and has a high gradient, and become progressively finer with increasing distance from the mountains. Thus Toklat River above Chitsia Mountain and for some distance north of it has in general a wide-floored valley of gravels, over which the heavily loaded stream flows in many branching and constantly shifting channels. Farther north, as the gradient becomes more gentle, the stream drops the coarser materials, carries mainly sand and silt, and flows in a single channel between steep silt banks. Bearpaw River, by contrast, flows clear water, is little inclined to anastomose, has only a narrow flood plain, and meanders deviously between steep banks of sand and silt.

SOIL FLOWS.

Stream erosion in the higher mountains in this region, as in all well-watered regions of high relief, is vigorous, and the streams are actively engaged in shaping the surface by the rapid erosion of the steep, mountain-side gulches, where vegetation is sparse, and by their attacks upon the valley walls as they cut laterally. In the foothills and the intervening basins, however, where the slopes are more gentle, and where the lower elevation is more favorable to the growth of vegetation, a group of subarctic plants, including sphagnum and other mosses, many varieties of grasses, and low shrubs have formed a tough mat of vegetation over the surface that effectually retards the removal of rock waste by streams. Furthermore, in this region the ground remains permanently frozen a short distance below the surface, especially in places where the surface cover of plants affords effective insulation from summer melting, so that stream cutting is thus further retarded by frozen ground. As the matlike cover of turf and moss prevents the streams from attacking the frozen ground, the products of disintegration and weathering are removed by soil creep, or soil flow. Many types of soil flow or of rock-waste movement have been recognized, varying in activity from landslides and sudden flows of soil and mud to soil creep and flowage, in which the movement is much too slow to be visible but which gives surprising results in the amount of transportation accomplished. In the Kantishna region both types of soil movement are in operation. At many places great scars appear on the hillsides—scars formed by the sudden breaking of the turf and the rapid downward flow of large volumes of mud, rock fragments, and turf, which, being suddenly released, moved to a position of equilibrium in the nearest valley bottom. About a dozen such mud flows, which had evidently moved only a few weeks before the region was visited, were observed, and a few of these were so recent that the surface mud had not begun to dry. The flows ranged in length from 100 to 500 feet and generally showed an expanded, spatulate form at the upper end of the break and a confused piling up of materials in the valley bottom, with a lobelike extension downstream. At many places the flows had dammed small valleys to a depth of 8 or 10 feet above the previous level of the streams. An examination of one very recent flow showed that the soil and vegetable matter, locally called "muck," were saturated with water, and that all the material above the level of ground frost, a distance of 3 or 4 feet below the surface, had moved. The material from the upper end of the scar had slipped along the surface of the ground-frost level. In the neighborhood of the recent flows, and in fact throughout the entire region, countless similar scars on the hillside, now overgrown by a new cover of vegetation, show the process has long been in operation and that the aggregate amount of material moved in this way is very great.

The physics of these sudden soil flows are not well known; they offer an interesting and almost new problem for the investigator. The controlling factors, however, are believed to be slope, vegetative cover, water content, and temperature. Vegetation quickly establishes itself on any favorable slope and, by forming a tenacious fibrous mat, almost completely inhibits the removal of loose material by surface waters. The insulation afforded by the vegetation also favors the permanent freezing of the ground to a level within a short distance from the surface. During the summer, when melting lowers the ground-frost level, frost action and physical disintegration, accompanied by chemical decay, bring about the accumulation of soils and fragmental rock materials. At the same time the accumulation of vegetation and the trapping of wind-blown material by the vegetation build up a layer of wind-blown materials. This mass is saturated with water, and the intermittent growth and melting of ice crystals within the mass makes it very porous. During the long, warm days of spring and early summer the surface portion of this mass thaws, and the melting snows supply abundant water to saturate the whole layer of thawed material. As the mass thaws it becomes semifluid but is held in place by the feltlike cover of roots and moss. As thawing proceeds still further, the mass of water-soaked soil may become too heavy for the vegetation to hold, and if so the turf parts, releasing a great quantity of mud and rock fragments, with slabs of the overlying turf. This material moves down the slope to the valley bottom, where it flattens out, and the scar above is later recovered by a new growth of plants.

The slow type of soil flowage is in operation over large areas, and though less spectacular than the sudden movements, it is actually in the magnitude of its results a much more effective agent of transportation.

The origin and action of the slow soil flows are much the same as those of the sudden and violent flows. The mantle of residual soil, fragmental rock, muck, and vegetation accumulate in the same way. The flows are large and numerous only in areas of permanently frozen ground and the soil in motion consists only of the surficial layer that thaws during the summer. The flows occur only in soil having a large content of water. The types of slow soil flow, however, are numerous. On some high slopes, where the elevation is unfavorable to the rapid growth of vegetation, soil flow may take place uniformly over considerable areas, and the whole surface layer may move downward under the impulse of repeated freezings, the frost heave accomplishing a slight forward movement each time the freezing temperature is exceeded. In such areas the surface slopes are smooth and rounded, and the active movement of the soil may be recognized by the arrangement of rock particles and of vegetation along the lines of downward movement. In general such flows bear only a scanty and incomplete cover of vegetation. A second type of slow soil flow, and one that produces in the aggregate a vast amount of transportation, is in fact almost identical in operation with the sudden flows described above, but in this type the turf is not completely ruptured. In these flows the fairly steep surface slopes, the mantle of soil and muck, the permanently frozen subsoil, the matted plant cover, and the complete saturation with water are all present. After the superficial layer of muck and soil has thawed the semifluid mass tends to sag down the hillside, stretching the turf into a flat, bulbous form. As the turf is tenacious and feltlike, however, it stretches but does not break, and by the continued growth of the surface plants its strength is maintained as the stretching proceeds. In this way a hillside may be entirely covered by mammillary lobes, closely grouped and constantly creeping downhill. The lobes vary greatly in size, ranging from small flows a few feet in height and width at the front edge to large flows, 8 to 10 feet high, having a continuous scalloped front edge several hundred feet long. A single hillside may show many small, separate lobes and a few larger ones, formed by the coalescing of many smaller ones. One variety appears as long, wavelike terraces, successive waves appearing one above the other, the front of each wave lying along the hillside at a nearly uniform elevation.

Though several distinct types of soil flows have been mentioned, there are gradational phases between the types. Thus at one place on the upper slope of a hill there were lobate or mammillary flows; farther down the slope the turf was torn into irregular patches that had been separated from one another by the soil creep; and still farther down much of the surface was free from vegetation, the movement was of nearly uniform speed over the bare slope, and the rock particles and vegetation appeared in linear, ribbon-like bands. In the mammillary or lobate flows the turf may be completely ruptured and produce a small sudden mud flow similar in every respect except size to the large sudden flows already described. (See Pl. XV, *A*, p. 47.)

Soil flowage of all the slow types is effective on low slopes. The sudden flows of mud were observed only on fairly steep hillsides, but the lobate and terrace-like flows and the areas of uniform movement on nearly bare surfaces occur on mild slopes, some of them as gentle as 10°.

The downward flow of soils, whether rapid or scarcely perceptible, has a direct economic bearing upon the gold placer deposits at different places in the Kantishna Hills, and the effects of the flow may be seen in many valleys where mining is in progress. In the headward portions of the streams the valleys are steep and narrow, and the creeks flow over flood plains that are little wider than the streams themselves. Mining operations have disclosed the fact that in many places flows of detritus containing muck, soil, and coarse talus have moved down the valley sides and out upon the stream gravels, and have buried the pay streak to a depth of many feet. Such "slides," as they are locally called, have been encountered by miners on Eureka, Friday, Glacier, and Little Moose creeks, and on Little Moose Creek a large mass of material, rendered unstable by the excavation of the creek gravels at its base, flowed suddenly into the placer workings, covering the sluice boxes, and filling the cut with a great mass of talus-bearing mud. At some places the unusual depth of bedrock is no doubt due to the influx of surface material from the valley sides, and many claims containing placer gold that are now unavailable for mining would probably yield a profit if the overburden due to soil flowage were absent.

An interesting example of the manner in which a small stream may be rendered ineffective as an agent of erosion was observed in the valley of upper Stampede Creek, where at some places soil flows have encroached so rapidly upon the stream bed that the creek has been unable to remove the material as fast as it reached the valley bottom. Even in stretches where the creek gradient is steep the vegetation-covered banks bulge out from each side and have almost met in places above the stream, which flows in a bed only a few feet wide between high, overhanging banks. At many points a slight advance of the two opposing banks would completely block the stream and force it to flow at a level several feet above its present bed; and no doubt such an event has not been uncommon in the history of that valley.

SUMMARY OF GEOLOGIC HISTORY.

The various rock formations represented in the Kantishna region have now been described, and their age and stratigraphic relations to one another have been discussed, as far as the information available warrants. From the character of the rocks, their degree of metamorphism, their structure, and their interrelations, some of the main events in the geologic history of the area may be almost certainly inferred. Definite correlations of the older formations are, however, unfortunately, not yet made, for they contain few fossils, which are so essential in determining the age of sedimentary formations. Furthermore, many pages of the record are missing, for long periods of the earth's history are unrepresented in this region by rock formations. Several such breaks that are not yet recognized may have occurred. The absence of sediments representing these periods must be accounted for either by assuming that the region was during these times a land mass and so received no water-laid material during these periods, or that beds were laid down but have since been removed by erosion. Fortunately, some formations that are missing here are represented in other parts of Alaska by sediments, the study of which yields information concerning the conditions that prevailed when they were deposited.

The earliest event recorded in the rocks was the deposition, in pre-Ordovician time, of a thick series of sediments, including quartz sands, shales, and a little limestone, with which were interbedded some basic lava flows. After its deposition this whole assemblage was closely folded and metamorphosed and was elevated above the surface of the waters, to be subjected for a long period—how long we do not know—to subaerial weathering and erosion. These materials now constitute the Birch Creek schist. The next event of which we have a record consisted of the submergence of the Birch Creek sediments and the laying down upon them, possibly in Ordovician time, of a series of black shales and limestone—the Tatina group. These sediments were also folded and metamorphosed, uplifted, and eroded, and were later submerged and covered, after a period of uncertain length, by a series of mudstones—the Tonzona group. The deposition of the Tonzona sediment was repeatedly interrupted by great flows of rhyolitic lavas, which finally completely buried the sediments and accumulated in great thickness. Another period of severe metamorphism followed which still further folded and altered the older sediments, and changed the Tonzona sediments to slates, and the rhyolite flows to gneisses, schists, and phyllites, forming the Totatlanika schist. A long gap in the record intervenes between the deposition of the Totatlanika lavas and the next well-defined sedimentary formation. This gap includes the later part of the Paleozoic era and perhaps all of Mesozoic time. The Kantishna region was probably not a land mass during all of that very long time. In other parts of Alaska sediments and volcanic materials, aggregating many thousands of feet in thickness, were laid down during that time, and the Kantishna region also was at intervals probably depressed beneath sea level and received sediments, and at other times lavas were outpoured upon its surface and igneous rocks were intruded at depths within the crust. The only sediments that have been recognized as apparently belonging to this period are certain small areas of limestone that may be of Mesozoic age and the thick beds of basic lavas and greenstones that may be either late Paleozoic or early Mesozoic. The granitic intrusive rocks that are so abundant in the main range south of this area and throughout many parts of Alaska were also intruded during middle Mesozoic time, when also the metamorphism of the Birch Creek schist, the Tatina sediments, and the materials of the Tonzona group and Totatlanika schist was continued until they had been converted almost to their present condition.

Thick deposits of detrital material accumulated in this region during the Tertiary period and it has apparently remained a land mass since the beginning of that period, as there is no evidence of its later submergence. Furthermore, it is believed that for a considerable period during late Mesozoic time the area now occupied by the Alaska Range and the foothills to the north was above water and that during that time it was eroded by streams and reduced to a region of low relief. An important geologic event that occurred during the closing stages of the Mesozoic era or at the beginning of the Tertiary period was the uplift of a part of the Alaska Range, probably along its present axis. This movement was the first of a series of uplifts that by their combined movements have given rise to the range that now contains the loftiest peak on the continent, Mount McKinley. To what height the range rose during the first upward movement we do not know, but certainly to an elevation high enough to rejuvenate the streams so that they flowed over steep gradients and handled coarse materials. The detritus thus removed by the streams at first consisted of coarse gravels, which were carried to the flanks of the mountains and there deposited as widespread gravel fans of low slope. As erosion in the mountains and deposition in the lowlands continued, the stream-laid deposits were increased until accumulations several thousand feet thick were formed. Gravel beds are present from the top to the bottom of this material, the Cantwell formation, but its upper part contains a much larger proportion of fine sandstones and shales and a smaller proportion of gravels than the basal part, indicating that erosion had already reduced the ruggedness of the mountains from which the material came. The accumulation of detritus in the lowlands also decreased the gradient of the streams and rendered them less able to handle coarse gravels.

After the Cantwell formation had been laid down another uplift of the range occurred, which involved not only the area previously uplifted but also the basins in which the Cantwell sediments were deposited. The Cantwell beds, now consolidated into firm conglomerates, sandstones, and shales, were uplifted, folded, and faulted and rapidly eroded by the once more steepened streams. Great valleys were cut into them and into the associated older formations. The rugged topography of the mountain belt was again reduced to modern slopes and the streams discharged little coarse material.

A second group of Tertiary sediments now began to accumulate in the broad valleys and basins of the area north of the mountain crest. These materials included some fine gravels but were predominantly sands and muds. The deposition of clastic materials was, however, only intermittent, and during long periods vegetation grew and accumulated in the lowlands and formed thick beds of peat. From time to time the growth of the peat deposits was interrupted by renewed stream deposition and the organic accumulations were covered by sands and muds. In this way an alternating series of sedimentary beds and beds of organic material, the Tertiary coal-bearing formation, was built up and in places reached a thickness of nearly 2,000 feet. As the load of sediments above any peat bed increased, the organic materials were compressed, other chemical and physical changes took place, and the peat was gradually altered to lignitic coal.

