DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 538

A GEOLOGIC RECONNAISSANCE

OF THE

CIRCLE QUADRANGLE, ALASKA

BY

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WASHINGTON

GOVERNMENT PRINTING OFFICE

1913

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By Alfred H. Brooks.

Systematic geologic surveys and investigations of the mineral resources of the Yukon-Tanana region were begun in 1903 and were carried on in each succeeding year until 1911. For the first five years the work consisted of geologic exploration without base maps and afforded little opportunity for areal mapping. Meanwhile, however, topographic surveys of the region were being made, and during the last four years the geologist has usually had a base map on which to outline his stratigraphic units and has been able to make his investigations more detailed. For the most part, however, the work has been of a reconnaissance character except near Fairbanks, where a detailed geologic map covering about 436 square miles was made; elsewhere the results have warranted the preparation of very general geologic maps only. While these investigations were going on many reports covering the subject of mineral resources at some length and presenting geologic data were being published (see pp. 10–11), and it seemed best to defer the publication of the geologic reconnaissance maps until a large part of the field had been covered, thus permitting the correlation of the results obtained in the different districts.

The unit of publication for these maps is a quadrangle including 4° of longitude and 2° of latitude. The quadrangles mapped, named from east to west, are the Fortymile,[1] Circle, Fairbanks, and Rampart, all of which have, for the most part, been both geologically and topographically surveyed. A topographic base map for each quadrangle has been issued, and an account of the geology and mineral resources of the Fortymile quadrangle [2] has been published.

The geologic reconnaissance mapping of the Fairbanks quadrangle was completed in 1910, and the results are now in course of publication.[3] In 1911 the reconnaissance of both the Circle and Rampart [4]

[1] The Fortymile quadrangle, which is adjacent to the boundary, includes only 1° of longitude and 1° of latitude.

[2] The Fortymile quadrangle, Yukon-Tanana region, Alaska, by L. M. Prindle: Bull. U. S. Geol. Survey No. 375, 1909.

[3] Prindle, L. M., Geologic reconnaissance of the Fairbanks quadrangle: Bull. U. S. Geol. Survey No. 525, 1913.

[4] Eakin, H. M., Geologic reconnaissance of a part of the Rampart quadrangle, Alaska: Bull. U. S. Geol. Survey No. 535, 1913.

quadrangles was completed. None of the quadrangles were entirely covered by geologic mapping, but as the blank areas could be filled in only at the expense of much time and money it seemed best to issue the maps in incomplete form.

No one not familiar with the Yukon-Tanana region can realize the difficulties that are encountered in its geologic mapping. Though the region is now well known, much of it is so inaccessible that it can be investigated geologically only by a well-equipped expedition organized to work a hundred miles or more from a base of supplies. Inaccessibility, however, is the least of the difficulties. The complexity of the geology and the absence over large areas of bedrock exposures have made the geologic work extremely arduous. Most of the surveys have been made by expeditions moving rapidly and having little opportunity for exhaustive study of any particular locality. The geologist has been forced to seek his facts along routes of travel determined by physical obstacles, shortness of field season, etc., instead of being able to follow up special problems that might help to unravel the complexities of stratigraphy. Working under these conditions Mr. Prindle and his assistants have in less than a decade outlined the larger stratigraphic units in an area of more than 40,000 square miles and have thus paved the way for the detailed investigations which must be undertaken before a full knowledge of the sequence and structure of the rocks can be gained. The results are of value not only to the science of geology but also to the prospector and miner, to whom they supply a knowledge of the distribution and association of the mineral deposits. With the publication of this series of reports on the Yukon-Tanana region the first epoch of the geologic survey of the region will be closed. The completion of the work will be followed, as soon as circumstances will permit, by more detailed examinations of especially selected areas.

A GEOLOGIC RECONNAISSANCE OF THE CIRCLE QUADRANGLE, ALASKA.

By L. M. Prindle.

INTRODUCTION.

The Yukon-Tanana region comprises an area of about 50,000 square miles lying between Yukon and Tanana rivers west of the international boundary. For purposes of mapping and description this area has been divided into the Fortymile, Circle, Fairbanks, and Rampart quadrangles.

The Circle quadrangle (fig. 1) contains about 17,000 square miles and includes several districts that have been productive of placer

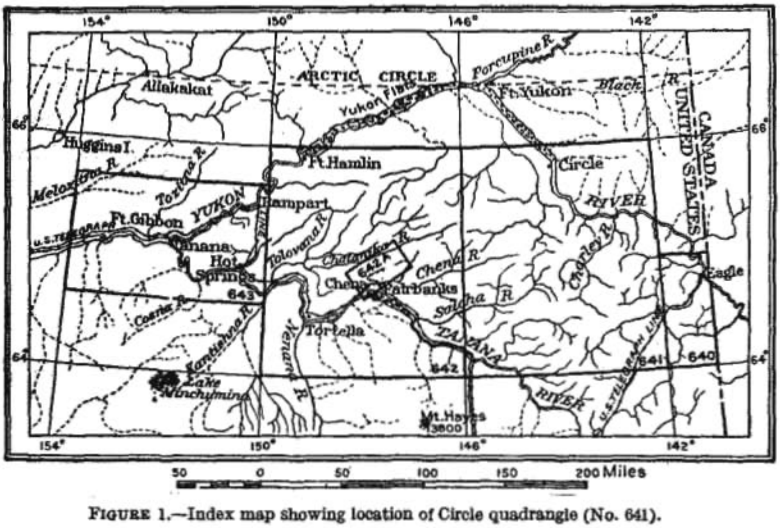

FIGURE 1.—Index map showing location of Circle quadrangle (No. 641).

gold. The most important of these, the Birch Creek district, was the site of some of the earliest prospecting in the interior of Alaska; and the abundant results of the discoveries of gold in it in 1893 led to the exploration of adjacent areas accessible from the Yukon and of small valleys tributary to the Yukon above Circle, including Woodchopper, Coal, and Washington creeks. In the eastern part of the quadrangle some placer ground was discovered in the upper valley of the Seventymile and on the North Fork of Fortymile. The establishment of a

Government telegraph line and stations and the construction of a trail from Eagle by way of North Fork of Fortymile and Goodpaster rivers to the Tanana rendered the eastern and southern portions more accessible. The discoveries of gold in the Fairbanks district in 1902 and the subsequent rapid development of that region afforded new bases of supply for prospectors and made large areas in the western part of the quadrangle comparatively easy of access.

The rapidly growing importance of the gold-placer districts in Alaska led to topographic and geologic work by the Government. Spurr[1] visited the Birch Creek district in 1895. Brooks[2] explored Tanana River, which sweeps the southwest corner of the quadrangle, in 1898. Collier[3] studied the geology of the northeastern portion of the quadrangle adjacent to Yukon River in 1902. Prindle spent a portion of the field seasons of 1903, 1904, and 1905 and the whole of the field season of 1911 in the area of the Circle quadrangle. Stone[4] traversed the northwestern portion of the quadrangle in 1905. Brooks and Kindle[5] studied the geology of the northeast portion adjacent to the Yukon in 1906.

The geologic work in 1903, 1904, and 1905 was done without a map. Rough foot traverses were made upon which the geologic results were assembled. The topographic map of the Circle quadrangle, the result of surveys made in 1903, 1904, 1905, and 1908, was available for the geologic work of 1911, and upon this map have been assembled for this report the available geologic data, both published and unpublished. The fact must be emphasized that in comparison with the size of the area the amount of work done is small and that the results are in very large degree only preliminary. Some of these results have already been published, and in this report free use has been made of these and of all Survey work in this area. In the reconnaissance work of 1904 the writer was assisted by Frank L. Hess, in 1905 by Adolph Knopf, and in 1911 by J. B. Mertie, jr.

The following list of publications of the Geological Survey contains not only the names of reports bearing upon the area immediately under discussion but also of those on the adjacent areas in the Yukon basin.

*The coal resources of the Yukon, Alaska, by A. J. Collier. Bulletin 218, 1903, 71 pp.

*The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, by L. M. Prindle. Bulletin 251, 1905, 89 pp.

Yukon placer fields, by L. M. Prindle. In Bulletin 284, 1906, pp. 109–131.

Reconnaissance from Circle to Fort Hamlin, by R. W. Stone. In Bulletin 284, 1906, pp. 128–131.

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* Survey stock exhausted; may be purchased from the Superintendent of Documents, Washington, D. C., or may be seen at most public libraries.

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

[2] Brooks, A. H., A reconnaissance in the White and Tanana river basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 425–494.

[3] Collier, A. J., The coal resources of the Yukon, Alaska: Bull. U. S. Geol. Survey No. 218, 1903.

[4] Stone, R. W., Bull. U. S. Geol. Survey No. 284, 1906, pp. 128–131.

[5] Brooks, A. H., and Kindle, E. M., Bull. Geol. Soc. America, vol. 19, 1908, pp. 255–314.

The Yukon-Tanana region, Alaska; description of the Circle quadrangle, by L. M. Prindle. Bulletin 295, 1906, 27 pp.

The Bonnifield and Kantishna regions, by L. M. Prindle. In Bulletin 314, 1907, pp. 205–226.

The Circle precinct, Alaska, by A. H. Brooks. In Bulletin 314, 1907, pp. 187–204.

*The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska, by L. M. Prindle, F. L. Hess, and C. C. Covert. Bulletin 337, 1908, 102 pp.

*Occurrence of gold in the Yukon-Tanana region, by L. M. Prindle. In Bulletin 345, 1908, pp. 179–186.

*The Fortymile gold-placer district, by L. M. Prindle. In Bulletin 345, 1908, pp. 187–197.

*Water-supply investigations in Alaska, 1906 and 1907, by F. F. Henshaw and C. C. Covert. Water-Supply Paper 218, 1908, 156 pp.

*Water supply of the Fairbanks district in 1907, by C. C. Covert. In Bulletin 345, 1908, pp. 198–205.

The Fortymile quadrangle, by L. M. Prindle. Bulletin 375, 1909, 52 pp.

Water-supply investigations in Yukon-Tanana region, 1906–1908, by C. C. Covert and C. E. Ellsworth. Water-Supply Paper 228, 1909, 108 pp.

*The Fairbanks gold-placer region, by L. M. Prindle and F. J. Katz. In Bulletin 379, 1909, pp. 181–200.

*Water supply of the Yukon-Tanana region, 1907–8, by C. C. Covert and C. E. Ellsworth. In Bulletin 379, 1909, pp. 201–228.

*Gold placers of the Ruby Creek district, by A. G. Maddren. In Bulletin 379, 1909, pp. 229–233.

*Placers of the Gold Hill district, by A. G. Maddren. In Bulletin 379, 1909, pp. 234–237.

*Gold placers of the Innoko district, by A. G. Maddren. In Bulletin 379, 1909, pp. 238–266.

The Innoko gold-placer district, with accounts of the central Kuskokwim Valley and the Ruby Creek and Gold Hill placers, by A. G. Maddren. Bulletin 410, 1910, 87 pp.

Sketch of the geology of the northeastern part of the Fairbanks quadrangle, by L. M. Prindle. In Bulletin 442, 1910, pp. 203–209.

The auriferous quartz veins of the Fairbanks district, by L. M. Prindle. In Bulletin 442, 1910, pp. 210–229.

Placer mining in the Yukon-Tanana region, by C. E. Ellsworth. In Bulletin 442, 1910, pp. 230–245.

Occurrence of wolframite and cassiterite in the gold placers of Deadwood Creek, Birch Creek district, by B. L. Johnson. In Bulletin 442, 1910, pp. 246–250.

Water supply of the Yukon-Tanana region, by C. E. Ellsworth. In Bulletin 442, 1910, pp. 251–283.

The Koyukuk-Chandalar gold region, by A. G. Maddren. In Bulletin 442, 1910, pp. 284–315.

*Gold placers between Woodchopper and Fourth of July creeks. In Bulletin 520, 1911, pp. 201–210.

Topographic maps.

Fortymile quadrangle; scale, 1:250,000; by E. C. Barnard. For sale at 10 cents a copy or $3 for fifty.

Fairbanks quadrangle; scale, 1:250,000; by T. G. Gerdine, D. C. Witherspoon, and R. B. Oliver. For sale at 50 cents a copy or $15 for fifty.

Rampart quadrangle; scale, 1:250,000; by D. C. Witherspoon and R. B. Oliver. For sale at 20 cents a copy or $6 for fifty.

* Survey stock exhausted; may be purchased from the Superintendent of Documents, Washington, D. C., or may be seen at most public libraries.

Fairbanks special map; scale, 1:62,500; by T. G. Gerdine and R. H. Sargent. For sale at 20 cents a copy or $6 for fifty.

*Yukon-Tanana region, reconnaissance map; scale, 1:625,000; by T. G. Gerdine. Contained in Bulletin 251, 1905. Not published separately.

*Fairbanks and Birch Creek districts, reconnaissance maps; scale, 1:250,000; by T. G. Gerdine. Contained in Bulletin 251, 1905. Not issued separately.

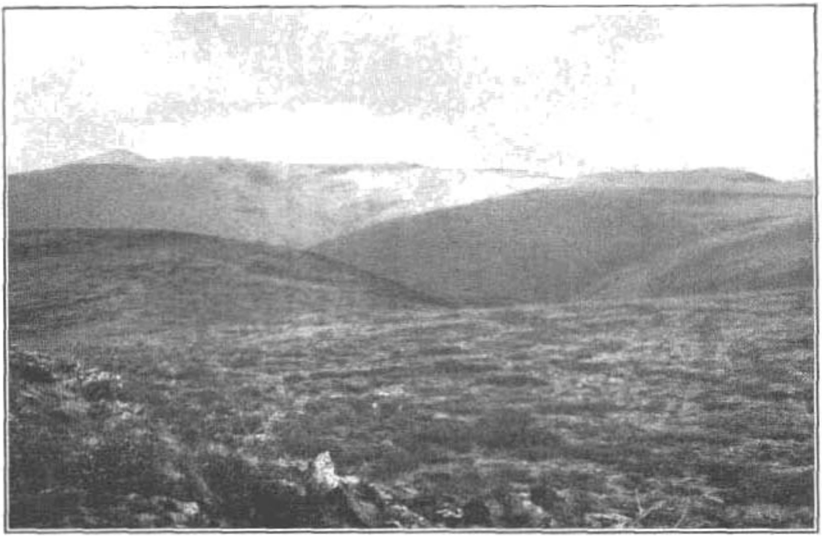
Circle quadrangle, Yukon-Tanana region; scale, 1:250,000; by D. C. Witherspoon. Contained in Bulletin 295. For sale at 50 cents a copy.

GEOGRAPHY OF THE YUKON-TANANA REGION.

The portion of the central plateau province of Alaska included between Yukon and Tanana rivers is similar in its major features to the related portions north and south of those streams. It is an upland characterized by a general level above which rise many ridges and isolated domes and below which a minutely ramifying drainage system has deeply intrenched itself. In the eastern portion the general surface attains its greatest elevation, rising to about 4,000 feet above sea level. The northern edge of the upland overlooking the Yukon Valley rises to about 3,000 feet and the southern edge overlooking the Tanana Valley to about 2,000 feet. The elevation of the Yukon Valley is about 800 feet in the extreme eastern portion of the region and about 400 feet at the mouth of the Tanana, in the extreme western portion. The highest domes that rise above the general level attain altitudes of about 5,000 feet and several mountain groups and ridges stand from 5,000 feet to over 6,500 feet above sea level. Among these are the Glacier Mountains in the vicinity of Eagle, the mountainous country of the Charley River and Goodpaster regions, the White Mountains in the Beaver Creek region, and the group of hills of steep relief near Rampart. Most of these areas of high relief are due to the fact that the rocks composing them are mainly igneous and are more resistant to weathering than the rocks of adjacent regions.

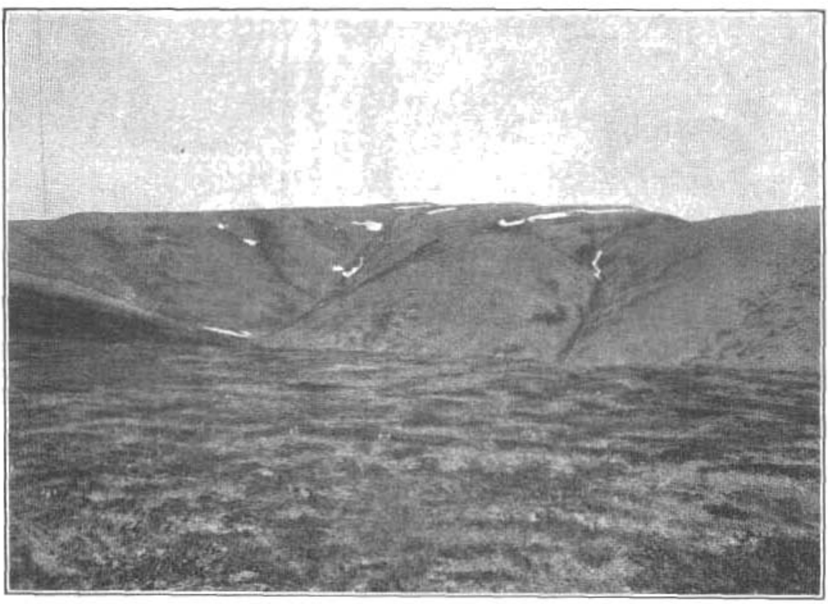
The drainage of the region belongs entirely to Yukon and Tanana rivers. The valley of the Yukon in this region is made up of an upper narrow canyon-like portion, a wide flat lowland known as the Yukon Flats, and a lower canyon-like portion extending from the lower end of the flats to the mouth of the Tanana. Tanana River is close against the southern edge of the upland, and the Tanana Flats, similar to the Yukon Flats, separate the Yukon-Tanana upland from the similar upland flanking the northern base of the Alaska Range. The tributaries of the two rivers in the Yukon-Tanana region are not separated by any well-defined divide but are most intimately intertwined. In general, the interstream or upland areas predominate over the stream or lowland areas. The valleys are comparatively narrow and canyon-like, and the lowlands are not extensively developed except near Yukon and Tanana rivers and especially near their confluence. In general, then, the Yukon-Tanana region is a compact body of upland deeply dissected by comparatively narrow stream systems.

* Survey stock exhausted; may be purchased from the Superintendent of Documents, Washington, D. C., or may be seen at most public libraries.



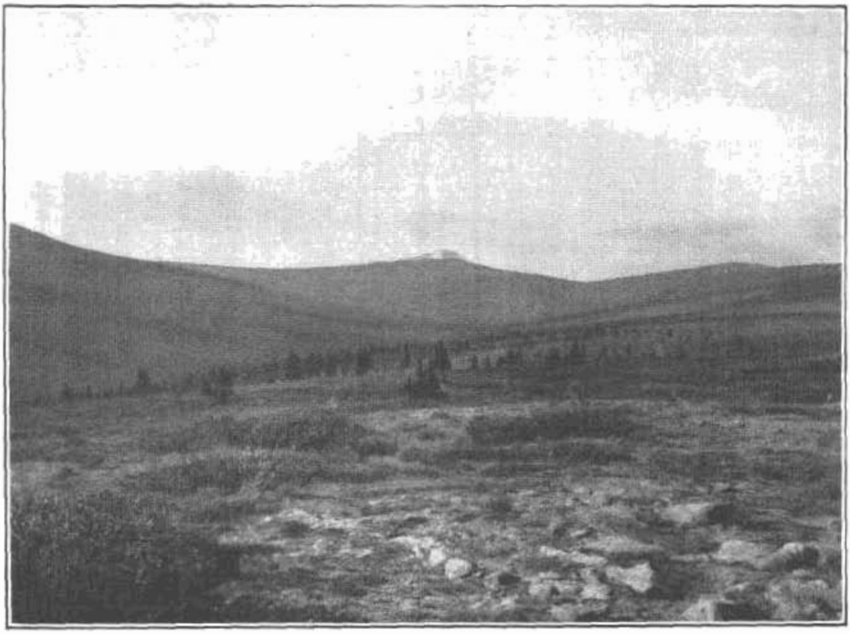
A. SCHIST RIDGE BETWEEN NORTH FORK OF BIRCH CREEK AND CROOKED CREEK.

Altitude about 3,400 feet.

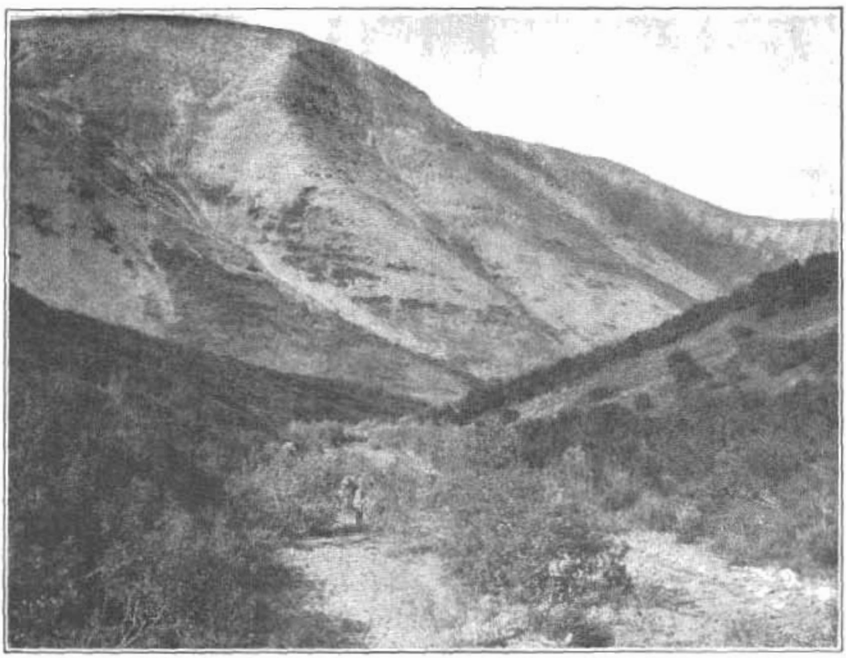


B. FLAT-TOPPED RIDGE OF QUARTZITIC SCHIST BETWEEN DAVIS AND POKER CREEKS.

Altitude about 3,800 feet.



A. OPEN VALLEY, TRIBUTARY OF CHARLEY RIVER.



B. NARROW VALLEY, HEAD OF CHENA RIVER.

GEOGRAPHY OF THE CIRCLE QUADRANGLE.

LOCATION AND EXTENT.

The Circle quadrangle lies between meridians 142° and 146° west longitude and parallels 64° and 66° north latitude. It is about 140 miles long from north to south, about 120 miles wide, and has an area of about 17,000 square miles. The northeast corner of the quadrangle, including about 3,000 square miles lying north of Yukon River, is unmapped, has not been traversed by Survey parties, and is not included in this discussion.

RELIEF.

The surface of the Circle quadrangle is the most diversified in the Yukon-Tanana region. It is separable into two main topographic subdivisions—the Tanana lowland and the upland, which is bounded on the north by the Yukon Flats.

The upper end of the Tanana lowland, which comprises a comparatively small area in the southwest corner of the Circle quadrangle, has an elevation above sea level at the mouth of Delta River of 940 feet. Delta and Tanana rivers, whose flats constitute most of the lowland, are distributed in many interlacing channels in which the water flows swiftly between gravel bars. The valleys of the tributaries of the Tanana from the north widen sharply as they approach the main stream and finally merge with the Tanana lowland. Long ridges from the upland terminate abruptly at Tanana River.

The Circle quadrangle contains a greater proportion of upland than any other quadrangle in the Yukon-Tanana region. It also contains the highest points in the region, among these being two peaks in a high ridge near the head of Charley River (6,284 and 6,340 feet above sea level) and a peak at the head of Healy River (6,515 feet, the highest elevation in the region).

The upland has an extreme elevation of about 4,000 feet in the central part of the quadrangle near the headwaters of Fortymile, Charley, and Goodpaster rivers. This general level is strikingly maintained in the long flat-topped spurs that extend both north and south from the divide separating Goodpaster and Fortymile waters, and it is traceable to the vicinity of both Yukon and Tanana rivers, where its elevation is about 3,000 feet above sea level. The uniformity of level is shown in Plate III, *A*. For comparison the same feature is shown in Plate III, *B*, from a point more than 100 miles farther east.

In the vicinity of the Yukon in the northeastern part of the quadrangle a belt 10 to 25 miles wide, lying 2,500 to 2,000 feet above sea level, contrasts with the higher, rougher country to the south and is characterized by more uniform and more even-topped ridges that continue to the Yukon.

The ridges rising above the general level are most conspicuous. The highest, so far as observed, are composed of igneous rocks and owe their pronounced relief to their resistance to weathering. As igneous rocks form one-third or more of the total area of the quadrangle, ridges due to their influence predominate.

The ridges have no general trend. They are bulky forms, many of which are surmounted by narrow, saw-tooth ridge crests culminating in precipitous peaks. The steep ridge slopes are strewn with masses of granitic blocks, which in many places assume a more or less lobelike arrangement. On some ridges the granite has weathered into grotesque forms, which at a distance resemble monuments and buildings. Isolated domes are common, rising from a few hundred to 1,000 feet or more above the general level. Like the ridges, they owe their existence to the resistance to weathering of the rocks composing them.

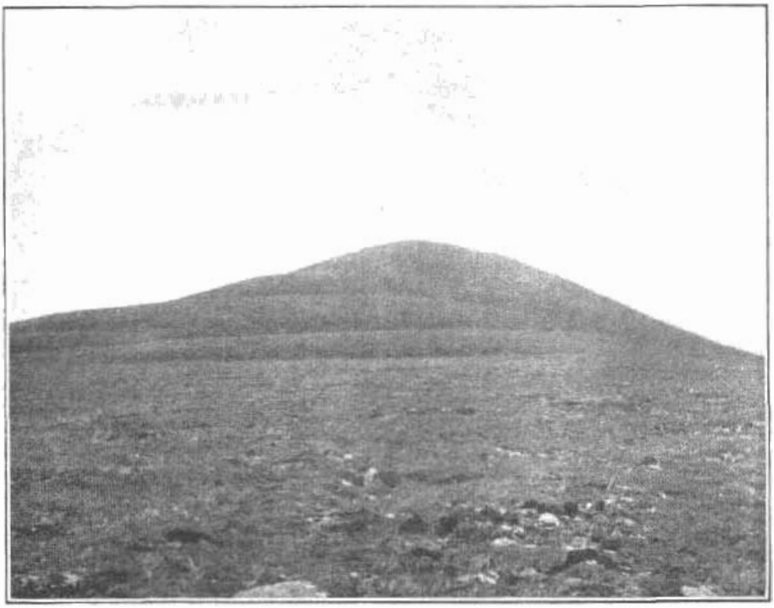
DRAINAGE.

