DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 498

HEADWATER REGIONS OF GULKANA AND SUSITNA RIVERS ALASKA

WITH ACCOUNTS OF THE VALDEZ CREEK AND CHISTOCHINA PLACER DISTRICTS

BY

FRED H. MOFFIT

WASHINGTON

GOVERNMENT PRINTING OFFICE

1912

CONTENTS.

	Page.
Preface, by Alfred H. Brooks	7
Introduction	9
Geography	11
Location and area	11
Topography	12
Relief	12
Drainage	13
Climate	15
Vegetation	16
Population	18
Trails and transportation	19
General geology	21
Stratigraphy	21
Introduction	21
Gulkana and Susitna river region	21
Chistochina district	23
Pre-Ordovician (?) rocks	24
Birch Creek schist	24
Age	26
Probable pre-Carboniferous sedimentary rocks	26
Distribution and character	26
Age	26
Carboniferous rocks	27
Sedimentary deposits	27
Character and distribution	27
Age and correlation	28
Basic lavas and tuffs	29
Character and distribution	29
Age	29
Triassic rocks	31
Character and distribution	31
Age and correlation	33
Jurassic (?) rocks	33
Character and distribution	33
Age of the diorite intrusives	35
Tertiary rocks	35
Character and distribution	35
Age and correlation	38
Quaternary deposits	39
Deposition	39
Glacial deposits	39
Stream and lake gravels	41
Structure	45

	Page.
Historical geology	47
Early geologic history	47
Later geologic history	49
Topographic development	49
Glaciation	51
Economic geology	53
Gold	53
Valdez Creek district	53
History and production	53
Source of the gold	55
Lode deposits	56
Placer deposits	57
Distribution	57
Valdez Creek proper	57
Lucky Gulch	63
White and Rusty creeks	64
Timberline Creek	65
Delta River district	65
Conditions affecting mining	66
Suggestions	68
Coal	69
Chistochina district	70
Introduction	70
Geography and drainage	70
History	71
Trails	71
Mail and telegraph facilities	72
Gold placers	72
Output	72
Detailed descriptions	72
Miller Gulch	72
Slate Creek	73
Big Four claims	74
Ruby Creek	75
Chisna River	75
Lime Creek	78
Origin of the gold	78
Influence of glaciation	79
Economic conditions	79
Index	81

ILLUSTRATIONS.

Page.

PLATE I. Topographic reconnaissance map of the region between the headwaters of Susitna and Gulkana rivers ... In pocket.

II. Geologic reconnaissance map of the region between the headwaters of Susitna and Gulkana rivers ... In pocket.

III. Geologic reconnaissance map of a part of the central Copper River region ... In pocket.

IV. *A*, Landslide on northern tributary of Eureka Creek; *B*, Conglomerate associated with Triassic sediments between Roosevelt Lakes and Big Clearwater Creek ... 32

V. *A*, Basalt Mountains on the south side of Windy Creek; *B*, Upper valleys of White and Big Rusty creeks ... 40

VI. *A*, Rock glacier on Big Rusty Creek; *B*, "Soil flows" at the head of Valdez Creek ... 44

VII. *A*, View across Gulkana Glacier from the west side, showing a type of Alaska Range topography; *B*, Topography of lower Valdez Creek from the north ... 52

VIII. *A*, Bowlder deposits on Valdez Creek; *B*, Wing dam in canyon on creek claim adjoining the "Tammany bench," Valdez Creek ... 58

IX. *A*, Tertiary conglomerate and sands on a tributary of Phelan Creek; *B*, The Monahan tunnel and second creek claim above Discovery on Valdez Creek ... 60

X. *A*, Gold nuggets from Lucky Gulch; *B*, Boomer and dam on Rusty Creek ... 62

FIGURE 1. Outline map of a part of southern Alaska, showing the area represented by Plates I and III ... 11

2. Section of Pleistocene on Klawasi River ... 42

3. Section of Pleistocene on Klutina River, 6 miles above Copper Center ... 43

4. Section of Pleistocene on west bank of Copper River ... 43

5. Structure of the Alaska Range in the vicinity of Chistochina River ... 46

6. Structure of the Alaska Range in the vicinity of Delta River ... 46

7. Relations of present and Eocene land surfaces in the Copper River valley ... 50

8. Sketch map of part of Valdez Creek, showing location of producing claims ... 59

9. Relations of the old canyon of the Tammany bench claim to the present channel of Valdez Creek ... 61

PREFACE.

By Alfred H. Brooks.

Systematic geologic and topographic reconnaissance surveys of Alaska were begun in 1898 and have now (1911) been carried over about one-fifth of the Territory. The first few years were largely devoted to exploration, the areal surveys being limited to the regions adjacent to the routes of travel. Later, areal surveys were made of the more important mining districts, and by 1910 geologic and topographic reconnaissance maps had been completed of most of the districts that had made any considerable contribution to the annual mineral output of Alaska. In addition to this, detailed maps had been made of several of the best-developed mining camps, such as Juneau, Fairbanks, and Nome. This progress made it possible in 1910 to extend the surveys into new fields and thus to cover some of the less important mining districts.

As a result, the survey was undertaken of the area here described, which, prior to 1910, had been known only through the journeys of the indefatigable prospectors. One of the chief purposes of this survey was to map and investigate the Valdez Creek placer district, which has been producing gold for a number of years.

The geologists, F. H. Moffit and B. L. Johnson, and the topographers, D. C. Witherspoon and C. E. Giffin, results of whose surveys are here published, deserve great credit for the work accomplished. In a season comprising only 74 days the two topographers surveyed an area of 4,980 square miles and the two geologists mapped about 2,000 square miles besides making a somewhat detailed study of the Chistochina and Valdez Creek placers. The geology of the Chistochina region was investigated by W. C. Mendenhall in 1902, and the results of his investigations were published,[1] but as a part of that district lies in the same geologic province with Valdez Creek and was reexamined by the Moffit party it was decided to include a summary of Mendenhall's report in this volume.

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1904.

Among the important geologic discoveries here set forth is the occurrence of Triassic sediments in this part of Alaska. They are locally metamorphosed by the great belt of intrusive rocks that bound them on the north. The auriferous gravels of Valdez Creek are derived from Triassic sediments, and those of the Chistochina region from Carboniferous sediments. In both districts the mineralization is genetically related to granitic intrusives, and, as in other parts of Alaska, the gold-bearing veins seem to occur chiefly outside the zone metamorphosed by the intrusives. Igneous intrusion is common in this province, and it seems probable that the conditions favorable to the occurrence of gold may be repeated elsewhere than in the districts in which placers have already been developed.

HEADWATER REGIONS OF GULKANA AND SUSITNA RIVERS, ALASKA, WITH ACCOUNTS OF THE VALDEZ CREEK AND CHISTOCHINA PLACER DISTRICTS.

By Fred H. Moffit.

INTRODUCTION.

The purpose of this paper is to describe the geology and mineral resources of an area between the upper parts of Susitna and Gulkana rivers. The work on which the description is based was wholly reconnaissance in character and was not sufficiently careful or extensive to permit accurate mapping of formation boundaries in many places nor to determine fully the structural and stratigraphic relationships between the various rock masses referred to here.

The lateness of the spring and the time consumed in traveling to and from the field of work at the beginning and the end of the summer reduced the time available for geologic work during the open season of 1910 to 59 days, of which a week was spent in visiting the Chistochina gold-placer district, leaving only 52 days for studying the region west of the Gulkana. The geologic work was part of a larger plan that included topographic as well as geologic mapping, with the object of extending westward the surveys begun by T. G. Gerdine and W. C. Mendenhall in the upper Copper River valley in 1902. This work, the first done by the United States Geological Survey in the headwater region of Susitna River, was undertaken primarily because of the importance of the Valdez Creek gold-placer district and the numerous requests that have been made for information about it.

The topographic mapping was in charge of D. C. Witherspoon, who was assisted by C. E. Giffin. Their surveys are embodied in the topographic map published with this report (Pl. I, in pocket) and form the base for the geologic map that accompanies it. The geologic map (Pl. II, in pocket) represents the work of B. L. Johnson and the writer. Mr. Johnson was associated with the writer in the field studies and prepared the office drawings of the geologic map. These maps, together with those surveyed by J. W. Bagley and S. R. Capps[1]

[1] Capps, S. R., The Bonnifield region: Bull. U. S. Geol. Survey No. 501, 1912.

in this same year (1910), give a complete section across the Alaska Range.

Although the investigations were carried on in a district that had not been previously described, reference should be made to earlier work in adjacent districts both to the east and to the west. The earlier investigations were begun in 1898, when G. H. Eldridge[1] and Robert Muldrow, of the United States Geological Survey, ascended the Susitna to Indian Creek, where they left the main river and made their way north into the Alaska Range as far as Yanert Fork of Nenana River. Their trail along Jack River brought them to a point within 30 miles of the head of Susitna River and directly west of it. This trip was made under great difficulties, owing to unfavorable weather conditions, failure of supplies, and inexperience in Alaska work, but it yielded the only information yet secured concerning the geology of the district between Susitna River and the Nenana.

In the same year (1898) W. C. Mendenhall,[2] of the United States Geological Survey, who was attached to a military expedition under Capt. Glenn, crossed the Copper River lowlands from Matanuska River to Delta River and descended the latter stream to a point less than 10 miles from Tanana River. The route followed by this expedition was from Matanuska River, at Hicks Creek, in a general northeasternly direction past the east end of Lake Louise, one of the large Susitna lakes, to the Tangle Lakes. Two large branches of Gulkana River were crossed between Lake Louise and the Tangle Lakes and were supposed at that time to be the Gakona and Chistochina rivers represented on Lieut. Allen's map. From the Tangle Lakes country the route led down the east bank of Delta River as far as Jarvis Creek, at which point the greater part of the expedition turned back because of failing supplies.

The surveys of 1902 differed in character from the two exploratory expeditions just referred to. In that year T. G. Gerdine and W. C. Mendenhall[3] made a reconnoissance topographic and geologic map of a large area, including the central Copper River district and the south slope of the Alaska Range from Delta River to a point within a few miles of Mentasta Pass. Their work will be referred to later in this report.

Reports of minor scouting trips made to their superior officers by members of the two military expeditions in charge of Capts. Glenn and Abercrombie, in 1898, are contained in the reports of these two officers to the War Department.

---

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

[2] Mendenhall, W. C., A reconnaissance from Resurrection Bay to Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 271–340.

[3] Mendenhall, W. C., and Schrader, Frank C., The mineral resources of the Mount Wrangell district, Alaska: Prof. Paper U. S. Geol. Survey No. 15, 1903. Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905.

The writer wishes to express his appreciation of the kindness shown to himself and to members of his party by the miners of Valdez Creek. They are too many to mention individually, but he is particularly indebted to Mr. Peter Monahan, Mr. William Grogg, and Mr. Clark Duff for information about the history of mining on Valdez Creek and for many facts concerning its gold placers that he would not have obtained except for their interest in the work. The writer is also greatly indebted to Mr. B. L. Johnson for many suggestions and for much valuable aid in the preparation of this paper.

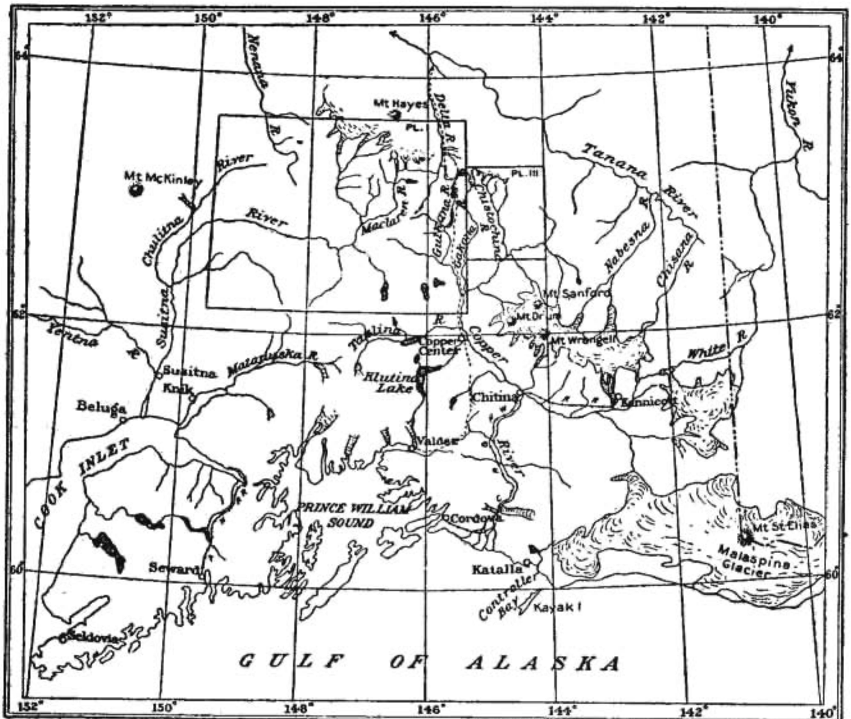


FIGURE 1.—Outline map of a part of southern Alaska, showing the area represented by Plates I and III (in pocket).

GEOGRAPHY.

LOCATION AND AREA.

The district under consideration lies south of the Alaska Range and includes parts of the drainage basins of Copper River, Susitna River, and Tanana River. It is included within meridians 145° 20′ and 147° 40′ west longitude and parallels 62° 20′ and 63° 40′ north latitude. Approximately 5,000 square miles of the quadrangle thus defined was surveyed in 1910 and is represented on the topographic map (Pl. I, in pocket). The location of this quadrangle is shown on the outline map of southern Alaska (fig. 1).

Gulkana, on the military road from Valdez to Fairbanks, is just within the southern boundary of the area mapped, and at the present time is the point of entry for the district. The mapped area extends from the latitude of Gulkana north to the summit of the Alaska Range. Gulkana River and Susitna River mark its eastern and its western limits.

TOPOGRAPHY.

RELIEF.

The topographic map represents a district whose northern border is made up of high, rugged mountains (Pl. VII, *A*, p. 52), most of which are well above snow line, and consequently form a gathering place for snows and ice that supply scores of glaciers and give rise to hundreds of streams. The axis of the Alaska Range, within the limits of the map, runs west-northwest from the mountains at the head of Gulkana Glacier through Mount Hayes to Cathedral Mountain, near the western border of the map, where it swings to the west, and finally to the southwest, beyond Nenana River, toward Mount McKinley.

South of the high, snowy mountains that here form the backbone of the Alaska Range is a parallel range, scarcely separated from the main range west of Maclaren River, but entirely distinct to the east. The mountains composing this parallel range are also rugged, but their peaks are not so high as those on the north, and the snow fields and glaciers are absent or are too small to be considered. Like the main range on the north, the trend of these mountains changes from west-northwest to west from Delta River and becomes southwest beyond Susitna River. Still farther south is a third parallel ridge with an east-west trend, made up of low rounded hills. This ridge is separated from the higher one on the north by a broad depression and merges on the south into the lake-dotted flats of the Copper River lowland. Thus, within a distance of 50 miles from north to south, the remarkably rugged topographic forms of the snow-covered Alaska Range change to the monotonous level of the great interior basin of Copper River and the upper Susitna.

The difference in relief between the highest and the lowest points within the district is approximately 12,000 feet; Gulkana is 1,300 feet above the sea; and Mount Hayes, the highest peak in this part of the Alaska Range, is almost 14,000 feet above sea level. Susitna River, at the mouth of the Maclaren, is approximately 2,400 feet above the sea. In a very general way it may be said that the elevation of the main part of the Alaska Range from Delta River to Mount Hayes ranges from 7,000 to nearly 14,000 feet above sea level; the average elevation of the next range to the south is about 6,000 feet; and that of the third and lowest range about 5,000 feet above sea level, or only 3,000 feet above the lowlands of the Copper and the Susitna. Such figures, of course, are not intended to be accurate, but they serve to give a better idea of the relief of the region than would be gained without careful study of the topographic map.

The topography of the northern half of the mapped area everywhere gives evidence of the effects of intense and recent glacial activity. This is shown most plainly in the rugged mountain areas by the forms of the valleys and in the more open country flanking the mountains by morainic deposits. Farther south the evidences of glaciation are not so marked, but the broad gravel plains with their hundreds of lakelets and their acres of marshy ground are doubtless closely connected in origin with the invasion and retreat of the ice.

Topographic forms in the southern half of the mapped area present a marked contrast to those of the northern half. The hills and mountains rise from a basement lowland where flat or rolling country predominates. A few prominent isolated mountains, like the one north of the lower part of Maclaren River, together with the ridge south of it, appear to belong to an older topography than the high country to the north. Angular outlines have been replaced by smooth, rounded contours, and in many places flat-topped and terraced hills are prominent features of the sky line.

The lowland area possesses little relief. Low gravel ridges are scattered over it and the streams have intrenched themselves in its surface, but these features are so slight as to attract little attention when seen from the bordering hills. From the vicinity of Lake Louise the lowland slopes gently toward Susitna River on the west and toward Copper River on the east. Copper River and the lower parts of its tributary streams have incised their channels several hundred feet below the general surface. Susitna River, on the other hand, in that part of its course represented on the map, has not been able to depress its channel much below the level of the adjacent gravel plains and shows no such gravel bluffs as those present along Copper River. The central part of the lowland seems as yet scarcely to have been affected by stream erosion.

DRAINAGE.

The district extending west from Gulkana River to Susitna River on the south side of the Alaska Range belongs to three main drainage systems—those of Copper, Susitna, and Tanana rivers. The eastern half of the district is drained by Delta and Gulkana rivers and the western half by Susitna and Nenana rivers and their tributaries. Both Delta River and Nenana River belong to the Tanana drainage basin, for although they originate on the south side of the Alaska Range, they cut through it and flow into Tanana River. Delta River drains approximately one-fifth of the eastern half of the district;

Nenana River only a few square miles in the northwest corner of the western half. Most of the Susitna drainage is from the glaciers and snow fields of the high mountains; most of the Gulkana drainage is from the lowlands; but that of the Delta is derived in about equal amounts from the glacier waters of Eureka and Phelan creeks and the clear-water streams of the intermediate range and the Tangle Lakes region.

Gulkana River heads in Gulkana Glacier, but receives most of its water from two branches that rise in the lake country on the west. It is a clear-water stream below Gulkana Lake, because Summit Lake and Gulkana Lake act as settling tanks for the silt-laden water from the glacier. Moreover, for a year or two most of the glacier water has been diverted to Phelan Creek and thence to Delta River, so that only a very small part reaches the Gulkana. These conditions were reversed a few years ago, and doubtless will be again, for the river swings back and forth across the gravel bars as the débris from the glacier accumulates along the channel.

Three streams, fed by the melting ice of three large glaciers, unite to form the head of Susitna River. The water from this source is augmented by a number of smaller clear-water streams, including Boulder Creek, Valdez Creek, Windy Creek, and Clearwater Creek, and by a large glacial stream, Maclaren River. The part of Susitna River shown on the map flows over a broad gravel plain, but just west of the mapped area it makes a great bend to the right and flows westward for nearly 75 miles in a succession of rapids and smooth-water stretches through a narrow, mountain-inclosed valley.

The northern or high-mountain part of the district under consideration has a well-developed drainage system. Lakes are few, but streams are many and vigorous. The quantity of water in the run-off, like that of all glacier districts, depends on the season of the year, local weather conditions, and the time of day; in other words, it depends largely on the amount of glacier ice melting, as well as on the rainfall.

The southern lowland district, on the other hand, including most of the Gulkana drainage and a part of the Susitna drainage not represented on the map, is poorly drained. It is a lake country with a great area of marshy land, crossed by a few deep, sluggish streams. From any elevated point around its border hundreds of small lakes can be seen, and a journey across the lowland in summer involves continuous effort to avoid wet ground. All these small lakes, as well as the Susitna lakes, including Lake Louise, which is drained by Tyone Creek, and the large unnamed lakes between Lake Louise and Gulkana River, owe their existence to the lack of a well-developed drainage system. The streams have not yet intrenched themselves deeply enough into the gravel plain to drain away the water that accumulates on its surface.

CLIMATE.

The climatic conditions of the upper Susitna and Copper River regions that are of most interest to miners and prospectors have to do with the length of the summer and winter seasons, the variations of temperature, the amount of precipitation, and the proportion of fair or stormy days. These conditions can be described here only in a general way, because no weather records are available for more comprehensive discussion.

For practical purposes the year may be regarded as made up of an open season—summer, and a closed season—winter. The length of these seasons differs slightly in the mountain and lowland districts, the summer being a little shorter and the winter a little longer in the mountains than in the open country. Mining is begun on the placer claims along Valdez Creek early in June. Those who have horses leave the creek by September 10, in order that they may reach the coast before grass fails. Others stay a few weeks longer and go out with dog teams on the first ice of November. From 90 to 100 days, therefore, are available for mining operations and the rest of the year may be said to be winter. Underground mining, of course, can be carried on through the whole year.

Ranges of temperature in this interior region are great. The mercury sometimes falls to 40° or 50° below zero on the coldest winter days and sometimes rises to 85° or more in summer. A temperature of 94° has been known at Copper Center. Most of the summer days, however, are comfortably cool, and many of the nights are cold.

Snow may fall on the higher mountain tops at any time of the year, but in summer precipitation in the valleys is in the form of rain. During the months of August and September rain in the valleys is nearly always accompanied by snow on the mountain tops, but such snow usually disappears within a few hours. A few inches of snow covered the valley of Valdez Creek on September 1, 1910, but doubtless soon melted. A heavy snow that remained till the following spring fell at Paxson on September 17, 1909. These early snows afford good traveling, because they are not deep enough to make trail breaking difficult.