The building of the coal-bearing formation was interrupted by another period of uplift in this region. This uplift was most pronounced in the region south of the largest coal-bearing areas, but the movement extended far enough northward to involve parts of the coal formation also. The steepened streams again brought down abundant coarse material—the Nenana gravel—which accumulated along the flanks of the growing mountains. At many places the Nenana gravel appears to lie conformably upon the coal-bearing formation, but at other places the coal-bearing beds were apparently uplifted and eroded before they were covered by the gravel or other material, indicating that the uplift of the foothills region proceeded unequally in different places, some areas remaining quiescent while others were being elevated and tilted. At some places the gravels reached a thickness of 2,000 feet; at others they were much thinner.

After the Nenana gravel was deposited the main range and the foothills were still further elevated. The mountains grew both by bodily uplift and by folding and faulting, and all the Tertiary beds were more or less deformed. The folding, however, was less severe than that to which the Cantwell formation had been earlier subjected, and consisted of compression that tended to narrow the basins of coal-bearing materials into shallow synclines. Faults trending east and west, some of which have displaced the coal-bearing beds and the Nenana gravel for several hundred feet, have been observed, and the development of the foothill ranges is due to both folding and faulting. At the close of Tertiary time the Alaska Range and its subsidiary foothill ridges had probably been elevated to approximately their present position, and the agencies of erosion had actively attacked the young mountains and had cut great valleys in them. The gravels of the foothills and the associated coal-bearing beds had also been greatly eroded, and had been reduced to rounded and well-drained topographic forms. Across the hard-rock ridges that lay athwart their valleys the streams had cut deep, narrow canyons, but in intervening areas that were floored with unconsolidated Tertiary materials great basins had been excavated.

In early Pleistocene time in Alaska, as at many other places on the continent, extensive glacial deposits were formed. Just when the first glacial expansion took place in the Kantishna region we do not know, but there is strong evidence of at least two glacial stages here and there may have been others of which we have no proof. The ice advanced from the mountains and spread northward along the main valleys to the foothills. Boulders on the high ridges near Nenana Valley indicate that an earlier glacier there reached a great thickness and extended to the north front of the foothills within 30 miles of Tanana River. By its erosion and transportation of materials it must have greatly modified the topography of the mountains and of the lowlands, into which its outwash gravels were carried by the streams. This earlier glacial stage was followed by a period of ice withdrawal in which the normal agencies of stream erosion and atmospheric weathering were active. During the last stage of glaciation ice tongues again advanced northward through the valleys, repeating the earlier advance, though perhaps on a reduced scale, and further impressing ice-carved features on the valleys. Having reached their maximum expansion the glaciers, influenced by a change of climate, again shrank back into the mountains to about the positions they now occupy. After their retreat stream erosion and deposition again became active, talus and soil were formed anew by the erosion and weathering of the surfaces laid bare by the ice, and vegetation once more established itself on the rock slopes, morainal deposits, and outwash gravels. The streams are still engaged in the task of adjusting their gradients, disturbed by ice erosion, to conditions of normal stream transportation and erosion.

The present surface forms in this region are the composite result of the many vicissitudes that the region has undergone since the beginning of the Tertiary period. Elevation, folding and faulting, the accumulation of Tertiary detritus, and repeated periods of stream erosion, each followed by deposition and renewed uplift, have each had an effect in shaping the surface. Unequal uplift in the foothills, giving rise to alternating belts of hard rock and of unconsolidated materials, formed stream valleys in which broad, mature basins are interrupted by deep, narrow canyons. Several periods of erosion, during which the surface was reduced to a somewhat uniform plain, may still be recognized at favorable places. Thus along the depression which extends east and west between the head of Dry Creek and Teklanika River, as well as in places on the Kantishna Hills, an inclined-plane surface, cut from the rocks of the Birch Creek schist, appears on the mountain flanks. The plane of this erosion surface coincides with the base of the Tertiary coal-bearing formation, and seems to represent a part of the surface upon which the coal-bearing sediments were deposited. This erosion surface was thus protected from dissection for a long period by the Tertiary deposits, which upon elevation have locally been removed to bare once more the old rock plain on which they were laid down. Elsewhere in the mountains parts of old erosion surfaces whose age has not been definitely fixed may still be recognized. The problem of deciphering the physiographic history of the region is complicated by the number of erosion surfaces, by their unequal warping and tilting, and by the fact that the erosion by ice and by streams occurred at intervals in the Quaternary period. Enough of the old erosion surfaces probably remains, however, to afford abundant results to the student of physiography who has the opportunity to study this area carefully.

ECONOMIC GEOLOGY.

HISTORY OF MINING.

The basin of Tanana River first became of interest as a placer-mining region on the discovery of rich placer gravels in the Fairbanks district. Gold seekers, attracted by that discovery, rushed to the Tanana Valley in 1903 and 1904. Most of them went to the new town of Fairbanks or to the creeks in that vicinity, but a few penetrated to the north slope of the Alaska Range and carried on the search for gold there. The discovery of gold in the Kantishna district was an indirect result of the Fairbanks rush. In 1904 Joe Dalton and his partner, Reagan, prospected in the basin of Toklat River, and after having found gold in encouraging amounts returned to Fairbanks that fall. The next spring Dalton and another partner, Stiles, returned to the Toklat and prospected on Crooked Creek, a tributary heading in the Kantishna Hills 16 miles south of Mount Chitsia. In the summer of 1905 two other prospectors, Joe Quigley and his partner, Jack Horn, had been told by some trappers that there was gold in Glacier Creek, and they came in to investigate. They found gold in paying quantities, staked the creek, and in June of that year carried the news of their discovery to Fairbanks and so started the stampede to Kantishna. The stampeders began to arrive at the scene of the discovery about July 15, 1905. Meanwhile Dalton and Stiles, having heard nothing of the Quigley-Horn discovery, had traveled along the southeast side of the Kantishna Hills and arrived at Friday Creek. Prospecting there they found gold, and on July 12 they staked that stream. On July 20 they staked Discovery claim on Eureka Creek, but thinking themselves entirely alone in the country they staked only that claim, having determined to prospect first the upper part of the stream. They went up Eureka Creek, and on their way back to the mouth of that stream they met a man named Cook, who had come in with the rush and had made his way up Moose Creek to the mouth of Eureka Creek. Cook said he had staked claims No. 1 to No. 4 on the Eureka, so Dalton and Stiles returned and staked the rest of the creek above claim No. 4.

Late in the summer and in the fall of 1905 the Kantishna district was the scene of great excitement. Several thousand people then arrived, most of them coming by boat up Kantishna River and its tributaries, Bearpaw and McKinley rivers during the season of open water, and by dog and sled later in the fall after snow had fallen. Practically every creek that heads in the Kantishna Hills was staked from source to mouth, and the benches and intervening ridges were not ignored. Within a few weeks a number of towns were built, the largest of which were Glacier, on Bearpaw River at the mouth of Glacier Creek; Diamond, at the mouth of Moose

Creek; and Roosevelt and Square Deal on Kantishna River. At each of these places log cabins, stores, hotels, and saloons were erected, and between them and the creeks a constant stream of gold seekers traveled back and forth. By midwinter, however, it became generally known that rich, shallow diggings, the eternal hope of the prospector, were restricted to a few short creeks, and an exodus began. The richest ground was mined vigorously during the summer of 1906, but by fall the population had dwindled to about 50, those who remained being the few who had staked paying claims or who were convinced that thorough prospecting held out sufficient promise of new discoveries.

In the winter of 1906 Roosevelt, Square Deal, and Diamond were almost completely deserted. Glacier, being nearest to the creeks, is still used as winter quarters by a number of miners who prefer to spend the cold months in the shelter of the timber, near their fuel supply, rather than to haul wood to their summer camps.

Since 1906 the population of the Kantishna district has remained nearly stationary, ranging from 30 to 50. In 1916 there were 35 persons in the district, and more than half of this number were men who had staked claims during the first stampede and who had worked them more or less continuously since that time. It was placer gold that first attracted attention to this camp, and the only production so far has been made from the placer gravels. In recent years, however, considerable attention has been given to prospecting for lode deposits. Veins carrying gold and silver and the sulphides of lead, zinc, and antimony occur in the district, and a large number of lode claims are now held. No lode mine has yet been brought to the stage of production, but eventually the lodes will probably outstrip the placers in the value of their metal output.

GOLD PLACERS.

GENERAL FEATURES.

The productive gold placer deposits of the Kantishna district are all in the basins of the streams that head in the Kantishna Hills and radiate outward in all directions from the higher peaks. The so-called Kantishna Hills are actually rugged mountains of considerable size and are known as hills only because of their nearness to the towering peaks of the Alaska Range. As each stream basin is separated by high dividing ridges from its neighbors, and as direct travel from one basin to another is difficult, the routes generally used extend around the base of the higher mountains, and the placer workings are therefore much farther apart by trail than their close spacing on the map would indicate. This condition has produced a number of small and rather isolated mining camps between which there is little travel during the busy summer. In 1905 and 1906 paying deposits of gold placer gravel were found on all the streams that are now productive except Little Moose Creek, and although considerable prospecting has been done during the last 10 years only a small amount of workable ground has been found since the early years of this camp. This may be due in part to the fact that only the richest claims can now be worked, but most of the men in the district own ground from which they are confident they can make a living, and they employ the summer in mining the proved ground rather than in prospecting areas in which there is less certainty of finding valuable placers.

The creeks that have added to the gold production of the district are Moose Creek and its tributaries Glen, Eureka, Friday, and Eldorado; Glacier and Caribou creeks, tributaries of Bearpaw River; and Little Moose Creek, which flows into Clearwater Fork of Toklat River.

MINING CONDITIONS.

All the placer mining that has so far been done in the Kantishna district has been open-cut work, in which the upper gravels are groundsluiced off to within a foot or so of bedrock and the remaining gravels and the necessary amount of bedrock are shoveled into the sluice boxes by hand. Most of the miners plan to complete the season's ground sluicing early in the spring, during the period of greatest stream flow, but a few have built automatic dams and are thus enabled, by alternately storing the water and releasing a large volume for a short time, to groundsluice even at times of low water. The whole operation of open-cut placer mining is, however, definitely limited to the period of stream flow. Nearly all the placer mines in this district lie above timber line, from 1,600 to 3,000 feet above sea level. At such altitudes the streams commonly run free from ice sometime in May and remain open until late in September, and the mining season is therefore limited to a period of about four months. Late in summer, too, some of the smaller streams diminish so much in volume that they do not supply sufficient water for sluicing, this lack of water restricting the mining season still further. The experienced miners in this camp count upon a working season of 100 to 120 days.

Most of the gravel deposits along the streams are in thawed ground, and few miners encounter difficulty with ground frost. Some of the elevated benches, however, in which gold occurs in commercial quantities are permanently frozen, and before the gravels can be sluiced they must be thawed by steam or must be stripped of their insulating cover of surface vegetation and muck to allow the warm air and the direct rays of the sun to thaw out the frost.

This camp is so far from established lines of transportation that the cost of mining is much greater than it would be in a more accessible district. Few men are employed at a stipulated wage, for most of the claims are worked by the owners or on a royalty, but those who are employed usually receive $6 a day and board for a 10-hour day or $1 an hour without board. Even at such wages, however, it is difficult to obtain labor, as there is no ready communication with any settlement, and the men in the camp at any one time include only those who remained from the previous year and those who came in over the ice in the winter or by boat in the spring.

The supplies and mining equipment needed for the season's work are brought to the district by the operators, either by launch to Diamond and thence by sled to the mines, or by sled all the way from Fairbanks during the winter. By this method the quantity and assortment of each miner's supplies must be determined by him several months in advance of the working season, and demands a considerable investment of capital for an unusually long period. No store is maintained in the district, and whatever supplies a man unexpectedly needs during the summer must be procured from his neighbors or can not be had at all. As a result of the difficulty and expense of carrying freight to the mines and of the long time required to procure a desired article, only the most primitive methods of mining have yet been employed. All the gold recovered so far has been taken out by pick and shovel.

With the exception of the mining claims on Moose Creek, all the placer ground mined in 1916 lies above timber line, and wood for fuel as well as lumber for mining must be brought from a distance, which varies on the different creeks. On Glen Creek timber grows within 1 mile to 3 miles of the mines. Eureka and Friday creeks are devoid of timber, which must be obtained from the basin of Moose Creek at points 1 mile to 5 miles from the workings. On Glacier Creek no timber is obtainable for 8 miles from the head of the creek, and the length of haul for the uppermost placer claims now worked is about 6 miles. The mine on Caribou Creek is 5 miles from timber line, and that on Little Moose Creek is perhaps 2 miles from the nearest trees that are large enough to supply sluice-box lumber. Sawmills were operated to furnish lumber in the early days of the camp, but these were soon dismantled, and now all needed lumber must be cut by whipsaw.

ORIGIN OF GOLD PLACERS.

As is shown in Plate II, the underlying rock in the Kantishna mining district is the Birch Creek schist, which is cut by relatively small bodies of intrusive rocks that differ widely in age. Some appear to have been as greatly metamorphosed as the schists that inclose them; others are somewhat metamorphosed but less so than the schists and were intruded after the metamorphism was started but before it was completed. Still other intrusions are not at all folded and were injected after the schists had reached their present condition. Among the class last mentioned were some dikes and stocks of granite porphyry and quartz porphyry, which may be genetically related to the mineralized quartz veins. The schists are locally highly siliceous and include beds of quartzite schist. Numerous quartz veins and veinlets are everywhere distributed through the Birch Creek schist. Gash veinlets and lenticular bodies of quartz lying parallel to the schistosity are particularly abundant, but most quartz veins of this character are not regular or continuous for long distances but pinch and swell abruptly. Tiny reticulating veinlets of quartz, cutting the schist in all directions, are also common. Many quartz veins of this type have been twisted and metamorphosed with the inclosing schist. In the Kantishna Hills, especially along the main divide from the heads of Caribou and Myrtle creeks westward to the basin of Moose Creek, there are many large quartz veins that cut across the cleavage planes of the schist, stand at steep angles, and maintain a uniform strike, dip, and thickness for considerable distances along the outcrop. Most of these veins are younger than the gash veins that follow the schistosity and are true fissure veins of more recent age than the last period of vigorous metamorphism. Several quartz veins of this type contain visible free gold in encouraging quantities, and mortar tests show that native gold is rather widely distributed in these veins. Furthermore, the largest and most continuous gold-bearing quartz veins that have been found are in the basins of the streams which had the richest gold placer ground. This fact seems to prove conclusively that at least a large part of the gold of the stream placer gravels was derived by erosion from the fissure quartz veins that cut the schists. The gash veins and veinlets of quartz in the schist may also have added their contribution of gold to the stream placers, and the presence of placer gold in greater or less amount in almost all the streams that flow through the schists indicates that some of these veins also are gold bearing, but the richest placer gravels have been found in basins in which the larger fissure veins occur.

