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THE CHISANA-WHITE RIVER DISTRICT ALASKA

BY

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CONTENTS.

ILLUSTRATIONS.

PREFACE.

By Alfred H. Brooks.

A number of Geological Survey parties (see pp. 10–11) have traversed the region drained by White and Chisana rivers. In 1914, however, there still remained a large unmapped area, and, moreover, some of the old exploratory surveys, not being up to the present standards, needed revision. For these reasons further work in this field was desirable. The reason for undertaking this work in 1914 lay in the interest excited by the Chisana placer district. The only developed resources in the region described in this volume are the gold placers of the Chisana district, which were discovered in 1913. There has also been considerable prospecting of copper lodes, but in the absence of railroad communication no copper has been produced. A few auriferous lodes have also been discovered in this field.

In the following report Mr. Capps presents evidence that the gold placers thus far developed have been formed because of certain local geologic conditions, which may, though it is hardly likely, be repeated in other parts of the field. The outlook for finding other placer deposits in this intensely glaciated region is not very favorable. On the other hand, there is evidence of rather wide distribution of both copper and gold mineralization, and the field is rather promising for the lode miner, provided it is made accessible by a railroad.

THE CHISANA-WHITE RIVER DISTRICT, ALASKA.

By Stephen R. Capps.

INTRODUCTION.

LOCATION AND AREA.

The Chisana-White River district, as the name is here used, comprises that portion of the White River basin which lies west of the international boundary and the headward portion of the Chisana River basin east of that river and south of the north front of the

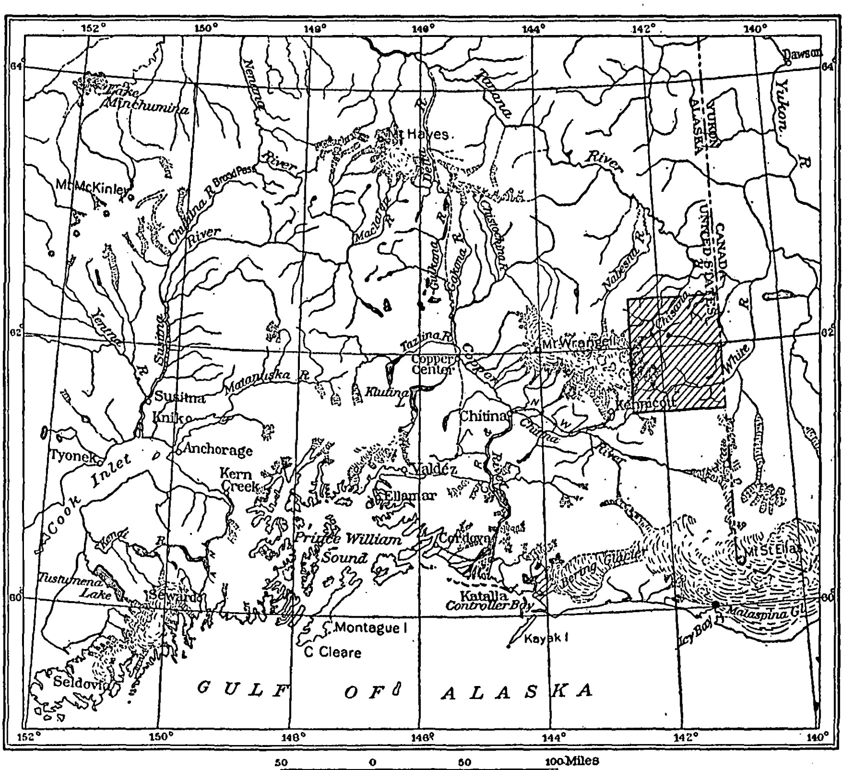


Figure 1—Index map showing position of the Chisana-White River district.

Nutzotin Mountains. For convenience it is made to include also the valley of Skolai Creek, although that stream lies within neither of the drainage basins mentioned but drains by Nizina and Chitina rivers into Copper River. The area as a whole is irregular in outline (see fig. 1 and Pl.I, in pocket) and is included between parallels 61° 30′ and 62° 40′ and meridians 141° and 142° 50′. It comprises an area of about 1,300 square miles and includes a part of the northern portion of the St. Elias-Wrangell mountain chain, a portion of the Nutzotin Mountains, and an intermontane area of lesser relief.

PREVIOUS WORK.

The recorded history of this portion of Alaska dates back only to 1891, when C. W. Hayes and Frederick Schwatka, who were conducting an expedition in the interest of a syndicate of newspapers and were accompanied by Mark Russell, a prospector, proceeded up Taku River, crossed the divide to the Teslin drainage basin, and traveled down to Fort Selkirk, on the Yukon. From Fort Selkirk they went southwestward on foot toward the head of White River. Beyond the Donjek they were in unexplored country, but, relying on information obtained from the natives, they sought and found at the head of White River a pass across the mountains to the Pacific slope and proceeded by way of Skolai Creek and Nizina, Chitina, and Copper rivers to the coast. Their expedition obtained the first authentic information on this region, and they established the fact that placer copper was present in the stream gravels of upper Kletsan Creek.

The next expedition which left a published record of its results was that of W. J. Peters and A. H. Brooks, in 1899. As a field party from the United States Geological Survey they carried an exploration from Pyramid Harbor to Yukon River. They reached Alaskan territory in the valley of White River at the international boundary, proceeded up that stream to a point near its head, followed the north base of the Wrangell Mountains across Chisana River to the head of the Nabesna, and thence moved northward to the Yukon at Eagle. During the same year the War Department sent Oscar Rohn and A. H. McNeer up Nizina River and Nizina Glacier to the summit of the Wrangell Mountains and thence down the Chisana Glacier, westward to the headwaters of Copper River, and down that stream to the coast.

In 1902 F. C. Schrader and D. C. Witherspoon, of the United States Geological Survey, carried the reconnaissance geologic and topographic mapping eastward from Copper River to the valley of Chisana River. In 1908 F. H. Moffit and Adolph Knopf, accompanied by the writer, resurveyed, geologically, a portion of the area previously visited by Schrader and carried both the geologic and topographic mapping eastward to the international boundary on White River. In 1913 D. D. Cairnes, of the Canadian Geological

Survey, spent some time in this area, on both sides of the international boundary. In 1914 A. H. Brooks wrote a brief account of the geologic and physical conditions to be found in the new gold-placer district.

The following reports contain the results of these investigations:

Hayes, C. W., An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, pp. 117–162, pls. 18–20, 1892.

Brooks, A. H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the upper White and Tanana rivers: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 333–391, 1900.

Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: Idem, pp. 393–445.

Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: U. S. Geol. Survey Prof. Paper 15, 1903.

Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska, with a section on the Quaternary, by S. R. Capps: U. S. Geol. Survey Bull. 417, 1910.

Cairnes, D. D., Chisana goldfields: Canadian Min. Inst. Bull. 24, pp. 33–64, 1914.

Cairnes, D. D., Upper White River district, Yukon: Canada Geol. Survey, Summary Rept. for 1913, pp. 12–28, 1914.

Brooks, A. H., The Chisana placer district, Alaska: U. S. Geol. Survey Bull. 592, pp. 309–320, 1914.

In addition to the listed publications above, a number of newspaper and magazine articles have been published on the gold-placer district discovered in 1913. These articles are, for the most part, popular and descriptive, and contain little scientific information.

PRESENT INVESTIGATIONS.

On the discovery of the Chisana gold placers in 1913 a considerable demand arose for more detailed information about that district than was available. The last geologic field work in this region had been done in 1908, and the area then visited covered only a part of the gold-bearing region. Furthermore, the supply of the report issued at that time was approaching exhaustion. It therefore seemed advisable to extend the topographic mapping northward into the unsurveyed portion of the region, to extend also the areal geologic mapping, and to examine the conditions under which the placer gold deposits occur. Accordingly two field parties were organized, one in charge of C. E. Giffin to carry on topographic work and one in charge of the writer to make the geologic investigations. The topographic party consisted of Mr. Giffin, his assistant, and three camp hands, with 10 pack horses. The geologic party was composed of the writer, a packer, and a cook, with 4 horses. Supplies for both parties had been sledded to Chisana during the previous winter, so that it was necessary to take at the start of the season only enough provisions to last until Chisana was reached. On June 10, 1914, both parties left McCarthy, and a few days later field work began in the upper Nizina basin. The topographic party continued field work until August 23 and returned to Chitina by way of Nabesna and Copper rivers. About 3,000 square miles of country was mapped (Pl. I, in pocket) on a scale of 1:180,000. Of this area about half had been previously surveyed. The geologic work comprised the areal mapping of the Skolai Creek valley and an area between White River and the crest of the Nutzotin Mountains (Pl. II, in pocket). In addition a special study of the geologic conditions in the vicinity of the Chisana placer mines was made, all the placer mines and many of the prospects were visited, and a number of copper and gold lodes were examined. The purpose of the investigation was to supplement the earlier reports that touched on this same area. Time was not available for revisiting all the copper prospects of the region, and this was unnecessary, for on most of them little development work had been done since they were examined in 1908. For the sake of completeness a number of copper properties not visited by the writer are described in this report, the descriptions being taken from the report by Moffit and Knopf, with such additional facts as were obtained. In the discussion of the geology, also, the writer has drawn liberally on the facts supplied by Moffit and Knopf, and the geologic interpretations here advanced are those which they reached, with certain modifications based on evidence that they did not obtain at the time of their field work. As the writer accompanied Moffit and Knopf on their expedition, he acquired a familiarity with the geography and geology of the whole region that was of great value in extending the geologic units which they had recognized eastward to the boundary.

GEOGRAPHY.

DRAINAGE.

GENERAL FEATURES.

The principal streams of the district here discussed are Chisana River, a tributary of the Tanana; White River, which flows to the Yukon; Beaver Creek, a branch of White River; and Skolai Creek, which drains to Copper River. With the exception of Beaver Creek, all these streams rise in glaciers, receive glacial tributaries, and are supplied in large part by waters from melting ice fields. Being of similar origin, they have many characteristics in common. All receive large amounts of rock waste from the glaciers during the melting season and are heavily loaded with gravel and silt. The valley gradients are steep near the stream heads but diminish downstream, so that the detritus is dropped to form glacio-fluvial deposits, which consist of coarse gravels near the glaciers but of progressively finer materials as the distance from the glaciers increases. The streams flow over their aggrading valley floors in a braided network of channels, the number of channels varying with the stage of water. In periods of extreme flood the streams may spread over almost the entire stream flat, forming a thin sheet of water of great width. In intermediate stages the maximum number of channels is reached, and in periods of low water the streams withdraw into a few of the deepest depressions and are comparatively clear. During the winter, when the glaciers are inactive, little water is discharged and the streams are free from sediment. In the summer the glacial rivers are subject to rapid fluctuations, having a pronounced daily rise during the hours of greatest glacial melting and a corresponding fall at night. Bright, sunny days or warm rains on the ice fields cause the stream discharge to be exceptionally heavy, and cold, cloudy weather diminishes it. In crossing these rivers on foot or horseback the traveler does well to acquaint himself with the causes which determine the stream flow, for streams that may be waded only ankle deep on one day may on the following day be rushing torrents of sufficient depth to swim a horse. By choosing a favorable ford and a time of proper weather conditions any of the rivers in this area may be safely crossed on foot during most of the open season.

CHISANA RIVER.

Chisana River heads in Chisana Glacier, one of the largest ice tongues in the Wrangell Mountains. From the glacier it flows northward through a broad, open valley as far as the Nutzotin Mountains, where it enters a deep, narrow gorge cut directly across the axis of that range. North of the mountains its course is northeastward to Tanana River, of which it forms the head. On the earlier maps the stream was called the Tanana to its source in the glacier. In that portion of its course between the glacier and the Nutzotin Mountains the river flows over a broad expanse of gravel and silt bars, with a multitude of branching channels. Through the Nutzotin Mountains the valley is also gravel floored, but the flat is narrow, and the stream flows in only a few channels, or as a single stream. Between the Wrangell and Nutzotin mountains the Chisana receives tributaries, from both the east and west, which flow through comparatively broad basins, separating the two mountain ranges. West of the river the intermontane depression is less well marked than to the east, where it forms a broad area of smooth-topped hills. Chathenda Creek is a tributary of the Chisana from the east. Its lower basin, containing the gold placer fields, lies between the two great mountain belts, although its headward tributaries drain portions of the south flank of the Nutzotin Mountains. Gehoenda and

Chavolda creeks, as well as some large streams within the Nutzotin Mountains, are also tributary to the Chisana from the east.

WHITE RIVER.

White River has its source in Russell Glacier, from which it flows for a few miles in a northeast direction, and then turns directly east to cross the boundary into Yukon Territory 28 miles from the glacier. In Canada it turns sharply to the north and joins Yukon River about 70 miles above the town of Dawson. In Alaska the river is fed from the mountains to the south and west by Lime, Middle Fork, Sheep, Holmes, Traver, and Kletsan creeks. All these tributaries are glacial streams heavily burdened with débris, and all have formed large alluvial fans that head at the mountain front and spread out to merge with the alluvial fill of White River. The tributaries from the north, namely, Solo, North Fork, and Cache creeks, receive their waters from an area in which there are no glaciers. They are therefore clear streams, discharge only the material eroded from their basins, and have relatively small alluvial deposits at their points of emergence in the valley of White River.

The main valley of White River, west of the international boundary, is a remarkable example of a valley in the process of vigorous aggradation by material supplied to the streams by glaciers. From the glacier to Pingpong Mountain the stream flows through a waste of gravel and sand bars which reach a width of 3 miles. Locally there are small patches of spruce trees or willow bushes, or a scant covering of low annual plants, but large areas are totally devoid of plant covering, and during the high winds which prevail there the sand and silt are blown about in clouds. Between the outwash fan of Holmes Creek and the boundary the deposition of gravel by streams from the south has been so rapid that White River is crowded against its north bank and spreads out much less than it does above that point.

BEAVER CREEK.

Beaver Creek flows eastward along the south flank of the Nutzotin Mountains and lies about 18 miles north of and parallel to the upper part of White River. It is fed from the north by Carl, Kline, and Horsfeld creeks and from the south by Flat and Ptarmigan creeks and a number of unnamed tributaries. In many of its characters it differs widely from the other large streams of the area. As it drains a district in which there are only a few minor glaciers, it is supplied by clear-water streams which are fed by the rains and melting snows. It heads in Beaver Lake and flows as a clear stream of moderate current in a somewhat winding course as far as the mouth of Carl Creek. Below that point it is entrenched somewhat in its valley floor, the inner valley becoming gradually deeper as the international boundary is approached. In flood times it becomes turbid, but ordinarily it is clear.

SKOLAI CREEK.

Skolai Creek drains a minor, westward-facing lobe of Russell Glacier, flows west for 15 miles, and disappears beneath Nizina Glacier to emerge as Nizina River, a tributary of the Chitina in the Copper River basin. Itself heading in a glacier, it receives several ice-fed tributaries, is heavily loaded with débris, and has built an extensive gravel fill near its head and another in its lower basin. The intermediate portions flow through narrow, rock-cut canyons. Near the upper end of the stream there is a considerable lake, whose waters are muddy from the influx of glacial silt. At the mouth of the stream also there is at times a lake, dammed by Nizina Glacier. The glacier periodically closes the subglacial outlet of this lake, which then rises rapidly until the hydraulic pressure is sufficient to reopen a channel beneath the ice. Once opened, the lake waters pour out with a rush, flooding Nizina Valley below and leaving icebergs stranded high on the sides of the deserted lake basin. This usually happens early in the summer, and the subglacial channel remains open until the following winter. In the winter the outlet is again cut off and the lake gradually refills, to repeat its periodic rise and disappearance.

GEOGRAPHIC NAMES OF STREAMS IN THE CHISANA DISTRICT.

It is unfortunate that there is some confusion in the use of names for a number of the streams in this district. Chisana River, the name used on Witherspoon's map of 1902, was approved by the United States Geographic Board and has appeared on all official maps since. Many prospectors in that vicinity have, however, persisted in pronouncing the name as if it were spelled "Shushana," and that spelling was for a time rather widely used by the newspapers in reporting the discovery of placer gold in 1913 and appeared on some sketch maps of the region. In a similar way the prospectors ignored the authorized names of other streams in that vicinity and rechristened Chathenda Creek as Johnson Creek, and Chavolda Creek as Wilson Creek. In 1914, with the establishment of a post office called Chisana, there was a growing tendency among the miners to accept that name for the river and glacier also, but in common parlance "Johnson" and "Wilson" were used to denote Chathenda and Chavolda creeks. In this report, however, the original, authorized names are retained, the local nomenclature being given in parentheses and only for the purpose of avoiding confusion.

RELIEF.

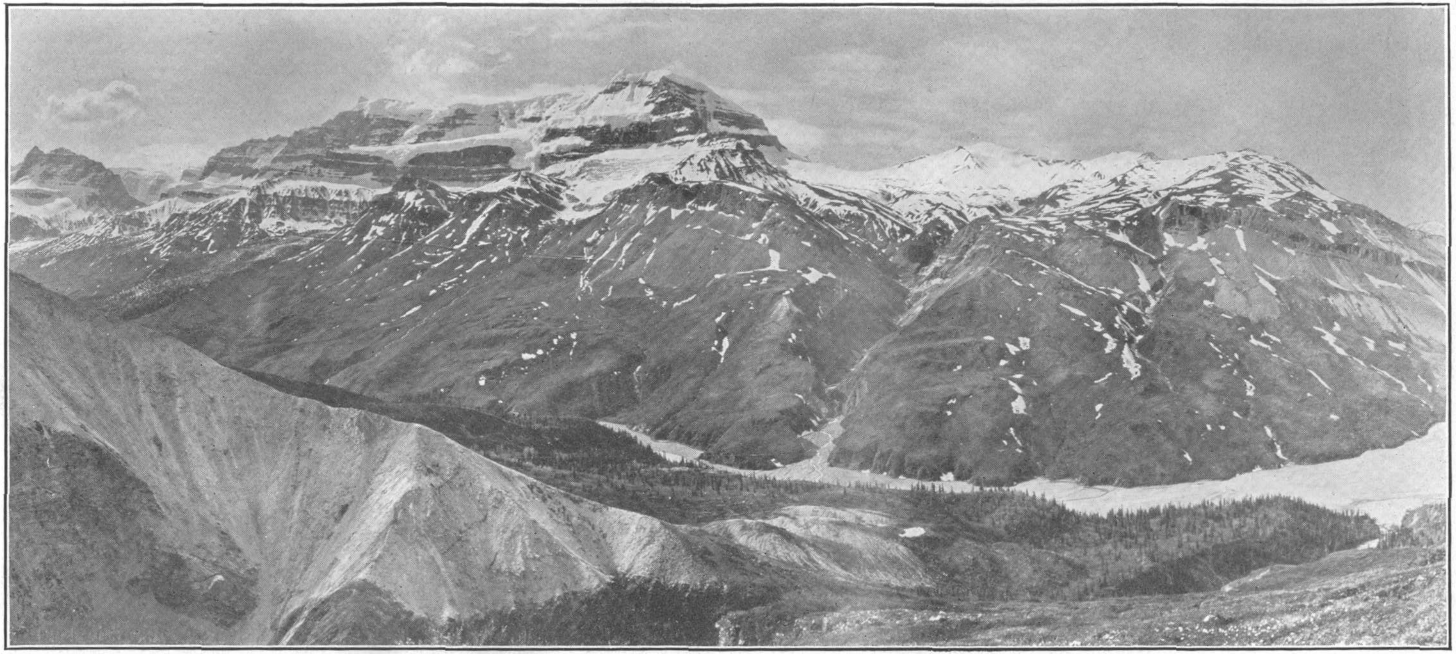
WRANGELL AND ST. ELIAS MOUNTAINS.

The Chisana-White River district may be divided into three distinct topographic provinces, consisting of the Wrangell and St. Elias mountain chain on the southwest, the Nutzotin Mountains on the northeast, and an intermontane area of lesser relief. The Wrangell Mountain mass is separated on the south by the broad Chitina Valley from the coastal Chugach and St. Elias ranges, and on the north by a series of lowlands and low passes from the Nutzotin Mountains. On its eastern border it merges into the St. Elias Range, a somewhat arbitrary boundary being drawn through Skolai Pass. Topographically and structurally the two ranges are continuous; the same rock formations continue from one to the other, and probably both masses responded to the same mountain-building forces. Both ranges are decidedly alpine in character. Many of the peaks and ridges, attacked on all sides by glacial erosion, are sharp and bordered by steep cliffs. Two peaks, Mounts Blackburn and Sanford, rise over 16,000 feet above sea level, and a large number of crests are more than 10,000 feet high. The St. Elias Range contains still higher mountains, but these lie to the southeast of this area and are not visible from it. The abrupt northern face of the St. Elias Mountains, south of White River, culminates near the international boundary in Mount Natazhat, a double-peaked mountain 13,486 feet in elevation, and this beautiful mountain dominates the landscape throughout the Chisana district. The Wrangell Mountains also have in this area a steep northern front, rising abruptly from the intermontane basin. Although they contain several peaks higher than Mount Natazhat, none of these are generally visible from the Chisana district, and the range gives the impression of a vast number of mountains of about the same height, no one peak greatly overtopping its neighbors.

The Wrangell and St. Elias mountains are the sources of unnumbered glaciers. In their higher portions all surfaces not too steep to prevent the lodgment of snow are glacier covered, and each range supports one or more ice caps. All the higher valleys are occupied by glaciers, many of which are large. As viewed from a distance, these ranges have perpetual snows above an elevation of about 7,000 feet, and on only a few sharp projecting ridges and steep cliffs can any rock surfaces be seen.

NUTZOTIN MOUNTAINS.

The Nutzotin Mountains, though also alpine in character, are in general much lower than the mountains to the south. They consist of a series of sharp ridges, separated by deep valleys, and the



CARBONIFEROUS LAVAS AND SEDIMENTS OVERLAIN BY YOUNGER VOLCANIC ROCKS ON LOWER SKOLAI CREEK.

See also fig. 4, p. 38.

topography is that of a severely glaciated mountain mass. The highest peak, Mount Allen, has an elevation of 9,489 feet, and the height of the mountain crest between the international boundary and Nabesna River ranges from 7,000 to 9,000 feet. The range differs materially from those to the south in its comparative freedom from a snow covering and from valley glaciers, especially on its south side. There a few peaks and protected slopes support perpetual snow fields, and some of the higher valley heads contain small glaciers, but as a whole the valleys are ice free and the mountains would not be classified as a snowy range. On the north slope the snow line is much lower, and several of the larger valleys have glaciers at their heads.

INTERMONTANE AREA.

Between the Nutzotin Mountains on the northeast and the Wrangell and St. Elias mountains on the southwest is an intermontane area of much milder relief. It comprises the main valley of Beaver Creek and some of its headward and southern tributaries, parts of the basins of Chavolda, Chathenda, and Gehoenda creeks, and the basins of the southern tributaries of upper White River. In this area the valleys are broad and open and are connected by numerous low passes, and the intervening hills are of smooth outlines, with rounded or flat tops. The valleys range in elevation from 4,000 to 5,000 feet, and the hills rise to heights not generally exceeding 7,000 feet above sea level. At its eastern edge this hilly area merges gradually into a belt of mountains of moderate height which lie on both sides of Ptarmigan Creek valley, near the international boundary.

INFLUENCE OF ROCK TYPES UPON TOPOGRAPHY.

There is a constant tendency for a particular kind of rock to yield topography of a definite type on erosion by ordinary agencies, although the form is greatly influenced by the structure of the rock. The mountain areas here discussed have all, however, been carved by vigorous glaciers, and the effects of glacial erosion have in many places served to impress upon the surface a characteristic glacial topography, irrespective of the type of the rocks from which the forms were sculptured. Nevertheless, even in areas of severe glacial carving certain rocks exhibit rather characteristic forms. The massive limestones develop sharp, ragged pinnacles wherever they form the mountain crests and steep cliffs in those places where they crop out on the mountain sides. (See Pl. III.) The younger lava flows, which were poured out as nearly flat sheets and which have been little deformed since their extrusion, give in the high regions a striking terraced appearance to the mountains. (See Pls. III and IV, *A*.) In the intermontane area the smooth, flattopped hills owe their shape to a capping of nearly horizontal lavas. The northern portions of the Wrangell and St. Elias ranges are composed, for the most part, of tilted Carboniferous lava flows, but the form of any particular topographic feature has been determined largely by the local attitude of the beds and by glacial erosion. The Nutzotin Mountains consist in large part of bedded sediments which have been much folded and contorted but are of fairly uniform composition. From these sediments have been eroded mountains with sharp peaks and narrow ridges, but with fairly uniform slopes that are little broken by vertical cliffs. (See Pls. IV, *B*, and V.)

The valley floors of the glacial rivers, except in the canyons, are the product of aggrading rather than of eroding streams, and are therefore not erosional but depositional features.

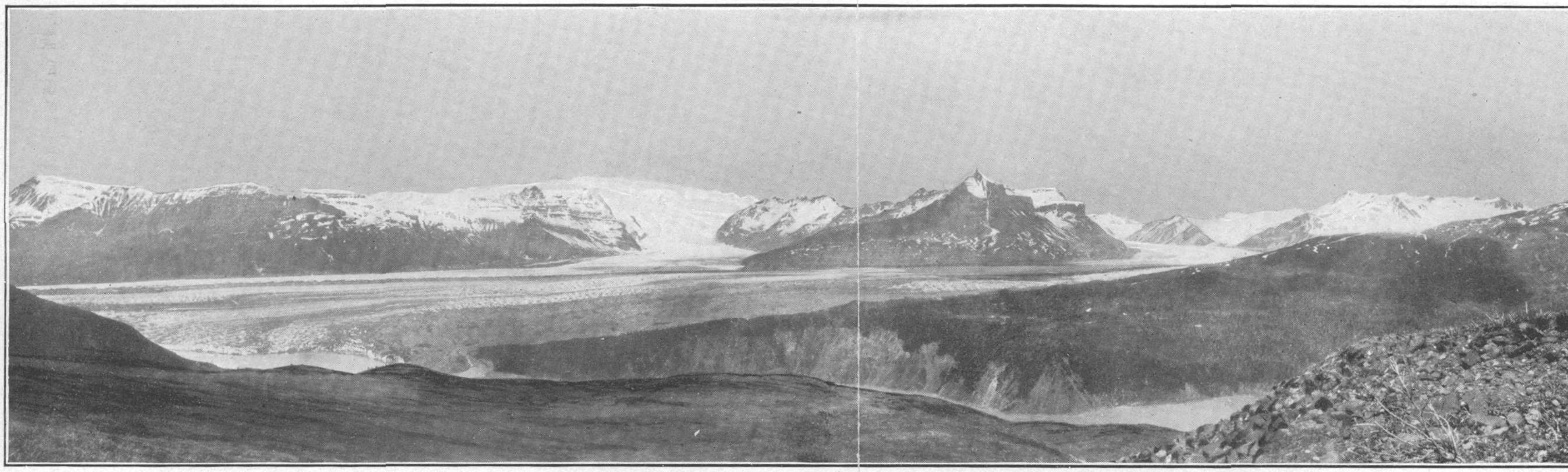
CLIMATE.

The Chisana-White River district lies beyond the influence of the moderating Pacific Ocean currents, and its climate is more nearly that of the interior than of the coastal belt. No records of precipitation are available, but the winters are said to be much like those of interior Alaska in general. The winter weather is not excessively cold and the snowfall is moderate. The following record of temperatures for over a year shows the general range of temperature during parts of 1913 and 1914:

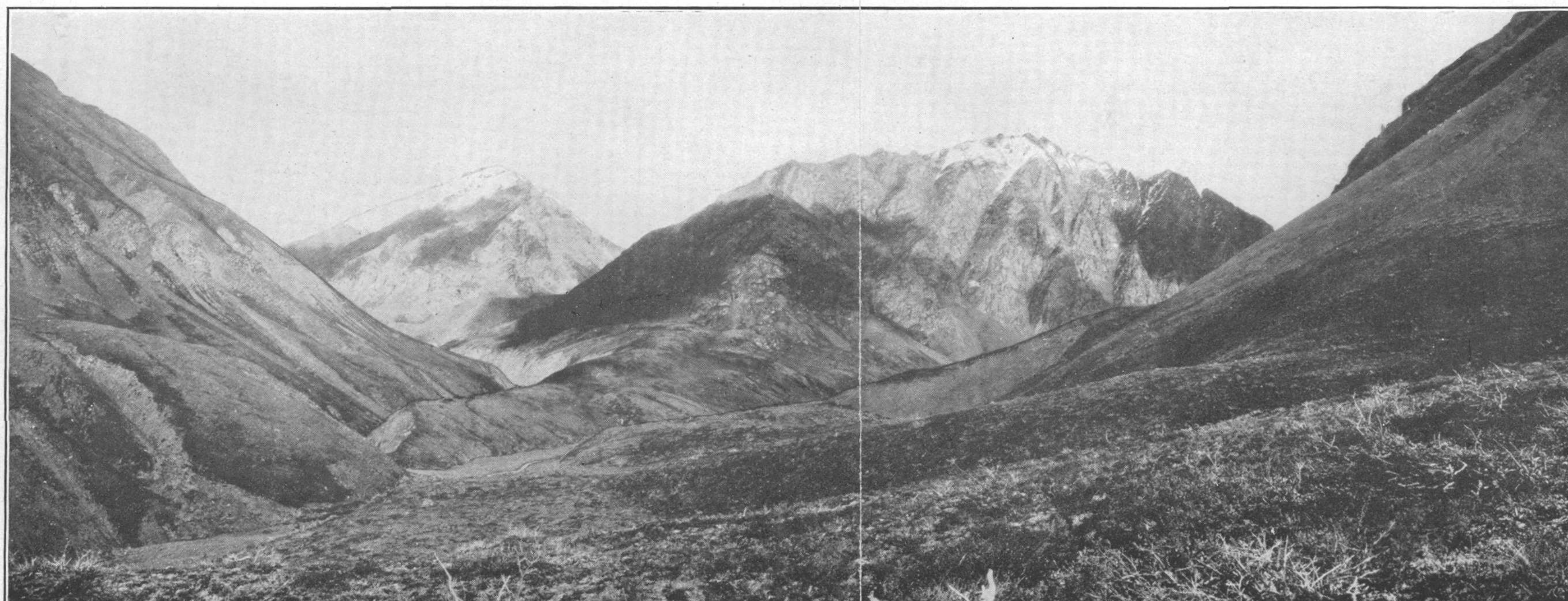
Temperature on Wilson Creek, Chisana district, Alaska, 1913–14.

[Recorded by Howard H. Fields. Temperature (° F.) taken daily at 7 a. m., in the shade of the porch of a cabin on the north side of Wilson Creek at the mouth of Glacier Creek. Elevation above Wilson Creek, 20 feet.]

Day.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1	30	30	30	10	−2	−10	1	10	33	28	46	48	35
2	31	32	20	10	10	0	−3	11	25	30	49	50	31
3	30	32	15	9	10	−2	−2	16	32	32	42	48	42
4	31	37	0	9	6	10	18	19	30	42	40	50	45
5	32	35	10	8	0	8	15	20	32	40	52	40	35
6	33	30	2	7	−2	6	8	19	40	39	60	42	28
7	33	24	0	18	−2	4	17	20	45	38	56	40	27
8	34	20	0	18	2	17	25	22	45	42	58	38	34
9	33	16	3	18	12	10	21	20	52	46	60	46	30
10	34	19	10	−1	−3	14	−12	22	45	46	52	40	39
11	34	19	10	−2	−5	12	−14	22	34	50	46	40	38
12	33	14	30	5	8	5	−14	9	37	52	46	36	32
13	32	12	18	20	0	−1	−6	0	40	43	44	40	34
14	31	12	20	23	15	1	−10	1	38	51	42	50	28
15	30	10	15	9	2	23	−12	−2	34	51	46	48	......
16	29	6	−10	−19	−12	8	−18	−8	40	44	52	45	......
17	28	6	−10	−11	−12	18	7	4	44	44	50	45	......
18	29	12	22	5	−13	23	16	4	40	42	45	46	......
19	29	36	4	12	−10	20	10	6	42	44	45	43	......
20	28	30	−12	20	5	16	25	20	42	44	36	45	......
21	28	28	15	15	2	14	25	25	46	45	40	50	......
22	40	31	2	10	−8	4	23	25	32	50	40	45	......
23	54	28	6	16	−8	14	22	28	32	43	45	40	......
24	39	15	6	10	−10	3	15	30	30	43	46	38	......
25	44	15	−6	7	2	7	10	29	32	40	45	47	......
26	37	13	−7	−8	−10	12	9	30	28	43	62	40	......
27	32	8	−3	−9	−24	2	−12	25	35	43	56	44	......
28	32	4	6	−6	−8	9	9	25	28	50	50	42	......
29	34	30	6	19	−10	......	−6	26	35	50	52	36	......
30	25	32	6	15	−2	......	−1	36	30	54	50	41	......
31	......	30	......	5	−14	......	1	......	30	......	48	36	......



A. PANORAMA OF NIZINA GLACIER FROM THE EAST, SHOWING BEDDED YOUNGER VOLCANIC ROCKS.



B. CHARACTERISTIC TOPOGRAPHY OF A GLACIAL VALLEY IN DEFORMED MESOZOIC ARGILLITES AND GRAYWACKES ON UPPER CHAVOLDA CREEK.

Horses have been turned loose to winter in both Beaver and White valleys and have found sufficient food, either by pawing through the snow or on the wind-swept stream flats, to keep alive during the winter. The summers are cool and have much more rain than in the Yukon and Tanana basins. The summer of 1914 was said to be unusually wet, and a record kept for July and August showed that it rained more than half the time in the localities where the geologic party happened to be during those months, but prospectors who have spent many years in this district report that the summers are usually rainy. Light snows, covering the mountains and even extending down into the main valleys, may be expected at any time during the summer. In 1914 the entire district was covered by 2 or 3 inches of snow on July 3 and another snow fell on July 23. The valleys of Chisana and White rivers are subject to strong winds which blow downstream from the glaciers. The White River valley especially is windy in both summer and winter.

VEGETATION.

The only tree that attains sufficient size to furnish lumber is the spruce, which is found in the lower portions of the larger valleys. Figure 2 shows the distribution of timber throughout the district. In the White River valley a good growth of spruce trees covers the lower valley walls and portions of the stream gravels up to Russell Glacier. The lower Beaver Creek basin also has a small area of spruce forest, and the Chisana Valley is well wooded up to Chisana Glacier. At only a few places were trees seen above an elevation of 4,000 feet, and large areas below that elevation are untimbered. In portions of the White River valley the trees attain sufficient size to furnish small saw logs, and in Chisana Valley, near the town of Chisana, the timber is especially good. Logs 2 feet through at the butt are not uncommon and can be cut into lumber of very fair grade for sluice boxes and other mining purposes. The placer mines of the district all lie above timber line, and lumber for mining uses, as well as wood for fuel, must be brought from a distance. The valley of lower Chathenda Creek contains areas of timber that are most convenient to the mines on Bonanza, Little Eldorado, and Skookum creeks. Some rather scrubby trees formerly grew in that valley for a mile or so above the mouth of Bonanza Creek, but the demands for fuel in 1913 and 1914 caused the cutting of nearly all the trees for several miles below the former timber line, and future supplies will have to be procured from the vicinity of the town of Chisana. At that place there were, in 1915, two sawmills and for a time one was operated at Bonanza. The price charged at Bonanza is said to have been $150 a thousand feet and at Chisana somewhat less, but in addition to the sawmill prices the cost of transportation to the mines is high. Cordwood is said to bring $40 a cord delivered at the mouth of Little Eldorado Creek. In the valley of Chavolda Creek timber grows for several miles above the mouth of Glacier Creek, and at the mouth of that stream there are good trees. Timber from that valley is used for the mines on Glacier Creek and its tributaries and on Big Eldorado Creek.

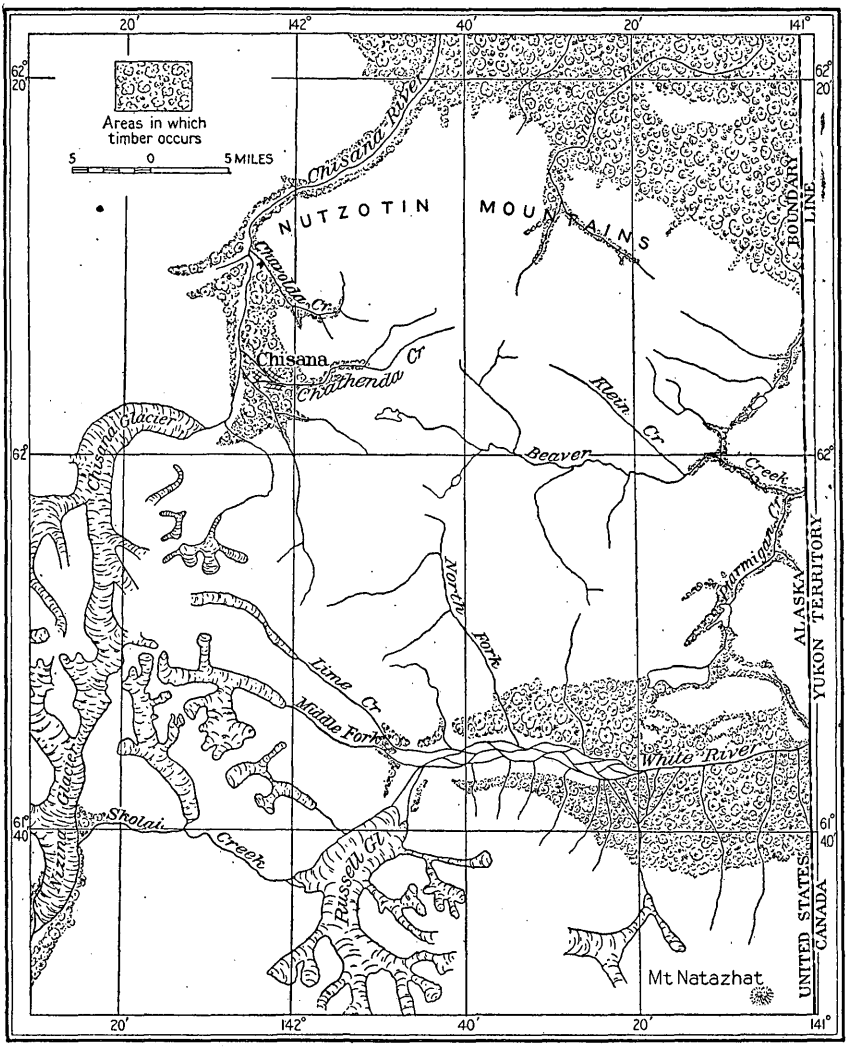
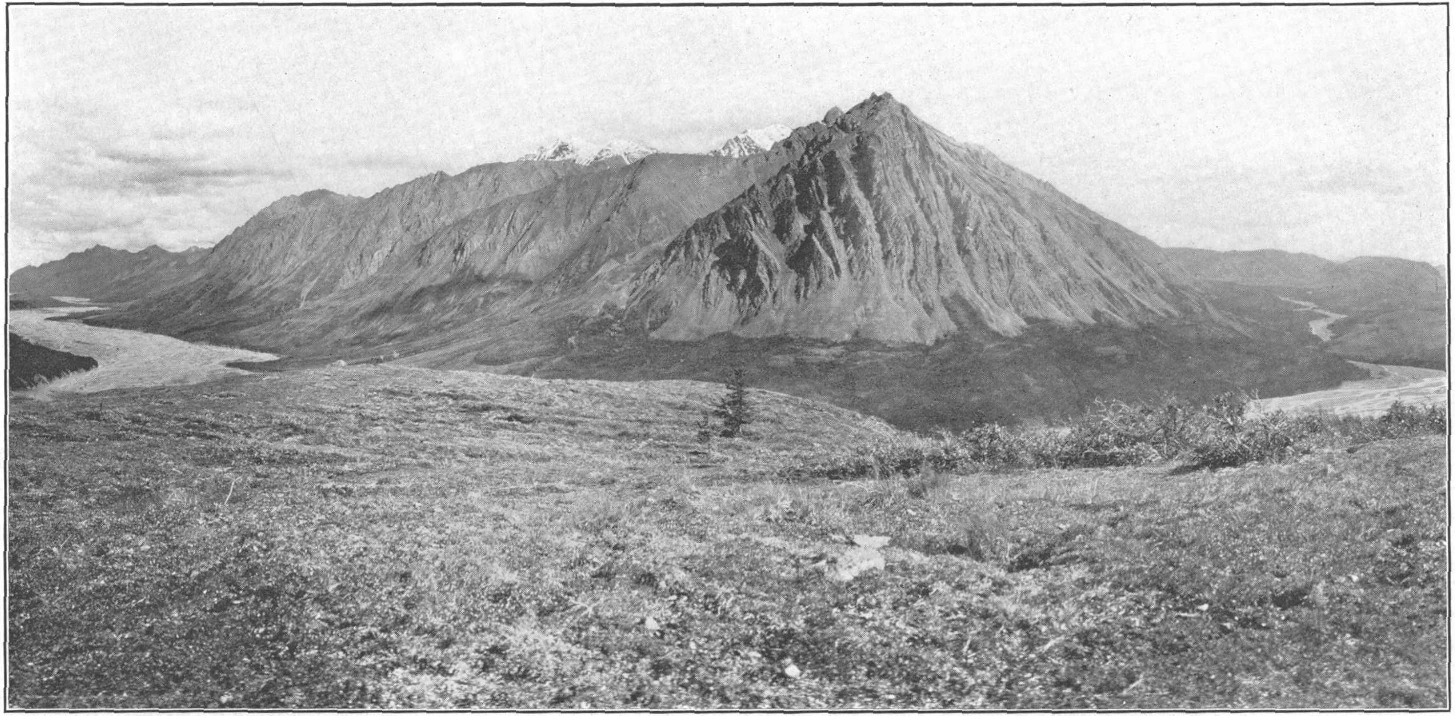
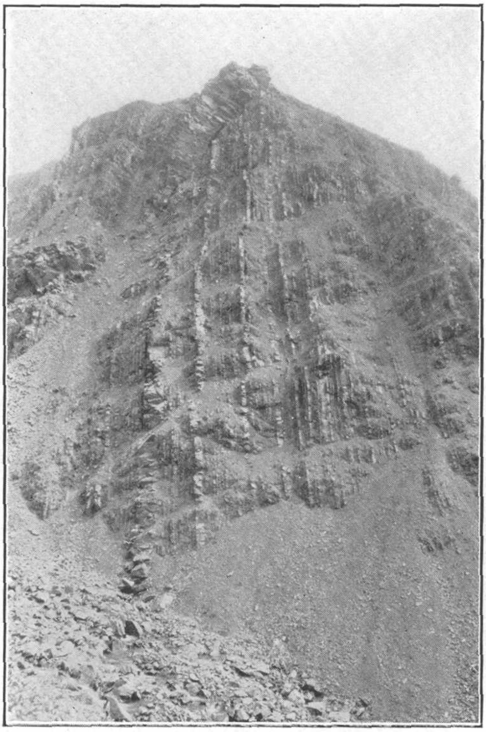


FIGURE 2.—Sketch map of the Chisana-White River district, showing distribution of timber.