The valleys are very uniform. Similar streams head at about the same level, are intrenched to about the same depth, have approximately the same grade, and carry about the same amount of water. These facts have an important bearing on hydraulic development, limiting the use of the streams for power. Most of the valleys are narrow, and the total amount of open valley land is small and is confined to the immediate vicinity of Yukon and Tanana rivers.

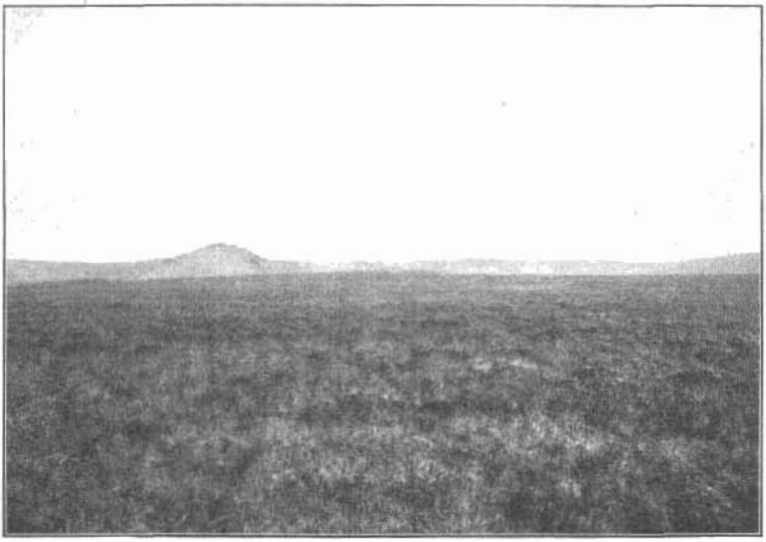
The most important tributaries of the Yukon are Birch Creek, Charley River, and Fortymile River. These streams are all formed of many large and widely divergent tributaries which drain widely separated areas, and the main trunk streams which they finally form by their union are comparatively short. Their upper valleys are for the most part open and are characterized by flats of considerable extent, which are especially well developed in the upper valley of Charley River. The valleys of the main trunks before the streams leave the upland and enter the valley of the Yukon are narrow and canyon-like. (See Pl. VI, *A*.)

The most important tributaries of the Tanana are Chena, Salcha, and Goodpaster rivers. These streams flow in more or less parallel courses and differ from the tributaries of the Yukon in consisting each of a long main stream with subordinate branches entering from either side. Their valleys are comparatively narrow except in the immediate vicinity of Tanana River, and most of them become narrower headward, merging into the deeply intrenched, canyon-like valleys of the headwaters. The head of Salcha River is an exception; owing to the slow process of cutting across the granite area at West Point its upper valley has become open.

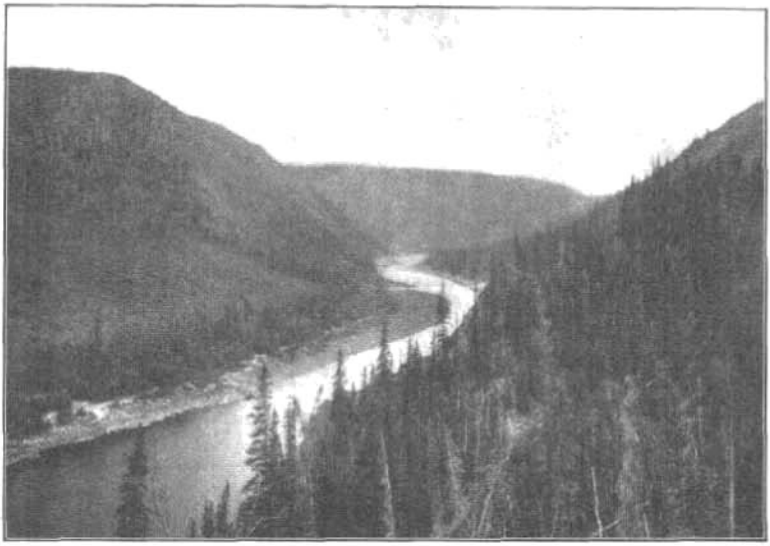
In following the very irregular and ill-defined drainage parting between Yukon and Tanana rivers the contrast between the open valleys of the head of the Yukon drainage and the canyon-like



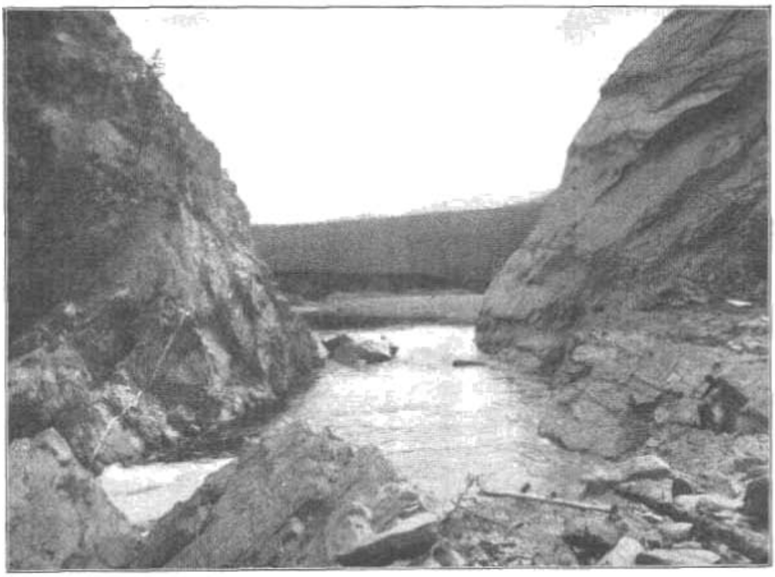
A. BENCH IN SCHIST 4,000 FEET ABOVE SEA LEVEL.



B. BENCH 500 FEET ABOVE SEVENTYMILE CREEK.



A. CANYON OF FORTYMILE CREEK 500 FEET BELOW THE LEVEL OF THE OLD VALLEY.



B. ARTIFICIAL CUT-OFF IN SCHIST AT THE "KINK," NORTH FORK OF FORTYMILE RIVER beginnings of the Tanana drainage is found to be very general and very striking. (See Pl. IV.)

Very many of the smaller valleys are unsymmetrical in cross section, having on one side a comparatively steep slope with the stream flowing close to its base and on the other side a long gentle slope rising gradually for 1,000 feet or more and merging with a gentle ridge slope. This feature is in most places independent of the geologic structure and is most common on the west side of the valley, where the sun has more influence than on the opposite side. The western slope is the first to get the influence of the morning sun and has consequently undergone more rapid weathering.

Benches are conspicuous in some of the valleys, notably in that of Seventymile River, along which a very prominent bench about a mile wide lies about 500 feet above the stream level (Pl. V, *B*). Other benches occur at lower levels, and the stream is now flowing in a bed limited by a sharp rock-cut bench whose height averages about 15 feet above the stream. Above the level of these benches, all of which are definitely related to the present stream system, are other benchlike flats, which lie on the slopes of the ridges to a height of about 4,000 feet or more above sea level. (See Pl. V, *A*.)

Incised meanders are common on some of the streams. A notable occurrence is on North Fork of Fortymile River near the eastern edge of the quadrangle, at a place called the Kink. North Fork meanders in a narrow rock-cut canyon about 600 feet below the benches which formed the old valley of the Fortymile. The meander forming the Kink is 2¾ miles long, but the distance across the neck, which is formed by a ridge of schist about 100 feet high, is only 100 feet. The narrowness of the barrier made it possible to blast a cut through it and to draw off the stream, draining the river bed for the whole 2¾ miles and facilitating prospecting. The entire stream now flows through the cut over a fall and rapids about 17 feet high (Pl. VI, *B*).

Some of the conditions affecting the development of the streams in the Circle quadrangle are unlike those prevailing in more temperate regions. Normally the ice of lakes and the larger rivers may freeze in winter to a thickness of 5 or 6 feet, but in spite of the extreme cold much water remains in circulation in the streams, and the thickness of the ice is often increased at the top by the breaking out of the water at some point higher upstream and the consequent flooding of the ice already formed. Repetitions of this process may result in a considerable thickening of the ice. Areas of ice, acres in extent and 10 feet or more in thickness, formed in this manner linger in the valleys of some of the streams throughout most of the summer. (Pl. VII, *A*.) The ice exercises a determining influence in the distribution of the water as spring begins. Erosion starts first along the margins of the mass and the water beneath the ice becomes rather evenly distributed over a more or less flat body of gravel, which in some places is packed nearly as smooth as a pavement. (See Pl. VII, *B*.) Lateral erosion is accelerated and flats several hundred feet wide and a mile or more in length may be formed. This process has been observed to be effective in many valleys and has undoubtedly been active in the production of the flats so characteristic of many streams.

Another influence that has modified the normal valley development has been the local glaciation described in more detail on pages 34–35. Cirques and U-shaped valleys have been formed and morainal material has been deposited and has to some extent modified the drainage.

CLIMATE.

TEMPERATURE.

The climate of the Yukon-Tanana region, though influenced in part by distance from the coast and altitude above sea level, is determined mainly by the latitude. Long, cold winters, short summers, and permanently frozen ground are among the main characteristics. Temperatures of 80° F. below zero and 90° or more above zero have been reported. The alluvial deposits are for the most part permanently frozen to great depths, some having been reported frozen for more than 300 feet below the surface. Ice freezes on deep, quiet water to a thickness of 5 to 6 feet.

The Yukon at Circle closes to navigation about the middle of October and opens again about the middle of May. At the level of the Yukon killing frosts seldom occur during June and July, but during the later half of May and early June and the later half of August they may be frequent.

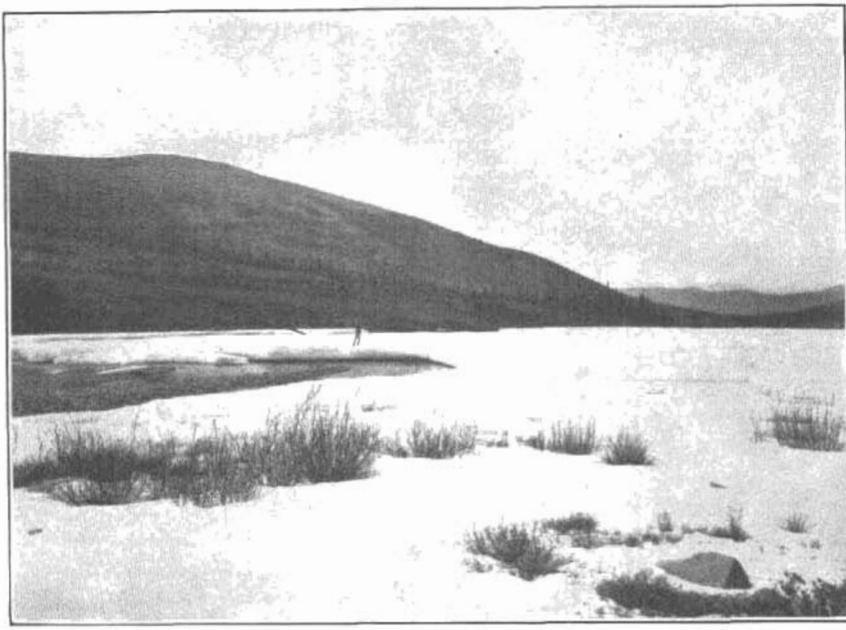
PRECIPITATION.

The summers vary greatly in character. In some of them long periods of fine weather occur in June and July, and but little rain falls throughout the season. In others thunderstorms and rainy periods are frequent, and the total rainfall is comparatively heavy. In general, however, the area is semiarid and the total precipitation during the summer is less than 1 foot.

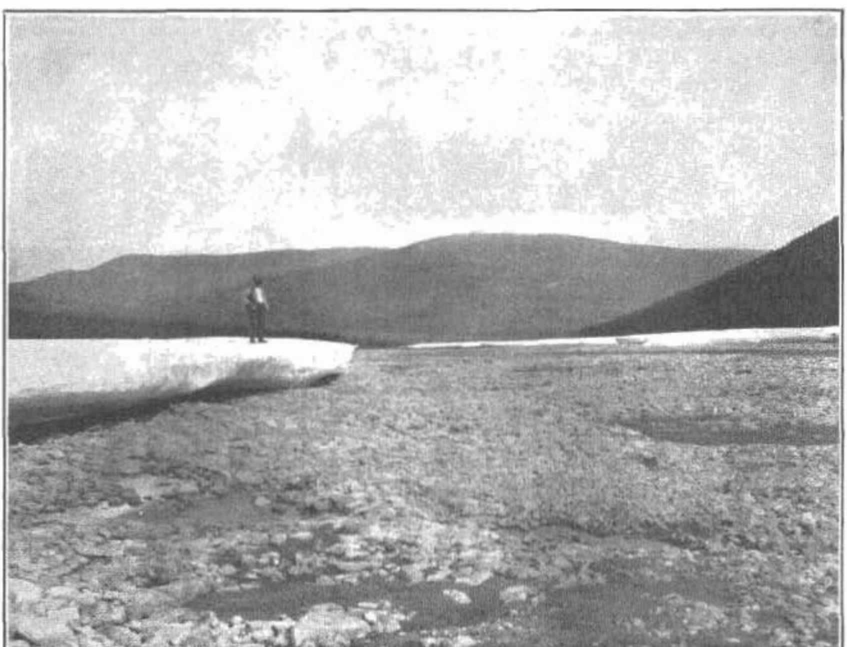
The following data on precipitation are abstracted from the report of Ellsworth and Parker.[1]

Precipitation records for 1910 show that the rainfall at Fairbanks was about 15 per cent below the average from 1906 to 1910; at Fort Gibbon it was about 6 per cent below the average from 1904 to 1910; and at Fort Egbert it was about 2 per cent above the average from 1903 to 1910. At Rampart a precipitation of only 5.32 inches was recorded, which is lower than that of any other year since the beginning of records at that station, in 1905, and only about one-half the average for the last six years.

[1] Ellsworth, C. E., and Parker, G. L., Water supply of the Yukon-Tanana region, 1910: Bull. U. S. Geol. Survey, No. 480, 1911, pp. 176–178.



A. ICE-FILLED STREAM FLAT, GOODPASTURE RIVER.



B. GRAVEL FLAT BENEATH ICE, TRIBUTARY OF CHARLEY RIVER.

A comparison of the records of 1910 with those of 1909 shows a small decrease at Fairbanks and Fort Gibbon and a considerable increase at Fort Egbert. At Rampart the decrease was nearly 50 per cent from the precipitation of 1909.

Although there is a wide difference from month to month and from year to year in the rainfall at the several stations in the Yukon-Tanana region, the mean yearly precipitation at each station for the period covered by the records is uniformly close to the average of the means of all the stations. In other words, the records show no uniform difference in precipitation throughout this area.

The following table gives the monthly precipitation at all points in the Yukon-Tanana region where records have been kept subsequent to 1903. Such scattered records as were kept previous to 1903 have been compiled by Abbe.[1]

Monthly precipitation, in inches, at stations in Yukon-Tanana region, 1903–1910.

[Rainfall or melted snow is given in the first line; snowfall in the second line.]

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Central	1906	0.56	0.06	0.05	0.47	0.86	4.91	4.82	1.85	0.52	0.70	0.80	0.35	15.95
		6.1	1.0	1.4	4.7	2.0	......	......	......	......	7.0	8.0	4.0	34.2
Do	1907	1.04	.42	2.57	.93	.57	2.21	1.40	......	......	......	......	......	......
		10.0	4.0	4.0	8.0	1.5	......	......	......	......	......	......	......	......
Circle	1906	......	......	......	......	......	......	......	......	......	......	......	.75	......
		......	......	......	......	......	......	......	......	......	......	......	9.5	......
Do	1907	1.02	.57	.28	.15	.29	......	1.36	2.79	1.73	......	......	.63	......
		8.5	7.8	3.25	......	......	......	......	......	......	......	......	8.2	......
Do	1908	1.23	.25	.76	1.45	.29	.20	.87	1.08	2.21	.40	.75	1.11	10.60
		9.2	2.5	6.8	8.0	......	......		......	......	3.0	8.5	11.2	51.2
Do	1909	.44	.47	.17	.75	.60	2.24	3.25	1.02	......	......	......	......	......
		4.5	5.2	1.0	3.0	......	......	......	......	......	......	......	......	......
Charity Creek	1908	......	......	......	.11	.27	1.33	2.80	2.33	2.28	.20	......	......	......
		......	......	......	......	......	......	......	......	......	3.0	......	......	......
Cleary	1907	......	......	......	......	......	.84	2.55	2.88	3.82	......	......	......	......
Eagle Creek	1908	......	......	......	......	......	......	......	2.99	......	......	......	......	......
Fairbanks	1904	......	......	......	......	......	......	......	......	......	......	1.10	2.00	......
Do	1905	.92	.50	.05	.20	......	......	......	2.63	.86	......	1.20	.60	......
		9.1	5.0	.5	2.0	......	......	......	......	......	......	12.0	5.1	......
Do	1906	1.75	.37	.33	.10	.36	1.05	2.82	1.50	.25	.30	.65	1.15	10.63
		17.5	3.7	3.3	1.0	......	......	......	......	......	.6	6.5	11.5	44.1
Do	1907	3.30	.86	2.42	.03	.35	1.47	1.51	1.81	3.58	2.44	.35	.59	18.71
		33.0	8.6	24.2	.3	......	......	......	......	......	24.4	3.5	5.9	99.9
Do	1908	.42	.21	1.10	.11	.52	.96	.73	.71	1.57	.47	.51	.65	7.96
		4.2	2.1	11.0	.8	......	......	......	......	......	......	......	8.1	26.2
Do	1909	.90	.08	.05	.66	.38	1.64	1.90	1.73	.39	.80	.52	.80	9.85
Do	1910	.70	.14	.02	.36	.39	2.16	.46	1.69	1.91	.66	.50	.76	9.75
Faith Creek	1907	......	......	......	......	......	......	1.87	3.00	2.97	......	......	......	......
Fort Egbert	1903	.58	.81	.54	.12	1.38	.57	2.40	.97	2.97	......	......	......	......
Do	1905	......	......	......	......	.33	1.95	1.52	2.72	3.38	2.96	.93	.68	......
Do	1906	......	.14	2.19	.00	.54	.51	2.54	1.28	.01	1.71	.51	.07	......
		......	1.0	11.0	......	......	......	......	......	......	.46	8.5	1.0	......
Do	1907	1.45	.21	0	.25	.40	1.89	1.48	1.98	1.45	1.12	.40	.31	10.94
		2.0	2.0	0	.15	.55	......	......	......	......	13.0	4.0	......	......
Do	1908	.12	.25	.75	.10	1.02	2.16	2.47	1.02	1.48	.18	.82	1.09	11.46
		3.0	2.5	7.5	1.0	......	......	......	......	......	6.0	7.0	11.0	38.0
Do	1909	.16	.07	.11	.34	.28	2.35	1.77	.95	.88	.81	.30	......	......
		2.0	1.0	1.0	2.0	......	......	......	......	6.1	11.7	3.0	......	......
Do	1910	.83	.01	.53	.25	.28	1.05	2.28	2.63	2.98	.69	.25	.30	12.08
Fort Gibbon	1903	.37	.73	1.14	.23	.16	.38	1.76	......	.48	.22	.33	Tr.	......
Do	1904	.08	.55	.35	.09	.22	.33	1.95	3.80	.35	.39	.07	.70	8.88
Do	1905	.37	.47	Tr.	.32	.84	1.50	4.90	3.02	.59	.50	1.10	.18	13.79
Do	1906	.65	.20	.30	Tr.	1.00	......	......	......	......	[a].50	.99	.27	......
		6.0	2.0	3.0	......	......	......	......	......	......	[a]5.0	9.9	2.7	......
Do	1907	1.26	......	.53	0	.80	......	2.58	2.31	2.32	1.22	.03	.31	......
		12.6	......	5.0	0	......	......	......	......	4.0	12.0	1.5	......	......
Do	1908	.23	.26	.90	0	1.16	......	.96	1.13	1.60	.45	.08	.60	......
		4.0	6.0	17.0	0	......	......	......	......	2.25	6.0	......	6.5	......
Do	1909	.05	.10	.37	.39	1.51	.77	1.49	2.27	.90	.49	.46	.80	9.60
		.5	.5	......	2.2	......	......	......	......	......	4.8	4.6	8.0	20.6
Do	1910	1.23	.08	.60	.28	.69	.57	1.79	2.26	.74	.38	......	.59	......

[1] Abbe, Cleveland, jr., Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 189-200.

[a] Oct. 7 to 31.

Monthly precipitation, in inches, at stations in Yukon-Tanana region, 1903–1910—Con.

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Hot Springs...	1909	......	......	......	......	......	......	1.76	3.19	.25	.44	1.10	2.26	......
											4.4	11.0	22.6	
Do........	1910	1.64	.03	.60	.20	.34	.76	a2.16	......	1.32	......	......	......	......
		16.4	.3	6.0	2.0	3.4								
Kechumstuk..	1904	......	......	......	......	1.80	.83	2.23	.94	.64	.30	.03	.23	......
Do........	1905	.90	.10	.05	.40	.20	1.58	.40	1.48	2.16	1.18	.36	.20	9.01
Do........	1906	.36	.05	.06	.27	1.69	1.61	3.25	2.51	.51	.31	.29	.20	11.11
		4.0	.5	1.0	5.0						4.3	.5	3.0	18.3
Do........	1907	.12	.20	.27	Tr.	1.30	2.03	1.60	2.14	.49	.72	.40	......	......
		2.0	3.0	4.0		12.0				2.0	9.0	4.0		
Do........	1908	0	0	.41	.40	1.78	1.77	2.30	2.22	1.35	......	.90	.20	......
		0	0	5.0	4.0							9.0	2.0	
Do........	1909	0	.30	.10	.20	0	3.66	3.39	......	......	......	......	......	......
		0	.5	1.0		0								
Miller House..	1909	......	......	......	......	......	......	2.98	1.26	.60	.93	.30	.30	......
										4.0	8.0	3.0	3.0	
Do........	1910	......	......	......	.20	......	1.94	2.37	.30	1.03	......	......	......	......
North Fork...	1905	......	......	......	......	......	......	......	1.91	1.86	......	.50	.20	......
Do........	1906	.70	.50	.10	.80	1.98	2.74	2.69	1.01	.72	.42	.55	.38	12.59
		7.0	5.0	1.0	8.0						3.2	4.5	4.5	33.2
Do........	1907	.69	.28	.27	Tr.	1.34	1.92	1.57	3.19	2.0	1.40	.20	......	......
		15.5	3.0	3.0		4.0				5.0	12.0	2.0		
Do........	1908	.50	......	......	......	......	......	......	......	......	......	......	......	......
		5.0	Tr.											
Poker Creek...	1907	......	......	......	......	......	......	......	1.40	3.70	1.70	.25	1.09	......
											24.0	3.3	6.8	
Do........	1908	......	1.32	......	.42	.58	1.80	2.02	.99	2.45	.75	.35	.61	......
			10.5		5.0					4.5	6.9	4.4	12.6	
Do........	1909	.68	.09	.03	.42	1.11	1.22	2.01	2.01	......	......	......	......	......
		8.8	2.0	.5	8.0	2.5								
Rampart......	1905	......	......	......	......	......	1.33	1.99	2.19	1.70	1.20	1.43	.33	......
Do........	1906	.63	.08	.17	.04	.40	.15	1.86	2.40	.59	.61	.95	.33	8.21
		7.2	2.0	1.8	.5							10.2	3.5	25.2
Do........	1907	1.17	.44	1.17	.02	.44	1.64	2.29	3.38	2.52	.65	.55	1.26	15.53
		12.0	4.5	12.8	2.5							6.3		
Do........	1908	1.08	.52	.81	.58	.82	1.38	1.13	.46	1.56	.39	.73	1.14	10.60
		11.5	6.9	8.1							5.1	3.6	16.8	52.0
Do........	1909	.09	.10	.37	.51	1.04	.85	2.01	1.41	.36	1.14	.35	1.99	10.22
		1.4	1.2	6.2	5.6					1.5	14.4	3.6	20.2	54.1
Do........	1910	.84	.08	.36	.07	.20	.98	.71	.62	.43	.45	.26	.32	5.32
		11.1	.8	4.7	1.0						6.0	3.5	5.0	32.1
Summit road house.......	1907	......	......	......	......	......	......	2.71	3.27	b3.33	......	......	......	......
Tanana Crossing........	1904	......	......	......	......	.76	......	.78	.89	1.06	.15	.10	.90	......
Do........	1905	.24	.08	.18	.00	.14	......	.37	2.95	......	1.40	.60	......	......
Do........	1906	.30	.00	Tr.	......	......	......	......	......	......	......	......	......	......

a July 16 to 31. b Sept. 1 to 22.

Precipitation records for June to September, inclusive, at several points in the Yukon-Tanana region may be summarized as follows:

Summary of summer precipitation in Yukon-Tanana region.

Station.	Maximum.		Minimum.		Mean (inches).	Duration of records.	Precipitation for 1910 (inches).
	Inches.	Year.	Inches.	Year.			
Circle..............................	7.64	1907	4.36	1908	6.38	1907–1909	....
Fairbanks..........................	8.37	1907	3.97	1908	5.97	1906–1910	6.22
Fort Egbert........................	9.57	1905	5.95	1909	7.09	1903, 1905–1910	8.94
Fort Gibbon........................	10.01	1905	4.98	1908	6.59	1903–1905, 1907–1910	5.36
Kechumstuk........................	7.88	1906	4.64	1904	6.41	1904–1908	....
Rampart............................	9.83	1907	2.74	1910	5.66	1905–1910	2.74
Mean..............................	......	......	......	......	6.35	....	5.82

Uniformity of precipitation throughout the Yukon-Tanana region is also noticeable, though less apparent, in the summer months. In the above table Fort Egbert has the highest average precipitation from June to September and is 12 per cent above the mean for all the stations; Rampart has the lowest average precipitation and is 11 per cent below the mean for all the stations.

The table also shows that a total precipitation as high as 10.01 inches and as low as 2.74 inches has occurred during the mining season, and it leads to the conclusion that the general scarcity of water for mining uses during 1910 throughout the Yukon-Tanana region (with the exception of the Rampart district) was not due to an unusually small amount of rainfall in the aggregate but rather to its distribution with respect to time and area. A study of the run-off from adjoining drainage basins during the four years from 1907 to 1910 indicates that a wide difference in stream flow may be expected even though geologic and topographic conditions are apparently very similar. In order to arrive at any definite conclusions regarding the areal distribution of the rainfall by a comparison of simultaneous records, it would be necessary to have a greater number of rain gages more systematically located. Such comparisons as can be made with the existing data, however, confirm the general opinion that the precipitation is distributed rather unevenly. This condition is often noticeable in the summer, when local showers visit one portion of the drainage basin and do not reach another portion.