The local origin of the placer gold is also confirmed by the appearance of the gold itself. In Friday and Eureka creeks, immediately below the outcrops of some large quartz veins, the placer gold is surprisingly rough and angular. Many nuggets show the unworn crystalline forms that the gold had as it lay within the vein quartz, and few nuggets in any clean-up show appreciable effects of attrition. To anyone familiar with the usual appearance of placer gold it is immediately evident that this gold is recovered at no great distance from the outcrop of the vein in which it originated. It becomes finer and more smoothly worn as it passes downstream and away from the outcrops of gold-bearing quartz, as would be expected if it had been derived from the quartz veins and had been transported to increasingly greater distances from its bedrock source.

The influence of glaciation on the distribution of gold placer deposits in the Kantishna region has varied in the different stream basins, and although the glaciers have doubtless played their part in the erosional history of the district, the ice was here much less abundant than in the higher mountains of the Alaska Range. The fact is now established that there have been at least two stages of glaciation on the north side of the Alaska Range, one long before the last one, the evidence of which is best preserved. This fact being recognized, it is difficult in certain places to determine the limits reached by the separate ice sheets, for glacial deposits or action of the earlier stage can easily be mistaken for those of the later, and a proper discrimination can be made only after more detailed field work has been done. Nevertheless, it is certain that at one time Muldrow Glacier was much larger than it is now, that it overflowed the northern border of its present basin and spread northward across the upper basin of Moose Creek, to lie against the south flank of the Kantishna Hills. One tongue of this ice lobe flowed north onto Clearwater Fork of Toklat River, another flowed down through the canyon of Moose Creek past Eureka and Eldorado creeks, and still another flowed westward along the present course of McKinley River. The highest ridges of the Kantishna Hills were never overridden by ice, but some of the higher valleys in them supported small ice tongues, which extended radially from the crest in all directions but never attained sufficient length to reach beyond the confines of the narrow valleys. Of the gold-producing streams Glen, Glacier, and Caribou creeks were glaciated in their upper ends, but the basins of Eureka, Friday, and Eldorado creeks were not sufficiently elevated to originate glaciers. Abundant erratic boulders occur throughout the basin of Moose Creek above Eureka and in the valleys of Eldorado and Eureka creeks nearly to their heads. These boulders are not directly associated with morainal deposits, but their presence indicates that at one time the basin of Moose Creek was filled with ice, which lay high against the south flank of the Kantishna Hills. The peculiar courses followed by lower Spruce and Glen creeks also indicated changes of drainage due to glacial occupancy.

To just what extent the gold-producing streams were once occupied by glaciers and their preglacial placer deposits removed by ice erosion has not been definitely determined, for evidence of glacial action is inconspicuous and poorly preserved. The fact can be stated, however, that in those parts that were glaciated the ice disturbed or removed the greater part of the preexisting gold placer deposits, so that any concentration of gold that is now present is due to erosion by streams since the ice retreated. Below the edges of the glaciers stream erosion was retarded during the ice advance, for the waters were burdened with an unusually large supply of rock waste, which they deposited as outwash gravels beyond the edge of the ice. The streams sorted in some degree the outwash gravels but much less than they would have been sorted by normal lightly loaded streams.

After the glaciers had disappeared from the Kantishna district the streams commenced the task of readjusting their valleys to conditions of normal erosion. Less heavily loaded than when they received glacial waters, they began to intrench themselves into the deposits of glacial outwash gravels, which now appear as high benches or terraces along the lower streams, especially those on the north side of the Kantishna Hills. In cutting down through these gravels the streams in places flowed in somewhat different courses from those along which they had formerly flowed, and canyons show the position of obstructions they encountered in their downward cutting.

The bench or terrace gravels along Moose, Glacier, and Caribou creeks contain some placer gold, and in one or two places sufficient to warrant mining. While the streams were intrenching themselves in these gold-bearing gravels the gold in the gravels, as well as that supplied by the erosion of gold-bearing quartz veins, was deposited in their beds, forming the present workable placer gravels.

WHITE GRAVELS.

Among the miners in this district a misconception prevails regarding certain white quartz gravels that occur along the north flank of the Kantishna Hills. These gravels have been noted especially in the valley of Glacier Creek, near the point where the schist bedrock plunges downward to the northwest and disappears beneath the deposits of unconsolidated materials. The gravels form no conspicuous surface features but have been noted in the stream deposits of Glacier Creek below the point where the schist bedrock disappears. The most complete information concerning the white gravels was obtained from a prospect hole sunk on the bench west of Glacier Creek, opposite the upper end of claim 13. This shaft, after penetrating a few feet of the ordinary bench gravels, encountered a body of white, rounded quartz gravel, which continued without interruption to a depth of 114 feet, at which place the sinking was discontinued without reaching bedrock. Most of the material on the dump is vein quartz, distinctly rounded and water worn, ranging in size from fine sand up to pebbles 6 inches in diameter. The resemblance of this material to the "white channel" gravels of the Klondike was at once apparent to the prospectors, who entertained high hopes of finding rich deposits of placer gold in it, but no paying concentration of gold was found, although some fine gold was panned from the material excavated. A study of the geologic relations on Glacier Creek indicates that the white gravels there constitute the base of the Tertiary coal-bearing formation which is so fully developed farther east, near Nenana River. There the base of the Tertiary beds, where they lie upon the Birch Creek schist, is commonly made up of a nearly pure deposit of white quartz pebbles and sand. This relation is found to continue westward across the basin of Teklanika River, and no doubt the white gravels of Glacier Creek are of similar origin. The gravels are believed to represent the detritus from an old land mass that had been deeply weathered and from which the more easily decomposed materials had been removed, leaving abundant residual quartz scattered over its surface. Later a period of more active stream erosion followed and this quartz was removed, rounded by the streams, and deposited as a widespread blanket over the lowlands. It was brought to the lowlands by many small streams rather than by a single large one, and in the lowlands that were aggraded by the gravel deposit any gold that may have been present in the quartz showed little tendency to concentrate. Throughout the area in which they have been studied these white quartz gravels contain a little gold, but nowhere have concentrations sufficiently rich for placer mining been found. At the Glacier Creek locality the exposures are not good, but, so far as known, the white gravels are not overlain directly by the coal-bearing Tertiary beds but by a heavy deposit of tilted, oxidized gravels which in the Nenana district succeed the coal-bearing beds. This means either that the coal-bearing beds were removed by erosion from over the white quartz gravels before the later yellowish gravels were laid down, or that in this place the coal-bearing beds were never developed, and that the oxidized gravels were laid down directly upon the white quartz gravel beds. The white gravel deposit on Glacier Creek therefore differs in mode of origin from the "white channel" of the Klondike, and being probably of early Tertiary age is apparently much older than the gravels of the Klondike.

SOIL FLOWS.

A factor that has exercised an important influence upon the gold-placer deposits in many valleys is the large volume in which detrital material from the valley walls moves down the slopes and out onto the stream-gravel deposits and the rapidity with which this movement takes place. A brief description of the various types of soil flows and a discussion of the factors that cause them have already been given on pages 66–70.

MINES AND PROSPECTS.

During August, 1916, all the mines and prospects on which work was being done were visited, and the following pages contain brief

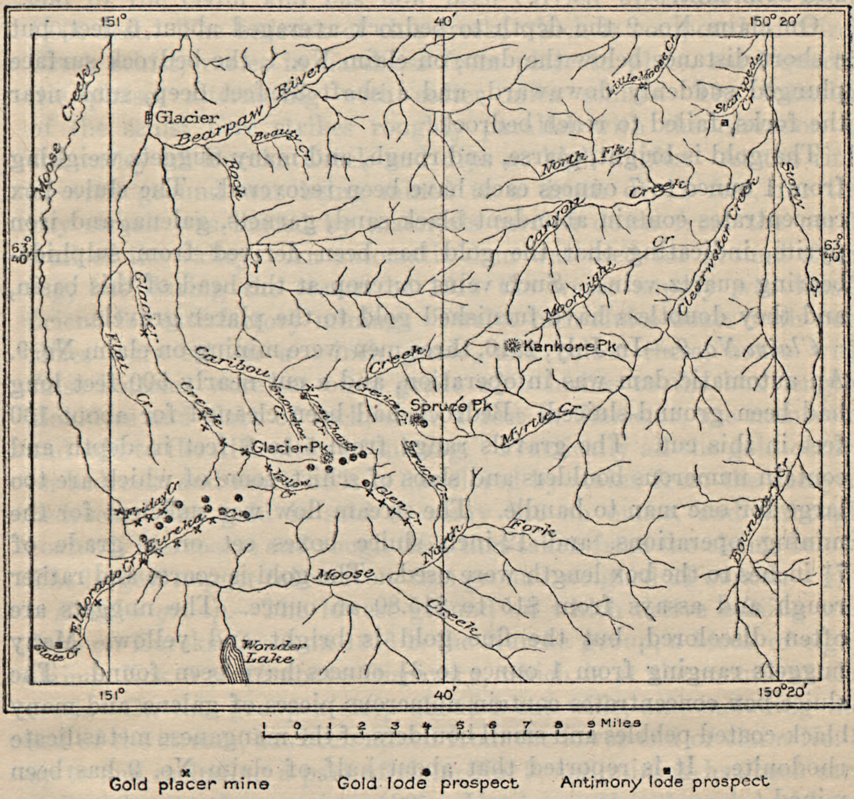

FIGURE 6.—Sketch map of a part of the Kantishna region, showing approximate positions of mines and prospects.

descriptions of the general conditions prevailing on these claims at that time. The positions of the mines and prospects are shown in figure 6, and in their discussion they are grouped under the name of the stream valley in which they occur and are described in order from the uppermost claim downstream.

GLEN CREEK.

Claims 1 and 2 on right fork.—Some mining was done by one man on claim No. 1, the lowest claim on the right fork of Glen

Creek. A large part of the season was spent in building an automatic dam, but during low water the dam leaked so badly that it would not fill up and flush, and only 36 linear feet of bedrock below the dam had been cleaned at the time of visit. In previous years considerable work was done on claim 2 by the ordinary method of ground sluicing and shoveling in. Boxes 12 inches wide, set on a grade of 10 to 12 inches to the box length, are used. Bedrock is composed of quartzite and micaceous schist, and boulders are large and abundant.

On claim No. 2 the depth to bedrock averaged about 6 feet, but a short distance below the dam, on claim No. 1, the bedrock surface plunged suddenly downward, and a shaft 34 feet deep, sunk near the forks, failed to reach bedrock.

The gold is bright, coarse, and rough, and many nuggets weighing from 1 ounce to 7 ounces each have been recovered. The sluice-box concentrates contain abundant black sand, garnets, galena, and iron pyrite, indicating that the gold has been derived from sulphide-bearing quartz veins. Such veins outcrop at the head of this basin, and they doubtless have furnished gold to the placer gravels.

Claim No. 9.—In July, 1916, three men were mining on claim No. 9. An automatic dam was in operation, and a cut nearly 500 feet long had been ground-sluiced. Bedrock had been cleaned for about 150 feet in this cut. The gravels range from 5 to 8 feet in depth and contain numerous boulders and slabs of schist, some of which are too large for one man to handle. The stream flow was sufficient for the mining operations, and 12-inch sluice boxes set on a grade of 7½ inches to the box length were used. The gold is coarse and rather rough and assays from $15 to $15.80 an ounce. The nuggets are often discolored, but the fine gold is bright and yellow. Many nuggets ranging from 1 ounce to 3½ ounces have been found. The sluice-box concentrates contain numerous pieces of galena and many black-coated pebbles and small boulders of the manganese metasilicate rhodonite. It is reported that about half of claim No. 9 has been mined.

Claim No. 7.—No one was present on claim No. 7 at the time it was visited, but one man is reported to have been mining there in 1916. In July, 1916, some ground sluicing had been done, but little gravel had been shoveled into the sluice boxes. The mining conditions on this ground, a large part of which is said to be worked out, are much the same as on claim No. 9.

Other claims on Glen Creek.—Some mining has been done on Glen Creek each year since 1906, and a number of claims have produced gold. Claim No. 6, below which little more than prospecting has been done, has been partly mined and No. 7 is largely worked out. Parts of claim No. 8 and 8 fraction have been worked, and claim

No. 9 is about half exhausted. No extensive mining has been done above claim No. 9 on the main creek but parts of claims No. 1 and No. 2 on the right fork have been mined.

EUREKA CREEK.

Claim No. 13.—The uppermost claim on Eureka Creek on which mining has been done is claim No. 13, where one man has been working every season since 1906. Sluicing was begun on the lower end of the claim and has now been carried upstream for about 1,000 feet. The bedrock of this creek, which is composed of Birch Creek schist, varies in hardness from place to place, hard quartzitic phases alternating with softer mica schists. The foliation of the schist here strikes roughly parallel with the direction of the valley of Eureka Creek and dips at high angles. At the time of visit ground was being mined to a depth of 11 feet, for the pay streak was buried by materials carried down from the north wall of the valley. An automatic dam was used for ground sluicing, but during the season of 1916 the water supply was insufficient for satisfactory mining. Twelve-inch sluice boxes with pole riffles were set on a 9-inch grade, and below these, boxes with false bottoms were set on a grade of 5 inches to the box length. Boulders and slabs of rock, some 4 feet in diameter, are numerous and add to the difficulties of mining. Practically all the gold occurs on bedrock, and much of it is discolored by stains from the decayed bedrock. The gold is said to assay $16 an ounce, and although coarse is less coarse and rough than that taken from the claims below. The largest nugget taken from this ground weighed 2¼ ounces.