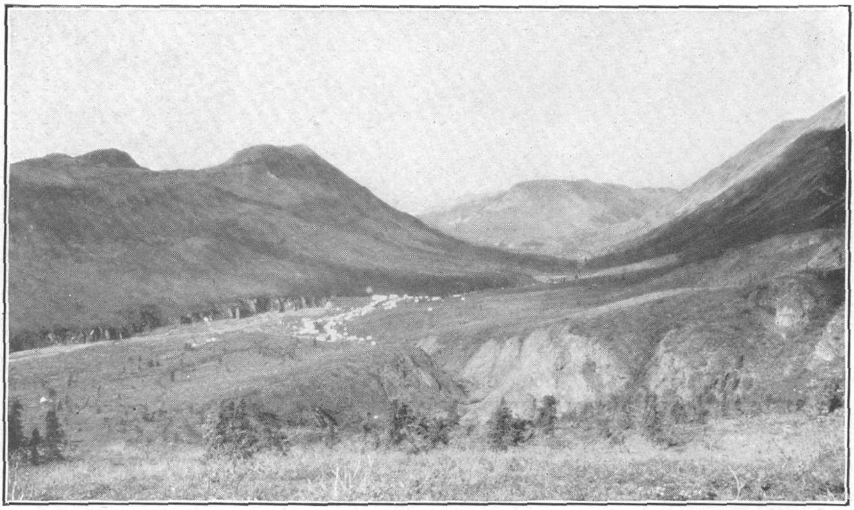
Willow and alder brush grow in many places that are devoid of trees and furnish sufficient fuel for the camp purposes of the prospector, but in the area between upper Beaver Creek and White River and in all the higher mountain masses brush of any kind for fuel is almost entirely lacking, and for even the small requirements of a temporary camp wood must be brought from a distance.



MOUNTAINS ON EAST SIDE OF CHISANA RIVER BELOW MOUTH OF CHAVOLDA CREEK, SHOWING STEEPLY TILTED MESOZOIC SEDIMENTS.



A. VERTICALLY DIPPING MESOZOIC SHALES AND GRAYWACKES CUT BY DIKE ON UPPER BONANZA CREEK.



B. THE GLACIAL VALLEY OF CHATHENDA CREEK AND THE TOWN OF BONANZA.

Lower Bonanza Canyon in foreground.

Grass for horses may be found in favorable places throughout the region, although it is abundant only locally. Good forage for horses is especially plentiful in the valley of White River and on Beaver Creek near the mouth of Horsfeld Creek, and horses have passed the winter successfully at both places. During the winter of 1913–14, however, many horses died in the White River valley. This was due to a number of unusual causes. Most of the horses had been brought in during the stampede late in the fall, when grass was scarce, and were at the point of starvation when turned out. The number placed upon this scanty range was much too large for the amount of feed, and the rabbits, which were unusually plentiful, destroyed large areas of willow brush and of a small vetch, known locally as the "pea vine," on which the horses feed. The experience of prospectors for many years has shown that a small herd of horses, if in good condition in the fall, will winter there with few losses. There is said to be a much larger and better winter range in the vicinity of Kluane Lake.

GAME.

The whole region at the headwaters of Nabesna, Chisana, and White rivers is exceptional for the abundance and variety of game which it contains, and the food furnished to the prospector by his rifle has been an important economic factor in the prospecting and exploration of this remote region where supplies are so difficult to procure. White mountain sheep were formerly plentiful in all the areas of rugged topography and are still abundant except in the vicinity of the mines. It is estimated that 2,000 sheep were killed within a distance of 20 miles of the placer camps during the winter of 1913–14, and in that area they have been almost completely exterminated. In the more remote valleys, however, large bands of sheep may still be seen. Caribou are numerous in the less rugged area between Beaver Creek and White River, but constant hunting has much reduced their numbers. Moose range in the valley of White River near the international boundary and are said to be very abundant on the north side of the Nutzotin Mountains. They are seen occasionally also in other parts of the area. Black and grizzly bears are sometimes seen, and the pelts of many fur-bearing animals are taken in the winter, notably those of the fox, lynx, mink, and marten. Rabbits and ptarmigan have been unusually numerous during the last few years and have supplied a large amount of food for both men and dogs.

POPULATION.

The population, both native and white, was small before the recent placer gold discoveries. In 1908 it was estimated that there were only 45 or 50 Indians in the headwater areas of Copper, Nabesba, Chisana, and White rivers, and less than half of that number occupied the region here discussed. The only settlement then, as now, was on Cross Creek, opposite the mouth of Notch Creek, in Chisana Valley, where a few families had their winter houses. In the summers they moved to White River or to other localities where game was plentiful. The Chisana natives were then little in contact with the white man, and although they had to some extent adopted clothing of his type, they subsisted largely on the fish, game, and berries of the country. It is to be feared that with the coming of large numbers of miners the natives will lose their independent manner of living and will become dependent on the white man for food and clothing.

The white population in the years preceding 1913 was variable but generally small. In 1902 a reported gold placer discovery brought on a small stampede, but no workable ground was found, and most of the prospectors immediately left the district. A few stayed to prospect, and from 1903 to 1913 there were always a dozen or two prospectors in the district. A small village, known as Canyon City, was established on White River a few miles east of the international boundary and was used as winter quarters by some of those who stayed through the winter. In 1913, after the news of the gold discoveries was circulated, several thousand persons, including a number of women, came to the district. Most of them made only a brief stay, so that there were probably at no one time more than 500 or 600 people in the camp. Perhaps 200 of these spent the winter, most of them at Chisana. During the summer of 1914 the average number of people, distributed among the towns of Chisana and Bonanza, the placer mines, and the creeks which were being prospected, was about 350. The town of Chisana contained in 1914 about 150 log cabins scattered along Chathenda Creek and through the timber, two sawmills, a post office, restaurants, stores, and a few other buildings. Most of the cabins were vacant in the summer, as the owners were mining or prospecting on the creeks. The town of Bonanza consisted during that summer of over 100 tents and a few log cabins and contained the assortment of stores, etc., characteristic of a temporary mining settlement. (See Pl. VI, *B*.) It was reported that between 150 and 200 persons planned to spend the winter of 1914–15 in the district.

TRAILS AND ROUTES.

DIFFICULTY OF ACCESS.

The Chisana district is remote from all the well-established systems of transportation in Alaska and Canada, and all the routes to it present certain difficulties, so that communication with the district is slow and the transportation of supplies is tedious and expensive. The length of time required to make the journey to this district and the cost of transporting supplies to it depend on the route chosen, so that it seems proper to describe here in some detail the various routes of approach.

Seven different routes to the Chisana mines are available, and each has been traveled by many people. The route chosen by any person is naturally determined to some extent by the direction from which he wishes to approach the district, but one coming to Alaska from Seattle may choose from a number of routes. Between Seattle and Alaska coast points several steamship lines maintain a regular service. The vessels are large and comfortable and are similar to those used in the coastwise trade generally in the United States. The steamship schedules call for sailings in each direction at intervals of only a few days.

Some published articles have made much of the difficulties encountered in traveling to this district, and especially of the dangers on the trails which lead from McCarthy both by way of Nizina and Chisana glaciers and over Chitistone Pass and Russell Glacier. It is true that during the stampede in 1913 several persons were drowned in rashly attempting to ford the glacial Chitistone and Nizina rivers or their tributaries during periods of high water, but so far as could be learned only one man of the several thousand who crossed the glaciers was lost. None of the routes are easy, and none should be attempted without proper equipment, but the difficulties to be met on any of the routes here described are not sufficient to deter one who is familiar with the conditions of travel by trail in Alaska.

PRINCIPAL ROUTES.

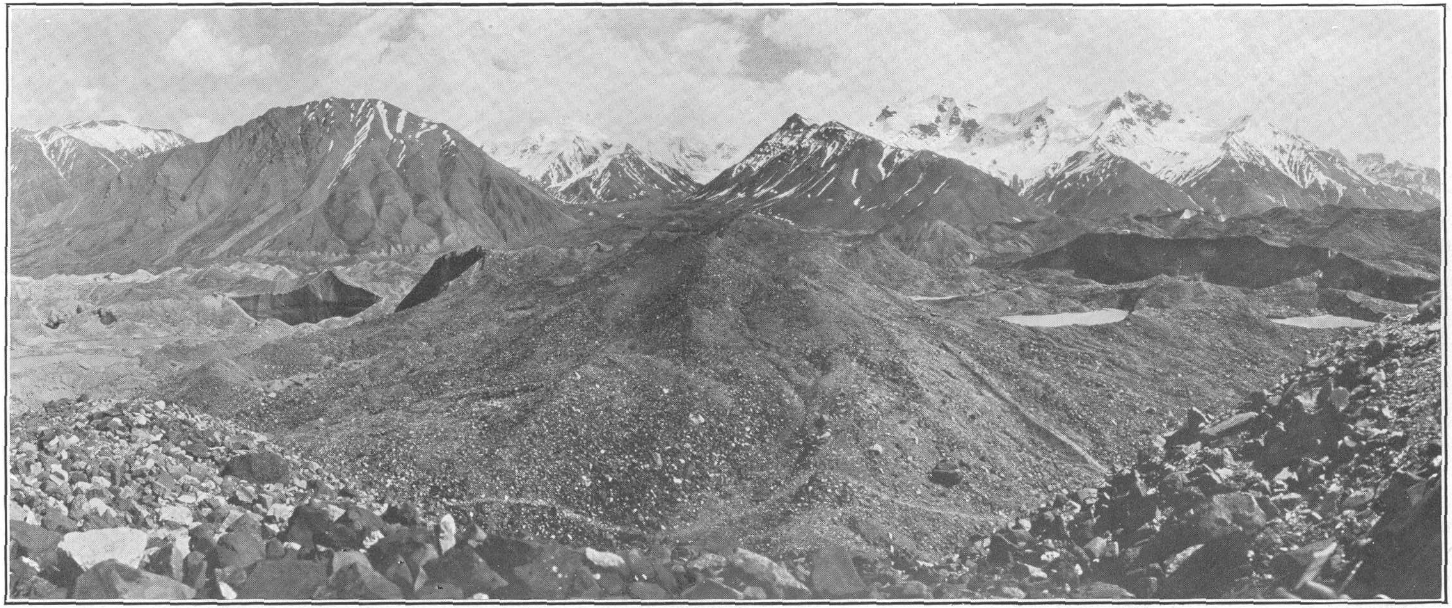
NIZINA-CHISANA ROUTES.

The shortest route from the coast and the one most used during the winter of 1913–14 was the Nizina-Chisana route, which utilizes the Copper River & Northwestern Railway between Cordova and McCarthy, a distance of 191 miles. From McCarthy the trail leads over Sourdough Hill to Nizina River and up Nizina Valley to the mouth of Chitistone River, where it forks. For winter travel a trail was established up the Nizina to Nizina Glacier, up that glacier to its head, across a high ice divide at an elevation of about 8,000 feet, down Chisana Glacier to its terminus and down Chisana Valley to the town of Chisana, a distance of about 75 miles from McCarthy, of which about 40 miles is on glacial ice. This route was much used both by foot travelers and for hauling freight during the winter of 1913–14 and has the advantage of being the shortest of all the routes from a railroad to the mines. It is nevertheless a difficult and dangerous trail and was made passable only by the building of many temporary bridges across crevasses in the glaciers, and by a careful staking of the trail so that crevasses could be avoided when the snows had covered and concealed them. The movements of the glaciers also frequently cause the crevasses to engulf the bridges, and opened new cracks which in turn necessitated bridges. Constant repair work on the trail was therefore necessary throughout the winter. Furthermore, almost all the work done on the trail over the glaciers is destroyed each spring on the renewal of activity of the glaciers and must be done again in the following fall. Portions of the old trail must be entirely abandoned as the result of changed ice conditions, and a new trail must be staked. No attempt is made to use this route in the summer, so that it is traveled for less than half the year. It seems probable, therefore, in view of the impossibility of establishing a permanent trail over the glaciers and the cost of restaking the trail and building new bridges over the crevasses each winter, that this route will not long be used but will be abandoned in favor of a route which can be used the year round and on which improvements will be permanent.

NIZINA-WHITE RIVER ROUTE.

For summer travel the same route is generally followed from McCarthy to the mouth of the Chitistone River, from which two alternate routes are available. One continues along the Nizina-Chisana trail up to and for a few miles up Nizina Glacier, but branches toward the east, crossing that glacier to the mouth of Skolai Creek. The Skolai Valley is then followed for 15 miles to its head. The other branch ascends Chitistone River to its head and crosses a high pass to the head of Skolai Creek, where the two branches join. Each of these branches presents some advantages and some disadvantages over the other, and travelers are about equally divided in their preferences. The Nizina-Skolai Creek branch is some miles the longer of the two and necessitates the fording of Nizina River and the crossing of Nizina Glacier, but the trail is fairly good, the grade is moderate, and there is a better distribution of grass for horse feed. The Chitistone branch, while shorter, crosses Chitistone River several times, and that stream is subject to sudden floods. It also crosses a high divide over a narrow and somewhat dangerous trail known as the "goat trail." Furthermore, it is impassable on account of snow until early in July, and snow in the fall may block it by the first of September. To the cautious traveler the somewhat longer but safer Nizina-Skolai Creek branch recommends itself.

From the head of the Skolai Valley the trail continues for about 14 miles across Russell Glacier. It follows for most of that distance



VIEW EASTWARD FROM LOWER RUSSELL GLACIER INTO THE VALLEY OF MORAINE CREEK.

Trail in foreground.

the moraine-covered portion of the glacier, winding back and forth over its irregular surface. (See Pl. VII.) Although the melting of the glacier affects the trail somewhat, rendering certain spots impassable from time to time so that short detours are necessary, the crossing of the glacier is not difficult and requires only 5 to 6 hours for pack horses. From the head of White River to the placer mines various routes may be followed through a rolling country with many low passes, no difficulties being encountered other than some soft ground. One of these routes leaves White River near the mouth of Lime Creek and proceeds in a northwesterly direction across a high flat to the head of Gehoenda or Trail Creek and down that stream to Chisana River at the town of Chisana. A branch of this trail leaves it near the head of Solo Creek and runs northward past Beaver Lake to the town of Bonanza.

There seems to be no good reason why a better route than any now used for both summer and winter travel could not be established by way of Nizina River, Skolai Creek, and White River. It is known that at times Nizina Glacier is impassable for horses, but the glacier can be entirely avoided by a detour around its eastern edge, and horses have been taken that way on a number of occasions. With a moderate amount of work a good trail around the glacier could be constructed. Russell Glacier can now be crossed, both in summer and winter, but the present trail over it is tortuous, being about 14 miles long to cover an air-line distance of 7 miles. It is reported that a route along the west side of the glacier, which almost entirely avoids the ice and which is many miles shorter than the present route, can now be used by one familiar with it, and by means of a little trail building this route could be made much easier than the route now traveled.

COPPER-NABESNA RIVER ROUTE.

The Copper-Nabesna River route starts at the town of Chitina, on the Copper River & Northwestern Railway, 131 miles from Cordova. It follows the Government military road from Chitina up Copper River to Gulkana. From Gulkana a trail parallels the north bank of Copper River to the Indian village of Batzulnetas, whence it takes an eastward direction to the head of Platinum Creek and follows Cooper and Notch creeks to Chisana River, 8 miles below the town of Chisana. By this trail the distance from Chitina to Chisana is about 235 miles, and the route is little used for summer travel. In winter, however, the greater distance is largely offset by the gentle gradient, the avoidance of glaciers, and the abundance of timber for fuel along the entire route. The only high pass to be crossed is Cooper Pass, an ice-free divide at an elevation of about 6,000 feet, approached by moderate grades. Considerable freight was taken over this route in the winter of 1913–14 in competition with the much shorter Nizina-Chisana route, although the sledding distance is nearly three time as great, and many freighters are said to contemplate a change from that route to this one for future freighting.

DAWSON-WHITE RIVER ROUTE.

Many of the gold seekers in this district came from Dawson by way of White River. Freight may be taken by steamer up the Yukon to White River, a distance of about 70 miles, and by poling boats or shallow-draft power boats up White River as far as the mouth of Donjek River, or even in favorable stages of water to the mouth of Beaver Creek, and poling boats can be used to Canyon City, a village on White River a few miles east of the international boundary. From White River freight is taken in winter by sled to the placer mines. A winter trail has now been cut from the mouth of Beaver Creek to the point where that stream finally crosses the boundary into Alaska, and this route is said to offer no great difficulties, although the distance from Dawson is about 175 miles by boat to the mouth of Beaver Creek and about 85 miles overland from that point to the placer mines.

COFFEE CREEK ROUTE.

From the mouth of Coffee Creek, which joins the Yukon from the south 110 miles above Dawson, a good trail has been built to the junction of Beaver Creek with White River, a distance of about 80 miles, and another branch leads to Canyon City, 120 miles by trail from the Yukon. From the mouth of Beaver Creek the trail to the Chisana placer mines again reaches Beaver Creek at the international boundary, and thence proceeds up the creek to its head. The total distance by this trail from the Yukon to the town of Bonanza is about 160 miles.

WHITEHORSE-KLUANE LAKE ROUTE.

The route from Whitehorse, at the terminus of the White Pass & Yukon Route, to Canyon City, by way of Lake Kluane, is available for travel both in summer and winter, though the winter trail is shorter, as it crosses some bodies of water which the summer trail skirts. A wagon road has been built from Whitehorse to Lake Kluane, a distance of 143 miles, and a trail extends about 170 miles from the upper end of the lake to Canyon City, on White River, and thence 55 miles farther up Beaver Creek to the placer mines. The total overland distance by this route is about 368 miles in summer and perhaps 20 miles less in winter.

TANANA-CHISANA ROUTE.

On the circulation of the report that rich placer discoveries had been made in the Chisana basin, a considerable number of men made their way up Tanana and Chisana rivers by launches and small boats. Under favorable conditions launches may be taken up these rivers as far as the north front of the Nutzotin Mountains, and boats were lined or poled all the way up to the mouth of Chathenda Creek. The route from Fairbanks, the base of supplies, is, however, long and difficult and, although possible, will never be an economical route for bringing in supplies. In the fall of 1914 many persons availed themselves of this water route, and built boats in which they rowed downstream to Fairbanks.

ACCOMMODATIONS ON THE TRAILS.

Along all the most used trails to the gold fields there were, in 1913 and 1914, road houses at intervals of 15 to 30 miles, at which meals and lodging could be procured by the traveler. Thus along the Nizina-Chisana and Nizina-White River routes it was possible to travel from one road house to the next each day for the entire distance. On the Copper-Nabesna River route there are road houses along the Government military road as far as Gulkana. On the Whitehorse-Kluane Lake route road houses are maintained between Whitehorse and Kluane Lake, but none west of that portion of the trail. The rates charged at these road houses vary on the different routes and with the distance from established lines of transporation, but range from a minimum of $1 a meal and $1 for lodging to $1.50 and $2 a meal in the more remote parts of the region.

COST OF TRANSPORTATION.

The cost of travel by trail from steamship or railroad points to the placer mines varies so greatly with the route traveled and the method of travel used that no comprehensive statement of the expense involved can be made here. For the man who travels afoot, carries his own bed and simple and compact food, prepares his own meals, and sleeps out, the cost is little more than the value of his time while on the way. For the man who rents or purchases a horse and stops at the road houses, the expense depends to a great degree on the time spent in reaching his destination. For parties that travel by pack train, carrying their own camping outfit and provisions, the cost is much the same as for the same length of time spent on any other Alaska trail. The regular scheduled rates for first-class passengers on the steamship lines from Seattle to Skagway in 1914 was $30 and to Cordova $45. By rail from Skagway to Whitehorse the fare is $20, and by steamboat between Whitehorse and Dawson the downstream trip costs $30 and the upstream trip $50. From Cordova to Chitina by rail the fare is $15.60 and from Cordova to McCarthy $22.80.

The cost of freighting supplies to the mines varies greatly with different shipments, being controlled by the efficiency with which the work is done, by the route traveled, and by the quantity of material moved. During the winter of 1913–14 little information was available as to the cost by the different routes, and each person chose the route which seemed best to him at that time. Most of the freight was taken over the Nizina-Chisana route, though the other routes had some traffic. Reported costs of sledding from railroad or steamboat lines to Chisana or Bonanza ranged from 12 to 50 cents or more a pound, but most of the contracts let for freighting were at prices between 20 and 30 cents a pound. A considerable amount of supplementary equipment and provisions was brought in by pack train from McCarthy by way of White River during the summer of 1914, the rate charged ranging from 25 to 35 cents a pound.

GEOLOGY.

PRINCIPAL FEATURES.

The areas covered by the several rock formations which have been differentiated in this district are shown on the accompanying geologic map (Pl. II, in pocket). Only reconnaissance geologic work has been done in this area, and the formation boundaries shown are subject to change as more detailed information becomes available. The determination of the age of certain rocks is based largely on the evidence furnished by fossils, which could not be examined and identified in the field, this work being done in the office, several months after the field work upon which this report is based had been completed. As shown by the fossils, the district contains rocks belonging to two great divisions of the Paleozoic, although on account of the similarity of structure and lithology of these divisions no field distinction was made between them. Similarly, the Mesozoic rocks seen are all much alike lithologically and were not separated during the field work, although the fossils obtained from them show that they belong to two and possibly three great systems. On the geologic map it has therefore been necessary to group certain systems together. It is highly desirable that these systems should be separated, but sufficient information is not now available upon which to make this separation, and more field work will be necessary before it can be accomplished. Furthermore, because of the large area to be covered during a brief season of reconnaissance mapping, it was impossible to examine carefully all parts of the area, and it is likely that the larger units mapped include areas of rocks that do not properly belong with the divisions in which they have been placed. Nevertheless, it is believed that the formational boundaries as given delineate with a fair degree of accuracy the major geologic subdivisions here described. The same general stratigraphic and lithologic units into which the rocks were divided by Moffit and Knopf[1] are shown also on Plate II of this report (in pocket), so that the two maps are directly comparable. That portion of the map which shows the geology of the north front of the Wrangell Mountains between Chisana and White rivers, the valley of Gehoenda Creek, and much of the area in the St. Elias Mountains south of White River is the result of the work of Moffit and Knopf. The area north of White River and east of Chisana River and the valley of Skolai Creek were mapped according to the information procured by the writer in 1914.

The rocks of the Chisana-White River district range in age from Devonian to Recent and comprise a wide variety of rock types, including all the common sediments and igneous rocks of many kinds, both intrusive and extrusive. In general it may be said that the portions of the St. Elias and Wrangell ranges included in this district are composed dominantly of igneous rocks, with which are associated considerable quantities of sediments, and the Nutzotin range is composed primarily of sedimentary beds cut by dikes and intruded by large masses of crystalline igneous rocks and contains also some surface lava flows. The lava flows also cover a large area between the St. Elias and Nutzotin mountains. The following list gives the stratigraphic sequence for the district as determined by the geologic studies that have so far been made:

Quaternary:
- Glacial deposits, gravels, volcanic ash, peat, and other unconsolidated materials.
- Glacial morainal deposits, with associated lava flows.

Tertiary:
- Conglomerates and unconsolidated gravels.
- Sandstones, shales, conglomerates, and tuffs, locally containing lignite.

Cretaceous:
- Shales, slates, and graywackes.

Jurassic:
- Shales, slates, graywackes, and conglomerates.

Triassic:
- Thin-bedded limestone of Cooper Pass. Possibly includes also part of the slates and graywackes of the Nutzotin Mountains.

[1] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, pl. 2, 1910.

Carboniferous:
- Lava flows.
- Massive limestone.
- Lava flows and pyroclastic rocks.
- Massive limestones and shales.
- Basic lavas and pyroclastic beds, with minor amounts of sediments.

Devonian:
- Lavas and pyroclastic beds, with considerable black shale.

Although all the materials listed above are not of sedimentary origin, the lava flows and pyroclastic materials included have a definite place in the succession of the rocks. In addition to these bedded materials, all the rocks from the Devonian through the Tertiary have been cut by dikes and sills, and at least the Devonian and Carboniferous and perhaps also the Triassic beds have been intruded by great masses of plutonic rocks.

The geologic history may be briefly summarized in a few paragraphs. The oldest recognized rocks consist of basic lavas and pyroclastic rocks, with a considerable amount of black shale of Devonian age. They were recognized at only one locality and were separated from the overlying Carboniferous rocks only on the evidence of their fossils, no structural break between the two systems being observed.

The next succeeding system, the Carboniferous, consists of a great thickness of materials, but the succession of rocks is nowhere exposed continuously, so that the sequence has been determined at a number of separate localities. The lowest known portion comprises a great thickness of interbedded lavas, tuffs, agglomerates, and breccias, containing very little sedimentary material. For the sake of brevity in description the tuffs, agglomerates, and breccias are in this paper sometimes referred to as the pyroclastic beds. Upon these there is a bed of massive limestone, associated with thin-bedded limestones and shales. Above the limestones and shales is a great thickness of lavas and pyroclastic rocks similar to those already described, again interrupted by other massive limestones. These in turn are succeeded by more bedded basic lava flows, which form the highest part of the Carboniferous system recognized in this district.

The rocks next younger than the Carboniferous in this district are of Triassic age. Whether or not Triassic beds occur east of Chisana River is not known, but at Cooper Pass, a few miles west of that stream, there is a massive limestone carrying Triassic fossils. This limestone was not seen in the area here treated. The Nutzotin Mountains are composed in large part of banded slates or shales and graywackes which are very scantily fossiliferous, and it may be that a part of this great thickness of sediments belongs to the Triassic.

Shales and graywackes of Jurassic age have been recognized on Bonanza Creek, but their upper and lower limits were not determined. The fossiliferous rocks of Jurassic age lie stratigraphically above the thick section of unfossiliferous sediments which forms the Nutzotin Mountains, and the lower beds may be either Triassic or Jurassic, or they may be in part Jurassic and in part older.

Shales and graywackes, carrying Lower Cretaceous fossils lie immediately above the Jurassic beds, on Bonanza Creek, without any observed stratigraphic break. They are separated from the adjoining Devonian and Carboniferous formations by a profound fault.

Tertiary sediments are represented by small, detached areas of shale, sandstone, conglomerate, and tuff, with minor amounts of lignite. Certain old but unconsolidated gravels are also probably of Tertiary age. The extrusion of widespread lava flows was also begun in Tertiary time and has continued intermittently ever since, so that it is difficult to separate the Tertiary from the Quaternary lavas.

Quaternary deposits are present in considerable variety and abundance. The oldest consist of glacial till and outwash gravels interbedded with lava flows, representing a stage of glaciation much earlier than the last notable ice advance. These older glacial deposits are overlain by extensive lava flows. During their last great advance the glaciers left deposits of morainal material scattered throughout the district. Large deposits of outwash gravels were laid down during the retreat of the ice and are still accumulating in the valleys of the glacier-fed streams. Accumulations of talus, peat, and muck, with some volcanic ash, and the products of normal stream deposition make up the postglacial materials in the areas not now receiving glacial and glacio-fluvial deposits.

STRATIGRAPHY.

DEVONIAN SYSTEM.

CHARACTER AND DISTRIBUTION.

The oldest rocks that have been recognized in this district are of Devonian age. They were identified at only one locality, on Bonanza Creek near the mouth of Little Eldorado Creek. The rocks consist of basic lavas, agglomerates, and tuffs, associated with considerable black shale and minor amounts of graywacke. The beds lie beneath the Carboniferous lavas and pyroclastic rocks of lower Bonanza Creek, and so far as known are conformable with them. As the Devonian rocks include a dominant proportion of lavas and pyroclastic beds and have the same general structure as the Carboniferous rocks they were supposed in the field to be Carboniferous, and the age determination has been based solely on the fossils which they contain. The Devonian rocks contain a greater abundance of shale than the portion of the Carboniferous which they adjoin, but the presence of shale can not be generally used as a criterion for separating the two systems, as the Carboniferous locally also includes thick shale beds. The Devonian rocks are in general scantily fossiliferous—in fact, fossils were found at only one locality. Devonian beds may therefore be present over considerable areas in this district, or their occurrence may be limited to the area in which they were identified. In the absence of more complete knowledge as to the boundaries of the area in which they occur they have not been differentiated from the Carboniferous rocks on the geologic map (Pl. II, in pocket).

STRUCTURE AND THICKNESS.

Structurally the Devonian lavas, pyroclastic rocks, and shales where observed have much the same attitude as the overlying Carboniferous beds. In general they strike a little north of west and dip 10°–45° SW. Their monoclinal dips carry them beneath the Carboniferous rocks on the south, and they are separated from the Cretaceous beds on the north by a profound fault. The line of demarcation between the Devonian and Carboniferous was not made out, so that it can not be stated definitely that the two systems are conformable, although their similarity in both lithology and structure suggests that the ejection of lavas and pyroclastic material, begun in Devonian time, was continued into the Carboniferous. The fault separating the Devonian from the Cretaceous brought the youngest Mesozoic rocks into contact with the oldest rocks of the region, and as the pre-Cretaceous Mesozoic beds are certainly many thousand feet thick, this displacement must have been of great magnitude.

The Devonian beds, in addition to their monoclinal tilting, have been gently folded and are cut by some faults. These variations in structure add to the uncertainties in estimating the thickness of the beds, but it is probable that the beds, which lie structurally below the horizon of the fossiliferous rocks, are at least 1,500 feet thick. How much of the material above this horizon is Devonian is not known.

AGE AND CORRELATION.

As already stated, the age determination of the Devonian rocks is based on fossils found at a single locality on Bonanza Creek near the mouth of Little Eldorado Creek. Among the numerous specimens collected only two species were identifiable. The fossils were submitted to Edwin Kirk, who made the following report:

Lot No. 4. From agglomerate series on Bonanza Creek, just below the mouth of Little Eldorado Creek: Pentamerella? sp., Dalmanella sp. The pentameroid is most closely allied to Pentamerella, and seems clearly indicative of the Devonian age of the containing beds. It is probably referable to the Middle Devonian. A very similar if not identical species occurs at Freshwater Bay, in southeastern Alaska.

The only known areas of rocks within the bordering regions with which those on Bonanza Creek can possibly be correlated are the beds of the Wellesley formation, described by Brooks.[1] This formation occurs in the isolated hills and ridges of the great lowland which lies between Nabesna and White rivers, north of the Nutzotin Mountains. It consists of a lower part composed of a massive conglomerate with some beds of clay slate and an upper part made up almost entirely of clay slates. The whole formation is probably between 1,000 and 2,000 feet thick. A few fossils were collected from a slate bed within the massive conglomerate. They were not sufficiently characteristic to furnish a definite age determination, but the beds were referred to the Devonian or Carboniferous. The Wellesley formation is therefore probably to be correlated with some portion of the Devonian-Carboniferous section of the Chisana-White River district, but sufficient evidence is not now available to justify its correlation with any definite portion of this section. In the Broad Pass region, described by Moffit,[2] there are limestones, shales, and conglomerates which are of Devonian age, probably upper Middle Devonian. Brooks and Kindle[3] have described a section of Paleozoic rocks in Yukon Valley in which sediments of Devonian age[4] conformably underlie lower Carboniferous rocks. The situation is therefore similar to that on Bonanza Creek, where the relations between the two systems seem to be conformable, except that the tentative age reference of the rocks on Bonanza Creek is to the Middle rather than the Upper Devonian, as the beds immediately underlying the Carboniferous on the upper Yukon were referred by Kindle.

CARBONIFEROUS SYSTEM.

DISTRIBUTION AND CHARACTER.

Rocks of Carboniferous age are of widespread distribution in the area here discussed and extend westward toward the head of Copper River and eastward into Yukon Territory. They comprise a great variety of materials, of both igneous and sedimentary origin, including lava flows, agglomerates, tuffs, and breccias, interbedded with

[1] Brooks, A. H., A reconnaissance in the White and Tanana river basins, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 431–494, 1900.

[2] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 24–26, 1915.

[3] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, pp. 291–304, 1908.

[4] It should be noted that there is some question about the Devonian age of these rocks.

shales, limestones, and conglomerates, all of which are cut by intrusive rocks of various kinds. Carboniferous rocks make up the north flank of the St. Elias Mountains south of White River and the north face of the Wrangell Mountains between White and Nabesna rivers. They also crop out over considerable areas on both sides of Beaver Creek and are probably continuous between Beaver Creek and White River, though covered in part by later lava flows and by unconsolidated morainal and stream deposits. (See Pl. II, in pocket.) In the area just north and east of Ptarmigan Lake the Carboniferous rocks form the greater part of the mountains but are covered on some of the summits by a comparatively thin layer of younger lavas. The land surface at the time the younger lavas were extruded was of mild relief but included some low rolling hills of Carboniferous rocks. Time was not available during the season of field work to trace out carefully the entire contact between the Carboniferous and the overlying lava flows, and the contact shown on the map is more nearly a plane than the true contact. In the area south of upper Beaver Creek also the overlying lavas form only a thin layer on top of hills composed of Carboniferous materials. The contact, however, dips to the south from upper Beaver Creek and to the south and west from Ptarmigan Creek, and in the main basin of the North Fork of White River the younger lavas have completely covered the older rock formations.

Within the area shown on Plate II (in pocket) as dominantly Carboniferous there are some older and some younger rocks which could not be differentiated in the brief field season that was available for this study. Thus on Bonanza Creek, as already described, there are rocks which carry Devonian fossils but which seem to grade without interruption into the Carboniferous. The line of separation was not made out. Likewise, on Bryan Creek, fossils of Jurassic age were collected, but the outcrops of rock in the stream bed are surrounded on all sides by later gravel deposits, and their relations to the surrounding Carboniferous beds are not known. Jurassic fossils, said to have come from the upper basin of the Middle Fork of White River, have been found. It is apparent, therefore, that within the areas composed predominantly of Carboniferous rocks there are minor amounts of beds of both older and younger formations, which have not yet been outlined. The task of accurately separating these formations remains for the future, when more detailed studies are made.

The Carboniferous rocks of this district are dominantly of volcanic origin, and consist for the most part of lavas, volcanic breccias, tuffs, and agglomerates. The fragmental materials or pyroclastic beds were in part, at least, laid down in water, for they are in places interbedded with sedimentary materials and locally contain the fossils of marine animals. It it probable that some of the lavas also were discharged into the sea and cooled under water. Since their deposition both the sediments and the volcanic rocks have been more or less faulted, folded, and tilted, but the deformation has metamorphosed them but little. Only in the neighborhood of intrusive masses, where contact metamorphism has taken place, have the rocks been greatly altered from their original condition.

Lithologically, the volcanic portion of the Carboniferous consists dominantly of bedded basaltic and andesitic lava flows, interbedded with varying amounts of tuffs and breccias. The tuffs and breccias are made up of materials which were ejected violently from volcanoes and which fell into bodies of water, there to be deposited in company with shales and sandstones and with flows of lava that entered the water and cooled. The pyroclastic beds are composed of angular fragments of rock, little decomposed, and contrast with the materials derived from the decomposition and erosion of land masses, carried by streams or ocean currents and deposited to form ordinary sandstones and shales. The pyroclastic beds are generally of light color, in tones of cream, brown, buff, or gray, and vary in coarseness from very fine grained rocks to agglomerates containing angular blocks a foot or more in diameter.

The lava flows are bedded and single flows may be found which range from a few feet to 100 feet or more in thickness. The prevailing colors are reds, purples, browns, and greens, but the rocks are generally dark colored. The lavas are commonly amygdaloidal, and in most of them the amygdules are filled with zeolites, calcite, chlorite, epidote, and chalcedony, although locally the cavities are still open. According to Moffit and Knopf[1] the lavas are essentially plagioclase-augite aggregates, more or less thoroughly altered. In some specimens a little olivine may originally have been present.

The shale members of the Carboniferous are generally well indurated and vary in color from black to bluish and gray. In many places they are dense and hard and might well be termed argillites. All gradations may be seen from typical fine-grained black shale through limy shale to impure argillaceous limestone, and from sandy shale to sandstone. The surface forms produced by the weathering of the shales depend on their structure, texture, and composition. Where massive and dense they are resistant and have been eroded into rugged, bold forms. Where less indurated they break down readily and are subject to rapid stream erosion. Beds which have a high lime content and approach limestones in composition have been worn into forms resembling the ragged cliffs and pinnacles of a limestone topography.

On lower Ptarmigan Creek, near its junction with Beaver Creek, a series of distorted argillites and cherts appears, striking in general

[1] Op. cit., p. 20.

about N. 70° W. and having prevailingly steep dips to the northeast and southwest. These rocks are cut off on both the south and the north by intrusive masses, and as they yielded no fossils and their stratigraphic relations could not be made out their age was not definitely determined. They are here provisionally included with the Carboniferous.

The limestones are in general little altered, although they have been extensively faulted and folded. Where massive they invariably form bold cliffs or sharp, rough peaks of gray, white, or buff color and may be recognized at great distances by their topography and color, for they contrast sharply with the prevailing dark shades of the other Carboniferous rocks. Within this district the limestones were nowhere observed to be marmarized, although in the area between Chisana and Nabesna rivers Carboniferous limestones in the neighborhood of dioritic intrusive masses have been completely converted into marble by contact metamorphism.

STRUCTURE AND THICKNESS.