VEGETATION.

The distribution of vegetation is shown on the map (fig. 2). Timber line is about 2,500 feet above sea level. There is a minimum of vegetation on the high ridges and their rock-strewn slopes, and a maximum in some of the larger valleys of tributaries to Tanana River. The upper zone of vegetation is characterized by more or less grass, lichens, moss, low bushes, and particularly by dwarf birch and alder. On many ridges of intermediate height the growth of dwarf birch is very dense. Most of the lower ridges and spurs near the main drainage lines are covered with a dense growth of small spruce. In the larger valleys timber is more or less abundant, especially on the sunward-facing slopes of the valleys near the main drainage lines and over portions of the valley floors. Considerable timber is more than a foot in diameter; spruce predominates, but poplar and birch are abundant in places, especially in the vicinity of the Tanana, where tamarack also is common. The most striking feature of the distribution is the contrast between the upper valleys of tributaries of the Yukon and those of the Tanana. Most of those of the Yukon are comparatively bare or are dotted only with scattering groups of spruce, and those of the Tanana are thickly timbered from their heads. Willow and alder grow profusely along the smaller stream beds throughout the area. Grass for horse feed is abundant in many of the valleys, particularly near Yukon and Tanana rivers.

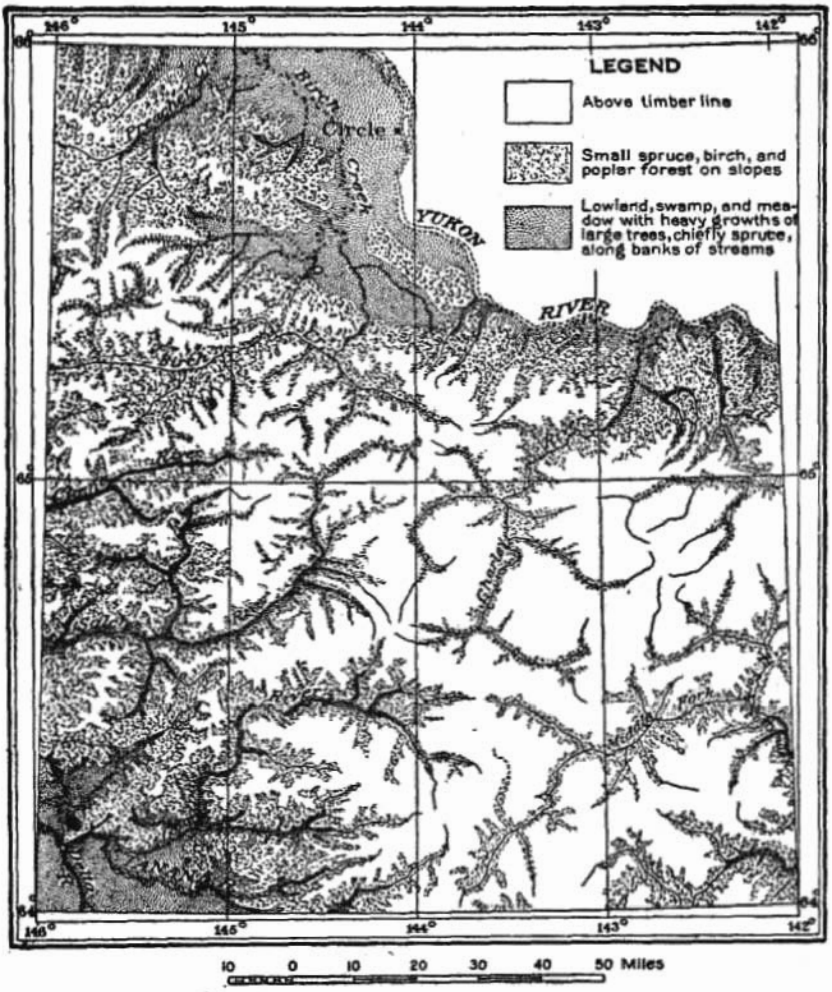


FIGURE 2.—Map showing distribution of timber in the Circle quadrangle.

Blueberries are abundant throughout a large part of the area. Currants and red raspberries grow in the vicinity of both the Yukon and the Tanana. All the hardy vegetables are grown in abundance in fine gardens in the Circle district.

POPULATION.

Most of the residents live in the northern part of the quadrangle, in the Circle district and on tributaries of the Yukon above Circle. A few prospectors are at work in the eastern, western, and southwestern portions of the area, and a few Indians spend part of the year at Kechumstuk and the mouth of the Goodpaster. The total permanent population does not exceed a few hundred.

In the Birch Creek district most of the population dwells on Mammoth, Mastodon, Miller, Eagle, and Deadwood creeks, 40 to 60 miles from Circle.

TRANSPORTATION.

The town of Circle, near the upper limit of the Yukon Flats, is the general supply point for the district and is connected with the creeks by a Government wagon road. Most of the heavy freighting is done in the winter at a cost of 3 to 6 cents a pound, but the construction of the wagon road has made it possible to obtain many kinds of supplies during the summer at only a slight advance over the winter rates, instead of, as formerly, only by pack trains at a cost of 20 to 25 cents a pound. Good road houses are located at intervals of about 12 miles along the wagon road from Circle to the creeks and others have been built upon the creeks. The trail from Circle to Fairbanks is traveled more or less every summer. The installation of a Government wireless station at Circle, connecting with other stations at Eagle, Fairbanks, and Rampart, has been of great advantage to the district.

The route for transportation from Pacific coast points to Circle is by way of either Dawson or St. Michael. The first-class passenger rate from Seattle to Circle by Dawson and the upper river in 1911 was $85. Freight rates have a great range, depending on the freight classification; on general merchandise the rate is about $60 a ton.

GEOLOGY OF THE YUKON-TANANA REGION.

The Yukon-Tanana region comprises many formations and has been affected by extensive metamorphism, great igneous activity, and close folding with two dominant trends—southeast-northwest and northeast-southwest.

One of the most extensive groups of rocks is made up of crystalline schists which are mostly of sedimentary origin and are regarded as pre-Ordovician. The presence of Ordovician, Silurian, Devonian, Carboniferous, Cretaceous, and Tertiary rocks has been established.

A few small areas of glacial material show that some glaciation has occurred. The alluvial materials include silt, sand, and gravel deposited either on benches or in the valleys of the present streams.

Igneous rocks are abundant. Basaltic and diabasic material, in part volcanic and in part intrusive, is plentiful, particularly in the Paleozoic sediments. Granitic and related rocks occur in many places and become increasingly abundant toward the east. They are in part metamorphosed to granitic gneisses but are mostly unmetamorphosed, and they are all, so far as observed, in intrusive relation to the rocks with which they are in contact. The period of their maximum intrusion was the Mesozoic. The evidence available points to the igneous rocks as the cause of the widespread mineralization.

The present surface is mainly the product of fluviatile action and subaerial erosion acting on a surface that has changed in elevation with reference to the sea level.

GEOLOGY OF THE CIRCLE QUADRANGLE.

GENERAL FEATURES.

The mapping of the geology of the Circle quadrangle by means of a few rapid traverses has necessarily been incomplete. It has been impossible to cover the entire area, and those areas about which no information was available have been left blank. The formational boundaries indicated have not been traversed in detail and, except at a few points, must be regarded as only approximate. It is believed, however, that practically all the different formations have been observed and that the map indicates somewhat accurately their distribution.

Practically all the formations in the Fairbanks quadrangle occur in the Circle quadrangle. Some of them enter it from the western edge and extend across it into the Fortymile quadrangle. The main geologic feature in which the Circle quadrangle differs from the others is in containing large areas of igneous rocks, which occupy about one-third of the quadrangle and which, by disturbance or by contact metamorphism, have obscured the preexisting contacts between the other formations. They have intensified the metamorphism already present in the schists and have in places rendered schistose some of the Paleozoic sediments.

The following table shows the stratigraphic succession:

Stratigraphy of the Circle quadrangle.

Era.	System.	Series.	Description.
Cenozoic.	Quaternary.	Recent.	Silt, sand, and gravel.
		Pleistocene.	Morainal deposits in small isolated areas. Up to about 400 feet thick.
			Unconformity
	Tertiary.	Eocene.	Conglomerate, sandstone, shale, and lignitic beds. Probably about 3,000 feet thick.
			Unconformity
Mesozoic.	Cretaceous.	Upper Cretaceous (?).	Conglomerate and arkosic sandstone, occurring in disconnected areas. Probably about 1,000 feet thick.
		Lower Cretaceous.	Slate, slaty sandstone, and quartzite.
			Unconformity
Paleozoic.	Carboniferous.		White crystalline limestone. About 200 feet thick.
			Unconformity
	Devonian.	Middle Devonian.	Limestone and greenstone.
	Probably mostly Devonian but in part older.		Undifferentiated greenstones. Diabasic and basaltic flows, tuffs, and breccias, and serpentine. Up to 1,000 feet thick.
	Probably including Ordovician, Silurian, and Devonian.		Undifferentiated quartz-feldspar sandstone, in part schistose; quartzite, green and black shale; slate; purple and green phyllite; chert; chert conglomerate; and limestone. Probably several thousand feet thick.
			Unconformity
	Pre-Ordovician.		Birch Creek schist; quartzitic schist; quartz-mica schist; garnetiferous, staurolitic, hornblendic, and carbonaceous schist; and crystalline limestone. Probably several thousand feet thick.

SEDIMENTARY ROCKS.

PRE-ORDOVICIAN ROCKS.

BIRCH CREEK SCHIST.

Lithologic character.—One of the most widespread formations in the quadrangle is the Birch Creek schist, which includes quartzite schist, quartz-mica schist, garnetiferous, and staurolitic schist, carbonaceous schist, hornblende schist, and crystalline limestone. Its most common type is a rather blocky quartzite schist in beds which have a maximum thickness of several feet and which alternate with thin-bedded micaceous schist that is locally garnetiferous. (See Pl. VIII, *A*.) Mica, both muscovite and biotite, is the most widely distributed metamorphic mineral and by its abundance distinguishes the Birch Creek schist from the Paleozoic formations, in which mica has been developed but rarely, except in close contact with igneous rocks. Garnets are generally found throughout the area where the schists form the bedrock, and near some of the granitic contacts they are especially abundant. In some places, notably about the heads of Coal and Woodchopper creeks, the garnets are accompanied by staurolite, which is abundant in crystals half an inch or less in length. The crystalline limestones interbedded with the schists are also schistose in part, containing considerable mica and in some places much garnet. The distribution of metamorphism is not uniform. In some localities the rocks are comparatively massive quartzites, with but a small amount of mica and but slight schistosity, and there are all gradations between such rocks and quartz-mica schists that show little evidence of their origin. At many localities in the vicinity of granitic intrusives the schists are feldspathic and, close to the contact, are essentially augen gneisses.

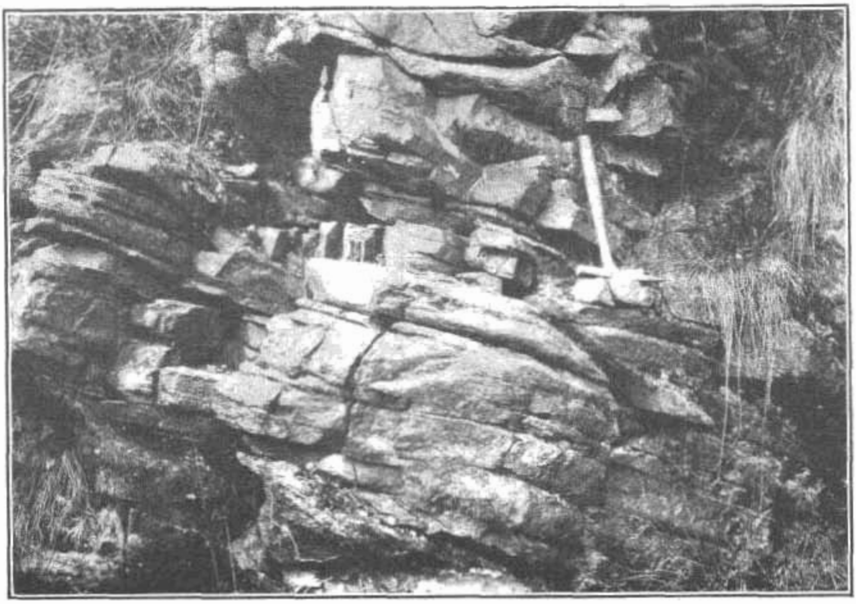
The formation apparently becomes increasingly gneissoid with depth, and the observed facts indicate that at the base it is closely welded to ancient granitic intrusives that have been metamorphosed to gneisses by the same process that metamorphosed the quartzites and interbedded slates to schists. The gneisses are in part more or less even and medium grained and in part coarse augen gneisses with feldspars 2 inches or more in diameter. (See Pl. VIII, *B*.) Most of them occur in bands from a few inches to several hundred feet in thickness, lying parallel to the structure of the schists.

The contact-metamorphic action on the schists has apparently increased the schistosity, developed garnet, staurolite, feldspar, additional mica, especially biotite, and in some places andalusite. The prevailing contact metamorphism in the Paleozoic rocks, on the other hand, consisted in the production of hornfels with more or less andalusite or cordierite.

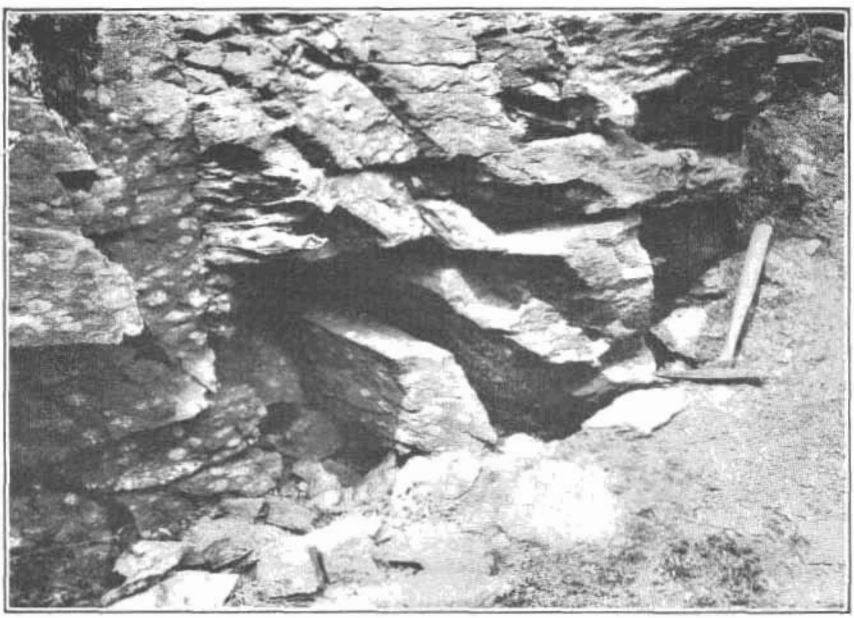
The original succession of the schists is obscured by the complex structure resulting from several periods of folding. The succession from bottom to top is apparently fine-grained quartzitic and quartz-mica schists; garnetiferous quartz-mica and hornblende schist with thin interbedded quartzitic beds; quartz-mica schist, very micaceous; and carbonaceous schists.

Limestone occurs sparingly at different portions of the section and apparently becomes more abundant toward the top. It appears not to be persistent, but to occur in more or less lenticular form. The fact that it is particularly abundant in the Fortymile quadrangle caused Spurr[1] to name it the Fortymile series. In the other quadrangles, however, it seems to be but a subordinate nonpersistent phase of the formation.

[1] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 145-155.



A. BIRCH CREEK SCHIST.



B. AUGEN GNEISS INTRUSIVE INTO BIRCH CREEK SCHIST.

The upper limit of the formation is not everywhere distinctly separated from the succeeding unconformable Paleozoic rocks. In most places, however, the coarser detrital material of the lowest Paleozoic and its prevailingly lesser degree of metamorphism serve to differentiate it. In different areas, too, different members of the Paleozoic rest upon the schist, and in some localities there is a distinct, lithologic change from the schists to the overlying rocks.

Structure.—The schists have a very complex structure. They have been closely folded, and most of the folds have been closely appressed and overfolded to a nearly horizontal position. The planes of schistosity thus correspond to a certain extent with the planes of the axes of the minor folds and the structure simulates the horizontal.

Distribution.—The fact that most of the occurrences of gold in the Yukon-Tanana region, including those of the Fairbanks and Circle districts, are within areas of Birch Creek schist renders the distribution of these rocks a matter of economic importance. The main body of schist that includes the Circle district is continuous to the southwest with that of the Fairbanks district, and is flanked on both the northwest and the southeast by belts of Paleozoic rocks. It extends eastward, round the heads of Woodchopper and Coal creeks, flanking the large mass of granite on Charley River, and terminates in the Seventymile region. Another belt extends northwest and southeast just north of the Tanana. A part of it forms apparently but a narrow strip of schist flanking the large area of granite that lies southeast of the Circle quadrangle, and another part extends more or less uninterruptedly to the area in the Fortymile region between Middle Fork of Fortymile River and Mosquito Fork.

Age.—The age of the Birch Creek schist is not definitely known. The oldest fossils that have been found in the Paleozoic rocks of the Yukon-Tanana region are Ordovician. These, however, occur at a considerable distance above the base of the Paleozoic, and in the absence of more definite information and in view of the possibility that some of the schists may be of Cambrian age it has seemed desirable to call them pre-Ordovician.

PALEOZOIC ROCKS.

CORRELATION WITH ROCKS OF THE FAIRBANKS QUADRANGLE.

Paleozoic rocks occur extensively in the western portion of the Yukon-Tanana region and in the Yukon Valley between the mouth of the Tanana and the international boundary. The Paleozoic rocks in the Circle quadrangle are extensions of those in the Fairbanks quadrangle. The same lithologic types are present and detailed work would probably reveal the same formations. From reconnaissance work, however, the fact seems fairly well established that except in the area along the Yukon, the Paleozoic section in the Circle quadrangle is thinner than that in the Fairbanks quadrangle and that the strata composing it are less persistent, less individualized, and represent the peripheral rather than the main portions of the formations. For example, the conspicuous limestones so characteristic of the Fairbanks quadrangle are represented in the Circle quadrangle by more or less lenticular beds not much exceeding 100 feet in thickness. The same is true of the greenstones, which form a considerable proportion of the Paleozoic rocks and in some localities attain topographic prominence but which, in general, are less abundant and less conspicuous than in the western portion of the Yukon-Tanana region. Therefore, although the available facts indicate the stratigraphic equivalence of the Paleozoic of the Circle quadrangle with that of areas farther west, they further indicate that it is less differentiated into formations.

LITHOLOGIC CHARACTER.

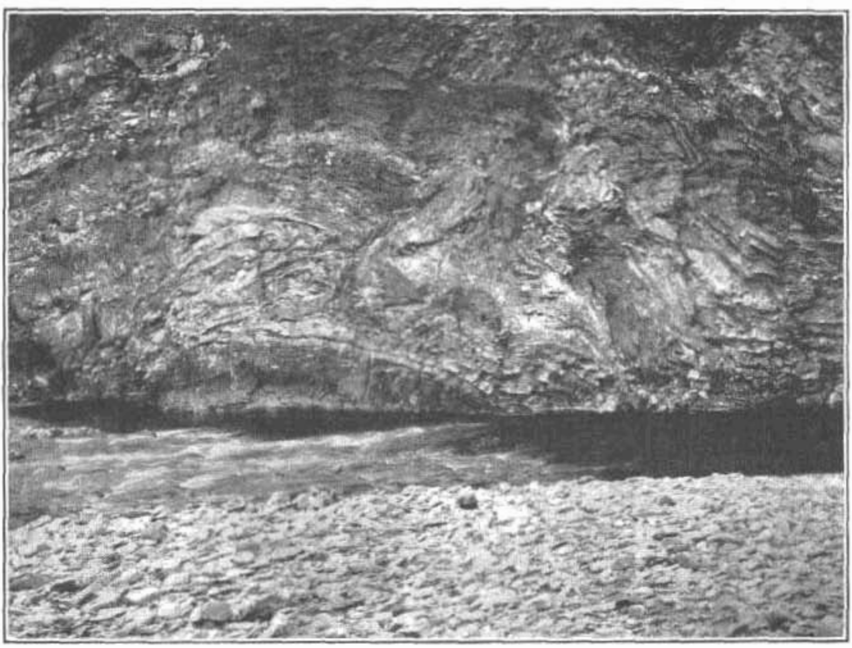
The principal Paleozoic rocks of the Circle quadrangle are coarse quartz-feldspar sandstones, metamorphosed and more or less schistose, quartzite, shale, slate, phyllite, chert, chert conglomerate, greenstone, and limestone. The dominant lithologic types have been derived from sandy and argillaceous sediments.

The quartz-feldspar sandstone is like that which forms so large a part of the Tatalina group in the Fairbanks quadrangle and is regarded as being of the same age. The most common type is composed of about equal proportions of rather coarse quartz and feldspar grains in a finely granular matrix of the same materials admixed with considerable argillaceous matter. In the coarsest varieties the grains are half an inch or more in diameter. The rocks are in general considerably metamorphosed. The quartz and feldspar grains are reduced more or less to augen, and considerable sericite mica has been developed. These rocks are interbedded in some places with fine-grained quartzitic beds, purple, drab, or green shaly slates, and limestones. In some areas the fine-grained beds have become typical phyllites. Where these rocks have become schistose some of them resemble the Birch Creek schist, but in general they may be distinguished from the Birch Creek by their composition.

The most common colors of the shale are gray, green, and black. Black carbonaceous shales are abundant and in some areas are interbedded with cherts. Green shales also are widely distributed and occur in very many places in close association with the greenstones.

The greenstones are mostly altered diabasic and basaltic flows and tuffs, but they include also some reddish-weathering serpentine derived from more basic rocks. The serpentine is described in more detail in connection with the igneous rocks (p. 42). The greenstones are characteristic of the Paleozoic section in the Yukon-Tanana region, and wherever they appear they accentuate the relief, forming

A. CONTORTED FELDSPATHIC QUARTZITE, SALCHA RIVER.



B. CONTORTED CALCAREOUS SHALES, INDEPENDENCE CREEK.

steep, pointed, jagged ridges, or being cut by streams into steep-walled narrow canyons. Their distribution, so far as known, is shown on the map (Pl. II), but the fact must be emphasized that only some of them are shown and that they may be found in any of the Paleozoic areas.

Owing to the fact that the Paleozoic limestones occur chiefly as interbedded members of little thickness, it has not been practicable to show them on the map. They are prevailingly gray or bluish; are more or less massive, and have been so closely folded that in most places their primary structures have been practically obliterated. At one locality on the Yukon west of Coal Creek a white limestone of Carboniferous age outcrops.

STRUCTURE.

The close folding (Pl. IX) has rendered the succession difficult to interpret. The lower part of the section seems to be composed mainly of coarse and fine sediments, largely feldspathic, succeeded by shales, chert, and chert conglomerates. The top seems to be mainly greenstone and limestone, the limestone being thicker and more massive than that in the lower portion. At some localities greenstones were observed to underlie the limestone and at others to overlie it.

AGE.

Apart from the Devonian localities and the locality of Carboniferous limestone, the relation of which to the rocks above described is not known, the only locality where paleontologic evidence of the age of the Paleozoic rocks has been obtained is near the eastern edge of the quadrangle, west of North Fork of the Fortymile, where a few poorly preserved fossil corals were found. These fossils, however, are too indefinite to be of value in correlation.

In the lack of definite evidence in the rest of the quadrangle it seems very probable, on lithologic grounds alone, that the same periods are represented as in the western part of the Yukon-Tanana region and that the Ordovician, Silurian, and Devonian and possibly other areas of Carboniferous are all present.

DEVONIAN SYSTEM.

The Paleozoic rocks along the Yukon within the Circle quadrangle have been studied by Brooks and Kindle,[1] who found them to be mainly Devonian. The following fossils obtained by them were referred by Kindle to the Middle Devonian:

Fossils were found at a number of localities in the limestones. At some exposures opposite the mouth of Woodchopper Creek and about 1 mile farther up the Yukon the fauna following occurs in limestones interbedded with tuffs.

[1] Brooks, A. H., and Kindle, E. M., Bull. Geol. Soc. America, vol. 19, 1908, pp. 277-291.

Cyathophyllum sp.
Crinoid stems.
Stropheodonta cf. calvini Miller.
Camarotœchia, small sp.
Atrypa reticularis Linn.
Atrypa cf. flabellata Goldf.
Schizophoria striatula (Schlotheim).
Ambocœlia cf. umbonata (Conrad).
Anoplotheca? concava (Hall).
Dalmanella sp.
Spirifer sp.
Rensselaeria? sp.
Cypricardinia sp.
Conocardium sp.
Actinopteria near perstrialis Hall.
Pleurotomaria sp.
Sigaretus? n. sp.

This is the same fauna and horizon as that occurring at the mouth of Salmontrout River on the Porcupine. *Atrypa* cf. *flabellata* is one of the most abundant species in both faunas. The very peculiar gastropod here referred doubtfully to Sigaretus and *Stropheodonta* cf. *calvini* are also common to both.

About 2 miles below Woodchopper Creek the igneous beds, which are there the predominant rocks, are interrupted by a cliff of bluish-gray Devonian limestone rising 200 feet above the river. Fossils are very scarce here. The following species were obtained:

Crinoid stems.
Atrypa reticularis.
Camarotœchia sp.
Stropheodonta sp.
Conocardium sp.

The section in this area has been summarized by Brooks and Kindle as follows:

If one were to venture on a subdivision of this great series on the facts in hand, it would be to recognize three general groups. The lowest group would comprise the heavy cherty bluish-white limestones and associated argillites, quartzites, and thin-bedded limestones occurring below Woodchopper Creek, which may be Silurian and are characterized by a relatively small amount of igneous material. The cherts, quartzites, and limestones of the Washington Creek area are provisionally included with the formation. The lowest member of the Devonian or upper Silurian described by Prindle in the Rampart region, and probably also the rocks of the Stewart River, assigned to the Devonian by Keele, can be provisionally correlated with this general horizon.