Eureka group.—The lowest ground on which active mining was done on Eureka Creek in 1916 is the Eureka group, a block of eight claims, Nos. 5 to 12 above Discovery, which is at the mouth of the creek. On this group a strip about 1 cut wide, and including the bed of the stream, has been mined from the lower end of claim No. 5 up to and including a part of claim No. 9, and mining has been carried on here each year since 1905. Until recently all work had been done with pick and shovel, and only the richest gravels—those in the creek bed—would warrant mining. In 1916 an automatic dam was built on the upper end of the group, and through its use the cost of mining has been reduced from $45 to $20 a box length (168 square feet). By the new method a much wider strip of gravels can be profitably exploited. The gravels are sluiced off until the high points of bedrock are exposed, and only about 6 inches of gravel is shoveled by hand. The owner reports that the tests show little loss of gold by this method. The gravels have averaged about 7 feet in thickness in the stream bed and 8 to 9 feet on the low benches. Coarse boulders are not unusually abundant and, although a few are broken by explosives, most of them can be thrown aside by hand. On the lower end of claim No. 9 the creek flat widens to about 40 feet, and the whole flat was being worked at the time of visit (August, 1916). The owner plans to continue using the present automatic-dam method on the Eureka group of claims and also intends to use it on the lower claims on either side of the creek channel—ground that would not pay if worked by the old method. The bedrock is composed of the various phases of Birch Creek schist, the character of which changes from place to place. In cleaning bedrock it is necessary to remove only the surface of the schist where that material is comparatively soft, but in the harder phases the gold has penetrated more deeply into the cracks, and 2 feet of bedrock must be removed to recover all the gold. The gold is bright yellow, except those pieces that have lain on decayed and rusty bedrock and are discolored. It assays from $15 to $15.20 an ounce and is remarkably coarse, a large part of it being in rough, angular pieces that show little or no evidence of stream abrasion. A number of pieces show unworn crystal surfaces and are certainly derived from near-by gold-bearing lodes. In many nuggets quartz is intermingled with the gold, and the sluice-box concentrates contain abundant galena. These facts furnish additional evidence that the gold is a concentration from the quartz veins that outcrop on the ridges around this stream basin. Stibnite and black sand are also caught on the riffles. The placer gold from Eureka Creek is unusually coarse. Half of that recovered is said to occur in pieces having a value of 5 cents or more, and much is in coarser nuggets. One nugget from claim No. 9 had a value of $100, and another, taken from Discovery claim in 1906, was worth $900.

The water supply on Eureka Creek is ordinarily abundant for sluicing throughout the open season. Four boxes 11 by 13 inches in cross section and set on a grade of 9 inches to the box length are used, two of which are equipped with pole riffles and two with Hungarian riffles, and the lower boxes, with false bottoms, are set on a grade of 5 inches to the box length. Two or three men were employed throughout the season.

On claim No. 12 of the Eureka group one man operating on a lease was mining for part of the season. The conditions were much the same as on claim No. 9, the gravels being from 7 to 9 feet in thickness.

Other mining.—In the earlier years of mining in this district placer mining was done on all the claims from the mouth of Eureka Creek up to claim No. 5, and, as already stated, the main stream bed has now been mined up to and including part of claim No. 9. Throughout the length of these nine claims, however, patches of gravel that lie here and there on each side of the creek contain considerable placer gold that was left by the miners in their haste to work the richest and most easily accessible ground. As the richer gravels of the main creek bed become exhausted, however, the less easily handled "side pay" on these claims will be mined, and in these neglected areas the use of more economical methods, such as automatic-dam sluicing, will probably yield satisfactory profit to the miners.

FRIDAY CREEK.

General features.—Friday Creek is a small tributary of Moose Creek from the east, joining that stream 1½ miles below the mouth of Eureka Creek. The valley of Friday Creek is narrow and only 2 miles long, and the gradient of the stream is steep. The stream flat is in general not more than 15 to 20 feet wide, and for a considerable part of its length the creek flows in a narrow canyon-like cut between rock walls, so that the gravels in the stream bed are only narrow and shallow.

Claim No. 2.—One man was mining on the upper end of claim No. 2, the creek bed in the lower part of the claim having already been mined out, although some workable ground is said to remain along the sides of the strip of worked ground. The mining conditions here are much the same as on the other claims on this creek. The stream gravels range in width from 15 to 150 feet, and in places the pay streak runs under slides from the valley sides. Locally this slide material is frozen. Boulders and slabs of the schist bedrock too large to pass through the sluice boxes are abundant, but none are too big for one man to handle. The gold is rough and coarse, nuggets worth $50 having been found. The gold taken from the surface of bedrock is usually discolored and rusty, but that obtained from the gravels is bright.

Claim No. 1.—Claim No. 1 has been mined since 1914 by the owner, who also holds a 300-foot fractional claim adjoining the upper end of claim No. 1. The ordinary method of ground sluicing and shoveling in is employed, and a hose, with water under pressure, is used to clean bedrock. Sluice boxes set on grades varying from 8 to 16 inches to the box length are lined with pole and Hungarian riffles. The schist bedrock ranges from hard dense rock to soft, soapy, decayed material, and experience has shown that though the hard bedrock has retained most of the gold, the softer phases of bedrock are in general only meagerly productive. The creek-bed gravels range in depth from 3 to 4 feet, but in places the pay streak is covered with slide material from the valley sides and overburden 10 to 15 feet thick must be removed to reach the bedrock. The gold is coarse and very rough, having come from the eroded portions of quartz veins that outcrop on the mountains near by. The largest nugget taken from this claim weighed 6½ ounces, and many pieces weighing more than an ounce have been found. Black sand and galena are abundant in the sluice boxes. Most of this claim has now been mined, but the fractional claim immediately above it is still unworked.

Discovery claim.—The lowest claim on which active mining has been done on this creek is Discovery claim, the second claim above the mouth of the stream. Two men have been mining there each summer since 1908, and the stream channel has been about worked out, the only unworked ground being a side cut near the upper end of the claim. In the upper part of this ground the bedrock consists of schist, the foliation striking roughly parallel with the trend of the valley and dipping at high angles. About 300 feet above the lower end of the claim the bedrock floor steepens and disappears beneath a gravel filling of such thickness that prospect holes have failed so far to penetrate it. The mining here has been done only by pick and shovel, the pay gravels ranging between 3 and 4 feet in thickness. Two sluice boxes lined with pole riffles and one with Hungarian riffles, set on a grade of 9 inches to the box length, are used, and below them boxes with false bottoms are set on a 5-inch grade. The gold is bright, coarse, and extremely rough. Many nuggets show the crystalline form of the gold as it came from the vein quartz, and quartz is common in the nuggets. Few pieces show conspicuously the effects of stream abrasion, and much of the placer gold certainly had its bedrock origin in the gold-bearing quartz veins that outcrop in this basin, particularly on the ridge between Friday and Eureka creeks. The gold is said to assay $14.82 an ounce and is associated in the sluice boxes with abundant galena and black sand.

ELDORADO CREEK.

At several places on Eldorado Creek, especially at a point about 2 miles above the mouth of that stream, some placer mining has evidently been done, though no one was working there at the time of visit. The bedrock at that place is a black slaty phase of the schist, striking in general northeast and dipping steeply southeast. The gravels apparently range from 2 to 4 feet in thickness. The gold, which is reported to be too unevenly distributed for successful mining, is said to be bright, well worn, and finer than that on Friday or Eureka creeks and to assay about $16.25 an ounce.

MOOSE CREEK.

The valley of Moose Creek from the mouth of Eldorado Creek for 3½ miles downstream is held as a block of claims by men who have mined on this ground each year since 1906. Discovery claim lies at the upper end of the property, and it is apparent that most of the placer gold in this part of the valley of Moose Creek has been supplied by Eureka, Eldorado, and Friday creeks, for no workable ground has been found in the valley above the gravels contributed by Eureka and Eldorado creeks. In this valley gold has been mined on a small scale only, by pick and shovel. Moose Creek is a large, clear stream, flowing over a gravel flat, generally bordered by gravel benches, though in places it swings to one side of its valley or the other and cuts against rocky walls. About 3 miles below the mouth of Eureka Creek it enters a rock canyon through which it flows for some distance. Its gradient is so slight that difficulties are encountered in obtaining water under sufficient head for sluicing and in obtaining a dump for tailing from the sluice boxes.

At the time of visit two men were mining opposite the mouth of Eureka Creek on a gravel bench the lower edge of which stands 10 or 12 feet above the level of Moose Creek. Water was obtained through a ditch that is supplied by Eldorado Creek. Pick and shovel methods were used. Twelve lengths of sluice boxes, 12 by 14 inches in cross section and set on a grade of 5 inches to the box length, were so arranged as to dump directly into Moose Creek. The gravels mined averaged 8 feet in thickness and lay upon a false bedrock composed of blue clay, sand, or semiconsolidated gravels. The gold is distributed throughout the whole thickness of gravels but is notably concentrated on the false bedrock. Practically no gold has been found within the materials composing the false bedrock, or beneath them, and no one has so far succeeded in sinking a hole through this material to the underlying schist. The gold taken from the gravels is coarse and yellow, but that taken from the surface of the false bedrock is discolored, some of it being nearly black. Although it has probably been derived in large part from Eureka Creek basin, the gold from Discovery claim averages finer than that found in Eureka Creek, and most of it is in flat, well-worn particles. It is reported that considerable mining has been done at three other localities on this block of claims and that assessment work, including the clearing away of brush and timber, and prospecting have been done each year.

GLACIER CREEK.

General features.—Glacier Creek heads against the north side of the Kantishna Hills, flows about 5 miles northwestward through a deep valley eroded in schist, from which it emerges from the mountains and flows northward to its junction with Bearpaw River through a valley intrenched into a broad, gravel-covered upland. For the upper 5 miles of its course the stream occupies a valley floored with stream gravels of moderate depth lying on schist bedrock. North of the mountains the depth to bedrock increases so much as to be below the limit of ordinary open-cut placer-mining, except in a few short stretches where the stream passes through shallow canyons in the schist. With the exception of these short canyons the stream in the lower 10 miles of its course flows over a gravel flat that is bordered by high, smooth-topped ridges in which no hard rocks outcrop but which are composed for the most part of rather ancient, tilted gravels—the Nenana gravel.

Placer gold has been found both in the stream gravels and on the benches of Glacier Creek throughout its length, but mining has been successful only in the upper 8 miles of the valley.

Claim No. 20.—The uppermost claim on which mining was done in 1916 is claim No. 20, situated 1½ miles above the point at which Glacier Creek emerges from the mountains. There two men were sluicing gravels that averaged about 5 feet in thickness and lay on schist bedrock. Sluice boxes 12 inches square in cross section, lined with pole and Hungarian riffles, and set on a grade of 6 to 8 inches to the box length were in use. The gold is said to occur both in the stream gravel and on the surface of bedrock. That from the gravels is bright and yellow, but that from bedrock is generally stained and discolored. The gold is coarse but is said to be unevenly distributed, rich spots being surrounded by lean areas in which there is insufficient gold to pay the cost of mining.

Claim No. 18.—One man was mining on claim No. 18 and had worked there each summer since 1908. A splash dam and a bedrock drain had been constructed, but a freshet in the spring washed out the dam and filled the drain, making mining difficult. Large boulders are especially abundant on this claim, and the difficulties of mining are increased by the tendency of the pay streak to run beneath the coarse angular talus of the valley sides. The gravels in the stream bed range in depth from 3½ to 9 feet. Black sand and garnets are said to be abundant in the sluice-box concentrates.

Claim No. 14.—Claim No. 14 on Glacier Creek is the site of the first discovery of placer gold in paying quantities within the Kantishna district, and it has been mined intermittently since 1905, during which period about 900 feet of the creek bed and a portion of the west bench have been worked. One man was mining on the lower end of this ground in 1916. A bedrock drain had been installed, and mining was carried on by the usual method of ground sluicing and shoveling in the gravels and the surface of the bedrock. The schist bedrock varies in character from soft, decayed material that contains little gold to hard, firm rock in which it is abundant. Some gold occurs in the stream gravels, but the richest concentration is on the surface of the bedrock. The gold deposits vary markedly within short distances, almost barren stretches of gravel succeeding stretches of rich ground. Few large nuggets are found on this claim, as the gold occurs mostly in flat, well-worn pieces the size of rice grains.

Mining has been done in an irregularly shaped area, measuring in its maximum dimensions 160 by 200 feet, on the west side of Glacier Creek, on a bench that has a steep face 40 feet high at the creek edge and slopes upward toward the west. As shown in the section along the creek, this bench is composed for the most part of schist, on the surface of which lies a gravel deposit of varying thickness, laid down by Glacier Creek when the bench surface was the valley bottom and before the present stream canyon was eroded. This bench was mined by building a ditch to tap Glacier Creek at the lower end of claim No. 16, and at the lower end of claim No. 14 the width of the bench below the ditch line is about 200 feet. Mining was done by running successive cuts from the ditch to the edge of the bench, and the tailings were discharged over the bench into Glacier Creek. The gravels on the bench surface ranged from 3 to 20 feet in thickness and were frozen in places, so that it was necessary to strip the cut and allow the material to thaw for a while before the loosened material could be removed. In working down the valley an old channel on the bedrock surface of the bench was found, diverging to the northwest, away from Glacier Creek. Along this channel the gravels became constantly thicker, and mining was discontinued at the point where the channel passed so far below the surface of the bench gravels that the bedrock would no longer drain to Glacier Creek. The bench gravels that were worked are said to have yielded a good profit to the miners, but the increasing depth of the ground and the difficulties encountered in keeping the ditch in repair so increased the costs that no mining on this bench has been done for several years.

Claim No. 12.—Two men were mining on the upper end of claim No. 12 by pick and shovel. A cut about 240 feet long had been ground-sluiced and most of the cut has been shoveled into the boxes. The gravels, which lay on schist bedrock, averaged 6 feet in thickness and contained comparatively few boulders. Although one nugget, valued at $80, is said to have come from this claim, most of the gold is comparatively fine and nuggets are not common. Only a small part of this claim is reported to have been mined.