The Carboniferous rocks of this district everywhere show evidences of considerable deformation and are tilted, folded, and faulted. In some places the deformation has been intense; in others only moderate tilting or gentle folding has occurred. Although the Carboniferous rocks are probably continuous between the Nutzotin Mountains, at the head of Beaver Creek, and the Wrangell and St. Elias mountains, to the south and east, they are concealed by wide areas of younger lavas and unconsolidated deposits, so that it is difficult to correlate accurately the beds at the separate localities. For example, the lavas and pyroclastic beds of Bonanza Creek, which are believed to form a gradational series between the Devonian rocks already described and the main body of Carboniferous rocks, are thought to represent the lowest portion of the Carboniferous of this region. They have a general northwest strike and dip rather steeply to the southwest, toward the Wrangell Mountains, and this structure, if continuous through the intervening covered area, would place the rocks at Chisana Glacier far up in the Carboniferous system. The rocks are faulted and folded, however, so that such a conclusion is not justified. It is apparent that the basal portion of the Carboniferous in this locality is composed primarily of a thick series of lavas and pyroclastic beds, with minor amounts of interbedded sediments. Near the head of Eureka Creek there is a massive limestone, associated with black shales, which has yielded a few fossils that suggest an age greater than that of the other limestones of the region, and these sediments also may belong in the basal portion of the Carboniferous section. The fossil collection was, however, too scanty to permit a definite age determination.

The lavas and pyroclastic beds are succeeded, without any known structural break, by a portion of the series in which clastic sediments predominate over igneous materials. They consist of the massive limestones which are so conspicuous throughout the region, black shales, calcareous and arenaceous shales, thin-bedded limestones, and a little conglomerate. The massive limestone, with the overlying black shales, is well exposed on Kletsan Creek near the international boundary and at several places in the White River valley. The stream gravels discharged by the creeks that drain from the St. Elias Mountains into White River also include much shale and limestone that contain Carboniferous fossils, indicating that these sedimentary beds are widely developed in the high mountains along the north flank of the range. Near the terminus of Russell Glacier the massive limestone, with black shale overlying it, crops out on the west valley wall, and a great thickness of folded and contorted shales and thin-bedded limestones is exposed on the east side of the valley,

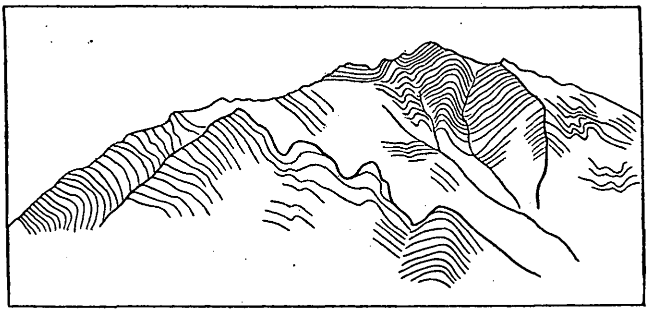


FIGURE 3.—Sketch showing structure of Carboniferous shales and limestones between the mouths of Wiley and Moraine creeks.

between Wiley and Moraine creeks, though the massive limestone is not developed there. At the locality shown in figure 3 the shales and limestones have a thickness which can not fall far short of 2,000 feet.

The massive limestone has at many places a thickness of 200 feet and locally may be over twice that thick. Both the thick limestone beds and the associated shales and thin limestones are locally very fossiliferous, and on the evidence of their fossil content many of the limestone patches may be correlated with one another. In this district the limestone outcrops are discontinuous, but it is probable that the present patchy distribution is due to faulting and that the limestone when deposited was continuous over large areas. At the locality west of the terminus of Russell Glacier the fossil evidence shows that Carboniferous sediments of two distinct ages are represented there. The beds are folded and faulted, and the contiguous position of beds of the two horizons may be due to the accidents of dislocation.

Succeeding the massive limestone and shales is another thick series of lavas and pyroclastic rocks, closely resembling those of the lower Carboniferous. They are exposed continuously between the

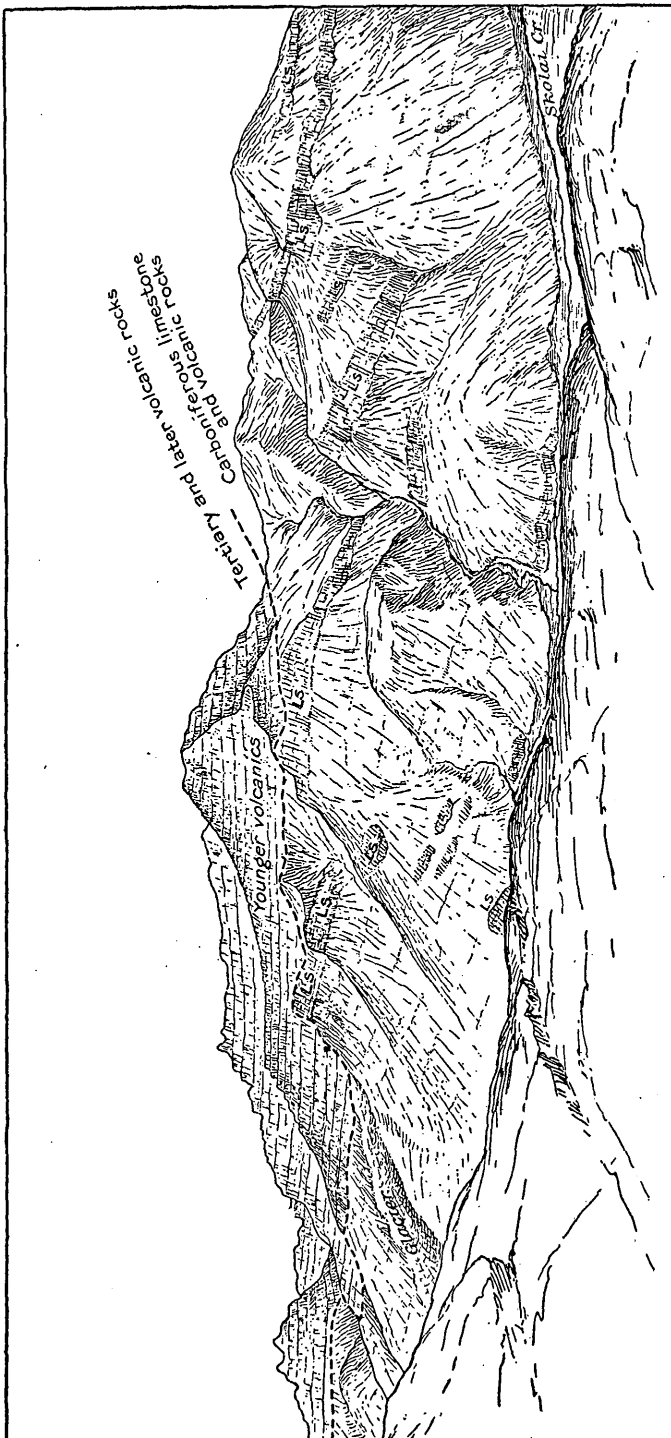


FIGURE 4.—Sketch showing structural relations of the Carboniferous volcanic and sedimentary rocks to the younger volcanic rocks on lower Skolai Creek. Ls, Limestone.

head of White River and lower Skolai Creek, and throughout that distance they contain little sedimentary material. On lower Skolai Creek there are other massive limestones which closely resemble that already described, but which have been determined on the evidence of their fossils to be younger than the limestone of White River. Associated with the limestone are a small amount of shale and some fine conglomerates composed of small cherty pebbles in a limy matrix. The limestones crop out as massive beds 200 feet or more in thickness, and at one place on the south side of the valley there appear to be at least three distinct beds, separated by lava flows. (See Pl. IV, *A*, p. 18, and fig. 4.) The lack of continuity of the limestones over any considerable distance and the presence in the section of numerous limestone blocks and lenses, abutting against lavas on all sides, suggest strongly that faulting has been vigorous, and instead of three horizons of heavy limestone there may normally be but two, or even only one. The rocks here strike in a general northeast direction and dip 15°–45° NW.

Upon the limestones is another very thick series of basic amygdaloidal lava flows, containing little sedimentary material. These beds form the uppermost portion of the Carboniferous that has been recognized.

To summarize briefly the sequence of the Carboniferous beds described above, they consist of the following divisions, named in ascending order:

1. Lavas and pyroclastic beds, with some shales.
2. Massive limestone, associated with shales, thin-bedded limestones, and a little sandstone and conglomerate.
3. Lavas and pyroclastic rocks, with a small amount of sediments.
4. Massive limestone beds of Skolai Creek, with interbedded lavas and minor amounts of shale and conglomerate.
5. Basic bedded lavas, with little sedimentary material.

No reliable figures can be given as to the thickness of the entire series, for faulting, with possible reduplication, has affected the rocks in all parts of the district. The lower lavas and pyroclastic rocks may be several thousand feet thick at their maximum. The lower limestone in many places reaches a thickness of 200 feet or more, and the associated shales and limestones east of Russell Glacier are probably 2,000 feet thick. The continuous section between White River and lower Skolai Creek shows lavas and pyroclastic rocks, with a general westward dip, for a distance of 15 miles, and this may represent a vertical thickness of many thousand feet. Above the thick limestones of lower Skolai Creek there are again lavas which must be measured in thousands of feet. Too little work has yet been done to justify an estimate of the total thickness of the Carboniferous rocks, but it certainly can not fall short of 10,000 feet and may greatly exceed that figure.

AGE AND CORRELATION.

The Carboniferous limestones and shales have yielded marine fossils at many localities, and in places the tuffaceous rocks also are fossiliferous. From the evidence furnished by these remains the age of the containing rocks has been determined. Some difficulty arises in attempting to correlate the rocks of this region with the better-known Carboniferous terranes of the United States, for the fossils are more closely related to those found in Russia than to those of North America. With the exception of a single doubtful collection from Eureka Creek, all the fossils found seem to belong to rocks of upper Carboniferous (Pennsylvanian) age. These may be divided into two groups, of which the older, the Gschelian, includes all the fossils from the White River basin and others previously collected from the Chisana and Nabesna basins, and the younger, the Artinskian, embraces only the fossils collected on lower Skolai Creek. The scanty means of transportation available to all the geologists who have worked in this district has made it possible to bring out only small collections of fossils, so that only a few forms are known from most of the localities, and all the collections are incomplete. It has therefore been difficult for the paleontologist to make definite correlations between any two localities. Fossils are abundant, however, in most of the Carboniferous sediments, and a special paleontologic study of the region should yield more conclusive results than so far have been obtained.

The fossils collected from this district in the course of this present investigation, as well as those collected by Moffit and Knopf in 1908, are listed below. They have all been examined by George H. Girty, who makes the following report:

Lime Creek.
- Lot 7108.
  - Productus semireticulatus Morton.
  - Productus aff. P. humboldti D'Orbigny.
  - Productus aff. P. koninckianus De Verneuil.
  - Productus sp.
  - Camarophoria aff. C. crumena Martin.
  - Squamularia aff. S. perplexa McChesney.
  - Martinia aff. M. semiglobosa Tschernyschew.

North Fork of White River.
- Lot 7098.
  - Spirifer arcticus Houghton.

Middle Fork White River.
- Lot 7106.
  - Rhombopora sp.
  - Productus aff. P. gruenewaldti Krotow.
  - Spiriferina sp.
- Lot 7101h.
  - Productus sp.

Skolai Pass, between Wiley and Moraine creeks.

Lot 701.

Chonetes aff. C. morahensis.
Productus cora D'Orbigny.
Productus aff. P. irginæ.
Productus aff. P. longus Tschernyschew, not Meek.
Camarophoria aff. C. kutorgæ Tschernyschew.
Rhynchopora aff. R. nikitini.
Dielasma aff. D. bovideus Morton.
Spirifer aff. S. interplicatus.
Spirifer aff. S. cameratus Tschernyschew, not Morton.
Squamularia aff. S. perplexa McChesney.
Spiriferina aff. S. pyramidata Tschernyschew.
Platyceras? sp.
Fusilina sp.
Zaphrentis aff. Z. ovidos.
Zaphrentis sp.
Clisiophyllum? sp.
Lithostrotion aff. L. portlocki.
Lithostrotion aff. L. irregulare.
Phillipsastræa? sp.
Fenestella sp.
Polypora sp.
Stenopora aff. S. carbonaria.
Bastostomella sp.
Lingula sp.
Orthotichia? aff. O. morganiana.
Rhipodomella sp.
Chonetes aff. C. granulifer.
Chonetes aff. C. morahensis.
Productus aff. P. cora.
Productus aff. P. tuberculatus.
Productus aff. P. irginæ.
Productus aff. P. longus Tschernyschew, not Meek.
Productus aff. P. fasciatus.
Productus aff. P. koninckianus.
Productus aff. P. wallacianus.
Productus aff. P. tartaricus.
Productus sp.
Tegulifera? aff. T. uralica.
Marginifera? aff. M. typica.
Marginifera? aff. M. clarkei.
Proboscidella? aff. P. genuina.
Camarophoria aff. C. kutorgæ.
Rhynchopora aff. R. nikitini.
Spiriferina aff. S. pyramidata.
Spirifer aff. S. cameratus Tschernyschew, not Morton.
Spirifer aff. S. nikitini.
Spirifer aff. S. interplicatus.
Reticularia sp.
Squamularia aff. S. perplexa.
Cliothyridina aff. C. roissyi.
Hustedia aff. H. remota.

Skolai Pass, between Wiley and Moraine creeks—Continued.

Lot 701—Continued.

Lima? sp.
Platyceras sp.
Worthenia? sp.
Omphalotrochus sp.
Griffithides? sp.

Skolai Pass, north side, west of terminus of Russell Glacier. [Since the original list of fossils from this locality was described it has seemed advisable, as the result of a greater familiarity with this fauna from later studies, to revise the determinations first made. This accounts for certain discrepancies between the list here given and that published by Moffit and Knopf. Concerning this lot Mr. Girty makes the following statement: "I have reviewed the old collections from White River west of the terminus of Russell Glacier in connection with the new collections from the same district. The old collections were given Nos. 7102 to 7102h in the survey locality register, but as I now learn that those divisions merely represent different packages of the same collection—not different collections—the numbers may be disregarded. Taken as a whole, then, this collection shows two conspicuous lithologic aspects, with which go hand in hand two conspicuously different faunal aspects. One set of fossils occurs in a whitish limestone and contains species shown in the accompanying list. The other set of fossils occurs in a dark-gray limestone and contains the species shown in the other list accompanying. The collection in dark limestone agrees faunally and lithologically with lot 1, made this year, which I am calling Artinskian. These two faunas have very little in common, a fact which comes out more clearly when it is recognized that the material does not represent nine small collections but one of larger size. In the revised lists a few changes in identification have been made from the list originally published."]

Lot 7102—Dark limestone.

Productus aff. P. cora.
Cliothyridina aff. C. roissyi.
Productus aff. P. irginæ.
Dielasma aff. D. bovidens.
Productus sp.
Chonetes aff. C. morahensis.
Chonetes aff. C. granulifera.
Aviculipecten aff. A. occidentalis.
Lima? sp.
Aviculipecten sp.
Aviculipecten aff. A. curticardinalis.

Lot 7102—Light limestone.

Spiriferella arctica.
Productus aff. P. timanicus.
Productus aff. P. gruenewaldti.
Marginifera aff. M. involuta.
Cliothyridina aff. C. roissyi.
Squamularia aff. S. perplexa.

Moraine Creek, Skolai Pass.

Lot. 7105.

Lophophyllum? sp.
Spirifer arcticus Houghton.

Skolai Pass, south side, 2 miles east of Moraine Creek.
  Lot 7109.
    Productus aff. P. wallacianus Derby?
    Camarophoria aff. C. sella Kutorga.
    Martinia aff. M. semiglobosa Tschernyschew.
    Spiriferina sp.
South side of White River, 10 miles east of Skolai Pass.
  Lot 7099.
    Chonetes aff. C. flemingi var. verneuilianus Norwood and Pratten.
    Productus sp.
    Orthotichia? n. sp.
    Lima aff. L. retifera Shumard.
    Sedgwickia? sp.
  Lot 7099a.
    Stenopora? sp.
    Derbya? sp.
    Chonetes aff. C. flemingi var. verneuilianus Norwood and Pratten.
    Marginifera? aff. M. wabashensis Norwood and Pratten.
    Schizophoria? supracarbonica Tschernyschew.
    Rhynchopora sp.
    Spirifer aff. S. keokuk Hall.
    Spirifer aff. S. nikitini Tschernyschew.
    Squamularia aff. S. perplexa McChesney.
    Pleurotomaria sp.
  Lot 7099b.
    Martinia? sp.
    Parallelodon sp.
    Pleurotomaria sp.
  Lot 7099c.
    Camarophoria aff. C. sella Kutorga.
Holmes Creek.
  Lot 7100.
    Stenopora sp.
    Productus aff. P. fasciatus Kutorga.
    Productus aff. P. pseudaculeatus Krotow.
    Camarophoria aff. C. kutorgæ Tschernyschew.
  Lot 7100a.
    Productus aff. P. fasciatus Kutorga.
    Squamularia? sp.
  Lot 7100b.
    Lima aff. L. retifera Shumard.
  Lot 7100c.
    Squamularia aff. S. perplexa McChesney.
  Lot 7100d.
    Campophyllum sp.
  Lot 7100e.
    Campophyllum? sp.
  Lot 7100f.
    Productus aff. P. fasciatus Kutorga.
    Camarophoria aff. C. crumena Martin.
    Spirifer sp.
  Lot 7100g.
    Spirifer aff. S. nikitini Tschernyschew.

Holmes Creek—Continued.

Lot 7100h.

Marginifera? aff. M. wabashensis Norwood and Pratten.
Productus sp.
Camarophoria aff. C. crumena Martin.
Spirifer arcticus Houghton?

Lot 7100k.

Spirifer arcticus Houghton?

Lot 7100m.

Lophophyllum? sp.

Lot 7100n.

Productus sp.

Lot 7100p.

Rhombopora? sp.
Productus aff. P. wallacianus Derby?
Spirifer arcticus Houghton.

Lot 7100r.

Productus 2 sp.
Spirifer aff. S. nikitini Tschernyschew.

Lot 7100s.

Rhombopora sp.
Productus aff. P. mammatus Keyserling.

Kletsan Creek.

Lot 7101.

Chætetes sp.
Chonetes flemingi var. verneuilianus Norwood and Pratten.
Productus sp.
Rhynchopora sp.
Cliothyridina aff. C. roissyana Keyserling.

Lot 7101a.

Marginifera? aff. M. wabashensis Norwood and Pratten.
Productus aff. P. gruenewaldti Krotow.

Lot 7101b.

Productus aff. P. gruenewaldti Krotow.
Schizophoria? aff. S. supracarbonica Tschernyschew.

Lot 7101c.

Platyceras aff. P. parvum Swallow.

Lot 7101d.

Chonetes aff. C. flemingi var. verneuilianus Norwood and Pratten.
Productus aff. P. fasciatus Kutorga.
Productus aff. P. aagardi Toula.
Marginifera aff. M. wabashensis Norwood and Pratten.
Productus aff. P. wallacianus Derby?
Enteletes hemiplicatus Hall.
Camarophoria aff. C. crumena Martin.
Cliothyridina aff. C. roissyana Keyserling?

Lot 7101e.

Spirifer aff. S. nikitini Tschernyschew?

Lot 7101f.

Spirifer aff. S. nikitini Tschernyschew?

Lot 7101g.

Lophophyllum? sp.

Eureka Creek.
  Lot 7107.
    Productus aff. P. alternatus Norwood and Pratten.
    Reticularia aff. R. setigera Hall.
Skolai Creek, lower end.
    Zaphrentis sp.
    Clisiophyllum sp.
    Crinoidal fragment.
    Productus aff. P. horridus.
    Marginifera? sp.
    Spiriferella? arctica.
    Spirifer aff. S. cameratus.

The following collection was made from Kletsan Creek by A. H. Brooks in 1899 and identified by Charles Schuchert:

Kletsan Creek (9 A. B. 171), white crystalline limestone:
    Productus cora.
    Productus 2 sp.
    Seminula sp.
    Stenopora sp.
Pebble from Kletsan Creek (9 A. B. 150):
    Fusulina (not the common American species F. cylindricea).

These two localities are of one general horizon in the upper Carboniferous, which seems to be the same zone as that near Circle City discovered by Spurr (Takandit series) or a closely related one. I have made no specific determinations, since the fauna is not to be correlated with the upper Carboniferous of the Mississippi Valley, but with the Fusulina zone of China, India, and the eastern slopes of the Urals.

Rocks of Carboniferous age are widely distributed throughout Alaska and in Yukon Territory, and as the paleontologic and stratigraphic evidence accumulates it becomes possible to correlate with increasing certainty the rocks of the different localities. The Nutzotin Mountains merge into the Alaska Range at their western edge, and the rock formations which constitute the Nutzotin Mountains may be traced westward into that range. Thus Mendenhall[1] studied in the upper Copper River basin a series of sandstones, shales, limestones, tuffs, lava flows, and intrusive rocks, 6,000 or 7,000 feet thick, which he called the Mankomen formation. The fossils obtained from these beds were at that time considered by Schuchert to be of Permian age. These beds may be correlated, both on stratigraphic and paleontologic grounds, with the limestone of Nabesna and White rivers, which holds a fauna that is now regarded as closely related to the Artinskian of Europe. Mendenhall divides the Mankomen into two parts, a larger upper division consisting mainly of calcareous rocks and a lower division composed primarily of arenaceous and tuffaceous materials. The upper division contains two principal limestones, of which the lower, a white massive limestone about 500 feet thick, is

[1] Mendenhall, W. C., The geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, pp. 40–52, 1906.

separated by several hundred feet of shale from an upper thin-bedded limestone about 600 feet thick. The Mankomen of Mendenhall and the Carboniferous of White River are both characterized by the presence of large quantities of lavas and volcanic material.

An unusually complete section of Carboniferous rocks and the underlying and overlying formations, as exposed along Yukon River, has been described by Brooks and Kindle.[1] There the Carboniferous beds apparently lie conformably upon Devonian rocks and are conformably overlain by Mesozoic beds. The Carboniferous was divided by them into three well-defined units, including the Calico Bluff and Nation River formations, both of Mississippian age, and a third, still younger, unnamed formation. The lowest formation, the Calico Bluff, consists of shales, slate, and a little limestone, apparently conformable upon the Devonian but separated by a stratigraphic break from the overlying Nation River. The Nation River formation consists of about 3,700 feet of sediments, predominantly shales, with smaller amounts of slates, conglomerate, and sandstone. Above the Nation River formation is a limestone at least 200 feet thick, which on the basis of its fossils was considered to be of either Carboniferous or Permian age, but which is now provisionally assigned to the Pennsylvanian. This limestone lies conformably beneath sediments of Mesozoic age.

There are many apparent resemblances between the section on Yukon River, above outlined, and that in the Chisana district. In the Chisana basin, as on the Yukon, no stratigraphic break has been recognized between the Devonian and the lower Carboniferous. In both localities the Devonian contains much material of igneous origin, but in the Chisana district the igneous activity was continued into Carboniferous time, while on the Yukon the lower Carboniferous sediments are free from igneous materials. The unconformities recognized within the Carboniferous of the Yukon section have not been found in the Chisana-White River district but may be present. In the Skolai Creek-Nizina section, as on the Yukon, there seems to be no structural break between the upper Carboniferous and the Mesozoic.

In the valley of Nizina River, below Nizina Glacier, there is a massive limestone called the Chitistone limestone, which reaches a maximum thickness of 3,000 feet. This was originally correlated by Schrader and Spencer[2] with the Carboniferous limestone of White River, on stratigraphic and lithologic grounds, for no fossils had then been found in it. Later investigations[3] proved conclusively

[1] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, pp. 255–314, 1908.

[2] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska: U. S. Geol. Survey Special Pub., p. 46, 1901.

[3] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, p. 26, 1908. Moffit, F. H., and Capps, S. R., The Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 23–25, 1911.

that this limestone is of Triassic age and lies conformably upon basic lava flows, the Nikolai greenstone, the age of which is not known. Moffit and Knopf[1] in discussing the correlation of the Carboniferous of White River with the rocks of Chitina Valley, said:

It is suggested that the Nikolai greenstone, which conformably underlies the Chitistone limestone of Chitina Valley, may probably be the equivalent of some of the upper lava flows referred to the Carboniferous in White River valley. Proof of this correlation is lacking and will remain so until the upper limit of the Carboniferous is determined, but the seeming transition, without interruption, from Carboniferous to Triassic deposits in Yukon Valley suggests the possibility of such a condition holding at the head of White River, and that an unconformity between Carboniferous and Triassic deposition may not occur there. Whether the volcanic beds occurring between the massive limestones of the White and Chitina valleys should be referred to the Carboniferous or Triassic may be difficult if not impossible to determine.

During the present investigation strong evidence in support of the suggestion of Moffit and Knopf was found. On lower Skolai Creek, only a few miles distant from the outcrops of the Chitistone limestone, late Carboniferous limestones were found interbedded with volcanic materials, and overlain conformably by massive lava flows that closely resemble the Nikolai greenstone. Fossils collected from this limestone show it to be of late Carboniferous age, and to be equivalent to the top of the Carboniferous in the Yukon section. The overlying lava flows are separated by only a few miles from the outcrops of the Nikolai greenstone and dip in such a way as to give strong presumptive evidence that they are a part of the same formation. If they represent the lowest portion of the Nikolai formation, then they form the link between the top of the Carboniferous and the base of the Triassic, and as in the Yukon section, no structural break exists between the two. The final proof of the age relation between the upper Carboniferous lavas of Skolai Creek and the Nikolai can be found only when the actual continuity of the beds is shown, or when fossils are found in both formations.

MESOZOIC ROCKS.

CHARACTER AND DISTRIBUTION.

Mesozoic sedimentation is represented in the Chisana-White River district by a very great thickness of beds that form practically all of the Nutzotin Range, as exposed along Chisana River. Most of the beds are of similar lithologic character and are remarkably barren of fossils, so that the exact age of most of the rocks in the range is not known. In the vicinity of the placer mines, however, fossils of Jurassic and Cretaceous age were found, and west of the district here dis-

[1] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, p. 26, 1910.

cussed, at Cooper Pass, Triassic fossils have been collected, so that all three of the major divisions of the Mesozoic are known to be represented. On the geologic map (Pl. II, in pocket) only the southern margin of the Mesozoic rocks is shown, although it is known that rocks of similar character and almost certainly of Mesozoic age extend northward to the north flank of the Nutzotin Range. Furthermore, the uniform composition, the absence of conspicuous lithologic members, and the complicated structure of the Mesozoic rocks render a field distinction of even the major subdivisions difficult. No stratigraphic breaks between the divisions are known, and any separation must be based largely on the evidence furnished by fossils. Fossils are generally scarce, and no separation of the rocks was made in the field, so that on Plate II all the Mesozoic rocks are mapped with a single color.

The transition from Paleozoic to Mesozoic time is characterized by the cessation of pronounced volcanic activity. The youngest known Carboniferous rocks, as already described, are lava flows, and both the Carboniferous and Devonian rocks of the district consist predominantly of materials of igneous origin. The oldest determined Mesozoic rocks, by contrast, have little or no lavas or pyroclastic materials interbedded with the clastic sediments, and the outpouring of lavas and the accumulation of fragmental volcanic material had almost completely ceased before Mesozoic sedimentation on a great scale commenced. The numerous dikes and intrusive masses that cut the Mesozoic rocks are, of course, younger than the sediments which they cut. It may be that the igneous activity of Carboniferous time extended into the early part of the Mesozoic era, but if so, the extrusion of lavas and the ejection of pyroclastic material terminated abruptly before the main body of Mesozoic sediments was laid down.

East of Chisana River the greater part of the Nutzotin Range is composed of hard, banded shales or argillites and graywackes, with minor amounts of conglomerate. These materials were deposited in comparatively shallow water and were derived from the disintegration and erosion products of some older land mass, the location of which is not now known. That the basin in which the materials were laid down subsided gradually as the sediments accumulated is indicated by the great thickness of the beds, all of which show by their character that they were deposited in shallow water.

As already mapped by Moffit and Knopf,[1] rocks of Mesozoic age constitute practically all of the Nutzotin Mountains between Chisana River and the head of the Copper River basin, and the southern limit of the Mesozoic materials corresponds closely with the line of division between the Wrangell and Nutzotin mountains. East of the Chisana Mesozoic rocks still predominate, but older rocks have been

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

recognized in the range at a number of places. In that area Mesozoic rocks are not so closely confined to the Nutzotin Mountains, but occur farther south at a few points. Thus on lower Bryan Creek fossils of Jurassic or Cretaceous age were collected from the creek bed in a locality at which Carboniferous rocks prevail. Likewise, Jurassic fossils are reported from the upper valley of the Middle Fork of White River. It is possible, therefore, that throughout the areas composed dominantly of Carboniferous beds there may occur small patches of Mesozoic rocks folded or faulted down into the older materials.

Lithologically the Mesozoic sediments are predominantly hard banded clay shales and graywackes of black, gray, or bluish color. Those which form the main portion of the Nutzotin Mountains along Chisana River are characteristically composed of interbedded argillites and graywackes in about equal amounts. (See Pl. VI, *A*, p. 21.) Generally the individual beds are thin, ranging from a fraction of an inch to a few inches in thickness, although locally single beds of uniform composition reach a thickness of several feet. On some weathered surfaces a ribbon-like banding is conspicuously displayed, the bands consisting of dense black layers separated by other bands of a brownish cast. On freshly fractured specimens this banding is scarcely distinguishable, but it is brought out by weathering, the brownish layers having a somewhat more sandy composition than the intervening purer argillites. The graywackes have the texture of sandstones, but instead of consisting largely of quartz, are composed of fine fragments of a large variety of minerals, or even of small particles of rock. They are derived from rock masses that have been mechanically disintegrated, rather than from rocks that have been deeply decayed by chemical processes, and they contain, besides quartz, bits of feldspar, ferromagnesian minerals, and, in short, most of the minerals that composed the rocks from which they were derived. Conglomerates are present, but in only subordinate amounts. Some fine conglomerates were seen on Glacier Creek near the mouth of Poorman Creek, and a coarse conglomerate with rounded pebbles and cobbles as much as a foot in diameter is reported on the mountain east of Chisana River, just below the mouth of Chavolda Creek. At the main forks of Chavolda Creek there is a conglomerate containing slate pebbles as much as 6 inches in diameter, and the associated beds have a well-developed slaty cleavage. At many other places also a secondary slaty cleavage has been developed. The thick series of unfossiliferous banded slates and graywackes is remarkably free from rocks of igneous origin, either as interbedded lavas and fragmental materials, or as dikes and sills, although some intrusions were seen.

The rocks that have yielded Jurassic and Cretaceous fossils on upper Bonanza Creek are dominantly shales and argillites, with much less interbedded graywacke than is present in the sediments which form the main mountain mass. Some fine conglomerates are present, and a little impure limestone was seen, but the shales preponderate greatly. The proportion of graywacke is greatest in the lowest part of the section exposed and decreases upward. The shales are cut by abundant dikes and sills, which in places form 10 per cent or more by volume of the total amount of material present. The relations of these intrusive rocks to the shales are excellently shown in the steep bluffs which border the gravel flat of upper Chathenda Creek. (See Pl. VIII, *B*, p. 54.)

STRUCTURE AND THICKNESS.

The Jurassic and Cretaceous beds of the district, as displayed on upper Bonanza and Chathenda creeks, are generally tilted but have been little metamorphosed except at the contacts with intrusive rocks. They strike east or southeast and dip southward at angles which range from 10° or 15° to nearly vertical, with an average dip of perhaps 30°. This portion of the series has been little affected by folding. Faults are probably present but are difficult to recognize in rocks of such uniform composition. The Cretaceous beds of this group lie immediately adjacent to the oldest known rocks of the region, the Devonian, and are separated from them by a profound fault. The displacement along this fault line must have been very great, for the Mesozoic rocks cut out by the fault comprise a very thick series of sediments, and the Carboniferous sediments and igneous rocks also reach a great thickness. The fault line has been traced in an east-west direction for only 12 or 15 miles, but it seems probable that this great dislocation is considerably longer, and that the contact between the Paleozoic and Mesozoic beds west of Chisana River is also along this line.

Although the Mesozoic beds that have yielded Jurassic and Cretaceous fossils have been but slightly metamorphosed and are deformed only by a monoclinal tilting, the argillites, slates, and graywackes which form most of the Nutzotin Mountains and seem to lie structurally beneath the recognized Jurassic beds have been subjected to deformational stresses that have produced intricate folds. The canyon of Chisana Valley, directly across the axis of the range, shows folds striking northwest, parallel with the range, and practically all exposures show folding in the same general direction. Figure 5 is a sketch of the structure on upper Chavolda Creek, looking northwest.

So many uncertain factors enter into such estimates as can be made of the thickness of the Mesozoic beds that only round numbers can be used. Where they are most extensive, in the Nutzotin Mountains, the unfossiliferous argillite and graywacke beds are so intricately folded and faulted that the beds may be many times reduplicated in any section examined across the range. They are continuously exposed, however, for a distance of 13 miles along Chisana Canyon and form mountains on both sides of the river which reach heights of 5,000 to 7,500 feet above the stream. It seems certain that the beds must be many thousand feet thick to form this mountain range. The younger, fossiliferous slates of known Jurassic and Cretaceous age, as exposed on Bonanza and Chathenda creeks, are of less intricate structure, for they have rather uniform monoclinal dips to the southwest. They may also be reduplicated by faulting, but if the series is not reduplicated, the beds have a minimum thickness of 3,000 feet and may exceed that figure.

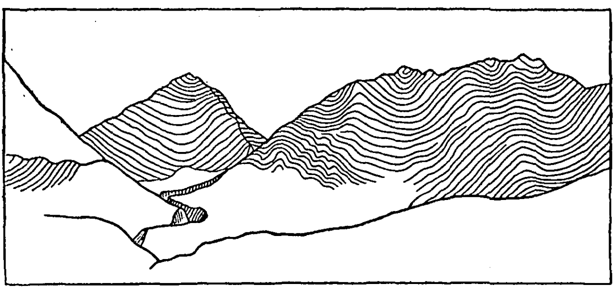


FIGURE 5.—Sketch showing structure of Mesozoic argillites and graywackes on upper Chavolda Creek.

AGE AND CORRELATION.

The oldest Mesozoic rocks that have been recognized in this general region are some limestones which occur at Cooper Pass and on Cooper Creek between Chisana and Nabesna rivers. Limestones of this age were not found in the area here discussed, but were noted at the above-mentioned localities by Moffit and Knopf.[1] They are associated with the massive Carboniferous limestone and were distinguished from it only by an examination of the fossils. The Mesozoic limestone has been closely folded, faulted, and intruded, so that neither its thickness nor its relations to the adjacent sediments could be determined. Fossils collected from it showed its age to be Upper Triassic.

No fossils have been procured from the argillite and graywacke beds which form the main Nutzotin Mountain mass, and their age is not definitely known. They are younger than Carboniferous and apparently lie structurally above the Upper Triassic limestone and beneath the shales of Upper Jurassic age. The structural relation

[1] Moffit, F. H., and Knopf, Adolph, op. cit., pp. 28–29.

between this limestone and the near-by slates and graywackes of the Nutzotin Mountains was not made out, but a number of considerations lend weight to the conclusion that the limestones underlie the slates and graywackes. Among these is the fact that in the vicinity of the Chisana placer mines the unfossiliferous slates and graywackes lie directly beneath the Jurassic sediments, but no limestone corresponding with that at Cooper Pass is present. At Cooper Pass, as well as in other parts of the Wrangell Mountain region, the oldest recognized rocks of Mesozoic age consist of Upper Triassic limestones, and the Lower Triassic beds are missing. It therefore seems safe to say that the slates and graywackes which form the greater part of the Nutzotin Mountains are younger than the Upper Triassic limestone and older than the Upper Jurassic shales. So far as the evidence now available goes they may be either wholly Upper Triassic, in part Triassic and in part Jurassic, or wholly Jurassic.

Structurally above the typical slates and graywackes of the Nutzotin Mountains, in the vicinity of the Chisana placer mines, is a series of shales and graywackes, with some conglomerate, which has yielded fossils that are possibly of Upper Jurassic age. Its lower limit is not known, but its upper part merges, without any observed stratigraphic break, into rocks that are similar in lithology but bear Lower Cretaceous fossils. The fossils collected from this shale and graywacke series were submitted to T. W. Stanton, who made the following report on them:

8807. No. 3. From black shales of Nutzotin (?) series on Chathenda (Johnson) Creek, Alaska:
Aucella crassicollis Keyserling.
Lower Cretaceous.

8808. No. 6. From black shale on claim No. 9, Bonanza Creek:
Aucella crassicollis Keyserling.
Belemnites sp.
Lower Cretaceous.

8809. No. 7. Black shale on claim No. 14, Bonanza Creek:
Aucella sp.
This lot is probably somewhat older than lots 3 and 6 and is possibly Upper Jurassic.

8810. No. 8. From black shales of southeast fork of Chathenda (Johnson) Creek, 1¼ miles above the mouth:
Aucella crassicollis Keyserling.
Aucella sp.
Lower Cretaceous.

8811. No. 9. From shales and graywackes of Gold Run Creek, near its mouth:
Aucella sp.
Probably Lower Cretaceous and, in my judgment, from a somewhat lower horizon than Nos. 3 and 6.

Another lot of Jurassic or younger Mesozoic fossils was collected from the bedrock drain of a placer prospect on lower Bryan Creek. Only a small area of bedrock was exposed, and its relations to other formations could not be made out. The nearest rock outcrops, to the east, are of Carboniferous age, and it is probable that a small area of Jurassic beds has been faulted or folded down into the Carboniferous at this place. The fossils are described by Mr. Stanton as follows:

9109. No. 11. Bryan Creek:
Terebratula sp.
Pecten sp.
Pecten? sp.
Inoceramus sp.
Alaria? sp.
Ammonite, fragmentary imprint of an undetermined genus.
This lot is certainly Mesozoic, and not older than Jurassic. The collection is too small and fragmentary for closer determination.

There is difficulty in correlating many of the Mesozoic formations of the Chisana district with the extensively developed Mesozoic section of the south flank of the Wrangell Mountains in the Chitina basin, although the distance between the two districts is not great. The Nutzotin Mountains have evidently had a quite different history from the Wrangell Mountains. The Triassic limestone of Cooper Pass, which contains *Pseudomonotis subcircularis*, is evidently not to be correlated with the Chitistone limestone, as suggested by Moffit and Knopf,[1] but rather with the overlying thin-bedded limestones that form the basal portion of the McCarthy shale. The absence of fossils in the great body of shales and graywackes of the Nutzotin Mountains prevents their accurate correlation with any of the formations of the Chitina basin, if, indeed, the equivalent rocks are represented in the Chitina section. Recent studies by G. C. Martin[2] show that the post-Triassic rocks of the Chitina Valley include not only the Upper Jurassic Aucella-bearing beds, but also a thick series of Upper Cretaceous shales. The Aucella-bearing rocks of the Chisana district, of Upper Jurassic and Lower Cretaceous age, are possibly to be in part correlated with the Upper Jurassic Aucella-bearing beds of the Kennicott formation, but they include also Lower Cretaceous rocks which have not been recognized in the Chitina Valley and which were laid down during the time interval represented by the pre-Upper Cretaceous unconformity.

TERTIARY ROCKS.

SEDIMENTS.

DISTRIBUTION AND CHARACTER.

Sediments, supposedly of early Tertiary age, occur at a number of localities in the Chisana-White River district. (See Pl. II, in

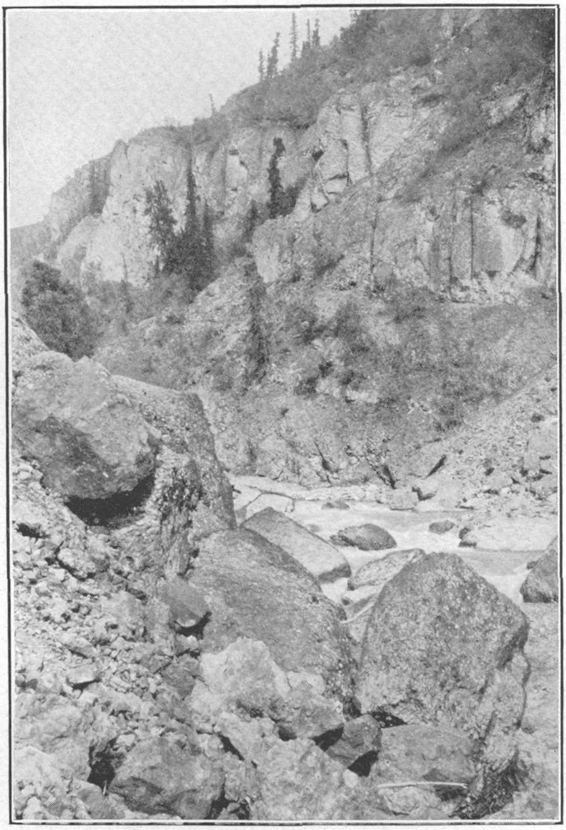
[1] Op. cit., p. 28.
[2] Martin, G. C., The Mesozoic of Alaska: U. S. Geol. Survey Prof. Paper (in preparation).

pocket.) They differ from the Mesozoic and Paleozoic rocks already described in that they are generally less indurated and consist of conglomerates, sandstones, arkoses, and shales, with some tuffs and interbedded lava flows, locally contain lignite or carbonaceous shales, and in one place are composed of unconsolidated gravels. Sediments of this group now occur only in small isolated areas, surrounded by older rocks. That they were formerly more extensive is certain, and it may be that Tertiary sediments were once widely distributed throughout this district.