The amount of rain and snow that falls on the south slope of the Alaska Range is considerable, yet much less than that along the Pacific Coast of Alaska. Valdez Creek is regarded as a rainy district by the miners, although the precipitation there is probably less than it is farther east. Rainfall seems to vary much with local conditions, so that marked differences are noticed in localities only short distances apart; for example, it was said that the number of cold wet days in the summer of 1910 was greater at Paxson, on the military road, than at Myers, only 16 miles south at the edge of the foothills.

The rainfall at Gulkana and other points in the lowland along the military road is decidedly less than in the mountains; the grass on the benches dries before the end of summer, and it is necessary to provide some means to irrigate gardens. The snowfall of the lowland is also light. Snows come first in the latter part of September or early in October and remain till May, depending on the elevation above sea level and the character of the season. The heavy snows come late in the winter, and the miners endeavor to land supplies and other freight at the mining camps before the snow gets deep enough to be a serious obstacle to travel.

A record of the weather conditions, kept by the writer in the summer of 1910, covers 72 days, from June 28 to September 7, inclusive, and shows 28 days that were called fine, 16 that were fair, 7 that were cloudy all day, and 21 on which it rained part or all of the day. The summer of 1910 was regarded by the miners of the district as an unusually favorable season in respect to weather conditions.

VEGETATION.

It is not the purpose of this report to describe the vegetation of this district further than to give the more general facts concerning the distribution of timber and the supply of grass for stock.

Spruce is the only wood of particular value in the area visited. Cottonwoods grow along the lowland streams, and willows along the streams that extend above the limits of spruce in the mountain areas, especially along the bars of the creeks; but spruce is the important timber, both in respect to economic value and to distribution. Timbered areas as described here are in general, therefore, areas of spruce, and the timber line is the upper limit of spruce.

If a line is drawn across the map (Pl. I, in pocket) in an east-west direction through the middle of Gulkana Lake, it will represent approximately the northern boundary of the timbered country. Nearly all the country to the south is timbered land, and most of the country to the north is without timber, but there are a number of important exceptions to this general condition. Spruce grows scatteringly along the Susitna River as far north as the glaciers at its head, and small areas along the river are heavily timbered. Small patches of spruce are found, too, on the upper part of Clearwater Creek, on Maclaren River, to a point a few miles above the mouth of the west fork, and around the Tangle Lakes. Timber is present on Delta River at Garrett's cabin, on Phelan Creek, on Delta River northward from Phelan Creek, and north along Gulkana River to within a mile or two of Summit Lake.

The timber line ranges from 2,500 to 3,000 feet above sea level. It is commonly not higher than 2,500 feet in the lower country south of the middle range of mountains, but it reaches 3,000 feet at the head of Susitna River. Spruce timber is heavy on the south slope of the mountains between the two big glaciers at the head of Susitna River up to an elevation of 3,000 feet above the sea. Good timber also grows about the lower end of Valdez Creek, extending south along the lower hill slopes beyond Windy Creek. This is a fortunate circumstance for the miners, for it furnishes them with lumber and firewood almost at their doors. Timberline Creek, which enters Valdez Creek from the south about 2 miles above the mouth of Valdez Creek, was so named because it marks the eastern limit of spruce timber in the Valdez Creek valley.

Most of the streams are bordered with willows to an elevation considerably above the timber line. These willows are of great value to the traveler, for they provide the only firewood available in many places within the mountain area. Small willows and a dwarf birch, usually called "buck brush" in this region, grow on the lower mountain slopes and on the tops of the lower hills; but they are of no value to the miner and in many places are a serious obstacle to travel. The birch is especially troublesome because it grows so thickly as to form a tangle hard to penetrate; its stems, rough and crooked, hang together so that a pedestrian must exercise great care to prevent them tripping him or tearing his clothes, and at best make travel exceedingly tiresome. Alder is not so plentiful in this district as it is on the coast or in many parts of the Copper River and Susitna regions, yet there is a considerable growth in the vicinity of the Delta River forks and in a number of other places.

In the lowland areas spruce trees are intermingled with large cottonwoods along the streams and with groves of poplar or aspen on the higher land. The spruce does not attain as great a size on the open higher ground as along the stream channels, and the timber seen along the military road or in crossing the lowlands at other places is small. Many acres of it have been burned years ago, leaving the country covered with a forest of bare poles that fall as the roots decay and the wind overturns them. Extensive fires in the timber of the lowland area in the fall of 1910 destroyed many of the new bridges and culverts along the military road. Some of these fires were probably set deliberately, either to see them burn or to get rid of the mosquitoes, but probably most of them were due to carelessness in one form or another on the part of travelers. Settlers use the dry poles of the burned districts for firewood and for fencing, but most of it is practically valueless. In fact, it may be said of most of the lowland timber away from the stream courses that it is either of inferior quality or entirely unfit for lumber.

No attempt was made to collect or study the numerous grasses of the district between Gulkana and Susitna rivers. The supply and distribution of the grasses, however, are of great importance to the traveler with horses. Forage is scarce in the lowland district, although grass grows around some of the lakes and in places along the streams. Only a few places along the military road between Gulkana and Summit Lake afford enough grass for horses, so that travelers dependent on the country for supplies for their animals are obliged to make their camps according to the distribution of the grass and not by the length of day or the strength of the stock. On the other hand, grass is plentiful about the timber line in the mountain region, both in the stream valleys and on the hill slopes. In places the growth is luxuriant. Grass as high as a man's shoulder was seen on Valdez Creek where the brush had been burned off several years ago.

The end of the working season for many of the miners who use horses is determined by the severe frosts, because the horses are obliged to leave for the coast before the feed gives out. Most of the grass loses its value for forage as soon as frost strikes it. Although it appears to be good, horses eating it lose strength rapidly unless grain can be fed at the same time. According to Mr. A. J. Paxson, native grass for horse feed can not be depended on earlier than June 15 or later than September 5 in the vicinity of Gulkana and Summit lakes. In some years it may start earlier in the spring or live longer in the fall, but these dates define the limit of safety in that locality. The growing season is shorter than in the lowland, where grass comes up a week or two earlier and lasts about as much longer. The supply of native feed along the military road is less important now than formerly, for grain can be purchased at nearly all the road houses.

POPULATION.

The population of the district is small. The white population is confined to Valdez Creek and to a few localities along or near the military road. There are three military telegraph stations and nine road houses between Gulkana River and Canwell Glacier. At the three telegraph offices there are in all about a dozen soldiers, including operators and linemen belonging to the Signal Corps. The number of people, exclusive of transients, who live at each of the road houses ranges from two to six in summer, but is perhaps a little greater in winter. Between 20 and 25 men were mining on Valdez Creek in 1910, and about 10 more were either prospecting or mining in other localities. Thus it appears that the white population in the summer of 1910 was about 60 or 65 in all.

The district has a small native population, but no estimate of its number was attempted. Several of the Indian families have their winter quarters at Gulkana and others near Susitna River and the Susitna Lakes. One family lives on Valdez Creek. These families are widely scattered in the summer at the fishing stations along the rivers and later in the season in the hunting grounds. It is therefore difficult to get a correct idea of their number at these times, when little is seen of them on the regular lines of travel.

TRAILS AND TRANSPORTATION.

Transportation in this district, as in almost every other part of Alaska, is one of the most serious difficulties connected with mining.

In the early days supplies for use on Valdez Creek were freighted across Valdez Glacier to Klutina Lake and from there to Susitna River at the mouth of Tyone Creek, from which place they were taken over the river ice to their destination without serious difficulties. The most objectionable part of this route is Valdez Glacier, where the obstacles to be overcome are so serious that the route was given up as soon as the military trail was well established. The trail ascended St. Ann River, on the north side of Klutina Lake, crossed Lake Hudson, Taslina Lake, and the Susitna Lakes, and then descended Tyone Creek to Susitna River. The grades after crossing Valdez Glacier are not heavy.

Nearly all the supplies used on Valdez Creek for the last five or six years have been freighted over the military trail from Valdez to Gulkana, and thence to Valdez Creek by way of the west fork of Gulkana River and Maclaren and Susitna rivers. The difficulty of crossing the coast range by this route, as by the other, is serious and is one of the principal causes of the high cost of freighting into the Copper River basin, but improvements made from year to year on the military trail, which was at first suitable only for pack horses and narrow sleds, have transformed it into a road, which is practically ready for travel with wagons throughout its full length from Valdez to Fairbanks. A few large bridges and a number of culverts still remain to be completed, but doubtless most of them will be in place before the end of 1911. Ditching and grading will also be required on some stretches, but even in its present condition the road represents a great improvement over the old trail and reflects much credit on Col. Richardson and his associates of the Alaska Road Commission. During the summer of 1910 a new road was cut through from the military road to Chitina, the new town on the Copper River & Northwestern Railway, on the west side of Copper River, opposite the mouth of Chitina River. The new road branches off the old road at Willow Creek, about halfway between Tonsina and Copper Center. It runs east-southeast to Copper River and follows its west bank to the railroad. A bridge over Tonsina River, which was necessary to make this road available for general use, was completed in the winter of 1910–11.

The winter trail from Gulkana to Valdez Creek, as previously stated, follows Gulkana River to the head of its west fork, then passes the round-topped hill on the north by way of a low divide and comes out on Maclaren River about 7 miles from the Susitna. From the mouth of Maclaren River it follows the Susitna to Valdez Creek. The distance from Valdez to Gulkana is 128 miles, and from Gulkana to Valdez Creek approximately 125 miles. This trail, after the coast range is passed, offers very favorable grades for freighting. From Gulkana travel is almost continuously on the river ice, snowplows being used to break the trail ahead of the sleds. In favorable seasons travel is attended with little difficulty, but an effort is always made to reach Valdez Creek before the heavy snows of the late winter. This is accomplished more easily now than in former years, because the road through Keystone Canyon makes it possible to start from Valdez with freight before the river freezes in the canyon, thus saving a month or more at the beginning of the trip.

The cost of freighting from Valdez to Valdez Creek averages about 30 cents per pound. Under the most favorable circumstances it might be reduced to 20 cents, but the experience of several years has shown that 30 cents is not far from the average cost. It seems likely that the cost of freighting may be somewhat reduced with the opening for business of the Copper River & Northwestern Railway, but this will depend, of course, on the rates established.

Summer travel between Valdez Creek and the military road is over a somewhat different route from that followed in winter. The trail leaves the road at Bear Creek, about 1 mile south of Gulkana, and runs northwest to Maclaren River. It keeps to the east of the round-topped mountain between Maclaren River and Clearwater Creek, and leads to Valdez Creek by way of the Roosevelt Lakes pass. This trail is indicated on the map (Pl. I, pocket). Much of it is over wet ground, and travel with horses is so difficult that there has been a desire since the military road was put through from Gulkana to Fairbanks to find some shorter and better route connecting with it.

Two other routes have been tried. The more northern one is by way of Eureka Creek to the east fork of Maclaren River and thence across Maclaren River and its west fork to Roosevelt Lakes, west of Clearwater Creek. The other trail starts at Paxson and passes through the northern part of the Tangle Lakes district to the west fork of Maclaren River, from which point the trail is practically the same as the one just described. The distance is about 65 miles. The Eureka Creek trail is slightly shorter and crosses fewer ridges than that from Paxson; but it has the disadvantage of considerably increasing the total distance between Gulkana and Valdez Creek. Both trails are above timber line and the supply of firewood is limited to willows, so that neither route would be practicable for winter travel under present conditions, even if they afforded as favorable grades as the one now used. Either, however, would be a practicable summer mail route.

An attempt was made several years ago to establish a winter freighting route between Valdez Creek and Indian Creek, on Susitna River, but it was not found practicable at that time and there has been no attempt since then to renew it. A small amount of freight is brought from Fairbanks each winter by way of Nenana River.

GENERAL GEOLOGY.

STRATIGRAPHY.

INTRODUCTION.

The hard-rock formations of the region under discussion are complicated in structure and a clear understanding of their stratigraphic relations and areal distribution was not gained in the short time available for study in the field. They include both sedimentary and igneous rocks, and range in age from pre-Ordovician (?) Birch Creek schist, through Carboniferous or possibly earlier to upper Eocene.

GULKANA AND SUSITNA RIVER REGION.

In summarizing the general geology represented on the map (Pl. II, in pocket) it may be said that, aside from the Birch Creek schist, the rocks of this region which are thought to be oldest consist of greenstones, slates, tuffs, conglomerates, and quartzitic beds, together with a minor amount of limestone, all metamorphosed to a greater or less degree and locally changed into schists. These sediments, which are probably of Carboniferous age, form a belt extending east and west along the south flank of the high central part of the Alaska Range. (See Pl. II.) They were not fully differentiated from the massive rocks to be mentioned later. South of these sediments is a belt of heavy dark-colored, igneous rocks, consisting largely of amygdaloidal lava flows, with which is associated a minor amount of tuffs and tuffaceous conglomerates. The age of this succession of flows and tuffs is in doubt, but they are thought to be younger than the Carboniferous rocks previously referred to and older than the Upper Triassic rocks. Somewhat later than the extrusion of the lavas there was laid down a succession of slates, sandy shales, and limestone that contain fossils and are definitely determined to be of Upper Triassic age. Their distribution is only partly known.

The formations enumerated, which include everything in the region older than Eocene, are cut by granular intrusives, which are believed to be of Jurassic or later age. The most common and notable of these are diorites or quartz diorites and related granular and porphyritic rocks. They occupy a considerable proportion of the mapped area and are especially abundant in the vicinity of upper Susitna River.

They are not the only intrusives in the region, however, for dark basic dikes were seen at various localities. Lastly there was deposited a succession of shales, sandstones, and conglomerates of different degrees of consolidation, containing beds of lignite, and these are correlated with the Kenai formation of the Susitna Basin and are believed to be chiefly of Eocene age. Part of these beds, however, consist of unconsolidated deposits difficult to distinguish from the later unconsolidated Quaternary sands and gravels.

All the rocks mentioned have been folded and locally at least are much faulted. No unconformity in deposition was actually observed either below or above the Upper Triassic sediments, but the absence of upper Carboniferous and Lower and Middle Triassic deposits below and of later Mesozoic deposits above is attributed to erosion intervals during these times or to erosion intervals and faulting. Such erosion intervals might result in unconformity of deposition between the Carboniferous sediments and the lava flows, between the lava flows and the Triassic deposits, and between the Triassic and the Eocene deposits.

The following table presents in a somewhat different way the summary just given:

Geologic column of the upper Susitna-Gulkana district.

Quaternary:	
Recent	Stream gravels, sands, and silts.
Pleistocene	Glacial gravels and moraine deposits.
Unconformity.	
Tertiary:	
Upper Eocene (Kenai formation?)	Unconsolidated sand and gravel with lignite deposits. Sandstone, shale and conglomerate with lignitic coal beds.
Unconformity.	
Jurassic (?) or later	Granular intrusives, diorite, quartz diorite, and related forms.
Upper Triassic	Shale, sandstone, slate, arkose, limestone, tuffs, and lava flows.
Unconformity.	
Carboniferous or later	Basic lava flows, tuff, and tuffaceous conglomerate.
Carboniferous	Slate, tuff, quartzite, limestone conglomerate, and granular intrusives.
Probably pre-Carboniferous	Greenstones with some schist and granitic and basic intrusives.
Pre-Ordovician (?) (Birch Creek schist)	Highly altered sediments with igneous intrusives.

CHISTOCHINA DISTRICT.

It will be necessary in the pages that follow to make frequent reference to the work of Mendenhall[1] in the adjacent region on the east, and for that reason it is desirable to introduce here a summary of the geology described by him and to give a reprint of part of his geologic map (Pl. III, in pocket) in order that the areal distribution of the rock formations may be understood.

The oldest rocks represented on his map are micaceous schists that here make up the central part of the Alaska Range. They were mapped by him as the Tanana schist, but the "Tanana" schist has since been correlated with the Birch Creek schist, the older name, and "Tanana" has been abandoned. No conclusive evidence for the age of the Birch Creek schist has been found, but the formation is believed to be older than Ordovician.[2]

Next in order of age is the Chisna formation, which includes beds of quartzite, arkose, pyritiferous tuff, conglomerate, and limestone, and is cut by porphyritic dikes and igneous rocks, such as diabase and diorite. It is assigned to the Carboniferous on the basis of a few imperfect fossils and its probable stratigraphic position with reference to the formation next mentioned.

The Mankomen formation follows the Chisna in the stratigraphic column. It may be separated into two divisions, the lower of which is prevailingly arenaceous and tuffaceous and more than 2,000 feet thick, the upper prevailingly calcareous and approximately 4,500 feet thick. The total thickness of the Mankomen is therefore about 6,500 feet. It includes beds of sandstone, shale, limestone, quartzite, and tuffaceous sandstone, intercalated with flows or intrusive sheets of diabase and andesitic lava. Fossils collected from the Mankomen at different localities place the time of its deposition late in the Carboniferous. Originally the fossils were determined as Permian (latest Carboniferous), but later work in other parts of Alaska has led to the belief that they are really Pennsylvanian, and that the Mankomen formation, together with other sediments at the head of White River and on the Yukon at Nation River, are to be correlated with and are related to upper Carboniferous sediments in the Ural Mountains of Russia.

The Gakona formation of Mendenhall is much younger than the rocks just described. It is of upper Eocene age, and consists of coarse conglomerate and soft gray or buff-colored shales interbedded with gravel, sand, and lignite beds. Marked differences exist in the degree of consolidation of the sediments comprising this formation.

---

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No 41, 1905.

[2] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 59.

The basal member is a thoroughly indurated coarse conglomerate, not less than 500 feet thick, underlying compact and fissile shales, above which are slightly indurated clays and sands topped by an iron-stained pebble bed or cemented gravel, the highest member recognized by Mendenhall. The total thickness of the beds included in the Gakona formation is estimated at not less than 2,000 feet. Fossil plants collected from these beds were pronounced by Dr. F. H. Knowlton to be typical of the Kenai formation (upper Eocene), which is of fresh-water origin.

Quaternary gravels and glacial deposits are widely distributed and complete the geologic section of sedimentary deposits in this district.

In addition to the numerous dikes and sills intruded into the Carboniferous sediments, two formations wholly of igneous origin are represented on Mendenhall's map of the Chistochina district. They are the Tetelna volcanics and the Ahtell diorite, regarded by Mendenhall as of upper Paleozoic age. The Tetelna volcanics consist largely of altered andesites intruded by basic dikes, for the most part of diabase, but in some places of diorite. The Ahtell diorite is a massive quartz diorite, pink or brownish red in color, and was considered by Mendenhall to be older than the Mankomen formation. Possibly, however, the diorite may belong to the period of Mesozoic intrusion, to be described later.

Structurally the Mankomen formation lies between the Birch Creek schist and the Chisna formation. It is separated from the Birch Creek schist by a great fault which finds expression in a prominent topographic depression, and from the Chisna formation by another fault, making it appear to have been dropped below its proper stratigraphic position. The displacement between the Mankomen formation and the Birch Creek schist is considered by Mendenhall to be not less than 10,000 feet. In general the beds of the Chisna formation dip southward, and those of the Mankomen dip to the north. A general southward dip is characteristic of the beds of the Gakona formation in their exposures between West Fork Glacier and Gakona Glacier, where they cap a high ridge and form the southern slope of the mountain.

These four formations include the most important rocks of the Chistochina district; all but the Mankomen are also represented in the district west of Gulkana River.

PRE-ORDOVICIAN (?) ROCKS.

BIRCH CREEK SCHIST.

A small area of Birch Creek schist along Delta River is represented on the geologic map (Pl. II, in pocket). It, however, is outside the district visited by the writer, and the description of the rocks found there is based chiefly on that of Mr. Capps,[1] who studied the geologic formations on the north slope of the Alaska Range between Delta River and the Nenana in this same year (1910).

A more general description of the Birch Creek schist is given by Brooks,[2] who describes it on his geologic map as consisting of "Micaceous, graphitic, garnetiferous quartz schists, and schistose quartzites with some limestones, also including some greenstones and other igneous rocks, locally mineralized and auriferous."

The known areas of Birch Creek schist extend eastward in the region north of the Alaska Range from the vicinity of Mount McKinley into Yukon Territory. Capps describes the formation where studied by him as showing much variation in the character of its component members, yet distinctive as a whole and easily recognized. Highly contorted and fissile mica and quartz schists and phyllites, green, red, brown, or gray in color, are the predominant rocks. In a few localities the fresh unaltered rocks are comparatively massive and mica is inconspicuous, but in weathered outcrops the fissility is made prominent and the large amount of mica present gives the surface a glistening silvery luster. Oxidation of the iron pyrite changes the prevailing green color of the original rock to red or brown in weathered exposures. Variation in the degree of schistosity is the rule rather than the exception, some of the rocks, as previously stated, being massive and without well-developed cleavage, while others split readily owing to the large amount of mica present. Beds of metamorphosed quartzite are interbedded with the mica schists, in places showing an imperfect cleavage due to the development of mica scales. Dense beds of graywacke and fine black slate or slaty schist are also associated with them. Quartz-mica schist predominates in the district west of Little Delta River, but in the vicinity of Mount Hayes the less metamorphic quartzitic and slaty schists become important, so that the whole succession more nearly resembles that of the type locality north of Fairbanks. On Delta River quartz-mica schist forms an important part of the stream wash and is believed to be well developed, although Capps was unable to study the area carefully.