A second group would include limestones and the associated igneous rocks, argillites, and cherts. The igneous rocks of this group would appear to be identical with Spurr's Rampart series; but it must be remembered that it is only for the limestone member of this group that the age has been determined and that the igneous rocks may be somewhat younger. In its typical occurrence this igneous group is undoubtedly the best defined of the stratigraphic subdivisions here proposed for the Devonian. As a cartographic unit, however, it is not serviceable, because including, as it does, some intrusives, these are likely to be found as dikes crosscutting various older formations. Moreover, the equivalent of this igneous complex in adjacent areas may be found among the purely sedimentary rocks. The stratigraphic relations of Middle Devonian horizon to the older rocks here assigned to the Devonian is not known, but may very likely be one of unconformity.

The third group includes the argillites and subordinate sandstones and siliceous slates, which occur immediately underneath and conformable to Mississippian terranes. These rocks are but sparingly fossiliferous, and may be found to be in part of synchronous age with the igneous complex of the second group. If the argillite group is distinct from the igneous group, there may be an unconformity between the two, and the apparent absence of the latter in many localities may be due to erosion, which removed the igneous rocks before the sediments were laid down.

Little can be said of the thickness of the Devonian in this Province. The heavy limestones and associated rocks of the lowest group may measure several thousand feet.

It is probably safe to estimate that the exposures along the upper Yukon of Middle Devonian limestones and associated greenstones indicate a thickness of from 5,000 to 8,000 feet, much the larger part of which is made up of igneous rocks. The upper argillites and associated sandstones are roughly estimated to have a thickness of about 1,000 feet.

CARBONIFEROUS SYSTEM.

The Carboniferous limestone on the Yukon near Coal Creek has been described by Brooks and Kindle[1] as follows:

The upper Carboniferous limestone is typically exposed in some large open folds, accompanied by more or less faulting, along the north side of the Yukon for some 3 or 4 miles above Nation River. The same horizon was identified about 30 miles below, on the south side of the river and just west of the mouth of Coal Creek. Here it is exposed in a small area closely associated with some pyroclastic material similar in every way to that occurring with the Devonian rock. Were not the paleontologic evidence in regard to this occurrence conclusive, this limestone would have been placed with the Devonian. The occurrence, however, goes to prove that there was some igneous activity during late Carboniferous time. It also suggests the possibility that some of the igneous rocks which have been mapped as Devonian may eventually prove to belong to the Carboniferous.

The fauna characterizing this highest Carboniferous limestone is shown in the following list of fossils determined by Dr. Girty:

Lot 14: Fossils from west bank of Yukon, 1½ miles above Nation River.

Zaphrentis sp.
Stenopora sp.
Streptorhynchus aff. S. pelargonatus Schlot.
Chonetes aff. morahensis Waagen.
Productus aff. horridus Sowerby.
Productus aff. aagardi Toula.
Productus aff. P. porrectus Kut.?
Productus aff. mammatus Keys.
Productus aff. irginæ Kut.
Productus aff. koninckianus Vern.
Productus sp.
Aulosteges sp.
Marginifera aff. splendens Norwood and Pratten.
Spirifer aff. marcoui Waagen.
Squamularia aff. perplexa McChesney.
Spiriferella arctica Houghton.
Cleiothyrodina n. sp.
Rhynchopora aff. nikitini Tschern.
Schizodus sp.
Aviculipecten sp.
Omphalotrochus sp.

Lot 15: Fossils from limestone 1½ miles southeast of mouth of Nation River.

Streptorhynchus aff. S. pelargonatus Schlotheim.
Productus aff. aagardi Toula.
Productus aff. koninckianus Vern.
Aulosteges sp.
Marginifera ? aff. splendens Norwood and Pratten.
Spiriferella arctica Houghton.

Lot 22: Fossils from south bank of the Yukon below Glenn Creek.

Polypora sp.
Rhombopora sp.
Streptorhynchus aff. pelargonatus Schlotheim.
Productus aff. transversalis Tscherny.
Productus aff. aagardi Toula.
Productus aff. koninckianus Vern.
Productus aff. porrectus Kut.?
Marginifera? aff. splendens Norwood and Pratten.
Spirifer aff. cameratus Tscherny. non Morton.
Spiriferella aff. artiensis Stuckenberg.
Spiriferella arctica Houghton.
Squamularia aff. perplexa McChesney.
Camarophoria margaritovi Tschern.
Aviculipecten 2 sp.
Fish tooth.

[1] Brooks, A. H., and Kindle, E. M., op. cit., pp. 295-297.

"This fauna is unlike anything known in central and eastern North America, and appears to be rather closely allied to that of the Gschelstufe of the Ural Mountains. Probably the fauna of the Hueco, Weber, and Aubrey formations of western United States will be found more or less closely related. In Alaska it has been collected also in Pybus Bay and on Kuiu Island."

Lots 14 and 15 represent the limestone in its typical development, while the limestone which furnished lot 22 is associated with beds of igneous origin. The limestone, which is of upper Carboniferous age, terminates the Paleozoic section in the upper Yukon region. The succeeding strata in the section were not observed in direct superposition, but a series of argillites, with one or more limestone beds, is believed to hold this position. A collection of fossils was made in this series half a mile above the mouth of Nation River, from a limestone about 15 feet in thickness. A species of Halobia is the most abundant fossil in this collection. Dr. T. W. Stanton refers the fauna provisionally to the Triassic. If this provisional determination is correct, the upper Carboniferous limestone of the Yukon section is limited above by rocks of Triassic age.

The Carboniferous rocks above described show practically no metamorphism, and are in strong contrast in this respect to all the older rocks of the Yukon except the uppermost member of the Devonian. It is also noteworthy that, with the single exception of the pyroclastics found with the upper Carboniferous limestone at Glenn Creek, there is no evidence of igneous activity during the deposition of the Carboniferous sediments of the upper Yukon.

Near the mouth of Michigan Creek, on the south side of the Yukon, nearly opposite the mouth of Nation River and east of the Circle quadrangle, Mr. Mertie obtained in 1911 additional paleontologic material, on which Mr. Girty made the following report:

The species which these collections contain are as follows:

A(JB M)40. Michigan Creek, about 6 miles from mouth (south of Yukon).

Stenopora? sp.
Streptorhynchus? sp.
Chonetes aff. morahensis Waagen.
Productus aff. horridus Sowerby.
Productus aff. aagardi Toula.
Productus aff. wallacianus Derby.
Dielasma n. sp. aff. elongatum Schlotheim.
Rhynchopora aff. nikitini Tschernyschew.
Squamularia aff. perplexa McChesney.

A(JB M)41. Michigan Creek, about 3 miles from mouth.

Derbya? sp.
Productus aff. horridus Sowerby.
Productus aff. mammatus Keyserling.
Productus aff. aagardi Toula.
Productus aff. wallacianus Derby.
Rhynchopora aff. nikitini Tschernyschew.
Spirifer aff. marcoui Waagen.
Spiriferella artica Houghton.

The fauna of the two lots is essentially the same and clearly corresponds to that obtained by Brooks and Kindle on the Yukon near the mouth of Nation River. [See p. 29.] From its resemblance to the fauna of the Russian Gschelstufe, as described by Tschernyschew, I take the geologic age to be "upper" Carboniferous rather than Permian. The facies is, of course, widely different from either the Pennsylvanian or the Permian of the Mississippi Valley and Appalachian regions.

MESOZOIC ROCKS.

LOWER CRETACEOUS SERIES.

The only rocks of known Mesozoic age in the Circle quadrangle are the Lower Cretaceous rocks on the south side of the Yukon. These rocks were studied in 1906 by Brooks and Kindle,[1] from whose report the following statement is quoted:

The Lower Cretaceous of the upper Yukon comprises a series of closely folded rocks characterized by a large amount of silica. They included primarily siliceous slates, slaty sandstones, and quartzites, with which are associated some argillites and pyroclastics. One heavy bed (50–75 feet thick) of massive tufaceous conglomerate was observed within the Mesozoic area about 5 miles below Washington Creek, but may be an infolded older or younger terrane. The pebbles of this conglomerate, which are chiefly limestone, are well rounded, and some are 2 feet in diameter. The dominating rock type of the Lower Cretaceous is a siliceous slate or quartzite, sometimes interbedded with a clay slate. These rocks are usually pyritiferous and iron-stained when weathered. Three miles below Washington Creek there is a series of beautifully banded slates and quartzites. Here the brittle quartzite is broken by a series of fractures at right angles to bedding, while the same movement has in large measure been taken up in the cleavage of the slate. A quartz filling, sometimes carrying pyrite, is not uncommon along these fractures. In at least one instance it appears to be established that quartz veins cutting these Cretaceous rocks are auriferous. This conclusion is not without importance in its bearing on the age of the mineralization which produced the auriferous deposits of the Yukon.

These rocks in a general way strike easterly and northeasterly, but there are many local variations. They are usually closely folded, and no determination of thickness, which probably does not exceed a few thousand feet, could be made. On Washington Creek they appear to rest unconformably on the Devonian and in turn are unconformably overlaid by the Tertiary beds. Near Coal Creek the Aucella-bearing beds seem to underlie the upper Carboniferous limestone, which has apparently been thrust over them.

Fossils were collected from three localities in this formation, which were reported upon by Dr. T. W. Stanton as follows:

"Lot 18. South bank of Yukon River, 400 yards below Glenn Creek. This lot includes many fragmentary specimens and impressions of an Inoceramus, with a few imperfect specimens of Pecten, Pinna, two small specimens doubtfully referred to Aucella, and a few other small undetermined bivalve shells, together with very imperfect fragments of an ammonite possibly belonging to the genus Perisphinectes, or some other genus with a similar sculpture. The horizon of this lot is evidently either Jurassic or Lower Cretaceous, but the nature of the material does not permit a discrimination between these two periods. I judge that these fossils came from the same series as the Aucella mentioned below.

"Lot 19. North bank of Yukon River, 6 miles above Charlie village. This collection contains numerous specimens of *Aucella* cf. *crassicollis* Keyserling. This is provisionally referred to the Lower Cretaceous, although the possibility that it may be Jurassic should not be forgotten.

"Lot 21. South bank of the Yukon River, 1½ miles below Sams Creek. This small lot contains two imperfect specimens of Aucella and a few small fragmentary imprints of Inoceramus. The horizon is probably the same as that of lot 19.

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[1] Brooks, A. H., and Kindle, E. M., op. cit., pp. 306–307.

"The reference of these three lots of fossils provisionally to the Lower Cretaceous is made with the same reservation that has so often been expressed when similar collections containing Aucella and only a few associated forms have been submitted from this and other areas in Alaska—that is, while the Aucella itself is indicative of probable Cretaceous age, closely related species are known in the Jurassic, and it may be that all of the Aucella beds of Alaska are Jurassic."

UPPER CRETACEOUS (?) SERIES.

A few areas of conglomerate and arkosic sandstones were found in 1911 near the main divide between the drainage areas of Charley River, Goodpaster River, and Salcha River. The areas, so far as observed, are comparatively small and occur in different valleys at elevations between 3,000 and 4,000 feet above sea level.

The material varies greatly in coarseness. The coarsest varieties contain a large proportion of granitic bowlders, some of them nearly 6 feet in diameter, locally embedded in fine sandy beds. The next commonest type is made up of beds of cobbles not exceeding 6 inches in diameter alternating with shaly beds that in places carry poorly preserved plant remains. A common type is a medium-grained even-bedded arkosic sandstone that splits readily along the planes of sedimentation into slabs, many of whose surfaces are more or less colored with carbonaceous matter derived from plants. These rocks are composed of about equal quantities of quartz and feldspar grains, with some mica. They are gray in color, well consolidated, and gritty. The material has apparently traveled but a short distance from the granitic rocks from which it has been derived and it is apparently coarsest where closest to its source. The rocks where observed are but slightly tilted and their thickness probably does not exceed 1,000 feet.

No similar rocks have been observed in other areas of the Yukon-Tanana region. Conglomerates and gritty carbonaceous sandstones, found by the writer in the Rampart region,[1] contain Upper Cretaceous fossils and have at their base a conglomerate that in degree of coarseness resembles the medium coarse type of those under discussion.

The Upper Cretaceous rocks of the Rampart region have been intruded by granitic bodies, and the fact that the similar rocks of the Charley River country are composed largely of granitic material shows that they were deposited subsequent to some granitic intrusions, and in the lack of definite evidence they are referred provisionally to the Upper Cretaceous.

[1] Prindle, L. M., The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska: Bull. U. S. Geol. Survey No. 337, 1908, pp. 23-24.

CENOZOIC ROCKS.

TERTIARY SYSTEM.

Distribution.—Rocks of Tertiary age occupy an area of considerable extent in the vicinity of Yukon River. They enter the area from the Fortymile quadrangle and extend in a probably continuous belt, with a maximum width of about 10 miles, to Woodchopper Creek and beyond toward Circle. It is probable that Tertiary rocks occur also in the upper Charley River valley, as lignite has been reported from that locality, but if they do they probably form an isolated occurrence in the large mass of granitic intrusive rock.

Lithologic character.—The Tertiary rocks include clay, sandstone, shale, lignite, and conglomerate of very different degrees of consolidation, some of the sandstone and conglomerate being but loosely cemented, some of the clays having become shales, and some of the conglomerates having been thoroughly cemented. Clay and sandstone and interbedded lignite apparently constitute the basal formation.

The most conspicuous portion of the Tertiary is the conglomerate which forms the upper part of the section. This rock makes rugged topography. Most of the valleys cut into it by the main streams are narrow canyons with somewhat wider upper portions bordered by spurs that are in general precipitous or comparatively steep sided.

The conglomerate is composed mostly of fragments of black, gray, green, and red chert, quartzite, and vein quartz but includes numerous fragments of Birch Creek schist and a few pebbles of granite, found mostly near the southern edge of the formation. The pebbles of the conglomerate are well worn and commonly range from about 1 to 3 inches in size, though the maximum is about 5 inches. Bowlders 2 feet or more in diameter occur sparingly. The conglomerate merges into a coarse whitish sandstone resembling mortar. Ferruginous material is a common cement not only of the conglomerate but also of the brownish Tertiary sandstones. On the ridges the conglomerate is for the most part weathered to heaps of gravel resembling ordinary stream gravels.

The thickness of the Tertiary is perhaps 3,000 feet, about equally divided between the argillaceous, sandy, and lignitic lower portion and the conglomeratic upper portion. The rocks have been in places closely folded, and at many localities along Seventymile River are nearly vertical.

Deposition.—The origin of the Tertiary deposits has been a subject of much discussion among the miners. The conglomerates are regarded by them ordinarily as old channel gravels of river origin.

The underlying fine materials—clays, sandstones, and lignites—contain the same fossils as the conglomerates. The lower deposits are the product of conditions under which predominantly fine material was deposited. The conglomerates, on the other hand, are the product of conditions under which predominantly coarse but well-worn material was deposited. It would appear that the finer material was deposited in a lowland area where the streams were sluggish, where lakes could form, and where in swampy areas material for lignite beds could accumulate. The conglomerate, on the other hand, was probably deposited where more active erosion was in progress and is probably in larger part the product of fluviatile action. It must be borne in mind, however, that the Tertiary deposits could not have been laid down by any river system that was not much older than the present valleys; that they are in no wise related to the White Channel gravel of the Klondike or to any other high gravels that are referable to the present drainage systems; that since their deposition they have undergone not only consolidation but folding, until many of their beds are vertical; and that their history, therefore, is entirely discontinuous with that of the present drainage systems.

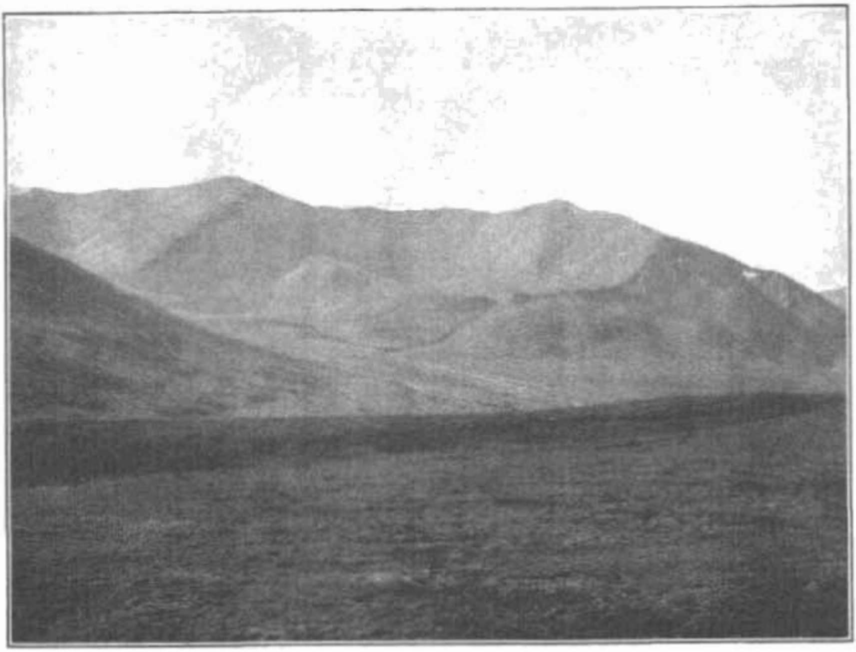
Age.—By means of the fossil plants, which are in places very common, the age of the rocks has been determined to be Eocene (Kenai). A few miles east of the quadrangle, in the Seventymile Valley, fossil leaves occur in ferruginous nodules in the lower shales, in sandstones interbedded with the shales, and in shales interbedded with the conglomerates.[1]

QUATERNARY SYSTEM.

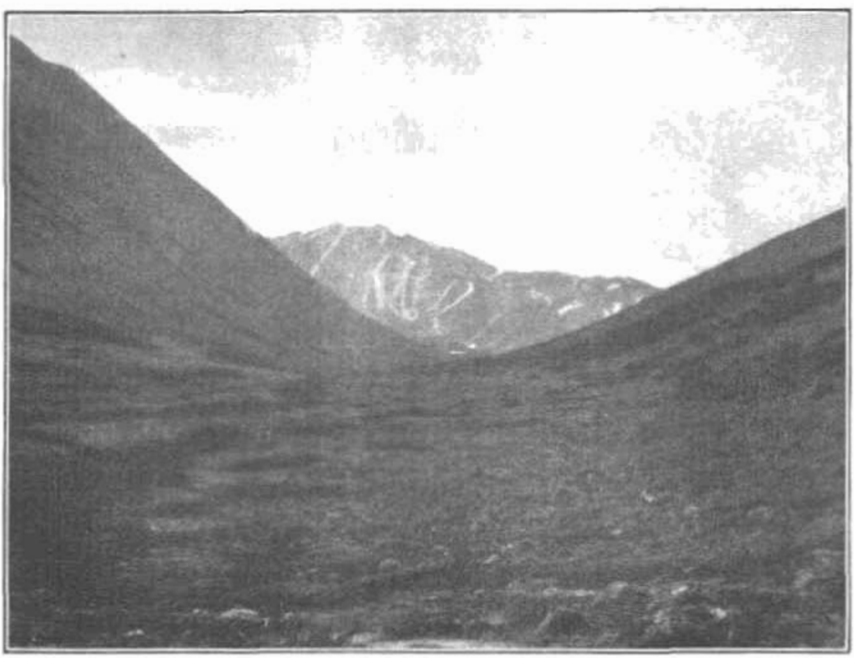
Glaciation and glacial deposits.—Evidence was obtained during 1911 that glaciation formerly occurred to a minor extent in some of the highest portions of the quadrangle and that the normal drainage had been somewhat modified thereby. Only the heads of valleys and the valleys of minor tributaries were affected. Cirques, U-shaped valleys, and morainal deposits were observed. Some of the cirques are firmly developed (Pl. X, *A*) and form hanging valleys, the present drainage having cut only narrow V-shaped gashes in their mouths. Some of the U-shaped valleys (Pl. X, *B*) are also clearly shown. They are flat floored and are practically bare of deposits except at their very heads. The morainal material begins near their opening on the larger valleys and extends into these valleys more or less irregularly. (See Pl. XI, *A* and *B*.)

The distribution of the glacial deposits as far as known is shown on the map (Pl. II), but more detailed investigations would undoubtedly reveal their presence in many other localities. Their occurrence is governed largely by the intrusive rocks and their immediate con-

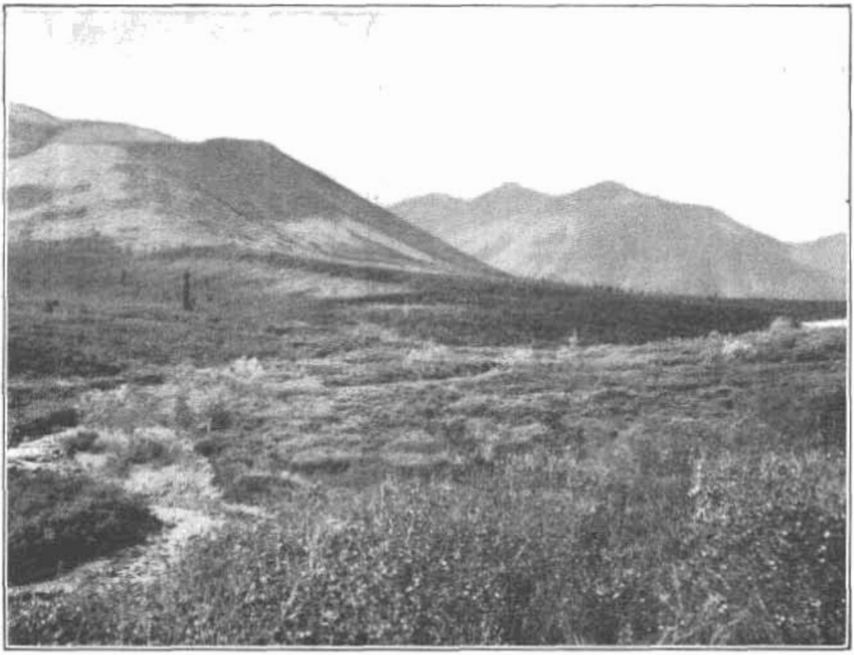
[1] Prindle, L. M., The Fortymile quadrangle: Bull. U. S. Geol. Survey No. 375, 1909, p. 26.



A. CIRQUE, HEAD OF SALCHA RIVER.



B. U-SHAPED VALLEY, TRIBUTARY OF CHARLEY RIVER.



A. MORAINE PARTLY DAMMING VALLEY.

B. TERMINAL SLOPE OF MORAINE FROM SMALL VALLEY.

tacts, because these are the only areas that attained sufficient altitude to furnish conditions favorable for the development of glaciers. They are most common on the headwaters of Charley River.

One of the most conspicuous glacial deposits in the quadrangle is a moraine about 1½ miles long and half a mile wide occurring in a small valley trending N. 15° W. from a peak 6,284 feet high. (See Pl. XII.) The valley is U-shaped and has a floor about 500 feet wide. The morainal material begins near the mouth, where it has a thickness of about 400 feet. At the lower end of the moraine, 1½ miles distant in the main valley of Charley River, the thickness is about 100 feet. The material is arranged in three more or less concentric ridges, the outermost being the largest. The innermost ridge is confined to the immediate vicinity of the mouth of the valley.

These deposits constitute an unconformable feature among the normal alluvial deposits. Nothing very definite is known regarding their age. They have been somewhat reworked by the present streams but are younger than the main valleys. It is probable that they were more or less contemporaneous with the benches of intermediate height (p. 15). The conditions favoring their development may have prevailed from late Pleistocene to comparatively recent time in only a small area where the altitude was favorable, but later these conditions shifted northward and at present prevail in the mountains north of the Yukon, as shown by small existing glaciers.

Alluvial deposits.—The alluvial deposits include gravel, sand, and silt that have been deposited either on benches at various levels or on the flood plains of the present streams. The high bench gravels so common in the Fortymile and Rampart quadrangles, where they occur at various levels not exceeding 500 feet above the present streams, have been observed at but a few localities in the Circle quadrangle. High benches are well developed in places, notably in the valley of the Seventymile (Pl. V, *B*, p. 14), where a bench 500 feet above the stream seems so closely related to the present valley of the Seventymile that it is probably a part of the old valley in which the river has cut its present canyon-like valley. No gravels, however, were observed on this bench, though they occur on the lower rock-cut benches, especially on a sharply defined bench about 20 feet above the present stream.

The gravels have been derived from the bedrock of the valleys in which they occur, and with the exception of the small aggregations of morainal material above described are of fluviatile origin. They are described in more detail in connection with the gold placers.

The silts are characteristic deposits along Yukon and Tanana rivers and occur in places in the lower valleys of their tributaries. They have been deposited at various levels at and above that of the present streams.

IGNEOUS ROCKS.

By J. B. MERTIE, JR.

GENERAL FEATURES.

Roughly, probably one-third of the Circle quadrangle is occupied by eruptive rocks and the greater part of the remainder by crystalline schists and gneisses. Many of the gneisses and some of the schists are closely connected in origin with the eruptive rocks, and igneous activity has therefore played a very important part in the history of the region.

For purposes of discussion the igneous rocks may be divided into plutonic rocks, such as granites and diorites, and volcanic rocks, such as rhyolites and basalts, although these classes, strictly speaking, are not mutually exclusive. In the class of plutonic rocks are included all the intrusive rocks that crystallized at considerable depths beneath the surface or under conditions similar to those that exist at considerable depths. All such rocks appear wholly crystalline to the naked eye. In the class of volcanic rocks are included all the rocks that crystallized at the surface or under conditions simulating those at the surface, as, for instance, in many dikes and volcanic plugs. The volcanic rocks thus include all the extrusive and some of the intrusive rocks. Such rocks are either microcrystalline or partly glassy.

PLUTONIC ROCKS.

DISTRIBUTION AND AGE.

The plutonic rocks, both geographically and geologically, are the most important igneous rocks of the Circle quadrangle. They occur as dikes and irregular intrusive bodies and the areas covered by them vary greatly in size. In the east-central part of the Circle quadrangle there is an area of granitodioritic rock approximately 70 miles long and 50 miles wide, which connects on the east with the intrusive mass that forms Glacier Mountain in the Fortymile quadrangle. As prospectors have reported coal from the center of this mass it is probable that it contains a small basin of younger unaltered sedimentary rocks. Nevertheless, its extent gives some idea of the large scale on which the intrusive action has occurred.

It is probable that all the plutonic rocks were not intruded simultaneously, for in several localities acidic granites cut basic granites and diorites. A conglomerate which is regarded as Cretaceous in age has been found to contain bowlders of basic granite and diorite, and for this reason it is likely that some of the more basic granodioritic rocks were intruded previous to a part at least of the Cretaceous. The intrusions probably took place at several periods during the Mesozoic

MORAINE NEARLY FILLING MAIN VALLEY FROM SMALL VALLEY HEADING IN PEAK IN BACKGROUND.

era. In the Rampart region, farther west, Upper Cretaceous rocks have been intruded.