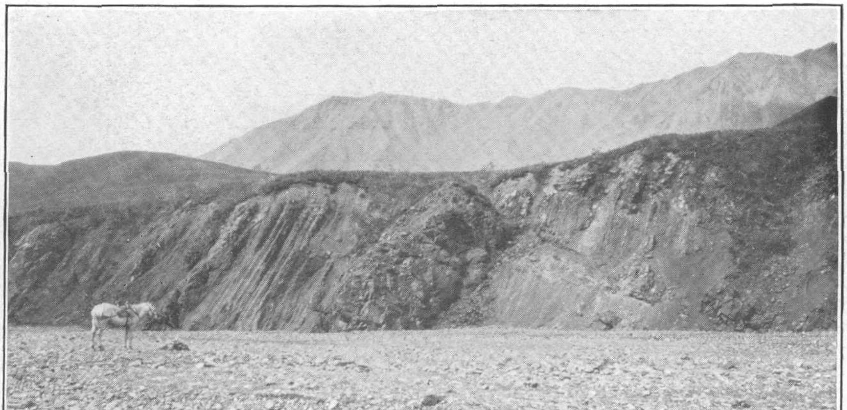
The economic importance of the Tertiary beds is out of proportion to their small areal extent, for they locally contain workable beds of lignitic coal. Furthermore, the gold placers of the Chisana district are believed to be in part derived by secondary concentrations of placer gold from Tertiary gravel deposits. The mineral resources of these beds, both in coal and in gold, are discussed elsewhere in this report.

In the basin of Rocker Creek, near the international boundary, there is a small area of a formation consisting of slightly consolidated shales, arkosic sandstones, and conglomerates, with some lignite, presumably of Tertiary age. The known areal extent of these rocks is small, but they may extend beneath the later lava flows which cap the mountains a short distance to the south. These beds are for the most part nearly flat, but in places they have been folded. At one locality where a tunnel has been driven on a bed of lignite, interbedded with soft greenish arkose and some conglomerate, the bedding strikes S. 50° W. and dips 68° NW. The sediments at this locality have been extensively cut by intrusive rocks. Another small area of Tertiary rocks containing some lignite is reported to occur 3 miles southwest of the mouth of Ptarmigan Creek.

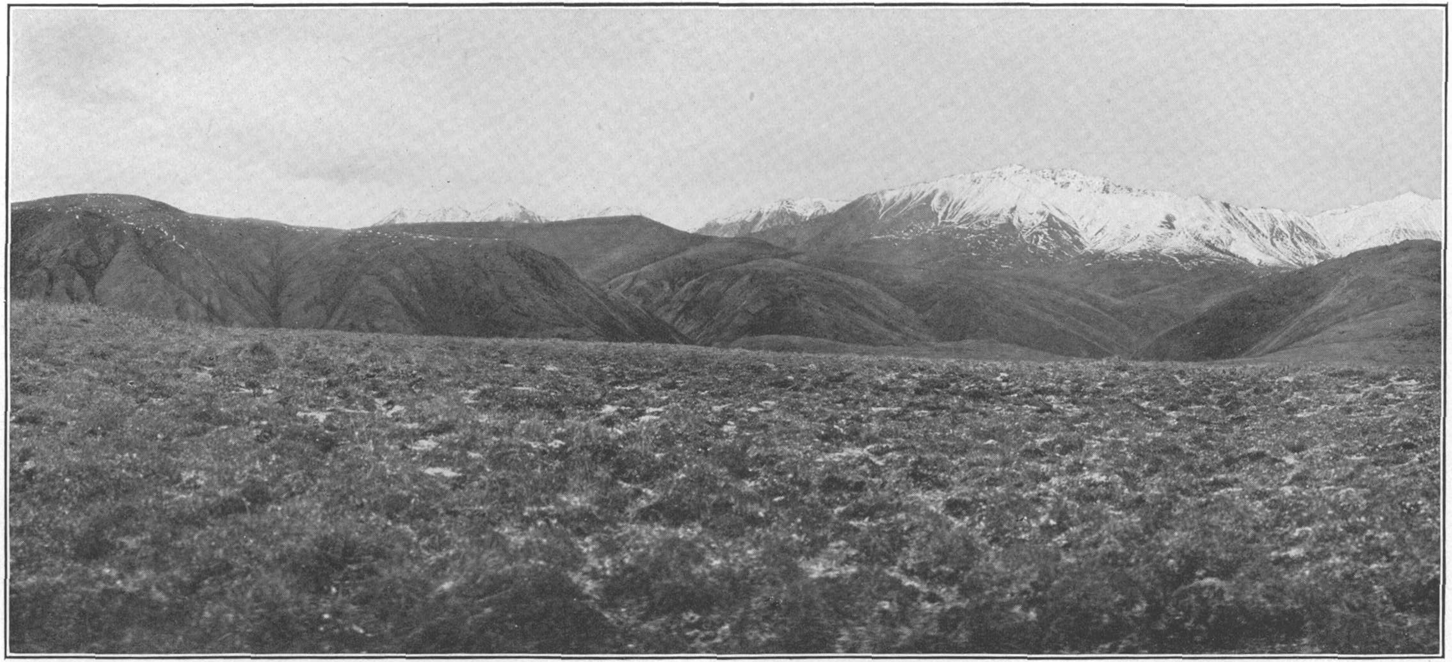
East of the broad pass between Beaver Lake and Chathenda Creek there is a considerable area of Tertiary rocks. The lowest beds exposed consist of hard sandstones and fine conglomerates composed of small pebbles of quartz, slate, and various igneous rocks embedded in an arkosic matrix. Some shale, which on weathering quickly breaks down to soft mud, was seen, and thin layers of lignitic material 2 inches or less in thickness occur in places. Above these clastic beds of relatively fine materials there occurs a thick conglomerate, with some gritty sandstones. Some of the pebbles are a foot or more in diameter, and they are composed for the most part of igneous rocks such as are found in the Carboniferous terranes of this district, including diorite, lavas, and pyroclastic materials, in an arkose matrix. The conglomerate covers an area of several square miles and forms prominent cliffs 200 feet or more in height. The beds have been mildly tilted, the general strike being a little west of north and the dips 5°–20° E.



A. MASSIVE TERTIARY CONGLOMERATE ON CHATHENDA CREEK BELOW THE MOUTH OF DRY GULCH.



B. HIGHLY INCLINED MESOZOIC SLATES CUT BY DIKES AND SILLS ON UPPER CHATHENDA CREEK.



VIEW NORTHWARD ACROSS BONANZA VALLEY.

The smooth-topped hill in the center is Gold Hill, capped by Tertiary gravels.

Another area of Tertiary rocks lies in the basins of Rhyolite and Chathenda creeks, and good exposures are offered by the walls of Chathenda Canyon below the mouth of Dry Gulch. The formation there consists of conglomerates, sandstones, and shales, with some volcanic tuffs and interbedded basic lava flows. (See Pl. VIII, *A*, p. 54.) Some carbonaceous shales with thin beds of impure lignite are present, but no coal beds of workable thickness have yet been found. The beds form a synclinal trough, which is folded down into the older lavas and pyroclastic rocks and has an easterly strike.

Similar small bodies of Tertiary sandstones, shales, and conglomerates, with some lignite, are reported from the north flank of the Nutzotin Mountains in areas not yet geologically mapped, and are significant as indicating that Tertiary deposits occur over a wide area. It is also possible that within the area shown on Plate II there are small patches of Tertiary beds which were not seen, and such deposits are probably present in places between White River and Beaver Creek beneath the covering of later lava flows.

A deposit of gravels, presumably of Tertiary age but of different character from those already described, forms the upper portion of Gold Hill, between Chathenda and Chavolda creeks. (See Pl. IX.) It has been mapped (Pl. II, in pocket) only on the top of Gold Hill, where it is well developed, but scattered gravels derived from this deposit occur on all the slopes of this mountain and in the beds of the streams that drain it, and they may locally be of considerable thickness outside of the area shown. These gravels, while apparently of great age, are entirely uncemented. The pebbles are well rounded, smooth, and generally small. Some cobbles and small bowlders as much as 1 foot in diameter were seen, but most of the pebbles are only a few inches or less in diameter. The deposit is rudely stratified, coarse gravels alternating with finer gravels or with sandy layers, and the whole bearing a close structural resemblance to the beds now being laid down in this district by streams. A shaft 150 feet deep has been sunk into the gravels without going through them, and it is evident that at their maximum they are 200 feet or more in thickness. The pebbles include a great variety of rock types, the most numerous of which are lavas and pyroclastic and intrusive rocks, like those which make up the near-by Devonian and Carboniferous terranes, with a lesser number of argillite and graywacke pebbles, which may have been derived from the Mesozoic sediments.

That the gravels are of great age is attested by a number of facts, among the most evident of which is their topographic position. They occupy the summit of a high mountain, which has valleys 1,500 to 2,000 feet deep on both its north and south sides. It is plain that the gravels must have been laid down at a time when the topography of the district was greatly different from that of to-day. The present top of Gold Hill must then have been a depression, and the deep bordering valleys had not been eroded. It is probable also that the gravel deposit, as formed, had a much greater area than it now has, the existing deposit being but a remnant left by erosion. The great age of the gravels is also shown by their deeply oxidized and decayed condition. The material taken from a shaft 150 feet deep was all of reddish or brownish color, and many of the pebbles were so decayed that they crumbled and fell to pieces, although they must have been hard and firm when rounded by the streams that transported them. The gravels also contain pieces of lignitized wood which, although not determinable by the paleobotanist, indicate by their composition that they have been long buried. The gravel deposit on Gold Hill is of great economic importance, for it is believed that the gold placers of the streams in this vicinity have in large part been formed by a secondary concentration of gold from these gravels. The relation of the gravels to the gold placer deposits is discussed in another part of this report.

STRUCTURE AND THICKNESS.

Brief mention has already been made of the structure of the Tertiary sediments in the different localities where they have been observed. Taken as a whole, the beds correspond rather closely in character and structure to deposits of similar age, which have been studied in many parts of the Alaska Range. The coarsely clastic nature of most of the material of which they are formed, the absence of marine fossils, the presence of abundant though generally imperfect remains of land plants, and the patchy distribution of the deposits all suggest that the beds were laid down as river-valley or estuarine deposits. If this is true, the original areas of deposition were long and narrow, and later erosion would naturally tend to cut the deposits up into relatively small, isolated patches. Great mountain-building forces have been in operation since the Tertiary sediments were laid down, and these deposits have been deformed by folding and tilting. The deformation has in general been parallel to the trend of the mountain ranges, though local exceptions occur. Thus at the coal prospect in the basin of Rocker Creek the Tertiary beds strike northeast at right angles to the Nutzotin Mountains, but at that place the sediments have been intruded by igneous rocks and their attitude may be due to compression developed during the intrusion. In the western part of the Beaver Creek basin and on Chathenda and Rhyolite creeks the Tertiary beds strike in a general northwest or west direction, roughly parallel to the faults and folds of the Nutzotin Mountains. The unconsolidated gravels of Gold Hill are apparently little disturbed.

No continuous exposure through the whole series of Tertiary sediments was anywhere observed, so that only approximate figures of their thickness can be given. In the Rocker Creek basin the beds have a thickness of at least 300 feet and may exceed that figure. East of Beaver Lake the shales, sandstones, and conglomerates are apparently at least 1,000 feet thick, as they are also in the canyon of Chathenda Creek. At all these localities the beds have suffered an unknown amount of erosion, and the whole formation as originally deposited is perhaps nowhere preserved.

AGE AND CORRELATION.

Although the fossil remains of plants are locally abundant in the deposits just described, most of those collected were too fragmentary or too imperfectly preserved to supply evidence for a definite age determination. The only identifiable plants, collected from Chathenda Creek near the mouth of Rhyolite Creek, were submitted to F. H. Knowlton, who made the following report:

Lot 6906. Sandstone on Chathenda (Johnson) Creek, just above mouth of Rhyolite Creek:

Pecopteris arctica? Heer.
Cyperacites sp.
Juniperus? sp.
Nyssa? sp.

This material is very fragmentary, and hence the identifications are open to more or less question, but so far as can be made out it is Tertiary.

The beds here represented in many ways resemble the Kenai deposits, of Eocene age, which are widely distributed throughout Alaska. The points of resemblance include the character of the material, the amount of induration, and the presence of lignitic coal. Moffit and Knopf,[1] in describing the beds in the basin of Rocker Creek, said:

The resemblance of these rocks to those of similar patches scattered throughout the Yukon basin leaves little doubt as to their Tertiary and probable Kenai age. Rocks of identical character occur near the head of Chitistone River and, like those of the White River region, are covered by a heavy series of volcanic flows.

As this formation is younger than the Cretaceous rocks of the Chathenda basin and is older than the last great period of glaciation, there seems to be little chance for error in referring it to the Tertiary, and it is tentatively correlated with the Kenai formation, of Eocene age. This age determination applies only to the more or less indurated sediments and does not include the gravels of Gold Hill. That the Gold Hill deposit is of great age has already been shown,

[1] Op. cit., p. 32.

but its unconsolidated condition and freedom from deformation suggests that it is younger than the rocks correlated with the Kenai. It is also much older than the time of the last great glaciation, and in the absence of more definite information it is referred to the Tertiary, but probably it represents a portion of the Tertiary later than the Kenai.

TERTIARY AND LATER LAVAS.

DISTRIBUTION AND CHARACTER.

As is shown on the accompanying geologic map (Pl. II, in pocket), large areas in the Wrangell Mountains and in the region between them and the Nutzotin Mountains are covered by lava flows and fragmental volcanic materials. The igneous rocks in general are discussed in a separate section of this report, but the lavas, having been poured out upon the surface, have a definite place in the stratigraphic succession and are therefore discussed here in chronologic order.

The higher parts of the Wrangell Mountain mass are composed of lava flows and fragmental volcanic materials which were ejected from vents within this mountain range and which accumulated to form a great thickness of bedded rocks. Similar lavas, perhaps supplied from the Wrangell volcanoes or perhaps arising from local vents, occur also in the St. Elias Mountains and in the less rugged area that lies between the Wrangell-St. Elias chain and the Nutzotin Mountains. Mendenhall,[1] who studied these rocks in the western part of the Wrangell Mountains, called them the Wrangell lavas and described their structural and microscopic character in some detail, so that further description is unnecessary here. The chief center of dispersion of the lavas and pyroclastic rocks seems to have been in the area outlined by Mounts Regal, Blackburn, Wrangell, Drum, Sanford, and Jarvis, and within that area the volcanic rocks are piled up to a thickness of many thousand feet. There the beds still retain their original attitude, showing slight dips toward the periphery of the mountain mass and away from the centers from which the rocks were ejected. Outside of the area of greatest volcanic activity, already outlined, the lavas extend in all directions to varying distances, but in general they become progressively thinner as the distance from the old volcanoes increases. Along the valley of Skolai Creek (see Pl. III, p. 16) and on the northeastern front of the Wrangell Mountains, between Russell and Chisana glaciers, the lavas appear as nearly horizontal beds forming the upper portion of the mountains, and they extend east of Russell Glacier into the St. Elias Mountains, although they are probably not so widespread

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, pp. 54-62, 1905.

there. Between Beaver Creek and White River the lavas cover wide areas, though they are not generally so thick as in the Wrangell Mountains. In that part of the district the lavas are associated with andesitic intrusive masses and may have been poured out from local vents rather than from the Wrangell Mountain centers of extrusion.

A characteristic feature of this group of rocks is the pronounced bedding which they everywhere display. The bedded structure may be recognized at a distance of many miles and is emphasized by erosion, so that many lava mountains have a pronounced terraced appearance. The great variety of colors displayed by different beds also makes the bedding conspicuous. Deep shades of brown, red, and green predominate, but they alternate with bright reds, yellows, pinks, and grays, the whole series being in striking contrast to the somber-colored formations with which it is commonly associated. Columnar jointing is locally developed and is especially noticeable in the lavas that form the ridge of which Pingpong Mountain is the most prominent point.

As already stated the series is composed of lava flows and of the fragmental volcanic material ejected from the vents intermittently during the period of volcanic activity. The fragmental materials include tuffs, composed of finely comminuted rock particles and pumice; volcanic breccias, of coarser, angular fragments; and layers of volcanic bombs. All the fragmental materials were derived from the same magmas which yielded the lava flows and are of the same types of rocks. The lava flows consist mainly of pyroxene andesites, usually containing hypersthene, and olivine basalts, and to a less degree dacites. They range in texture from glassy to holocrystalline. As will be shown, the volcanoes of this region have been active intermittently from Tertiary to Recent time, and it is natural that the materials ejected should show much variety, both in composition and in appearance. It is noteworthy, however, that although there is great diversity in the appearance of the different beds, the average composition of the volcanic rocks first extruded is remarkably like that of the youngest phases, and the stratigraphic position of the flows at any particular place must be relied upon to determine the portion of the series to which they belong.

STRUCTURE AND THICKNESS.

The younger volcanic rocks have in general been little deformed, and their most characteristic structural feature is the nearly horizontal bedding which is commonly displayed. As seen from a distance the higher portions of the Wrangell Mountains appear to be generally composed of nearly flat lava flows and pyroclastic beds. Locally, however, the beds have been tilted or gently folded. Thus in looking from Nizina Glacier up Regal Glacier toward Mount

Regal (see Pl. IV, *A*, p. 18) the lava beds are seen to dip northwest, apparently toward the source from which they were extruded. In the White River basin, near the mouth of Lime Creek, lava flows associated with deposits, presumably of Quaternary age, stand nearly vertical, or dip steeply to the northeast. On the south side of the Beaver Creek basin, near the northern margin of the lava-covered area, the beds dip to the south. These facts prove that deformation of the surface has continued to a time which, in geologic terms, is very recent, and suggest that the mountain-building processes in this district may still be in operation.

The thickness of the younger lavas varies greatly from place to place, as is inevitable with deposits of this kind. They accumulated to form great mountains at the vents from which they were discharged but thinned out radially away from the vents. The thickness of these materials was also influenced by the topography of the country that they covered. Mendenhall[1] recognizes a prevolcanic relief of at least 3,000 feet on the west slope of the Wrangell Mountains. Schrader and Spencer,[2] in describing the same formation in the eastern part of the Wrangell Mountains, state that the lavas were deposited upon the uptilted and folded rocks which had been eroded to a general, uniform surface. In the basin of Skolai Creek, at the eastern edge of the area visited by Schrader and Spencer, the land surface beneath the lavas had a relief of at least several hundred feet. (See Pl. III, p. 16, and fig. 3, p. 37.) It is evident, therefore, that volcanic rocks poured out over so wide a territory in such abundance would cover flat, level areas, ranges of hills, and even low mountains, and would in places enter bodies of water and interrupt the ordinary processes of sedimentation. That they did stop the deposition of water-laid sediments is shown by the observations of Moffit and Knopf[3] at Chitistone Pass, where a formation of shales and sandstones is interrupted by a stratum of volcanic breccia, followed by a thin bed of shale. The shale is overlain conformably by a great thickness of bedded lavas.

A general idea of the range in thickness of the lavas may be given by rough measurements made at a number of localities. Thus on Regal Glacier, 5 miles above its junction with Nizina Glacier, the lava series is believed to be at least 4,000 feet thick. On Skolai Creek, south of Frederika Glacier, 3,000 feet of lava beds are exposed. (See Pl. III, p. 16.) Between White River and Beaver Creek the thickness of the lava series ranges from at least 1,600 feet near Pingpong Mountain to only a few feet at its northern border,

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[1] Op. cit., p. 57.

[2] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska: U. S. Geol. Survey Special Pub., pp. 51–52, 1901.

[3] Op. cit., p. 35.

near the mouth of Carl Creek. The upper 1,800 feet of Euchre Mountain, on Chisana River, is composed of this formation.

AGE AND CORRELATION.

It is a generally accepted fact that the land surface upon which the basal lavas flowed was developed in part in Tertiary time. Certain of the Tertiary beds of the Chisana district had been uptilted and eroded before the deposition of lavas over them, but other Tertiary beds, presumably of Eocene age, contain both lavas and fragmental volcanic beds. If the tentative correlation of the Tertiary sediments with the Eocene is accepted, then some of the lavas in that district are Eocene. Mendenhall[1] concluded that the oldest of these flows must be nearly as old as Eocene, and Schrader and Spencer[2] assigned them to the post-Eocene portion of the Tertiary. The evidence as to the age of the beginnings of volcanism in this region is therefore conflicting, and it is probable that volcanism began locally in Eocene time, but that the general burial of the Wrangell region by lavas did not take place until the post-Eocene portion of the Tertiary period. Schrader and Spencer, however, apparently assigned the whole group of volcanic rocks to the Tertiary. Mendenhall recognized that volcanic activity has been shown by Mount Wrangell in historic times, and believed that most of the lavas are very young. The facts noted by the writer in a study of the lava series in the Chisana district seem to prove that the lavas present there are relatively young and for the most part, at least, of post-Tertiary age. As already stated, the Eocene (?) sediments contain some interbedded lavas and tuffs, yet the basal lava flows near the head of White River, which lie upon an erosion surface cut from Carboniferous rocks, are associated with glacial gravels and tillites, presumably of Quaternary age, and most of the lavas between White River and Beaver Creek are apparently younger than the tillite. The older glacier materials can not yet be correlated with any of the continental glacial stages, but they, as well as the overlying lavas, are certainly Pleistocene. The last great glaciation, probably of Wisconsin age, was later than any of the lava flows studied. It can therefore be stated definitely that a large part of the lava series north of White River is of Pleistocene age.

QUATERNARY SYSTEM.

PREGLACIAL CONDITIONS.

As has been shown, the volcanoes of the Wrangell Mountains were active in Pleistocene time, and great quantities of lava and

[1] Op. cit., p. 57. [2] Op. cit., p. 52.

pyroclastic material were ejected. Nevertheless, the deposition of volcanic materials is always of a somewhat intermittent character, and in the intervals between volcanic outbursts the ordinary processes of erosion were active. Some of the intervals were probably long, and at such times streams may have succeeded in dissecting the accumulated deposits to a considerable degree. Furthermore, many of the areas bordering the volcanic mountains had not in early Pleistocene time been flooded with lavas, and in these areas stream erosion and deposition had been long continued, probably since at least the middle of the Tertiary period.

ADVANCE OF ICE.

The Pleistocene epoch was characterized at many places throughout the higher latitudes of the northern hemisphere by accumulation of glacial ice. Through some climatic change having to do with a reduction of the temperature or an increase in precipitation, or both, the amount of annual snowfall in the higher mountains began to exceed the annual melting, and glaciers were formed. At first they existed only on the protected slopes of the highest peaks, but as the conditions became more favorable for ice accumulation glaciers started at lower elevations and the ice tongues already formed lengthened. By continued growth the smaller glaciers joined one another and advanced downward, ultimately occupying all the mountain valleys and extending outward from the mountains into the lowlands.

The erosion accomplished in the mountain masses by the multitudes of valley glaciers was enormous. Each small glacier and each valley ice tongue was effectively engaged in modifying the shape of its bed. By the abrasion of rock fragments held in the ice and by the plucking out of blocks of rock from its walls and floor each slowly moving glacier gradually removed from its path such obstructions as opposed its advance or restricted its channel. Deep, steep-walled cirques were developed, overlapping spurs and irregularities of the valleys were removed, and the channel occupied by each ice tongue was widened and deepened to form a great trough that was U-shaped in cross section. Beyond the borders of the mountains the effects of the glaciers on the topography of the land that they covered was of a different character but was nevertheless great. Many ranges of hills were overridden by the ice and were smoothed and rounded, and broad gaps were cut through them, but in general deposition predominated over erosion, and the waste materials, removed from their headward basins by the glaciers, were dropped near the wasting margins of the ice tongues. Stream courses were obliterated, great moraines were built, and the river valleys through which the discharge from the melting ice flowed received enormous quantities of gravel, sand, and silt, the outwash from the glaciers.

OLDER GLACIAL STAGE.[1]

During Pleistocene time the continental glaciers, formed at several centers of accumulation in Canada, advanced southward into the United States, and the glacial period included a number of glacial advances, separated by periods of retreat and deglaciation. The glaciation of the Alaskan mountains, however, was not of the continental type but consisted exclusively of the development of mountain glaciers. Furthermore, the glaciers formed in Alaska during the last great stage of glaciation were so vigorous and so large that they rendered difficult the recognition of earlier glacial stages by modifying the topography and by removing or covering the older glacial deposits. It has seemed fair to assume that climatic changes of sufficient magnitude to cause the formation of the great continental glaciers would have affected the Alaskan mountains also, and that there should have been successive stages of glaciation in Alaska to correspond with those of the continental glaciers. Nevertheless, the problem has been beset by many uncertainties, for little evidence of more than one great ice advance has been found. In 1890 and again in 1891 I. C. Russell[2] observed on the southern slopes of Mount St. Elias certain elevated marine deposits of fine clastic sediments containing bowlders which he believed to be of glacial origin. The same terrane was observed in 1913 by A. G. Maddren[3] in the Yakataga district, and his interpretation of the origin of the bowlders is in agreement with that of Russell. For the most part, however, the literature on Alaska fails to discuss the probability of earlier stages of glaciation in this region, although the suggestion has been made that there may have been earlier glacial advances, but if so, they were less extensive than the last, and the evidence has been destroyed or obscured by the more extensive and more recent ice invasion.

In the investigation on which this report is based observations were made which prove definitely that there has been in the valley of White River a glacial advance that antedates by a long period of time the last glacial stage, the effects of which are so conspicuous. Such a development of glacial ice could hardly have been due to purely local causes but must have been brought on by climatic con-

[1] Capps, S. R., Two glacial stages in Alaska: Jour. Geology, vol. 23, pp. 748–756, 1915.

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

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

ditions which affected large areas, and it seems to offer a sufficient basis for assuming that in other parts of the same mountain range, at least, and possibly in general throughout the mountains of Alaska, there have been two stages of Pleistocene glaciation, if not more.

Near the source of White River in Russell Glacier, between Lime and Solo creeks, two tributaries of the White, there are certain foothills which in 1908 were seen by the writer to consist for the most part of gravels, but no careful study of them was made at that time. In the summer of 1914 a single day was available in which to revisit this locality, and heavy rains and fog during that day prevented as thorough an examination as was desirable. The accompanying section (fig. 6) is therefore not complete, and the thicknesses given are only approximate, yet certain significant facts are made clear.

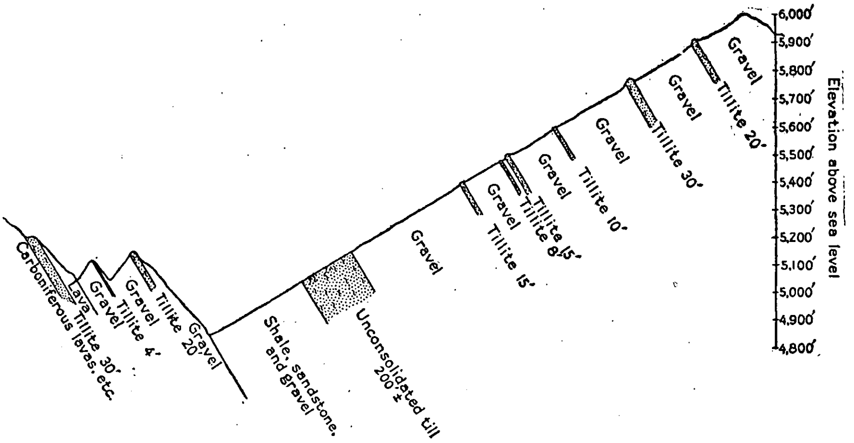
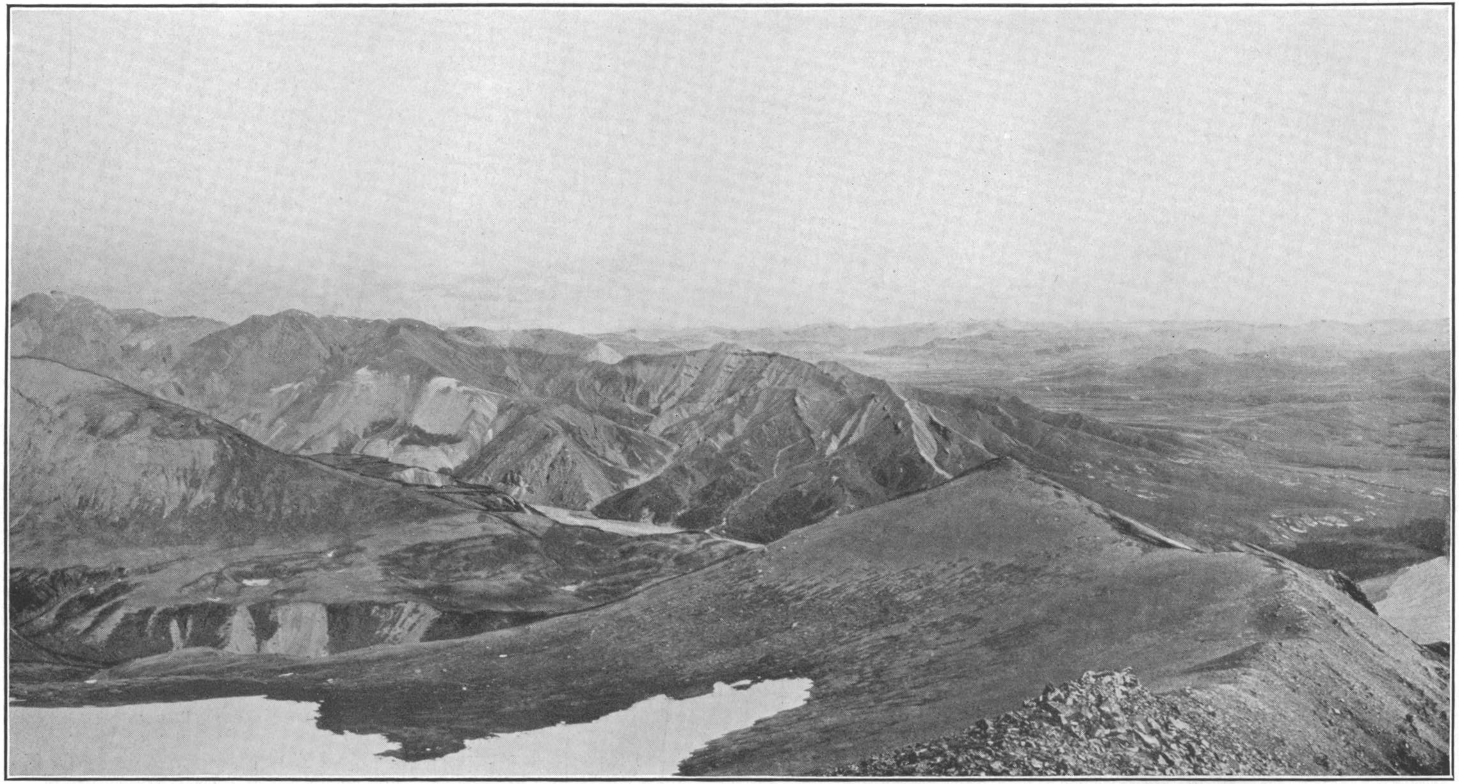


Figure 6.—Diagrammatic section of old glacial deposits in upper White River basin.

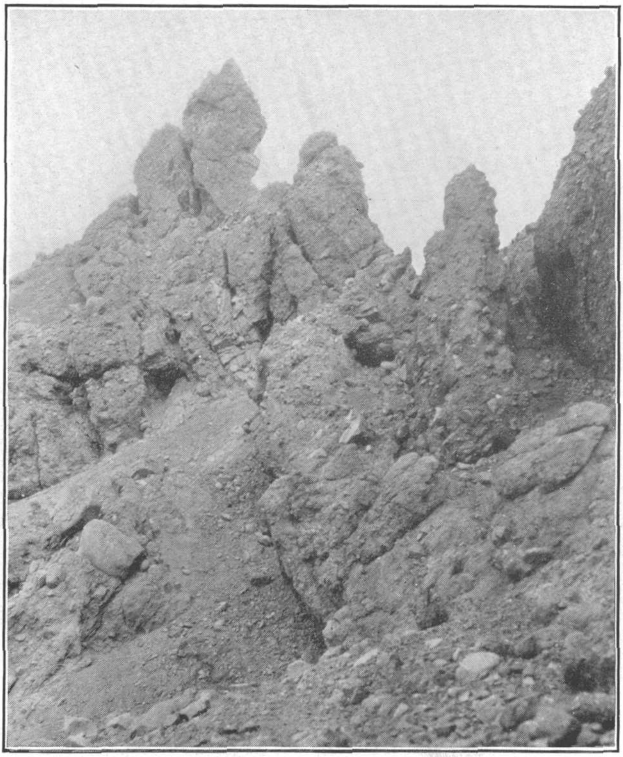
The exposure from which the section was drawn is unusually good, the surface of the hills being almost entirely free from vegetation and cut by a number of clean, steep-sided gullies, so that practically every foot of the section is exposed. (See Pl. X.)

The section covers a vertical distance of 1,150 feet and shows a great thickness of unconsolidated gravel beds, with some soft shales and a little sandstone, interrupted by sheets and lenses of glacial till in different stages of induration and by lava flows. Measured perpendicular to the dip, over 3,000 feet of beds were examined, and the thickness of the upward continuation of the series is not known, but is considerable. The gravels, which form much the greater part of the entire thickness, are well rounded, but only fairly well assorted, and are apparently stream laid. The pebbles are composed of the Carboniferous lavas and limestones that form the mountains imme-

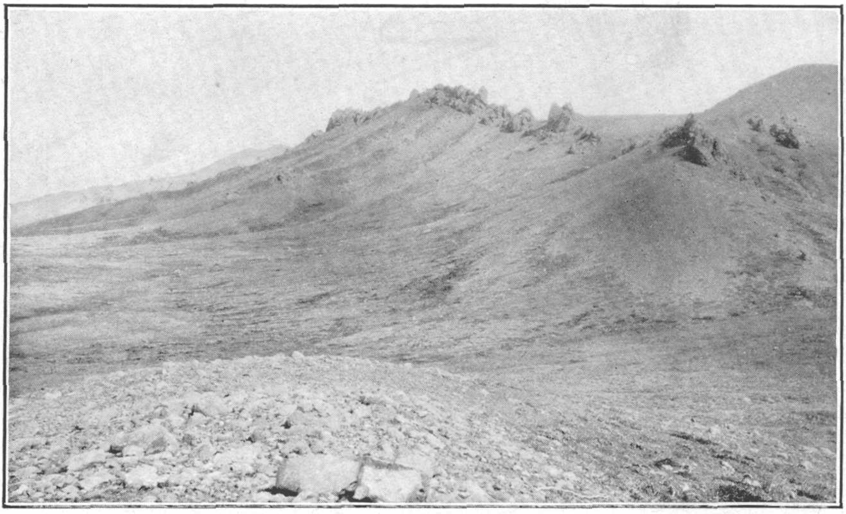


VIEW NORTHWARD ACROSS VALLEY OF LIME CREEK.

Mountains at left are Carboniferous volcanic and sedimentary rocks; hill in center consists of tillite beds and associated outwash gravels.



A. CLOSE VIEW OF A TILLITE BED.



B. STEEPLY TILTED BEDS OF TILLITE AND OUTWASH GRAVELS IN UPPER WHITE RIVER BASIN.

diately adjacent on the southwest. In one place a considerable thickness of arenaceous shales and sandstones occurs. Only one lava bed is shown in figure 6, but in other localities near by similar lenticular lava flows were seen much higher in the section, and farther east, on the North Fork of White River, the glacial series here described is overlain by lavas of considerable thickness.

The tillite beds, although forming only a small proportion of the whole series, are nevertheless the most conspicuous members of it, for their outcrops are left in high relief by the removal of the softer surrounding materials. The uppermost bed shown in figure 6 in places forms the crest of the ridge and stands up in high, ragged pinnacles (Pl. XI). The tillite exactly duplicates, except for its induration, the ordinary glacial till that is so widely distributed throughout this general region. It has a clayey matrix full of small, angular fragments of rock, many of which are several feet in diameter. The included bowlders and blocks consist of the materials which compose the mountains to the southeast, mostly basic extrusive rocks of brown, purple, and reddish color, and the matrix has a slight purple tinge.

Striæ were found abundantly on many of the bowlders, especially on those of fine texture. Large bowlders in particular showed plentiful striations, but typically striated hand specimens were not easily found. The characteristic subangular bowlders, so typical of glacial deposits, are plentiful throughout the tillite, and the whole aspect of these beds leaves no doubt of their glacial origin. The specimens shown in Plate XII were broken from the solid matrix, and numberless other larger but equally characteristic striated and subangular bowlders were found embedded in it, so that no suspicion can be entertained that the glaciated bowlders were deposited upon the surface at this place by a later glacier.

In the particular part of the section measured, shown in figure 6, there are nine beds of tillite, ranging from 4 to 30 feet in thickness, and one bed of uncemented glacial till, largely covered by waste from above but apparently at least 200 feet thick. Probably no other portion of the section would be like that figured, for the tillite beds are lenticular in the cross section exposed and probably also down the dip. The uppermost tillite bed shown, however, persists along the strike for at least a mile, though its thickness is variable.

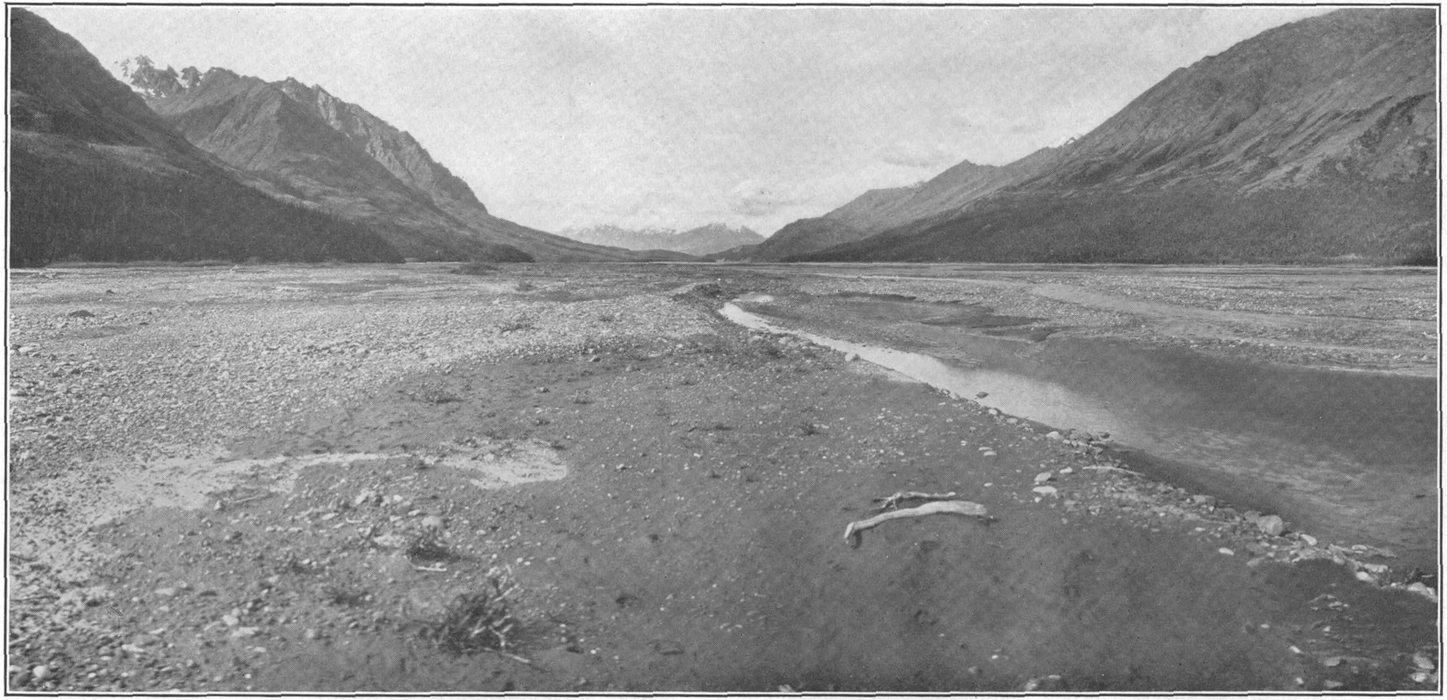
About 6 miles east of the locality just described tillite beds are exposed in the canyon of the North Fork of White River in at least two places. The tillite is of the same general appearance and about as much indurated as that already described, and is overlain by lava flows. The structure of the beds at both localities indicates the probability that they are parts of the same series of glacial beds, although in the intervening area they are not exposed.