The Birch Creek schist is intruded by a variety of igneous rocks ranging from greenstones and hornblende rocks to more acidic varieties and varying in texture from fine-grained cherty types to granite porphyries. These intrusives differ widely in metamorphism also, for some are entirely fresh, while others show almost as great alteration as the inclosing schist. Capps believes that the Birch Creek schist in this area is derived chiefly from clastic sediments, but shows that igneous members were associated with them.

[1] Capps, S. R., jr., The Bonnifield region: Bull. U. S. Geol. Survey No. 501, 1912, p. 20.
[2] Brooks, Alfred H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, pp. 56–60.

The members of the Birch Creek schist have been closely folded and intensely metamorphosed, so that the structure is intricate and difficult to determine. In most places the bedding is obscured by the schistosity, yet the major structural features may be made out from a study of large masses of the rocks, and it is seen that the strike of the beds is roughly parallel to trend of the Alaska Range, while the dips of the beds range from 15° to 60°.

AGE.

The age of the Birch Creek schist has not been determined. No fossils have been found in it. It appears to be overlain unconformably by a succession of quartz feldspar schists containing slates and a little limestone that is considered by Brooks[2] to be of Silurian or Devonian age. He regards the Birch Creek schist, therefore, as probably pre-Ordovician.

PROBABLE PRE-CARBONIFEROUS SEDIMENTARY ROCKS.

DISTRIBUTION AND CHARACTER.

About a mile north of Myers road house on the military road there is an area of greenish mica schist cut by light-colored granitic intrusives and by dikes of dark, heavy, basic rock. The granitic intrusives are sheared and have a definite cleavage, but the dark-colored dikes are fresher and apparently younger. The exposures are too poor and the examination was too brief to yield definite information, but the schists show much greater metamorphism than the nearest Carboniferous sediments toward the north nearer the zone of more intense folding in the Alaska Range.

In the vicinity of the Tangle Lakes similar schists are intruded by dikes of light-colored, fine-grained rock, containing small hornblende phenocrysts, probably related to the diorite.

The schists of these two areas lie south of the principal zone of lava flows and are thought to be part of a larger area of schists and associated igneous rocks, chiefly greenstone and diorite, that form the low rounded hills at the northern border of the Copper River lowland.

AGE.

Any estimate of the age of the schists would be little more than speculation. So far as the degree of metamorphism is of value in determining age it indicates that the schists are older than the nearest Carboniferous sedimentary formations toward the north (at the head of Gulkana River), which are so situated with reference to the

[2] Brooks, A. H., The Mount McKinley region: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 59.

axis of the Alaska Range that a greater degree of folding and more pronounced schistosity would be expected in them than in the schists if the disturbances that produced the range accounted alone for the alteration in both. Local schistosity, however, is not uncommon in the Carboniferous deposits.

CARBONIFEROUS ROCKS.

Under the heading "Carboniferous rocks" are grouped a number of formations of widely different character. They consist of sedimentary deposits, such as conglomerates, limestones, quartzites, volcanic tuffs laid down in water, and intercalated lava flows or intrusive sheets. The age of the sediments may be referred to Carboniferous time with considerable, but not absolute, certainty. The massive Carboniferous limestones have been distinguished from associated rocks on the geologic map (Pl. II, in pocket), although they are not treated as a distinct formation in the text. The basic lavas and tuffs are referred to the Carboniferous with less certainty, and they may prove to be of Triassic age.

SEDIMENTARY DEPOSITS.

CHARACTER AND DISTRIBUTION.

East of Phelan Creek and west of Delta River northward from Eureka Creek to Canwell Glacier, the high mountains consist of slates, tuffaceous beds, quartzitic sediments, and local limestone beds associated with diabasic flows or intrusions and with light gray or greenish gneisses that probably represent metamorphosed diorite intrusions. These beds are much folded and in places a schistose structure has been developed. The weathered surfaces of many of them have a rusty red color that renders them particularly conspicuous and makes them recognizable at long distances. The same rocks extend eastward to the Chistochina River region, where they were named the Chisna formation by Mendenhall, and westward on the north side of Eureka Creek to at least as far as the glacier at the head of the main fork of Maclaren River. Whether they continue west to Susitna River was not determined, but it is thought probable that they may extend even farther westward into the headwater region of Nenana River.

In the vicinity of Canwell Glacier and eastward the Carboniferous deposits abut against the Birch Creek schist on the north, this position being due to a profound fault whose extension and location west of Delta River is not known. The possibility that the rocks described as Carboniferous include some infolded Mesozoic sediments will be discussed in the description of the Triassic deposits.

AGE AND CORRELATION.

The evidence for the age of the Carboniferous sediments is not sufficient to determine definitely the time at which they were deposited. The only fossils collected are crinoid stems from the massive limestone beds outcropping east of Gulkana Glacier and on Eureka Creek, and the evidence they afford is merely presumptive. No fossils were obtained from the other sedimentary beds here referred to the Carboniferous.

Some light is thrown on the problem by the relations existing in the region immediately east of that under consideration. Mendenhall[1] found a great thickness of Carboniferous strata in the headwater region of Chistochina River and divided them into the two formations which he named Chisna and Mankomen.

Parts of the Mankomen formation are abundantly fossiliferous, and on the basis of the fossil determinations the formation was originally referred by Schuchert to the Pennsylvanian and then to the Permian, but was later reassigned to the Pennsylvanian by Girty and is correlated with the Pennsylvanian of the White River region[2] and with the Nation River formation[3] of the Yukon. Girty's determinations show the fauna of these localities to be unlike that of central and eastern North America and to represent the Russian Gschelian of the Ural Mountains.

Mendenhall correlated the tuffaceous beds of Phelan Creek with the Chisna formation, and there can be little doubt that the correlation is correct. The Mankomen formation, however, appears to have been faulted out, for no evidence of it has been recognized west of Gulkana Glacier. Mankomen fossils abound in the high mountain east of the lower end of Gulkana Glacier some distance above the massive limestone bed there exposed, but all collected were from loose material on the mountain slopes, and it was considered quite possible in the field that the material was not in place, but came from somewhere nearer the head of the glacier. No similar fossils were found west of Delta River. The best available evidence for the age of the rocks north of Eureka Creek, here correlated with Mendenhall's Chisna formation and referred to the Carboniferous, indicates that they are older than the Mankomen formation. It is entirely possibly, however, that more field work would have shown that they include Mesozoic sediments, such as were found farther west in the neighborhood of Valdez Creek but were not recognized east of Maclaren Glacier.

---

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, p. 33 and following.

[2] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: Bull. U. S. Geol. Survey No. 417, 1910, p. 17.

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

In a broader way Brooks[1] has correlated the Chisna formation with the Cantwell formation at the head of Nenana River, the Wellesley formation on White River, and the Nation River formation of the Yukon. The Cantwell formation, as described by Brooks, is a massive quartz and chert conglomerate, with brown sandstone interbedded with black clay shale and volcanic rocks. It has a thickness of more than 3,000 feet and is provisionally assigned to the Carboniferous on stratigraphic and not on fossil evidence. If this assignment proves correct, Carboniferous sediments form an important part of the Alaska Range, at least from Mentasta Pass to Nenana River.

BASIC LAVAS AND TUFFS.

CHARACTER AND DISTRIBUTION.

The belt of heavy, dark-colored, volcanic rocks extends from the vicinity of Summit and Gulkana lakes westward beyond Susitna River. These rocks consist largely of diabase and locally are amygdaloidal, showing that in part, at least, they are surface lava flows. They are associated with argillites, tuffs, and tuffaceous conglomerates in a number of places and are intruded by diabases and by dikes of less basic, light-colored porphyritic rock. Intrusions of peridotite have taken place in the Tangle Lakes vicinity and probably also in other places, for bowlders of this character were found in some of the younger conglomerates near the glacier at the head of the east fork of Maclaren River. The lava flows have been deformed in the general folding of the region so that steep dips are common, and schistosity is occasionally developed. These flows form a prominent range of mountains parallel with the axis of the Alaska Range and not sharply separated from it in the vicinity of Maclaren River. This secondary range is characterized by sharp angular outlines, due chiefly to recent glaciation but probably dependent also on the nature of the rock forming it (Pl. V, *A*, p. 40). The main belt of these volcanics is at least 15 miles wide on the east side of Maclaren River, and isolated hills and another lower range made up in large part of similar rocks lie to the south and are perhaps a part of the same succession of flows. A great difference in the appearance and amount of alteration at different localities suggests that the volcanic outbursts were intermittent during a long period, but the field studies were not sufficient to prove that such differences exist within the main belt of volcanics.

AGE.

The evidence available as to the age of the basaltic lavas is not sufficient definitely to determine the geologic time in which the flows

[1] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 83.

took place and possibly not even the relative age of the flows and of the sedimentary formations with which they are associated. The circumstances from which the conclusions of the report are deduced are as follows:

Near the mouth of Eureka Creek a succession of limestone beds, black and gray slates, and associated diabases, dipping 40° to 50° S., appear to pass beneath lava flows and are, therefore, supposed to be older. A possibility of error, however, lies in the fact that the exact relation between the sediments and the lava flows is not known and that faulting or an overturned fold may have obscured the facts. Southern dips of the lava flows were observed at other localities, particularly on Maclaren River, but in none of these places were conditions for observation so favorable as on Eureka Creek.

The mountains west of Clearwater Creek and south of the pass to Valdez Creek are made up in part of lava flows and in part of sedimentary deposits which include a number of small limestone beds containing Upper Triassic fossils. In several places these limestone beds overlie the basic eruptive rocks and both eruptives and sedimentary beds dip to the north. Here again the exact nature of the contact relation between the two formations is in doubt, but the evidence at hand seems to indicate that the sediments are younger than the volcanics. It therefore appears probable that the lavas were poured out either in late Carboniferous time or during early or Middle Triassic time.

In this connection it may be stated that the massive Carboniferous limestone of the upper White River corresponding to the Mankomen formation is underlain by Carboniferous shales, tuffs, and lava flows and is overlain by similar rocks in which the lava flows predominate greatly. In the Chitina Valley the Upper Triassic Chitistone limestone rests on several thousand feet of diabasic lava flows known as the Nikolai greenstone. The lava flows of Eureka and Windy creeks resemble the Nikolai greenstone both in character and in their relation to the associated Triassic sediments and suggest a strong probability that their extrusion was approximately synchronous.

On the other hand, a large area of Middle Jurassic volcanic rocks in the Talkeetna Mountains just south of Susitna River and much nearer the region under consideration than the Wrangell Mountains, differ from the volcanic rocks along Windy Creek and south of Eureka Creek in the important respect that they consist of less basic materials, being made up of andesite greenstones, dacites, rhyolites, and associated tuffs. For this reason and for the stratigraphic reasons already given it is thought that the lavas of Windy Creek are not equivalent to those of the Talkeetna Mountains.

TRIASSIC ROCKS.

CHARACTER AND DISTRIBUTION.

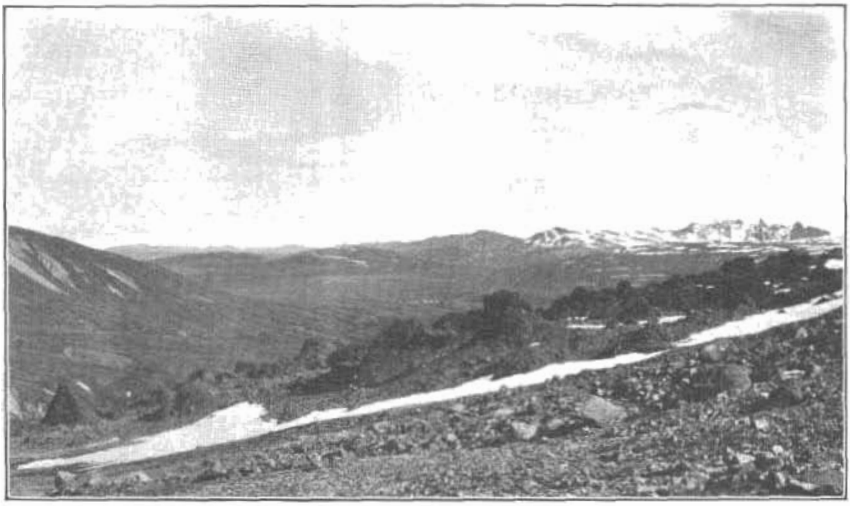
On the south side of Coal Creek, a tributary of the Clearwater, several hundred feet of horizontal, thin-bedded, shaly limestone and calcareous sandstone are exposed, extending from the creek nearly a third of the way up the mountain. The main mass of the mountain consists of basalt, against which the sediments abut in such a way as to suggest that the contact relation is due either to faulting or to unconformity of deposition. The limestone fragments show numerous Upper Triassic fossils. Many bowlders of black fossiliferous limestone are found in the creek bed and are probably derived from a bluish-gray limestone, not less than 60 feet thick, overlain by red weathering shaly or tuffaceous rocks, which appears in the lower part of the mountain on the north.

West of Clearwater Creek and south of its tributary which heads near the Roosevelt Lakes bluish-gray limestone beds yielding Upper Triassic fossils were found in several places resting on the volcanic rocks. They are little metamorphosed and are associated with banded slates, black slates, red weathering slates or shales, graywackes or fine tuffs, tuffaceous conglomerates, and diabase flows or intrusions. In general the beds dip north. They are intruded by diorite and related hornblende porphyries and feldspar porphyries. Fossiliferous limestone is exposed in one of the gulches on the north side of the creek heading near the Roosevelt Lakes, and although the fossils collected yielded no evidence as to the age of the limestone this is thought to belong with the Triassic sediments to the south. It appears, therefore, that except for this one undetermined outcrop the known fossiliferous Triassic sediments are near the boundary of the belt of lava flows. A number of limestone outcrops near this boundary, north and northeast of the head of Windy Creek, differ slightly in appearance from the beds previously mentioned and may possibly be of different age, although the only reasons for such an assumption at present would be that the limestone is crystalline in character and apparently contains no fossils. The presence of intruded igneous rocks in the vicinity, however, is believed to explain sufficiently the alteration of the limestone and the absence of fossils, for the recrystallization of the limestone would tend to destroy any animal remains that might have been present.

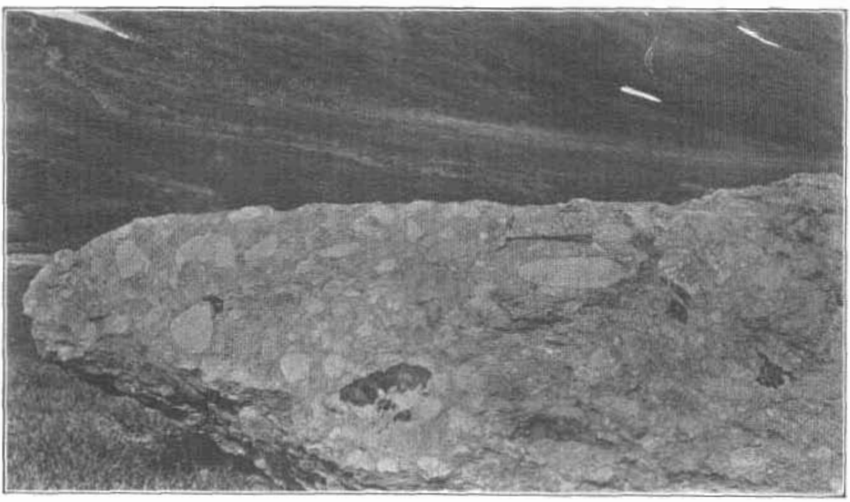
The heterogeneous character of the rocks associated with the Triassic limestones and the rocks immediately north of the limestones and apparently overlying them, especially a massive conglomerate a mile or more southeast of the Roosevelt Lakes, suggests the presence of younger Mesozoic or possibly Tertiary sediments in this region, but no fossils were found to support this possibility. The best exposure of this conglomerate is in the mountain between the branch of the tributary of Clearwater Creek heading against Windy Creek and the branch heading toward Roosevelt Creek. The western face of this mountain is a massive conglomerate made up almost entirely of igneous rocks, chiefly dark, basic volcanics, but with a considerable amount of granitic rock in a groundmass of tuffaceous material. The pebbles and cobbles are well rounded and many of them are a foot or more in diameter (Pl. IV, *B*). This conglomerate, although it forms a large part of the mountain, is restricted to a small area, probably less than 2 square miles. No similar conglomerate was seen at any other locality during the summer.

The belt of rocks included between Valdez and Windy creeks on the west and extending eastward along the boundary of the lava flows to Maclaren Glacier includes an assortment of rock types that confuses and hides the main geologic facts. This belt includes the Triassic limestone beds and the conglomerate just described, but consists largely of slates and intercalated basic igneous flows or intrusives, all of which are cut by granular intrusives of dioritic or related characters. They differ from the rocks bounding them on the north in that they show less metamorphism, the sediments being changed to slates rather than schists and the diorites being little altered, thus presenting a strong contrast to the schistose and gneissic diorite north of Valdez Creek. These differences are brought out in the area north and west of the head of Clearwater Creek, where the slightly altered graywackes and shales or slates are in contact with schistose diorite, a relation which may be due either to faulting or to depositional unconformity, but which, from the seeming absence of conglomerate or sandstone, is probably due to faulting rather than to deposition. Unconformity of deposition or faulting would also account for the difference of metamorphism in the slates south of Valdez Creek and the schists north of it.

The hills immediately north of Valdez Creek consist of schistose sedimentary rocks and much-altered diorite intrusives. Schistosity is greatest in the vicinity of the diorite, particularly around the borders, where thin dikes or sills have been forced into the sediments along the bedding or cleavage planes, and is accompanied by the formation of garnet and kyanite. Kyanite is a mineral characteristic of the highly metamorphic sediments and is believed to be formed under deep-seated conditions of high pressure and temperature. At the time this locality was visited it was supposed that the schists represented a local advanced state of metamorphism in the general slate area of Valdez Creek, due to the intrusion and immediate presence of the diorite, but the possible existence of the fault previously mentioned places the supposition in doubt and makes it possible that the schists north of Valdez Creek and the slates south of it are not equivalent. With the evidence now at hand it is impossible to



A. LANDSLIDE ON NORTHERN TRIBUTARY OF EUREKA CREEK.



B. CONGLOMERATE ASSOCIATED WITH TRIASSIC SEDIMENTS BETWEEN ROOSEVELT LAKES AND BIG CLEARWATER CREEK.

determine whether the schist area should be mapped as part of the Carboniferous rocks to the east, as part of the Triassic sediments, or as differing from both.

AGE AND CORRELATION.

The age of the Triassic rocks was determined on the evidence of the fossils collected from them and submitted to Dr. T. W. Stanton for identification. The substance of his report follows, the numbers given to the three lots being those of the National Museum:

No. 6570.—Limestone area on a small western tributary of Clearwater Creek.

Halobia sp. related to H. superba Mojsisovics.
Tropites sp.
Discotropites? sp.
Arcestes sp.

These fossils belong to the Upper Triassic fauna.

No. 6571.—Coal Creek, a tributary of Clearwater Creek, 15 miles east of Susitna River.

Pseudomonotis subcircularis (Gabb).

This is a characteristic Upper Triassic species.

No. 6572.—West of Clearwater Creek, about 2 miles northwest of the locality from which No. 6570 was taken.

Serpula sp.

Horizon not determinable from this fossil.

The first two lots of fossils show that the Triassic limestones of this region are equivalent in age to the Chitistone limestone and the McCarthy shale of the Chitina Valley and with the Triassic limestone of the Nabesna River region. Upper Triassic sediments in Chitina Valley attain a thickness of not less than 6,000 feet, of which the lower part, known as the Chitistone limestone, comprises 3,000 feet. The thickness and areal extent of the Triassic sediments in the Nabesna region is unknown.

Upper Triassic deposits are also found in the Cook Inlet and Alaska Peninsula regions.[1] They consist of thin-bedded cherts, limestones, and shales generally much contorted and containing many intrusive masses. The base of the succession has not been observed.

A large proportion of the known Triassic deposits of Alaska lie south of the Alaska Range, and future work will probably show that they have considerable development in the upper Susitna region, as well as the Cook Inlet and Chitina River regions.

JURASSIC (?) ROCKS.

CHARACTER AND DISTRIBUTION.

The Jurassic, if present in this part of the Alaska Range, is represented by igneous rocks. No sedimentary deposits are known here

[1] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Bull. Geol. Soc. America, vol. 16, 1905, p. 410.

that can with much certainty be referred to the Jurassic period, notwithstanding the fact that both sedimentary and igneous rocks of this age are widespread in the Talkeetna Mountains, only a short distance southwest, and are found in other parts of the range.

The rocks tentatively referred to the Jurassic, chiefly quartz diorites and related granular intrusives, occur as dikes, sills, and large masses of irregular form intruded into the older sedimentary and igneous rocks. True granites were not found in the region studied.

The diorites are prevailingly gray in color and differ considerably in alteration. In some exposures they appear to be perfectly fresh, but in others they show well-developed cleavage and are schistose. Examination with the microscope shows that the typical diorite of the region is composed essentially of soda-lime feldspar, hornblende, biotite, and quartz. Hornblende is more plentiful than biotite in nearly all the specimens examined. Pyroxene is generally present and alters to hornblende. Both hornblende and biotite alter to chloritic material. Other secondary minerals are epidote and zoisite. Titanite, apatite, magnetite, and pyrite are accessory minerals. Such intrusives are widely distributed near the head of Susitna River, and are believed to be connected with the source of the gold on Valdez Creek.