Other mining on Glacier Creek.—During the years since 1905 considerable mining has been done on Glacier Creek on claims that were not being worked in 1916. Thus some mining was done on claim No. 13. Claims No. 15, No. 16, and No. 17 were largely exhausted, but No. 18, No. 19, and No. 20 produced some gold. Certain claims on Yellow Creek are said to have been very rich, but they, too, were mined out. A good deal of prospecting and a little mining have been done on the claims below No. 12, but the stream gravels are so deep that ordinary mining methods fail to reach bedrock, except in the stream flat through a canyon extending for about a mile below Discovery claim and that in another canyon just above the mouth of the stream. The deep ground is said to begin on claim No. 11, and it is reported that an 80-foot prospect hole sunk on claim No. 10, a 90-foot hole on claim No. 9, and an 80-foot hole on claim No. 7 all failed to reach bedrock.

CARIBOU CREEK.

In its upper part Caribou Creek flows almost due west and is fed from the south by a number of tributaries that drain the highest peaks of the Kantishna Hills. Ten miles below its head Caribou Creek swings to the north and flows between broad, gravel-topped ridges to its confluence with Bearpaw River.

The only ground in the Caribou Creek basin on which mining was done in 1916 comprises a group of eight claims extending along the valley of Caribou Creek from Last Chance to Crevice Creek. The area that has been mined is a strip extending 1,200 feet upstream from the mouth of Last Chance Creek and varying in width from 10 feet through the canyon to 70 feet at the upper end of the cut, where the creek flat widens above the head of the canyon. The gravels were from 2 to 3½ feet thick in the stream bed and reached a thickness of 7 feet on some of the bars. Large boulders, some of them so large that it was necessary to mine around them, were numerous in the canyon, but above it none that were encountered were too big for one man to handle. Sluice boxes 10 inches square in cross section, lined with pole riffles, were set on a grade of 9 inches to the box length. Water is always sufficiently abundant in Caribou Creek at this place for pick and shovel mining. In fact, inconvenience is more likely to result from too much rather than from too little water. The slopes in the basin of Caribou Creek are so steep that the stream responds quickly to any rainfall, and after a heavy rain the stream is likely to be so flooded that mining must be suspended until it falls. The gold occurs throughout the whole thickness of the stream gravels but is especially concentrated on bedrock. That in the gravels is bright and yellow, but that on the bedrock is usually darkly stained and discolored. The gold taken from the canyon is coarse, the largest nugget found having a value of $110; but that from above the canyon is fine, occurs in flat, flaky pieces, and is said to assay $13.50 an ounce. Pebbles of magnetite, ilmenite, and the calcium tungstate, scheelite, and numerous large garnets are associated with the gold in the sluice boxes. Four men were employed during most of the summer.

A small amount of gravel has in former years been sluiced on claims No. 3 and No. 4, and a good deal of prospecting has been done, both in the stream gravels and on the high benches. The benches are said to carry promising gold deposits, but the bench gravels are frozen and the cost of thawing has so far prohibited mining on them.

LITTLE MOOSE CREEK.

Little Moose Creek is a small western tributary of Clearwater Fork of Toklat River, and joins it 3 miles above its mouth. For its entire length it flows through a deep, narrow valley bordered by rugged mountains of schist. The only mining in progress on this stream in 1916 was being done at a point 5 miles above its mouth, on claim No. 20, where two men were working. An automatic dam had been constructed but was not completed until late in the spring, by which time the water supply had become too small for the most satisfactory operation of the dam. In the mining done in 1916 no bedrock had been uncovered up to the middle of August, though some gold had been recovered from the gravels. Large boulders are confined almost wholly to the surface gravels.

It is said that the gravel in all the ground below claim No. 18 excepting claim No. 7 is so deep that bedrock can not be reached by ordinary methods of open-cut mining.

Some mining has been done in past years on claims No. 18 and No. 19. The stream gravels are reported to range from 8 to 10 feet in thickness, although in many places slide material from the valley sides has covered the pay streak to a depth so great that mining costs were prohibitive. The gold is coarse and shotlike and not greatly worn. Although one-third of the gold recovered is said to be in pieces worth 50 cents or more, very large nuggets are not common, the largest taken from this creek having a value of $20. The gold is of low grade, and is said to assay about $12 an ounce. Small nuggets of native silver are reported to be present in almost every clean-up.

The creep of soil and talus is especially rapid in the valley of this and adjacent streams. The small excavations made in the course of placer mining have at times been sufficient to disturb the equilibrium of the adjoining valley slopes, and large quantities of muck, soil, and coarse rock have suddenly slid into the mining cuts, burying sluice boxes and causing much annoyance. The unusual depth of the stream gravels in this valley is due, in part at least, to the rapid downward creep of valley-side detritus, which fills the valley floor more rapidly than the small stream can remove it.

GOLD PLACER PROSPECTS IN THE KANTISHNA REGION.

The foregoing description includes all claims in this district on which mining was in active progress in August, 1916, and makes some mention of the results of mining in earlier years on ground that was not being worked at the time of visit, but a historical sketch of the mining done in a camp where so many men have come and gone, and where the only record of past work is in the memory of those who have remained, must necessarily be incomplete. During the two years following the discovery of gold in this camp and the attendant stampede a large amount of prospecting was done on all the streams that drain the Kantishna Hills as well as in adjacent regions. Evidence of the work of the early prospectors is seen everywhere—in old cabins, prospect holes, and pits—and by their work they found that the gravels which would yield pay under the conditions then prevailing were limited to the streams already described. They also found, however, that placer gold is widely distributed, and that it occurs in many places in quantities almost sufficient to warrant mining at that time. Unfortunately, most of the information obtained by these men at so great a cost of money and effort is now lost. With the better means of transportation that will be afforded by the Government railroad to be built along Nenana River the cost of mining may be so greatly reduced that placer gravels heretofore unavailable may be worked at a profit.

Among the streams in the district that may become productive in the future are Rainy and Spruce creeks, tributaries of upper Moose Creek from the north; Myrtle, Moonlight, Stampede, and Crooked creeks, all eastward-flowing streams tributary to Clearwater Fork or to Toklat River; Flume Creek, which flows northwestward from the northern end of the Kantishna Hills to Bearpaw River, and a number of headward tributaries of Bearpaw River. On all these streams coarse gold has been found in encouraging quantities. By simple panning with only a little preliminary excavation members of the Geological Survey found coarse gold, in nuggets ranging in value from 10 to 30 cents, on at least three streams on which no mining had been done. Numerous coarse colors were found on the benches of Clearwater Fork of Toklat River, and prospectors report that gold may be found at many places between Toklat and Nenana rivers.

TOTAL PRODUCTION OF PLACER GOLD.

Mining has been done in the Kantishna district for 12 years by many men, who have made no accurate record of the gold they produced. A comparison and combination of the estimates made by men who are most intimately acquainted with the work done on the numerous creeks shows that the total production of placer gold in the district to the close of 1916 was about $380,000. Many will consider this estimate too small, for there is a constant tendency among most miners to overestimate the production on creeks with which they are least familiar. The figures for about half the total production, however, were furnished by men who actually mined the gold, and the total is believed to be not more than 10 per cent in error. The annual production for the last few years has been between $30,000 and $40,000.

FUTURE OF PLACER MINING.

As has already been stated, no placer mining by other than the simplest methods has ever been done in this district. The inaccessibility of the region, the small size of most of the rich creeks, and the small amount of ground to be worked on any one claim, have perhaps prevented the use of hydraulic or mechanical methods in working the gravels and have also favored the use of the more elastic method of mining by pick and shovel. The richest shallow gravel deposits have now been worked out, however, and the leaner but more extensive deposits that still remain must be worked by more elaborate methods. The man with sufficient capital and with an understanding of the problems involved would gain much greater profit by installing a hydraulic plant, a mechanical elevator, or a dredge, than can be gained by the man who has little equipment and who must rely upon only his own muscle and resourcefulness. The gravels of the creek flat and benches of Moose Creek below Eureka locally contain gold enough to justify mining by hand, and systematic prospecting may show that these gravels are of great enough extent and value to justify the installation of a hydraulic plant or a dredge. Both the bench gravels and the stream flats of lower Glacier and Caribou creeks are also gold bearing and may sometime yield a profit if mined on a large scale. The large gravel deposits on Clearwater Fork may also be sufficiently rich to justify extensive mining. The success of any such operations will depend, however, upon thorough and systematic prospecting to determine the value, extent, and characacter of the gravel deposits; upon the careful and wise choice of the proper equipment for mining; upon a close determination of the probable cost of operation; and last, but by no means least, upon wise and honest supervision and control.

LODE DEPOSITS.

GENERAL FEATURES.

There has been much active prospecting for lode deposits in the Kantishna district during the last few years, and a number of veins containing gold, at least one rich in silver, and three containing antimony, have been discovered, and more or less of development work has been done on them. No ores obtained from lode deposits in the district have yet been reduced, however, so that no metal has been recovered from them, yet the prospective value of the lodes can not be judged by the fact that they have so far yielded no metal. Their inaccessible situation has delayed their development, and most of the prospectors for lode deposits have been men of small means, without the financial resources required for extensive underground mining, or for building milling plants. The time and effort required to reach the lode prospects in summer have prevented capitalists from visiting them, but the completion of the railroad to the Tanana Valley may, perhaps, establish lode mining in this district. Although no single vein has been so far developed as to assure a successful mine, there are nevertheless a number of prospects that are of sufficient promise to warrant thorough exploration and that are likely some day to bring this camp into the list of gold lode producers.

All the lodes that have been considered worthy of development lie along the highest part of the Kantishna Hills, in a belt 27 miles long and 6 miles wide, extending from Clearwater Fork of Toklat River S. 60° W. to and across Moose Creek, but it is by no means certain that other valuable lodes do not occur outside of this area. Quartz float is abundant outside of this high area, but the steep slopes and the absence of a continuous surface cover of vegetation in this high and more rugged ground have made prospecting there easiest, so that most of the prospects lie high on the ridges. More thorough prospecting will probably disclose many veins at lower altitudes.

All the lodes so far found occur in similar rocks. The prevailing rock throughout the district has been called the Birch Creek schist, as it is believed to be a part of the schist series of that name which crops out in the area between Yukon and Tanana rivers. This schist is highly metamorphosed, much folded and contorted, and shows a variety of phases from place to place. It is commonly a dense, quartzitic rock, locally rather massive but generally containing much mica and exhibiting schistose cleavage. It includes fine, silvery mica schists, which show highly developed cleavage and in places are studded with garnets. It contains also dark, carbonaceous schist and greenstone in various degrees of metamorphism. The foliation of the schist usually strikes northeastward and dips at all angles, as the beds are in general closely folded.

The larger quartz veins, including those that carry gold, silver, and antimony, all cut the Birch Creek schist. The strike of the main veins so far exposed is decidedly uniform—between N. 45° E. and N. 70° E. Although their strike is parallel to that of the schist, most of the veins cut across the foliation of the schist which incloses them. The ore-bearing veins dip at angles ranging from 50° to 90°, and as far as can yet be made out hold their direction of strike and angle of dip rather constantly. They thus fall into a different category from the numerous lenticular and distorted veinlets and stringers of quartz in the schist that lie parallel to its foliation. The ore-bearing veins here described are therefore fissure veins, which were opened and filled after a large part of the regional metamorphism to which the schists have been subjected was completed. Some movement has occurred along the vein openings since the ore was deposited, but this may be ascribed to local uplift or warping without much deformation, for the veins themselves have not been notably deformed since they were deposited. The study of the ore deposits was hampered by the meagerness of the underground workings. The 11 longest tunnels together measure only 891 feet, and the two deepest shafts together measure only 70 feet. The longest tunnel that could be entered is but 188 feet from portal to breast, and each of five other tunnels measures little more than 100 feet. Several of the tunnels are now caved in and could not be examined. The veins have been exposed not only by the underground workings but by a large number of open cuts, yet as most of these were slumped it would have been necessary to clear them in order to examine them, and no time was available for that work.

The veins examined differ greatly in the abundance of the metallic minerals that they contain and in the proportions of those minerals to one another. The assemblage of minerals, however, is much the same in all the veins. The more important minerals recognized were gold, silver, arsenopyrite, pyrite, galena, sphalerite, stibnite, and chalcopyrite. All these minerals are considered primary—that is, they were deposited directly from ore-bearing solutions or were formed by chemical action between these solutions and the inclosing country rock. At the outcrops of the veins there is in places a zone of leaching and oxidation in which secondary minerals such as iron oxide and lead carbonate are found, but this zone of weathering is shallow, and tunnels driven only a few feet beneath the surface into the quartz veins show unaltered vein material. Along some open cracks, and in places where the ore is shattered and broken, oxidation and weathering have penetrated more deeply.

There are no facilities in the Kantishna district for making assays, and most of the samples of ore that are taken out by prospectors for assay have been sent to Fairbanks. Communication with Fairbanks is difficult and infrequent, so that a long delay elapses between the collection of a sample of ore and the receipt of the assay return. This delay causes rather haphazard prospecting, for the prospector who has found a promising-looking quartz ledge may spend several months in development work before his assay return confirms his judgment or brings him disappointment. As a consequence of the difficulties in procuring assays, the prospector has been forced to

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rely upon such simple methods of determining the value of ore as he has at hand, the most common method being to crush the ore in a small hand mortar, and to pan the pulp thus obtained. This method determines, in a way, the presence or absence of free gold, but its quantitative results are uncertain and may be misleading. Only a small piece of vein material can be crushed at one time, and as the labor involved is considerable, the prospector is likely to crush only what he considers the most promising pieces of ore, so that the result is apt to raise false hopes as to the average value of his ore body. The average tenor of a vein can be determined only by taking accurately representative large samples at frequent intervals across the entire vein.

Furthermore, tests made by mortar and pan give no information concerning the gold in the ore that may not be in the form of free gold. Most gold-bearing sulphide ores contain a certain percentage of gold that is so combined with the sulphides that it is not released by simple crushing and amalgamation and can be recovered only by chemical treatment or smelting. The quantity of gold so carried may be sufficient to justify mining, and reliable assays should always be made to determine the value of any ore in order to ascertain whether or not the opening of a mine and the construction of a mill are justified.