The tillite series here discussed is thought to have been laid down near the oscillating edge of a glacier. The record shows repeated advances, with deposits of morainal material, followed by recessions during which the till was covered by outwash gravels from the ice front, and one period during which finer sediments, represented by the shales and sandstones, were laid down. These finer materials may be lake deposits. There were also occasional extrusions of lava over the surface of till and outwash. The lenticular shape of the tillite beds may be due either to the original shape of the morainal deposits or to local erosion after a time of ice recession. The lack of induration of one thick till bed may be the result of the impermeability of the till itself or of the underlying shale and is not believed to affect the general interpretation of the age of the materials. The whole series of beds, with the exception of the lava flows, is composed of materials similar to those now being deposited near the lower ends of many glaciers in this same mountain range.

As will be shown later, the evidence is rather definite that the last great ice advance in this region was contemporaneous with the Wisconsin stage of continental glaciation. At one point at the edge of the Lime Creek gravel flat the unconsolidated till of the last great ice advance was found lying unconformably upon the upturned and glaciated edges of the older tillite, proving definitely that the tillite series was laid down during a glacial advance which antedated the last ice invasion. Several lines of evidence indicate that the time which elapsed between the two recognized stages of glaciation was long. The induration of the tillite beds, compared with the unconsolidated condition of the till beds deposited by the last great glaciers, indicates that the tillite is much older. The tillite series was deposited during intermissions in the eruption of the younger lava flows, the deposition was interrupted by outpourings of lava, and after the cessation of glacial activity the glacial deposits were deeply buried by volcanic materials. The tillite was then indurated, and the glacial beds and associated lavas were locally tilted and deformed. After the period of tilting, erosion attacked the land forms resulting from earth movements and from the great accumulation of volcanic beds and developed upon them and the underlying rocks a rather mature topography. All these changes took place during the interval between the two recognized stages of glaciation.

Little can now be said regarding the areal extent of the glacier which left these old morainal deposits. The elevation of the present exposures of tillite is of little importance in determining the height

STRIATED AND SUBANGULAR PEBBLES FROM TILLITE.



VIEW UP VALLEY OF CHISANA RIVER IN NUTZOTIN MOUNTAINS, SHOWING ITS NARROW FLOOR AND HIGH, STEEP WALLS.

reached by the old glacier, for the beds show by their structure that they have been tilted, with minor folding, and their present elevation may be greatly different from that at which they were laid down. In the section shown in figure 6 the 3,000 feet of beds described are found within a vertical range of only 1,150 feet. The beds there dip 55°-60° E., but the dips gradually become less as the distance from the mountains increases, and in the canyon of the North Fork of White River the tillite is nearly horizontal. All the known outcrops of tillite lie well within the limits reached by the ice during its last great advance, and no comparison can yet be made of the extent of the ice fields during the two stages.

It is presumed from the generally unconsolidated condition of these beds, other than the tillites, that this series of deposits represent a stage of glaciation during Pleistocene time, but of much greater age than the materials left by the ice during its last advance. There is no positive proof, however, that the beds are of Quaternary age. They may be older, but the writer is inclined to ascribe them to the great period of Pleistocene glaciation.

LAST GLACIAL STAGE.

EXTENT AND THICKNESS OF ICE.

As has been shown, during the long interval between the two stages of glaciation lavas were poured out, the beds were then uplifted and warped, and next followed a long period of erosion. The last great stage of glaciation was brought about by a recurrence of climatic conditions similar to those which had produced the earlier glaciers. The last stage was so recent a geologic event, however, that the surface forms developed by the erosion and deposition of the ice have been but little modified and the effects of glaciation are clearly recognizable. The outer limits reached by the great glaciers of this district have not yet been closely outlined, for the ice fields terminated in areas that have so far not been carefully studied. It is known, however, that the glaciers pushed out far beyond the mountains from which they received their supply of ice. The White River glacier was of great depth and thickness at the international boundary. It completely surmounted and smoothed off the mountain ridge that lies between Ptarmigan Lake and White River, and was therefore more than 2,200 feet thick at the boundary, where it had a width of 13 miles. Ice from this valley overflowed the basin at two points at least. It moved northward through the basins of Solo Creek and the North Fork of White River and over the hills between them into the valley of Flat Creek and thence into the Beaver Creek basin and also poured through the gap at Ptarmigan Lake into the valley of Beaver Creek by way of Ptarmigan Creek. It received tributary glaciers from all the valleys draining to it from the St. Elias and

Wrangell mountains but none from the mountains to the north. The area in which the White River glacier terminated has been little studied, and the outlines of the glaciated area have been drawn only approximately. Hayes[1] states that the former presence of ice is shown by a sheet of bowlder clay north of Donjek River, near its mouth, and he maps the northern limit of glaciation in the White River valley a short distance above the mouth of the Donjek. This would give the old glacier a length about 130 miles greater than that of the present glacier.

The glacier that occupied the Chisana basin also reached large proportions. There is evidence that on Euchre Mountain its surface reached an elevation of 5,700 feet, 2,500 feet above the present stream, and a similar thickness is indicated by the glacial topography of the hills between Chathenda and Chavolda creeks. This glacier was fed by the great ice tongue coming from the head of the Chisana basin, by many smaller glaciers rising from the flanks of the Wrangell Mountains between the White and Nabesna basins, and by a number of glaciers which originated on the south slope of the Nutzotin Mountains. All these valleys poured their ice into the upper part of the Chisana basin and filled it to a depth of more than 2,500 feet. The present outlet of the basin, through a deep, narrow valley that has been cut directly across the Nutzotin Mountains (Pl. XIII), was inadequate to carry off the flood of glacial ice, and it accumulated until it overflowed the margin of the basin on the east, into the valley of Beaver Creek. A number of gaps were utilized by the overflowing ice and were widened and deepened by the glacier as it moved through them. It is apparent that during the time of the greatest development of the glaciers the glacial field was continuous between the White and Chisana basins. The ice movement was most rapid through the gaps from upper Trail Creek across the head of the North Fork of White River into Flat Creek, over the Trail Creek and Willow Creek divide, and from Bryan Creek into the head of Beaver Creek, and the main discharge went through the present canyon of Chisana River. Between these overflow channels there were areas where the ice was thinner and comparatively stagnant, and erosion was less severe. The terminus of the main glacier, which passed through Chisana Canyon, was on the broad lowland several miles north of the north front of the Nutzotin Mountains. Its border lay in an area which has not been studied and is therefore not accurately known.

The Beaver Creek glacier was fed by tributary ice streams within its own basin, both from the north and the south. These tributary glaciers were, however, all relatively small, for the mountains they

[1] Hayes, C. W., An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, p. 157, 1892.

drained are of much less elevation than those of the Wrangell and St. Elias chain, and their basins are small. In addition to the ice from its normal drainage basin, the Beaver Creek glacier received considerable accessions of ice as overflow from the White and Chisana glaciers, and its valley bears testimony to the severity of the glacial scour. This glacier also overflowed its basin and sent a large ice tongue to the northeast through the gap between Horsfeld and Eureka creeks. To the east of this district both branches joined the glacier in the White River valley.

Several smaller valleys on the north flank of the Nutzotin Range, notably that of Snag River, were occupied by ice tongues of considerable size, which pushed beyond the mountains and debouched upon the lowland, but their boundaries have not yet been delineated.

AGE OF LAST GLACIAL STAGE.

It has long been recognized that the higher mountains of Alaska have been severely glaciated at a time which in terms of earth history was not long ago. Brooks[1] in 1906 prepared a map that showed the glaciated areas as then outlined, and Tarr and Martin[2] have more recently prepared a similar map, based on later information. The glaciers of Alaska were distinctly of the mountain glacier type, and no continental glaciers have been developed there. It has therefore been difficult to correlate the Alaskan glaciation with any of the stages of continental glaciation, and no attempt, based on trustworthy evidence, has hitherto been made at such a correlation. A few writers have suggested that there may have been more than one widespread ice advance in Alaska, but in general the references in the literature to a former extensive glaciation have applied only to the last great glacial advance.

Quantitative studies of the variations of certain coastal glaciers of Alaska, some of which have advanced or retreated long distances within a comparatively short term of years, have established a rather general impression that the greater portion of the retreat of all Alaskan glaciers from the points of farthest advance to their present positions has taken place rather recently. Few men have been willing to hazard a guess as to how many years ago a particular valley was bared of ice, but that the time should be measured in centuries, rather than in thousands of years, would probably have seemed reasonable to most of those who have thought on the subject. This feeling has also been strengthened by the small amount of postglacial erosion which can be discovered in many strongly glaciated valleys.

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[1] Brooks, A. H., Geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pl. 22, 1906.

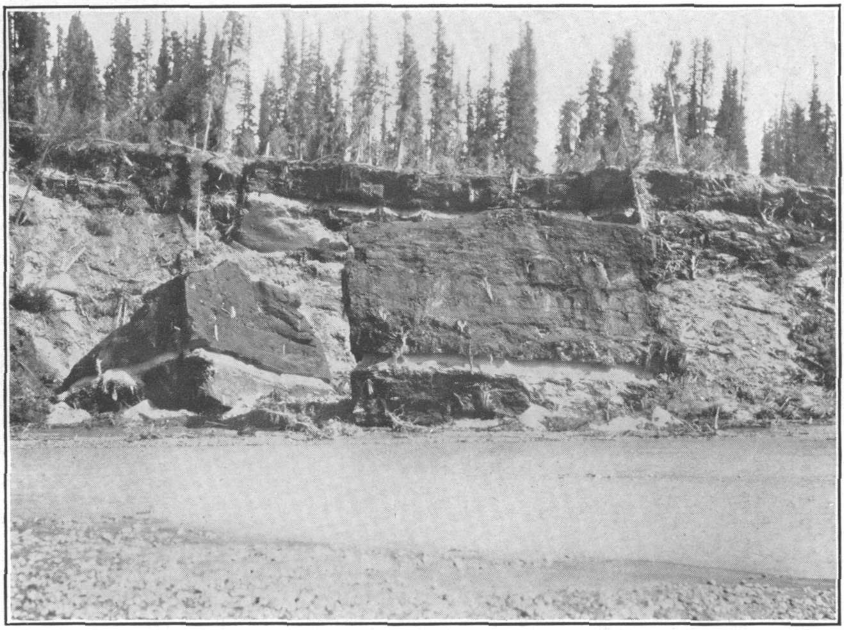
[2] Tarr, R. S., and Martin, Lawrence, Alaskan glacier studies, map 1, National Geographic Society, 1914.

During the present investigation certain facts were obtained which throw light on the problem of the length of time that has elapsed since the White River glacier retreated to approximately its present position.[1] Russell Glacier, in which White River now heads and which is described in another portion of this report, is large and vigorous, and draws its ice supply from the high mountains of the Wrangell and St. Elias group. It may fairly be considered as an average example of the glaciers of that mountain group, and the inference seems justifiable that the major events of its history have been roughly duplicated by the other similar glaciers in this general region.

At a point on the north side of White River, about 8 miles below its source in Russell Glacier, the river has eroded its bank to form a high bluff that for an east-west distance of over a mile shows excellent exposures. (See Pl. XIV, *A*, and fig. 7.) Although its height and the thickness of its constituent members vary somewhat from place to place, a single section will illustrate the general conditions found there. The base of the bluff at the point measured shows 30 feet of typical unconsolidated and unoxidized glacial till, with an uneven, rolling surface. Above the till and extending to the top of the bluff is 39 feet of fibrous, peaty vegetable material, full of stumps and roots but probably formed for the most part of the remains of sphagnum moss. (See Pls. XIV, *B*, and XV.) About 7 feet below the top of the bluff the peat is interrupted by a 2-foot layer of white volcanic ash. The surface of the ground above the bluff is covered by a thick coating of sphagnum moss and supports also a dense forest of spruce, with scanty underbrush. The peat, ash, and glacial till are permanently frozen a few inches back from the face of the bluff, even though having a southern exposure and subjected to the long hours of summer sunshine, the light, fluffy waste from the peat acting as an effective insulator. Even the surface moss was solidly frozen at a depth of 6 inches early in July. The cut bank, therefore, shows generally a nearly vertical face and erosion takes place by the formation of great vertical cracks through the peat and the falling outward of large tree-covered blocks which tumble down to the stream level and are gradually thawed and removed. An examination of this section suggested that if the rate of accumulation of the peaty material could be determined, then a fairly accurate estimate could be made of the length of the time which has intervened between the final retreat of the ice from this locality and the present day.

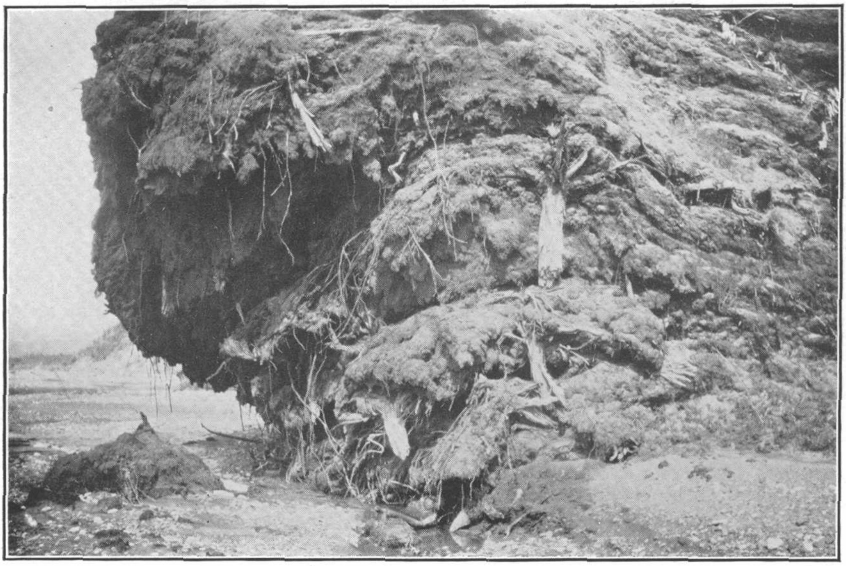
The peculiar appearance of the roots of the spruce trees that grow on the edge of the bluff and of the stumps that make up a considerable portion of the peaty deposit suggested that it might be possible

[1] Capps, S. R., An estimate of the age of the last great glaciation in Alaska: Washington Acad. Sci. Jour., vol. 5, pp. 108–115, 1915.

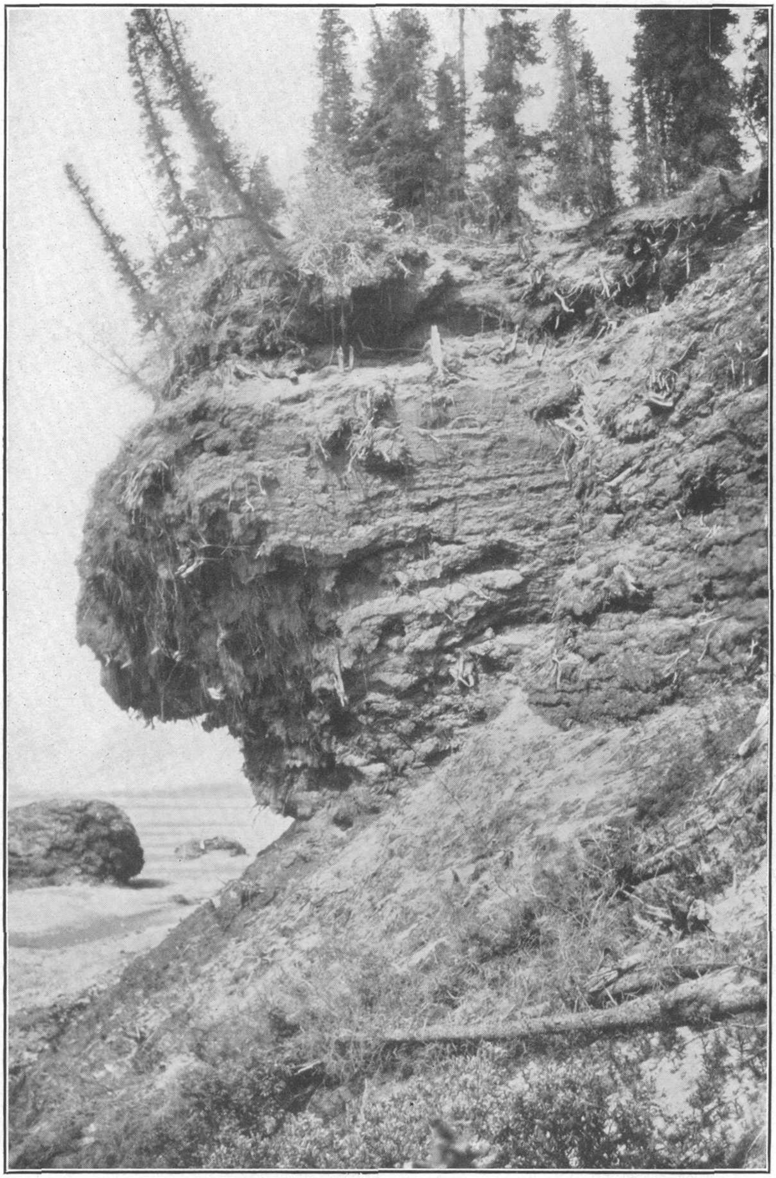


A. BLUFF OF WHITE RIVER NEAR MOUTH OF NORTH FORK, SHOWING PEAT AND VOLCANIC ASH.

Blocks in foreground are overturned.



B. CLOSE VIEW OF AN OVERTURNED BLOCK OF PEAT WITH INCLUDED SPRUCE STUMPS.



SECTION OF WHITE RIVER BLUFF, SHOWING GLACIAL TILL OVERLAIN BY PEAT AND VOLCANIC ASH.

to determine approximately the rate of accumulation of the peat at this place. The ordinary spruce, growing on solid ground, either frozen or unfrozen, sends its roots out radially, parallel with the sur-

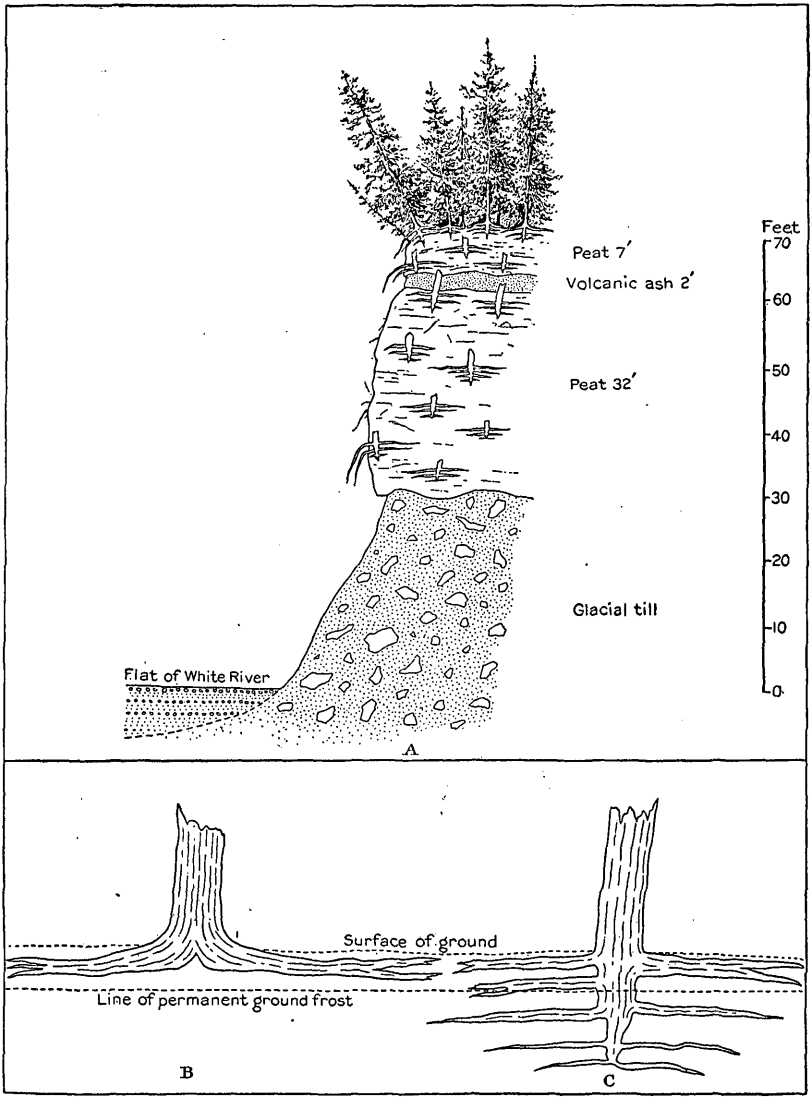


FIGURE 7.—Diagram showing relations of glacial till, peat, and volcanic ash in bluffs of White River. A, Normal spruce stump with flat root base, growing on solid ground; B, Spruce stump growing on rapidly accumulating peat. Below the line of ground frost, which rises with the growth of peaty material, the roots cease to function, and the tree is forced to throw out additional roots in the unfrozen surface portion of the ground.

face of the ground, the roots penetrating only a few inches below the surface. (See A, fig. 7.) The uprooted spruce tree, with its flat root base, is a familiar object to all who have traveled through an

Alaskan spruce forest. In the White River locality examined, however, the roots of the spruce trees, both those growing at the edge of the bluff or recently overturned and those deeply buried within the peat mass, show quite different characteristics. (See B, fig. 7.) Instead of a single, flat-based set of radial roots, each of these trees show a central stem, many of them several feet long, from which roots branch off at irregular intervals, with an upper set of roots near the surface, corresponding to those of the normal tree. An attempt to dig out one living tree for the purpose of examining its roots resulted in failure, for the ground was found to be solidly frozen 6 inches below the top of the mass and an excavation 18 inches deep did not reach the lowest roots. Below the frost line the roots were sound and undecayed, but they were of a darker color than the live surface roots and were apparently not functioning. It is evident that the living tree derives nourishment from the ground only through the roots nearest to the surface and that the lower roots cease to function as soon as the line of permanent frost rises above them.

From the above-stated facts it appears that a seedling spruce, having established itself on the mossy soil in this area of rapidly accumulating vegetable material, sent out radial, flat-based roots in a normal way, but the constantly thickening moss and the consequent rising level of ground frost cut off the food supply from the lowest roots and caused the tree to throw out periodically new sets of roots near the surface in its efforts to survive. If these premises are correct, then the vertical distance between the lowest horizontal roots of a living tree and the surface of the ground represents the thickness of the peaty accumulation during the lifetime of the tree, and the rate of accumulation can be determined by ascertaining the age of the tree, as shown by the annual rings.

Any figures for the rate of accumulation of peat obtained in the way outlined are of course subject to many uncertainties and before they can be considered final should be checked by a much larger number of measurements than could be made in the single day that was available for this study. Most of the qualifying factors, however, seem to fall on the side of conservatism and to give a minimum rather than a maximum figure. Among the unweighed factors the following may be briefly mentioned:

1. It would appear at first thought that the vegetable matter accumulating near the surface would be less compact than that deeper in the section, and that the material making up a layer a foot thick around a living tree would shrink considerably after it had become deeply buried. In view, however, of the fact that the permanent frost level now approaches within a foot or less of the surface, and probably has always been near the surface, there seems to be little

chance for compression of the solidly frozen peat, so that if the rate of accumulation has been uniform, then a figure for that rate, derived from a study of present surface conditions, would probably apply closely for the whole deposit.

2. Toward the edge of the bluff, where the spruce roots could be best examined, the accumulations near the surface contains a considerable admixture of wind-blown dust from the bare sand and silt flat below. The deeper portions of the peat bed are comparatively free from such extraneous material, and it is probable that at the time they were laid down they were at some distance from the bare gravel plain of White River.

3. A considerable period of time probably elapsed after the retreat of the ice before vegetation had completely established itself upon the bared area of glacial till. Similarly, the deposition of the heavy layer of volcanic ash, although it failed to kill the spruce forest, doubtless destroyed the surface covering of sphagnum moss, and the moss cover may have been a long time in reestablishing itself. Even now there are on the mountain front to the south large areas of bare ash on which there is little or no vegetation.

4. According to Mr. F. V. Coville[1] trees of very slow growth may fail during unfavorable years to form distinct annual rings, and therefore the age of a tree, as shown by a count of the rings, may be considerably greater than the figures obtained. Mr. Coville also states that during the first years after germination the spruce tree grows very slowly, so that a count of the rings made 4 feet above the present surface, or say 6 feet above the lowest horizontal roots, would fail to show the first 20 years or so of the tree's growth.

Sound trees so situated that their roots could be studied and their rings counted were not easily found, and only one of the trees on which a count was made seemed to have developed under conditions that approached the average. On this tree one count made 6 feet above the present surface of the ground, where the tree had a diameter of 7½ inches, showed 373 annual rings. At 8 feet above the ground another count made on the same tree, as a check, gave 362 rings. The tree had an accumulation of 24 inches of vegetable matter above its lowest horizontal roots. With an allowance of 27 years for the growth of the tree up to the point where the lower count was made, a rate of accumulation of the vegetable material of 1 foot in 200 years was obtained. In the peaty material around the roots of this tree there was considerably more wind-blown sand and silt than in the peat lower in the section. Another count, made on a tree 5½ inches in diameter, gave 133 rings, and the roots had 16 inches of very sandy peat about them. The unusually sandy condition of the peat about

[1] Oral communication.

this tree must indicate an unusually rapid burial of the tree, and consequently the figures of the rate of accumulation derived from it are too small to be generally applied. Emphasis is again placed on the fact that the unweighed factors which are recognized to have influenced the rate of accumulation all point to a slower rather than a more rapid rate of accumulation than that used as a basis for calculation, and the figure in which most confidence is placed—200 years to the foot of peat—may be much less than the true figure.

Disregarding, however, the uncertain factors, all of which would tend to give a slower rate of accumulation, and assuming the rate of 200 years to the foot to be correct, we reach the conclusion that a period of at least 7,800 or in round numbers 8,000 years has been required for the formation of the 39 feet of peat exposed in this section, and that the final retreat of the front of Russell Glacier from this point, within 8 miles of its present position, had taken place some 8,000 years ago. This figure of 8,000 years is by no means to be considered as exact, but is believed to express merely the proper order of magnitude of the term of years since the disappearance of the glacial ice from this locality. The writer is inclined to believe that the estimate falls considerably short of the time which has actually elapsed, but if the estimate is within 25 or even 50 per cent of the truth, it gives a broader basis from which to consider the geologic and physiographic history of Alaska since the withdrawal of the last great glaciers.

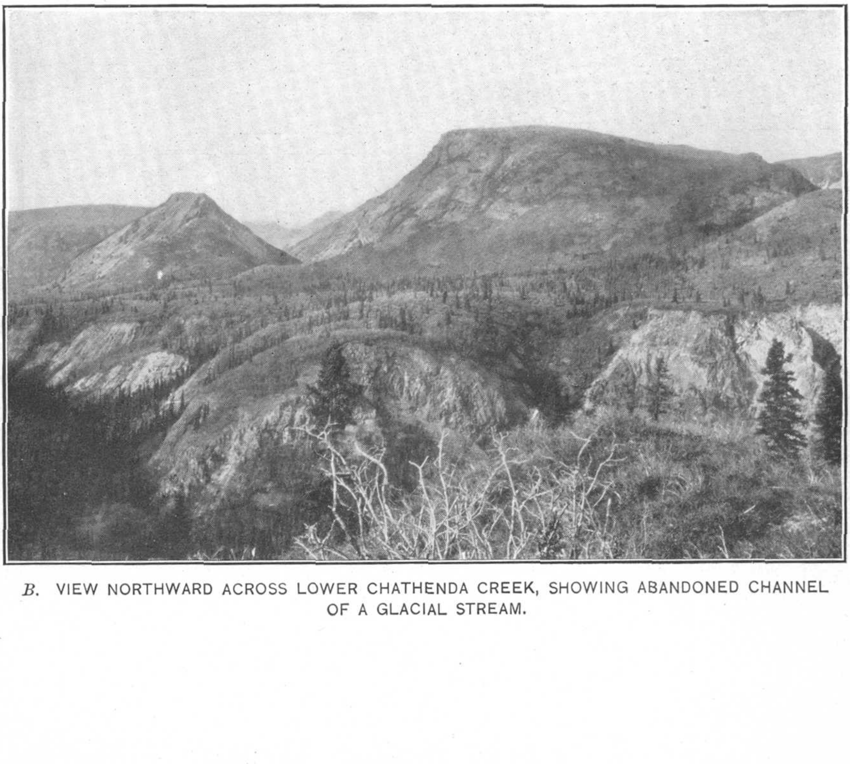
At the time of its maximum extension Russell Glacier, according to Hayes,[1] extended as far north as the mouth of Donjek River, about 130 miles beyond its present terminus. Its retreat over 94 per cent of this distance had, therefore, been completed 8,000 years ago. This 94 per cent of retreat, however, must not be considered to represent 94 per cent of the time that has elapsed since the retreat began, for the withdrawal of the ice was probably comparatively rapid until the front had reached a point somewhere near its present position, and the front may have remained nearly stationary for a long time. On the other hand, it is possible that the retreat was relatively slow up to the point of the peat bluff and more rapid beyond it. Russell Glacier, however, was first seen in 1891, and has been visited at intervals since, and during the last 20 years its outer margin has changed little, indicating a rather long period of comparative stability.

Various estimates have been made of the length of time since the Wisconsin continental ice sheet began to retreat. Chamberlain and Salisbury,[2] after reviewing the evidence, place the time at some-

[1] Hayes, C. W., An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, p. 157, 1892.

[2] Chamberlin, T. C., and Salisbury, R. D., Geology, vol. 3, p. 420, 1906.

A. GRAVEL BLUFFS ON LOWER CHATHENDA CREEK.



B. VIEW NORTHWARD ACROSS LOWER CHATHENDA CREEK, SHOWING ABANDONED CHANNEL OF A GLACIAL STREAM.

where between 20,000 and 60,000 years ago. The determination made in the White River valley, at a point that was not bared until a large part of the retreat had been completed, is of the same order of magnitude as the figures gained from other widely different lines of research, and it therefore now for the first time seems safe to say that the last great ice advance in Alaska was contemporaneous with the late Wisconsin continental glaciation.

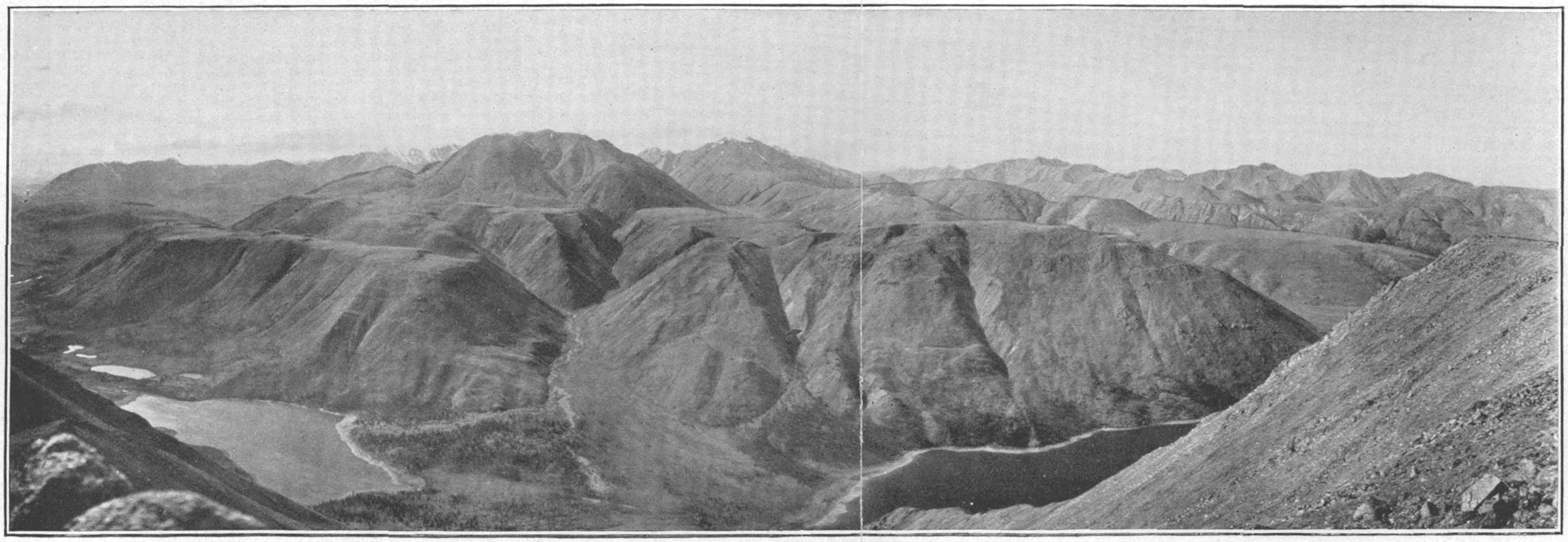
RETREAT OF ICE.

After the last great glaciers had reached their maximum expansion a progressive change in climate that made conditions less favorable for ice accumulation began, and the glaciers diminished both in thickness and in length and began to withdraw from the areas which they had covered. The retreat of the ice was probably not continuous but consisted of alternating retreats, pauses, and readvances. The aggregate result of these movements, however, was a diminution of the glaciated area. The first result of a decreased ice supply was the shrinkage of the piedmont terminal lobes of the main glaciers and their gradual withdrawal toward the mountain valleys from which they emerged. During a somewhat later stage of the retreat the bare and eroded valley walls began to appear above the edge of the glacier, hills previously submerged by the ice reappeared in the form of islands or nunataks, and as the glacial surface lowered still further the overflow outlets from the main valleys were abandoned. Thus at an intermediate stage of the retreat the Beaver Creek glacier ceased to send ice northward through the pass to Eureka Creek, the White River glacier no longer used the outlets through Ptarmigan Creek and by way of North Fork and Solo Creek to the Beaver basin, and Chisana glacier also abandoned the eastward outlets into the Beaver basin. No doubt all these old ice channels were used for a time to carry off the waters discharged by the melting glaciers, and during their occupancy by such streams they received large deposits of glacial outwash gravels. In addition, at various stages during the shrinkage of the ice the bordering streams that carried the discharge from the melting glaciers intrenched themselves in parts of their courses which they happened to occupy for a sufficient length of time. With a further shrinkage of the glaciers these old channels were abandoned and left stranded high above the present stream beds. (See Pl. XVI, *B*.) Extensive gravel deposits were also formed at places along the sides of the glaciers over areas in which the drainage was still impeded by the ice. Thus at the time the White River glacier filled its bed to a depth of 500 or 600 feet at the mouth of Solo Creek, outwash gravels were deposited in the basins of Solo Creek and upper North Fork by a glacial stream that flowed into

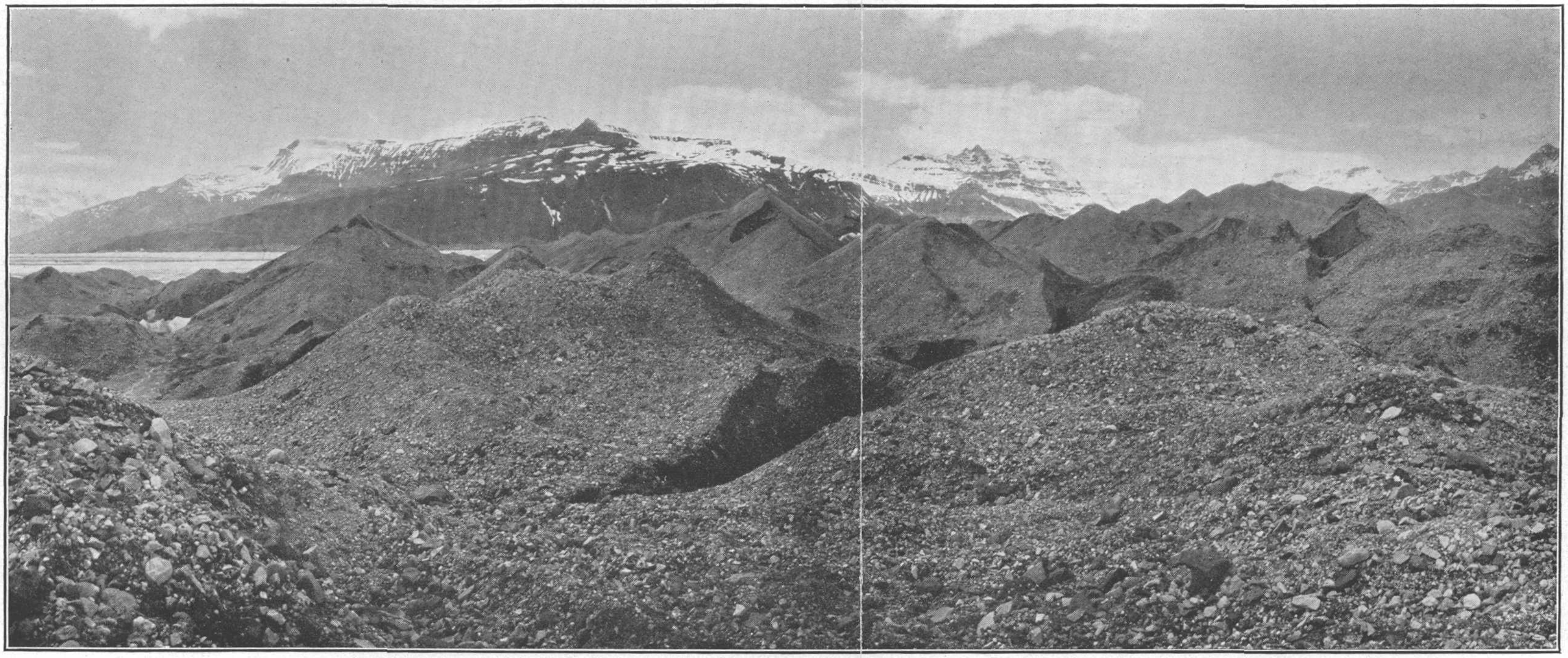
Beaver Creek. Similarly, the streams that drained Chisana Glacier built thick gravel deposits along the east side of the Chisana Valley (Pl. XVI, *A*) at a time when the ice stood 400 or 500 feet deep on the east side of Euchre Mountain. The final stage of retreat, which brought about a reduction of the glaciers to about their present size and position, bared the valley of ice, exposed the extensive upland areas of glacial till to erosion, and subjected the channels of the glacial rivers to rapid deposition of glacial outwash gravels at some places and to erosion at others.

GLACIAL EROSION.

Mention has already been made, in the discussion of the earlier glacial stage, of the profound influence that glacial erosion exerts upon the topography of the glaciated area. The results of ice erosion are especially evident in high mountain regions, for in the lowlands deposits of glacier-brought débris obscure the effects of ice sculpture upon the underlying rock surface. In the Chisana district the present surface forms are due in large degree to the modeling effects of glacial ice. The mountain valleys are broad, U-shaped troughs with relatively flat floors and cliff-like walls. Glacial cirques are everywhere present in the valley heads, but only those formed in the lower mountains can be seen in their entirety, for those of the higher mountains are still occupied by glaciers. In the eastern part of the area bordered by White and Chisana rivers and Beaver Creek there are some mountains of sufficient height to have originated small glaciers, but in the lower western part of that area the hills were rounded and smoothed by the glaciers, which passed over or around them, and are cut by many broad passes along the lines followed by the outflowing ice. The laws that determine the path of a glacier differ in some respects from those that govern the course of a stream, and glaciers formerly moved continuously through valleys which are now shared by tributaries of two or more drainage systems. The direction of flow of the present streams is therefore at many places different from the direction of movement of the glaciers that formed the valleys. Furthermore, as the ice supply in both the White and Chisana basins was influenced by local conditions it is probable that the glacial movement through the broad passes connecting these basins was at times in one direction and at other times in the opposite direction. Similarly, the topography of the upper Beaver Creek and Chavolda Creek basins indicates that at the time of greatest ice supply in Chisana Valley and the congestion of the glacier by its narrow northern outlet ice moved from upper Chavolda Creek through Caribou Pass to the Chathenda basin and thence southeastward into Beaver Creek.