Most of the smaller masses, such as dikes and sills, have a porphyritic structure. A few of the dikes show large phenocrysts of feldspar, but hornblende porphyries are far more common. There seem to be all gradations between quartz-hornblende, diorite, and rocks consisting almost entirely of hornblende. A specimen of this last type, found in the mountains between Roosevelt and Windy creeks, consist of large blade-like crystals of hornblende in which are scattered grains of feldspar, apatite, and magnetite. A little vein of epidote cuts the hornblende in one specimen. This dark hornblende rock is present at many localities in the Alaska Range between Susitna River and Chistochina Glacier.

Diorite intrusives are common at many places in the district, as is shown by the geologic map (Pl. II, in pocket). They cut the Triassic sediments, and are, therefore, younger, but they do not appear in the Tertiary deposits. On the north side of Valdez Creek they intrude slates and show a great number of apophyses extending as sills and dikes from the main mass of the intrusive into the sediments. Both the intrusive and the host have since undergone further alteration, for the diorite is schistose, but there may have been considerable contact-metamorphic action at the time of intrusion. The slates in the vicinity of the contact are much altered and have developed in them a great deal of garnet and kyanite. Kyanite, though it is generally a product of dynamic metamorphism and is usually found in the crystalline schists, occurs locally in contact-metamorphic zones.

AGE OF THE DIORITE INTRUSIVES.

The principal evidence as to the age of the diorite found in this region is the fact that it intrudes the Upper Triassic sediments, but has not invaded the upper Eocene deposits. On this evidence, therefore, it is younger than Upper Triassic and older than upper Eocene. Paige and Knopf[1] have presented evidence to show that the quartz diorite intrusions of the Talkeetna Mountains are younger than Middle Jurassic and are contemporaneous in a general way with the great series of intrusions that affected the whole cordilleran region of North and South America. Brooks and Prindle[2] consider the period of intrusion to have been post-Middle Jurassic and to have extended into the Cretaceous. The diorite intrusions of the Chitina Valley are younger than Upper Jurassic, for they cut the Kennicott formation, which is probably of Upper Jurassic age, and possibly extend into the Cretaceous.[3]

It appears probable that the dioritic intrusions of the upper Susitna region may have extended over a considerable length of time, as is suggested by the different degrees of alteration which the intruding rocks present, and that they are to be referred to the late Jurassic and early Cretaceous epochs.

TERTIARY ROCKS.

CHARACTER AND DISTRIBUTION.

A small creek that comes down from the mountain on the east and joins the Gulkana Glacier stream a short distance below the south end of the glacier has cut its channel in a succession of folded conglomerates and partly indurated clays with which are interbedded thin seams of coal ranging in thickness from a fraction of an inch to 3 inches. The clays are banded and show fragments of plants. This succession of sedimentary beds strikes east and west and dips steeply to the north. With it are associated soft, highly-colored clays, yellow, white, and bluish gray, which extend up the hill on the north to a point several hundred feet above the creek.

The hills east of the part of Gulkana River between Summit Lake and the glacier show bluish-gray clays in some of the stream cuttings, but are made up in large part of consolidated sands and gravels, tilted at angles as great as 45° to the horizontal. In many places they contain beds of carbonized wood or lignite. Gravels of this character are exposed on both sides of Isabel Pass and seem to extend

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 20.

[2] Brooks, A. H., and Prindle, L. M., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, pp. 117 and 153.

[3] Moffit, F. H., and Capps, S. R., The geology and mineral resources of the Nizina district, Alaska: Bull. U. S. Geol. Survey No. 448, 1911, p. 38.

up the mountain on the north side to an altitude of nearly 2,000 feet above the creek, or almost to the summit. The high mountain east of the south end of Gulkana Glacier appears to be made up of a massive but poorly consolidated conglomerate containing a great many fossiliferous fragments from the Mankomen formation.

The tributary of Phelan Creek on which the road house and the military telegraph station are located cuts a deep canyon in a high bench flanking the mountains on the east. In the lower part of this canyon the wall rock consists of brownish-yellow conglomerate interstratified with thin sandstone beds (Pl. IX, *A*, p. 60). The conglomerate is firmly cemented and confines the creek between vertical walls, but it can be readily broken down with the pick. It strikes N. 65° W. and dips 20° to 30° NE., in contrast to the gravel and sand beds south of Isabel Pass, which dip 45° S. Associated with the conglomerate and sandstone are several hundred feet of unconsolidated sands and gravels, separated from the conglomerate by a north-south fault. Apparently the unconsolidated material, which is composed of gray clays, pure white quartz sands of exceedingly fine grain, and beds of lignite up to 2 and 3 feet in thickness, is the lower part of the succession of beds to which the conglomerate belongs. The lignite beds are filled with sand and resemble broken driftwood accumulations on a beach. Carbonization of the wood has advanced only a little way and the woody structure is distinctly visible, so that the pieces resemble charcoal rather than coal. All these deposits are overlain unconformably by glacial till and gravels.

Yellow conglomerates like those described are exposed on Delta River below Wild Horse Creek and in the hill between Phelan Creek and Delta River. In fact this hill appears to be almost made up of Tertiary deposits, covered by a thin veneer of glacial till.

Rocks referred to the Tertiary were found at two localities west of this point. The first of these is north of the head of Eureka Creek. On a small tributary heading in the mountain east of the glacier from which Eureka Creek flows yellow iron-stained conglomerate and sandstone like those previously described are exposed. This outcrop appears to be small, but on the west side of the same stream near its head are other rocks of very different appearance that are probably of equivalent age. The south end of the mountain between this stream and the glacier is capped by a massive, loosely cemented conglomerate made up almost entirely of igneous rocks, most of which are derived from the basaltic hills to the south. There is, however, a small proportion of granitic material. Many bowlders in the conglomerate reach a diameter of several feet. The whole deposit weathers to rusty red and shows an abundance of iron oxide. Apparently a landslide has taken place here, or possibly from time to time the conglomerate has broken off in large masses from the mountain top and rolled down the eastern slope, for an area of perhaps 20 acres is covered with immense blocks of conglomerate, some of which are 30 or 40 feet long (Pl. IV, *A*, p. 32). They break down rapidly under the influence of the weather and form immense heaps of loose bowlders and iron-stained gravel.

The second western locality is on the south side of Coal Creek near its head, where an exposure of coal 5 or 6 feet thick, associated with yellow shales, stands vertically. The coal and shales are so folded, crushed, and faulted that it is difficult to find a good firm piece of either. A fault on the north side of the coal, running N. 65° W., marks the course of the bed. The exposure is not more than 100 feet long, but the coal blossom is seen along the creek for at least half a mile farther east and is nearly everywhere associated with yellow and white clays like those found on Gulkana River. The coal of this locality is entirely different from any previously mentioned; it does not have the woody character and contains no sand. Apparently the bed was originally a clean deposit that has since been much folded and broken. It is similar to the coal described by Mendenhall as occurring in the bed of Slate Creek,[1] and like that seems to be a remnant of the Tertiary folded into the older rocks.

These areas include all the observed deposits thought to belong in the Tertiary, but it is highly probable that such deposits are more extensively developed in this region. The largest area is that around the heads of Delta and Gulkana rivers, which comprises the western extension of Mendenhall's Gakona formation.

One of the important features of the Tertiary deposits as described is their separation into an underlying succession of fairly well consolidated material and an overlying succession of unconsolidated material. Firm beds of conglomerate may be locally interbedded with unconsolidated sands and gravels, but the distinction indicated seems to be well founded. Both consolidated and unconsolidated beds are much folded, but if a generalization can be made from the examination of so few localities it appears that the consolidated material has suffered most. Detailed work on the Tertiary deposits of the region would doubtless result in a distinction being made between the two divisions here considered together.

The character of the unconsolidated upper part of the Tertiary deposits make it impossible in reconnaissance work of this nature to differentiate them from the younger sands and gravels produced and laid down during the time of glaciation. In mapping areas of this kind, therefore, uncertainty exists as to whether gravels such, for example, as those at Paxson should be assigned to the one formation or to the other. Part of these bench gravels are undoubtedly of

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, p. 53.

glacial origin, but it is possible that the remainder belong among the unconsolidated Tertiary deposits.

AGE AND CORRELATION.

No fossils were collected for determination from the sedimentary deposits referred to the Tertiary. Fragmentary plant remains were found at a number of places and lignitic coal is common. The lithologic similarity of these deposits with the coal-bearing beds of the Kenai formation of the Cook Inlet, Susitna River, and Copper River basins, and of the north side of the Alaska Range is the principal reason for referring them to the Tertiary.

Mendenhall found sedimentary deposits of this age well developed on the east side of Gulkana Glacier and called them the Gakona formation.[1] The Gakona formation consists of a succession of fresh-water deposits, including a massive conglomerate which appears to be overlain by soft, gray, or buff-colored shales associated with beds of gravel, sand, and lignite. (See p. 23.) Mendenhall found marked differences in the degree of consolidation of the material making up the formation. The basal conglomerate and the shales resting on it are indurated; the higher beds, however, are only slightly indurated, and he describes the highest recognized member of the formation as a cemented gravel.

These rocks extend west along the flank of the Alaska Range at least to Delta River and occupy an area much greater than in the Gakona type locality. Careful work would probably show that they are more widely developed in the valley of Eureka Creek than they are now known to be. The soft yellow conglomerate and sandstone described as occurring at the head of Eureka Creek is similar to that of Delta River and Phelan Creek, but the beds on Coal Creek probably belong among the basal beds if they are correctly referred to the Tertiary. Coal alone does not afford conclusive evidence of the age of the beds, for coal occurs in the Jurassic deposits at the head of Matanuska River;[2] but in this particular locality it appears probable that a remnant of Tertiary beds has been caught and preserved in the folds of older rocks.

The Kenai formation (upper Eocene) has wide development on Cook Inlet, in the Matanuska valley, and in the valley of the Susitna, in all of which places it includes extensive coal deposits. It has also been recognized on the north side of the Alaska Range between Nenana and Delta rivers and in many other parts of Alaska.

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, p. 52.

[2] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, p. 56.

QUATERNARY DEPOSITS.

DEPOSITION.

The Quaternary deposits include unconsolidated materials laid down by ice and water during the glacial epoch and those since deposited by the streams. They include also unconsolidated material, such as talus slopes and mantles of rock waste on the hillsides, that has never been subjected to the action of glaciers, lakes, or streams; these, however, do not call for extended description here. In a region like this, where considerable glacial activity still prevails, a time distinction between glacial and stream deposits can not be drawn, for the ice still transports and deposits morainic matter just as it did when the glaciers were far more extensive, and the glacial débris is being sorted and resorted by the glacial streams just as it has been during all the time the ice has been present. The two processes of transportation and deposition by ice and by water have gone on side by side, and the products can not be absolutely distinguished.

GLACIAL DEPOSITS.

Two types of glacial déposits are easily distinguished in this region by those familiar with the character or topographic forms shown by glacial débris. The first is the ground moraine or till sheet, which forms a thin veneer over the underlying formations and is widely distributed in the northern part of the area, particularly over the more level parts, such as that of the Tertiary formations at the head of Delta and Gulkana rivers. Such deposits do not always assume conspicuous topographic forms but may often be recognized by the erratic bowlders on the surface. The best method of detecting them is undoubtedly from sections exposed in stream cuttings, where the peculiar characteristics of unsorted glacial débris may be recognized with little difficulty and the features distinguishing it from water-sorted and water-laid material may be made out. The till sheet is easily recognizable in many gravel sections about Summit Lake, on the broad, round-topped hills from Gakona Glacier to Delta River, and in the broader valleys, such as those of Eureka Creek, Valdez Creek, Maclaren River, and Susitna River. In the Summit Lake region the ground moraine rests unconformably on the tilted beds of the unconsolidated gravel and sand referred to the Tertiary, and in many places is only a few feet thick. Probably all the area in this region formerly occupied by ice was covered at one time by a veneer of till, much of which has since been removed by erosion.

A more noticeable form of glacial deposit is the moraine material deposited along the front and sides of the ice during times of relatively small movement in the margin. Many conspicuous examples of such moraines appear in this region. One of the best is on Maclaren River below the mouth of the west fork and in the valley to the west between Maclaren River and Little Clearwater Creek. The ice front faced the south and left a conspicuous terminal moraine several miles long extending over the ridge west of the river and across the valley that succeeds it to the next ridge beyond. This moraine has a height of 50 feet in places, but is only a part of a great mass of deposits of similar nature in the vicinity. Another good illustration of such morainal topography is furnished by the district about the head of Delta River in the vicinity of the Tangle Lakes.

Practically all the present-day glaciers in this part of the Alaska Range have small terminal moraines, some of which show very distinctly the form and recent position of the ice front and the recession that has taken place. An excellent illustration is furnished by the glacier in which Eureka Creek and the east fork of Maclaren River head. Two concentric moraines several hundred yards apart cross the valley half a mile or more from the ice front and form dams which hold back the water in a number of small lakes. Terminal moraines of this kind rarely escape destruction for any great length of time unless they are situated at the side of the stream above the flood plain. They are nearly always undermined by water from the glacier and are carried away and deposited as stream gravels. Only in rare instances are their remnants found in the gravel-floored valleys of glacial streams, although it is evident that they must have once existed there, unless the former action of the glaciers was entirely different from what it is at present.

Lateral moraines border the present glaciers and appear as benches along the sides of valleys from which ice has long been absent. They are especially conspicuous in valleys with steep high walls, such as the upper part of Maclaren River and its west fork, and it is generally possible to find them in any of the smaller valleys. They mark positions at which the ice level on the valley walls was relatively stable for a time, and are much more apt to be preserved than terminal moraines of valley glaciers, inasmuch as they are away from the influence of the streams.

The southward extent of unmodified glacial deposits in the upper Susitna River region is not known, but it is highly probable that all the region under consideration has been covered by ice at one time or another; and it is therefore possible that the till sheet may also have covered the entire area. This, however, does not mean that the till is present everywhere in the area now, for part of the material that formed it may have been sorted and redeposited by streams since it was laid down by the ice. The lowlands extending west

A. BASALT MOUNTAINS ON THE SOUTH SIDE OF WINDY CREEK.

B. UPPER VALLEYS OF WHITE AND BIG RUSTY CREEKS.

from the south end of Gulkana Lake to Susitna River were not visited by the geologic party, and it was not learned whether the morainic topography such as that described on the upper part of Maclaren River and in the northern part of the Tangle Lakes district is developed there.

Another peculiar topographic feature either produced directly by glaciation or closely associated with it is described by S. R. Capps[1] under the name of rock glacier. Several excellent examples of loose-rock accumulations of this type were seen during the course of the field work. The best of these (Pls. V, *B*, and VI, *A*) is at the head of Big Rusty Creek, a tributary of White Creek, which, in turn, is a tributary of Valdez Creek. This mass of loose-rock material is more than a mile long and is fully 50 feet high at its lower end. It heads in two cirques from which glaciers formerly issued, and has the appearance of a glacier, except that it is made of rock fragments instead of ice and is narrower than most glaciers—even than those commonly found in valleys so comparatively small as this one. Deep depressions like those between a valley glacier and its confining walls intervene between it and the valley walls on either side, so that its close resemblance to a glacier in form at least is immediately evident to one who has had an opportunity to see both. No ice is visible in the sides or top of this particular example, but it shows the longitudinal markings described by Capps as characteristic of the much better developed rock glaciers in the Chitina Valley. Another rock glacier, not so well developed, however, as that on Rusty Creek, was found on the south side of the branch of Valdez Creek called Grogg Creek.

STREAM AND LAKE GRAVELS.

A detailed description of the present-day stream gravels in this region would not be of great interest even if the character of the field work and the opportunities for observation were such as to make close account possible. Gravels, important because of the gold contained in them are, however, described under "Economic geology" (pp. 58–62). Some of the stream gravels were produced by ordinary processes of erosion without the aid of glacial ice, but most of them in this region are reworked deposits of former and present glaciers. Practically all the larger streams, except Delta River, within the northern half of the mapped area, head in glaciers that are actively engaged in transporting rock waste from the high mountains to the valleys. All this material sooner or later is taken up by the streams, the fine and coarse fragments are separated, and the whole is redeposited and reworked time after time till no semblance of its original glacial character remains. The broad flood plains of

[1] Capps, S. R., Rock glaciers in Alaska: Jour. Geology, vol. 18, No. 4, 1910, pp. 359–375.

the glacial streams are not fixed and unchangeable, but are built up or cut down as the channels shift from side to side across their surfaces.

The unconsolidated deposits of the southern or lowland area differ from those just described. They are believed to be closely connected in their origin with the more intense glaciation of the region and to have been deposited when the ice extended far southward from the Alaska Range. These gravels are seen in the high banks bordering Copper River, Gulkana River, and all the streams that have incised their channels in the lowland. No opportunities for detailed study of sections of the gravels were presented, but certain general statements can be made. The unconsolidated deposits exposed in the river banks consist of water-laid deposits associated with a smaller amount of glacial material. Glacial till and bowlder beds interbedded with the water-laid gravels are less evident in the northern than in the southern part of the area and very much less evident than in the part of the Copper River lowland south of the part now under consideration. As has been stated, the ground moraine overlies the gravel deposits on the northern border of the lowland, but similar beds were not observed interstratified with them. The point which it is desired to bring out will appear more clearly if a comparison is made with some of the localities studied by Mendenhall.[1]

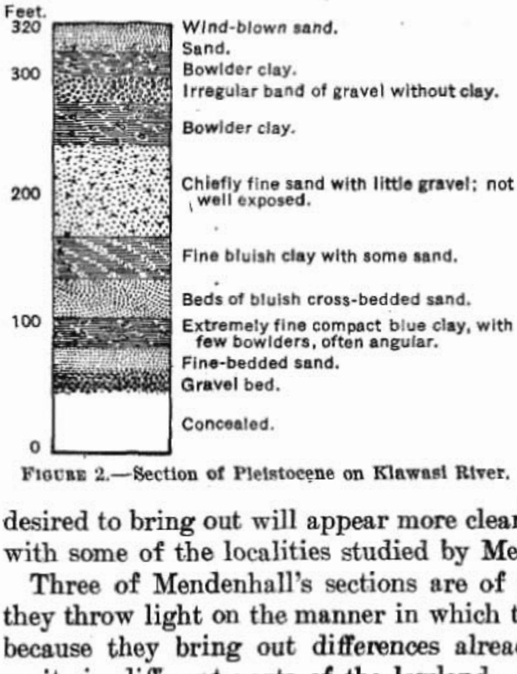


FIGURE 2.—Section of Pleistocene on Klawasi River.

Three of Mendenhall's sections are of particular interest because they throw light on the manner in which the deposits were made and because they bring out differences already noted between the deposits in different parts of the lowland. The localities are all near Copper Center, the most distant being a little more than 20 miles south of Gulkana. Mendenhall describes them as follows:

> One and one-half miles above the mouth of the Klawasi, which flows into Copper River opposite and a short distance above Copper Center, is a section of 320 feet (fig. 2), of which all but the basal 40 feet are sufficiently well exposed for examination. * * * Above the 40 feet at the base, which are concealed, is a 10-foot bed of rounded gravel, over which are 20 feet of fine-bedded sands, underlying 20 feet of blue bowlder clay. The succeeding 100 feet con-

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, p. 62 et seq.

sists of interbedded fine clays and sands. Above this member are a bed of bowlder clay and some stratified pebble-bearing clays similar to those at Tonsina bridge. The top of the section is a wind-blown sand drift. This section reveals a succession of rapidly-deposited water-laid beds, with at least two short epochs of ice invasion represented by the sheets of till near the top and bottom of the bluff. The water-laid deposits are usually sands or gravels, and may well have accumulated just beyond an ice front as a sand or gravel plain. * * *

On the north bank of the Klutina, about 6 miles above Copper Center, is a bluff 400 feet high, the beds of the upper 300 feet being fairly well exposed. The lower 100 feet of this exposure consists of compact, structureless, pebble-bearing clays, without lamination. The pebbles are well rounded, are sparingly distributed through the clays, and represent a variety of rock types. * * * Overlying it are about 85 feet of well-laminated beds entirely free from coarse material. They are believed to indicate lacustrine conditions. Above these is a bed of typical till 40 feet in thickness, full of striated and rounded bowlders. This is succeeded, in turn, by lenses of river cobbles overlain by more clays with embedded pebbles. The highest member of this section, as of most, is a bed of cobbles immediately under the peat and moss of the surface.

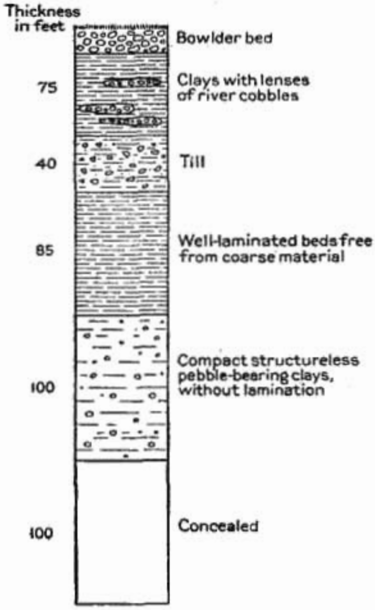


FIGURE 3.—Section of Pleistocene on Klutina River, 6 miles above Copper Center.

This section is illustrated in figure 3.

Mendenhall regards the pebble-bearing clays at the base as having been produced by rapid deposition in quiet water, and believes the pebbles to have been scattered through the clays by the agency of floating ice.