The regional strike of the crystalline schists is northwest and southeast, and many of the intrusive bodies lie in conformity with this major structural direction. For instance, the large intrusive mass 50 miles wide, previously mentioned, narrows toward the southeast to 12 miles and toward the northwest, along the ridge at the heads of Coal, Woodchopper, Webber, and Thanksgiving creeks, to but 2 or 3 miles.

METAMORPHISM.

In general, the plutonic rocks have not suffered extensive regional metamorphism. The Eocene conglomerate, however, which is younger than the plutonic rocks of the region, has been closely folded, the strata at some localities being vertical. This Tertiary movement should have had some effect on the plutonic rocks, and possibly the gneisses that occur on the periphery of the large granite and diorite masses were largely due to it. The later metamorphism was probably insufficient to leave traces in the interior of the large intrusive bodies, but was able to affect them along their contacts, where the movement was locally intensified. On the other hand, some of the gneissoid structure seems to be primary.

UNMETAMORPHOSED PLUTONIC ROCKS.

GRANITIC ROCKS.

Granitic rocks are the most common igneous rocks in the Circle quadrangle, occurring in many varieties depending on the character and amount of the femic minerals. The common femic minerals observed were muscovite, biotite, hornblende, tourmaline, and epidote, and the rocks have been so named as to indicate the dominant one of these minerals present.

Muscovite granite and alaskite.—In the hand specimens the muscovite granite and alaskite range from fine to coarse grained varieties and are invariably light in color. In composition they range from the muscovite granite proper, in which muscovite is abundant, to alaskite, which consists essentially of quartz and feldspar, with muscovite or biotite developed only in subordinate amount. As accessory minerals garnet, apatite, zircon, and oxides of iron commonly occur. The feldspars are chiefly orthoclase and microcline, with subordinate amounts of plagioclase, ranging in composition from albite to basic oligoclase. In some specimens the orthoclase and microcline are graphically intergrown with the quartz, giving rise to a graphic granite.

The muscovite granite and alaskite occur in small amount compared with the biotite and hornblende granite, and it is evident that they are relatively unimportant. Good-sized bodies of muscovite granite are present in a few localities, as for instance along the divide at the head of Coal Creek, but for the most part it occurs as dikes cutting the other granitic rocks and the metamorphosed sedimentary rocks.

Muscovite-biotite granite.—Muscovite-biotite granites or granites which carry muscovite and biotite in approximately equal amounts represent the true granite type, or granite as the term is used in the narrow sense. They do not differ greatly in appearance or in general character from the muscovite granite and alaskite group. In the field some of them appear slightly darker by reason of their content of biotite, but in others the biotite has been leached and can be told from muscovite only by the aid of the microscope. In the specimens examined the potash feldspar is chiefly orthoclase and the plagioclase is oligoclase. The accessory constituents are apatite, zircon, and garnet. In places epidote is developed as a secondary product.

In mode of occurrence and relative importance the true granites do not differ materially from the muscovite granite and alaskite. They occur both in dikes and in larger bodies and are probably more closely related in age to the acidic granites than to the basic types. In general they appear to grade into muscovite granite and alaskite on one hand and into biotite granite on the other.

Biotite granite.—Biotite granite seems to be the dominant rock in the Circle quadrangle. It is composed largely of quartz, feldspar, and biotite, all three of which are as a rule visible in hand specimens. Orthoclase and microcline are both developed, although the former is the more common. The plagioclase varies in composition and in many specimens shows zonal growths with acidic rims. One section of a zonal growth cut parallel to 010 gave extinctions of $+6°$ to $-23°$ measured against the 001 cleavage, indicating a variation from oligoclase to acidic labradorite. In general, however, the variation is not quite so great as this.

Biotite is evenly distributed throughout the rock, but much of it is altered, chiefly to chlorite, though in some degree also to epidote and muscovite. A specimen taken along Goodpaster River, just above the mouth of Indian Creek, illustrates well the formation of muscovite from biotite. The common accessory minerals are apatite, zircon, titanite, garnet, magnetite, and other oxides of iron. Secondary products in addition to chlorite, epidote, and sericite are calcite, pyrite, and hematite.

Any large mass of granitic or dioritic material in this area commonly contains a biotite granite facies. Biotite granite is found along the ridge between Coal Creek and Charley River, on the ridge between Birch Creek and North Fork of Birch Creek, on the ridge at the head of Buckskin Creek, on Hutchinson Creek, on a stream entering Salcha River from the south just below The Splits, and at many other localities. Much of the granite along Goodpaster River is also of this kind. Biotite granite occurs likewise in some of the larger dikes of the district.

Amphibole granite.—Through a decrease in the amount of biotite and an increase in the amount of hornblende, the biotite granite grades imperceptibly into hornblende granite. Hence many specimens show both biotite and hornblende. The biotite-hornblende granites are darker than the pure biotite varieties, mainly because they contain a larger proportion of femic minerals. As a rule it is not possible in the field to separate them from quartz diorites. In granularity they do not differ greatly from the other granites described, although those in which hornblende is the chief femic mineral may be a little coarser. As in the biotite granites, the feldspar is seen under the microscope to be largely orthoclase, with subordinate plagioclase having an average composition of basic oligoclase. Where hornblende is present titanite appears to be the most important accessory constituent. The other accessory minerals are apatite, magnetite, and zircon, and the secondary minerals epidote, calcite, and sericite. A specimen from a point 2½ miles west of the junction of Manila Creek with Middle Fork of Fortymile River shows evidence of considerable metamorphism, which has resulted in the development of undulatory extinction in the quartz crystals and in the formation of myrmekite or secondary quartz and feldspar within the feldspars. Another specimen of particular interest, collected from the north side of Slate Creek where it joins the Fortymile, is a basic differentiate of the granitic magma, consisting largely of hornblende and biotite with subordinate quartz, orthoclase, and albite that show strain phenomena. The hornblende is zonally grown, being brown in the center and grading outward into the ordinary green variety.

Hornblende granite forms much of Veta Mountain and is found also on the spur between Ole and Independence creeks, on the spur between Pittsburg and Portage creeks, and at numerous other localities. It is not nearly so plentiful, however, as biotite granite.

One specimen—the only one found in the quadrangle—of a granite carrying pyroxene was obtained on the spur between Ole and Independence creeks about half a mile north and 2½ miles east of the junction of the two creeks. This specimen, however, is not a true pyroxene granite, for the diopside which it contained was subordinate in amount to the hornblende and biotite. It is better described as a pyroxene-bearing hornblende granite.

Tourmaline granite.—At several localities in the area tourmaline-bearing granite has been noted. It does not differ in general appearance from the hornblende granite, but in thin section it is seen to consist of quartz, orthoclase, oligoclase, and tourmaline, accompanied in many specimens by muscovite, apatite, garnet, and zircon.

Epidote granite.—At one or two localities, notably on the spur northwest of the mouths of Comet and Champion creeks, granites containing considerable amounts of epidote have been found. The epidote is fresh looking, but the presence of calcite and chloritized biotite indicates that it is of secondary origin. Microcline and albite are the feldspars commonly developed.

MONZONITIC ROCKS.

A monzonitic type of granitodioritic rock occurs on the ridge between Mosquito Fork and Buckskin Creek, close to the east edge of the quadrangle. At this point rocks that consist of quartz, orthoclase, plagioclase, hornblende, biotite, titanite, apatite, and magnetite were found. The plagioclase varies from andesine to acidic labradorite, and is present in about the same proportion as the orthoclase. In the Fortymile quadrangle, just across the border, another specimen of the same type was found. These rocks are of interest chiefly on account of the fine examples of myrmekite which they afford.

DIORITIC ROCKS.

Granodiorite.—In association with the granitic and dioritic intrusives granodiorite has been found. Like the monzonite, however, it has been noted at only a few localities and is relatively unimportant. It contains less orthoclase than the monzonite and more than the quartz diorite, and thus, with the monzonite, it constitutes a transition from the granites to the quartz diorites. The plagioclase ranges from oligoclase to acidic labradorite. In other respects the granodiorite does not differ materially from many of the hornblende and biotite granites.

Quartz diorite.—In most hand specimens the quartz diorite and related rocks are darker than the granitic and monzonitic rocks, this being due to the larger amounts of femic minerals which the diorites as a rule possess. Several varieties of quartz diorite, depending on the character of the dominant femic minerals, have been noted, among them quartz-mica diorite, quartz-mica-hornblende diorite, and quartz-hornblende diorite. Quartz diorite porphyry has also been found. The primary minerals are quartz, plagioclase, orthoclase, biotite, hornblende, apatite, augite, titanite, magnetite, ilmenite, and zircon, and the secondary minerals sericite, epidote, zoisite, chlorite, calcite, pyrite, and quartz. Quartz and feldspar are the most plentiful, although biotite and hornblende commonly form an important part of the rocks. In general the fabric of these rocks is hypidiomorphic granular, but in some occurrences the feldspar and locally both the feldspar and the quartz have developed in part as phenocrysts, giving rise to a porphyritic fabric. Augite is an accessory femic mineral and does not occur in quantities sufficient to form quartz-augite diorite. The plagioclase is characterized by well-developed zonal growths, most of which have basic centers and acidic rims. Extinction angles on 010 sections measured against the 001 cleavage gave from $+5°$ to $-25°$, indicating compositions varying from oligoclase to labradorite. Where alteration has taken place, the zonal growths are usually more changed than the outer rims. The chlorite and sericite are derived largely from the biotite, and the epidote and zoisite are formed for the most part as alteration products of hornblende.

Quartz diorite occurs at many localities in the Circle quadrangle, both in association with more acidic intrusives and in large masses separated from the granitic rocks. With the more acidic intrusives, it is found along Goodpaster River, on the ridge at the head of Miller Creek, on the ridge at the head of Coal Creek, on the ridge east of Granite Creek, at the head of Shaw Creek, and elsewhere. More extensive occurrences are at Twin Mountain and West Point.

Diorite.—Two main types of diorite are developed in the region. The more plentiful is hornblende diorite, which consists essentially of feldspar and hornblende with a few crystals of apatite and pyrite. The feldspar is largely plagioclase with an average composition of andesine, although the zonal growths that characterize the rocks vary in composition from oligoclase to labradorite. Orthoclase is relatively unimportant.

The other type is the augite diorite, which differs from hornblende diorite in having augite and biotite in place of hornblende. Orthoclase is commonly present, although subordinate in amount to the plagioclase. The accessory constituents are apatite, magnetite, and titanite, with small amounts of secondary epidote.

No large bodies of true diorite have been found, but the occurrences noted are associated with larger bodies of dioritic and granitic rock. In the Circle quadrangle hornblende and augite diorites, like the monzonites and granodiorites, are doubtless to be regarded as facies of the granodioritic magma rather than as characteristic rock types.

GABBRO.

As a rock type gabbro is of little importance in the area under consideration. It is found in two or three places only, and is probably a differentiated facies of a more acidic magma. Specimens have been collected on the ridge at the head of Fisher Creek and at the junction of Shaw Creek with North Fork of Birch Creek. The specimens examined consist largely of feldspar and augite, with accessory magnetite and apatite. The feldspar is exclusively plagioclase, varying somewhat in composition but averaging about the composition of labradorite. Chlorite is commonly present and is probably derived from biotite. In the specimen from Shaw Creek quartz was also found to be present, so that the rock from this locality is really a quartz gabbro. The gabbros differ from the augite diorites mainly in their total lack of orthoclase.

PERIDOTITE AND PYROXENITE.

Along the ridge at the head of Fisher Creek there is a body of peridotite of considerable size. The rock is a dunite and consists entirely of olivine, much of which is altered in part or wholly to serpentine.

Pyroxenites have been noted at several localities. At the junction of the two large streams which make up South Fork of Salcha River is an altered pyroxenite that consists entirely of pyroxene, probably augite, which has been altered subsequently to tremolite and tremolite asbestos.

On Joseph Creek, about 1½ miles above Joseph village, specimens of pyroxenite were collected which in thin section are seen to consist largely of augite, with small amounts of hornblende, apatite, basic labradorite, and oxide of iron, probably magnetite. Some of the hornblende is probably of secondary origin, and calcite also occurs as a secondary product. One specimen was considerably mineralized by pyrite, which occurs along cracks, replacing augite. In this specimen the apatite was very noticeably biaxial.

Along the divide between Salcha River and Shaw Creek, about 10 miles south and 2½ miles east of The Splits, a diallagite was collected, which consists essentially of diallage, with small amounts of olivine, tremolite, feldspar altered to chlorite, and magnetite.

Peridotites and pyroxenites have also been found at several localities in this region outside of the Circle quadrangle. About 20 miles southeast of the quadrangle, in the valley of Dennison Fork of Fortymile River, lherzolite and websterite occur as inclusions in the basaltic lava of a small extinct volcano near the east branch of Dennison Fork.

METAMORPHOSED PLUTONIC ROCKS.

Granite gneiss.—Along the periphery of some of the larger granite masses granite gneiss is found. The gneissoid character can not well be attributed to regional metamorphism, for the main intrusive mass shows no evidence of such alteration. It is therefore probably the result of local metamorphism along the contacts. A few of the gneisses, however, show no signs of strain phenomena in thin section and are possibly of primary origin.

In composition the granite gneisses do not differ materially from the granite. Quartz, orthoclase and microcline, acidic plagioclase, biotite, and hornblende form the essential constituents. Augite also occurs in some specimens. As accessory constituents garnet, apatite, tourmaline, magnetite, zircon, and titanite are developed. The secondary products are sericite, chlorite, epidote, and calcite. In general the quartz and feldspar show undulatory extinction caused by the strain which the rocks have suffered. The banded character of the gneisses is very apparent in all hand specimens and in many thin sections.

In addition to the granite gneisses along the edges of the large intrusive masses still older gneisses have been found. Augen gneiss occurs in considerable amounts at certain localities in the Birch Creek schist. It is granitic in character but differs from the gneisses previously mentioned in the amount of metamorphism it has suffered. The feldspars, as a rule, are drawn out in elongated "augen" and are more commonly microcline than orthoclase. In many occurrences the gneissoid banding closely approaches schistosity. These rocks are doubtless the metamorphosed representatives of earlier plutonic rocks.

Quartz diorite gneiss (metadiorite).—The dioritic rocks, like the granites, have undergone metamorphism in many places along the contacts of the large intrusive bodies. Different varieties occur among the gneissoid representatives as they do among the quartz diorites proper. In general, the gneisses differ from the quartz diorites chiefly in the strain phenomena exhibited by the quartz and feldspar and in the banded character of the rock. In addition, some of their plagioclase shows an inclination toward the combination of albite and pericline twinning. Some of the quartz diorite gneisses show evidences of primary gneissoid character.

VOLCANIC ROCKS.

DISTRIBUTION AND AGE.

The volcanic rocks of the region, as here grouped, include all the lava rocks resulting from volcanic or fissure eruptions, together with the aphanitic intrusive rocks of related origin. Like the plutonic rocks, these fine-grained rocks show acidic, basic, and intermediate varieties, but the acidic and basic rocks are more sharply separated and are of about the same relative importance.

Geographically, the unmetamorphosed volcanic rocks are of less importance than the plutonic rocks and show less variation in composition. Surface lava occurs in many localities in the region and it is possible that a great deal more of it was poured out and later removed by erosion. The large number of acidic and basic dikes in the quadrangle tend to corroborate this view. In at least one place around the head of Charley River it can be shown that the rhyolite porphyry flows were connected with one or more underlying dikes. On the other hand, at the basaltic Dennison Fork volcano, outside of the quadrangle, the eruption was of the central type. It is therefore probable that both kinds of eruptive action were important in the volcanic history of the region.

The general strike of many of the dikes is north-south to northeast-southwest, and at the head of Charley River the surface flows also conform to this direction. This trend is almost at right angles to that assumed by the crystalline schists and plutonic rocks.

The volcanic rocks, as might be inferred from what has been said, differ in age from the plutonic rocks. In general, the dike rocks and surface flows are to be regarded as Tertiary or later, although, like the deep-seated rocks, they are not to be ascribed altogether to one time. They comprise both acidic and basic rocks, and it is probable that the two types are of different age. The basic rocks are so fresh and unaltered that it has seemed best to regard them as younger than the acidic rocks, which, further, appear in one or two places to have been cut by basic dikes, although this relation has not been definitely established. Both acidic and basic dikes, however, cut conglomerate regarded as of Cretaceous age, and it seems safe, therefore, to regard most of the volcanic rocks as subsequent to a portion of the Cretaceous at least and as probably belonging to the Tertiary period.

RHYOLITIC ROCKS.

The rhyolitic rocks are light colored and commonly porphyritic, with phenocrysts of quartz and feldspar. In hand specimens the groundmass is generally aphanitic, although it is often possible to tell the character of the dominant femic mineral. Many rocks of rhyolitic composition occur throughout the region.

The rhyolite and rhyolite porphyry of the region consist essentially of quartz, orthoclase, and acidic plagioclase, together with some dominant femic mineral and accessory minerals. The plagioclase varies in composition from albite to andesine, but has an average composition corresponding approximately to basic oligoclase. Some microcline occurs along with the orthoclase. The three essential constituents—quartz, orthoclase, and plagioclase—occur both as phenocrysts and as components of the groundmass, although not uncommonly the plagioclase occurs only in the groundmass. Many of the phenocrysts are corroded, showing the effects of magmatic resorption.

Biotite and muscovite are the commonest rock-forming femic minerals, occurring singly in some rhyolites but generally in combination. Two specimens show an altered pyroxene as the chief femic constituent, but alteration has proceeded too far to permit the original character of the pyroxene to be determined. As accessory constituents, apatite, zircon, garnet, magnetite, ilmenite, and titanite are developed.

Chlorite, sericite, epidote, calcite, and pyrite are the common secondary minerals.

The fabric of the rhyolitic rocks is somewhat variable, depending chiefly on the content of glass. A complete range of fabrics from holocrystalline-porphyritic to vitrophyric has been found, but the percrystalline porphyritic type is the most common. Where much glass is present many "Sphaerocrystallen" (circular areas showing aggregate polarization) occur in the glassy base. One or two of the more crystalline specimens show the development of typical flow structures.

As a rule the rhyolitic rocks are very little metamorphosed, although in many places they are much altered by general aerial and aqueous agencies. Only one specimen among those examined showed any considerable amount of metamorphism. In this rock, collected along the telegraph line about 6 miles west of the mouth of Liscum Slough, the phenocrysts of orthoclase have been much strained and drawn out, although they still retain the outlines of their crystal form. In addition, a decided schistose fabric has been developed. The phenomena of dynamic metamorphism in these rhyolites, however, are of purely local significance.

The rhyolites occur as flows, dikes, and tuffs. The sheets around the head of Charley and Goodpaster rivers are the best examples of the flows. The dikes occur in many localities throughout the field, but mostly in the vicinity of larger granitic bodies. One or two occurrences of true rhyolite tuffs have been found in the quadrangle, but except for their tuffaceous fabric and altered character they differ in no way from the other rhyolites.

DACITIC AND ANDESITIC ROCKS.

Dacites and andesites constitute the fine-grained rocks of intermediate composition. Like the rhyolites, they are commonly found in association with deep-seated rocks of the granodioritic magma, and they may well be regarded as the surface equivalents of the quartz diorites and diorites. In general the dacites and andesites are likely to be darker than the rhyolitic rocks, but in many occurrences they can not be discriminated except by microscopic examination.

Dacite.—Rocks of the dacite type consist essentially of plagioclase, orthoclase, quartz, and some dominant femic mineral, together with accessory minerals. Orthoclase is not always present in the mode, but many of the rocks are somewhat glassy, so that it can not always be said that potash is low when it does not appear in one of the rock-forming minerals. Dacite is generally porphyritic, most of the phenocrysts being plagioclase, orthoclase (if present), and quartz. These minerals also occur in the groundmass.

The plagioclase varies considerably in composition, as in the quartz diorites. Sections parallel to 010 show extinctions varying in character from parallel to $-18°$ on the 001 cleavage, indicating a composition from basic oligoclase to acidic labradorite. Most of the zonally grown feldspars which exhibit these variations have acidic rims and basic centers, and the rims commonly withstand alteration better than the centers. The chief femic mineral is biotite, though hornblende may be more conspicuous in the mode. Where it is, orthoclase is not likely to be present and the plagioclase is likely to be more basic. Apatite, augite, magnetite, zircon, and garnet occur as accessory minerals. Sericite, chlorite, epidote, and calcite are the chief secondary minerals. The sericite is derived both from feldspars and from biotite. Chlorite, however, occurs for the most part as an alteration product of biotite. Epidote results from the decomposition of both biotite and hornblende, but in one or two specimens it is accompanied by calcite as the alteration product of garnet.

The fabric of the dacitic rocks is rather diverse, depending on the physical conditions under which the rock solidified. Almost all these rocks are porphyritic, but they vary from holocrystalline to vitrophyric. A specimen of hornblende dacite showed under the microscope a poikilitic fabric, with hornblende as the oikocrysts. Flow structures may also be seen here and there.

Dacitic rocks occur chiefly as dikes, which are distributed throughout the region, although they are not so plentiful as either the rhyolitic or the basaltic rocks. They seem to be more closely related to the rhyolites than to the basalts and diabases.

Andesite.—In general character and mode of occurrence the andesites do not differ materially from the dacites except in containing no quartz. They are rather scarce and do not merit any further mention.

BASALTIC AND DIABASIC ROCKS.

Basalt.—The basalts are dark gray to black fine-grained to aphanitic rocks. Some of them are megaporphyritic, though much less so than the more acidic volcanic rocks. Through extensive alteration they have been altered in some places to dark-green rocks that constitute a part of the so-called greenstones.

Under the microscope the basalts are seen to consist essentially of plagioclase and augite. Other minerals, such as olivine, quartz, hypersthene, biotite, and basaltic hornblende, appear here and there in considerable amounts, giving rise to different varieties of the rock. Magnetite and apatite are the accessory constituents. In addition, considerable amounts of glass are common. The chief varieties of the rock are feldspar basalt (the common variety), olivine basalt, and quartz basalt.

The plagioclase ranges from andesine to bytownite. Zonal growths measured on 010 sections have extinction angles of $-7°$ to $-34°$ on the 001 cleavage. It occurs usually in subhedral lath-shaped individuals. The augite occurs in angular grains between the feldspar. Not uncommonly weakly pleochroic crystals of hypersthene take the place of the augite, either in part or altogether. Biotite and basaltic hornblende occur less commonly. Quartz is abundant as anhedral grains in the groundmass or as phenocrysts showing resorption. Where resorption has taken place, the quartz is generally surrounded by a rim of glass, which is in turn surrounded by a rim of radiating monoclinic pyroxene needles. Where quartz has been observed, olivine is usually lacking. Considerable glass is generally present, and "Sphaerocrystallen" occur in the glassy base.

The fabric of the basaltic rocks varies considerably, depending largely on the amount of glass. One or two specimens are holocrystalline and show a true doleritic fabric. Others are dominantly glassy, with resulting vitrophyritic fabrics. Between these extremes intersertal and hypocrystalline porphyritic fabrics occur. Where the rock is porphyritic, olivine, augite, and feldspar may occur as phenocrysts.

The basalt occurs both as flows and as intrusive bodies. The Dennison Fork volcano is the best example of extrusive lava. The intrusive dikes and plugs occur at many localities throughout the quadrangle.

Diabase.—Diabase occurs in part as an intrusive rock of Paleozoic age and in part as an intrusive rock of probable Tertiary age, associated with the basalts. The older diabases occur mostly as sills and larger intrusive bodies, which by metamorphic processes have been altered largely to greenstones and serpentine. Rocks of this type outcrop at numerous localities on both sides of the Yukon above Circle. A diabase butte rises at the headwaters of Salcha River.

The younger diabase rocks occur for the most part as dikes and do not differ materially from the basalts in mineral constituents. True diabase, quartz diabase, and olivine diabase occur, but as a rule the rocks are holocrystalline or very nearly so. In many dikes the plagioclase and augite are poikilitically intergrown, giving rise to the ophitic fabric. In others, however, the augite is less plentiful and a little glass occurs, causing the intersertal fabric. Like the basalts, the younger diabase rocks are fresh and but little altered. They have been found on Sheep Creek, Hutchinson Creek, Granite Creek, North Fork of Fortymile River, and elsewhere.

SUMMARY.

In the Circle quadrangle a considerable variety of igneous rock types have been found. They vary on the one hand from granites and quartz monzonites through granodiorites and diorites to gabbros, peridotites, and pyroxenites; and, on the other hand, from rhyolites and dacites to andesites and basalts. In none of these rocks, however, have any minerals rich in alkalies been found, other than the ordinary feldspars. The rocks of the region then are predominantly derivatives of a granitodioritic magma.

The uniform presence of quartz is worthy of mention. In almost all the rocks examined quartz enters as one of the components of the mode, and rock types lacking in quartz are very sparsely represented. Monzonites and syenites have nowhere been found and diorites and andesites are very subordinate. Even many of the basalts, which in other regions ordinarily have no quartz, in the Circle quadrangle contain considerable amounts of it. This abundance of quartz fits in naturally with the absence of alkali minerals.

Another striking feature is the absence of the basic dikes that are so common in regions of similar intrusive rocks. Differentiation resulting in the production of such rocks does not seem to have taken place. The proportion of femic minerals in the plutonic rocks differs in different localities, resulting locally in the production of a rock wherein one of the femic minerals is the dominant rock-forming component. Some of the hornblende-rich granites and diorites illustrate this condition, but the relation of these rocks to the granitodioritic magma is plain, some one mineral being merely accentuated without any marked modification in fabric or mode of occurrence. On the other hand, differentiated acidic rocks, such as pegmatite and aplite, are common.

Regarded as a whole, the igneous rocks of the Circle quadrangle are of importance chiefly on account of their wide distribution. Although many varieties occur, yet no specialized rock types have been noted. The rocks in their general character resemble the igneous rocks in southeastern Alaska and in the Alaska Range.

CONTACT METAMORPHISM.

The intrusive rocks have complicated the structures of the intruded rocks, have indurated them, and have developed new minerals in them. The zone of influence, however, except around the deep-lying intrusions, has been comparatively narrow and has probably nowhere much exceeded 1,000 to 2,000 feet.

Where the deeper rocks have been intruded, new minerals, principally quartz, feldspar, garnet, staurolite, and biotite, have been developed, and generally a considerable amount of pegmatitic material has been formed in the shape of many small apophyses crosscutting the schists and lying parallel to their structure. Through this process the schists lose their identity and become granitized. Where the limestones have been metamorphosed they have become in places garnetiferous. At one locality a large amount of diopside and some scapolite were developed.