A. VIEW WESTWARD ACROSS THE HORSFELD-EUREKA CREEK DIVIDE, SHOWING AN OLD EROSION SURFACE, A PART OF THE PREGLACIAL TOPOGRAPHY.



B. A MORAINE-COVERED PART OF NIZINA GLACIER WEST OF THE MOUTH OF SKOLAI CREEK.

Later, as the thickness of Chisana Glacier decreased, the ice from both Chathenda and Chavolda creeks followed the normal course to the Chisana. Similar conditions at many other places could be cited, for each line of long-continued glacial movement is recorded by a deeply eroded, rounded valley. This district offers a highly attractive field to the glacialist who has the opportunity and the insight to decipher the complex relations of Chisana, White, and Beaver glaciers at various stages of their development. One particularly promising field for the glacialist and the physiographer lies in the basin of Beaver Creek. Near the international boundary, along the low gap between Horsfeld and Eureka creeks, the mountain tops show flat interstream ridges, the well-preserved remains of a preglacial topography. (See Pl. XVII, *A*.) It should be easily possible to reconstruct the old land surface in this vicinity and to trace the drainage lines that existed at a level much above that of the present streams.

PRESENT GLACIERS.

Chisana Glacier.—Chisana River heads, at Euchre Mountain, in Chisana Glacier, one of the three great northward-flowing ice streams that drain the Wrangell Mountains. The Chisana ice field has not been completely surveyed, but is 30 miles long and has an area of over 135 square miles. It receives many tributary ice streams between the White and Nabesna basins and drains nearly all of the north slope of the Wrangell Mountains between these basins. Its headward portions are continuous with Rohn and Nizina glaciers, on the south side of the range, and routes up both those glaciers and down Chisana Glacier have been used for winter travel from the Chitina Valley to the Chisana mining district. The Nizina-Chisana divide has an elevation of about 8,000 feet, and the Rohn-Chisana pass is said to be more than 1,000 feet lower. Chisana Glacier was first seen and traversed by Oscar Rohn and A. H. McNeer in 1899. Since that year it has been visited at intervals, and the changes in its terminal border have been so insignificant during a period of 15 years that the glacier can be said to be practically stationary. It is characterized by its freedom from surficial débris, white ice appearing to its farthest edge, interrupted by only one prominent medial moraine. The glacier has a width of 2 miles at its terminus.

Russell Glacier.—Russell Glacier, the source of both White River and Skolai Creek, lies at the boundary between the Wrangell and St. Elias mountains. Its ice is all received from tributaries which drain the high valleys of the St. Elias Range, and much of its headward basin is unsurveyed, so that neither its length nor its area is known. The terminal lobe lies in a broad pass through the mountains, and although it discharges mainly into the Yukon basin by way of White

River, a minor lobe projects into the head of Skolai Creek and drains by way of Nizina and Chitina rivers into Copper River. The glacier was first seen and crossed by white men in 1891, when C. W. Hayes and Frederick Schwatka crossed it in journeying from the Yukon basin to the Pacific drainage area. Since that time it has been the main route of travel for men and horses between the Chisana-White River district and the Chitina basin. The ice divide between White River and Skolai Creek has an elevation of about 5,000 feet, only 900 feet above the head of White River. The Skolai Creek lobe is nearly free from moraines, but for several miles above the White River terminus the glacier is so covered with rock débris that little of the ice can be seen. The trail across this portion lies through a monotonous succession of irregular hills and hollows and winds back and forth to avoid lakelets, ice cliffs, and sharp, moraine-covered ridges. Above the morainal portion of the glacier much white ice appears, broken by a number of ribbon-like lines of medial moraine that become narrower and disappear toward the head of the glacier. Portions of the ice surface are fairly smooth, so that travel over them is not difficult, but at bends and on steep pitches the glacier is shattered into impassable areas of sharp ridges and deep crevasses. Since Hayes's observations in 1891 the terminus of this glacier has been almost stationary and changes in its outer margin have been small

Glaciers in the Nizina basin.—Although not within the Chisana-White River district proper, a portion of the district here discussed lies in the Nizina basin, in the valley of Skolai Creek. This valley terminates at the east margin of Nizina Glacier, a large glacier which drains a portion of the south slope of the Wrangell Mountains, opposite Chisana and Nabesna glaciers. (See Pl. IV, *A*, p. 18.) Although heading against the same peaks and occupying basins comparable in size and elevation, Nizina Glacier is only a fraction as large as Chisana Glacier, the discrepancy in the amount of ice on opposite sides of the range being largely the result of the difference in exposure to the sun's rays. The same contrast between the northward-facing and southward-facing glaciers is to be observed throughout the Wrangell Mountains, although the precipitation can not be greatly different on the two slopes. Nizina Glacier has three main branches, of which the northeastern one, known as Rohn Glacier, is the largest. The northern branch, regarded as the head of Nizina Glacier, is almost entirely free from surface moraines. Rohn Glacier has several bands of medial moraine, as has also Regal Glacier, the third branch. Nizina Glacier is, however, only locally moraine covered (Pl. XVII, *B*), and bands of white ice appear to its terminus. Some parts of its surface are badly shattered and crevassed, but a route can be chosen which for many miles above the terminus affords few difficulties to travel, even in summer. In winter trails have been followed up both Rohn and Nizina glaciers to the divide and thence down Chisana Glacier, but neither of these routes is passable during the summer. The southern margin of Nizina Glacier approaches within a few hundred yards of a heavy spruce forest, affording evidence that this glacier has now about as great a length as at any time since the forest was established, perhaps 200 years ago.

The Skolai Creek basin contains one ice stream of moderate size, Frederika Glacier on the north, and several smaller unnamed glaciers on its south side. These glaciers appear to have changed little in the last six years.

Glaciers in the Nutzotin Mountains.—A number of protected valley heads in the eastern portion of the Nutzotin Mountains contain glaciers, but they are small compared with those of the Wrangell and St. Elias chain. The longest observed ice streams lie at the head of Carl Creek, a tributary of Beaver Creek. They are 5½ and 3½ miles long, but only about half a mile wide. In the basin of the East Fork of Snag River, on the north slope of the range, three adjacent glaciers reach a length of about 3 miles each. All other glaciers in the portion of this range mapped (Pl. I, in pocket) are smaller than those mentioned.

GLACIAL DEPOSITS.

The glacial deposits shown on the geologic map (Pl. II, in pocket) include, in addition to the materials deposited directly by the ice as moraines, a great quantity of stream gravels of glaciofluvial origin. The separation of the glaciofluvial deposits from the gravels of the present streams is arbitrary, for in many valleys the present stream gravels are contributed to the streams by glaciers, and may therefore properly be considered glacial outwash materials, as the high mountains are still in the glacial period. Nevertheless, it seems desirable to make a distinction between the deposits made by streams under conditions approaching those of to-day and the deposits laid down under conditions of more extensive glaciation. The areas mapped as glacial moraines and associated gravels are not now covered by the streams, even in flood times, and have in general a covering of vegetation of sufficient age to indicate that the conditions controlling their deposition were different from those now prevailing.

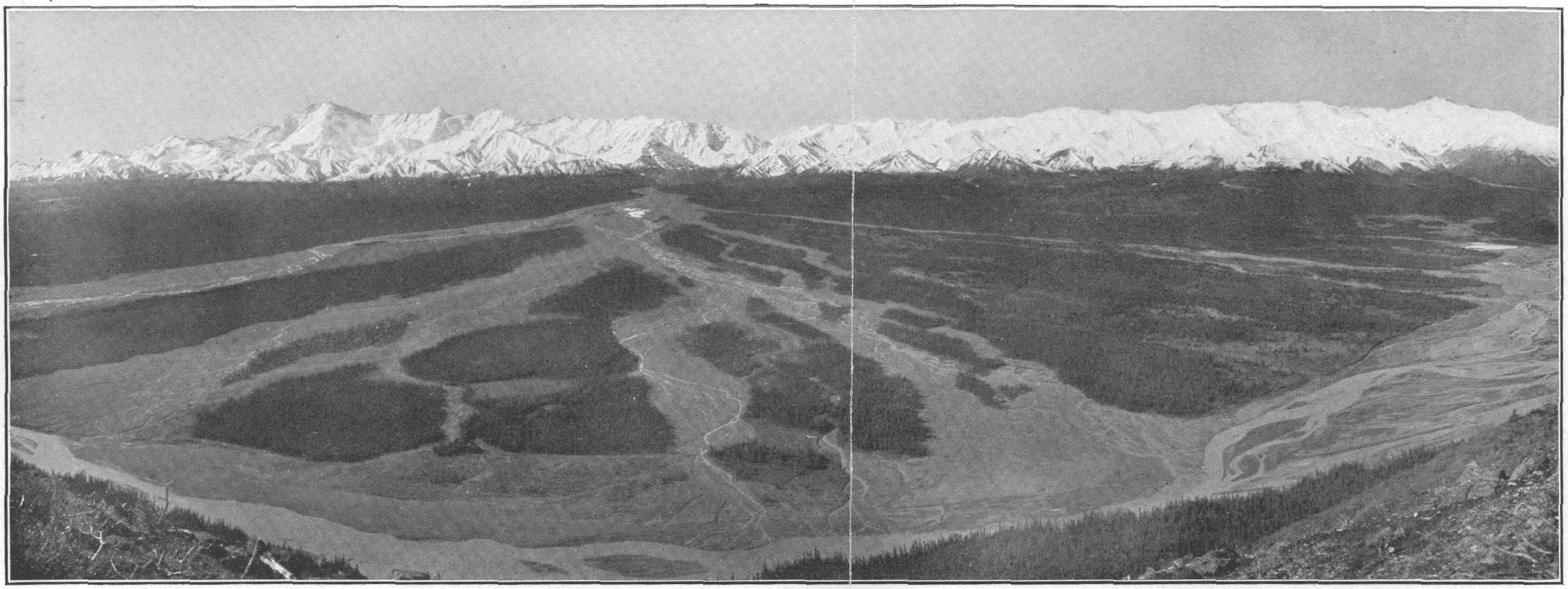
Unassorted glacial till is widely scattered throughout the area formerly covered by glacial ice, occurring as a thin veneer over the surface or as beds of considerable thickness. In general it has little of the characteristic hummock and kettle topography, but follows roughly the contour of the underlying rocks. Only locally were well-defined morainal ridges seen. The most conspicuous moraine ridges in the district are in the valley of Beaver Creek below the mouth of Carl Creek, where two moraines from 200 to 400 feet high extend from the north valley wall southward to Beaver Creek. They mark lines along which the terminus of the Beaver Creek glacier halted during the general retreat but do not represent its maximum extension, for the valley is severely glaciated far below the position of these moraines. Distinct terminal and lateral moraine ridges are rare in this district, even in the valleys now occupied by glaciers. To account for the scarcity of well-developed moraine ridges it is necessary to assume that in the past, as at present, the glaciers terminated in narrow valleys in which stream erosion was active, and that the waters from the melting ice flowed along the sides and fronts of the ice tongues, and removed the glacier-brought débris as fast as it was dropped by the ice.

Although it is not possible, in investigations such as the one on which this report is based, to separate everywhere the morainal beds from the deposits of glacial streams, and no such separation has been attempted on the accompanying geologic map, nevertheless deposits of one or the other type are known to predominate locally. Thus, between White River and the mountains to the south the lowland is formed primarily of stream-laid gravels, derived from the glaciers of the mountains and deposited as a coalescing series of alluvial fans. (See Pl. XVIII, *A*.) The deposition of outwash gravels is still active in that area. In the basin of Beaver Creek the glacial deposits are composed chiefly of morainal material, with subordinate amounts of stream gravels. The headward basin of Chisana River contains thick beds of assorted stream gravel and some finer sediments, as shown by the excellent sections exposed along lower Chathenda, Bryan, and Trail creeks. These beds are believed to have been deposited at a time when Chisana Glacier still extended down to its canyon through the Nutzotin Mountains, and to have been built up between the side of the glacier and the east valley wall. The lowland north of the Nutzotin Mountains has not yet been carefully studied, but even from a distance large areas of terminal moraine, deposited by the piedmont lobe of Chisana Glacier, can be recognized by their hummocky, lake-covered surface, and considerable areas of glaciofluvial gravel are known to be present.

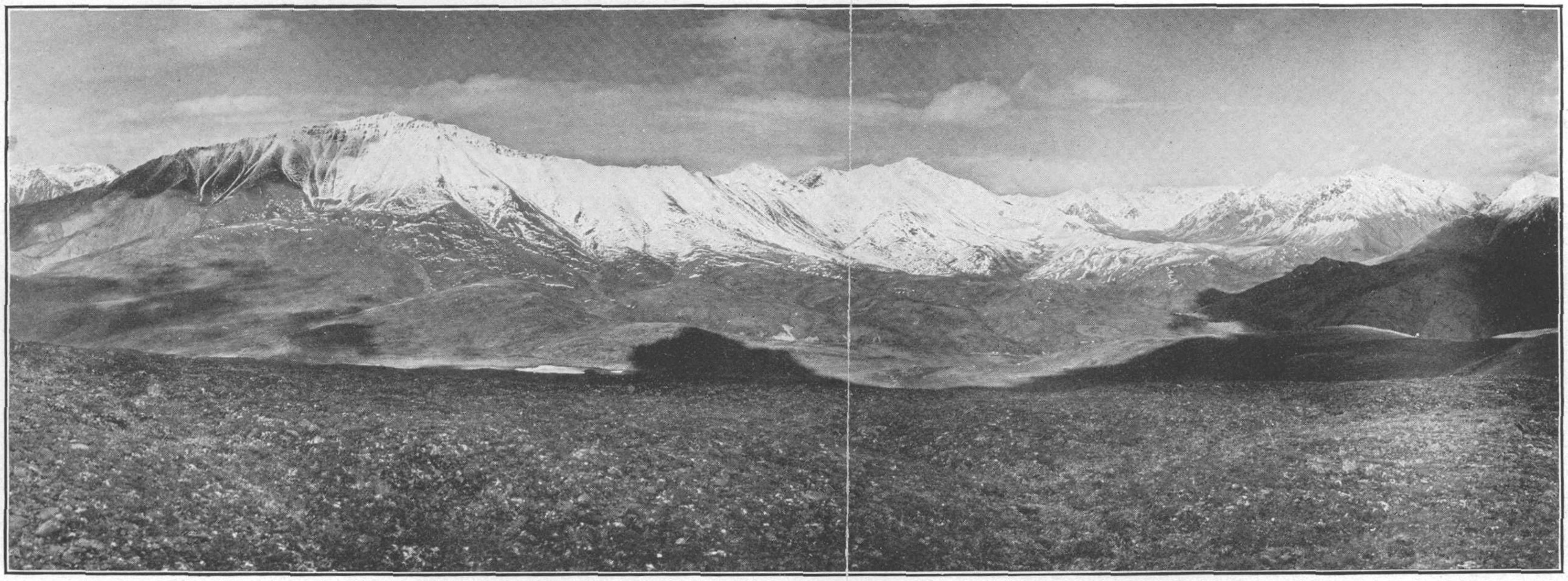
POSTGLACIAL DEPOSITS.

VEGETABLE ACCUMULATIONS.

As soon as the margins of the ancient glaciers began to withdraw finally from the land over which they had extended, the normal processes of erosion and deposition and the growth of vegetation began on the glacial deposits and the ice-eroded surface. In glacial time,



A. THE ALLUVIAL FAN OF HOLMES CREEK.



B. GLACIAL GAPS BETWEEN UPPER CHAVOLDA, BONANZA, AND CHATHENDA CREEKS.
The basin of Little Eldorado Creek, in the right center, contains some of the richest gold placers yet found.

as now, sphagnum mosses covered great areas beyond the borders of the ice, and as the ice retreated the mosses, with brushy plants, soon gained a footing on the surface bared by the retreating glaciers. Later spruce forests reestablished themselves in favorable places. The sphagnum mosses are especially adapted to hasten the accumulation of vegetable remains. They so insulate the ground that the permanent ground frost line lies close to the surface in this latitude, decay is retarded, and peaty material forms rapidly. This peat, or "muck," is generally found beneath the moss, in variable thickness, and locally is known to form thick deposits. As already described (p. 70), it forms on White River a bed 39 feet thick, and a depth of 3 to 10 feet is not uncommon. The aggregate amount of material of vegetable origin must be very great.

VOLCANIC ASH.

Of the postglacial geologic events in this district the most striking was a volcanic eruption that distributed a layer of volcanic ash over a wide area in Alaska and adjacent Canadian territory. The ash lies near the surface, commonly beneath a thin covering of soil or silt, and although its ejection antedates historic record in this part of the world, it was, in terms of geologic history, a very recent event. The ash was first seen and its character recognized by Schwatka,[1] in 1883, and a few years later Dawson[2] extended the known area of the ash and estimated its total area, the direction from which it came, and the approximate length of time since it was deposited. Hayes,[3] in 1891, added materially to the knowledge of the distribution and thickness of the ash in the White River basin, and Brooks,[4] in 1898 and 1899, confirmed Hayes's observations and extended the known limits of the ash-covered area westward into the basin of the Tanana and northward to the Yukon above Fortymile. In 1908 and again in 1914 the writer[5] visited portions of the region covered by the ash. A description from the information available concerning this volcanic eruption has already been published,[6] but a résumé of the salient facts seems appropriate here.

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[1] Schwatka, Frederick, Along Alaska's great river: Cassell & Co., New York, 1885.

[2] Dawson, G. M., Report on an exploration in Yukon district, Northwest Territory, and adjacent northern portion of British Columbia: Canada Geol. and Nat. Hist. Survey Ann. Rept., vol. 3, pt. 1, pp. 43B–46B, 1888.

[3] Hayes, C. W., An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, pp. 146–150, 1892.

[4] Brooks, A. H., A reconnaissance in the White and Tanana river basins, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 375, 1900; also unpublished notes.

[5] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, with a section on the Quaternary by S. R. Capps: U. S. Geol. Survey Bull. 417, pp. 42–44, 1900.

[6] Capps, S. R., An ancient volcanic eruption in the upper Yukon basin: U. S. Geol. Survey Prof. Paper 95, pp. 59–64, 1915. (Prof. Paper 95–D.)

The ash usually appears along the cut banks of streams as a persistent thin white band near the top of the bank, covered by only a thin layer of soil or of vegetable humus. It occurs prevailingly as a single layer, and although locally more than one layer may be present, only the lower one is the direct result of the volcanic explosion, the others having been formed of ash derived elsewhere from the original layer and brought in later by winds or streams.

The ash was evidently deposited on a surface essentially like that of the present day and follows the undulations of the surface. Its thickness increases from the borders toward a rather definite center of dispersion, which does not, however, lie centrally within the ash-covered area. The greatest thickness of ash is found on the north flank of the St. Elias Mountains near the international boundary, where an area of several hundred square miles is heavily covered with this material. Large districts are nearly devoid of vegetation, and the bare ash, apparently several hundred feet thick in places, forms great banks and wind-blown dunes.

From the location of this area of thick ash it is evident that the crater from which the material was violently ejected lies somewhere not far from the international boundary and near the north edge of the St. Elias Mountains. Thomas Riggs, jr., reports a crater-like vent in the headward portion of the Kletsan Creek basin, from which he thinks it likely that the ash came, but this locality has not yet been critically examined.

Various estimates of the area covered by the ash, of the total amount of ash, and of the age of the deposit have been made by several writers. Dawson, in 1887, from the meager data then at hand, made an estimate of at least 25,000 square miles for the area, and calculated the volume as about $1\frac{1}{3}$ cubic miles. Hayes estimated the area as 52,280 square miles and, assuming the ash to have the shape of a flat cone of that base and an apex 50 feet in height, calculated the volume of ash as 165 cubic miles. This figure is evidently much too large, for observations show that the ash is not in the form of a cone, but thins rapidly from the center. Brooks, in 1906, estimated the ash-covered area at 90,000 square miles. It is thus evident that with an increasing number of observations the area within which the ash is known to exist becomes constantly greater. A calculation based on the outer limits, drawn to include all points at which the ash has been observed, now gives an area for the ash layer of 140,000 square miles, and later studies in bordering districts will almost certainly increase the area still farther. In the summer of 1915 F. H. Moffit observed a large quantity of ash on the terminal moraine of a glacier that flows into the valley of upper Chitina River, and evidently heads not far south of the area in which the thickest ash was observed.

An estimate was also made of the volume of ash present by taking the ash area as 140,000 square miles and assuming an average thickness of 2 inches between the outer margin of the ash and the 1-foot contour, 15 inches between the 1-foot and 2-foot contours, and 10 feet within the 3-foot contour, giving a total volume of ash of about 10 cubic miles. The assumed thicknesses are believed to be below rather than above the average, and no account is taken of the great quantity of ash that unquestionably fell beyond the borders of the area within which it is now known. While the result, namely, 10 cubic miles, is only 16.5 per cent of that reached by Hayes, it is 8½ times as great as the amount calculated by Dawson. Katmai, in 1912, and Krakatoa, in 1883, are each estimated to have ejected about 5 cubic miles of ash, so that the volcanic eruption in the upper Yukon basin was comparable in magnitude with any of historic times.

Dawson argued that while it must be several centuries since the eruption, it could hardly have been more than 1,000 years ago. Hayes, basing his conclusions on the freedom of the glaciers within the ash area from an ash covering, believed that the ash fall took place several hundred years ago. As has already been described (p. 74), there is evidence that at a certain place on White River peat has been accumulating at the rate of about 1 foot in 200 years. At that place 7 feet of peat occurs above the ash layer, indicating that the volcanic eruption probably took place some 1,400 years ago.

INTRUSIVE ROCKS.

GENERAL CHARACTER.

Igneous rocks in the form of lava flows and pyroclastic beds make up a considerable part of the geologic section as exposed in the Chisana district. All these materials were, however, deposited on the surface, either as subaerial or submarine beds and have a definite place in the stratigraphic column. They have therefore already been described in this report in their proper order of succession. In addition to the effusive igneous rocks there are within this district considerable areas of intrusive rocks, which were injected into the preexisting sediments and surface flows and there cooled without having reached the surface in molten form. Rocks of at least two distinct periods of intrusion occur in this district—an older group, consisting dominantly of completely and rather coarsely crystalline diorites and granodiorites, including gabbro and gabbro porphyry, and a younger group, composed dominantly of oligoclase andesites and dacites with associated dikes and sills of gabbro and basalt porphyry. Only the larger masses of intrusive rocks have been shown on the geologic map (Pl. II, in pocket), the many smaller bodies of intrusive rocks, occurring as stocks, dikes, or sills, that were observed being too small to be shown on a map of this scale.

GRANITE INTRUSIVE ROCKS.

DISTRIBUTION AND CHARACTER.

The older group includes those masses of intrusive rocks which are holocrystalline and usually of coarse granitic texture. Although typical granites were not seen, many specimens can not be distinguished in the hand specimen from true granites, and the group is therefore described as consisting of granitic rocks. Rocks of this type occur locally throughout the region of the Wrangell and Nutzotin Mountains, but the areas occupied by them are usually small. In this district small bodies are found on the south side of White River and at the mouths of California and Rocker creeks, a larger mass between Chathenda and Chavolda creeks, and a large body with a probable area of over 75 square miles on the north side of Beaver Creek. The outlines of this large granitic area have not been carefully traced, and much of its northern boundary has not been determined.

The intrusive rocks of this group were examined microscopically by J. B. Mertie, jr. They range from granodiorites through diorites and diorite porphyry to gabbro and gabbro porphyry. Typical granodiorites form the bulk of the large intrusive mass north of Beaver Creek. The specimens examined showed a rock of hypidiomorphic granular texture, containing plagioclase and orthoclase feldspars, quartz, hornblende, biotite, magnetite, apatite, iron oxides, titanite (in part secondary), and secondary epidote. Associated with the granodiorite was a considerable amount of gabbro and gabbro porphyry. One specimen of gabbro porphyry showed phenocrysts of plagioclase and augite in an intersertal groundmass. The plagioclase ranged from acidic labradorite on the rims to acidic bytownite in the centers. The augite was partly chloritized. Iron oxides, considerable secondary chloritic material, and some sulphides, mainly pyrrhotite, were also present. The composition of the granodiorite between Chathenda and Chavolda creeks is very similar to that of the rock north of Beaver Creek.

AGE AND CORRELATION.

The age of the granitic intrusive rocks can be determined only by their structural relations to the associated rocks. They cut the Devonian and Carboniferous formations, and are therefore younger than the Carboniferous. It is possible, though not definitely proved, that they cut the Upper Triassic limestones of Cooper Pass. In the vicinity of the placer mines the diorite lies adjacent to Lower Cretaceous sediments, but the contact there is the result of faulting. Moffit and Knopf[1] state that the Upper Jurassic conglomerates of Chisana River inclose cobbles of diorite, and that as the associated grit beds contain much detrital volcanic material, evidently derived from the near-by Carboniferous formation, it is reasonable to believe that the diorites were intruded prior to late Jurassic time. They are not known to cut the Upper Jurassic or Lower Cretaceous beds of the Chisana district, although these beds have been extensively intruded by dikes, presumably younger than the diorites. Cairnes,[2] in discussing an adjacent area in Canada, states that the granitic rocks cut the early Mesozoic sediments at different points, and concludes that the period of injection of the intrusives covers a long-time interval, extending possibly from early Jurassic well into Cretaceous time. From the evidence at hand it seems safe to correlate these rocks with the other great batholithic intrusives of the Alaska Range and of the coast range extending from Alaska into British Columbia.

LATER INTRUSIVE ROCKS.

DISTRIBUTION AND CHARACTER.

Throughout various parts of this district there occur intrusive rocks of different character from the granitic intrusives already described and apparently younger. They are most abundant in the basin of Rocker Creek near the international boundary, but also occur at many other places as small stocks and as dikes and sills that are of too small area to be outlines on the geologic map. They are particularly abundant as dikes cutting the Jurassic and Cretaceous sediments of upper Bonanza and Chathenda creeks, and form small stocks in the Chathenda basin both above and below the mouth of Bonanza Creek.

This group includes intrusive rocks of a wide variety, both in composition and in texture, ranging from oligoclase andesites and oligoclase dacites to gabbro porphyry and basalt. Two specimens collected from the large area south of lower Beaver Creek were examined by Mr. Mertie. One, classed as an oligoclase dacite, is a microporphyritic rock with plagioclase phenocrysts consisting of andesine centers with oligoclase rims. The groundmass is a mixture of andesine and quartz in a cement which has about the composition of oligoclase albite. Iron oxides are present, as is also a considerable amount of secondary iron hydroxide and chloritic material. Another specimen, classed as an oligoclase andesite, consists of phenocrysts

[1] Op. cit., p. 44.

[2] Cairnes, D. D., Upper White River district, Yukon: Canada Geol. Survey Summary Rept., 1913, pp. 12–28, 1914.

of altered hornblende and plagioclase, ranging from labradorite to oligoclase, in a granular groundmass composed of a mixture of andesine and oligoclase albite. Magnetite and secondary chloritic material possibly derived from biotite are also present.

On lower Chathenda Creek there is a small body of oligoclase andesite, containing biotite and crystals of andesine in a groundmass of oligoclase laths and microaphanitic material.

Many dikes cut the Jurassic and Cretaceous beds in the vicinity of the placer mines. One on Glacier Creek is a basalt, of interstitial fabric, containing greatly altered plagioclase, altered augite, and secondary epidote and chloritic material. Another cutting the shales of upper Bonanza Creek is a gabbro porphyry, with phenocrysts of labradorite in a granular groundmass of labradorite, augite, and magnetite, containing also much chloritic or serpentinous material in the interstices.

AGE AND CORRELATION.

The dikes which cut the Upper Jurassic and Lower Cretaceous beds of the Chathenda Creek basin are certainly younger than Lower Cretaceous. On Chathenda Creek Tertiary beds, probably of Eocene age, are interbedded with lavas and cut by later intrusives. Similar Tertiary beds on Rocker Creek are also cut by dikes and associated with extensive masses of younger intrusive rocks. The younger post-Eocene lavas of Rocker Creek are also cut by intrusives, and it is likely that some of them are surface flows derived from the same magmas that furnished the intrusions. The younger lavas are in part at least of Pleistocene age, and it is likely that some of the intrusive rocks may also be Pleistocene. There is as yet no evidence from which it can be safely concluded that there was but a single period of intrusion after the injection of the great Mesozoic granitic masses. Moreover, the fact that there have been surface flows of igneous rocks at intervals from Eocene to late Pleistocene time implies that there were vents through which these rocks reached the surface, and that intrusive rocks have been formed at like intervals since the early Tertiary. It therefore seems unwise to attempt to correlate all the younger intrusives and to assign them to a single period of igneous activity. Each intrusive mass offers its own particular problem, and its age must be determined by the structural relations in its immediate vicinity.

SUMMARY OF GEOLOGIC HISTORY.

In the preceding pages the various rock formations have been described, and their age and relations to one another have been discussed as fully as the facts at hand warrant. It therefore seems desirable to epitomize, in terms of earth history, the important geologic events of this region. In so far as the stratigraphic record is complete, the history may be read with some certainty, for the rocks themselves bear witness to the conditions existing at the time they were deposited. There are, however, many recognized and perhaps some as yet unrecognized breaks in the record that represent times of land emergence, during which not only were the ordinary processes of sedimentation interrupted but the preexisting rocks were eroded and in part removed. Some of these gaps are represented in near-by portions of Alaska by sediments laid down while the Chisana district may have been above sea level. Others of the emergences were widespread.

The sequence of great geologic events in the region may be briefly stated. The earliest record, as found in the Devonian rocks, shows a period during which shales and arkosic sands were deposited under marine conditions and the sedimentation was first interrupted and later almost completely ended by the pouring out of lavas and fragmental volcanic materials. The lavas and pyroclastic materials were laid down, in part at least, in the sea. There is still some uncertainty as to the major events of early Carboniferous time. On Eureka Creek and lower Beaver Creek there are limestones, shales, and cherts that may be of lower Carboniferous age. On Bonanza and Chathenda creeks no break has been recognized between the lavas and pyroclastic beds of Devonian age and those believed to represent the base of the Carboniferous at that place. It is likely also that a period of emergence and erosion took place between lower Carboniferous (Mississippian) and upper Carboniferous (Pennsylvanian) time in this region, as is known to be true generally throughout North America, but the evidence on this point is obscure. The upper Carboniferous, like the Devonian and lower Carboniferous, was dominantly a period of volcanic activity and witnessed the outpouring of a huge amount of lavas and fragmental volcanic materials. The volcanism was interrupted at least twice by periods of inactivity, during which limestones and shales were laid down. The last period of normal sedimentation was cut short by a renewal of volcanic activity, and the extrusion of lavas may have extended from the Carboniferous into Triassic time.

The oldest recognized Mesozoic rocks of the Chisana district are the Triassic limestones of Copper Pass. These are apparently younger than the massive Chitistone limestone of the Chitina basin, and the Chitistone limestone was apparently never developed on the north side of the Wrangell Mountains. The limestones represent conditions of quiet sedimentation in waters comparatively free from shore sediments. Above the Triassic limestone, though whether conformably or not is not known, occurs a great thickness of argillites, graywackes, and conglomerates, indicating that the seas in which they were laid down received vast quantities of débris from some actively denuded land mass. The beds were all deposited in comparatively shallow water not far from shore. They may all be late Triassic, in part Triassic and in part Jurassic, or all Jurassic. Their relation to the underlying and overlying beds is not known, and unrecognized breaks in the stratigraphic column may be present.

After the Carboniferous but before late Jurassic time large bodies of intrusive rock were injected into the preexisting sediments and surface flows and cooled slowly there, without penetrating to the surface. These intrusions now form masses of coarsely crystalline granodiorite, diorite, and gabbro. Some of them are small, but others have areas of many square miles. At some time after their intrusion the granular rocks were uncovered by erosion, and pebbles and bowlders from them are now found in the younger conglomerates.

Late Jurassic time was characterized by the deposition of clastic shallow-water marine sediments, forming a thick series of Upper Jurassic shales and graywackes. These apparently grade into the Lower Cretaceous beds without stratigraphic break and without change in the character of deposition. Whether or not Cretaceous beds younger than those known were ever present in the Chisana district has not been determined, but certainly there was a long period of emergency from the sea and of denudation, possibly beginning at the end of Lower Cretaceous time. So far as the record has now been read, the Cretaceous marked the end of marine conditions, and the region was not thereafter generally invaded by the oceans.

Although this region was a land mass throughout Tertiary time, and erosion was active over most of its surface, there were local areas in which fresh-water river and lake sediments were laid down. These materials now form conglomerates, sandstones, shales, and lignites. During the period of their deposition there was some volcanic activity, and tuffs and lava flows are interbedded with the sediments derived from erosion of the land surface. In many parts of Alaska Tertiary subaerial beds were laid down in local basins, especially during the Eocene epoch, and it may be that the beds here described are of Eocene age. During later Tertiary time deformational movements took place, which involved the uplift and folding of the Nutzotin Mountains and to some extent the Wrangell Mountains also, and the earlier Tertiary beds were warped and locally folded. This period of deformation was followed by a long period of great volcanic activity. In general the lavas were poured out upon a land surface, but local areas in which water-laid sediments were accumulating were also flooded by lavas. Associated with the lavas were also some intrusive masses injected into the preexisting formations as dikes, sills, and stocks. Volcanism continued well into Pleistocene time, and Mount Wrangell still shows signs of mild activity.

The ejection of lavas and of fragmental volcanic material was not constant, however, but occurred spasmodically, with intervening periods of quiescence. There is evidence that in Pleistocene time, perhaps early in that epoch, there was a considerable expansion of glaciers, with occasional outpourings of lava during the epoch of glaciation. There may have been and probably were other glacial stages, of which no record has been found. After the earlier glacial stage that has been recognized, a great area in the Wrangell Mountains and in the area between them and the Nutzotin Mountains was deeply buried by volcanic materials. This period of volcanism was followed by a time of uplift, with some deformation, during which the earlier glacial deposits and the associated lavas were in places steeply tilted and mildly folded, and the lavas over wide areas were slightly warped. The chief movement was probably an uplift of the Wrangell Mountain mass. During and after the period of mild deformation the normal processes of erosion were active upon the great lava fields and other portions of the land mass, and a rather mature topography was developed.

The final important stage of geologic history comprised the advance and retreat of the last great glaciers and the readjustment of the streams to the glaciated surface. The ice at its maximum covered all but the highest peaks of the area here considered and by its erosion profoundly modified the earlier stream-developed topography. On the retreat of the glaciers to their present positions stream erosion and deposition again began on the deglaciated surface, and each river became occupied with the still unfinished task of adjusting its gradient to its volume and its load. Erosion and decay and the accumulation of talus and of vegetable débris commenced on the ice-freed surfaces and are now operative. The only postglacial interruption to the orderly processes of subaerial erosion and deposition was a short but violent volcanic outburst that spread a mantle of volcanic ash over this entire region. The present streams are cutting their beds in places and aggrading their valleys elsewhere, and the normal processes of denudation in a subarctic climate prevail.

ECONOMIC GEOLOGY.

HISTORY OF MINING.

When the first white men entered the basin of the upper Yukon persistent tales were heard from the Indians of great deposits of native copper toward the west. To support these rumors the natives exhibited many copper implements and nuggets, and copper was an object of barter between the interior Indians and those on the coast. Hayes, in 1891, established the fact that native copper exists within the basin of White River, but rich deposits, such as the natives had reported, were not seen.

The first serious attempt at prospecting or mining in this area was made in 1897 or 1898 when Jack Dalton built a cabin on upper Kletsan Creek and prospected there for placer and lode copper. He obtained a considerable amount of native copper from the stream gravels and located a vein of copper sulphides in the mountains near by, but the remoteness of the district and the lack of transportation for copper, even if rich deposits should be found, discouraged further work.

The great gold rush to Dawson in 1897 and 1898 stimulated prospecting throughout the upper Yukon basin, and during the next few years a number of men visited the upper White River in the search for valuable metals, encouraged by the indefinite but persistent rumors which attributed great mineral wealth to that district. The copper lodes, however, remained elusive, and no important discoveries were reported.

In 1902 rumors of a gold placer strike in the valley of Beaver Creek brought on a small gold rush from Dawson, but no rich gold deposits were discovered. Some placer gold was shown to be present on Beaver Creek and its tributaries, but no ground rich enough to mine was found. The stampede, however, was not altogether without good results, for it focused the attention of a number of men upon this part of Alaska and stimulated prospecting for several years. In 1905 a large deposit of copper sulphides was found near the head of Nabesna River. The first reports of this find were greatly exaggerated, but the deposit, though of low grade, is large and may some time be worked at a profit. In the White River valley a number of copper lodes have been staked, and on some of them considerable development work has been done, in spite of the fact that there are now no transportation facilities for the shipment of copper ore and no immediate prospect for them. The present cost of shipping out even pure metallic copper would far exceed the market value of the copper, so that even a copper lode of great richness could not now be mined profitably.

In addition to the discovery of copper lodes, several veins were staked for their gold content. On Jacksina Creek, a tributary of the Nabesna, a gold lode was developed, and a 3-stamp mill was operated for some time in 1906. At the mouth of Bonanza Creek a gold lode was staked and restaked several times, but no serious attempt was made to prospect it. On Beaver Creek, near the international boundary, two gold-copper veins were discovered and adits were driven on them. One of these properties was patented. On Eureka and Fourmile creeks near the international boundary development work was done on a number of strong quartz ledges, which are said to carry encouraging amounts of gold. A coal claim was also staked in the basin of Rocker Creek, near the boundary, and a 30-foot tunnel was driven on it.

Between 1908 and 1913 interest in this region was at a rather low ebb, and little more than the necessary assessment work was done on most of the claims, while on much ground that had been staked even the assessment work was not accomplished.

Late in the summer of 1913 a well-substantiated report reached Dawson and Whitehorse that rich placer gold had been discovered in the headward basin of Chisana River. The news came at a time when mining was rather slack at a number of the older rich camps, including Dawson and Fairbanks, and a stampede of considerable magnitude was started in the fall and continued into the winter. The newspapers of Alaska and of the United States printed exaggerated stories of the richness of this new camp, and another Klondike was widely predicted. As a result several thousand gold seekers rushed into the country, many of them without outfits or provisions and unaccustomed to the rigors of an Alaska winter. What small supplies of food there were in the region were soon exhausted, prices rose to prohibitive figures, and sufficient provisions were not available even for those who could afford to buy them. Fortunately the district was well supplied with game, and many lived for weeks at a time on a diet composed almost exclusively of rabbits and ptarmigan.

Soon after the first gold seekers arrived at the scene of the gold discovery, the gravels of all the neighboring streams, and even the valley sides and intervening ridges were staked, and most of the late comers, discouraged at the outlook, quit the district in disgust. Their reports, however, failed to discourage many of those who had started for the new camp, and a constant stream of travelers, both arriving and departing, flowed over the trails which led to the Chisana basin. Although no accurate figures have been kept, it is certain that several thousand persons reached the camp during the fall and winter, but only a few hundred were there at any one time. A few men, who had sufficient provisions, remained to prospect or to engage in business, but the supplies and equipment for those whose ground appeared to have sufficient gold to warrant mining were brought in during the winter after the influx of gold seekers had somewhat diminished.

The 200 or 300 men who stayed throughout the winter accomplished a large amount of prospecting, and, in a comparatively short time, the limits within which rich placer gravels occurred were marked out with a fair degree of accuracy. Many minor extensions of the known pay gravels may be expected, but it seems unlikely that any extensive rich placer deposits in this immediate neighborhood should have escaped the attention of the men who prospected there in 1913 and in 1914.

GOLD PLACERS.

DISCOVERY OF THE CHISANA PLACERS.

As is usual with history that is passed along largely by word of mouth, there are conflicting stories of the events that led to the discovery of this gold placer district. Nevertheless, when the different accounts have been heard and analyzed, there are certain salient facts which seem to be essentially correct, and the following statement is believed to embody the true account of the discovery.