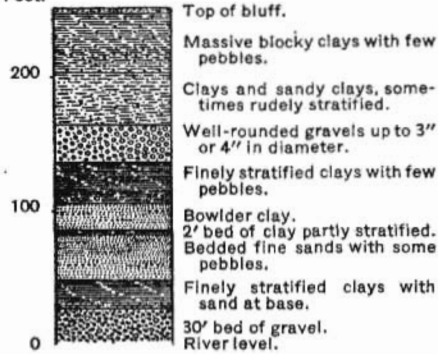


FIGURE 4.—Section of Pleistocene on west bank of Copper River.

Just below the mouth of the Tazlina (fig. 4), in a bluff on the west side of the Copper, is an excellent exposure of 250 feet, which includes stratified sands and gravels, laminated clays, pebble clays, and one 10-foot bed of bowlder clay about 100 feet above the base of the section.

These sections are seen to be made up of fragmental material deposited under varying conditions. Some of it was laid down in quiet water, some in running water, and some was deposited by ice.

The changes followed one another abruptly, and any given condition was perhaps repeated a number of times in the same section, as, for example, the two ice advances indicated by the bowlder clay beds in the section shown in figure 2.

In comparing these sections with those exposed farther north on Copper River, Gulkana River, and elsewhere the important difference to be noticed is that the northern deposits are composed more largely of lake and stream gravels and, except on the surface, show less glacial material. The explanation probably lies in the fact that the sections of the gravels exposed along the streams from Gulkana northward are not so thick as in the region of Copper Center. The streams have not cut so deeply into the gravel and have not yet reached the lower till beds, if such beds are present. The river banks at Gulkana show distinctly stratified clays and gravel. The clays or silts are probably due to glacial erosion, but were deposited in quiet water. Mendenhall[1] makes the following comment:

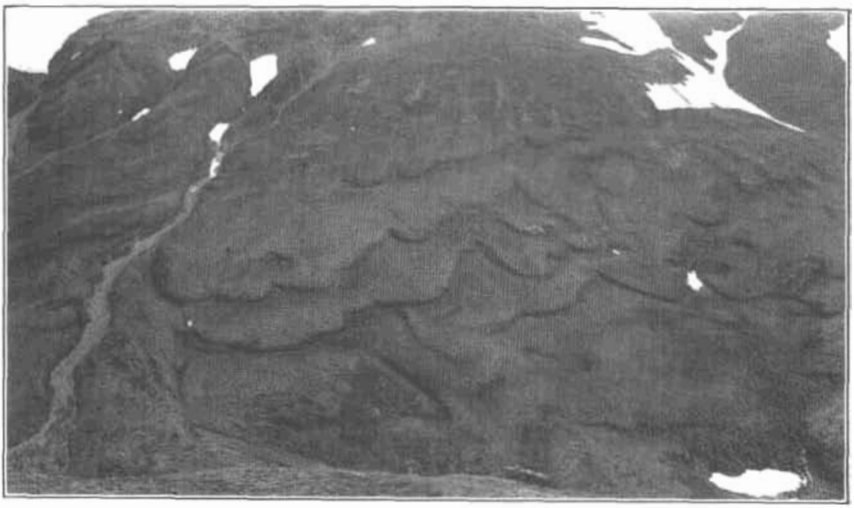
> The silt bluffs at the mouth of the Gakona, about 300 feet high, consist generally of fine, massive clays, through which pebbles are scattered. A few of the beds are laminated, and the general effect given at a distance is one of stratification in broad units.

These deposits are interpreted as the outwash gravels from a glacier front. It is probable that the whole of the Copper River basin has been invaded by ice that flowed into it from the mountain areas on every side. After the time of maximum extension the ice doubtless disappeared from the central region, but the high mountains continued to be a feeding ground of glaciers that moved down to the lowland and contributed an enormous quantity of rock waste to the streams produced by their own melting. This débris was spread out before the glacier front. Some of it came to rest in lakes or ponds and some was deposited by swiftly flowing streams. The retreat of the ice was not continuous, but was interrupted by advances that carried the margin out over the water-laid deposits and gave rise to the bowlder beds or till sheets interstratified with the gravels and clays. If this interpretation of the origin of these deposits is true it seems probable that the central part of the Copper River lowland will show the ground moraine only locally, for a large part of it must have been covered by the later outwash gravels or have been subjected to transportation and redeposition by streams.

One of the forms assumed by surficial deposits not due to the agency of glacial ice or to deposition in water deserves special mention because of its fine development in parts of this region. This form, which is that taken under certain conditions by rock waste on the hill slopes, will for convenience of description be referred to here as "soil flows," inasmuch as no better name seems available, though

[1] Op. cit., p. 70.

A. ROCK GLACIER ON BIG RUSTY CREEK.



B. SOIL FLOWS AT HEAD OF VALDEZ CREEK.

the number in use is great. The illustration (Pl. VI, *B*) represents some "soil flows" at the head of Valdez Creek. They are produced by a gradual downward movement of the soil on hill slopes, and may be compared to the flow of a viscous substance, such as thick tar, on an inclined plane. The movement, considered with reference to the total distance traveled down a hill slope, is exceedingly slow, so that years might be required to show any notable advance, although progress at a particular time may perhaps be rapid. The parts of the lobes in the example shown in the illustration are several feet high and are covered with moss and grass. The tops of the flows have a distinct radial striation and are also covered with vegetation. The presence of water in the soil, perhaps to the point of saturation, is necessary for such movements, but it is believed by the writer that one of the important causes for the "flowing" of the soil in the manner shown arises from repeated freezing and thawing of the water contained in the loose rock waste, for it seems doubtful that the presence of water alone is sufficient to produce the movement. "Soil flows" of this kind are very common on hill slopes in the more northern parts of Alaska, but are not frequently seen in the Copper River basin. The distinct radial markings shown on the "soil flows" of Valdez Creek are not common in such flows, at least in the experience of the writer, although they are very general in loose material on steep bare slopes and in rock glaciers. Doubtless in all these forms they result in part from a downhill movement of the material.

STRUCTURE.

The structure of the Alaska Range is highly complicated, and it is scarcely possible to understand it until more accurate knowledge of the stratigraphy is gained. Increased knowledge of the region indicates, however, that faulting plays a far more important rôle in the structural relations of the different rock masses than at first sight appeared. The range itself is one of the dominant structural features of Alaska, represented further by the Pacific coast line, the great interior valley, and the Endicott Mountain range. It is believed to represent a zone of weakness and adjustment that dates back beyond the present range and may, perhaps, have been the site of older ranges that long since disappeared.

It is not to be expected that all parts of the Alaska Range will show identical structure; because the forces acting to produce deformation could scarcely have been of equal intensity or quality in all places, and because the rocks involved differ greatly. Brooks[1] describes the Alaska Range southwest of Mount McKinley as a broad synclinorium made up of closely folded rocks in which minor

[1] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 111.

anticlines and synclines are recognizable. The succession of beds, however, on the inland slope of the mountains has been disturbed by extensive thrust faults. Mendenhall,[1] on the other hand, describes the range in the vicinity of Chistochina River as carved by erosional agents from a number of tilted fault blocks and shows that even on the southern or downthrow side the Tertiary beds dip gently away from the axis of the range and have a position relatively higher than their original one.

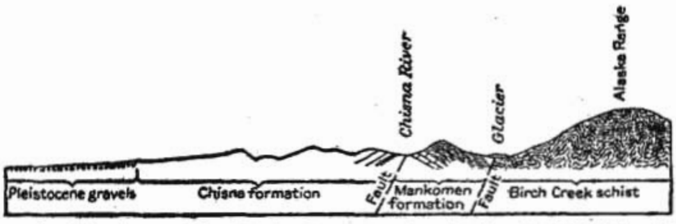


FIGURE 5.—Structure of the Alaska Range in the vicinity of Chistochina River.

These relations are better understood from the diagram (fig. 5), which is based on Mendenhall's description of the structure. The Mankomen formation abuts against the Birch Creek ("Tanana") schist on the north. The dip of the Mankomen is northward and increases in that direction so that it is greatest in the vicinity of the great fault between the Pennsylvanian slates and limestones and the schist. On the other hand, the underlying Chisna formation, which is separated from the Mankomen by a second great fault, dips to

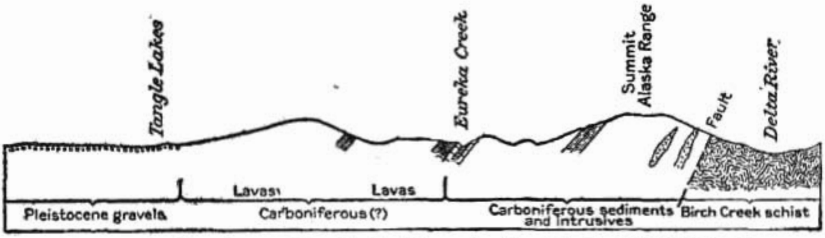


FIGURE 6.—Structure of the Alaska Range in the vicinity of Delta River.

the south, and in places, as in the area about Gakona Glacier, is overlain by southward-dipping Tertiary sediments.

In the region just west of Delta River still other conditions prevail which more nearly resemble those in the Chistochina district than in the McKinley region. The structure is shown diagrammatically in figure 6, which indicates that the high, axial part of the range is made up of the Birch Creek schist on the north, separated by the great fault from the Carboniferous rocks on the south. These

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, pp. 82–84.

Carboniferous beds, which are made up of intercalated sedimentary and igneous rocks, dip to the south beneath the lava flows of the ridge south of Eureka Creek. The lava flows are represented as folded into a broad syncline, but it is not intended to imply that the schists of the Tangle Lake district are to be correlated with the beds north of the syncline, although this may possibly be true. Diorite intrusions are common in the vicinity of the great fault, and, as suggested by Mendenhall, probably account for several of the high peaks, such as Mount Hayes, Cathedral Mountain, and Mount Kimball, in the axis of the range.

The structure of the Alaska Range at the head of Susitna River is more complicated than it is near Delta Pass and is not well enough understood to warrant the drawing of a section to represent it. In the vicinity of Valdez Creek the lava flows exposed south of Windy Creek appear to dip beneath the Triassic sediments, and these, in turn, to pass beneath the schists and the great diorite mass between Valdez and Bowlder creeks, but it has already been pointed out that a fault may exist between the slates and schists. The region between Valdez Creek and Mount Hayes is occupied, so far as known, by slates or schists and diorite, and it would seem, from the appearance of the lower hills on the flanks of Mount Hayes and Cathedral Mountain, that diorite forms a large part of the mass. Photographs of Mount Hayes show the beds at the base of the mountain dipping toward the north, but it is unsafe to base generalizations concerning structure on the meager evidence obtainable regarding this vicinity.

In summarizing these conclusions in respect to structure, it may be said that in the Alaska Range in the vicinity of Delta Pass and eastward toward Mentasta Pass a belt of Carboniferous and post-Carboniferous sedimentary and igneous rocks lies between schists on the north that are much older and others on the south that may be older. This belt of sedimentary and igneous rocks can not be interpreted as a simple synclinorium because the structure is complicated by profound faulting that has brought about relationships between the several formations entirely different from those that would have resulted from folding alone.

HISTORICAL GEOLOGY.

EARLY GEOLOGIC HISTORY.

In this section it is intended to outline in a very general way the most important geologic events indicated by the rocks of the region. The earlier events are obscure, but as the present is neared it is possible to recognize more and more distinctly the changes that took place.

The first geologic records found in this region are contained in the Birch Creek ("Tanana") schist, a series of sedimentary beds considered by Brooks to have been deposited in pre-Ordovician time,[1] which forms the north side of the Alaska Range from Nenana River to Mentasta Pass. They are intruded by igneous rocks, and because of the high degree of metamorphism which both sediments and intrusives show it is inferred that they were extensively folded, elevated above the sea, and subjected to erosion before the next younger sediments were deposited on them.

If the schists of very doubtful age near Myer's road house and at the Tangle Lakes be neglected, the next period of deposition concerning which knowledge exists took place in Carboniferous time and is represented by the rocks which are correlated with the Chisna formation. These were laid down in a time of volcanic activity, as is proved by the tuff beds and lava flows intercalated with the quartzites, slates, and other sediments of this epoch. The Carboniferous sea was an extended one, but changes took place in the relation of sea to land from time to time, and deposition in this region was not continuous. The best evidence at hand seems to indicate that there was an interruption in sedimentation between the part of Carboniferous time represented by the Chisna formation and that represented by the Mankomen formation of the Chistochina district. Probably the older Carboniferous formation was elevated above sea level with little deformation and was subjected to a period of erosion before the later sediments were laid down. Depression below the sea was followed by deposition of the latest Carboniferous rocks, the Mankomen formation. The Mankomen was also a period of volcanic activity, the outbursts being most pronounced while the lower beds were being deposited and diminishing toward the close of the period, for the upper beds in the Chistochina district appear to be free from volcanic deposits.

There is doubt concerning the time in which the great outpouring of lavas south of Eureka Creek and Windy Creek took place, but it is assumed tentatively that it was later than the Mankomen epoch. It is known definitely that the upper Carboniferous limestone at the head of White River, which is equivalent in age to the Mankomen formation of the Chistochina district, is succeeded by a great thickness of basaltic lavas and tuffs older than the Tertiary lavas which make up most of the Wrangell Mountain mass. Furthermore, the Nikolai greenstone of the Chitina Valley, consisting of at least 4,000 feet of lava flows, underlies the massive Chitistone limestone (Upper Triassic), and although it has not been proved that the Nikolai greenstone represents the upper part of the lava flows overlying the

[1] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 59.

Carboniferous limestone of White River there is a presumption that this is true.

The lava flows of Eureka and Windy creeks, in the absence of proof to the contrary, are thought to occupy a similar position relative to the Carboniferous and the Upper Triassic sediments and to have been erupted at the end of the Carboniferous period or during the early or middle part of the Triassic. Some of the lavas may have been poured out under water, for they are interstratified with tuff beds and slates, but many amygdaloidal flows among them suggest surface conditions. In any event the absence of Lower and Middle Triassic sediments indicates that the region was probably a land mass during part of that time. In Upper Triassic time the land was again submerged, and limestones, slates, and associated tuffaceous sediments were deposited. No conclusive evidence is at hand to show that any other Mesozoic sediments are present in the region under discussion, although sedimentary Jurassic rocks are widely distributed in the neighboring Talkeetna Mountains. The Jurassic period, however, was one of widespread intrusion throughout the Alaska Range and is represented by the great masses of diorite injected into the sedimentary deposits of this region.

It appears that after the Triassic beds were deposited the region became a land mass and continued as such through late Mesozoic and early Tertiary time. It was deformed to some extent, although the folding does not appear to have been great, and other changes took place that are indicated by the difference in metamorphism between the Triassic and the younger rocks. Erosion finally reduced the area to a lowland on which the fresh-water sediments of upper Eocene (Kenai) time were laid down.

LATER GEOLOGIC HISTORY.

TOPOGRAPHIC DEVELOPMENT.

Deposition of the fresh-water Tertiary sediments may appropriately be considered as beginning the later geologic history of this region. The Tertiary sediments were laid down in fresh inland waters and although widespread probably never formed a continuous deposit over all the region where their isolated masses now occur. They were deposited in an area of low or moderate relief, but were closely folded in the mountain-building movements that originated the present Alaska Range. These movements began soon after the Tertiary sediments were deposited and slowly raised the mountain area above the bordering low country, giving the streams an opportunity to attack and dissect it. The present drainage lines were established, but the topographic forms have since been greatly modified by glaciation. Profound faulting accompanied the folding, as is shown by the attitude of the Chisna formation to the Birch Creek schist and to the Mankomen formation.

The origin of the Alaska Range and its relation to the Copper River plateau has been discussed by Mendenhall,[1] who regards the high mountains as having been carved from elevated fault blocks and the lowland as a sunken area separated from the Alaska Range on the north by a great fault and from the Chugach Mountains on the south by a great fault or a flexure (fig. 7). Less evidence in support of this proposition was seen in the region between Gulkana River and Susitna River than was found by Mendenhall in the region east of Gulkana River, but it is the most plausible explanation yet offered and can not be discarded unless it is disproved or a more satisfactory one proposed. The questions involved are not local ones peculiar to this area, but are concerned with the later history of all southern Alaska, and will probably not be fully answered till much more extended work is done.

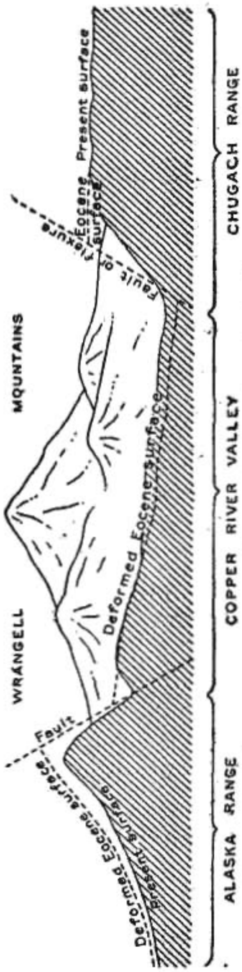


FIGURE 7.—Relations of present and Eocene land surfaces in the Copper River valley.

A problem of special interest is that concerned with the origin of Delta Pass through the Alaska Range and the similar pass to the west through which Nenana River flows. Delta River receives most of its water from the glaciers that feed Eureka Creek, from the Tangle Lakes, and from Gulkana Glacier, all south of the axis of the range, but it flows northward through the range and joins the Tanana instead of becoming part of the Pacific drainage, as would be expected. The same glaciers that feed Phelan and Eureka creeks also contribute water to Gulkana and Maclaren rivers. Almost the same conditions are true of Nenana River, which rises south of the Alaska Range, flows westward through the southern foothills for a considerable distance, and then cuts directly through it. Three explanations suggest themselves for this peculiar drainage feature—the Delta may be older than the Alaska Range and may have deepened its channel as fast as the mountains rose; it may have cut its way through from the north side by headward erosion; or it may owe its peculiar position partly to conditions that arose during glacial

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, pp. 82–88.

time. A low preglacial saddle, such as may probably have existed where the Delta Valley now cuts the range, would almost certainly have been taken advantage of by the ice as a northern outlet from the area south of the pass. It seems to be well established that the accumulation of ice on the south side of the range was greater than that on the north, and it is believed that some of this ice, instead of moving south, moved north through the gap and, partly by glacial erosion and partly by damming back the water on the south, enabled the Delta to establish itself there.

It is difficult to see how the river could have maintained its course across the Alaska Range while the latter was being elevated unless some special cause intervened, since it appears as if opportunity for drainage to the south was as good, if not better, than to the north. The same objection applies to headward erosion. The distance to the sea is less and the grade is greater on the south side than on the north side of the range.

The problem that the Delta presents is similar to that raised by Copper River in its course through the Chugach Mountains and it is not at all unlikely that the solution of one will contribute to the solution of the other.

GLACIATION.

Glaciation was one of the important agents in giving the mountains of the Alaska Range the form they have to-day. No doubt the drainage system was well established before the ice invasion took place, but the valleys owe their present form in large measure to ice erosion and to the deposition of rock waste that accompanied it. The present glaciers afford little idea of the former ice sheet in this region and in determining its extent dependence must be placed on other features, such as glacial deposits and striæ.

Much has already been said about the work of ice, especially in regard to the material laid down by it and the part such deposits have in the topography. The till sheets in the Pleistocene deposits of the Copper River lowland testify that the whole interior basin of Copper River, bounded by the Alaska Range, the Wrangell, the Chugach, and the Talkeetna mountains, was at one time or another buried by ice. Ice streams are known to have moved from all these high mountain areas to the lower country. The Alaska Range was an important place of ice accumulation; not only was the high central part of the range a gathering place for snow and ice, but the lower range to the south also contributed. Most of the ice moved southward, directed in part by the larger stream courses, such as Susitna, Maclaren, and Gulkana rivers, but it spread out as it left the confining valleys and probably covered many or possibly all of the low hills on the borders of the lowland. The round-topped hills near

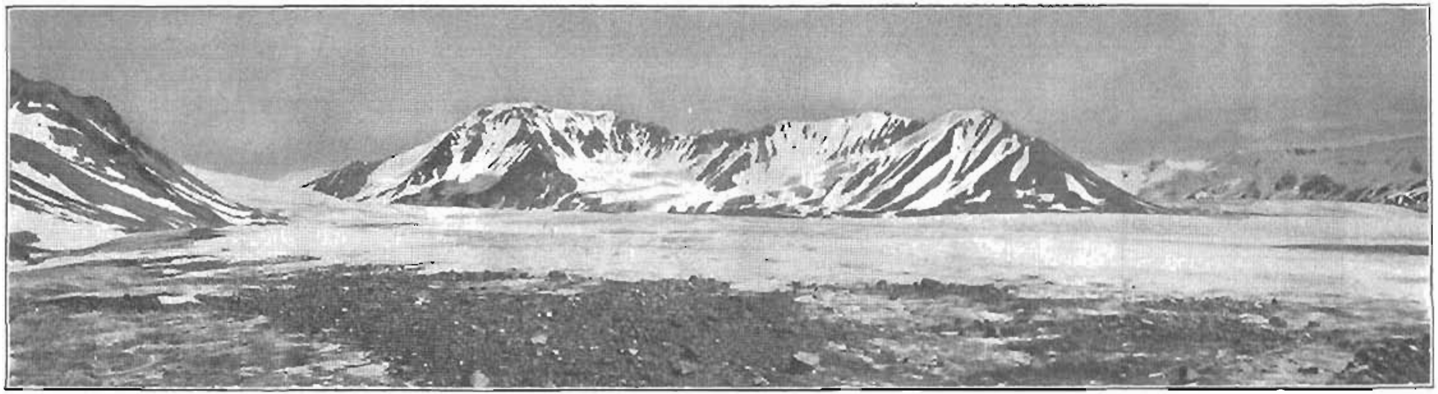
Myer's roadhouse are glaciated, as would be expected since they lie in the path of one of the larger ice streams which moved down the valley of Gulkana Lake from the north. Hills of similar form west of Gulkana River may also have been covered.