Where the Paleozoic carbonaceous rocks have been intruded andalusite is the most common contact mineral. The greenstones and limestones appear to have undergone but little alteration, though the limestones in some places contain considerable colorless amphibole. The pegmatitic intrusions are apparently rare in the Paleozoic rocks. Numerous dikes, however, are typical of the contacts and many of them are parallel to the structure of the intruded rocks. In composition they resemble the main intrusive mass or form a somewhat more basic rock related to it. About the only effects noticed in their vicinity are fracturing and induration. In comparison with the large areas of intrusive rocks the amount of contact metamorphism observed is relatively small.

MINERALIZATION.

In some places considerable pyrite occurs in the rocks adjacent to the igneous masses, and in the Circle district both cassiterite and wolframite have been obtained in the Birch Creek schist close to the biotite granite.

It seems highly probable that the gold also in the Circle district is more or less closely related in its origin to the intrusive rocks. On Homestake Creek, just beyond the western edge of the quadrangle, gold has been found in highly mineralized schist next to the contact with a dike of granite porphyry. On Mosquito Fork, in the southeastern part of the quadrangle near the boundary, gold and considerable iron pyrites occur in a mineralized zone, with many small quartz stringers in quartz diorite. Fine flour gold is readily panned from the weathered material. The occurrence is apparently a silicified shear zone in the igneous rock. Assays of two specimens gave for one 0.58 ounce gold and 0.1 ounce silver and for the other 0.36 ounce gold and 0.1 ounce silver to the ton. At another locality on Mosquito Fork, near the mouth of Gold Creek, gold has been found in veins in close association with igneous rock. Adjacent to both eastern and western boundaries of the quadrangle, then, gold has been found in close association with igneous rocks, and it seems highly probable that these rocks were active agents in the mineralization and that the contacts of the intrusive rocks and the adjacent portions of the intruded rocks are the most favorable localities for prospecting.

That the granitic intrusive rocks caused the formation of many of the quartz veins in the schists and later rocks is shown by the fact that good exposures around intrusive masses (as on canyon walls) show the main intrusive body to be fringed with apophyses of more or less related composition which farther away give place to abundant quartz veins, which in turn, still farther away, become less abundant and finally disappear, indicating that they bear a definite relation to the intrusive mass. For half a mile or more around many if not most of the intrusive bodies abundant quartz is present, and the facts seem to indicate clearly that it has resulted from the intrusion. The fact that intrusive masses occur within all the placer-mining districts and that auriferous quartz veins have been found most commonly in the vicinity of these masses suggests that the gold as well as the quartz had its origin in the process and products of intrusion.

STRUCTURE.

The complex structures characteristic of the sedimentary formations of the quadrangle have been rendered more complex by the extensive intrusions. The rocks have the two great prevailing structural trends so characteristic of much of Alaska—the southeast-northwest trend and the southwest-northeast trend. In the Circle quadrangle the southeast-northwest trend is the more apparent, but in places, especially toward the western margin of the quadrangle, the other trend, which is characteristic of the Fairbanks quadrangle, begins to assert itself.

In some places the sedimentary rocks have adapted themselves to the outlines of the igneous bodies and have bent round more or less in conformity to them. In other places they have been crumpled upon themselves or cut across by the igneous bodies.

The characteristic structure of the Birch Creek schist is one of closely appressed recumbent folds, the planes of whose axes are nearly horizontal. The rocks are much jointed and contain much lenticular quartz. The Paleozoic rocks also have been closely folded and in some places possess structures practically as complicated as those of the Birch Creek schist, though their original structures have not everywhere been so thoroughly obliterated. Cleavage is a rather characteristic structure.

The Mesozoic and in places the Tertiary rocks along the Yukon have also been closely folded. The Tertiary deposits, however, have not been so uniformly affected and in places are nearly horizontal.

A line connecting the Fairbanks and Circle districts apparently coincides with the axis of a large anticlinal area of the Birch Creek schist, flanked on both the northwest and southeast by Paleozoic rocks. The rocks flanking the northwest side bend round toward the southeast in the Crazy Mountains and extend across the northern edge of the quadrangle. The rocks flanking the southeast side parallel to some extent the belt on the northwest but are more complicated by the presence of intrusive masses. This second belt of Paleozoic rocks is bounded on the south by another area of schist that continues toward the southeast, flanking the large masses of igneous rock that occur in that direction. This belt of schist narrows to about 6 miles between the igneous rock and Tanana River a few miles southeast of the quadrangle.

In general, then, the two Paleozoic synclinal areas, separated by an anticlinal area of schist, bend round from the northeast trend to take on the northwest trend. This deflection, which is one of the most striking facts in the geology of Alaska, is shown also in the Alaska Range, in the southern coast line of Alaska, and in the course of Yukon River.

GEOLOGIC HISTORY.

EVENTS TO THE CLOSE OF THE TERTIARY.

The material available for constructing a geologic history of the region is scanty and it is only possible to summarize what appear to be the most important geologic events.

The evidence indicates that the area is one of sedimentary rocks, thousands of feet in thickness perhaps but thin in comparison with those of the Yukon-Tanana region as a whole, overlying batholithic masses of granitic rocks that form an intrusive foundation.

The lithologic character of the oldest rocks, the Birch Creek schist, indicates uniformity of conditions over wide areas. The interbedding of arenaceous, argillaceous, and some calcareous material is common wherever these schists occur. The formation becomes apparently more calcareous toward the top, where both limestone and carbonaceous schists are likely to be found. The apparent thickness of these deposits indicates a long continuance of conditions favorable for their deposition. The presence of gneissoid granites in intrusive relation to these schists indicates that the consolidation and folding were accompanied by the intrusion of granitic material which later underwent metamorphism along with the intruded rocks. The rocks become gneissoid with increasing depth, toward the intrusive contact. The top of the schists is regarded as unconformable to the Paleozoic on account of their prevailing greater metamorphism and their greater complexity of folding. The relations of the two, however, are nowhere clearly shown, being apparently obscured by welding and by metamorphism in the lower portion of the Paleozoic.

The Paleozoic was an era of great variation in conditions within somewhat narrow limits. Quartz feldspar and other siliceous sediments form an important part of the geologic section, but the prevailing sedimentary rocks are argillaceous, with abundant limestone and greenstone. The dominant characteristic of the Paleozoic is its abundant volcanic material. In some areas volcanic action commenced apparently near the beginning of Paleozoic time and continued at intervals until it reached a maximum, perhaps in the Middle Devonian. Diabasic and basaltic flows, tuffs, and breccias in close association with limestones of the Devonian are particularly abundant and indicate widespread volcanic activity during that part of the Paleozoic era. The Paleozoic areas in the Fairbanks quadrangle indicate that although the variation in sedimentation was great there was no appreciable stratigraphic discontinuity between the Ordovician, Silurian, and Devonian. Ordovician fossils occur in conglomerates underlying limestone and in the limestone itself near the base; farther up in the same body of limestone Silurian fossils occur; and still higher up fossils that have been determined as Devonian are found.

The Carboniferous is characterized by a large amount of limestone. So far as known only the upper Carboniferous appears within the Circle quadrangle, but further work may reveal the extension into it of other Carboniferous formations that lie just beyond its eastern limit. Deep-sea conditions prevailed during the deposition of the upper Carboniferous and fossils are abundant in its limestones.

The Lower Cretaceous was an epoch of shale and sand deposition, which was closed by extensive mountain making and abundant intrusion of granitic rocks that continued till the end of the Mesozoic. In the Rampart country the Upper Cretaceous has at its base a conglomerate composed of fragments of the underlying rocks which are regarded as in part Paleozoic and in part Lower Cretaceous. The Upper Cretaceous, therefore, is in part at least unconformable to the underlying rocks. Shore conditions are indicated in the Charley River region by the coarse conglomeratic rocks regarded as Upper Cretaceous, and also in the Rampart country, where dicotyledonous leaves and ammonites occur in close association in the Upper Cretaceous.

The Tertiary rocks include clay, sand, and lignites with abundant plant-bearing beds and indicate that Tertiary deposition began in an area of low relief where sluggish streams, lakes, and swamps prevailed. The later conglomeratic deposits, which are probably in the main of fluviatile origin, indicate a change of conditions that resulted finally in the rather close folding of many areas of Tertiary rocks.

The main events to the close of the Tertiary may be summarized as follows: Deposition of arenaceous, argillaceous, and some calcareous beds over wide areas; consolidation, elevation, folding, intrusion of granitic rocks; metamorphism; erosion; Ordovician, Silurian, Devonian, and Carboniferous deposition during which much basic material became interbedded with the sediments through the agency of the volcanic phenomena so characteristic of the Paleozoic; Lower Cretaceous deposition; abundant granitic intrusion throughout a large part of the Mesozoic continuing till the close of the Upper Cretaceous; volcanic phenomena producing rhyolitic, dacitic, and some basaltic rocks, probably accompanied by the intrusion of granitic rocks and lasting into the Tertiary and later; deposition, elevation, and folding of fresh-water Tertiary deposits.

DEVELOPMENT OF THE PRESENT SURFACE.

The plateau.—The development of the present surface during Pleistocene and Recent time has been complex and is very probably due to several processes. The lithologic character of the older formations indicates that during periods of erosion the surface became more or less reduced to a lowland of faint relief, and probably this has been the history of the portion of the present surface known as the Yukon Plateau. This plateau was described on pages 13–14 as the uniform level above which extended numerous ridges and domes and below which the valley systems had been cut. Its elevation is about 4,000 feet near the heads of Goodpaster and Charley rivers and about 3,000 feet in the vicinity of the Yukon and Tanana. It is one of the most conspicuous features of the relief in the interior of the Yukon-Tanana region. After its formation it was uplifted to its present altitude, so that rejuvenation of the streams tributary to the Yukon is general, and narrow canyons of the lower valleys, like those of Birch Creek, Charley River, and Fortymile River, are characteristic, as are also the open flat valleys that form the upper portions of the valleys of the same streams. As the present valley of the Yukon has been intrenched in an older valley floor, so the present canyons of these streams have been cut in older valley floors whose remnants appear as well-developed benches along their sides.

On the lower benches gravels are still present, but on the higher benches, like that of the Seventymile, 500 feet above the present stream, no gravels were observed. There seems little doubt, however, that this bench belongs very definitely to the history of the Seventymile Valley. It seems most reasonable to regard the still higher general level of the plateau as having been developed under former drainage conditions and as having later been elevated and subjected to great dissection, just as the benches of present streams are cut by minor tributaries into many fragments.

The larger irregularities of the surface above 4,000 feet are due predominantly to the presence of the more resistant igneous rocks that have withstood erosion. Among the minor details of form are the cirques, U-shaped valleys, and morainal deposits that have already been described as products of local glaciation. (See p. 34.)

Step-cut hills.—A feature that is very common in portions of the area was briefly described as follows by the writer[1] in the description of the Seventymile drainage area in 1905:

The hills rise to a height of 2,500 feet or more above the river and exhibit beautifully preserved rock-cut benches to their summits, which are flat topped, several acres in extent, and often correspond in level to the truncated tops of neighboring hills. The benches, except where obscured by gulches, can be traced around the hills; they are especially prominent on the spurs and occur at corresponding levels. The vertical distance between the steplike benches varies from a few feet to about 50 feet, the rise from one to the other often showing an outcrop of the bedrock. The rocks comprising this area are highly contorted metamorphic schists and granular intrusives. Whatever the bedrock or its attitude, the same forms have been developed and are most striking features of the landscape. Similar forms were observed in other localities on the northern side of the Yukon-Tanana country but nowhere exhibited such development as in the valley of the Seventymile.

Since 1905 similar step-cut hills have been observed in different parts of the Fairbanks region, where they are most prominently developed at 4,000 to 5 000 feet above sea level. The truncated domes, the many benches at apparently concordant elevations on the spurs of the ridges, and the flat passes through ridges form perhaps the most striking topographic detail in the quadrangle.

Under present conditions there seems to be no adequate cause that could produce such uniform results at approximately concordant levels over widely separated areas on spurs extending in different directions.

The efficacy of ice in developing flats in portions of river valleys has been noted, and it is very probable that snow banks have, to a considerable degree, the same kind of efficiency in protecting the surface beneath and in localizing erosion to the area in contact with the edge of the snow bank. The snow could thus protect from erosion forms already present and might even accentuate such forms. The snow banks lingering in the angles between different slopes would localize the erosion at the inner edges of the benches and maintain the sharpness of angle already existing. It seems reasonable, therefore, to conclude that the forms under consideration were produced by former drainage conditions and have been protected and even kept in repair by snow banks.

GOLD IN THE YUKON-TANANA REGION.

GENERAL FEATURES.

The Yukon-Tanana region has been known chiefly for its production of placer gold, which up to the present time has amounted to approximately $75,000,000. Most of this has come from the Fair-

[1] Prindle, L. M., The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska: Bull. U. S. Geol. Survey No. 251, 1905, p. 20.

banks district, the other chief producing areas being the Fortymile, Circle, and Rampart districts.

Most of the gold of the Fortymile district and all that of the Circle and Fairbanks districts has been derived from areas in which the Birch Creek schist forms the bedrock. Most of the gold of the Rampart district has been derived from areas where Paleozoic rocks form the bedrock. Some of the gold found on streams tributary to the Yukon above Circle has apparently been derived from quartz veins in Lower Cretaceous slates. At other localities in this region the gold has been derived from areas of Tertiary auriferous conglomerates.

In the Fortymile district gold has been found at one locality in place in quartz diorite and at another locality in Paleozoic rocks close to the contact with quartz diorite. Several sedimentary and igneous formations are known to have been sources of placer gold.

The origin of the gold is indicated by the fact that in all the most productive areas igneous intrusive rocks are present and the finding of gold in bedrock near them indicates that they are its chief source.

Placer gold is found in bench gravels at elevations not exceeding 500 feet above the present streams and also in the stream gravels, where it is almost invariably close to bedrock.

GOLD IN BEDROCK.

Birch Creek schist.—The occurrence of gold in the Birch Creek schist has been studied in the Fairbanks district, where the auriferous quartz veins range from small stringers to veins 15 feet or more in thickness. The richest portion of the veins that have been prospected, however, is as a rule not more than a foot thick. The veins strike in general northeast and southwest, about parallel with the strike of the country rock. They are generally almost vertical, in places parallel with and in places cutting the structure of the schist. The auriferous quartz is generally white and opaque; the barren quartz is gray and glassy. Most of the gold is associated with arsenopyrite and stibnite. Other associates are iron pyrites, limonite, galena, and sphalerite. Minerals in the stream gravels that have apparently been derived from similar veins are cassiterite, wolframite, and bismuth.

In the Birch Creek district, on Deadwood Creek, cassiterite and wolframite have been found associated with gold in the placers. On Eagle Creek there is a thin vein of gold in mica schist associated with some quartz.

The gold found in quartz veins is described by Brooks [1] as follows:

A general wide distribution of vein quartz is attested both by the bedrock exposures and by the character of the fluvial deposits. This quartz is very frequently found to be iron stained, and one naturally turns to it to seek a source of the placer gold. There is but little direct evidence on this point. The presence of pyrite-bearing vein quartz in the auriferous alluvium is a characteristic feature of these deposits. On Eagle Creek a 4-foot gold-bearing quartz vein is said to have been encountered in the drift mining, but the writer did not see the exposure, as the drift had caved in. A specimen of the quartz showed it to be iron stained and broken by thin seams of gold. The gold of the adjacent placer was angular and carried much quartz. A mineralized fracture zone about 8 inches in width has been found on the upper part of Deadwood Creek. Within this zone the schist is permeated by stringer veins carrying pyrite and galena, and it is reported to carry values of $6 in gold and $8 in silver.

Spurr [2] reported the finding of gold-bearing quartz on Harrison Creek. He describes the occurrence as follows:

"The best example of gold-bearing quartz found in the gravel is a rhomboidal block of quartz schist, about 4½ by 5 by 2 inches, found on claim 91, on North Fork, about three-quarters of a mile above the forks. On one of the larger surfaces of this block is a quartz vein which is richly spotted with flakes and specks of gold, ranging from three-sixteenths of an inch in diameter to mere specks, which finally become invisible to the naked eye."

These facts indicate that the placer gold is derived from zones of mineralization in the schist series. The wide distribution of the placer gold is not a favorable indication that the values are sufficiently localized in the bedrock to afford commercial ore bodies. It must be said, however, that there is little evidence on this point, and workable lodes may yet be found when a systematic search is made.

Paleozoic rocks.—Placer gold in Paleozoic areas has been found mainly in the Rampart district, where it has apparently been derived from quartz veins in carbonaceous slates. Cassiterite is commonly associated with the gold in the placers.

In the Chicken Creek valley, in the Fortymile district, gold has been found in small calcite veins in rocks regarded as Paleozoic close to an igneous contact.

On creeks tributary to the Yukon above Circle, Brooks observed a close relation between the alluvial gold and Lower Cretaceous slates, describing it as follows: [3]

The rocks exposed along the Yukon between Eagle and Circle do not anywhere include any of the older schists, such as are associated with the Birch Creek placers. In fact, over much of this belt the formations are slightly altered limestones, shales, slates, and conglomerates, which do not bear evidence of mineralization and will not attract the placer miner. Locally, however, some of these rocks are mineralized and contain more or less gold. Thus on Nugget Gulch, a tributary of Washington Creek, slates of Cretaceous age are found which are permeated with quartz veins, some of which must yield gold, as the associated alluvium is auriferous. The writer was not able to study this locality, but it appears that the coarse gold occurs in small patches

[1] Brooks, A. H., Bull. U. S. Geol. Survey No. 314, 1907, pp. 189-190.

[2] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 353-354.

[3] Brooks, A. H., op. cit., pp. 198-199.

on the bedrock. This occurrence, though probably of small commercial import, has a far-reaching significance, as it indicates that there has been an intrusion of mineralized veins since these younger rocks were deposited. The writer is, however, of the opinion that this mineralization is not general enough to encourage the search for placers where these Cretaceous slates form the country rock.

Tertiary rocks.—In the area just described are gold-bearing stream valleys that lie entirely in areas of Tertiary conglomerate, indicating that the gold was present either in the conglomerate or in some alluvial deposit that may have overlain the conglomerate and may have been for the most part removed. The bowlders mentioned on page 33 include vitreous massive quartzite and hard Paleozoic conglomerate. Their position in the Tertiary conglomerate is not definitely known. Mining has shown that they are rather common in the gravels of the present streams. They have not been observed by the writer except near the summits of the ridges where the Tertiary conglomerate occurs—that is, near what is apparently the highest portion of the conglomerate—and in these positions they occur only as loose bowlders among weathered material, so that it was impossible to determine whether they formed a constituent of the conglomerate or of a deposit of high gravels coarser than the conglomerate. However, in view of all the facts available, it seems probable that these bowlders formed a part of the conglomerate, probably about its highest part, and that the placer gold in the creeks was deposited with the gravels of the conglomerate rather than derived from a bed of alluvial deposits that formerly may have veneered the area in which the placers occur. Nevertheless, in considering the origin of the placer gold the possibility of its derivation from high-lying gravels that have in part been removed and in part merged with the weathered conglomerate can not be left out of consideration. As more detailed work is done further facts bearing on the problem may be discovered.

The material of the conglomerate has been derived from the older rocks, which have in places been auriferous. It would be perfectly natural, therefore, for placer gold to be present in the conglomerate, perhaps irregularly distributed and nowhere concentrated or perhaps confined to some particular horizon. However, even if confined to a particular horizon it was probably not sufficiently concentrated to form deposits of economic importance.

Igneous rocks.—The occurrence of gold in the quartz veins and silicified areas in the quartz diorites of Mosquito Fork has already been described. (See pp. 49–50.)

Primary source of gold in bedrock.—Igneous rocks are present in all the chief placer-mining districts of the region and are generally close to localities where gold has been found in bedrock. They have been active agents in opening the rocks to the influence of percolating solutions and have supplied heat to maintain for a long period the mobility of materials by keeping them in solution. The hot springs which are common close to granitic masses in different parts of the Yukon-Tanana region indicate the long continuance of the heat derived from igneous rocks. The point might be raised that important placers have been found only in the vicinity of small areas of igneous rocks and not around large areas like those present in the Circle quadrangle, and it is possible that the conditions for deposition are more favorable around the smaller masses. The same fact has been observed in California.[1] The most important mineralization apparently took place in the later part of the Mesozoic era.

PLACER GOLD.

Placer gold occurs in bench gravels and in the gravels of the present streams. The bench gravels occur at elevations not exceeding 500 feet above the level of the present streams, and but few of them have been found rich in placer gold. Most of the gold is found in the deposits of the present streams. These deposits vary greatly in thickness. Most of those of the Fortymile and Circle districts, and a part of the Rampart district, are comparatively shallow, and most of those of the Fairbanks district are deep, some of them measuring more than 300 feet. The greatest part of the alluvial deposits are more or less permanently frozen, in places to depths of more than 300 feet, but the distribution of frozen ground is irregular, depending on drainage conditions. In the Ester Valley, in the Fairbanks district, for example, about 100 feet seems to be the limit of the frost; below that level a large amount of live water is present in the gravels.

The stream deposits are generally separable into an upper layer of fine clayey and sandy material known as "muck," an intermediate bed of barren gravel, and a lower bed of auriferous gravel, ranging from a few inches to 6 feet or more in thickness. The productive gravels are almost invariably next to bedrock. Most of the gold is found close to bedrock, or, where this is blocky, in cracks and crevices to a depth of a foot or even 3 feet or more. The width over which the gold is found in sufficient quantity to pay for working under present conditions ranges from a few feet in the narrow valleys to several hundred feet in some parts of the wider valleys. The average width for the Fairbanks district is about 150 feet. In exceptional valleys, like that of Cleary Creek in the Fairbanks country, the productive gravels have been found to be continuous throughout the length of the valley.

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[1] Lindgren, Waldemar, The Tertiary gravels of the Sierra Nevada of California: Prof. Paper U. S. Geol. Survey No. 73, 1911, p. 65.

GOLD IN THE CIRCLE QUADRANGLE.

The bulk of the gold from the Circle quadrangle has been obtained in the Birch Creek district. A small amount is obtained annually from creeks tributary to the Yukon above Circle and a little has been obtained from the Seventymile, Fortymile, Salcha, and Chena drainage areas.

BIRCH CREEK DISTRICT.

GENERAL FEATURES.

Since its discovery in 1894 the Birch Creek district has been a continuous producer of placer gold. It has held its own in spite of discoveries made in other regions, and with the introduction of new methods of mining it is still maintaining its production. The following table shows its annual gold production from 1894 to 1911, inclusive, and the amount of silver contained in the gold.

Production of gold and silver from Birch Creek district, 1894–1911.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Quantity.	Value.	Quantity.	Value.		Quantity.	Value.	Quantity.	Value.
	Fine ounces.		*Fine ounces.*			*Fine ounces.*		*Fine ounces.*	
1894	483.75	$10,000	123	$77	1904	9,675.00	$200,000	3,144	$1,823
1895	7,256.25	150,000	1,886	1,226	1905	9,675.00	200,000	3,144	1,918
1896	33,862.50	700,000	8,794	6,080	1906	14,512.50	300,000	3,773	2,565
1897	24,187.50	500,000	6,289	3,773	1907	9,675.00	200,000	3,144	2,075
1898	19,350.00	400,000	5,031	2,968	1908	8,465.63	175,000	2,212	1,166
1899	12,093.75	250,000	3,144	1,886	1909	10,884.37	225,000	2,830	1,472
1900	12,093.75	250,000	3,144	1,886	1910	10,884.38	225,000	2,830	1,528
1901	9,675.00	200,000	2,512	1,507	1911	16,931.25	350,000	4,402	2,333
1902	9,675.00	200,000	2,512	1,331					
1903	9,675.00	200,000	3,144	1,698		229,055.63	4,735,000	58,914	37,212

The creeks of economic importance in the Birch Creek district flow from the ridge between the valleys of Crooked Creek and North Fork of Birch Creek and include tributaries of both. The principal gold-producing creeks tributary to Crooked Creek are Deadwood, Mammoth, Mastodon, Independence, and Miller; those tributary to Birch Creek are Eagle (with its tributary, Mastodon Fork) and Harrison. Several other creeks have produced small amounts of gold.

These areas have been visited frequently by parties from the Geological Survey and have been described in reports named in the list of publications. (See pp. 10–11.) These reports have been freely drawn upon in the preparation of the following description:

Most of the valleys are similar in development, having about the same length, width, and grade and carrying about the same amounts of water. Deadwood, Mastodon, and Miller valleys are all limited on the east by a steep slope (Pl. XIII, *A*), close to whose base the streams flow over a flat having a maximum width of a few hundred feet. West of the flat is a gradually rising slope more or less benched, a few hundred feet to a quarter of a mile in width, which merges with the gradually sloping ridges that form the west sides of the valleys. This unsymmetrical type of valley is very common. On some crests where the stream gravels have been worked out mining has been attempted on the benched slopes, and some productive ground has been found.

All the placer ground is within areas where the Birch Creek schist forms the bedrock. Some local intrusions of porphyritic biotite granite and a few basic dikes are present.

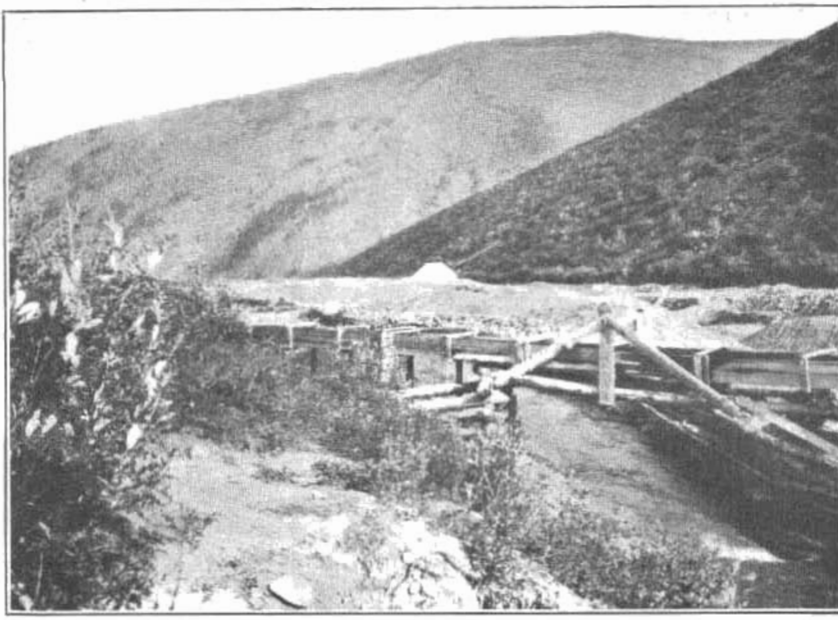
The gravels, which are composed entirely of the varieties of bedrock outcropping in the valleys, consist mostly of subangular and angular fragments of quartzite schist and quartz-mica schist and considerable vein quartz. Most of the pieces are small, not exceeding a foot in diameter, and are mixed with finer material of the same nature. The proportion of bowlders is small. The thickness of the deposit ranges from a few feet to 30 feet, but where most of the mining has been done generally does not exceed 8 feet.