In the summer of 1912 three partners, William James, Peter Nelson, and Frederick Best, came into the upper White River basin to prospect. During that summer a native, known as Indian Joe, brought James to the mouth of Bonanza Creek to show him a gold-quartz lode there, the same lode which had been staked several years earlier,[1] but on which no development work had been done. The Indian also claims that he had discovered placer gold near by and showed this to James, but this James denies. While in the neighborhood James did some panning and got encouraging prospects. In 1913 James, Nelson, and a Mrs. Wales returned to Bonanza Creek to do further prospecting and made their first discovery on a bench 10 feet above the creek on the left side, at the upper end of what is now Discovery claim. At this place they panned out $9. Andrew Taylor, another prospector, was at the time on Bonanza Creek, and as soon as the discovery was made he and Nelson started for the Yukon to obtain canvas hose and other supplies. This was in June, 1913. After they had gone James followed the gold-bearing gravels up Bonanza Creek to Little Eldorado Creek and up that stream for 700 feet, to a point from which he is said to have panned $30 or $40 in a few minutes. Meanwhile Taylor and Nelson had reached the Yukon, the news of the discovery leaked out, and the stampede already described was started. The first stampeders reached the vicinity from McCarthy about July 4, and others soon began to arrive by various routes. On Little Eldorado Creek James and his partners were sluicing rich gravels, said to have yielded approximately $300 a day for each man employed.

GENERAL FEATURES.

The productive gold placer gravels of the Chisana district all occur in the basins of Chathenda (Johnson) and Chavolda (Wilson) creeks, within a very small area. Exclusive of a few claims from which

[1] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nebesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, pl. 2, 1910.

some gold was taken during prospecting operations, all the gravels that have been profitably mined lie within a circle only 5 miles in diameter, with Gold Hill as its center. (See fig. 8, p. 94.) The valley of Bonanza Creek, the largest of the gold-bearing streams, has been found to contain workable gravels almost continuously from a point near its mouth, on claim No. 2, to claim No. 12, a distance of about 3 miles. The lower three claims on Little Eldorado Creek and the lowest claim on Skookum Creek have been profitably mined, Glacier Creek and its tributaries have yielded a moderate amount of gold, and Big Eldorado Creek has some gravels that contain valuable gold deposits. In the whole district mining was actively carried on during the summer of 1914 on about 21 claims, and a large number of other claims received varying amounts of attention from prospectors. An average number of about 325 men were employed in mining during the summer.

MINING CONDITIONS.

One of the most important of the factors which determine the cost of mining in this region is the shortness of the season during which surface placer mining can be carried on. Placer operations are dependent on stream flow and can not be commenced in the spring until the streams have run free of ice. Moreover, except at those places where artificial thawing is employed, mining can be done only when the gravels have thawed. In the Chisana camp there is a considerable range in altitude between the claims on lower Bonanza Creek and those on the headward portions of the streams, and the lower claims may be mined in the spring before the snow is gone from those at greater elevations. In general, however, mining can be started between the 1st and 15th of June and continued until early in September, when the streams become low and ice begins to form. A period of only 90 to 100 days is therefore available for surface mining.

The short season and the remoteness of the district from established lines of transportation are reflected in the wages paid for labor. The current rate for common labor is reckoned at $10 a day, or $6 a day and board. This high rate seems justified by the conditions in the district, yet much ground can not now be worked which would yield a profit if the cost of labor were less.

No timber occurs near the placer mines, and wood for fuel and lumber must be brought from lower Chathenda Creek or from Chavolda Creek, a distance of several miles. Two sawmills at Chisana and one at Bonanza, at which spruce lumber could be obtained, were in operation in 1914. The price charged at Bonanza was $150 a thousand feet and at Chisana from $150 to $125 a thousand feet, but in addition to the sawmill prices the cost of transportation to the mines is high. Cordwood is said to bring $40 a cord delivered at the mouth of Little Eldorado Creek.

Only the simplest of mining tools or equipment could be purchased at the stores, and practically all appliances were brought in by the individual operators for their own use. It has therefore been necessary for each miner to know in advance what equipment he would need so that it could be brought in by sled during the winter. The results of the isolation of the camp and of high freight charges is that only the simplest forms of mining have been done, and the gold is recovered almost entirely by pick and shovel.

ORIGIN OF GOLD PLACERS.

As shown in figure 2 most of the placer deposits occur within the areas of Carboniferous pyroclastic rocks and of the granitic rocks which are intrusive into the Carboniferous, the only exceptions to

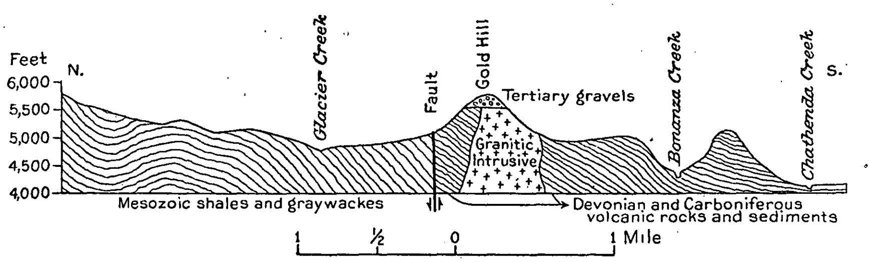


FIGURE 8.—Diagrammatic section through Gold Hill, to show relations of Tertiary gravels to the older formations.

this rule being the claims above No. 8, Bonanza Creek, and the rather low grade deposits in the basin of Glacier Creek, all of which lie on a bedrock of Mesozoic sediments. It is also a well-established fact that the headward tributaries of Bonanza, Chathenda, and Chavolda creeks, which flow over Mesozoic sediments exclusively, have little or no placer gold. The exceptions to this rule, claims Nos. 8 to 13 on Bonanza Creek and the placers in the Glacier Creek basin, are all in close proximity to Gold Hill.

Gold Hill (Pl. IX, p. 55), a high smooth-topped mountain, lies about in the center of the producing placer claims and is drained by Canyon, Bonanza, Little Eldorado, Skookum, Poorman, Glacier, and Big Eldorado creeks, and this group comprises all the streams which have been shown to contain workable placers. It is capped by a gravel deposit which is apparently over 200 feet thick and which lies upon the intrusive granitic rocks and upon the materials of the Carboniferous pyroclastic series. (See fig. 8.) The gravels are composed for the most part of pebbles derived from the Carboniferous and its intrusive rocks, but contain also an appreciable admixture of Mesozoic sedimentary pebbles. The material is unconsolidated but is deeply oxidized and contains pieces of lignitized wood, and many of the pebbles are decayed. The gravel is believed to be of late Tartiary age.

Prospect holes have been sunk in the gravels of Gold Hill, and although gold in sufficient concentration to be mined has not been found, some gold has been shown to be present. In the Carboniferous rocks near by (see p. 119) there are a number of lodes which carry free gold, and it is believed that the gravels of Gold Hill received their gold originally from such lodes where the Carboniferous rocks are cut by granitic intrusive masses. The close association of gold lodes with granitic intrusives has been shown so often that no further discussion of that relation is necessary here.

The placer gold on Bonanza, Little Eldorado, and Skookum creeks and in the Glacier Creek basin has a smooth, worn appearance and has apparently been subjected to considerable handling by streams. It seems evident to the writer that this gold is the result of a postglacial reconcentration, probably of materials from Gold Hill, the original source being the gold veins in the Carboniferous rocks.

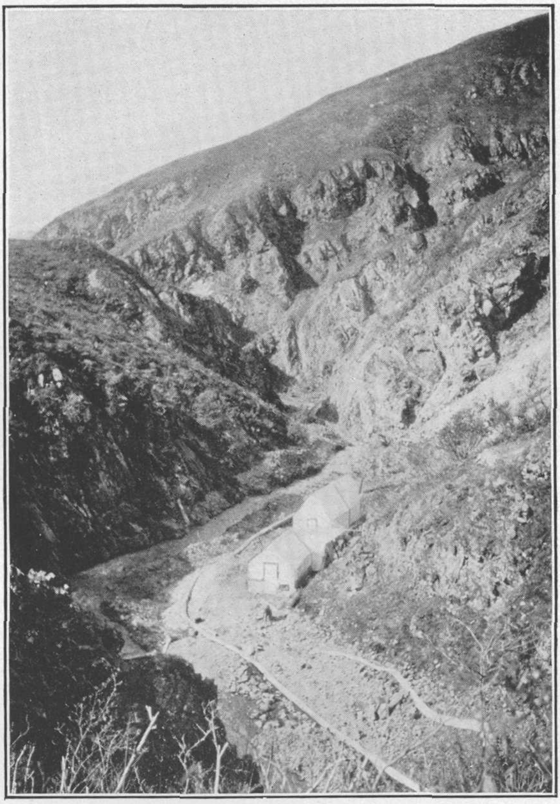
The placer gold of Big Eldorado Creek is in striking contrast to that of the other producing streams. It is bright, sharp, and angular and shows almost no evidence of stream wear. Quartz particles are attached to much of it, and sharp-angled pyramidal crystals of gold are common. This gold appears to be a primary concentration, for if it had been much handled by streams its sharp angles and crystalline faces would have been lost. The gold placer mines on Big Eldorado Creek are all in that portion of its basin which lies entirely within the area of Carboniferous pyroclastic rocks and granitic intrusives, and if the angular gold is a primary concentration, its bedrock source must have been in the materials of those rocks or in veins that cut them.

The gravels of Gold Hill are but a remnant of a former extensive gravel deposit, parts of which have been removed by stream and ice erosion. A relatively slight extension of their present area would carry them eastward over all the claims which contain placers on upper Bonanza and Little Eldorado creeks. The mines on lower Bonanza and Glacier creeks may also have been within the area of the gravel deposit, but they all fall in valleys which have headward tributaries in Gold Hill; and as the gold may have moved downstream to its present position, its presence can be explained without supposing an extension of the old gravels over them.

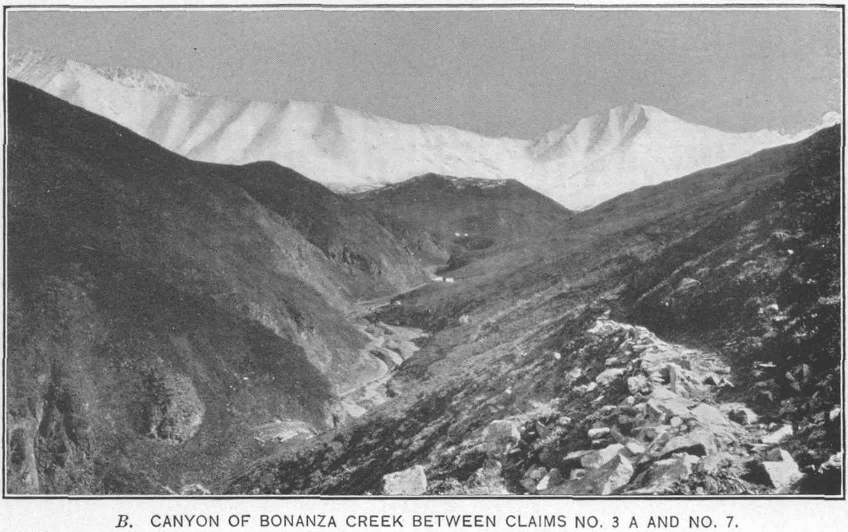
Cairnes,[1] as the result of a visit of a few days that he made to this district in the fall of 1913 in connection with his study of a near-by

[1] Cairnes, D. D., Canadian Min. Inst. Bull. 24, pp. 33–64, 1914.

portion of Yukon Territory, gave an account of the general geologic and physical conditions of the camp. He describes the rocks as being dominantly sedimentary and mainly of Mesozoic age. This description applies to only the northern portion of the placer district, and during his brief study he failed to recognize either the Devonian and Carboniferous age and pyroclastic character of the rocks which underlie nearly all of the most productive ground, or the fact that a great fault separates the Mesozoic sediments from the Devonian and Carboniferous rocks. He notes that the Mesozoic sediments at the heads of the Bonanza Creek tributaries in the Nutzotin Mountains are iron stained and somewhat mineralized and states that "From these mineralized sediments of the Nutzotin Mountains the gold of the Chisana placers has most probably been derived." At another place he says: "Prospectors and others searching for placer gold in these portions of Yukon or Alaska are accordingly advised to confine their attention primarily to those creeks which flow through the shales and slates of the Nutzotin Mountains, and particularly where these rocks are highly mineralized and colored red with iron stain, as they are at Chisana." With these views the present writer is at variance. The distribution of the placer gravels, as already shown, seems to point conclusively to the source of the gold in the older Carboniferous and Devonian rocks. Furthermore, none of the streams which lie exclusively within the Mesozoic sediments, such as the heads of the Bonanza and Glacier creek tributaries and the heads of both Chathenda and Chavolda creeks, which drain the same mountain mass, show workable placer ground, and many of them, after rather thorough prospecting, have yielded not so much as a "color" of gold. On the other hand, veins in the Carboniferous rocks near granitic intrusives have been found to carry gold on Nabesna River, in the Chisana district; on Beaver, Horsfeld, and Eureka creeks, near the international boundary; and at other places. Furthermore, the presence of rather abundant copper nuggets and less common silver nuggets associated with the placer gold in the stream gravels also indicates that the source of these metals lay in the Carboniferous volcanic materials. Native copper is widely distributed in the Carboniferous lavas of the St. Elias and Wrangell mountains and is in many places associated with some native silver. By contrast the writer has yet to learn of a locality within the Mesozoic rocks of the Nutzotin Range at which native copper has been found. It is not intended to imply here that the Mesozoic sediments nowhere contain gold or copper veins, or that they may not yield gold placers. Some small quartz stringers from these sediments on assay have been found to carry some gold, but so far as the writer has been able to learn no gold deposits of commer-



A. CANYON OF BONANZA CREEK AT CLAIM NO. 3 A.



B. CANYON OF BONANZA CREEK BETWEEN CLAIMS NO. 3 A AND NO. 7.

The present canyon has been intrenched in a broader glacial valley.

cial value have yet been found in the Mesozoic sediments of the Nutzotin Mountains.

The belief that much of the present placer gold is a secondary concentration from the lower-grade Tertiary gold-bearing gravels of Gold Hill implies great changes in the topography of the district since the older gravels were deposited. The gravels now occupy the top of a prominent mountain and are surrounded by lower valleys on all sides. At the time the gravels were laid down the present position of Gold Hill must have been low compared with that of the areas from which the gravels were derived. After the gravel deposit was laid down, probably over an area much greater than that which it now covers, the processes of normal erosion, stimulated by mountain building and uplift, carved valleys below the level of the gravels, and these too suffered erosion. What gold they contained was concentrated in the streams, and probably rich gold placers were formed. In the course of time glaciers formed in the mountain valleys and grew and joined in the lowlands, until at the time of their greatest development only the high peaks and ridges of the mountains projected. Gold Hill and the other mountains between Chathenda and Chavolda creeks were completely submerged by glacial ice, the valley and canyon of Chisana River were filled by ice to a depth of more than 2,000 feet, and the glaciers were continuous between the Chisana, White, and Beaver valleys. The erosion by this thick body of slowly moving ice was enormous, and its effect upon the present topography is still preserved with striking vividness. The submerged hills were rounded and smoothed, and the valleys were widened and deepened. The deposits of stream gravels, which existed before the ice advance and the gold placers which they may have contained, were eroded and in large part swept away and scattered by the glaciers. Ice in large volume moved from the upper Chavolda basin across Caribou Pass, across the ridge between Bonanza and Chathenda creeks, and into the head of Beaver Creek, thus passing over and eroding much of the area that now contains placers. (See Pl. XVIII, *B*, p. 80.)

With the withdrawal and shrinkage of the glaciers the rocks were again exposed to stream cutting. The valley gradients had, however, been changed by the ice erosion, and the streams found conditions greatly different from those which had existed in preglacial time. In reestablishing their courses the streams in general reoccupied their old preglacial valleys, but in places the old valleys were deserted and new ones formed. By the lowering of their outlets some streams had acquired steep gradients and soon cut canyons through portions of their courses. This is particularly true of Bonanza, lower Little Eldorado, and Glacier creeks. (See Pl. XIX.)

The present inner canyons of these streams have certainly been cut since the valleys were modeled by glacial ice.

The existing placer deposits are therefore almost entirely the result of postglacial concentration, and the gold-bearing bench gravels which have been found at places within the canyons, but above the present streams, are merely remnants of the gravels of the present streams left behind as the valley was rapidly lowered.

Cairnes[1] recognizes the youthfulness of the present canyons and says of the changes of drainage: "Such may have been produced by a somewhat sudden uplift of the district or by the glacial damming of portions of the stream valleys, caused by great accumulations of morainal material derived from the mountains to the north." The writer saw no evidence of postglacial tilting that would cause the rapid development of canyons on the streams tributary to Chisana River while Chisana River itself has been aggrading its valley flow. Furthermore, although there certainly were small ice tongues moving southward from the Nutzotin Mountains, they were trivial compared with the great glaciers that were moving northward from the Wrangell Mountains. The rejuvenation of Chathenda and Chavolda creeks and their tributaries is easily and satisfactorily explained by the glacial deepening of the main Chisana Valley by ice from the Wrangell Mountains moving northward through the Nutzotin Mountains. On the final disappearance of this ice tongue the tributaries of Chisana Valley were left in hanging valleys, and the present canyons are the result of their attempt to bring their gradients into accordance with that of the valley into which they discharge.

Caires[2] speaks of bench or "old channel" gravels and says:

As the bottoms of the old channels are in places above and in places below those of the streams of the present creeks, which they cross, these older gravels now occur both as bench deposits above those of the present streams and as buried gravels below the level of the present stream bottoms. * * * It seems possible, from what is now known of the different gravels in the Chisana district, that the bulk of the placer gold in the district was or is [in] the old channels and will be obtained either from the gravels of the old channels directly or from the gravels of the present streams where these cut the older gravels.

Cairnes therefore uses the term "old-channel gravels" in a very broad sense, including both bench and terrace gravels and gravels deposited along stream courses that are now abandoned. To the writer it seems that the term "old-channel gravels" should include only gravels deposited by streams in courses other than those now occupied by the present streams, that is, in courses now abandoned. The drainage system of the region has been so vitally affected by glaciation that portions of uneroded preglacial stream courses are

[1] Cairnes, D. D., Canadian Min. Inst. Bull. 24, p. 53, 1914.
[2] Idem, p. 61.

likely to remain, and the gravels in these would properly be called old-channel gravels. No deposits of placer gravel were seen in the district, after a season of vigorous mining and prospecting in 1914, that could in this sense be called old-channel gravels or that could not have been deposited by the present streams during the post-glacial cutting of their canyons, except the Tertiary gravel capping of Gold Hill. It is true that at one place, on upper Bonanza Creek, a diversion of drainage has been brought about by the deposition of a lateral moraine across the mouth of a small stream that was formerly tributary to Chathenda Creek but now forms the head of Bonanza Creek. A deep prospect hole at that place indicates a bed-rock channel draining to Chathenda Creek beneath this morainal material, but no placer gold was found there. In Dry and Alder gulches also there is a heavy fill of gravels along an old glaciated valley, deposited at a time when the present mouth of Chathenda Creek was blocked by Chisana Glacier and the drainage found an outlet through a high gap east of the ice tongue, but this valley was occupied by a stream for only a short time during the recession of the glaciers, and its gravels are not preglacial.

While it is possible, therefore, that preglacial placer-bearing stream channels younger than the gravels of Gold Hill but older than the present drainage system still exist in this district and that their erosion may have served to enrich the present stream gravels, no such source for the present placer deposits has yet been proved.

MINES AND PROSPECTS.

During the present investigation all the mines and most of the prospects which were being actively worked were visited. The following pages contain brief descriptions of the mining operations as they were at the time of visit, in the summer of 1914. With one exception the separate properties are described in order along the streams, those on each creek being grouped under a heading for that stream, and the descriptions beginning with the lowest claim and proceeding in order upstream. A number of claims were worked under one management, and the description of the mining done by this company on all its ground is given at only one place. The position of the mines and prospects is indicated in figure 9.

BONANZA CREEK.

No. 1 Fraction.

No. 1 Fraction is a fractional claim lying immediately above claim No. 1, through which Bonanza Creek flows for a distance of about 100 feet, in a steep-walled canyon. The stream occupies the canyon bed from wall to wall during periods of high water, and at ordinary stages of flow there are gravel bars of small dimensions at only a few points. Prospecting and mining were carried on here in a small way by one man, who confined his work for the most part to cleaning out the crevices of the agglomeratic bedrock and wash-

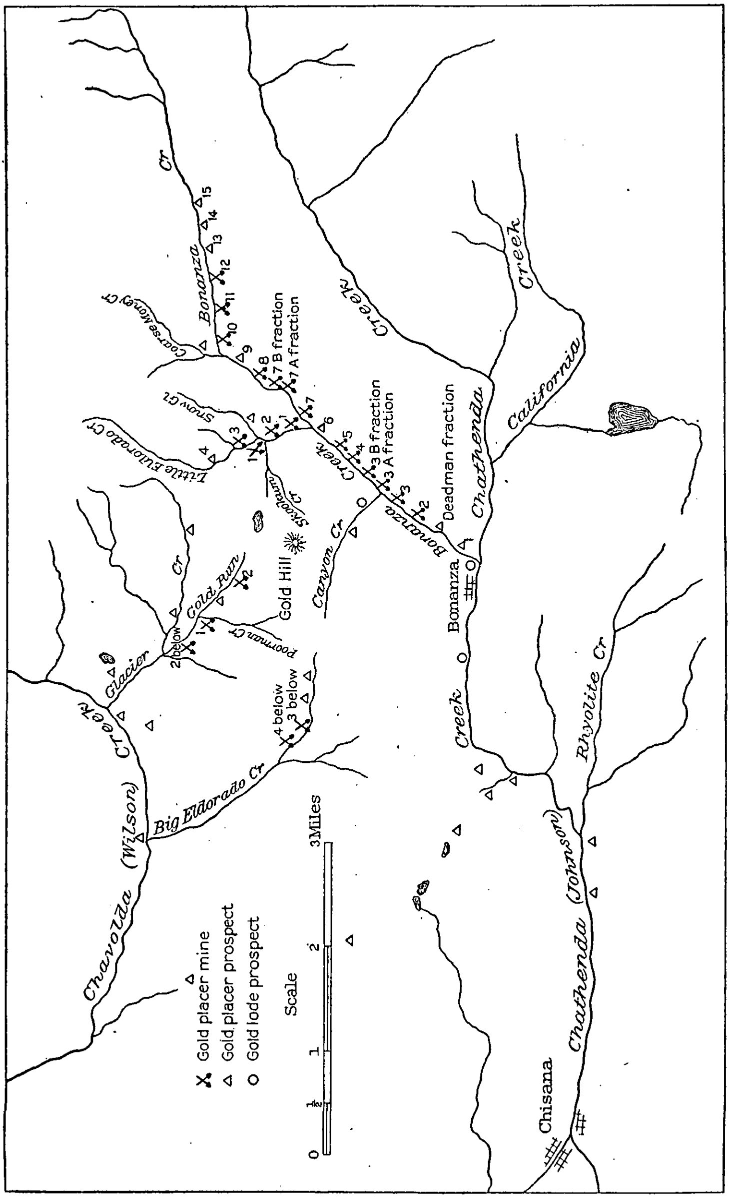


FIGURE 9.—Sketch map of the immediate vicinity of the placer mines, showing approximate position of mines and prospects.

ing out the small accumulations of stream gravels. The gold recovered had been scarcely sufficient to justify mining, but the variable tenor of the gravels on other parts of this stream encouraged the expectation that some richer spots might be found. There is insufficient workable ground here to warrant operations on an extensive scale.

Deadman Fraction.

The so-called Deadman Fraction is a fractional claim about 950 feet long, lying between No. 1 Fraction and No. 2. Like No. 1 Fraction, it lies along that portion of Bonanza Creek which is steeply intrenched in a deep canyon of Carboniferous pyroclastic rocks. At the time of visit, late in July, 1914, a party of four men was just beginning mining operations and no clean-up had yet been made, so that the value of the ground was not known. The canyon floor is narrow and if worked from rim to rim would give a width of bedrock of only about 12 feet, the gravels ranging from 2 to 4 feet in thickness. Large bowlders were abundant, and the quantity of gravel which could be shoveled into the boxes was small.

Claim No. 2.

Mining was conducted during most of the open season on claim No. 2 by laymen, seven men being continuously employed. Sluicing was begun on June 12, no work having previously been done on this ground. The workable width of the canyon floor there averages about 30 feet, and no flume was used, the creek being diverted first to one side of the flat and then to the other. The usual pick and shovel method was employed exclusively. The gravels, which contain rather abundant bowlders, consist for the most part of rather flat, slabby cobbles and bowlders and range from 3 to 12 feet in thickness, averaging about 5½ feet. Water for the sluice boxes was taken from the creek through canvas hose, and the boxes were set on a grade of 9 inches to the box length. The gravels here contain little clayey sediment, and the use of a dump box has been found to be unnecessary. The gold is said to occur almost entirely on bedrock or in the crevices within the bedrock, no considerable amount being found in the overlying gravels. The gold is rather irregularly distributed on the bedrock, which consists of lavas and agglomerates, some beds being much decayed and soft. The harder phases of the rock are in places worn smooth and have retained little gold, but immediately below such places there are often found spots of considerable richness. The high points of the hard, rough bedrock have in general retained the most gold.

The gold recovered from this claim is coarse, but nuggets are rare, the largest found having a value of $4. All the gold is smooth and flat, showing plainly that it has been subjected to much wear between the place of its bedrock source and its present position. On August 1, 1914, about 500 linear feet of the stream bed had been worked out.

Claim No. 3.

Claim No. 3 includes a deeply intrenched portion of Bonanza Creek, the canyon being cut into the Carboniferous pyroclastic rocks, which strike N. 75° W. and dip about 40° SW. Canyon Creek joins Bonanza Creek near the upper end of this claim. Mining operations were carried on by one outfit, 10 men being employed. Work was commenced in the spring at the lower end of the claim, but the gravels at that point were found to average 14 feet in thickness and to be too low in gold content to justify mining. Mining was then begun at a point 600 feet below the upper line of the claim and progressed during the summer until the upper part of the claim was worked out. The ground mined averaged only 20 feet in width and varied from 2 to 4 feet in depth. Large bowlders were very abundant, many of them being too large to move by hand, and these were not taken from the cut, but the finer gravel was removed from around them. About 300 feet of 42 by 24 inch flume was used to carry the creek past the cut, and eight lengths of sluice box and a dump box, set on a grade of 10 inches to the box length and equipped with pole riffles, were employed. The mining was all done by means of pick and shovel. The gold was coarse and well worn and was irregularly distributed, rich spots alternating with less productive areas. The most gold was commonly found on the higher portions of hard bedrock. In places where the bedrock was decayed and soft there was not enough gold to justify mining. Most of the gold lay on bedrock or in the cracks in it, and the gold content of the overlying gravels was said to be small.

No. 3 A Fraction.

No. 3 A Fraction is the lower of two fractional claims which lie between claims Nos. 3 and 4 and has a length of about 500 feet. On this ground six men were engaged in mining throughout the summer. Bonanza Creek is here deeply intrenched in the Carboniferous pyroclastic rocks, and the stream flat is winding and narrow, the workable ground having an average width of only 12 feet and a thickness of 2 to 8 feet. The stream was carried across the working cut by a flume 120 feet long and 42 inches wide, and the gravels were mined by pick and shovel and washed through a set of 12 sluice boxes and a dump box, lined with pole riffles and set on a grade of 10 inches to the box length. The gravels are not well rounded, and angular pieces of rock are common. A sticky clay mixed with the gravel makes the use of a dump box necessary, and even this fails to disintegrate all the clay, so that some loss of gold must certainly take place. Much of the bedrock is hard and blocky and retains the gold well, and most of the gold occurs on bedrock or in the crevices in it. It is necessary to take up from 2 to 5 feet of bedrock in order to recover all the gold. As on many of the other claims on lower Bonanza Creek, the most gold is found, not in the deepest channel in bedrock, but on the higher points of it. The gold is bright, coarse, flat, and well worn. The largest nugget had a value of $61.80, and half of that recovered is said to be in nuggets worth $5 or more. Some pieces having a rusty, reddish coating are found on decayed portions of the bedrock which have a bright-red or purple color, the gold doubtless acquiring a rusty cast from the iron in the underlying bedrock.

No. 3 B Fraction.

The claim known as No. 3 B Fraction is the upper of the two fractional claims lying between Nos. 3 and 4 and is about 900 feet long. Mining was begun on the lower end of this ground in 1913, and several thousand dollars' worth of gold was recovered. In June, 1914, mining operations were continued at the point where they were stopped the fall before, and 10 men were continuously employed during the open season. The creek at this locality flows through a deeply intrenched gorge in the Carboniferous lavas and agglomerates, and the bedrock is rough enough to retain the gold well. The creek gravels average about 25 feet in width and are shallow, the average depth to bedrock being less than 2 feet. Although bowlders are rather abundant, most of them can be moved by hand, and only a few require blasting. A flume 30 by 19 inches in section and 350 feet long is used to carry the creek past the cut and is adequate except in periods of flood. The pick and shovel method of mining is used exclusively, the gravels being washed through a set of 16 sluice boxes, each 12 feet long, 14 inches wide, and 12 inches deep, set on a grade of 8 inches to the box length and equipped with pole riffles. An abundance of sticky clay in the gravels requires the use of a dump box, and even this fails to disintegrate the clay completely, so that there is a constant loss of gold, equal, it is estimated, to about 10 per cent of that recovered. About 2 feet of bedrock is taken up and put through the boxes. The gold is practically all found on bedrock or in the cracks in the rock surface, the overlying gravels containing very little. The gold, which assays $16.36 an ounce, is bright, smoothly worn, and very coarse, the pieces averaging 10 to 15 cents in value, exclusive of the larger nuggets. One $40 nugget was found, and another worth $33.50, while pieces having a value of $3 to $20 constitute a large portion of the gold recovered. At the time this claim was visited it was said that the ground mined had carried an average value of about $2 to the square foot of bedrock.

A number of localities along the valley sides of this claim have small deposits of bench gravel, and the ground on which the tents are situated, 15 feet above the creek, is said to contain a good pay streak.

Operations by F. T. Hamshaw.

The claims staked in this district by James and Nelson, the original discoverers of placer ground in this camp, were leased by them to J. J. Price and J. J. Ives, who in turn assigned their lease to F. T. Hamshaw. The ground involved in these leases included, on Bonanza Creek, Discovery claim, and No. 1 below, and Nos. 1, 4, 5, 6, and 8 above Discovery; on Little Eldorado Creek, No. 1; and on Big Eldorado Creek, Discovery claim. With the exception of a few small subleases made by Messrs. Price and Ives, all the mining done on these claims in 1914 was carried on by Mr. Hamshaw, the principal operations being on claims Nos. 4 and 5, Bonanza, and No. 1, Little Eldorado.

The main camp was located on the south side of Bonanza Creek at the mouth of Little Eldorado Creek and consisted of about 16 tents, including offices, commissary, mess, and sleeping quarters. The camp is connected by fair trails and by telephone with the town of Bonanza, where there is a general warehouse. The number of men employed varied considerably during the season, ranging from a minimum of 30 to a maximum of over 100. The general mining practice followed was to ground-sluice off the upper portion of the creek gravels, leaving a foot or two above bedrock to be shoveled into the sluice boxes. Whenever a large gang of shovelers was employed, a horse team and scraper were used to clear away the tailings from the lower end of the sluice line. The average thickness of the stream gravels mined, including that portion of the bedrock which was removed, was only a little more than 6 feet, and the actual average thickness of the stream gravels was between 4 and 5 feet.

The following summary of mining operations on these claims is published because it is believed to contain valuable data on the actual cost of pick and shovel placer mining of shallow stream gravels in a region remote from established lines of transportation. Reliable figures on such operations are difficult to obtain, as they are rarely kept by the placer miner. Other operators in this same district state that their mining costs are lower than those given in the accompanying table, but their figures are not based on accurate measurements and can therefore not be given for comparison. It will be noted that the total working cost as shown would be somewhat reduced when proper account is made of the difference between the estimated and actual cost of board for the employees, but would be increased if allowance were made for amortization and if the cost of dead work were added.

Summary of mining operations by F. T. Hamshaw at Chisana, in the White River mining district, Alaska, during 1914.

[Published by permission of F. T. Hamshaw.]

	Linear feet of creek worked.	Value per linear foot.	Working cost per linear foot.	Square feet of bedrock mined.	Value per square foot of bedrock.	Working cost per square foot of bedrock.
No. 4, Bonanza	979	$22.17	$19.12	19,725	$1.23	$0.74
No. 5, Bonanza	833	26.45	20.13	23,182	.80	.67
No. 1, Little Eldorado	1,029	50.50	13.28	43,047	1.21	.32
Total or average	2,841	33.04	17.51	85,954	1.08	.576
Upper end of Little Eldorado Creek [a]	380	3.435	4.45	11,642	.14	.18
Operations of laymen				24,904	.55	.37
				122,500		

	Cubic yards of gravel moved.	Value per cubic yard.	Working cost per cubic yard.	Gold production.	Total working cost.
No. 4, Bonanza	4,530	$5.51	$3.21	$24,128.00	$14,787.20
No. 5, Bonanza	5,619.5	3.65	2.73	20,528.00	15,473.00
No. 1, Little Eldorado	9,219.5	5.63	1.48	51,952.00	13,610.70
Total or average	19,369	4.93	2.473	96,608.00	43,870.90
Upper end of Little Eldorado Creek [a]	1,391	1.25	1.56	1,646.00	2,177.80
Operations of laymen	3,222	4.22	2.85	13,697.06	
	23,982			111,951.06	

[a] Not in pay channel; worked out to make dumping ground for pay streak on left bench.

NOTE.—Labor is calculated at $6 a day and board, or $10 a day. Boarding-house account shows a cost of $2.75 a day per man. Working cost does not include amortization and dead work, as follows: Cost of sluices, flumes, dam, and dead work before sluicing, No. 4, Bonanza, $5,280; No. 5, Bonanza, $4,975; No. 1, Little Eldorado, $3,527; total, $13,782.

The gravels mined lie on bedrock composed of the Carboniferous and Devonian lavas and pyroclastic rocks, with some shales, all having a general northwesterly strike and dipping 10°–60° SW. The bedrock differs in character from place to place, some beds being much decayed and soft, while others are hard and rough. Throughout this district experience has shown that the greatest concentration of gold occurs on the hard, rough bedrock, the softer phases being relatively lean. Bowlders in the gravels are rather abundant, although those too large to be rolled aside by hand are uncommon. In general the gravels are unfrozen, but locally frozen patches were encountered, and many of these were subleased to laymen to be mined.

The gold is bright, coarse, and smoothly worn. The largest nugget found has a value of over $130, and pieces weighing a quarter of an ounce or over make up about 5 per cent of the total gold recovered. The gold is said to assay $16.67 an ounce.

The present stream gravels on claim No. 1, Little Eldorado Creek, were about worked out during the summers of 1913 and 1914, but it is reported that late in the fall of 1914 rich ground was found on the left bank of Little Eldorado Creek several feet above the stream and extending beneath the bench gravels at that place. On claim No. 5, Bonanza Creek, paying ground was found high on the north valley wall, and at a number of places along both Bonanza and Little Eldorado there are patches of bench gravels which have yielded good prospects.

Claim No. 7.

Mining was carried on by two parties on claim No. 7. On the lower half of the claim four men were mining by pick and shovel methods. The creek there flows through a narrow gorge with steep walls of pyroclastic rocks interbedded with black shales. No flume was used, the creek being turned first to one side of the flat and later to the other. Ten lengths of sluice boxes, 12 by 14 inches in cross section, and a dump box were employed for washing the gravels, and in order to obtain sufficient grade for the sluice its upper end was set so high that in parts of the cut the gravels were lifted by shovel as much as 10 feet. A relatively small amount of ground required to be shoveled, for the surface gravels were first sluiced off by the use of an automatic dam before shoveling was begun. Water was carried to the sluice boxes by means of canvas hose. The gold was unevenly distributed, rich areas of hard, rough bedrock being succeeded by nearly barren stretches of smooth, decayed bedrock. The gravels washed were from 3½ to 4 feet deep and contained few large bowlders.

At the time of visit, in July, 1914, the operators reported that the output from this claim, which lies adjacent to the rich ground on Little Eldorado Creek, was disappointingly small.

On the upper half of claim No. 7 a number of men were engaged in mining, several hundred linear feet of the creek bed being worked out. Conditions were similar to those on the lower half of this claim, the distribution of the gold, however, being especially irregular. The gravels had an average width of about 20 feet and a depth of 3½ feet and contained an unusual quantity of sticky clay which made recovery of the gold difficult. Late in July the tenor of the gravels then encountered had become too low to justify mining, and a prospecting ditch 100 feet long had been run without having again encountered workable ground.

No. 7 A Fraction.

Mining was conducted on the lower of two fractional claims lying between Nos. 7 and 8, known as No. 7 A Fraction, which is between 500 and 600 feet long. Four laymen were mining gravels that averaged less than 2 feet in thickness. At the time of visit a section of the stream gravels 300 feet long and 20 feet wide had been worked out.

Five lengths of 12-inch square sluice box and a dump box were used, with the upper end of the sluice line 9 feet above bedrock, the water being conducted to the boxes through canvas hose. Not many large bowlders were encountered, but numerous large pieces of angular rock were embedded in the gravels. The bedrock consists of pyroclastic materials and some shales and in places is worn so smooth that little gold was retained on its surface. The gold occurred for the most part on bedrock or in the rock crevices, and the overlying gravels contained little. The distribution of the gold was uneven, relatively lean areas being succeeded by richer spots.

No. 7 B Fraction.

No. 7 B Fraction is a fractional claim about 700 feet long, lying between No. 7 A Fraction and No. 8. Four men had been mining on this claim, the title to which is in litigation. In an area 200 feet long and from 14 to 20 feet wide, which had been worked, the gravels average about 3 feet in thickness. The bedrock is composed of pyroclastic materials, and the richest ground was found on the harder portions of it, some of the ground yielding $2 to the square foot of bedrock. The distribution of the gold was very irregular, and late in July, 1914, the ground sufficiently rich to mine had been worked out and mining was discontinued.

Claim No. 8.

On claim No. 8 mining was done by laymen for a part of the summer, and a stretch of the creek gravels about 400 feet long and having an average width of 12 feet was worked out. The gravels, of an average thickness of 3 feet, lay on a bedrock composed of pyroclastic materials. For several weeks 16 men were employed in two shifts, eight men working on each shift. Late in July the gold content of the gravels encountered became so low that active mining was discontinued, although two men were engaged in the endeavor to locate more ground which would warrant exploitation. The gold was said to be very unevenly distributed along the course of the valley floor and only locally to be abundant enough to justify mining under the present high cost of operation. The recovery ran from 10 to 22 cents to the square foot of bedrock. Practically all the gold was found on bedrock, the overlying gravels being of low tenor. There was considerable clay in the gravels, and although this clay contained some fine gold, the gold could not be recovered by the methods used. The largest nugget found on the ground had a value of $8, and the gold would all be classed as coarse, though large nuggets were much less common than on the next few claims below.

Claim No. 10.

Two parties were mining on claim No. 10 in July, 1914, one on the lower and one on the upper half of the claim. On the lower half four men, operating on a lease, were engaged in mining, although at the time of visit little ground had been sluiced. This claim lies above the contact between the pyroclastic rocks and the Mesozoic shale series, and the bedrock is composed of black shale, cut by numerous dikes. The gravels mined had an average thickness of about 4 feet, and the gold was for the most part on the surface of the bedrock, or less than a foot down in the crevices in it. The gravels are of comparatively small size and are easy to mine, few large bowlders being encountered. The gold is relatively fine and flaky, the only two nuggets recovered having values of $6 and $3.

On the upper half of claim No. 10 five men began mining late in July, 1914, and at the time of visit no sluicing had been done. A horse scraper was used to remove the surface gravels, but the sluice boxes had not yet been installed. It was said that the gold all lay in the lower 3 feet of gravels and on bedrock, and that the gold content of the upper gravels was too low to warrant sluicing. The bedrock is black shale, striking N. 65° W. and dipping 67° SW. The shale is cut by dikes which strike approximately parallel with it, but dip in the opposite direction.