It is fairly certain, however, that in an area including much of Phelan and Eureka creeks and part of Delta River the ice movement was north through Delta Pass instead of south, for the basalt mountains west of Summit Lake obstructed in considerable degree movement in that direction. Another reason why the movements here should have been northward is that the evidence, as previously stated, points to a much greater accumulation of ice on the south side of the axis of the range than on the north side. The tendency of the ice would have been to move in the direction of least resistance, and any large mass in the area south of Delta Pass to the basalt mountains would have sought relief from pressure by movement northward through the pass as well as southward through the few available gaps unless it were opposed by some larger mass of ice in that direction. This small area shows evidence of severe glaciation throughout its extent. The rock, where exposed, in such places as the low basalt hills bordering Eureka Creek on the south or on the lower slopes of the basalt ridge south of Garrett's cabin, is grooved and worn by moving ice.

It is impossible to say how thick the ice covering was, but it must have been measured in hundreds and perhaps thousands of feet. The mountain sides east and north of the upper branches of Susitna River show that where confined in the valleys it filled them to a height more than 2,000 feet above the present streams. The ice crossed the broad divide between Bowlder and Valdez creeks from the north at an elevation more than 1,500 feet above Susitna Valley, and it is probable that only the tops of the neighboring mountains were above it.

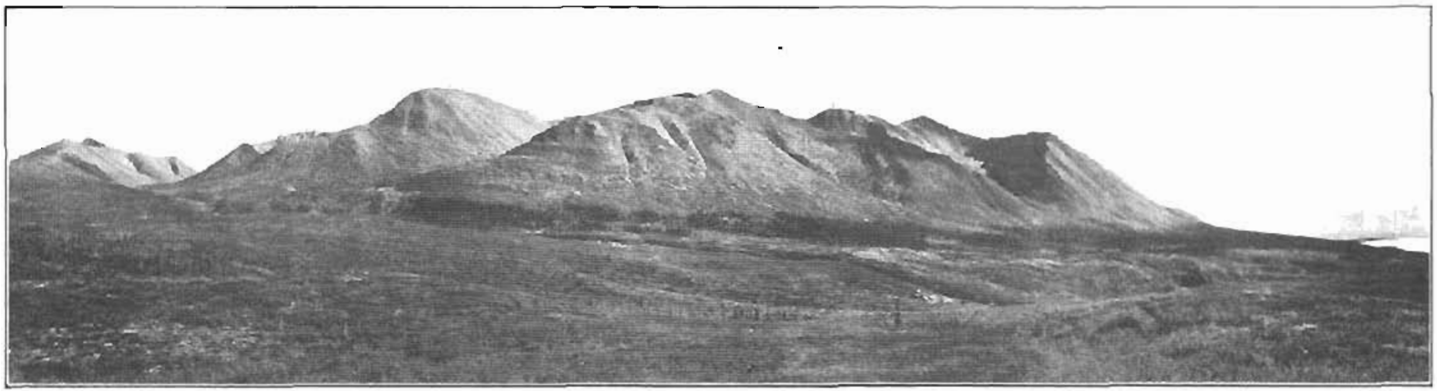
The east-west ridge north of West Fork of Gulkana River would present a serious barrier to ice moving from the north, because it stands from 1,000 to 3,000 feet above the lowland on that side and it seems doubtful whether it would have been overridden by glaciers from the north. These hills, however, may themselves have been a gathering ground for snow and ice. Such an obstruction, furthermore, would not have prevented the glaciation of the country south of the ridge for the Wrangell and Talkeetna mountains sent out streams of ice whose movements were unopposed by any such barrier.

The topographic map (Pl. I, in pocket) shows how numerous the present-day glaciers are in the high part of the mountain area and what an important element they are in the drainage. All the streams of consequence derive a large part of their water from melting glacier ice and flow through valleys floored with glacial gravels.



A. VIEW ACROSS GULKANA GLACIER FROM WEST SIDE.

Shows a type of Alaska range topography.



B. VIEW SHOWING THE TOPOGRAPHY OF LOWER VALDEZ CREEK VALLEY FROM THE NORTH.

The most conspicuous of these glaciers are Gulkana Glacier (Pl. VII, *A*), the glacier in which Eureka Creek and East Fork of Maclaren River head, Maclaren Glacier, and the two large glaciers at the head of Susitna River. The last two are much larger than any others in this region. They are fed by the snow fields in the high rugged country south of Mount Hayes and Cathedral Mountain and are the principal sources of the Susitna, although the glaciers to the east also contribute much water. The westernmost of the two large glaciers is about 25 miles long and more than 1½ miles wide throughout its whole length. The eastern glacier is about 2 miles wide, but is not so long as the first. Maclaren River Glacier is much smaller than either of these, being a little more than 10 miles long and not more than a mile wide at its lower end. Gulkana Glacier and Canwell Glacier, near the northwest corner of the area mapped (Pl. I, in pocket), are remarkable, as has been stated, in that they contribute water to both Bering Sea and Pacific Ocean drainage.

Most of these glaciers appear to be retreating. Their surfaces are smooth, they end in smooth slopes rather than ice cliffs, and most of them show by the position of terminal moraines that they have receded considerably in recent time.

Glaciation is the last of the great events that took place in the geologic history of this region, and it is still in progress. Its effects are for the most part concerned with topography, and are seen in the form of the mountains, the slopes of the valleys, the moraines, and the broad outwash plains of glacial gravel. These features have all been modified to some extent by postglacial erosion, but they are nevertheless the chief elements of the present-day topography.

ECONOMIC GEOLOGY.

GOLD.

VALDEZ CREEK DISTRICT.

HISTORY AND PRODUCTION.

The history of mining in the region between Gulkana and Susitna rivers is concerned chiefly with Valdez Creek. A few of the prospectors who came into the Chistochina River region in 1898 found their way to Delta River and its western headwater tributaries, but they were unsuccessful in their search for placer gold and did not make any important discoveries.

Gold was discovered on Valdez Creek on August 15, 1903, by a party including Peter Monahan, J. S. Smith, J. M. Johnson, and J. C. Clarkson, who, with several others, left Valdez with dog teams in February of that year and crossed the Valdez Glacier to Klutina

River. They made their way to Susitna River by following Klutina River, St. Ann River, and Tyone Creek, crossing Klutina, Hudson, and Taslina lakes and the Susitna Lakes on the ice. Their first base camp was near the "stick houses" at the mouth of Tyone Creek, from which they began their search for gold by prospecting the streams tributary to Susitna River below Tyone Creek. They found fine gold on the bars of a stream which they called Goose Creek (a creek rising in the Talkeetna Mountains and corresponding to the one named Oshetna River on later maps), but not satisfied with the results of their labor they left this region for the upper Susitna. At Maclaren River the company separated into two parties, one of which ascended that stream, and the other, known as the Monahan party and including the men named, made its way up the Susitna, prospecting the different tributary creeks as it went. Gold was found on Butte Creek and on its tributaries, Gold and Wickersham creeks, but not in sufficient amount to satisfy the prospectors. They then crossed Susitna River from the west side to a stream which the natives called Galina, and made their first important gold discovery below the mouth of a narrow rock-walled canyon on Discovery Bar. They renamed the stream Valdez Creek and spent the few remaining days of the season before going back to Valdez in getting out a "grubstake."

The following spring they returned with supplies and equipment, coming in over the Valdez Glacier as in the previous year, and accompanied by other prospectors anxious to secure claims on Valdez Creek or to discover gold in new placer districts.

The rich gravels of the old canyon on "No. 2 above" and the "Tammany bench" claims were found in the fall of 1904 in an attempt to learn why the gold content of the creek gravels suddenly fell at a particular point in ascending the stream. Panning in the talus on the north side of the creek led to the source of the gold in the earlier concentration of the old canyon, and the most important discovery of the district was made. Not much work was done in the old canyon, however, till the following year. In the fall of 1904 the miners of Valdez Creek, under guidance of a native, went out over the Gulkana trail for the first time, and the Valdez Glacier route was given up.

The value of the total gold production of Valdez Creek, including that of the summer of 1910, is estimated to be about $275,000. There has been a falling off for the last two years, owing to the decrease in yield of the creek gravels, but the reduction will probably not be much greater for some time to come, for there remains gold-bearing gravel that has not been touched, and the prospects for an increased yield from other creeks are good.

SOURCE OF THE GOLD.

A number of conditions make it possible to trace the gold of Valdez Creek to its principal bedrock source and to be fairly confident that the source is within an area of comparatively narrow boundaries. The most important of these is the distribution of gold in the creek gravels. Prospecting has shown that the tributaries of Valdez Creek that flow into it from the hills on the north yield practically no gold. On the other hand, tributaries such as Timberline Creek, White Creek, and Lucky Gulch, that rise in the mountains to the south, carry important gold-bearing gravels. The north side of Valdez Creek valley is a region of schist and altered intrusive diorite; the mountains on the south side of the valley are slates, locally schistose, intruded by diorite and related porphyritic rock. Intrusives are much less abundant than on the north side and are also less altered; in fact, many of them are practically unaltered. The slates therefore appear to be the rocks in which the principal mineralization took place. Prospecting has not yet shown the presence of gold in commercial quantities in the tributary streams east of Lucky Gulch or west of Rusty Creek, although fair prospects have been found on Timberline Creek. It should be kept in mind, however, that all the gravels of these southern tributaries contain small amounts of gold.

The hill between White Creek and Lucky Gulch, known locally as Gold Hill, is of special interest in connection with the bedrock source of gold. This hill is composed of slates, dipping north and intruded in places by a light-colored fine-grained igneous rock. The decomposed material on the hill slope yields fine gold on panning, as a result of which the gold has been traced to sources in bedrock at several places that have been staked as lode claims. None of these places have been opened up in a way to give satisfactory exposures of the gold-bearing rocks, but they show that some of the gold is associated with iron-stained siliceous veins containing pyrite, sphalerite, and galena. The decomposed material from these veins in places yields as much as $1 in fine gold to the pan. In nearly all the exposures examined it was found that the gold-bearing rocks were associated with fine-grained light-colored siliceous intrusives, whose presence leads to the belief that they are a factor in the origin of the gold. Large quartz veins containing scattered crystals of pyrite, but without visible free gold were seen in several places on Gold Hill, and in one locality veins of calcite associated with a little quartz and masses of fine, scaly biotite were found.

The placer gold from Lucky Gulch is of interest in this connection. It is remarkably coarse and contains many large nuggets, some of which are smooth but most of which are rough, with spines and protuberances. Sugary quartz is of common occurrence in the gold. It appears certain from the character of the nuggets and the narrow gulch in which they lie that the gold has traveled but a short distance from its source in the slates. Gold Hill is without much doubt one of the local centers of mineralization, but there is no reason to believe that there may not be other centers in the district. In fact it seems that there may be a nearer source than Gold Hill for some of the placer gold on the lower part of Valdez Creek.

The gold in the creek gravels is a concentration from the product of weathering like that on the slopes of Gold Hill. Some of it is a reconcentration from previous concentration in the gravel. The gold-bearing gravels of Valdez Creek below the Monahan Tunnel are of this kind. They derive their gold in large part from previous deposits in the old canyon. When the canyon of the present stream was being cut down through the old gravel-filled canyon formerly occupied by Valdez Creek the old gravels were reworked by the stream and their gold content was reconcentrated in the form they had when mining began there.

There are points of similarity between the occurrence of gold on Valdez Creek and in the Chistochina district. From the distribution of gold in the gravel Mendenhall[1] reached the conclusion that the placer gold of Miller Gulch, Slate Creek, and Chisna River is derived from an area of local metamorphism within the shales of the Mankomen formation. The mineralization, moreover, is restricted to an area of metamorphosed rocks which forms only a small part of the Mankomen formation as he mapped it. The slates are cut by light-colored granular intrusives, but the amount of these intrusives is much less than on Valdez Creek. The two districts resemble each other in that both are characterized by slightly altered slates intruded by granular igneous rocks.

LODE DEPOSITS.

Little attention has been given to the search for gold lodes in the Valdez Creek district and only a slight amount of work has been done to the present time (1910) toward proving the value of such gold-bearing veins as have been found. No gold has been produced from this source.

Two or three prospects on the north slope of Gold Hill were examined and some of the loose, decomposed vein material was panned, proving the presence of gold in each instance. At the Yellowhorn claim a small open cut had been made in loose talus material consisting of decomposed slate or schist and rusty quartz. No bedrock was in sight but the cut was partly filled with loose material that had slid down into it. Two pans of the waste material from the dump yielded about 10 or 15 cents worth of very fine gold. Much better pans have been obtained from this place.

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, p. 114.

The discovery ledge of the Accident claim is a small exposure of decomposed slates and siliceous fine-grained intrusive rock. The igneous rock is light gray in color and contains considerable pyrite. There is also some rusty vein quartz containing sphalerite and galena. Fine gold is present in the decomposed vein matter. About 300 or 400 feet above the Accident ledge and in the same steep gulch a little stream of water runs down over angular wash made up of slate and rusty quartz. A rocker had been set up at this point and very good prospects were obtained from the gravel. The fine-grained intrusive rock was exposed in the gulch just below it.

These prospects have not yet been shown to be of commercial value, but they are of importance in indicating how the gold occurs and offer encouragement for further search.

PLACER DEPOSITS.

DISTRIBUTION.

Most of the placer gold produced in the Valdez Creek district has been taken from a few claims at the western end of Valdez Creek just above the place where the canyon opens out into the flats of Susitna River, and from Lucky Gulch. It is probable that the gravels of Valdez Creek from the canyon to Roosevelt Creek contain a large quantity of gold, although the concentration may not be sufficient to make them of commercial importance with the methods of mining in use on the creek. The difficulties arising from the low grade of the creek, the depth of the ground, and the large amount of water have prevented careful prospecting to this time.

The three principal tributaries that join Valdez Creek from the south, Roosevelt, White, and Timberline creeks, have not contributed any considerable amount of gold to the total output. White Creek and its largest branch, Rusty Creek, have received more attention than either Roosevelt or Timberline Creek, and this attention appears to be justified by the results of prospecting on Rusty Creek during the last year.

The streams heading in the Alaska Range east of Valdez Creek have received some attention from prospectors, with the result that practically all of them are known to carry small amounts of gold, yet not enough to encourage mining except on Eureka and Windy creeks and near Delta River. A few men were at work on these two streams in 1910.

VALDEZ CREEK PROPER.

Geology.—Valdez Creek is approximately 14 miles long. It flows almost directly west from its source for 10 miles over the gravel floor of a broad, glaciated valley, then enters a canyon about 3 miles long, and finally emerges on the Susitna lowlands. The part above the mouth of Roosevelt Creek is about equal in length to Roosevelt Creek and carries approximately the same amount of water. Valdez Creek has a fall of 1,000 feet in the first 10 miles above the western end of the canyon, or an average fall of 100 feet per mile, but since the grade of the creek is 175 feet per mile through the canyon, the grade above the latter is slightly less than 53 feet.

The mountains about Valdez Creek rise more than 6,000 feet above sea level, or more than 3,000 feet above Susitna River. At the head of the creek they are made up of schist and slate on the south side and altered diorite on the north, but from Roosevelt Creek westward they consist of slate with diorite intrusives on the south side and schist with altered diorite intrusives on the north. The rocks exposed in the canyon are slates, intruded by dikes and sills of fine-grained diorite, which is porphyritic in places.

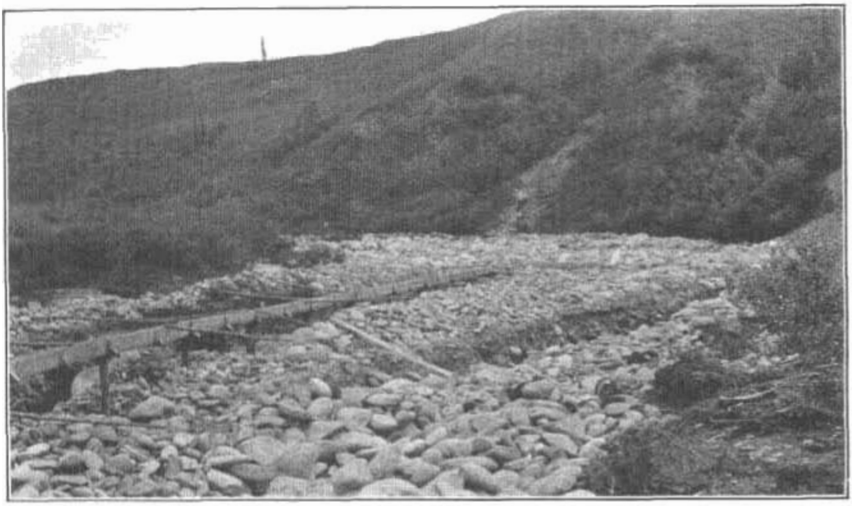
The valley is much glaciated, and in the lower broader part has a conspicuous morainal topography characterized by rounded knolls and swampy depressions. This is its character on both sides of the canyon where the valley begins to open out into that of Susitna River. The unconsolidated glacial deposits are spread over an uneven rock floor (Pl. VII, *B*, p. 52), which, though it doubtless owes its form in part to ice action, had a drainage system developed on it before the glacial gravels were laid down and the present channel of Valdez Creek was formed.

Valdez Creek has cut its canyon through the overlying gravels into the slates beneath to a depth of over 175 feet, and in so doing has intersected an older gravel-filled canyon whose bottom is 60 feet higher than the present creek level. The depth of the new canyon is greatest below the falls, a short distance downstream from the old canyon, at a point where the overlying gravels are shallow and almost the entire cut is in slates. Above and below, the depth of the canyon decreases.

Mining development.—Mining development on Valdez Creek has been concentrated on four or five creek claims and two bench claims. The creek claims are Discovery, No. 1 below, No. 2 below, No. 2 above, and No. 3 above; the bench claims are Tammany bench and the claim adjoining No. 1 below on the south. Their location is shown in figure 8.

Discovery, No. 1 below, and the lower half of No. 2 above were the richest of the creek claims, but none of them have equaled in value the Tammany bench claim. The first claim above Discovery includes the narrowest and deepest part of the canyon, where the stream is confined between perpendicular slate walls, and no mining is carried on.

Creek gravels.—It is unnecessary to describe the gravel deposits of each creek claim in detail, because the variation in character is not



A. BOWLDERS FROM STREAM GRAVEL ON VALDEZ CREEK.

B. WING DAM IN CANYON ON CREEK CLAIM ADJOINING THE "TAMMANY BENCH," VALDEZ CREEK.

great. In general the gravels range in thickness from 3 to 8 feet on the three most productive claims and consist of slate, schist, and diorite, with which is associated a small amount of light-colored porphyritic intrusives and dark basic and tuffaceous material. An important and unfortunate characteristic of the gravel is its large content of bowlders (Pl. VIII, *A*).

At the upper end of claim No. 3 above, the gravel deposit reaches a thickness of 10 to 12 feet. The upper 6 feet contains many diorite bowlders and overlies finer gravel consisting of slate and diorite cobbles. Such a bowlder bed might indicate either a change in glacial conditions or simply a concentration of bowlders from deposits whose

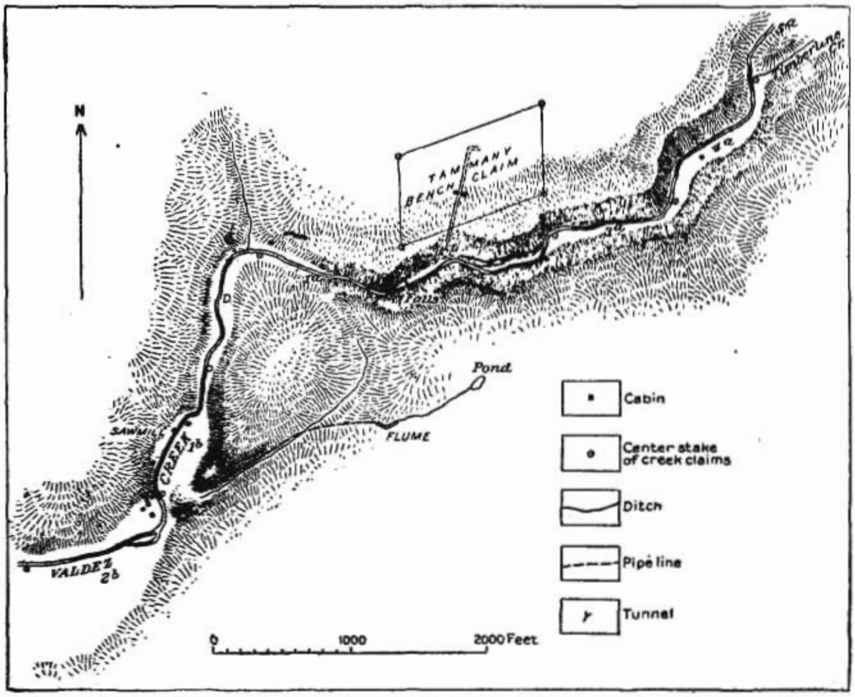


FIGURE 8.—Sketch map of part of Valdez Creek, showing location of producing claims.

finer material has been carried away, but the absence of large bowlders in the underlying material suggests some different condition of deposition.