The gold is found mostly close to bedrock, and the ground has been mined to a width of over 200 feet. Most of the gold is rather fine, the coarsest nuggets found weighing only 3 to 4 ounces. Considerable areas have yielded about 25 cents to the square foot of bedrock. Other areas, however, have yielded much larger amounts, and in 1903 some of the ground was reported to average $1 to $2 to the square foot. The average value of the gold has been reported by miners to be $17.73 an ounce. That from Eagle Creek has a somewhat higher value.

PLACERS.

DEADWOOD CREEK.

Deadwood Creek, which is about 20 miles long, heads in a ridge over 3,000 feet high and enters Crooked Creek at an elevation of less than 1,000 feet. Its valley is divided into two portions—an upper narrow portion about 12 miles long, and a lower portion about 8 miles long, where the valley merges in that of Crooked Creek. The stream flat, which in places is several hundred feet wide, is close against the steep east side of the valley. A more or less well-defined bench with a maximum width of several hundred feet rises gradually on the west from a level about 20 feet above the stream. Switch Creek, the most important tributary, is about 3 miles long and enters Deadwood Creek through a narrow V-shaped valley about 3 miles above the point where the main stream leaves the hills.



A. VIEW DOWN MASTODON CREEK.

B. VIEW UP EAGLE CREEK.

The bedrock in most of the valley is rather massive, blocky quartzite schist and quartz-mica schist. The rocks show minor folding and contain numerous small quartz stringers. Intrusive granite is very conspicuous in the region farther east, especially on Ketchum Creek, only a few miles east of Deadwood Creek, where weathering has carved it into some very striking pinnacled forms. On Deadwood Creek it is not so conspicuous, but forms the bedrock for about a mile. Near the mouth of the valley a diabasic dike was observed.

The gravels are composed of the varieties of rock mentioned. They consist of subangular fragments, mostly under a foot in diameter, more or less irregularly arranged in much finely broken material of the same nature. The depth to bedrock in the creek ranges from 3 to 12 feet and on the bench to the west, so far as known, from 6 to 20 feet. The gravels in the creek have a maximum thickness of about 8 feet and lie beneath a generally thin overburden. Some gold is found through the whole thickness of gravel, but most of it lies close to bedrock or in bedrock to a depth of 2 feet or more. Where the bedrock is massive and is divided into blocks through jointing, gold may have penetrated to a depth of 4 feet along the joint planes. The width of the pay gravel ranges from about 25 to 300 feet, the average being 175 feet. The average tenor of the ground for the entire creek is said to have been about 25 cents to the square foot of bedrock, but some ground has averaged much more, 50 cents to more than $1 per square foot having been obtained. Little is known of the extent or tenor of the gravels of the bench. In a few places, however, gold has been found, and at one locality it was reported to average more than $1 to the cubic yard of dirt moved. Two nuggets worth $8 and $10 were found. The gold on the creek is generally flattened and at the entrance of the valley is rather flaky; the largest piece recorded was valued at $122. That found on the bench is rougher and thicker.

More than a hundred 500-foot claims have been staked on Deadwood Creek and more or less work has been done on about 70 of these. Gold has been found in commercial quantities from a point about a mile above the mouth throughout the length of the creek. Switch Creek also carries pay gravel. Nearly all the mining on Deadwood Creek has been done by small operators using simple methods. In the lower mile of its course, where its valley broadens and gradually merges with that of Crooked Creek, the gold is more disseminated and is not susceptible to profitable exploitation by crude hand methods. This part of the field is worthy of careful examination by those looking for dredging ground. At a point half a mile above the mouth of the valley the depth to bedrock is only 10 feet. It does not seem probable that the bedrock floor slopes more than

25 feet to the mile, and therefore it is not to be expected that the depth to bedrock between this point and the mouth of the valley will be found to be more than 35 feet.

Among the minerals associated with the gold are wolframite and cassiterite. The occurrence of these minerals in the placer deposits of Deadwood Creek was studied in 1909 by Johnson,[1] who says:

> No exposures of the wolframite or cassiterite in place were seen. A small wolframite-bearing vein was reported to have been found in a prospect hole, sunk while prospecting the high-bench gravels for gold, on the high bench west of Deadwood Creek, near the junction of Deadwood Creek and Discovery Gulch. At the time of the writer's visit this prospect hole had caved in and was filled with water. No wolframite could be found on the dump.
>
> Wolframite and cassiterite occur most abundantly in the placer gravels of Deadwood Creek a short distance below the mouth of Discovery Gulch. Concentrates collected from the sluice boxes here are composed principally of these two minerals. Placer wolframite is also reported from Discovery Gulch. It is not known to occur in the stream gravels of Deadwood Creek above the mouth of this gulch, nor has any been detected in the examinations of the concentrates collected above this point. It is not known whether these minerals are present in the high-bench gravels. The placer wolframite is found on all the creek claims on Deadwood Creek for at least 4 miles below Discovery Gulch, but it is not as plentiful on the lower claims as above the mouth of Switch Creek. The coarsest and most abundant wolframite and cassiterite are found on the west side of Deadwood Creek, a short distance below Discovery claim. The wolframite occurs in water-worn cleavage fragments, with slightly rounded edges. The color and streak are both dark brown. The largest piece seen measured 1.7 by 0.8 by 0.8 inches, but pieces three times as large as this are reported to have been found. The largest piece of cassiterite observed in the concentrates measured 1 by three-fourths by one-half inch. Most of the concentrates collected, however, passed through an 8-mesh sieve.
>
> Concentrates from several claims on Deadwood and Switch creeks were examined. Associated with the gold in the concentrates were found wolframite, cassiterite, magnetite, ilmenite, arsenopyrite, pyrite, galena, limonite, garnet, tourmaline, and quartz. Wolframite was not detected in the Switch Creek concentrates. Cassiterite was found in all the concentrates examined, but most abundantly in those from Deadwood Creek between Discovery Gulch and Switch Creek. Magnetite was very abundant in the Deadwood Creek concentrates, but nearly absent from those collected on Switch Creek. The sulphides—arsenopyrite, pyrite, and galena—were found principally on Switch Creek.

BOULDER CREEK.

Placer gold has been found on Greenhorn Creek, a small tributary of Boulder Creek. The ground is shallow, but lack of water has prevented mining.

MAMMOTH CREEK.

Mammoth Creek has a broad flood plain 100 to 500 yards wide. The bedrock is chiefly schist but is cut by a continuation of the granite of Kechum and Deadwood creeks. The granite forms bowlders

[1] Johnson, B. L., Bull. U. S. Geol. Survey No. 442, 1910, pp. 246-248.

4 or 5 feet in maximum diameter. The slope of the bedrock is low. The alluvium is from 10 to 15 feet deep, most of it being about 10 feet. The upper 2 to 3 feet is overburden. The gold is rather fine and is reported to be rather uniformly distributed.

INDEPENDENCE CREEK.

Considerable gold has been taken out of Independence Creek. The valley floor is about 100 yards wide at its mouth, but narrows sharply upstream. The distribution of productive ground appears to be irregular and to swing from one side of the creek to the other. The gravels are from 3 to 9 feet deep. Some well-defined benches are present.

MASTODON CREEK.

The headwaters of Mastodon Creek are gathered from an amphitheatral area on the northern slopes of Mastodon Dome, 4,400 feet high, about 7 miles southwest from the point where the creek enters Mammoth Creek. The valley is bounded by even-topped spurs, which slope gradually in a direction parallel to the creek at an altitude of about one-fourth mile above it. The valley is unsymmetrical in cross section, the stream in its lower portion flowing near the steep ridge on the east and being bounded on the west by a bench that rises with a steep grade to the base of the spur. The valley floor is about 400 yards wide at its mouth, and gradually narrows to about 200 yards 2 miles above.

Quartzite schist and mica schist containing many small quartz veins are the most common varieties of bedrock. Small granitic dikes also occur. The strike of the schistosity is usually across the stream and the dip is to the south.

The gravels include subangular fragments of the bedrock, fine material of the same nature, and some sand and clay. Much of the gravel is but little worn and its arrangement is generally more or less irregular. The average depth to bedrock is 10 or 12 feet, the maximum about 20 feet. In some places muck, which attains a thickness of about 4 feet, lies on top of the gravels. The maximum of overburden is about 7 feet. In some places the gold is scattered through the gravel and in others it lies close to bedrock or a few feet within it. It is generally rather fine, the coarsest piece found thus far weighing only 3 or 4 ounces. It is reported to assay from $17.35 to $17.38 per ounce. Some of the ground averages $2 to $3 a cubic yard and some of it is considerably richer. The lowest 2 miles of the valley is the richest portion and contains the largest body of productive gravels, which attain in places a width of 200 feet.

MILLER CREEK.

The valley of Miller Creek is similar in its essential features to that of Mastodon Creek. The unsymmetrical character is particularly well developed, the steep east side of the valley so overshadowing the upper portion of the creek that the ice lingers there till late in the season and prevents mining operations.

The bedrock consists of quartzite and quartzite schist veined with quartz. Granitic dikes occur on the divide between Miller and Eagle creeks. The gravels are similar in character and arrangement to those on Mastodon Creek. The depth to bedrock varies from 8 to 16 feet, of which 4 to 8 feet is overburden. In a few places a clay, which has been found to be as much as 3 feet in thickness, intervenes between the gravels and bedrock and contains most of the gold.

The gold is about the same as that of Mastodon Creek. Pieces weighing an ounce have been found, but most of it is rather fine. That near the head of the creek is rough. The gold is scattered through several feet of gravel over a maximum width of about 50 feet. Some of the ground has averaged about $1.20 to the cubic yard. The creek has never been a large producer but has been worked more or less continuously since 1895.

EAGLE CREEK AND TRIBUTARIES.

Two small streams, Mastodon and Miller forks, unite to form Eagle Creek, a tributary of Birch Creek. Mastodon Fork heads on the northwest slope of Mastodon Dome and flows through a narrow V-shaped valley about 3 miles long to Miller Fork. The bedrock and gravels are similar to those of the other creeks described. As on Miller Creek, clay is in many places found next to the bedrock of quartzite schist. The depth to bedrock ranges from 8 to 10 feet or more, there being in some places 3 to 4 feet of overburden and 4 to 5 feet of productive gravels. Where clay occurs along with the gravels, much of the gold is found in seams in the clay a few inches above bedrock. It is also found in the bedrock to a depth of 3 feet. The gold is said to occur irregularly on the creek. Some ground has been very good and has yielded from $2 to $4 a cubic yard. Much of the gold is coarse. A flat nugget found during the season of 1903 was 2 by 1¼ inches in size and weighed 2½ ounces; some quartz was attached, and the nugget appeared to have been derived from a seam in the bedrock.

Eagle Creek is about 4 miles long. The valley widens sharply below the junction of the forks to one-fourth mile or more. Work has been done for about 2 miles below the junction. The depth to bedrock ranges from 14 to 18 feet. The bedrock and gravels are similar to those on other creeks. There is about 6 feet of overburden, and gold, ranging from 50 cents to over $2 a square foot of bedrock, has been found in about 6 feet of gravel over a width of 30 to 80 feet. Some of the gold is coarse, one piece worth $74 having been found. The grade of the gold of Eagle Creek and Mastodon Fork is the highest found in the Birch Creek district.

HARRISON CREEK.

Brooks[1] describes Harrison Creek substantially as follows:

Gold was found on Squaw Gulch, a tributary of Harrison Creek, as early as 1894, and considerable work was done on the main stream up to 1896. As no high values were found, Harrison Creek was neglected for richer placers, and it is only within the last few years that the problem of working its relatively low-grade deposits has been seriously considered.

The creek has two forks, North and South, on both of which gold has been found, but only the former is now being developed. One of the first discoveries of gold in the basin was at Pitkas Bar, at the junction of the forks.

Only the upper part of North Fork was visited. The flat valley floor is 200 to 300 yards wide. There is a steep slope on the south side, but on the north the slope rises more gently and is deeply covered with talus. There are no excavations in this slope, and no topographic evidence of benches was noted, but it seems possible that benches may exist beneath the slide material. Farther downstream the valley gradually contracts and it is said to become a steep-walled canyon before it joins South Fork, whose valley is somewhat broader and appears to be more symmetrical. From the junction the valley continues to broaden until it merges with the Birch Creek valley 12 miles below.

The bedrock on North Fork is probably chiefly quartz-mica schist, but the occurrence of some pebbles of granite in the alluvium indicates the presence of that rock within the basin. Few bedrock exposures were seen, but the character of the alluvium indicates that the schists are cut by numerous quartz veins, many of which are stained with iron, indicating mineralization. A slab of schist cut by a gold-bearing quartz vein was found near the forks.[2]

Just above the canyon the depth to bedrock is said to be 20 feet. Six or seven miles above, near Discovery claim, the depth is 8 to 9 feet on the north side of the valley near the center and only 3 or 4 feet near the south wall. A mile or more still farther upstream the depth

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[1] Bull. U. S. Geol. Survey No. 314, 1907, pp. 195-197.

[2] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 353-354.

is 8 to 12 feet. In this part of the valley the grade of the stream and of the bedrock floor is probably about 75 to 100 feet to the mile. Although no accurate data are available, the reconnaissance maps indicate that about the same grade continues throughout the basin.

Well-rounded gravels characterize the alluvial deposits so far as seen. Bowlders more than 2 feet in diameter are uncommon, though some measuring 3 feet were observed. Much the greater part of the material is schist, with some quartz and a little granite. The gravels are well stratified, are loose, and so far as known are not frozen. Their condition has prevented the creek from being thoroughly prospected, because the water flows in the gravel throughout the year.

Little turf or muck rests on the gravels, and the whole section is in most places made up largely of sand and gravel. Most of the bedrock is weathered and is broken by seams of clay, a secondary product, but so far as seen by the writer there is no well-defined stratum on the bedrock at the base of the gravels.

The gravels of both forks are known to be more or less auriferous. At a number of localities some gold has been mined by pick and shovel, but the tenor of the gravels, so far as determined, is too low to pay for working by this method. It is reported that as high as $5 a day has been made on this creek. The gold appears to be rather evenly distributed both horizontally and vertically. There is, however, a marked concentration in the lower 3 to 5 feet of the gravels, and much of the weathered schist carries gold to a depth of 1 to 2 feet. The gold is fine, flaky, and bright-colored. The largest nugget reported, with a value of $4, was found on the upper part of the creek. There has not been sufficient prospecting to determine the value of any considerable body of gravel; 5, 10, and 30 cent pans are reported from bedrock, but these of course can not be considered an average. Near the Discovery claim 13 pans taken from gravel near bedrock are said to have yielded about $1 worth of gold. Considerable garnet and pyrite occur with the concentrates.

MINING DEVELOPMENT.

Mining in the Birch Creek district, on account of the comparative shallowness of the alluvial deposits, has been carried on almost entirely by open cuts and shoveling into sluice boxes. Modifications of this method have from time to time been introduced. Automatic dams, for example, are used on some of the creeks. The use of bottomless scrapers for removing the overburden and bringing the gravel to the boxes has been employed with success, notably on Mastodon Creek. Summer work can be carried on ordinarily from about the middle of May to the middle of September. A small amount of ground is deep enough for drifting, and this method is employed to a small extent during the winter.

In 1903 the first power plants were used, and later, with the construction of ditches, the hydraulic method was introduced. (See Pl. XIII, *B*, p. 60.) This method has been found successful and, with modifications made necessary by the low grade of the creeks, is being rapidly extended wherever the conditions will permit. The process employed on Mammoth Creek is described by Ellsworth [1] as follows:

Mammoth Creek has a very low grade, and in order to overcome this difficulty a plant was installed which is novel in Alaska but is identical in principle to the one installed on Eagle Creek in 1908. The general plan of operation is as follows: First, a bedrock drain is excavated to dispose of the water in the cut and to carry away the overlying muck, which is hydraulicked off from the gravels to be handled by the first set-up. A channel is then groundsluiced back of and above the cut and opposite the hydraulic giants. In this channel substantially constructed sluice boxes (with block riffles), similar in design to those ordinarily used in hydraulicking, are set up with a grade depending on the character of the gravels to be washed. A sheet-iron back stop about 10 feet high is then erected back of and against the boxes. The auriferous gravels are driven directly by the water from the nozzles of the giants against the back stop, from which they drop into the sluice boxes. A gravel incline is formed in front of the boxes by the stream of water as soon as operations are begun, and for this reason the force of the moving gravel is not expended against the sides of the boxes. The water for transporting and washing the gravel, after it is dropped into the boxes, is diverted from the creek about 1 mile above and carried in a ditch to the head of the sluice and after passing through is carried away in the bedrock drain. The tailings which accumulate at the end of the sluice are "piped" back out of the way by a separate giant set up at any convenient place. It is not ordinarily necessary to operate this giant continuously. The frequency with which the tailings have to be moved depends on the dumping room at the end of the boxes and the rate at which the gravel is being moved. This process does, however, require a quantity of water which should be taken into account in considering the supply necessary for such a system.

This method is especially adapted to working creek deposits with medium depths of gravel, where the slope of the bedrock is insufficient to permit the removal of the tailings by gravity. It has several advantages over elevators. The initial expense is less and the water required is less. No such heavy parts are required, which is an important item, especially in the more remote districts, where transportation is always expensive and often uncertain. The cost of set-ups is not as great and the chances of delay incident to repairs and replacement of parts are no greater than in ordinary hydraulicking.

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[1] Ellsworth, C. E., Bull. U. S. Geol. Survey No. 442, 1910, p. 237.

WATER SUPPLY OF THE CIRCLE DISTRICT.

By C. E. Ellsworth and G. L. Parker.

GAGING STATIONS AND MEASURING POINTS.

Gaging stations were maintained or discharge measurements made in 1910 in the Circle district at the following places:

Gaging stations and measuring points in Circle district, 1910.

- Birch Creek drainage basin:
  - Birch Creek below Clums Fork.
  - Birch Creek at Fourteenmile House.
  - Fryingpan Creek below forks.
  - Great Unknown Creek near mouth.
  - Clums Fork at mouth.
  - McLean Creek at mouth.
  - North Fork of Birch Creek drainage basin:
    - North Fork of Birch Creek above Twelvemile Creek.
    - Ptarmigan Creek at mouth.
    - Golddust Creek 4½ miles above mouth.
    - Butte Creek at mouth.
    - Bear Creek at mouth.
    - Twelvemile Creek at mouth.
    - East Fork of Twelvemile Creek at mouth.
  - Crooked Creek drainage basin:
    - Crooked Creek at Central House.
    - Porcupine Creek above ditch.
    - Porcupine Creek below Bonanza Creek.
    - Bonanza Creek above ditch intake.
    - Mammoth Creek at Miller House.
    - Mammoth Creek ditch at intake.
    - Independence Creek at mouth.
    - Miller Creek at claim "No. 6 above."
    - Miller Creek at mouth.
    - Boulder Creek at trail crossing.
    - Deadwood Creek above Switch Creek.
  - Preacher Creek drainage basin:
    - Preacher Creek above Bachelor Creek.
    - Bachelor Creek below Costa Fork.
    - Bachelor Creek at mouth.
    - Costa Fork at mouth.

BIRCH CREEK DRAINAGE BASIN.

Birch Creek flows into Yukon River almost exactly on the Arctic Circle and about 25 miles directly west of Fort Yukon. Its mouth is about 5 miles west of the confluence of Chandalar River with the Yukon.

The drainage comes almost entirely from the south and west through a complex system of watercourses, and in outline the basin is extremely unsymmetrical. The headwaters interlock with those of Little Chena and Chatanika rivers and flow east for about 60 miles to the junction of the South Fork, where the stream makes an abrupt turn northward. About 12 miles beyond this point it leaves the mountainous country and enters the lowlands of the Yukon, through which it sluggishly flows in a meandering channel for over 100 miles, roughly paralleling the Yukon at a distance varying from 10 to 20 miles.

The principal tributaries are Clums Fork and South Fork from the south and east and North Fork and Harrison, Crooked, and Preacher creeks from the north and west. The headwaters of South Fork rise opposite those of Salcha and Charley rivers.

Monthly discharge of Birch Creek at Fourteenmile House for 1908 to 1910.

[Drainage area, 2,150 square miles.]

Month.	Discharge in second-feet.				Run-off (depth in inches on drainage area).
	Maximum.	Minimum.	Mean.	Mean per square mile.	
1908.					
June 26-30	1,190	1,020	1,090	0.507	0.09
July	2,630	847	1,140	.530	.61
August	1,620	825	1,080	.502	.58
September 1-29	6,070	900	2,150	1.00	1.08
The period, 96 days	6,070	825	1,423	1.48	2.36
1909.					
May 15-31	9,970	3,320	5,930	2.76	1.74
June	8,640	1,860	3,410	1.59	1.77
July	8,280	960	2,200	1.02	1.18
August	3,020	974	1,830	.851	.98
September	960	730	799	.372	.42
October 1-2	792	792	792	.368	.03
The period, 141 days	9.970	730	2,510	1.17	6.12
1910.					
May 13-31	6,620	3,200	4,790	2.23	1.58
June	6,000	1,160	2,500	1.16	1.29
July	5,460	551	1,430	.665	.77
August	1,880	432	950	.442	.51
September	3,280	1.040	1.620	.753	.84
October 1-6	1.140	1,080	1,090	.507	.11
The period, 147 days	6,620	432	2,010	.935	5.10

Monthly discharge, in second-feet, of Birch Creek and Fryingpan Creek for 1910.

Day.	Birch Creek below Clums Fork [a] (drainage area, 600 square miles).				Birch Creek at Fourteenmile House [b] (drainage area, 2,150 square miles).						Fryingpan Creek below the forks [c] (drainage area, 15.9 square miles).		
	June.	July.	Aug.	Sept.	May.	June.	July.	Aug.	Sept.	Oct.	June.	July.	Aug.
1	......	1,010	550	457	......	4,070	3,690	1,680	1,040	1,140	......	6.7	4.6
2	......	604	424	508	......	3,370	2,860	1,430	1,180	1,080	......	5.8	3.8
3	......	391	353	487	......	2,900	2,070	1,200	1,430	1,080	......	5.2	3.4
4	......	296	272	497	......	2,810	1,680	984	1,410	1,080	......	4.9	3.2
5	......	2,610	237	666	......	2,420	1,610	756	1,380	1,080	......	6.7	2.8
6	......	1,370	220	881	......	2,190	5,460	735	1,650	1,080	......	6.5	2.6
7	......	816	188	684	......	1,840	3,060	648	1,680	......	......	5.4	2.4
8	518	539	175	593	......	1,590	2,360	587	1,550	......	5.4	4.9	2.4
9	566	409	164	539	......	1,480	1,810	605	1,380	......	11.2	4.8	2.3
10	2,030	349	147	497	......	2,040	1,200	648	1,250	......	17.0	4.5	2.3
11	2,610	296	147	477	......	3,950	1,030	623	1,200	......	15.2	5.7	2.3
12	2,660	284	142	438	......	6,000	968	575	1,200	......	13.6	6.2	2.2
13	1,420	307	125	396	3,810	4,920	900	527	1,120	......	12.0	7.2	2.2
14	848	258	120	424	4,260	2,980	830	471	1,140	......	10.5	5.8	2.1
15	604	207	123	1,810	5,240	2,260	760	460	1,180	......	8.9	5.4	2.0
16	604	169	120	1,860	6,120	1,930	690	432	2,840	......	7.3	4.9	2.2
17	529	161	125	1,760	6,070	1,680	620	432	3,280	......	5.7	4.3	2.1
18	462	276	357	1,560	5,880	1,600	551	449	3,220	......	5.4	6.5	......
19	383	409	1,710	1,230	5,020	1,400	952	605	2,800	......	5.1	5.8	......
20	374	296	1,130	848	4,540	1,370	1,200	1,880	2,320	......	4.9	5.3	......
21	400	233	720	783	4,260	1,280	920	1,550	1,780	......	7.2	5.4	......
22	2,080	227	577	649	4,210	1,560	808	1,360	1,510	......	8.8	5.8	......
23	1,100	269	539	593	4,370	3,320	770	1,180	1,430	......	6.8	6.0	......
24	733	550	457	561	4,730	2,440	808	960	1,410	......	6.0	6.3	......
25	467	561	572	577	6,140	1,460	1,120	1,000	1,380	......	5.3	5.7	......
26	378	353	783	599	6,620	1,250	1,200	1,230	1,410	......	5.1	2.7	......
27	344	276	745	561	6,000	1,160	1,020	1,410	1,450	......	5.1	2.6	......
28	396	233	835	555	3,670	1,710	830	1,380	1,430	......	5.3	2.5	......
29	1,150	194	696	524	3,370	4,110	770	1,300	1,320	......	5.2	2.5	......
30	1,680	340	599	438	3,200	3,900	770	1,230	1,200	......	9.0	11.0	......
31	......	752	524	......	3,460	......	936	1,120	......	......	......	7.6	......
Mean	971	485	448	748	4,790	2,500	1,430	950	1,620	1,090	8.09	5.50	2.64
Mean per square mile	1.62	0.808	0.747	1.25	2.23	1.16	0.665	0.442	0.753	0.507	0.509	0.346	0.166
Run-off (depth in inches on drainage area)	1.38	0.93	0.86	1.40	1.58	1.29	0.77	0.51	0.84	0.11	0.44	0.40	0.10

[a] The discharges of Birch Creek below Clums Fork are based on a well-defined rating curve below 700 second-feet. Above 700 second-feet the curve was extended by means of the area and velocity curves, and it is believed to represent the true relation of gage height to discharge up to 2,000 second-feet.

[b] The discharges of Birch Creek at Fourteenmile House are based on a rating curve well defined between 500 and 2,300 second-feet.

[c] The discharges of Fryingpan Creek are based on a rating curve well defined between 2.5 and 5.5 second-feet.