As already stated, comparatively few assays of ores from this district have been made, and most of those are not available for publication. One or two mining engineers have made rather thorough examinations of certain properties and have collected average samples from the ore bodies which have been assayed, but naturally the assays were not made for general use.

Prospectors in this district have difficulty in keeping their tunnels in repair from year to year. A short distance below the surface the ground is permanently frozen. The tunnels when driven are usually dry, and in them the temperature tends to remain constantly below the freezing point, but if a tunnel is opened in warm weather the ground in it, which was solid and required no timbering, begins to thaw and slump. Many tunnels are therefore now caved in and inaccessible. Tight bulkheads and close-fitting doors that cut off the circulation of air, however, will keep the tunnels frozen in summer. As most of the tunneling has been done in winter, when the outside air is cold, work at that time is unimpeded by thawing. If underground work is done in summer and artificial ventilation is necessary, this tendency of the ground to thaw and slump is likely to necessitate the placing of heavier and more numerous timbers to keep the workings open and safe.

In the following pages the veins will be described in order from east to west.

GOLD LODE PROSPECTS.

MAMMOTH CLAIM.

At the head of Crevice Creek, a tributary of the Caribou, an open cut has been excavated on the Mammoth claim, which is high on the side of Spruce Peak, about 500 feet below the summit. This cut was reported to have slumped, so it was not visited, but it is said to display a large mineralized quartz vein. No information concerning its gold content was obtained.

LLOYD PROSPECT.

The Lloyd prospect is on the east fork of Glen Creek not far above its mouth, where a tunnel has been driven 24 feet into the face of a cliff on the north side of the stream. At the mouth of the tunnel in the face of the cliff there is a large bed of siliceous material that seems to be rather pure quartzite interbedded with the schist. Both the inclosing schist and the quartzite have been twisted into a close sigmoid fold that at one place gives a vertical exposure of quartzite 18 to 20 feet high. The quartzite is mineralized and contains some vein quartz, which carries pyrite, chalcopyrite, sphalerite, and, it is said, some gold. It is reported that no work has been done on this claim for several years.

HUMBOLT PROSPECT.

The Humbolt prospect lies at the head of the east fork of Glen Creek, on the high ridge that forms the crest of the Kantishna Hills. The schist here strikes N. 37° W. and dips 27° SW. A tunnel said to be 48 feet long, driven westward, was so caved in at the time of visit that it could not be examined. This tunnel was apparently started on the cropping of a vertical quartz vein that strikes N. 55° E., but it is said to have diverged from the vein and that no quartz showed at the breast. The main vein is 3 to 4 feet wide and consists of milky white to somewhat stained and rusty quartz. It is massive and shows no noticeable banding but includes some small inclusions of schist. Little mineralization except iron oxide was noted, though galena and sphalerite are reported. Associated with the main vein are two or three smaller parallel veins, all lying within a zone that measures about 30 feet across. Numerous large pieces of the vein quartz, broken from the croppings, lie about on the surface near the mouth of the tunnel, and it is said that several hundred pounds of this surface ore was shipped to Fairbanks for treatment and yielded good returns, mostly free gold. A tent and blacksmith shop have been erected at the mouth of the tunnel, and another tent stands in the valley below. No one was working on this property at the time it was visited, in August, 1916.

SKOOKONA PROSPECT.

The Skookona prospect consists of a number of open cuts on the top of a high ridge about a mile east of Glacier Peak, a high mountain on the ridge between the heads of Glen and Glacier creeks. The schist there strikes N. 20° E. and dips 15°–30° E. Several open cuts have been made and a 12-foot shaft has been sunk on a large quartz vein that seems to lie parallel to the schistosity and apparently has a maximum thickness of 20 feet. It forms a capping for the ridge on which the cuts are made, and the principal exposures may be on the same vein. The quartz is characteristically milk-white, though in places it is stained by iron oxide. Little mineralization is apparent. Too little development work has been done to show positively the structure or relations of this body of quartz.

GLEN PROSPECTS.

Two tunnels, known as the Glen prospects, have been driven near the top of Glacier Peak. The schist there strikes due north and dips 40° W. The upper tunnel, now caved in, is said to be 40 feet long, with a winze in the end. The lower tunnel was obstructed at the time of visit but was reported to be nearly 300 feet long and was evidently driven to cut the quartz vein that crops out on the slope above. Its shattered surface croppings indicate that the vein, which consists of white to gray banded quartz, is about 10 feet wide. Pyrite, sphalerite, and possibly galena were noted in the quartz on the dump. No evidence of recent work was seen, and no one was present on the property at the time of visit. The quartz is said to carry promising amounts of gold, but no figures were obtained as to the average gold content.

McGONAGALL PROSPECT.

A gold quartz prospect known as the McGonagall prospect lies near the head of Glacier Creek, at an elevation of about 3,400 feet, and a substantial cabin has been erected near the outcrop of the vein. The vein, as exposed by the surface outcrops and in an open cut, seems to strike N. 70°–110° E. and dip 50° to the south and is said to show a maximum thickness of more than 8 feet. A 12-foot tunnel, driven into the mountain at the outcrop of the vein, is lagged except at the breast, which showed only schist. On the surface many large pieces of white quartz, some 2 feet in diameter, show iron oxide along the broken faces, and inclose lenses and bunches of mica schist. Finely disseminated pyrite was observed along small fractures in the quartz.

It is reported that the best ore so far found on this property was taken from a small quartz vein in the creek bed below the cabin. A ton of this ore has been shipped to Fairbanks for mill test. No one was present on this ground in August, 1916.

GREISS PROSPECT.

The Greiss prospect comprises two adjoining claims, the Malachite and Azurite, both on the north side of upper Eureka Creek. On the Malachite claim a 13-foot tunnel has been driven on the north valley slope, opposite the upper end of placer claim No. 13. This tunnel, evidently driven to cut a zone of quartz-bearing schist, is timbered but shows in the breast black schist with small veinlets of quartz. An open cut west of the tunnel exposes black slate schist, fine banded and carrying numerous quartz veinlets lying parallel to the foliation of the schist, which strikes N. 45° E. and dips 30° NW. Pyrite, in cubes as large as a quarter of an inch in diameter, is locally abundant in both quartz and country rock. Tiny veinlets of calcite cut across the schistosity. The quartzose zone in the slate schist is at least 4 feet thick and contains streaks of white clayey material full of fragments of quartz. As the owner was absent at the time of visit no other workings were found, and no information was gained as to the value of the gold in the ore.

EUREKA PROSPECT.

A group of claims, said to be called the Eureka group but locally known as the Taylor property, lies on the north slope of the valley of Eureka Creek about 3 miles above its mouth. These claims have been worked by two tunnels, the Lower Eureka and the Upper Eureka, and by an open cut. A cabin has been built near the mouth of a southward-flowing tributary of Glacier Creek. The Lower Eureka tunnel is on the north side of Eureka Creek near the top of a steep bluff. It is timbered for 20 feet, beyond which it is caved in. The total length of the tunnel is said to be 40 to 50 feet. This tunnel was driven on a mineralized zone, about 8 feet wide, that apparently strikes N. 25° E. and dips 80° NW. This zone has a distinct hanging wall, though the footwall is not well exposed. It contains abundant quartz, inclosing numerous horses and lenses of schist, and the whole is much crushed and rusty, the broken quartz and schist being in part recemented by iron oxide. The inclosing schist strikes N. 15° E. and the tunnel is driven a few degrees east of north. The surface vein material is so greatly oxidized and so much coated with iron rust that little other mineralization can be seen. Some pieces on the dump, however, show white quartz with finely disseminated pyrite, some galena, and a little stain of copper carbonate.

The Upper Eureka tunnel is more than 600 feet higher than the lower Eureka and is about 4,000 feet northeast of it. It was driven N. 67° E. for 100 feet and from it have been run three branches. The total length of these underground workings is about 144 feet. The tunnel is driven along a vertical quartz vein. Its northwest side follows the wall of the vein, and its southeast side follows a straight, smooth parting in the vein. In the outer 100 feet of tunnel the vein quartz is at least 7 feet wide, and one wall of it is not exposed. Some movement has occurred along the contact between the quartz and the schist, as both are somewhat shattered and broken. The vein as a whole is fractured, and the broken surfaces of quartz are covered with iron oxide. One hundred feet from the entrance of the tunnel there is another quartz vein, at least 3 feet thick, striking N. 30° W. and dipping 20° SW., which seems to cut off the main vertical vein on which the tunnel started. Not enough work has been done to determine the relations of these veins.

The country rock at this place is a dense, quartzitic schist containing mica and coarse granules of quartz. It strikes N. 30° E. and dips 24° NW. The vein material varies from white, glassy quartz to gray, mottled quartz, and includes some dark rock containing quartz and sulphides, much stained and discolored. Iron pyrite is widely disseminated through the vein, and pyrite, sphalerite, and a little galena were locally abundant. No report was obtained as to the gold content of this lode.

PENNSYLVANIA AND KEYSTONE PROSPECTS.

The Pennsylvania and Keystone prospects are here described together, as they adjoin one another, are held by the same owner, and are staked along the strike of veins that are continuous from one claim to the other. These claims, which lie on the north side of Eureka Creek, are crossed by Iron Creek, a small southeastward-flowing tributary of Eureka Creek, and have been worked by a large number of open cuts. No underground work had been done on them at the time of visit.

The main vein on this property is a quartz vein averaging 3 feet in thickness, striking N. 50° E. and dipping 56° S. It crops out at the discovery on the Keystone, and has been traced thence along the strike northeastward across Iron Creek and up the opposite side of that valley. Between 15 and 20 open cuts, made by stripping off the vegetation and loose surface material, show that the vein is continuous and that it preserves its direction of strike, its angle of dip, and its thickness for at least several hundred feet along the outcrop. In the weathered surficial portions of the vein so far uncovered the quartz is broken and oxidized, and is generally rusty. Arsenopyrite and pyrite are abundant, and locally the quartz is heavily mineralized with arsenopyrite, sphalerite, and galena. Small pieces of vein quartz that were mortared and panned showed free gold, and on many pieces of ore coarse particles of free gold could be distinguished with the unaided eye. Development work had not progressed far enough to disclose the vein below its weathered surface portion, and no assays of average samples of ore had been made.

In the valley of Iron Creek, 100 feet above the crossing of the vein just described, there is another quartz vein which strikes N. 54° E. and dips about vertical. This vein shows a maximum width of 6 feet of quartz, 2 feet of which, on the southeast wall of the vein, is banded and broken. The quartz contains iron sulphides, and gold can be panned from specimens taken from the outcrop. If this vein maintains a trend uniform with that at the place where it has been uncovered, it should intersect the main vein a short distance east of Iron Creek.

An open cut just east of Iron Creek, made to intersect the main vein, encountered a small quartz stringer three-quarters of an inch to 6 inches wide, in the oxidized portion of which were pockets of very rich gold ore. Several ounces of fine crystalline gold was panned from the decayed surface of this veinlet, and specimens were preserved that showed a spongy network of delicate gold crystals, any sulphides that may originally have been present having been leached out and oxidized. This exceptionally rich ore was found in only slight amount in the small excavation made at that place, and its relation to the main vein had not been determined, but its presence indicates the possibility of the existence of rich ore shoots in these veins.

GOLD KING PROSPECT.

The Gold King prospect lies near the head of Iron Creek, high on the ridge between Eureka Creek and the head of Friday Creek. The work done on this claim consists of two tunnels, the lower of which, at an elevation of about 3,150 feet, is said to be 30 feet long but is caved 20 feet from the portal. The quartz vein in this tunnel is reported to average 4 feet in width. Fifty feet above the lower tunnel, on the same vein, a second tunnel has been driven for 7 feet. Though only one wall of the vein is exposed the vein there, which strikes N. 70° E. and dips vertical, is shown to be over 6 feet wide. The inclosing schist is fractured and disturbed but strikes about N. 80° E. and dips 20° S. The freshly fractured vein quartz is white and massive, though the outcrop and the old fracture faces are stained with iron rust. Arsenopyrite, sphalerite, and galena were noted, and the oxidized surface quartz is said to assay several dollars in gold to the ton and to carry a trace of silver. The residual material on the surface is reported to show colors of gold on panning.

GOLDEN EAGLE PROSPECT.

The Golden Eagle prospect is at the head of Friday Creek on the ridge that separates the basin of Friday Creek from that of Iron

Creek, a tributary of Eureka Creek. The property is developed by several open cuts and a tunnel. The open cut by which the vein was discovered showed that it is 3 feet wide, of which 2 feet consisted of vein material heavily mineralized with galena, pyrite, sphalerite, and copper carbonates and contained considerable free gold. The tunnel was driven on a crushed and slickensided zone to intersect the vein shown in the open cut. The inclosing schist there strikes N. 55° E. and dips 51° SE. and the crushed zone strikes parallel with the schist but dips at a steeper angle. The tunnel is 145 feet long and shows bunches of quartz along the crushed zone, within which both quartz and schist are mineralized. The heavily mineralized vein material that showed a width of 2 feet on the surface averages a width of only a few inches in the tunnel and has a maximum thickness of 18 inches, but it is said to carry considerable gold. Tests made by crushing specimens in a hand mortar and panning the pulp show abundant particles of free gold, and assays are said to have indicated a content of several hundred dollars a ton in gold.

LITTLE ANNIE PROSPECT.

The Little Annie prospect is on the northwest side of the Friday-Eureka creek divide a short distance below the summit. This claim is developed by a number of open cuts and a tunnel having a total length of 147 feet. The schist country rock here strikes N. 18° W. and dips 15° W. The main tunnel was driven southward to intersect a vein whose outcrop appears in an open cut on the hillside above. It encountered the main vein 90 feet from the portal, where a drift 42 feet long was driven S. 59° W. along the vein. A second drift, started 60 feet from the portal, runs S. 55° W. for 10 feet. The main vein consists of quartz 3 to 4 feet thick and dips 65° SE. The footwall is sharply defined and is much slickensided with striations, which show that horizontal movement has taken place between the vein and the footwall since the quartz was deposited. The quartz contains disseminated pyrite and pans a little gold. No galena or sphalerite was seen in the underground workings, but they are probably present, for large pieces of solid galena several inches in diameter have been found on the surface near the crop of the vein. A piece of this float galena on assay yielded 124 ounces of silver to the ton.