Claim No. 11.

On the lower end of claim No. 11 four men were prospecting in July, 1914, but had found no workable ground. The gravels were from 3 to 5 feet deep and lay on a bedrock of black shales with some interbedded sandstone, striking N. 55° W. and dipping 60° SW.

On the upper half of the same claim several men were beginning mining operations late in July. The gravels from a cut 4 to 5 feet in depth had been shoveled into the sluice boxes, but no clean-up had yet been made. It is reported that late in the summer ground yielding $6 to the square foot of bedrock was found on this claim and that one nugget valued at about $64 and others worth $30 were obtained.

Claim No. 12.

Three men, operating on a lease, were mining on the lower half of claim No. 12 in 1914. The gravels average about 5 feet in thickness, though they are locally as thick as 9 feet and lie on a bedrock of black shale. Wheelbarrows were used to take off the upper portion of the gravels, in which, it is said, not a color of gold could be found. The gravels are composed largely of rather flat pebbles of moderate size, and large bowlders were not abundant. The gold recovered was coarse and contained nuggets which had a maximum value of $8. No fine gold was found.

Three men were mining on the upper half of claim No. 12 and had sluiced the gravels from a cut 85 feet long and 18 feet wide. The gold found, almost entirely on the shale bedrock, was irregularly distributed, but was said to average 60 cents to the square foot of bedrock. From 1½ to 2 feet of the bedrock was taken up to obtain all the gold. The flow of water in Bonanza Creek at this place was just about sufficient to afford a sluice head.

Upper Bonanza Creek.

Late in July, 1914, no active mining was being done on upper Bonanza Creek, although prospecting was being or had been done at a number of places. On claim No. 13 one party had done considerable work, and it was reported that ground sufficiently rich to mine had not been found, although locally the returns were encouraging. Another party was just starting to prospect this ground.

Claims Nos. 14 to 18 have all received some attention from prospectors. On claim No. 15 several hundred feet of bedrock drains had been dug, but only an occasional color was found. On claim No. 18 there is a shaft said to be 85 feet deep, with a 25-foot drift from the bottom. The drift is on bedrock, but the bottom of the bedrock channel was not reached. No paying ground had been found at this place at the time of visit.

LITTLE ELDORADO CREEK.

Claim No. 2.

Active mining was conducted during the entire summer of 1914 on claim No. 2, Little Eldorado Creek, seven men being employed. On this claim the stream flat, though bordered by steep bluffs, is wider than on the claim below, having a width of 75 to 150 feet. The gravels average about 3 feet in depth, contain few bowlders, and are composed largely of flat, shingle-like pebbles of banded shale and graywacke. The bedrock is of the pyroclastic series and is locally termed "porphyry." Its surface below the stream gravels is fairly flat in cross section from one bluff to the other. The bedrock is much broken, and from 5 to 12 inches of it is shoveled into the sluice boxes with the overlying gravels. It is easily removed, as it comes up in angular fragment only a few inches in diameter. The gold is said to be recovered in large part from the bedrock, although the overlying gravels contain some gold. They are about 3½ feet deep throughout the claim, except in those places where detritus from the bluffs has moved down upon the stream gravels. At the time of visit 17 lengths of 11-inch sluice box, set on a grade of 8 inches to the box length, were in use, more boxes being gradually added as mining progressed upstream. The gravels contain little clay, and a dump box is not considered necessary. The pay streak is 36 to 40 feet wide and is taken out in three cuts. Water under pressure is brought through canvas hose to the lower end of the sluice boxes, and a nozzle is so set as to keep the tailings from piling up at the end of the sluice line.

The gold is very coarse, a large percentage of that recovered being in nuggets ranging in value from 50 cents to $20. It is bright yellow in color and fairly well worn and is said to assay $16.90 to the ounce.

Claim No. 3.

Mining was commenced in July, 1914, on claim No. 3 by three men and continued during the summer. At the time of visit a cut 65 feet long, about 50 feet wide, and averaging 3 feet in depth had been worked out. The gold was recovered from a false clay bedrock, underlain by 2 feet of gravels which rest on the true bedrock of lavas and intrusive rocks. The gravels are frozen at a depth of 2 feet below the surface and are stripped and thawed by water before being shoveled into the sluice boxes. They consist for the most part of shale and graywacke pebbles, with considerable material of various sorts which resembles the gravels found on Gold Hill. The gold, like that on claim No. 2, is bright and coarse, the largest nugget recovered having a value of $15.

SKOOKUM CREEK.

Skookum Creek is a small stream which joins Little Eldorado Creek from the west about 400 feet below the upper end of claim No. 2. The upper basin of this stream is a broad marshy tract without conspicuous drainage lines, lying on the east slope of Gold Hill. For the lower quarter of a mile of its course the creek flows through a well-defined though small gulch which shows outcrops of intrusive rock at a number of places, and the stream gravels lie on a bedrock locally called porphyry, which is composed of lavas and agglomerates, cut by later intrusive rocks. Six men were engaged in mining on the lower end of Skookum Creek throughout the summer of 1914. Work was begun near the mouth of the creek on ground which lies on claim No. 2, Little Eldorado Creek, and continued upstream to claim No. 1, Skookum Creek, the ground on both claims being operated on lease. At the time of visit, late in July, a strip of gravels 224 feet in length along the creek had been mined. The pay streak was narrow, averaging only 6 feet in width, but was unusually rich. The stream wash, consisting largely of rather angular material, is from 5 to 14 feet in thickness and averages about 6 feet. It contains a considerable admixture of rounded gravels, probably derived from Gold Hill. Numerous pieces of lignitized wood have been found during the mining operations. Both the stream wash and the bedrock were frozen, and they were thawed by stripping and by surface water before being shoveled into the boxes. Skookum Creek carries only a small volume of water, and even with an additional supply obtained from a ditch toward the head of Little Eldorado Creek, only about one-third of a sluice head was available, and it was necessary to store the water and to sluice only intermittently. The gold occurs for the most part upon bedrock and is very coarse, little fine gold being recovered. The largest nugget found had a value of $52, and pieces worth from $10 to $20 were numerous. The gold is said to assay $16.50 to the ounce.

At the head of the cut on August 1, 1914, the pay streak had widened to about twice the average width below and on one side of the creek was covered by 14 feet of overburden, of which 6 feet was nearly pure ice.

At the time of visit no prospecting had been done on Skookum Creek above the location of the mine.

GOLD RUN CREEK.

Claim "No. 2 below."

Claim "No. 2 below" on Gold Run Creek, the lowest claim on that stream which has been mined in 1914, lies a short distance above the mouth of Glacier Creek. The stream has there a rather deep, narrow valley cut into shales, graywackes, and fine conglomerates, which form the bedrock of the gold-bearing gravels. Six men were mining on this claim throughout the summer with pick and shovel. By August 1 a strip of ground 150 feet long and 15 feet wide had been mined. The gravels range from 4½ to 5 feet in thickness and are for the most part composed of imperfectly rounded slabs of shale and graywacke, with a smaller proportion of well-rounded lava and diorite pebbles like those of the gravel capping on Gold Hill. From 1 to 4 feet of bedrock was also taken up and washed. Nine lengths of sluice box and a dump box, set on a grade of 8½ inches to the box length, were used. The gold is found both on bedrock and distributed through the overlying wash, is bright and fairly well worn, and is in finer and more flaky particles than that found on Bonanza Creek. The largest nugget taken from this claim was worth $6.50. Operations on this claim are said to have yielded little more than the cost of mining.

Claim "No. 1 above."

Mining operations were begun late in July, 1914, on claim "No. 1 above," four men being employed. Winter shafts had shown that bedrock lay about 14 feet below the surface and that an encouraging amount of gold was present. A pit 500 feet long and 40 feet wide was therefore ground-sluiced through about 11 to 15 feet of frozen gravel, but no sluicing had been done by August 3. As the water supply from Gold Run Creek was too small for efficient mining, a dam was built to impound water for ground-sluicing and a ditch half a mile long to tap the upper part of Discovery Pup was under construction. It was thought that with this additional water supply sluicing could be started. The gravels are of poorly rounded shales and graywackes, with much well-rounded material derived from the gravels of Gold Hill. Few bowlders larger than two men could handle were encountered. The gold is said to be distributed throughout the gravels, without any noticeable concentration on bedrock.

Claim "No. 2 above."

On claim No. 2 above Discovery, well toward the head of the Gold Run Creek basin, one man was engaged throughout the summer of 1914 in prospecting the benches 10 to 15 feet above the creek. The bedrock is composed of much-fractured shale and graywacke, covered by a mixture of shale fragments and rounded pebbles evidently derived from Gold Hill, against which this creek heads. Gold occurs in the detritus from the surface down but is most abundant in the shattered bedrock. It is for the most part fine and flaky, but a few larger pieces worth as much as $4 have been recovered. Some gold has been found in the creek bed on this claim, but the amount was insufficient to justify mining. The stream at this place is of small volume, and mining can be conducted on only a small scale.

POORMAN CREEK.

On claim No. 1, near the mouth of Poorman Creek, four men were mining throughout the summer of 1914. The stream flows in a narrow, steep-sided gulch cut through shales and graywackes intruded by dike rocks. The stream flow is normally too small to furnish a sluice head of water, and two dams were constructed to store water. Sluicing was therefore carried on only intermittently. The stream wash ranges in thickness from 4 to 12 feet and averages about 7 feet, and a section of the stream bed 100 feet long and from 10 to 15 feet wide had been mined. Nine lengths of sluice boxes, set on a grade of 13 inches to the box length, were in use. The gold occurs both in the gravels and upon the bedrock, of which about 2 feet is taken up and sluiced. The gold is fine and flaky compared with most of that recovered in this district, the largest piece having a value of only 35 cents. It is reported that the gold taken from this claim was insufficient in quantity to justify further mining.

BIG ELDORADO CREEK.

Claim No. 4 below Upper Discovery.

On claim No. 4 below Upper Discovery, Big Eldorado Creek, two men were mining on leased ground in 1914. On this claim the stream has cut a deep, narrow gorge into the diorite, and the stream flat is steep and narrow, with many large bowlders. The stream gravels averaged 6 feet in thickness, and 4 feet of the surface material was ground-sluiced off before shoveling was begun. A pit 600 feet long and 12 feet wide had been mined. Most of the gold recovered was taken from the surface of the bedrock or from the fractures in the rock, from 2 to 4 feet of the diorite being taken up and washed.

The gold is unevenly distributed along the creek bed, fairly rich spots being succeeded by lean areas. The gold is bright and very rough. The operators reported that this claim yielded only a fair return for the expenditure of labor upon it.

Claim No. 3 below Upper Discovery.

Vigorous mining was conducted in 1914 on claim No. 3 below Upper Discovery, 10 men, operating in two shifts, being employed. Big Eldorado Creek is here intrenched into the valley floor and flows through a narrow gorge cut in diorite, which forms the bedrock of the placer gravels. About 250 linear feet of the creek bed had been mined to an average width of 30 feet, the stream gravels there averaging only 2 feet in thickness. The gold-bearing gravels, while containing a good deal of angular material, are better rounded than those farther upstream and contain some well-worn gravels, probably derived from the ancient gravels that were formerly distributed along the hilltops adjoining this basin. Large bowlders of diorite of local derivation are common. Some gold is said to occur throughout the gravels, but the richest concentration is on the rough bedrock surface or in the crevices in the diorite. From 2 to 4 feet of the diorite is removed in mining. The gold is bright, coarse, and very rough. Few pieces that showed signs of much wear were seen, and most of the particles are angular and sharp, some crystal faces being discernible. Many pieces show the imprint of the crystals of vein quartz upon them, and gold with some quartz attached is common. The gold is markedly different in appearance from the well-worn, smooth gold of Bonanza and Little Eldorado creeks, and it is evidently of local origin. The present creek placer is probably a primary concentration of gold derived from the rocks that form the upper basin of this stream.

Claim No. 1 below Upper Discovery.

Two men, operating on leased ground, were mining in 1914 on claim No. 1 below Upper Discovery. The stream gravels average about 7 feet in depth and consist of a mixture of angular blocks and well-rounded pebbles. Large bowlders are not numerous, and most of those encountered could be handled without difficulty. The gold occurs mostly on bedrock, but some is distributed through the gravels. It is coarse, bright, and rough and shows little evidence of stream wear. It is reported that operations on this claim yielded little more than wages to the men employed.

Upper Discovery claim.

Upper Discovery claim lies in the upper basin of Big Eldorado Creek. The valley of the stream is here a broadly U-shaped basin, and the creek has intrenched itself but little into the valley floor. Two men were prospecting this ground early in August, 1914. They reported many fine colors of gold throughout a vertical thickness of 10 feet of stream gravels, with a few small nuggets. The underlying rock is diorite, but the so-called bedrock in the cut made was a layer of tough clay and no hard bedrock had been uncovered. The stream wash consists of bowlders and angular pieces of diorite intermingled with a goodly proportion of well-rounded gravels from Gold Hill. The ground is frozen and must be thawed before it can be sluiced. Insufficient sluicing had been done to afford a basis for reliable estimates of the value of this ground.

CHATHENDA CREEK.

Prospecting and some mining were done in 1914 by two men on the Big Seven claim, on Chathenda Creek a short distance above the mouth of Rhyolite Creek. At that place Chathenda Creek flows in a deep, steep-walled canyon, cut through Tertiary sandstone, conglomerate, and shale and later gravels. The stream gravels average 4 feet in thickness and lie on a bedrock of sandstone. The south wall of the canyon is composed of a great thickness of gravels and shaly sand, and it is said that occasional colors can be found in these gravels and that the only stream gravels which carry encouraging amounts of gold are those immediately below the gravel bluffs. Considerable prospecting had been done, but little sluicing. The gold is rather fine and is unevenly distributed. The largest piece found had a value of $2. Numerous nuggets of native copper have been found in the stream gravels. Mining in this canyon is difficult on account of the large volume of Chathenda Creek, which in times of high water can not be controlled by ordinary means.

PROSPECTS.

Practically all the streams for many miles in each direction from this placer camp have been more or less thoroughly prospected, with varying degrees of success. In many places where little or no gold was found the prospectors have abandoned the ground and moved to other places, and the only evidence of their work is that given by the prospect holes and ditches that they excavated. Naturally the streams nearest to the rich placers of Bonanza and Little Eldorado creeks received the greatest share of attention, for all the adjacent streams were staked during the stampede in the summer and fall of 1913. Thus Chathenda (Johnson) Creek was staked from the town of. Chisana to the head of the stream, and numerous pits and cuts were made. In spite of rather thorough prospecting, Chathenda Creek above the mouth of Bonanza Creek has nowhere yielded even an encouraging prospect, and many of the excavations failed to show even a color of gold, although the stream lies parallel to and only a short distance south of Bonanza Creek and flows through the same geologic formations. Below the mouth of Bonanza Creek the gravels of Chathenda Creek as far west as the mouth of the lower canyon are known to carry varying amounts of gold, and locally they have been rich enough to encourage extensive prospecting and even a small amount of mining. Several men prospected continuously throughout the summer of 1914 at points between the mouth of Dry Gulch and the lowest canyon.

Snow Gulch, a tributary of Little Eldorado Creek from the northeast on claim No. 2, is reported to contain workable gravels, both in the creek bed and on the benches, but mining there is being delayed until a suitable dumping ground shall be made available by the exhaustion of the gravels in claim No. 2.

The upper portion of Bonanza Creek and its tributaries, Coarse Money and Shamrock creeks, while only partly prospected, have as yet revealed no pay streak. Snow Gulch, Bug Gulch, and Pensive Pup, tributaries of Little Eldorado Creek from the northeast, have not yet been thoroughly prospected, but it is said that workable ground has been found on Snow Gulch. The benches along these streams and along Little Eldorado and Bonanza creeks carry considerable gold locally and deserve further prospecting.

The valleys of Dry Gulch and Alder Gulch and the broad pass connecting them are floored by a heavy deposit of gravels. In Alder Gulch and upper Dry Gulch several shafts, two of which are said to be more than 60 feet deep, penetrate gravels without reaching bedrock. The gravels are reported to carry some gold. Near the mouth of Dry Gulch a shaft 92 feet deep penetrates through gravels almost to the level of Chathenda Creek, without reaching bedrock. This shaft is reported to have cut two layers of gravel which are sufficiently rich to warrant mining, but no gravels from this place had been sluiced.

Bryan Creek, the next tributary of Chisana River south of Chathenda Creek, was prospected in 1914. On claim No. 4 below

Discovery six men were working throughout the summer. A number of pits were sunk, and a drain 10 feet deep was excavated without reaching bedrock. Some gold occurs throughout the stream gravels and especially on a clay false bedrock, the largest piece found having a value of $1.26. Copper nuggets are abundant. No sluicing had been done, and the work was all directed toward the endeavor to reach bedrock, in the hope of finding a valuable pay streak.

On claim "No. 3 below," Bryan Creek, one man had dug a long bedrock drain in gravels that were in places 12 feet in depth. The bedrock of sedimentary and intrusive rocks showed some gold, but no paying ground had been found at the time of visit.

The main valley of Chavolda (Wilson) Creek has been prospected at a number of places, with very little success. There are high bluffs of washed gravel on the south bank of the stream both above and below the mouth of Glacier Creek, but a tunnel driven 65 feet into the gravel bluff, with a 15-foot winze, is said to have yielded only a few fine colors. Other prospects farther upstream have given no encouragement. It is reported that during the winter of 1914–15 encouraging prospects were found on Chavolda Creek near the mouth of Alder Gulch.

Glacier Creek proper and its northeastern tributaries, Sargent, Paulson, and Chicken creeks, have not yet been proved to contain profitable gravels, although the southern tributaries, Gold Run and Poorman creeks, have furnished some production.

Numerous tributaries of Beaver Creek and White River have been visited and prospected to a greater or less extent as a result of the stampede to the Chisana. It was reported that late in the fall of 1914 workable placer ground was found on lower Ptarmigan Creek, a northward-flowing tributary of Beaver Creek near the international boundary, but this report has not been verified. Lime Creek, a headward fork of White River, was the scene of one or two small stampedes, but only small amounts of gold were found.

The possibilities of the general district near the headwaters of White and Chisana rivers have by no means been exhausted, and much unprospected ground remains which may prove to carry gold placers, but it is nevertheless significant that the large amount of prospecting which was done in 1913 and 1914 failed to enlarge greatly the area of productive ground, as determined during the early days of the gold rush, and it seems evident that the conditions which brought about the formation of gold placer deposits are of comparatively local development.

TOTAL PRODUCTION OF PLACER GOLD.

As already stated, the first production of placer gold from this district was made in 1913. During that year an amount of gold variously estimated as between $30,000 and $40,000 was recovered. In 1914 over 20 claims contributed to the production, and gold to the value of more than $250,000 was mined. It is therefore safe to say that the total production of the district up to and including the year 1914 was not far short of $300,000.

CONDITIONS FAVORING THE FORMATION OF GOLD PLACERS.

Predictions as to the probable occurrence of commercially valuable deposits of gold in areas that have not yet been thoroughly prospected are not to be accepted with too much confidence, for of a dozen localities in which the conditions may seem to be alike one may contain rich gold deposits and the others no ground sufficiently rich to mine. Nevertheless, prospecting in areas within which the geologic conditions are encouraging is likely to yield larger rewards than an equal amount of effort spent in unpromising areas. From a study of the Chisana placer district certain principles of broader application may be laid down. Among these are the following:

Placer gold should be sought only in those places where gold occurs in the bedrock, or where material derived from such gold-bearing bedrock has been brought by streams.

In those areas in which glacial erosion was severe the preglacial concentrations of placer gold are likely to have been removed and scattered. Locally portions of preglacial stream gravels may be preserved, but their discovery is likely to result only from thorough prospecting.

In such severely glaciated regions postglacial placers will be present only in those places in which postglacial erosion has been sufficient to form new concentrations of gold, derived either from bedrock, from the scattered gold of preglacial placers, or from preglacial gold-bearing gravels which were not removed by ice erosion. In most places the postglacial erosion of bedrock has been too little to concentrate gold in sufficient quantities to form workable placers, although such a concentration seems to have taken place on Big Eldorado Creek.

In the Chisana district most of the stream placers have been formed by a concentration of gold derived originally from veins in the Carboniferous rocks near intrusive masses, somewhat concentrated in Tertiary gravel deposits, and later reconcentrated by streams before the last great period of glaciation. The glaciers scattered the stream concentrations of gold, but the postglacial streams have accomplished a later concentration into the deposits now being mined. This rather complicated chain of events may or may not have been duplicated in other parts of this general region, and therein lies the difficulty of stating the likelihood of other placer localities being discovered.

In a general way the conditions are promising. Between Nabesna River and the international boundary there are many places where granitic intrusive masses cut the Carboniferous sedimentary and volcanic rocks, and the borders of such intrusive masses deserve careful prospecting. If in such places bodies of unconsolidated Tertiary gravels are found, the streams draining the gravels should be prospected with care. Absence of severe glacial erosion would increase the probabilities of finding concentrations of placer gold.

GOLD LODES.

For many years the existence of low-grade gold lode deposits in this region has been known. In 1906 a small stamp mill was erected at a gold lode on Jacksina Creek, a tributary of Nabesna River, and 60 tons of ore crushed in this mill is reported to have yielded $12 a ton in free gold. This marks the most serious effort to develop a gold lode property in the region, but other lodes have been staked, and varying amounts of excavation have been done on them. As a result of the gold placer stampede in 1902 from Dawson into the basin of Beaver Creek near the international boundary, a large number of gold lode claims were staked in that general district. These claims, situated on Beaver Creek near the boundary and on Eureka and Fourmile creeks, have already been described elsewhere,[1] and little development work has since been done on them. On Chathenda Creek at the mouth of Bonanza Creek a mineralized dike, known to contain some free gold, has been staked a number of times within the last eight years, but no serious attempts to prospect it have been made. The discovery of the rich placer deposits in 1913 naturally stimulated the search for the gold lodes from which the placers were derived, and a considerable number of gold lode claims have been staked in the district surrounding the placer mines. At the mouth of Bonanza Creek the mineralized area, which was first staked several years ago, was prospected by two tunnels each only a few feet long. For a distance of several hundred feet along Bonanza Creek the walls of the rock canyon are composed of an intrusive rock, from pink to gray in color, mottled with phenocrysts of darker minerals and containing abundant pyrite, the whole being oxidized on the surface to a rusty red color. There are in places bunches composed almost entirely of pyrite, and some small quartz veins cut the mass. The dike cuts Carboniferous lavas and pyroclastic rocks and apparently strikes N. 20° W. and dips about 75° N. The quartz veinlets are said to carry several ounces of gold to the ton, and the whole dike is reported to be auriferous. It is said that free gold can be panned

[1] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, pp. 58–60, 1910.

from the oxidized and decayed surface portion of the outcrop. No assay reports of the gold content were available, and too little work had been done to determine the average gold tenor of the dike, the location of the ore shoots, or the extent of the auriferous portion of the dike.

In the canyon of Chathenda Creek, about halfway between the mouth of Dry Gulch and Bonanza Creek, there is a zone of mineralization in the Carboniferous rocks and the diorites which intrude them. This mineralized belt strikes approximately N. 65° W. and dips 78° SW., and a large group of claims has been staked upon it, extending from the canyon of Chathenda Creek up the mountain to the north. Two tunnels 10 and 15 feet long have been driven in a steep gully that joins the canyon, and several open cuts have been made. As shown by these disconnected openings, there is a belt, in places 10 feet wide, of rusty mineralized country rock, cut by some small quartz veins which carry sulphides and are stained by green copper carbonate. It is reported that assays taken from the quartz veins have yielded as much as $200 to the ton in gold. Other claims, supposedly on the continuation of this mineralized zone, have been staked on both sides of upper Dry Gulch.

Some quartz claims have also been staked on Canyon Creek about three-fourths of a mile above its mouth, but no development work had been done there at the time of visit, in August, 1914.

COPPER

GENERAL CONDITIONS OF OCCURRENCE.

The attention of prospectors was first called to the Chisana-White River region by the reports current among the natives that great quantities of native copper were to be found there. The earliest explorations by white men failed to corroborate the extravagant native reports, but they did establish the fact that copper was present in encouraging amounts, and as a result of the influx of prospectors into interior Alaska, stimulated by the Klondike gold discovery, there has been more or less constant prospecting in this district. By 1908 most of the promising discoveries that are now known had been made, and during that year practically all of the important claims were visited by Moffit and Knopf and were described by them.[1] Since the publication of their report little more development work than that legally required has been done on most of the claims, and practically nothing has been done on several groups of patented claims. The published descriptions of Moffit and Knopf are therefore still applicable to most of the claims described, and the facts given below

[1] Op. cit., pp. 52–60.

were for the most part collected by them, with such additional information as was procured by the writer in 1914. In discussing the general conditions of occurrence of copper they state:

Prospecting in search of these deposits has shown that copper in its bedrock sources is widely distributed in the form of sulphides (chalcocite, bornite, and chalcopyrite), and on the basis of the facts revealed by the little development work that has been done it may be stated that most of the native copper found in the region is an oxidation product of those sulphides. Some primary native copper, however, has undoubtedly been discovered. In mode of occurrence the copper ore shows two different habits, geologically distinct. In one, so far the better known, it occurs associated with the Carboniferous basaltic amygdaloids; in the other it is found in limestone at or near the contact with the dioritic intrusives.

Native copper occurs as nuggets in the gravels of many of the streams, and green-coated lumps of the metal up to 5 pounds or more in weight are occasionally found in the wash of creeks draining areas of amygdaloidal bedrock. This stream copper was the source from which the Indians obtained their supply when it was an object of barter among them. From the accounts of Hayes and Brooks, Kletsan Creek appears to have been the placer locality best known to the natives.

Metallic copper occurs also in the surface croppings of sulphide deposits in the amygdaloids, where it is undoubtedly an oxidation product of the sulphides that appear in depth. In such places it is directly associated with the dark-red oxide (cuprite) and more or less green carbonate. At the prospect known as "Discovery," on White River in Canadian territory a few miles below the international boundary, a slab of native copper averaging 8 by 4 feet by 4 inches thick and weighing nearly 6,000 pounds has been uncovered in the slide rock. A number of other sheets of copper, some of them weighing several hundred pounds, have been found in the near vicinity. On account of the stimulus that this find has exerted on the prospecting of the adjacent American territory the occurrence merits some description in this report. Stripping of the bedrock near the great nugget has exposed a face of green basaltic amygdaloid 20 feet high and 15 feet wide, and shows that the rock is traversed by numerous seams of native copper along fractures and slickensides. Toward the bottom of the open cut stringers of chalcocite begin to appear. About 150 feet from this prospect an opening on another but independent occurrence shows stringers of cuprite with admixed copper, stringers of glance and calcite, and chalcopyrite disseminated through the amygdaloid country rock. From these features it is clear that the metallic copper of this deposit is a superficial oxidation product of sulphides, that its downward extension is small, and that the prevailing sulphide at greater depth will probably turn out to be chalcopyrite.

At a few localities native copper is associated with certain highly amygdaloidal portions of the Carboniferous basalts and intergrown with the white minerals that fill the former steam cavities in the ancient lava flows. Slaggy-looking portions produced by the weathering and removal of the amygdules from the lava and amygdaloid that is cut by small irregular veinlets filled with the same minerals as those forming the amygdules appear to be the most favorable places for metallic copper. The copper in the vesicles and stringers is associated with calcite and delicately spherulitic prehnite, but in some of the veinlets calcite, prehnite, quartz, a black lacquer-like mineral, partly combustible, and chalcocite, instead of metallic copper, are associated together.

At a number of places throughout the region narrow stringers of chalcocite cutting the ancient basalts are encountered, but so far as known they have no great persistence. Near the head of Cross Creek, locally known as Copper Creek, a thin quartz-chalcopyrite vein cutting the bedded volcanics has been discovered. At other localities some irregularly disseminated sulphides, in some places chalcocite, in others bornite, occur in the basalts, but these do not appear to be connected with definite vein or lode systems and are consequently of an unencouraging character. Oxidation of these sulphides and disintegration of the containing rock give rise to the nuggets of cuprite and native copper that are found in the talus slopes at several localities in the region.

In contrast to these occurrences, which, as shown by the foregoing discussion, are limited to the ancient basalt flows, copper is found as bornite and as chalcopyrite intergrown with contact-metamorphic rock in limestone adjoining diorite intrusives. In deposits of this type the ore mineral is associated with garnet, coarsely crystalline calcite, epidote, specular hematite, and scattered flakes of molybdenite. The garnet is commonly crystallized in dodecahedrons and is intimately intergrown with bornite and chalcopyrite. On account of its weight, and especially its appearance, which is not unlike that of cassiterite, it was mistaken for tin ore by some of the early prospectors. Only two deposits of this character were seen in place, but evidences of energetic contact metamorphism were detected at a number of other localities. An extensive contact zone has been produced along the junction of the diorite and the massive limestone exposed on the ridge west of Cooper Pass. Various contact-metamorphic rocks, pyritiferous as a rule, are present in this zone, and these rocks on oxidation give rise to large iron-stained outcrops that contrast strongly with the surrounding white limestone. In connection with the discussion of the contact-metamorphic deposits it may be stated that the writers were shown some specimens of copper ore containing abundant large octahedrons of magnetite and blebs of chalcopyrite in a gangue of coarse calc spar. This ore was undoubtedly obtained near the contact of an intrusive diorite with limestone, but whether commercially valuable ore bodies of similar character exist in this region, which is so remote from transportation facilities, is yet to be demonstrated, in view of the fact that copper deposits of contact-metamorphic origin are characteristically bunchy and of low grade.

COPPER IN WHITE RIVER BASIN.

In the White River basin a number of groups of claims have been prospected more or less continually for a series of years. As it was reported that nothing of especial interest had been developed on most of these prospects since they were examined in 1908, and as the writer's time was fully occupied by studies in other unsurveyed parts of the district, many of the claims were not revisited in 1914. The following descriptions are therefore largely quoted from the report by Moffit and Knopf, with such additional data concerning later developments as could be obtained:

At the head of the Middle Fork of White River, a large tributary entering from the west 5 miles below the head of the main stream, some claims have been staked on outcrops of rock carrying native copper. Two small open cuts 1,450 feet above the stream were seen on the Copper King claim. The country rock at this locality consists of stratiform basalts of Carboniferous age intercalated with beds of breccia and brick-red tuffs, striking N. 85° E. (magnetic) and dipping 18° into the mountain. Native copper is apparently limited in its occurrence to a certain definite volcanic sheet—a reddish lava that is locally amygdaloidal to a high degree. For 200 feet along the outcrop of this sheet metallic copper intergrown with prehnite, calcite, and zeolites can be found here and there in encouraging amounts. The cupriferous portion of the amygdaloid appears to be about 6 feet thick, but as almost no development work has been done on the property figures of this kind have little value. The copper occurs as irregular reticulating masses of metal several inches long and as small lumps and minute particles embedded in the minerals that fill or line the former vesicles in the lava flow. In places these minerals either ramify in small veinlets through the body of the rock surrounding the amygdules or form irregular masses, and such places are eminently favorable for metallic copper.

This is the only deposit seen during the summer in which the native copper appears to be of undoubted primary origin. If the ore on the surface has any downward extension, a fact that can be established only by actual explorations, it can be predicted with a high degree of confidence that the metallic copper also will persist downward. To this extent the surface indications are distinctly favorable. Some doubt as to the probable amount of ore may perhaps be entertained, in view of the character of the deposit. Native copper associated with zeolites filling amygdules in basaltic lavas is found throughout the world in widely separated localities — the Faroe Islands; the trans-Baikal region, Brazil, Queensland, and Lake Superior—yet only the Lake Superior region has yielded ore bodies of commercial value.

Since the above was written it has been reported that two tunnels a short distance apart, each about 30 feet long, have been driven on the copper-bearing lava sheet, and that the conditions found underground are much the same as had already been observed from the surface croppings.

Assessment work is reported to have been done for several years on a group of claims high on the mountain side south of the Middle Fork of White River, about halfway between its source and its mouth. No one was present on this ground at the time of the writer's visit and the claims were not seen.

On the west side of White River near its head a number of claims have been patented, and no development work has been done on them for some time. The conditions there were described by Moffit and Knopf[1] as follows:

Near the head of White River the same Carboniferous volcanics form the west wall of the valley. They consist of basaltic tuffs, breccias, amygdaloids, and porphyritic sheets, dipping 10° N. The colors of the lavas are dark red-brown and greens. A number of prospects have been located on chalcocite croppings a few miles below the edge of the moraine of Russell Glacier. In the main these outcrops consist of chalcocite. At one prospect a thin glance stringer, an inch or so thick, cuts vertically across the nearly horizontal volcanics. It is adjoined by sheared amygdaloid walls, and veinlets of white earthy material ramify through the adjacent rock to great distances. A few hundred feet below this locality, on what is thought to be the same vein, is another open cut on a glance stringer about 3 inches wide, largely solid sul-

[1] Op. cit., p. 57.

phide, which is intergrown to some extent with a zeolite mineral of a specific gravity of 2.27, probably laumontite. The cliff above the cutting shows that the stringer pinches out vertically within 6 feet.

A group of claims adjoining the prospects just described has been staked and surveyed for patent. This group, the property of the Skolai Mining Co., consists of seven claims lying on the south side of a small gulch 1½ miles south of the Middle Fork of White River at an elevation of about 2,000 feet above the White River flat. The principal opening on this group is an open cut 18 feet long on the bottom and about 20 feet high at the face. The face shows small bunches and thin leaf-like reticulating veins of calcite and malachite, with scattered stains of copper carbonates, in a purple amygdaloidal lava flow. The rock shows slickensides, and the mineralization is in a zone of disturbance, though no well-developed vein system could be made out. On the other claims of the group there are shallow open cuts in which little mineralization is evident. The copper mineralization on this mountain is largely confined to a certain reddish bed of amygdaloidal lava, but so far as was observed there is nowhere any great concentration of copper. Copper "float" is abundant on the talus slides, particularly malachite-stained rock fragments, and one piece of greenish amygdaloid bearing a 2-inch vein of chalcocite was seen.

On Wiley Creek, a tributary of White River from the east, opposite the terminus of Russell Glacier, a group of eight claims held by the Skolai Mining Co. has been surveyed for patent. The claims lie about 2½ miles above the mouth of the stream, on the north wall of the valley. They are developed by a few shallow openings, the largest of which, 500 feet above Wiley Creek, is an open cut 12 feet long, with an excavation at the breast 3 feet under cover. The rock is an amygdaloidal lava of gray-green color, much altered and shattered, and includes small bunches and lenticular masses of shale half an inch to 2 inches thick. The shaly portions carry sulphides, mainly arsenopyrite. Small stringers of chalcocite are reported but were not seen. The Carboniferous lavas and pyroclastic rocks are in this vicinity associated with large amounts of shale and thin-bedded limestone and are cut by light-colored dikes.

Assessment work is reported to have been conducted each year on claims situated on Moraine Creek, which were described by Moffit and Knopf[1] as follows:

On Moraine Creek, a small stream in a glacier-filled valley on the east side of Russell Glacier, a number of claims were staked during 1907 and 1908. The bedrock here also consists of green and reddish amygdaloids with associated breccias striking N. 85° W. (magnetic) but dipping 55° S., an

[1] Op. cit., p. 56.

angle considerably steeper than on Middle Fork. In some places the upper portion of a lava sheet is more highly amygdaloidal than the rest of the flow. Malachite-stained fragments of rock can readily be found in the talus slopes. Copper occurs in place in small seams cutting the amygdaloid, the veinlets consisting of finely developed spherules of prehnite intergrown with calcite and flecked with red metal and chalcocite. Thin sections show small, clean grains of copper embedded in both prehnite and calcite; some chalcocite occurs similarly. A small amount of native copper is associated with a little hydrated iron oxide, and this copper may have been derived from the reduction of the chalcocite.

The amygdaloids are also traversed by small drusy stringers composed of quartz and prehnite and containing chalcocite and a black combustible mineral. At another point on Moraine Creek the lava, besides containing white amygdules of zeolite, carries irregular blebs of chalcocite, which give the rock somewhat the appearance of a glance-bearing amygdaloid. Such development work as has been done on Moraine Creek indicates that the amygdaloidal phases of the basalts here, too, are the most favorable and are likely to be found along the contacts of successive lava flows. As the superimposed sheets of lava commonly differ in color and texture the contacts can easily be located.

On Sheep Creek, a tributary of White River from the south between the mouths of Solo Creek and the North Fork of White River, a number of claims have been staked and some development work has been done. At the time of visit no one was to be found on the property, and it is possible that all the workings were not seen. The principal opening seen, a tunnel at an elevation of about 5,500 feet, was caved in and could not be examined, although from the size of the dump it is evident that considerable work has been done. At the portal the rock is a purple amygdaloidal lava, containing amygdules of calcite, probably zeolite, and a dark sulphide, apparently chalcocite, with a coating of copper carbonate. Cuprite and native copper have been reported from this valley.

An attempt was made to visit the copper deposits of upper Kletsan Creek, but a heavy fall of snow early in June prevented an examination of many localities of interest. No development work has been done in that valley for a number of years, and the interest in the copper deposits is largely historic, as it was from placer copper taken from the gravels of Kletsan Creek that the natives long ago obtained their supply of the metal. The gravels richest in placer copper are said to lie on the Canadian side of the boundary, within a few miles of Natazhat Glacier, in which Kletsan Creek heads. In 1902 an attempt was made to ascertain the copper content of the stream gravels. Some placer copper was recovered, but the amount was not considered sufficient to justify mining under the adverse conditions prevailing there. In 1914 a considerable amount of copper, probably that obtained in 1902, was seen at a cabin on upper Kletsan Creek. The nuggets varied in size from fine, shotlike particles and larger pieces weighing a pound or more to one large mass of metal having an estimated weight of between 75 and 100 pounds. At the same place there were many specimens of massive chalcocite, said to have come from a vein in a tributary valley 3 miles southwest of the cabin.

LIGNITE.

A formation consisting of conglomerates, sandstones, and shales, with some tuffaceous beds, all probably of Tertiary age, occurs at a few localities within this region and as shown by the structure and position of the beds was probably at one time much more widely distributed than at present. There is also a strong probability that other isolated patches of these same rocks occur within the area here discussed, but they have not been seen in the hasty reconnaissance work which has so far been done. These Tertiary rocks in places contain lignite, which occurs in thin carbonaceous layers and more rarely in beds of greater thickness.

On Coal Creek, a tributary of Rocker Creek near the international boundary, some development work has been done on a lignite bed. A tunnel, said to be 30 feet long but now caved in, has been driven on a lignite cropping in a small gulch. The lignite strikes N. 50° E. and dips 68° NW. As exposed in the gulch outside of the tunnel it occurs in two beds, one 3 feet and the other 1 foot thick, separated by a 1-foot clay parting. The lignite is clean and bright but rather friable and is said to burn readily and to be of sufficiently good grade to use in a forge for welding. A small amount has been mined and used by prospectors in this district, as this is the only known occurrence of workable coal or lignite in a large region where the demand for such fuel is considerable. The lignite is interbedded with greenish sands and conglomerates, but the whole outcrop of this formation is of small area, being surrounded by intrusive rocks, and the amount of lignite at this place is probably not large.

At a point 1½ miles west of Ptarmigan Creek, 2 miles above its junction with Beaver Creek, there is a small area of Tertiary rocks reported to contain some lignite. The lignite is said to strike approximately north and dip steeply to the east and to be of rather poor quality.

The Tertiary conglomerates and sandstones crop out along the east side of the low pass between Chathenda Creek and Beaver Lake, but no lignite was seen there. Along Chathenda Creek below the mouth of Dry Gulch and in the basin of Rhyolite Creek there is an area of Tertiary sandstones and conglomerates, with agglomerates and tuffs, locally containing a good deal of carbonaceous material. Several prospect holes on Chathenda Creek show lignite on the dumps, although the lignite could not be seen in place. At the first forks of Rhyolite Creek above its mouth a bluff shows carbonaceous shale and sandstone with beds of lignite an inch or two in thickness, but no workable coal has been found.

Lignite is reported from the north side of the Nutzotin Range on a tributary of Beaver Creek. The locality is 7 miles west of the international boundary and about 1 mile south of the mountain front, and the outcrop is on a stream bluff. The area of Tertiary rocks at this place is not known, but the lignite is reported to form a bed about 8 feet thick, striking nearly east and dipping steeply to the south. It is said to be of fair grade and to burn readily.

INDEX.

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