Miscellaneous measurements in Birch Creek drainage basin in 1910.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
July 26	Great Unknown Creek near mouth	41.2	16.7	0.40
July 25	Clums Fork at mouth	172	118	.69
Do	McLean Creek at mouth	15.4	3.0	.20

NORTH FORK OF BIRCH CREEK DRAINAGE BASIN.

Eagle and Ptarmigan creeks, whose headwaters are opposite those of Crooked Creek, join to form North Fork of Birch Creek. Below the junction North Fork flows southwestward for about 7 miles to the mouth of Twelvemile Creek, whence it flows southward for about 8 miles and unites with Harrington Fork to form Birch Creek proper, which flows east to its confluence with South Fork, a distance of approximately 45 miles.

Named from the head, the main tributaries from the north are Fish, Bear, and Twelvemile creeks. From the south, in the same order, Golddust and Butte creeks are the only important streams.

Miscellaneous measurements in North Fork of Birch Creek drainage basin in 1910.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
July 28	North Fork of Birch Creek above Twelvemile Creek.	87.1	55	0.63
Do	Ptarmigan Creek at mouth	19.0	15.0	.79
July 27	Golddust Creek 4½ miles above mouth	9.5	8.6	.90
July 28	Butte Creek at mouth	9.2	2.2	.24
Do	Bear Creek at mouth	12.4	6.7	.54
July 13	Twelvemile Creek at mouth	44.5	18.9	.42
July 28	do	44.5	14.6	.33
June 9	East Fork of Twelvemile Creek at mouth	22.9	60.0	2.62
July 13	do	22.9	7.4	.32
July 28	do	22.9	9.2	.40

CROOKED CREEK DRAINAGE BASIN.

Crooked Creek, which is formed by the junction of Mammoth and Porcupine creeks, meanders through a rather broad valley for about 30 miles and discharges its waters into Birch Creek about 10 miles above Fourteenmile House. Not far below Central House the valley loses its identity in the flats of Birch Creek.

Mastodon and Independence creeks unite to form Mammoth Creek, which receives Miller Creek from the west about 2 miles below this junction. The total length of the portion of the stream called Mammoth Creek is less than 4 miles.

Deadwood and Boulder creeks are tributaries from the south, below and above Central House, respectively. They follow parallel courses about 3 miles apart, with a length of about 18 miles.

Albert Creek, the principal tributary from the north, drains the southern slope of the Crazy Mountains.

Daily discharge, in second-feet, of Crooked, Porcupine, and Bonanza creeks for 1910.

Day.	Crooked Creek at Central House [a] (drainage area, 161 square miles).				Porcupine Creek [b] above ditch intake (drainage area, 17.8 square miles).		Porcupine Creek below Bonanza Creek [c] (drainage area, 39.9 square miles).					Bonanza Creek [b] above ditch intake (drainage area, 7.9 square miles).	
	May.	June.	July.	Aug.	July.	Aug.	May.	June.	July.	Aug.	Sept.	June.	July.
1	......	139	348	173	15	23	......	100	38	42	9.7	38	19
2	......	173	173	91	12	17.7	......	82	29	31	9.7	32	15
3	......	225	112	74	10	11.4	......	102	23	25	9.5	36	10
4	......	234	74	61	9.2	11.4	......	85	19.7	22	9.3	30	9
5	......	126	112	50	14	8.8	......	73	48	17.8	10.9	29	32
6	......	139	192	45	11	7.1	......	64	38	10.9	12.4	23	25
7	......	112	112	32	5.0	6.7	......	49	27	12.6	12.4	20	14
8	......	102	74	29	5.0	6.7	......	43	23	11.6	11.8	20	12
9	......	91	68	......	3.7	5.4	......	68	24	10.9	11.6	24	13
10	......	300	61	......	5.0	5.0	......	131	19.9	10.5	11.3	42	10
11	......	255	56	......	4.5	4.5	......	92	18.1	10.5	11.3	35	9
12	......	212	50	......	3.7	4.0	......	77	17.2	9.7	11.3	30	8
13	......	173	45	......	3.7	4.0	......	60	17.0	9.7	10.9	21	8
14	......	139	40	......	4.0	3.7	......	46	15.6	9.3	11.3	16	7
15	173	112	36	......	4.0	3.7	......	44	10.9	9.0	38	15	5
16	173	102	33	......	2.9	3.7	......	55	10.1	9.3	40	19	5
17	112	112	30	......	3.0	3.2	......	46	10.5	9.3	32	16	5
18	102	102	255	......	30	3.7	......	36	71	9.5	26	12	30
19	91	82	173	......	27	......	......	41	40	9.3	22	14	18
20	112	74	126	......	17.7	......	......	57	28	9.9	17.6	19	13
21	126	112	102	......	12.8	......	......	174	24	9.8	......	28	11
22	139	348	112	......	10.1	......	......	134	22	9.8	......	30	10
23	112	255	126	......	9.2	......	......	62	22	9.7	......	27	11
24	139	173	112	......	11.9	......	......	49	29	9.7	......	24	16
25	212	112	91	......	11.4	......	......	36	25	9.7	......	15	12
26	112	91	74	......	9.6	......	......	36	20	10.3	......	18	9
27	74	91	61	......	8.4	......	......	43	18.5	10.7	......	18	8
28	50	173	50	......	7.1	......	......	46	12.9	10.5	......	20	8
29	173	397	40	......	7.1	......	51	76	16.2	10.1	......	35	8
30	234	448	32	......	62	......	73	60	173	9.9	......	30	27
31	300	......	212	......	41	......	127	......	74	9.7	......	......	30
Mean	143	173	103	69.4	12.3	7.43	83.7	68.9	31.1	12.9	16.4	24.5	13.5
Mean per square mile	0.888	1.07	0.640	0.431	0.691	0.417	2.10	1.73	0.779	0.323	0.411	3.10	1.71
Run-off (depth in inches on drainage area)	0.56	1.19	0.74	0.13	0.80	0.28	0.23	1.93	0.90	0.37	0.32	3.46	1.97

[a] Discharges of Crooked Creek at Central House are based on a rating curve well defined between 30 and 350 second-feet.

[b] The discharges of Porcupine and Bonanza creeks above ditch intakes are only approximate on account of shifting channel conditions.

[c] The discharges of Porcupine Creek below Bonanza Creek are based on a rating curve fairly well defined between 10 and 60 second-feet.

Daily discharge, in second-feet, of Mammoth and Deadwood creeks for 1910.

Day.	Mammoth Creek at Miller House [a] (drainage area, 37.1 square miles).			Deadwood Creek above Switch Creek [b] (drainage area, 21.3 square miles).				
	May.	June.	July.	May.	June.	July.	Aug.	Sept.
1	......	80	47	......	58	68	15.3	5.0
2	......	95	25	......	58	25	11.0	5.5
3	......	77	21	......	55	15.3	8.7	5.0
4	......	66	30	......	39	13.2	7.7	5.0
5	......	66	90	......	35	18.2	6.4	5.8
6	......	62	54	......	27	13.2	6.4	6.4
7	......	54	33	......	27	11.0	5.8	5.0
8	......	54	25	......	16.4	11.0	5.6	5.0
9	......	63	17.5	......	39	7.7	5.0	5.0
10	......	79	17.5	......	35	6.4	5.0	5.0
11	......	64	17.5	......	41	6.4	5.0	5.2
12	......	63	17.5	......	31	5.8	4.5	5.5
13	......	58	17.5	......	27	5.0	4.5	6.4
14	......	49	21	......	21	5.0	4.3	7.7
15	......	48	17.5	......	21	5.0	3.8	25
16	......	53	14.8	......	21	4.5	3.8	18.2
17	30	51	19.0	......	21	8.4	3.8	18.2
18	47	30	11.8	......	15.3	50	5.0	15.3
19	47	32	49	......	15.3	25	5.5	13.2
20	35	49	37	......	18.2	13.2	6.4	11.0
21	25	91	36	......	21	13.2	5.7	......
22	17.5	77	25	......	25	13.2	5.0	......
23	54	61	25	......	21	8.7	4.5	......
24	70	33	35	......	15.3	8.4	3.8	......
25	47	25	25	......	13.2	7.2	5.5	......
26	45	53	21	......	11.0	6.4	5.0	......
27	44	67	17.5	......	11.0	5.5	6.4	......
28	41	47	16.4	......	98	5.5	5.0	......
29	65	115	14.8	......	102	9.4	5.8	......
30	78	47	48	66	44	27	5.5	......
31	93	......	38	77	......	19.9	5.0	......
Mean	49.2	60.3	32.0	71.5	32.8	14.2	5.84	8.92
Mean per square mile	1.33	1.63	0.863	0.336	1.54	0.667	0.274	0.414
Run-off (depth in inches on drainage area)	0.74	1.82	0.99	0.25	1.72	0.77	0.32	0.31

[a] The discharges of Mammoth Creek below Miller House are obtained by adding to the discharge of the creek the amount of water diverted by the Mammoth Creek mining ditch. They are only approximate for certain periods during low water on account of insufficient data regarding the flow of the ditch.
[b] The discharges of Deadwood Creek above Switch Creek are based on a well-defined curve throughout.

Daily discharge, in second-feet, of Bonanza Creek ditch at intake for 1910.

Day.	May.	June.[a]	July.[a]	Aug.	Day.	May.	June.[a]	July.[a]	Aug.
1	......	18.9	19.0	17.6	21	......	18.9	10.5	......
2	......	19.2	13.0	13.1	22	......	0	10.2	......
3	......	21	9.6	10.2	23	......	0	10.5	......
4	......	23	8.4	8.4	24	......	24	15.7	......
5	......	23	28	6.9	25	......	14.4	11.9	......
6	......	20	20	......	26	......	15.7	8.7	......
7	......	17.3	13.3	......	27	......	17.3	8.0	......
8	......	16.0	11.5	......	28	14.7	16.9	0	......
9	......	20	12.4	......	29	14.4	26	0	......
10	......	22	9.4	......	30	13.2	28	26	......
11	......	23	8.4	......	31	15.0	......	27	......
12	......	23	7.7	......	Mean	14.3	17	11.6	11.2
13	......	20	7.7	......					
14	......	16.0	6.6	......					
15	......	14.2	0	......					
16	......	18.6	0	......					
17	......	15.4	0	......					
18	......	12.1	27	......					
19	......	13.8	17.6	......					
20	......	18.9	12.2	......					

[a] A change in the relation of gage height to discharge occurred during the period June 6 to July 15. Discharges for this interval were derived by the indirect method for shifting channels.

Miscellaneous measurements in Crooked Creek drainage basin in 1910.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
May 29	Mammoth Creek ditch at intake		33	
June 5	....do		34	
July 14	Independence Creek at mouth	13.2	4.6	0.35
July 23	....do	13.2	6.8	.52
May 29	Miller Creek at claim "No. 6 above"	7.2	11.1	1.54
June 5	....do	7.2	17.4	2.42
July 14	....do	7.2	3	.42
Do	Miller Creek at mouth	10.5	3	.29
July 23	....do	10.5	6	.57
July 21	Boulder Creek at trail crossing	38.8	25	.64

CREEKS TRIBUTARY TO THE YUKON.

GENERAL FEATURES.

The creeks tributary to the Yukon from the south above Circle within the Circle quadrangle are Woodchopper, Coal, and Washington. Fourth of July Creek heads within the quadrangle, but most of its valley is east of the eastern boundary. Its description is included, however, as it completes that of the area where work is in progress along the Yukon.

The belt of country drained by these creeks is 10 to 25 miles wide from east to west and is characterized by broad, undulating, more or less even-topped ridges rising about 2,000 feet above sea level. The valleys of the streams are deeply cut and comparatively narrow.

The bedrock includes the Birch Creek schist; several shales, cherty limestones, and igneous volcanic rocks belonging in part at least to the Devonian and Carboniferous; Lower Cretaceous slate and sandstone; and Tertiary conglomerate, sandstone, and shale; these are overlain by Quaternary silt, sand, and gravel. Granitic intrusive rocks are present round the heads of Coal and Woodchopper creeks.

The gold is believed to have been derived in part from Lower Cretaceous slates, in part from Tertiary conglomerate, and in part from the Birch Creek schist.

PLACERS.

WOODCHOPPER CREEK.

Woodchopper Creek was visited in 1906 by Brooks,[1] from whose description the following is quoted:

Woodchopper Creek, which is about 12 miles long, enters the Yukon from the west, about 30 miles above Circle. Its flood plain is about half a mile in width, and the alluvium is probably 8 to 15 feet deep. Five miles from the Yukon, Mineral Creek, the scene of some placer mining, joins Woodchopper Creek from the south.

[1] Brooks, A. H., Bull. U. S. Geol. Survey No. 314, 1907, pp. 203–204.

The floor of the Mineral Creek valley is 100 to 150 [feet] wide, and the slopes are broken by benches. Woodchopper Creek has a gradient of about 100 feet to the mile. Remnants of benches are to be seen along the creek, the highest of these being marked by the ridge on the northwest side, which is flat and slopes toward the Yukon.

In the lower mile of Woodchopper Creek only massive greenstones were observed. Above these is a belt of black slate and limestones about a mile wide that continues nearly to the mouth of Mineral Creek, where it is succeeded by friable conglomerates in a belt said to be several miles wide. Chert and quartz pebbles dominate in the conglomerate, which is only imperfectly consolidated and outcrops in few places. This fact often leads to its being mistaken for bench gravel by the prospector.

So far as known the gold-bearing alluvium is confined to those creeks that cut the conglomerate, which, therefore, appears to be the source of the gold. Mineral Creek and its tributary, Alice Gulch, are the only streams which have thus far been found to be productive. Prospects are reported from Grouse and Iron creeks.

At the mouth of Mineral Creek the alluvial floor of the valley is about 75 yards wide but narrows upstream. A mile upstream, at the mouth of Alice Gulch, it broadens out again into a basin about 75 yards wide. On the south wall of Mineral Gulch three well-defined benches were observed, having altitudes of about 20, 150, and 250 feet above the creek.

Muck is encountered on some claims to a depth of 30 feet; the gravels underneath vary in thickness from 2 to 5 feet and are made up chiefly of well-rounded quartz and chert pebbles. The pay streak lies in parallel channels 12 to 14 feet wide, as many as three of these channels having been found in a width of 80 feet. The pay streak under present systems of mining is from 1½ to 4 feet in thickness. A varying amount of bedrock is taken up, depending on its looseness. Apparently gold occurs in bedrock beyond the depth to which it can be profitably extracted. The bedrock appears to be chiefly conglomerate, but in some places a plastic clay, which may be a weathered shale interbedded with the conglomerate, has been encountered. Prospectors report that the values are found in the conglomerate but appear to be absent in the clay. The conglomerate bedrock is invariably iron stained, where found under the placers. Gold has been found in the lower benches of the creek, but the higher benches have not been prospected.

The gold in the creek bed is usually bright colored, but that of the benches is dark. Most of the gold is coarse, the largest nugget having a value of $30. The value of the gold as reported by the miners is $19.09 to $19.30 per ounce, which would make it the highest of all found in the Yukon province. Values of 5 to 50 cents to the pan on bedrock are reported, but there are no data available for the average tenor of the pay streak.

In 1911 gold had also been found in the valley of Woodchopper Creek, about a mile above the mouth of Mineral Creek. The valley at this point has a flat half a mile or more wide on the west side of the creek, and in this flat several hundred feet from the stream gold had been discovered. The bedrock is conglomerate. The depth to bedrock is about 22 feet and the thickness of gravel about 11 feet. A large proportion of the bottom gravels consists of granite bowlders from the head of the creek. Gold is reported to be present in the lowermost 6 feet of gravel over a width of about 70 feet. Good returns were reported.

COAL CREEK.

Mining was reported to be about as active in the lower part of the Coal Creek valley during 1911 as it was on Woodchopper Creek.

The most noteworthy discovery of the year was at a point about 15 miles from the mouth of Coal Creek, where gold was found in but near the southern limit of an area of Paleozoic rocks. The bedrock includes chert, shale, greenstone, and limestone. The depth to bedrock at the place where work was being done is about 7 feet and the productive gravels are reported to be 100 feet wide. The proportion of garnets in the gravels is large. Fragments and bowlders of garnetiferous schist are also common and the facts suggest that the placer gold has been derived from the Birch Creek schist, which outcrops around the head of Coal Creek.

WASHINGTON CREEK.

Brooks[1] visited Washington Creek in 1906. He describes conditions as follows:

Gold.—Washington Creek flows through a northward-trending valley, whose floor is from half a mile to a mile in width. The bedrock for the lower 3 miles of the creek is black slate or shale of Cretaceous age.[2] Farther upstream the creek cuts a greenstone and chert formation, probably of Devonian age, and 10 miles from the Yukon it crosses another belt of Cretaceous slate, which forms the bedrock in Nugget Gulch, a small southerly tributary. These rocks are succeeded to the south by a broad belt made up of a Tertiary conglomerate, sandstone, and shale series, which contains some lignitic coal seams. This belt of coal-bearing rocks has a width of at least 10 miles. Still higher up the valley older rocks are said to occur again.

Placer gold has been found at two localities in the Washington Creek basin—(1) in Nugget Gulch, about 9 miles from the Yukon, and (2) on Surprise and Eagle creeks, about 10 miles above. The placers on Nugget Creek consist of very much localized accumulations of coarse gold on bedrock. Values are so irregularly distributed that it is questionable whether they can be mined at a profit. The gold appears to have its source in the Cretaceous slates, and it is worthy of consideration at least whether the mineralization of the bedrock is not sufficiently localized to pay the cost of extraction. The upper locality was not visited by the writer, but from the best accounts the gold here appears to be derived from a conglomerate. The value of the total production of Washington Creek does not exceed a few thousand dollars.

Coal.—Washington Creek has been the scene of some ill-advised attempts at coal mining. Though there is considerable lignite in the basin, much of the money spent in development has been wasted on experiments in transportation rather than in testing the seams as to extent and quality. The coal openings are from 10 to 14 miles up the creek, and as the seams exposed appear to be of no better quality or greater thickness than others which lie much closer to the Yukon, the outlook for profitable exploitation is not hopeful. The seam examined by the writer, about 14 miles from the river, occurs in friable sandstone and shale, striking about east and west and dipping 30° N., and showed the following section. The exposure is on the north side of the valley, about 40 feet above the stream level.

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[1] Brooks, A. H., Bull. U. S. Geol. Survey No. 314, 1907, pp. 200–202.

[2] Collier, A. J., Coal resources of the Yukon: Bull. U. S. Geol. Survey No. 218, 1903, pp. 28–32.

Section of coal seam on Washington Creek.

	Ft.	in.
Roof, soft blue-gray shale.		
Shaly lignitic coal	2	6
Clay		2
Shaly lignitic coal	2	
Bone parting		2
Good lignitic coal	1	
Clay		5
Good lignite	1	
Clay shale		1
Impure coal (lignite)		3
Clay shale		2
Coal (lignite)	1	4
Clay shale		2
Lignitic coal with some partings	2	
Clay shale		3
Impure lignitic coal	1	
Good coal (lignite)		1
Clay shale	4	
Good lignitic coal with bone partings	1	4
Clay shale with some bone partings	4	
Covered, but probably no coal.		

The coal carries considerable sulphur. On burning it produces many clinkers. The ash has a reddish tinge. The following is an analysis of a sample taken from this same district a little lower down the creek:

Analysis of coal from Washington Creek.[1]

Water	13.48
Volatile combustible matter	43.74
Fixed carbon	39.68
Ash	3.10
	100.00
Sulphur	.24

The remarkably low percentage of ash suggests that this sample was taken from one of the minor seams and was not an average of the entire section exposed. Such a grade of coal could probably only be secured by hand picking after mining.

During 1905 and 1906 a company attempted to establish a winter transportation system to the Yukon by the use of a 100-horsepower traction engine, which was expected to haul five sleds, each of 10 tons capacity. While such a scheme might be feasible with a good roadbed, it proved entirely impracticable without one. This plan involves the storage of the coal hauled in winter for consumption during the summer months—a doubtful experiment, because the lignite slacks readily after being exposed to the air.

In spite of the adverse conditions of mining and low grade of coals in this field, it shares with other fields of the Yukon a prospective value. There can be no question that, with the present increase in the demand for fuel and the rapid destruction of the forests, the time is not far distant when the Yukon lignites will play an important part in the commercial development of the inland placer districts.

FOURTH OF JULY CREEK.

Fourth of July Creek rises about 12 miles from the Yukon and flows northeastward for the greater part of its course. Crowley Creek, its largest tributary, enters it from the east about 6 miles below its head.

[1] Collier, A. J., Coal resources of the Yukon: Bull. U. S. Geol. Survey No. 218, 1903, p. 31.

Four miles farther downstream Fourth of July Creek leaves its valley, crosses the flat of the Yukon in a northwesterly course, and about 2 miles beyond is reported to enter a slough on the Yukon about 2 miles below Nation, which is situated on the south bank of the Yukon about 4 miles below the mouth of Nation River. Michigan Creek, a neighboring stream on the east, leaves its valley at about the same distance from the Yukon as Fourth of July and is reported to enter the same slough about a quarter of a mile farther up the river.

The main part of the valley of Fourth of July Creek is about 2,000 feet below the level of the ridges and has a comparatively narrow stream flat from 200 to 400 feet in width. Above the mouth of Crowley Creek the valley has a steep eastern slope, close to which the stream flows, and a gentle benchlike western slope about 1,000 feet wide that merges with the base of the ridge. Below the mouth of Crowley Creek it is mostly narrower, till it nears the valley of the Yukon, where its floor widens and merges with that of the river. At this point it has a benchlike slope on the east half a mile or more in width. The grade of the creek is about 100 feet to the mile. The drainage area being comparatively small and the precipitation for the general area being low, averaging hardly more than 10 inches a year, the quantity of water is generally insufficient for mining. The timber resources are limited to a comparatively light growth of small spruce and a little birch and poplar. Some larger spruce timber is available in the valley of the Yukon.

The bedrock of Fourth of July Valley from the mouth to Crowley Creek is predominantly limestone, which at the point where the creek enters the Yukon Valley forms picturesquely weathered cliffs towering above the stream on its west side. Upper Carboniferous fossils are abundant in similar limestone near the mouth of Michigan Creek, and the limestones at both these localities are considered to be of the same age and are correlated with the upper Carboniferous limestones on the north side of the Yukon above Nation River, described by Brooks.[1] The limestones occur as massive beds that have been so folded as to be vertical at some localities; where cut by Yukon River they are conspicuous as open folds.

The bedrock from Crowley Creek to the head of Fourth of July Creek and around all the headwaters, so far as observed, is conglomerate continuous with the conglomerate of the Seventymile district, the age of which has been determined as Tertiary. Along Seventymile River these rocks have been closely folded and in many places are nearly vertical. Their structure on the ridges is for the most part obscured by the gravel into which they have weathered. It

[1] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 295–297.

has been rather definitely determined that the gold of the placers has been derived from this conglomerate, for the only portions of the Fourth of July Valley and its tributaries where gold has been mined are those areas where the conglomerate is the bedrock and where the streams have had no access to any other bedrock.

Fourth of July Creek is reported to have produced altogether about $50,000. Most of the work on the main creek has been confined to about six claims. The depth to bedrock averages about 9 feet and the thickness of gravel mined 5 to 6 feet. Most of the gravel is comparatively fine, with pebbles reaching about 6 inches as a maximum, but a few bowlders of quartzite and hard Paleozoic conglomerate 3 feet or more in diameter were observed. All the pebbles and bowlders observed were well worn, and there is little doubt that all have been derived from the Eocene conglomerate.

The gold is mostly close to bedrock, the greatest proportion of it being found in the lowest foot of gravel. The width over which it is found had not been determined. Most of it is flat and in rather thick flakes, as much as one-fourth inch in diameter. It is reported to range in assay value from $18.89 to $18.91 per ounce. Returns ranging from $8 to $75 a box length (144 square feet), with an average of about $25, are reported.

The most noteworthy feature of mining operations during 1911 was the introduction of mechanical means for working the gravels on a larger scale. A steam scraper, with 86 horsepower available, was put into operation during the first week in September, 1911, and was intended to be used extensively during the summer of 1912. It was transported during the summer from the Yukon under its own power for a distance of about 10 miles over the brushy valley at an average speed of about half a mile a day. The method used was to dig holes at regular intervals in the frozen ground, insert a large hook for a deadman and then pull the scraper forward on its foundation of logs by cables attached to the drum.

Open-cut work was being done in 1912 on Ruby Creek, which enters Fourth of July Creek about 3 miles above the point where the scraper was in use. The only bedrock in this valley, so far as observed, is the conglomerate. The depth to bedrock at places where mining was in progress is 12 to 15 feet. The gravel is made up of material derived from the conglomerate, and the gold is found in the lower 20 inches. Returns are reported ranging from $50 to $75 to the box length of 144 square feet.

MISCELLANEOUS AREAS.

SEVENTYMILE REGION.

Placer mining in the upper Seventymile region has been in progress on Flume Creek near the mouth and on Alder Creek. The ground on both these creeks is shallow. Several nuggets ranging from $1 to $19 in value have been reported from Alder Creek.

FORTYMILE REGION.

Gold Run, a tributary of Slate Creek, about 75 miles southwest of Eagle, has been mined more or less for several years. The bedrock is a rather coarse schistose sandy quartzite regarded as Paleozoic. The area is close to the large granitic mass to the north and west and the gravels contain abundant quartz. The gravels are shallow and are worked by open cut and automatic dam. They were being mined in 1904 and two men were working on them in 1911.

A small amount of mining has been done on Hutchinson Creek and its tributaries, Coldfoot and Montana creeks, for several years; five men were reported to be working there in 1910. There has been a small production from this area.

Some work has been done on the quartz prospects on Mosquito Fork. (See p. 49.)

SALCHA REGION.

The first mining in the Salcha region was done in 1905, Butte and Caribou being among the creeks then prospected. The bedrock of the region is mostly Birch Creek schist. The thickness of deposits that were at that time being worked ranged from about 20 to 36 feet. The gravels consisted principally of schist, with some granite, vein quartz, and greenstone. The main difficulty encountered was thawed ground.

Work has continued in the region and in 1910 good results were reported from No Grub and Caribou creeks, where about 20 men were employed on about five claims.

CHENA REGION.

Chena River and tributaries have been under investigation by prospectors since 1905. Gold has been found on a few creeks, but no results of importance have been reported.

FUTURE PROSPECTING.

The chief importance of these miscellaneous occurrences just described lies in the fact that they illustrate the widespread distribution of mineralization. It seems probable that when conditions for the transportation of supplies to remote portions of the quadrangle become more favorable remunerative results will be possible in some of these areas. Such widespread distribution of mineralization, furthermore, is an incentive to further work in prospecting, particularly in the schistose rocks in the vicinity of the granitic intrusives.

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