Between the footwall of the main vein and the 10-foot crosscut there is a zone 27 feet wide and parallel to the main vein in which the schist is so much cut by small quartz veinlets a few inches thick that more than half the zone appears to be composed of quartz. Assays of the vein material have shown that the quartz carries a few dollars in gold to the ton.

SILVER PICK PROSPECT.

The Silver Pick prospect lies southwest of the Little Annie and Golden Eagle claims, already described, on the same ridge and at about the same elevation. It is worked by several open cuts and by a straight tunnel 188 feet long driven S. 30° E. The schist country rock strikes S. 5° W. and dips 50° W. At the portal of the tunnel one edge of a quartz vein that panned gold was cut, but the thickness of this vein was not determined. A vein striking N. 35° E. and dipping 68° NW. was penetrated 54 feet from the portal. This vein was 5 feet thick and is composed of rusty quartz containing numerous bunches of galena. A picked sample of this galena is said to have assayed 100 ounces of silver to the ton, and the ore is said to carry a fraction of an ounce of gold to the ton.

Near the breast of the tunnel the main vein consists of a 13-foot zone striking N. 35° E. and dipping 67° SE., and is therefore approximately parallel in strike with the vein already described but lies 130 feet northeast of it. This zone consists of 1 foot of calcite on the footwall and 12 feet of quartz and schist, more or less sheeted, the quartz predominating in bulk over the country rock. Little galena is seen in the tunnel, but it is abundant along the surface crop of the vein. The whole zone is brecciated and leached, and large open cracks extend from the tunnel to the surface. Pyrite, arsenopyrite, and small amounts of galena and sphalerite were observed, and along some of the cracks deposits of a soluble salt, which on analysis proved to be the iron sulphate melanterite, were found.

GALENA PROSPECT.

The Galena prospect lies on the northeast side of Moose Creek, on the end of the ridge between the basins of Friday and Eureka creeks. The work done consists of a number of open cuts, now caved in, and a tunnel, evidently driven to intersect a vein that cropped out in the open cuts. The tunnel, which runs S. 50° E., is 27 feet long and has a 6-foot crosscut at the breast, where a distinct plane of movement, with some gouge, strikes N. 45° E. and dips 63° SE. Next to the gouge-filled fracture, on the footwall side, there is a body of quartz, white to mottled with blue-gray patches, that is heavily mineralized with pyrite, arsenopyrite, galena, and sphalerite. Any one of these sulphides may occur in nearly pure bunches, or they may be intimately intermingled. Galena was seen in nearly pure stringers 2 inches or more thick, and an assay made of this galena yielded 131 ounces of silver to the ton.

There is no sharp break between the ore body and the country rock on the footwall side of the vein; the mineralization merely becomes less as the distance from the hanging wall increases. Veinlets of ore extend into the country rock but pinch out in short distances. An examination of the short stretch of the lode that is exposed in the crosscut shows that the heaviest mineralization occurs within 4 feet of the gouge-filled fracture. Exploration to determine the presence or absence of ore has not been carried beyond that fracture. As the owner was not in the district at the time this property was visited, the proportion of gold to silver in the ore is not known, though it is reported that it contains gold, and the deposit is therefore classed as a gold lode.

OTHER GOLD LODE PROSPECTS.

Many other lode claims have been staked in this district, and on some of them the annual assessment work is done, but others have been staked and later abandoned. The writer has described here only those properties that seemed of sufficient promise to the owners to warrant underground development or the excavation of sufficient open cuts to expose the vein. Some veins that have received little attention, however, may on exploration show great promise, and undoubtedly many veins exist that have not yet been discovered.

ANTIMONY LODES.

PRESENT CONDITIONS.

Within the Kantishna district there are several claims that are held for their content of the antimony trisulphide, stibnite. Genetically the antimony lodes are directly related to the gold lodes already described, and the veins have the same association of minerals, but in the antimony lodes antimony occurs in large masses, whereas in the gold lodes antimony, although occasionally recognized, is a minor constituent. The presence of veins containing considerable masses of stibnite has been known since the first years of mining in this region, but the remoteness of the district and the prevailing low price of antimony prevented the exploitation of the deposits, although some development work was done on two of them. After the outbreak of the European war the price of antimony advanced from 5 cents a pound to the unprecedented price of 40 cents a pound, which it reached at the end of 1915. As a result of this great demand interest in the Alaska stibnite ores increased, and production began at several mines.[1] In the Kantishna district increases in mining in response to the increased price of antimony were somewhat sluggish, for communication with that district is slow, and much uncertainty existed as to the value of antimony on any particular date. Furthermore, it was not feasible to take ore to the navigable water of Kantishna River, except by sled in winter and thence by boat to Tanana

[1] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, p. 7, 1916.

the following summer. Even after the ore reaches Tanana several weeks must elapse before it can be delivered to a purchaser in the States. At least three months and possibly a longer time must therefore elapse between the date the ore is mined and the date it reached the market. When to the cost of mining is added the cost of transportation by sled and small boat to the Tanana and the freight thence to Seattle or San Francisco, no great margin of profit is left for the producer even at the highest war prices. In addition to these high costs the instability of the market and the possibility of a sudden drop in the price of antimony must be considered. At 40 cents a pound the producer might make a fair profit in shipping stibnite ore, but at 25 or 30 cents a pound he might sustain a serious loss. As a result little stibnite ore was mined in 1915, and none was shipped. Some ore was mined and stacked in 1916, but at this time (1917) no antimony from the Kantishna region has reached the market.

TAYLOR MINE.

The Taylor mine, or, as it is commonly called, the Antimony mine, lies near the head of Slate Creek, a headward tributary of Eldorado Creek. The property was first staked in 1907, but the title lapsed and the ground was restaked by the present owner. It is said to include a group of claims, but the work done has been confined to the driving of a tunnel 97 feet long, with 22 feet of crosscuts, and to the excavation of an open cut immediately above the tunnel. The open cut and the tunnel show a strong fissure along which movement has taken place. This fissure strikes N. 50° E. and dips 82° SE., and forms the southeast wall of the main ore body, though a little ore is seen on its southeast side. The ore body has a maximum width of 15 feet and constitutes a reticulated stockwork of quartz and stibnite, with irregular bunches and horses of decomposed clayey schist, all much broken and confused. The inclosing quartzite schist strikes north and dips 29° E.

Almost pure stibnite occurs here in veinlets and in veins, the largest 2 feet thick, and in irregular lenses and bunches. In some places it is solid and unaltered, but in others it is crushed and broken and consists of small fragments of quartz and stibnite recemented by yellow and reddish secondary oxidation products, which on analysis are found to consist of the antimony ochers, stibiconite and kermesite. The principal ore bodies, which occur within 6 or 8 feet of the main fissure, seem to lie in the stockwork with their longest diameter oblique to the main fissure, the ore lenses and veinlets in general dipping 60° NW. The stibnite occurs predominantly as aggregates of acicular crystals but includes also masses of fine-grained material. About 125 tons of hand-sorted stibnite has been mined, most of which was taken from the open cut. That taken from the tunnel was of lower grade, as the pure stibnite occurred there in smaller bunches, and the ore contained more quartz and schist. In the absence of facilities for machine concentration much stibnite that could not be separated from the gangue by hand sorting was thrown on the dump. Three men were employed on this property in 1916, and a project was under way to bring in motor trucks to be used in hauling the antimony ore from the mine to navigable water on McKinley Fork of Kantishna River at a point about 4 miles above the abandoned town of Roosevelt, from which the ore was to be taken by small boat to Tanana River.

CARIBOU LODE.

Caribou lode, in the basin of Caribou Creek, near the mouth of Last Chance Creek, a tributary from the southeast, is a stibnite-bearing lode on which some development work has been done. This property was visited by Prindle[1] in 1906, and the following description is written from information gathered by Prindle and by the writer. Little work has been done on the property since 1906, and at the time it was visited in 1916 the shafts were full of water and inaccessible. The property consists of two lode claims, the Pioneer and the Caribou, which lie across the lower valley of Last Chance Creek. Two shafts have been sunk, one, 40 feet deep, on the west bank of Last Chance Creek, and another, 30 feet deep, on the east bank. The vein strikes N. 40° E. and dips about 67° SE., is about 4 feet wide, and consists of a mixture of quartz and stibnite. In the western shaft a vein of pure stibnite 1 foot wide is said to lie along the northwest wall and to become narrower toward the bottom of the shaft. The quartz is massive to crystalline and is intimately intergrown with the stibnite, which occurs as a mixed aggregate of fine-grained, massive sulphide intermingled with acicular crystals, the largest 2 inches or more in length. Within the coarsely crystalline stibnite there are mingled many long prisms of quartz, which lie parallel with and are surrounded by the stibnite. The country rock inclosing the vein is much-contorted hornblende schist, the general strike of which is N. 65° E. and the general dip 35° NW. On Caribou Creek, several hundred feet northeast of the shafts, is an outcrop of a fissure that strikes N. 45° E. and dips 75° SE. It is believed to be the continuation of the antimony lode but shows only a little quartz.

Three samples of antimony ore collected from this property in 1906 were assayed. One yielded 4 ounces of silver to the ton, one

[1] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, p. 219, 1906.

2.76 ounces of silver and 0.12 ounce of gold, and the third 0.12 ounce of gold but no silver. Another sample, assayed for gold only, yielded 0.02 ounce to the ton. No ore from this lode has been marketed.

STAMPEDE LODE.

About 2 miles above the mouth of Stampede Creek, a tributary of Clearwater Fork of Toklat River from the southwest, on the southeast wall of the valley, a claim has been staked on a lode deposit of stibnite, called the Stampede lode. The only work done here is a large open cut excavated in 1916. The country rock, a reddish quartzite schist, as seen at the nearest outcrop to the lode that seemed undisturbed, strikes northwest and dips 30° NE. At the outcrop of the lode, near the top of a rounded ridge, the surface is covered with a mantle of disintegrated rock, and the schist itself is much disturbed by frost and by creep, so that the relation between the ore and the country rock is difficult to ascertain. In the floor of the open cut and at its face is a large body of nearly pure stibnite, apparently at least 12 feet thick. The ore in the face of the cut was faulted and slickensided, and no good exposures of the contact of ore with schist were seen. The ore contains only a little quartz, and one man had in three weeks removed and stacked 40 or 50 tons of selected stibnite, almost entirely free from visible gangue or impurities and much of it in lumps 6 inches to 1 foot in diameter. The vein in which the stibnite occurs, probably as a large lens, strikes northwestward and apparently dips 65° SW. From this vein a branch vein of stibnite strikes northeastward. The stibnite is mostly a close-grained, massive aggregate containing small scattered crystals but includes some that is more coarsely crystalline. A sample of ore from this vein is reported to have showed on assay a content of 69.8 per cent antimony, 1 per cent arsenic, and no silver or lead.

Another stibnite-bearing vein, which follows the general course of the Stampede lode but contains much quartz, is said to crop out on the opposite side of Stampede Creek. No work has been done on it.

LIGNITE.

PRESENT DEVELOPMENT.

Tertiary deposits containing lignitic coal occur at intervals throughout the area considered in this report. They are of large extent just east of Nenana River, in the Nenana coal field, where deeply cut valleys expose the formation which there contains numerous beds of lignite. The coal-bearing beds in the Nenana field are overlain by a heavy body of oxidized gravels, which in many places seem to lie conformably upon them. West of Nenana River, in the area under discussion, outcrops of both the coal-bearing beds and the succeeding gravels are found here and there near the north flank of the Alaska Range, at least as far west as the headwaters of Bearpaw River. At some of these localities there are beds of lignite. No single exposure discloses lignite in the abundance in which it is found in the Nenana field, and it is doubtful whether it occurs so abundantly elsewhere. The area of coal beds and the quantity of lignitic coal west of Nenana River, however, may be out of proportion to the amount seen in the outcrops. In this area the beds are not generally dissected by deep valleys that have bare walls, as they are on Lignite and Healy creeks, but are bared by the cutting of small gullies. Furthermore, a widespread blanket of later gravel deposits covers the coal-bearing rocks, so that outcrops are infrequent and poor. The widespread geographic distribution of the beds of the coal-bearing series, however, and the presence of lignitic coal in these beds at widely separated localities indicate that a much larger quantity of lignite than is now known may lie beneath a covering of younger materials.

The localities west of Nenana River at which beds of lignite were seen are briefly described below.

TEKLANIKA BASIN.

Savage River.—Lignite is exposed at several places in the basin of Savage River, the eastern branch of Teklanika River. The southernmost of these exposures is near Ewe Creek, a small westward-flowing tributary that drains the north slope of the schist mountains north of the Dry Creek-Savage River divide. About a mile above the mouth of Ewe Creek, on its north side, there is a prominent light-colored bluff composed of decayed schist and blue-white clays. Just east of this bluff, at the mouth of a small southward-flowing stream, a 2-foot bed of weathered lignite is exposed. Its relations are obscured by vegetation and waste material. A few hundred yards up the same small gulch a 10-foot bed of lignite, striking about east and dipping 30° S., forms a waterfall in the gulch. As the schist crops out only a short distance both to the north and south of this exposure, the area underlain by coal at that place is probably small.

On the north side of Ewe Creek a bed of lignite that shows a maximum thickness of 9 feet crops out at intervals at the edge of the stream flat from the mouth of the creek eastward for nearly a mile. The relations of the lignite to the overlying and underlying beds were not exposed. As this bed strikes N. 75° E. and dips about 20° N. and thus lies beneath the broad benches north of the outcrop, it may have an area of several square miles. The lignite was free from partings and appeared to be of about the same grade as the average lignite of the Nenana field.