Much the larger proportion of the bowlders are diorite. They reach diameters of 5 or 6 feet and are a source of much expense to the miners, for they can be moved only at great expense and then only for short distances. It is customary when possible to undermine them on one side and cause them to roll over, thus permitting the gravel beneath to be taken away.

Gold from the creek claims shows variation in its form and appearance. Some of it is flat and well worn, but other specimens are rough and show little effects of wear. Gold from the claims above the Monahan tunnel is finer and less worn than that below, but a small proportion of smooth flat gold is present. The decrease in coarseness is more marked downstream from the tunnel than in the opposite direction, so that there seems to be no doubt that the old canyon gravels are responsible for the richness of Valdez Creek downstream from claim No. 2 above. The gold is associated with a large amount of red garnet or "ruby sand," and a little magnetite or "black sand." Magnetite is less abundant than might be expected from the quantity of igneous material in the gravel. An idea of the coarseness of the gold on claim No. 1 below may be gained from the statement that the largest piece found there in 1910 was worth $1.75 and the next largest $1.25.

The richest claim on the creek was Discovery claim, but the richest spot was on claim No. 1 below, a short distance downstream from the sawmill dam. A little more than one-third of the total gold production of Valdez Creek from 1903 to 1910 came from the creek claims, but so much of the rich ground has been mined out in that time that a falling off in production has taken place.

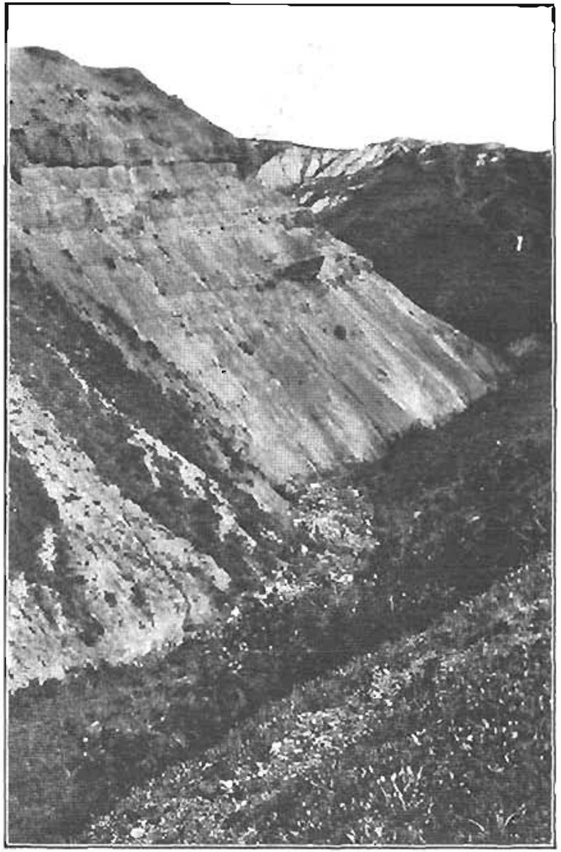
All the work on the claims above No. 2 below has been done with pick and shovel. The creek water is diverted by wing dams (Pl. VIII, *B*) or ditches, and the gravel is shoveled into the sluice boxes without the use of special mining appliances. Hydraulic mining was conducted on claim No. 2 below in 1909, and a Ruble elevator was used in disposing of the cobbles and bowlders; but the results were probably unsatisfactory, for the work was not continued in 1910.

Bench gravels.—Tammany bench and the claim adjoining No. 1 below on the southeast are the only bench claims on the creek that have been much developed.

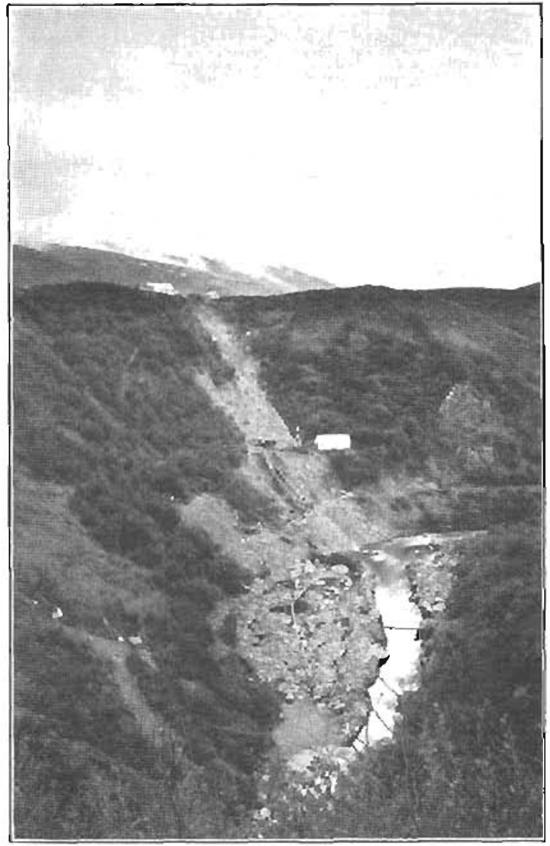
The Tammany bench is of particular interest both because of its unusual character and because it has yielded a large part of the gold produced in this district. The gold-bearing gravels are worked through a tunnel that follows the bottom of an old canyon in the slates now filled with gravel so that no trace of its presence is visible at the surface. The general course of the canyon so far as it has been traced is N. 15° E. It thus makes an angle of about 48° with the present course of Valdez Creek. (See fig. 8.)

The tunnel starts on the north side of claim No. 2 above, at an elevation approximately 60 feet above the present creek bed, and is driven across the north side of the creek claim into the adjoining Tammany bench (Pl. IX, *B*, p. 62, and fig. 9). Its length in August, 1910, was about 700 feet.

From the tunnel floor to the surface of the bench is a distance of 110 feet, which is the thickness of gravel filling in the old canyon,



A. TERTIARY CONGLOMERATE AND SANDS ON A TRIBUTARY OF PHELAN CREEK.



B. THE MONAHAN TUNNEL AND SECOND CREEK CLAIM ABOVE DISCOVERY, ON VALDEZ CREEK.

for on either side of the tunnel bedrock outcrops within a few feet of the surface of the bench. Variations in the course of the tunnel are slight and of no importance, unless the abrupt eastward turn at its end marks the beginning of a new course. Attempts to determine the position of the old canyon on the opposite side of Valdez Creek have been made, but without conclusive results.

The rocks of the canyon walls exposed in the tunnel are slate or schist. In places the walls are waterworn, and wherever exposed they rise steeply on either side. Two crosscuts were driven from different points in the tunnel, one about 100 feet to the west, the other 60 feet to the east, but the sum of these measurements exceeds the width of the canyon. The tunnel, being more nearly straight than the canyon, crosses from one wall to the other, so that the crosscuts exaggerate the width. The maximum width is probably about 100 feet.

No difference exists between the rock material in the gravel of the old canyon and that of the creek, but variations occur in the character of the deposit. The lower 50 feet of gravel in the canyon contains flat diorite bowlders with rounded edges, rounded slate and schist fragments, and fine black clay. The upper part of the filling presents a greater appearance of disorder, and contains a larger proportion of diorite bowlders, which are round rather than flat. The gravel, too, is not so clean. Probably this upper deposit is due either to a revival of glacial activity before the canyon was filled or represents the last bowlder material laid down as the ice retreated.

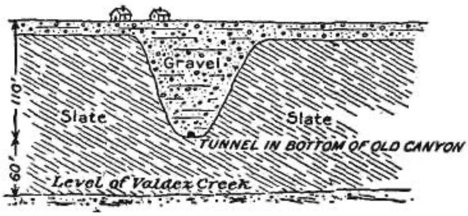


FIGURE 9.—Relation of the old canyon of the Tammany bench claim to the present channel of Valdez Creek.

Gold is found chiefly in the lower 5 feet of the gravel, although fine gold occurs in all the canyon filling. Most of it comes from the hard black clay and fine rounded slate gravel. It is coarse, flattened, and smooth for the most part, though rough pieces are present. Nuggets worth several dollars are common. As has been stated, the gold from the tunnel closely resembles that from the creek, the chief difference being a decrease in coarseness of the creek gold that becomes more pronounced downstream.

The tunnel is timbered with strong square sets and is lagged overhead but not on the sides. Great care is taken in framing the timbers and in fitting them together so that they will remain in place. Square sets are also used in the stopes but are not made of selected timber as are those in the tunnel. The stopes are generally from 25 to 35 feet wide, but reach 70 feet where the width of the gold-bearing gravel deposit was greatest.

The old canyon gravels are favorably situated for the application of hydraulic mining methods. Valdez Creek will supply water for moving the gravel without great expense, and its canyon provides an excellent dump for the disposal of tailings. A rough measurement, made a short distance above the Valdez Creek canyon at the end of August shortly after a rain, showed a flow of more than 150 cubic feet per second. This figure, however, is not intended to be used in calculations for the installation of hydraulic mining machinery. Measurements for that purpose should extend over a considerable period of time.

Steps have already been taken toward making the water available for mining purposes. A ditch, begun several years ago on the eleventh claim above Discovery, has been added to each year, till it now has a length of a little more than 4,000 feet and has reached a point 4,600 feet from the cabins on the Tammany bench. It was constructed as part of the assessment work on the claims which it crosses. The intake of the ditch is 525 feet higher than the creek at the sawmill dam on claim No. 1 below. The ditch runs over ground favorable for such construction and can be completed without unusual cost so as to furnish water for any of the claims below Timberline Creek.

The bench gravels east of claim No. 1 below are of entirely different character from those of the Tammany bench. They are in part the deposit of a small stream that joins Valdez Creek near the upper end of claim No. 2 below. This little stream drains a slight depression southeast of the creek heading near the canyon on claim No. 1 above, and at its lower end drops over the rock wall to the head of the main stream. The bedrock is slate and graywacke or fine slate grit. On the point between the little stream and Valdez Creek there are 15 to 20 feet of well-rounded gravel with a few bowlders, none of which are more than 12 to 16 inches in diameter and most of which measure not more than 10 inches. Many of the diorite pebbles are decomposed and can easily be broken with the pick, but a few are fresh and hard. In the cut from which the gravel has been mined, however, large diorite bowlders are abundant. The stream gravel carries gold which is believed to be a concentration from gravel like that on the point. Mining operations were carried on here in 1909. Water was brought from Timberline Creek, a distance of 1½ miles, by a ditch and short pipe line, and two hydraulic giants were used to move the gravel. The work was probably not very profitable, however, for it was not continued in 1910.

A. GOLD NUGGETS FROM LUCKY GULCH.

B. BOOMER AND DAM ON RUSTY CREEK.

LUCKY GULCH.

Lucky Gulch is about 6 miles east of the main camp on Valdez Creek. It is a steep gulch a little more than a mile long on the north side of Gold Hill, and was formed by a little stream whose principal source of supply is melting snow. The stream has cut a narrow V-shaped channel in slates that dip 20° N., about the same as the grade of the stream. The gulch is on the north side of the hill, and as a consequence the snow that drifts into it in winter melts slowly in summer, so that although it prevents the miners from beginning work early in the spring it provides the chief source of water later in the summer.

The gulch is too steep and narrow to permit the accumulation of a large body of gravel, but the depth of the deposits counterbalances in a measure their lack of breadth. The gravel is made up of angular fragments and slabs of slate like the bedrock, with very little well-washed and rounded material. A small amount of fine-grained diorite rock is present, as well as some quartz, but slate is the chief constituent. The slate bedrock has a well-developed cleavage and its surface in places is covered with small crystals of ottrelite.

Lucky Gulch gold is coarser than that from any other part of the Valdez Creek district. In general it is rough and many pieces contain fragments of granular quartz, although some of the gold is flattened and well worn. This difference in surface character probably indicates nothing more than a variation in the amount of rubbing and pounding the pieces have undergone in traveling down the gulch, for there is little doubt that the gold is derived from a small area and has not moved far from its source. Large nuggets form an important part of the gold product of this stream. One found in 1910 weighed 32 ounces (Pl. X, *A*), and a larger one weighing 52 ounces was taken from the gulch two or three years previously. Nuggets like these, which evidently are not far from their bedrock source, offer much encouragement to the prospector for gold lodes.

Lucky Gulch is free from the big diorite bowlders that give so much trouble on Valdez Creek. It contains a great many slabs of slate that must be moved, but most of them can be broken with a sledge or disposed of by aid of a little powder. A short season and scanty water supply counterbalance this advantage in a measure, however. The most effective method used for moving gravel in Lucky Gulch is by booming (see p. 64), but a small hydraulic nozzle and canvas hose is employed at times. Most of the gold lies on bedrock in the bottom of the gulch, and it is mined from a deep cut without disturbing the wash on either side, so that no more gravel is moved than is necessary. The walls of this cut are 25 feet high in places. Part of the gulch has been worked out, but a large amount of untouched gravel still remains.

WHITE AND RUSTY CREEKS.

White Creek joins Valdez Creek 4½ miles east of the main Valdez Creek camp. It has three branches, known as Big Rusty, Little Rusty, and Rusty creeks. These streams head in the complex of slates, tuffs, and basalt of the mountains between Valdez and Windy creeks, but their lower courses are in slates. Some prospecting has been done on White Creek, but it did not yield much encouragement, because it was carried on under great difficulty and expense, due in part to the high cost of supplies and lumber but chiefly to troubles arising from deep gravels and much water.

Prospecting on Rusty Creek has also been carried on in the face of many difficulties and great expense. During the years from 1908 to 1910, inclusive, a cut several hundred feet long and more than 25 feet deep in places (Pl. X, *B*) was made in the channel of the creek a short distance above its mouth. This cut follows the east side of what appears to be an old rock-walled channel or canyon where the northerly dipping slates of the bedrock are exposed, but is not wide enough to uncover the western wall if it is present. The gravels filling the channel include an upper deposit of unsorted glacial débris from 10 to 20 feet thick consisting of slate and basalt. Under this is a deposit of fairly well-sorted gravel and coarse sand showing a distinct cross-bedding dipping to the north. Many large bowlders on the bottom of the cut are derived from the upper bed of glacial material; most of them are basalt and come from the head of the creek, but a few of them are diorite, probably derived from the valley of Valdez Creek. Encouraging gold prospects were obtained from the projections of the rock wall on the east side of the cut and especially from the bottom of the cut where work ended in 1910. The gold is very rough and bright. Few pieces of greater value than 10 to 20 cents were found in the upper parts of the cut but the coarseness increases toward the bottom, and the deepest gold so far obtained was of such a character as to encourage the owners in the belief that they were near bedrock.

Booming has been adopted on Rusty Creek as well as on Lucky Gulch, and has made possible the large cut just described. The boomer consists of a dam with a gate (Pl. X, *B*) that opens automatically when the water level reaches a determined height and suddenly releases a large volume of water, which rushes through the cut, tearing up the gravel and carrying it away. The effectiveness of such a contrivance is hardly realized until the results of its operation have been seen.

Rusty and White creeks give more promise than any of the other tributaries of Valdez Creek for extending the known area of gold-bearing gravels, for they cut slates that have been shown to be auriferous. Undoubtedly some concentration of gold has taken place during the time the slates have been subjected to erosion, but only prospecting can determine whether the concentration has been sufficient to produce placer-gold deposits of commercial importance.

TIMBERLINE CREEK.

Timberline Creek joins Valdez Creek near the boundary between the fourth and fifth claims above Discovery. It is a little more than 2 miles long and flows through an area of slates into which a small body of diorite has been intruded. Its position with reference to Valdez Creek and its relation to Rusty and White creeks are such that it is doubtful whether it has invaded the area of mineralization from which these other streams derived much of their gold, and prospecting has yielded so little encouragement to the miners that no important amount of work has been done on the stream for several years.

DELTA RIVER DISTRICT.

The gravel bars of Delta River contain a small amount of fine gold, but not enough of the metal has been found to make them of importance commercially. Gold was panned by members of the writer's party from the gravels of Delta River near Garrett's cabin, 3 miles above the mouth of Eureka Creek, in 1910, and the presence of gold-bearing gravels in the river has been known since 1900 at least. Brooks[1] mentions a rumor of gold on Delta River as early as 1898, but was unable to verify the report. Eureka and Rainy creeks however, have produced a small amount of gold for a number of years. Mendenhall[2] states that the first prospectors on Delta River, who made their way there from Chisna River in 1900, "found colors generally on the stream bars, and what they regarded as fair prospects on Wilder Creek, or, as they called it, Rainy Creek. After the return of these men to the Chisna, a larger party was outfitted, and, returning to the region, organized the Eureka mining district. In the following spring (1901) from 200 to 250 people entered the new district and 20 or 30 of them began sluicing, but the results being unsatisfactory the field was abandoned."

The district was not entirely abandoned, however, for a few men have continued to prospect on Eureka and Rainy creeks and have taken out enough gold to give them some encouragement in the hope of final success in their effort to develop a producing district. Seven men were engaged on the two creeks in 1910—two on Eureka and the rest on Rainy Creek. They were visited by members of the topographic party at the beginning of the season, but not by members of

[1] Brooks, A. H., A reconnaissance of the Tanana and White River basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 1, 1900, p. 484.

[2] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, p. 117.

the geologic party, and the success of the summer's work was not learned. These two streams receive nearly all their water supply from the area of rocks north of Eureka Creek correlated with the Chisna formation. It is known that intrusions of diorite rocks exist in this vicinity and it is thought from analogy to the Valdez and Slate Creek districts that the presence of these is probably connected with the mineralization.

A few men were prospecting in 1910 on streams in the hills and lowland area west of Gulkana Lake about the headwater region of the western tributaries to Gulkana River, but with little success. The gravels contain a little fine gold, but so far as the writer knows the concentration is not sufficient to give them commercial value.

CONDITIONS AFFECTING MINING.

Practically all the conditions affecting mining have been referred to in previous pages, but the more important ones are brought together here for the convenience of the reader. Only the Valdez Creek district will be considered because it is the only part of the region described that has been an important producer of gold in the past or, so far as now known, gives much promise for the future.

Aside from the amount of gold contained in the gravel and the possibility of recovering it, the important conditions that affect mining have to do with transportation and the supply of water and timber for mining purposes. Many other factors, such as stream gradient and cost of labor, also have a bearing on the success of placer mining, but in most places the three first named are of most importance.

It has been mentioned (p. 20) that most of the supplies used on Valdez Creek have been brought from Valdez in winter with horses and sleds at an average cost of about 30 cents per pound. The improvements on the military road will doubtless make it possible to reduce this cost considerably and a further reduction may be brought about by sending freight part way by railroad. The cost of carrying freight from Gulkana to Valdez Creek, however, can hardly be reduced unless closer communication with a railroad shall be established, which is not likely in the near future.

Valdez Creek has a supply of water for hydraulic operations on the lower part of the creek adequate for any demands likely to be made on it. The water can be obtained by ditching over favorable ground without unusual expense and delivered with a head of 200 to 300 feet, depending on the point where it is to be used. The canyon, moreover, affords a good dumping ground for tailings, but any plan for mining must provide means for handling the great number of bowlders in the gravel. Water can not be procured under such favorable conditions above the canyon, that is, higher on the stream than the eleventh claim above Discovery, for the grade is lower and the ditches would, therefore, have to be longer. For the same reason the disposal of tailings would be more difficult.

A supply of timber for use in mining and for fuel when coal is not available is essential to the success of any mining operation. The most productive part of Valdez Creek is situated at the upper limit of spruce timber, but the hill slopes bordering the flats of Susitna River provide a supply sufficient for many years to come. Most of the larger and better trees within several miles of the sawmill on claim No. 1 below have been cut since 1903, so that it is necessary to haul logs for lumber a considerable distance. Firewood may be obtained more easily. All the logs for sawing and for fuel and all the timbers used for square sets in the tunnel are hauled to the sawmill or to the place where they are to be used before the snow melts in the spring. Cutting the timber and bringing it in is the first work that receives attention after supplies for the summer are landed on the creek.

The cost of labor is $10 a day, without board, for work during the mining season. It is, therefore, evident that this item of cost is higher than in placer-mining districts where communication with a labor market is easier. It is possible that this expense may be reduced when the line of travel over the military road becomes better established, thus making it easier for men to move about from place to place; but Valdez Creek is 65 miles from the road and is not connected with it by a trail sufficiently well marked to enable a stranger to follow it. Furthermore, there are no camps or road houses along the way where men could get food or rest.

At present there is no mail service to Valdez Creek, although mail was brought from Gulkana by private carrier during the summer of 1910. The military telegraph line which follows the road from Valdez to Fairbanks does not connect with Valdez Creek.

The miners of Valdez Creek are dependent on game for fresh meat. Most of it is obtained from the natives by trading tea, sugar, flour, tobacco, and clothing. Caribou and moose are the most important game animals, but all game is much less plentiful than when the miners first entered the region, and sheep have practically disappeared from the south side of the Alaska Range from Susitna to Delta rivers. None were seen by members of the writer's party in 1910, and the miners report that there are none. Caribou, however, are still sufficiently plentiful to provide the chief source of meat. During the summer they seek the higher parts of the Alaska Range, and their tracks are often seen along the glaciers and on the tops of high ridges where one would ordinarily expect to find sheep. Possibly they go there to seek relief from flies and mosquitoes. Toward the end of summer they come down to lower ground and often can be taken with little difficulty.

Moose, on the other hand, seek the thickets along the mountain streams in winter or early spring and return to the lowland areas in summer. They are far more difficult to find than caribou and more skill is required to shoot them after they are found. The swampy lowland between the Copper and the Susitna is an excellent country for moose.