On the west side of Savage River, about a quarter of a mile below the mouth of Ewe Creek, a short section of a 14-foot lignite bed is poorly exposed in the bluff above the stream. It strikes N. 85° E., dips 15° N., and is overlain stratigraphically by 40 feet of cross-bedded sandstone. The coal-bearing beds at the top of the bluff are covered unconformably by a horizontal bed of coarse yellow gravel 8 feet thick above which lies a horizontal bed of fine gravel 20 feet thick. A mile and a half below this outcrop, along the same bluff, the following section, which shows a total of 25 feet 8 inches of lignite, in five beds, is excellently exposed:

Sections of lignite-bearing beds on Savage River, 1¾ miles below the mouth of Ewe Creek.

	Ft.	in.
Horizontal terrace gravels	15	
Unconformity.		
Clay	24	
Lignite	6	
Clay	1	6
Lignite	9	
Clay	24	
Lignite	1	2
Clays, sands, and silts	32	
Shale	3	
Gray sandstone	3	
Lignite	3	6
Dark gray shale	2	
Light gray shale	3	
Dark gray shale	2	
Gray sands	4	6
Dark gray shale	3	
Gray sands	3	
Lignite	6+	

The strike of the beds at the south end of the exposure is about N. 20° W. and the dip is 10° W., but toward the north end the dip steepens in a sharp flexure. At that end a lignite bed, poorly exposed but apparently 5 or 6 feet thick, crops out and is seemingly at a higher stratigraphic position than the top of the section given above. The whole coal-bearing series is covered unconformably, at the top of the bluff, by a horizontal bed of terrace gravel. On the east side of Savage River, a short distance above the exposure just described, a bed of lignite, much disturbed by surface creep but apparently 8 feet thick, crops out in a small tributary valley. Its relations to the beds in the section listed above are not clear, but it should probably be correlated with one of them.

The numerous outcrops of lignite observed in the part of Savage River basin that lies between the schist hills on the south and the high gravel ridges on the north indicate that there is at this place a coal field, probably several square miles in area, in which lignite occurs in beds of workable thickness. Time was not available for the careful structural work necessary to determine the probable extent of the several beds of lignite.

A little impure lignite was observed in the east bank of Savage River about 1½ miles above its mouth, but no large beds of lignite were seen there.

Sanctuary River.—On the east side of Sanctuary River, 3 miles above its mouth, a 15-foot bluff along the stream shows a 3-foot lignite bed interbedded with gray clays and gravels. The beds here have been compressed into an anticlinal fold, on the north flank of which the lignite dips below the stream level. The general strike of the anticline is east.

TOKLAT BASIN.

East Fork of Toklat River.—The East Fork of Toklat River is formed by the junction of a number of northward-flowing streams that drain the crest of the Alaska Range. The stream bars below the junction contain a considerable amount of lignite in pebbles and in small piles of fragments formed by the weathering of larger pieces. The source of this material was not ascertained, but it is almost certainly in the basin-like depression that forms a low divide extending from a point near the head of East Fork of Toklat River to Toklat River at its forks.

Toklat River.—On Toklat River, near its upper forks, a low pass connects the valley of the Toklat with the valley of upper Stony Creek. Three miles above the mouth of the stream flowing eastward from that pass three beds of lignite from 1 foot to 4 feet thick are reported by members of the Survey party to crop out on the south side of the stream, but they were not visited by the writer. In the same valley, about a mile above the mouth of the stream, a bluff composed of the shales, gravels, and sands of the coal-bearing formation shows a 2-inch bed of impure lignite.

KANTISHNA BASIN.

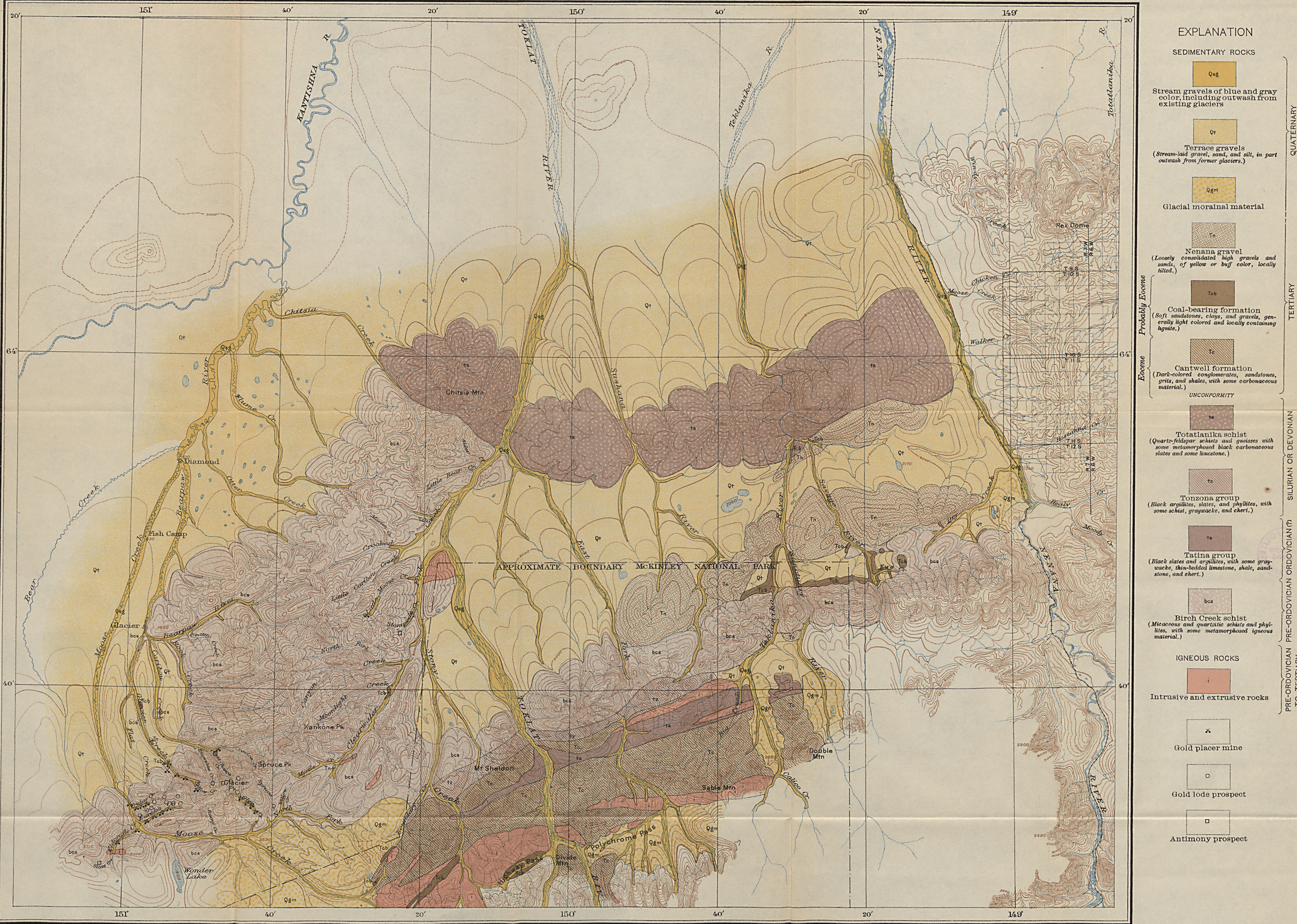
Moose Creek.—Near the extreme head of Moose Creek, a tributary of Bearpaw River, in the Kantishna basin, which rises in the high mountains 9 miles northeast of the terminus of Muldrow Glacier, there is a basin-like area floored with beds of the Tertiary coal-bearing formation. A number of exposures there show thin beds of carbonaceous materials and impure lignite. At one locality near the Moose Creek-Stony Creek divide, on the north side of the valley and 350 feet above its floor, is a weathered outcrop of a 12-foot bed of lignite, which strikes N. 80° E. and dips 55° S. This bed seems to lie near the base of the coal-bearing formation at that place, and overlies a purple discolored shale, which is underlain by volcanic material. The outcrops of this bed of lignite were observed for a short distance along the flank of the mountain, but the areal distribution of the bed is not known, though its structural relations indicate that it dips beneath the beds to the south, and in this basin it may possibly have an area of a few square miles.

Six miles below the lignite exposure just described Moose Creek forks, and fragments of lignite were seen in the stream gravels of the northeast fork also. A hasty examination failed to disclose the bed from which these fragments were derived, but it is reported that a bed of lignite 10 feet thick is exposed along the south bank of that fork about 2 miles above its mouth. Coal from this place has been taken to the placer mines on Moose Creek and is said to be of fair quality. Lignite is also reported to occur in the canyon along the north edge of Muldrow Glacier a few miles above its terminus.

Some fragments of lignite were noted on the bars of Glacier Creek about 1½ miles above its mouth. The deposit from which they were derived was not seen, but it is evident that there are areas of the coal-bearing formation in this locality, though they are for the most part covered by younger gravels.

80549°—19——8

INDEX.



Alfred H. Brooks, Geologist in charge of division.
Topography and control by C. E. Giffin, J. W. Bagley, R. B. Oliver, and D. C. Witherspoon.
Land surveys and included topography by General Land Office.
Geodetic position by General Land Office and U. S. Coast and Geodetic Survey.
Railroad location and survey of Nenana River by Alaskan Engineering Commission (railroad under construction).
Datum of C. E. Giffin area is mean lower low water, Portage Bay, derived from elevations by Alaskan Engineering Commission.
Elevations of other portions as previously published.
Surveyed in 1906, 1910, 1913, and 1916.

A. HOEN & CO. BALTIMORE, MD.

GEOLOGIC RECONNAISSANCE MAP OF NENANA-KANTISHNA REGION, ALASKA

Scale $\frac{1}{250,000}$

5 0 5 10 15 Miles

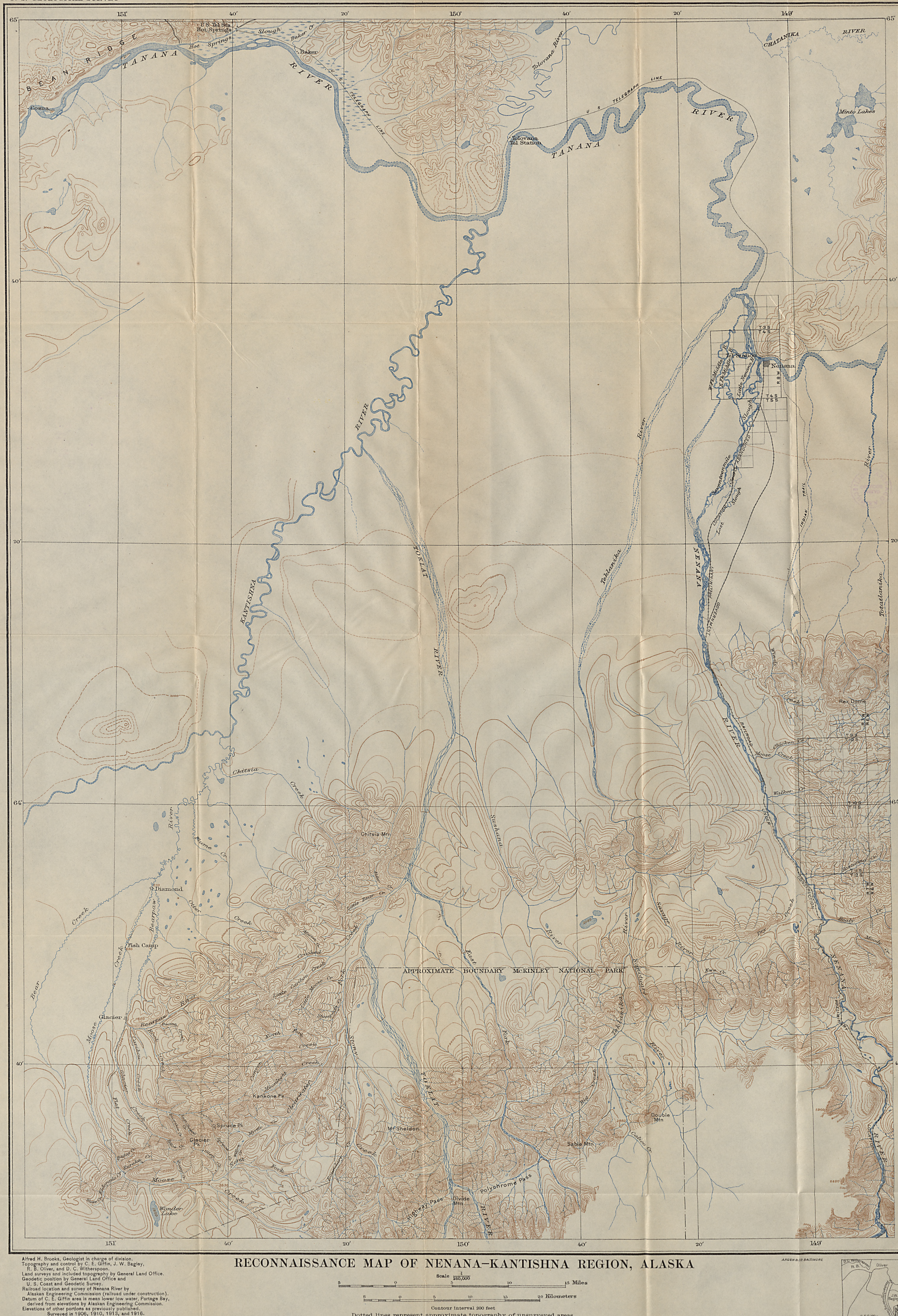
5 0 5 10 15 20 Kilometers

Contour interval 200 feet

Dotted lines represent approximate topography of unsurveyed areas.

1919

Geology by A. H. Brooks, L. M. Prindle, and S. R. Capps.
Surveyed in 1902, 1906, and 1916.



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Elevations of other portions as previously published.
Surveyed in 1906, 1910, 1913, and 1916.

RECONNAISSANCE MAP OF NENANA-KANTISHNA REGION, ALASKA

Scale $\frac{1}{250,000}$

5 0 5 10 15 Miles

5 0 5 10 15 20 Kilometers

Contour interval 200 feet

Dotted lines represent approximate topography of unsurveyed areas.

1919