Fish are abundant in many of the lakes and in some of the clear-water streams. Grayling are plentiful in Delta River above Eureka Creek, but, except for the salmon, the finest and largest fish in the region is a trout found in some of the lakes, such as Summit Lake and the two lakes at the head of Roosevelt Creek.

SUGGESTIONS.

A few suggestions may be of aid to the prospector. The known areas of mineralization in the headwater region of Copper and Susitna rivers are areas of slates intruded by diorite. It is believed that a genetic relation exists between the presence of gold in the slates and their intrusion by the diorites and the related porphyritic dikes and sills. It is, therefore, advisable to give attention to gravels derived from such sources, for although they can not be predicted with certainty to carry gold they are at least more favorable places for search than areas where only one of these rocks is present. Failure to find mineralized zones at the contacts of the diorite and the slate is not evidence against the influence of the igneous rocks as a factor in the deposition of gold in the slates, for the physical or chemical conditions may have been such that the influence was effective only at some distance from the intrusive mass. Gold deposits of the contact-metamorphic type are known at the head of Nabesna River but have not yet been recognized either in the Slate Creek or the Valdez Creek districts.

Those parts of the region occupied by basaltic lavas, such as the south side of Windy Creek and the area south of Eureka Creek, do not offer much encouragement for prospecting, for although some of the streams in these areas have gravels that contain fine gold it is probable that the gold has been transported there from other sources. So far as now known the same statement is true of the diorite areas.

Another characteristic which the Valdez Creek gold placers possess in common with the placers of Chititu and Dan creeks in the Nizina district and perhaps also with part of those in the Slate Creek district is that the richest of them are reconcentrations from previous concentrations in older gravel deposits. It is, therefore, important to examine the gravels of those streams in mineralized areas where the water is now cutting away and re-sorting the bench gravels—a generalization the truth of which was at once recognized by those who first discovered that the rich gravels of Valdez Creek below the Monahan tunnel owed their value to the fact that Valdez Creek, in cutting its present canyon, had tapped the previous concentration of gold in the older canyon. Although this instance is exceptional and should not be expected to be commonly duplicated, it is probably true that a very large number of rich placer deposits owe their existence to reconcentration from previous concentrations of gold in older gravel deposits and that this reconcentration may have been repeated many times.

COAL.

A small outcrop of coal occurs on Coal Creek, a tributary of Clearwater Creek, near the boundary between the slate and the basalt areas. It is on the south side of the creek about halfway from the mouth to the head and is exposed in a bed whose thickness is uncertain but is probably at least 6 or 8 feet. The coal, which is much faulted and crushed, stands on edge between walls of yellow shale that break down in angular fragments and show evidence of great disturbance. The contact between the coal and the shale on one side is a vertical fault contact, which strikes N. 65° W. Coal dust and small fragments of coal, such as coal miners call blossom, are exposed about this outcrop north of the creek for nearly half a mile, but it is doubtful whether the bed persists so far with equal thickness.

The coal is a lignite. It has been tried for blacksmith's use but proved less satisfactory than charcoal. It would be of some local value for cooking and heating if it could be conveniently carried to Valdez Creek, but it probably has no other value.

CHISTOCHINA DISTRICT.

INTRODUCTION.

The term Chistochina district is here used to include the gold-producing streams at the head of Chistochina River (Pls. III and XI), of which the most important are Slate Creek, its tributary, Miller Gulch, Chisna River, and Ruby Creek. Lime Creek or Lake Creek and the Big Four claims north of Slate Creek, on the mountain slope facing Chistochina Glacier, complete the list of localities whose gold production in 1910 contributed more than a nominal amount to the total output of the district.

The Chistochina gold placers were visited by Mendenhall in 1902, three years after the first mining locations were made.[1] The present description is based very largely on his report and contributes little to it further than to bring the account of the development up to date. The sections on "geography and drainage" and "history" are quoted from Mendenhall without change.

GEOGRAPHY AND DRAINAGE.

The gold field does not lie in the Alaska Range proper, but in a group of foothills that are separated from the main chain by a conspicuous piedmont valley, which extends 20 or 30 miles east of the head of Chistochina River and is occupied by Chistochina Glacier and the upper courses of Middle Fork, the Slana, and the Tok, and the various passes which connect these streams.

North of this feature the peaks of the great range rise abruptly to elevations of 8,000 or 9,000 feet. South of it the nearest foothills are 6,000 or 6,500 feet in height, but decrease in altitude as their distance from the axis of the range increases. These foothills are in detached groups, which, near the main range, occupy relatively large areas, the valley lowlands separating them occupying relatively small areas. This relation is in a measure reversed along the lower Chistochina near the Copper, where the foothills are often small islands rising above the general gravel plain of the Copper Valley.

The particular foothill group in which are found all of the producing claims of the district lies between Chistochina and Middle Fork and south of the western end of the piedmont valley that has been described. It is drained by tributaries of one or the other fork of the Chistochina, the largest of these tributaries being the Chisna. This small river rises in a cirque 3 or 4 miles south of the east end of Chistochina Glacier. It flows north of west for 2 miles or more, directly toward a low pass leading to Slate Creek, then turns abruptly southward and joins the Chistochina 7 or 8 miles below the mouth of West Fork. Its total length is only 12 or 13 miles. Slate Creek lies west of the

[1] Mendenhall, W. C., The central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, pp. 107–117.

upper Chisna, its lower course occupying the western end of the same depression which has controlled the upper course of the larger stream. Before entering this cross valley it flows southward for a little more than 1½ miles from the two small glacial remnants in which it rises, and after entering it follows it westward for 2 miles to the Chistochina, which it joins just at the foot of the glacier. Its total length, therefore, is not over 4 miles. Miller Gulch, the most important producer of the district, is a small northern tributary of Slate Creek, less than a mile long.

HISTORY.

The first locations in the Chistochina gold field were made by Hazelet and Meals, in the summer of 1899. These gentlemen were among the army of argonauts who crossed the Valdez Glacier in the spring of 1898 with the idea of prospecting within the Copper River basin. Building a boat on the Klutina, they descended that stream and ascended the Copper and the Christochina, reaching the present location of Chisna post office in early July. They found encouraging prospects here, but their provisions becoming exhausted, they returned to Copper Center for a larger supply, reaching the Chisna again in August of the same year. In September they returned to Copper Center and during the following winter sledded supplies to a point on the Chistochina near the mouth of the East Fork, and from this base continued their work on the lower Chisna throughout the summer of 1899. Coarse gold was discovered at this time, and several locations were made.

In the spring of 1900 these operators, together with a number of the present Miller Gulch and Slate Creek claim owners, returned to the Chistochina with a good stock of supplies, a sawmill, and some hydraulic machinery. During this summer gold was discovered on Slate Creek and Miller Gulch by Coles, Jacobson, Kramer, and Levell, the ground staked at that time having since proved to be much the richest in the district.

TRAILS.

The regularly used winter trail from Gulkana to Chisna River and Slate Creek follows Copper River to Chistochina and ascends the stream of that name. All freight is taken in during the winter months by this route, and until recently most of the summer travel followed it also. Since the military trail was turned into a road there has been a tendency to make use of it in the summer months and thus avoid the exceedingly bad, swampy trail along Copper River. It is approximately 25 miles from Paxson on the military road to Slate Creek. The trail offers good footing for horses most of the way and presents no serious obstacles to travel, its most objectionable points being at two crossings of West Fork of Chistochina River in the canyon, where the water is confined to a single channel. Like all glacial streams, this one is subject to quick changes in the amount of water discharged from the glacier and may be impassable to-day where yesterday it afforded an easy crossing. The stream is a small one and is not hard to cross where it spreads out, but when confined to one channel it often presents difficulties. Doubtless these can be avoided when better trails are made and more favorable crossings are chosen.

MAIL AND TELEGRAPH FACILITIES.

A post office established at Dempsey, on the west side of Chistochina River near the mouth of the Chisna, has a regular bimonthly service in summer and a monthly service in winter. The mail route follows Copper and Chistochina rivers, thus serving Gakona and the telegraph station at Chistochina as well as Dempsey.

The military telegraph station at Chistochina is 35 miles from Dempsey and 45 from Slate Creek. Slate Creek, as already indicated, is about 25 miles from Paxson, the nearest telegraph station on the military road.

GOLD PLACERS.

OUTPUT.

Mining began in the Chistochina district in 1899 and continued with a steadily increasing gold production for several years until, as in all placer districts, the richest and more easily mined gravels approached exhaustion. It is estimated that the total gold production of the Chistochina district, including the year 1910, has been a little more than $1,500,000, of which Miller Gulch has produced a large proportion.

Between 40 and 50 men were employed in the Chistochina district in 1910, most of them on Slate Creek. The population is much less than it was two or three years ago, the decrease corresponding approximately to the falling off in gold production.

DETAILED DESCRIPTIONS.

MILLER GULCH.

Miller Gulch is a deep, narrow depression cut in the slates north of Slate Creek by a little stream less than a mile long. The ground was not staked till after Slate Creek was taken up, for no one suspected that its gold-bearing gravels were more valuable than those of the main stream, as later turned out to be true. There were originally eight 600-foot claims on the stream, but only seven are now held. As described by Mendenhall:

> The bedrock floor of the gulch is sheeted with coarse gravel to a depth of from 4 to 8 feet. This gravel is derived principally from the slate country rock and its diabasic and "bird's-eye porphyry" intrusives, but contains also noticeable percentages of granitic cobbles derived from the "round wash" which covers the surrounding hills. The gold is reputed to be generally distributed horizontally across the gulch, without definite pay streaks, but vertically it exhibits the usual concentration near bedrock. Ill-defined benches exist on either side of Miller Gulch at 100 or 200 feet above creek level. They are reported to prospect well, but are not now (1902) worked for lack of water. Their origin is probably connected with the glacial history of the region.

The gold of the gulch is usually flat and smooth and is very rarely found attached to quartz or country rock. It occurs as rather coarse dust and small nuggets, the largest of these reported so far weighing about 4 ounces. One-ounce nuggets are not at all rare. The gold increases in average coarseness toward the head of the gulch, whence most of the finer dust has been removed. Its assay value is said to be about $18 per ounce.

Small copper nuggets, bits of cinnabar, magnetite grains, and an occasional silver-white fragment of osmiridium are found associated with the gold in the sluice boxes.

Less mining was carried on in Miller Gulch in 1910 than in any previous year since work began there. This was not due to the exhaustion of gold-bearing gravels, but to a temporary suspension of work in order to avoid covering unworked gravels in Slate Creek with tailings. The water supply of Miller Gulch available for mining operations is small, so that it has been the custom of the two principal claim owners to use it in alternate years. In this way all the bed of the gulch has been worked out, but there still remain bench gravels that will be exploited as soon as the ground below can be used for dumping.

SLATE CREEK.

Slate Creek, as previously stated, joins Chistochina River a short distance below the glacier and is approximately 4 miles long. Its channel marks the boundary between the Chisna and the Mankomen formations, but the bedrock also includes some infolded Tertiary beds with which coal is associated. The gravel deposits of Slate Creek are to a considerable extent intimately connected with the glaciation to which the region has been subjected. Mendenhall says:

During the recent glaciation of the region the drainage has been considerably disturbed, and in this disturbance the channel of Slate Creek has been much modified. Two shafts sunk during the last two years just east of the bed of Slate Creek, opposite Chisna Pass, reached rock at 75 and 90 feet, respectively; that is, at from 40 to 55 feet below bedrock level in Slate Creek, less than 100 yards away, a difference probably attributable to the shifting of the channel of the creek during the late occupancy of the valley by ice.

It is to be noted in this connection that if Chistochina Glacier were to advance slightly the waters of Slate Creek would be dammed and forced out over the Chisna divide, thus reproducing a condition which has probably prevailed in the recent geologic past.

Difficulty is also encountered in the attempt to reach bedrock on the claims immediately above the mouth of Miller Gulch. The difficulty here is probably due more to the filling from a tributary stream whose fan has spread out over the Slate Creek bottoms than to any extensive excavation because of glacial action.

In that part of the upper Slate Creek channel where any sluicing has been done the gravels are from 4 to 10 feet in depth and the yield has been practically the wage of the district, $10 to $15 per day per man. As has been stated, one or two of the claims just below Miller Gulch are rich, and are being extensively worked at a profit, but the other workings on the lower part of the creek, like those on the upper, are erratic. * * *

A narrow bench 10 or 15 feet above the level of the bed of Slate Creek, opposite the mouth of Miller Gulch, was one of the first areas in the district worked. Several thousand dollars were sluiced here from a space covering a few hundred square feet. The bench presumably represents a portion of the old Miller Gulch fan, and the gold is regarded as derived from the gulch.

The Slate Creek gold is similar in form, color, and purity to that of Miller Gulch, but is not quite so coarse.

About 20 claims on the channel of Slate Creek and a number of bench claims adjoining them have been located. The first three claims above the mouth of Slate Creek are virgin ground, but are difficult to work because of the depth of gravel and the large amount of water. A hole 21 feet deep near the south side of the gravel flood plain did not reach bedrock. Tailings from above are another source of trouble on the lower claims. A dam was built near the mouth of the creek in 1910 to furnish water for booming a low bench on the north side, but was not completed in July when the district was visited.

On the fourth, eighth, and ninth claims above the mouth mining was confined to the bank on the south side of the stream. A heavy deposit of glacial material, consisting of blue clay or glacier mud and large bowlders, is exposed there. It is overlain by a deposit of frozen yellow talus or "slide" rock from 5 to 25 feet thick, derived from the mountain slope on the south. The glacial material contains gold and is exploited by undermining and caving. Bowlders are piled back from the cut to form a channel along the foot of the bank, and then the water is turned in to undermine the bank and wash away the fine gravel. Afterward the remaining gravel and gold is shoveled into the sluice boxes. This work is slow and dangerous, because the high bank of frozen gravel above sloughs off continually as it thaws and at times breaks down in large masses, so that men must be constantly on the alert and ready to jump to a place of safety.

The largest force of men at work on the creek in 1910 was near the mouth of Miller Gulch on ground that has been the richest in the district and still produces gold. This Tacoma claim, as it is called, together with the lower part of Miller Gulch, has yielded more gold than all the other claims of the district. The gravels of Slate Creek above Miller Gulch are of lower grade, and only a few men were employed there, but their contribution to the gold production of the creek is important.

BIG FOUR CLAIMS.

The Big Four claims are on a little stream that heads against Miller Gulch and flows down to Chistochina Glacier on the north side of the mountain between the glacier and Slate Creek. It has not been an important contributor to the gold output of the district, but has given employment to a few men for a number of years. It is of importance in a geologic way as giving some additional support to the belief that the slates north of Slate Creek are the source of the gold in Miller Gulch and Slate Creek rather than, as is held by some, that it came from a distant foreign source. The gold is finer than that from Miller Gulch.

RUBY CREEK.

The most important gold-producing stream in this district, after Slate Creek and Miller Gulch, is Ruby Creek, a tributary of Chisna River, which lies just east of Slate Creek and is separated from it by a broad low divide. Ruby Creek has thrown out a wide fan of gravel extending in a semicircle from the point where the creek leaves a narrow gulch in the mountains at the head of Chisna River, thus forming a long smooth slope to the west, south, and east. The creek has cut a channel ranging from 15 to 20 feet in depth in this gravel fan. The gravels are gold bearing, and mining is carried on in them and also in a short bend of filled and abandoned channel at the head of the fan just within the gulch, where for some reason the creek cut a new rock-walled channel within a few feet of its former position. So far as now known the gold content of the gravels that filled the old channel is low, though great enough to encourage prospecting and to pay its cost. The old channel is adjacent to some of the richest ground discovered on Ruby Creek. Work is hindered by snow and ice, which do not always melt in summer, so that even the water for sluicing is brought through a tunnel in the ice.

Bedrock has not been exposed in Ruby Creek where it crosses the gravel fan. The false bedrock which holds the gold is a thin gravelly clay bed only a few inches thick. In cutting its present channel Ruby Creek concentrated the gold contained in the gravel removed and left it on these clay beds or lenses. Only a few feet of gravel are shoveled into the sluice boxes and care is taken not to go below the false bedrock into the barren gravel beneath. These gravels are the source from which most of the gold from Ruby Creek is derived. Mendenhall states that the gold of Ruby Creek is "similar to that of Miller Gulch, bright yellow, smooth, and flat, only occasionally rough or in rounded pellets. A number of small nuggets have been found, the largest of which is worth $12.75. The assay value of this gold is reported to be $18 or $18.50."

CHISNA RIVER.

Chisna River occupies an intermediate position between the main stream of Chistochina River on the west and its middle fork on the east. Its valley is separated from Slate Creek by a broad low divide and from Middle Fork by another slightly higher divide. Between the stream and Chistochina Glacier is a rough, high ridge of limestone and slates belonging to the Mankomen formation, but it flows for most of its length in rocks of the Chisna formation.

Chisna River, as is seen from the description given, is separated from the area of most intense glaciation on the north, but its own valley was formerly occupied by glacial ice, and much of the unconsolidated deposits are the products of glaciation. It is evident, however, that these deposits are not entirely derived from within the valley, but were in part poured into it from east and west when the valleys of the two branches of Chistochina River were filled with ice and part of their water and débris was discharged over the two low divides previously mentioned into the valley of Chisna River.

When Mendenhall visited the district in 1902 he found that mining developments were confined to the upper and lower parts of the river. He gives the following description of the stream:

In both of these regions bedrock had been reached on some of the claims at varying and usually not excessive depths, and wherever found it carried sufficient gold to enable the operators to wash the gravel at a profit.

Throughout the intermediate portion of the river the bedrock lies at unknown depths beneath a mantle of glacial material. In one place, one-half mile above the mouth of Powell Gulch, a shaft was sunk from creek level through 21 feet of compact till into an underlying bed of sand, which admitted water and forced a suspension of operations. It is improbable that the sorting and concentrating effect of water throughout this middle portion of the Chisna Valley has at any postglacial time been operative down to bedrock, so that, even could the latter be reached, it is unlikely that gold in sufficient quantities for profitable exploitation would be found. The clay layers within the glacial deposits which are reached in prospecting carry colors, but are not sufficiently rich to invite extensive operations.

* * * * * * *

The operations along this [the lower] portion of the Chisna Valley are confined to a group of properties within 2 or 3 miles of the mouth of the river. They extend through the canyon and for short distances above and below it, where alone bedrock is accessible. * * *

Bedrock is easily accessible through the canyon, but the latter is so narrow that the bars not swept by the swift current are very small and probably carry but little gold. At the mouth of the canyon bedrock is easily reached, but having a somewhat greater slope downstream than the river it soon passes below a point where it is at present practicable to reach it in sluicing. It is reported that bedrock lies only from 4 to 8 feet below the surface of the flood plain for a considerable distance above the canyon, but since there are many coarse bowlders in the flood-plain material it can not be handled to advantage by ordinary sluicing methods. It is believed that hydraulic work at this point will prove profitable.

The gravels contain a considerable variety of rock types, contrasting strongly in this respect with those of Slate Creek, Miller Gulch, and the upper Chisna. Such a contrast is of course to be expected, because the gravels of the latter streams are derived from limited areas within the small drainage basins of the creeks themselves, where few rock varieties are known, while the gravels of the lower Chisna are of all the various types in the much larger Chisna basin, and probably also of material brought from outside sources by glacial action.

The gold from the lower Chisna is much like that from Slate Creek and Miller Gulch in general appearance, but is finer and somewhat more uniform in grain. Nuggets are rare, but flakes one-eighth inch or more in diameter are abundant. An assay value of $18.72 per ounce is reported.

The developments have not yet determined fully the values to be won, but the gravels below the canyon are said to run from 1.7 to 5.5 cents per pan, with a maximum of $1 on bedrock. A small corner of Discovery claim, just at the head of the canyon, is reported to have yielded $1,000 as the result of a few weeks' work with a short string of sluices, so that the available gravels here, if carefully handled by hydraulic methods, should yield good profits.

In 1910 the work done on Chisna River was in the nature of assessment work and was confined to the lower part of the stream. Considerable ground is held there by different persons, who are awaiting the time when the introduction of hydraulic machinery or other economical methods shall make mining more profitable. At present the price of labor and supplies prevents development of much of the gold-bearing gravels, for with wages at $10 per day and the cost of freighting at 20 to 25 cents per pound none but the richest gravels can be exploited at a profit.

At Dempsey, on the west side of the Chistochina, near the mouth of Chisna River, are deposits of bench gravels that carry fine gold. Prospecting has been conducted there for a number of years in the expectation of discovering a definite pay streak, but without much success as yet. The principal work done is represented by a tunnel driven into the gravel bench.

That the gold of Chisna River is chiefly derived from the Mankomen formation is indicated by the fact that, so far as the writer knows, those streams cutting rocks of the Chisna formation are not gold-bearing except where they have received some contribution of foreign gravel from the north. Rich pay streaks with coarse gold should therefore not be expected on the lower Chisna and Chistochina except where glaciation has brought about unusual conditions of transportation, for the common experience in gold-placer districts is that the gold becomes finer and more widely distributed in the gravel as it travels farther from its source. When the high-bench gravels are known to carry gold, particular attention should be given to streams that are cutting channels through them or undermining their banks, for in such places a reconcentration is going on that may give a deposit of economic importance where it would not otherwise exist. Where there is no reconcentration of this kind the best hope of the prospector is in the discovery of large supplies of low-grade gravels that may be exploited in an extensive way by economical methods.

LIME CREEK.

Lime Creek is a tributary of the middle fork of Chistochina River heading against Chisna River; it appears on the older maps under the name of Lake Creek. Morainal topography characterizes much of the valley of Lime Creek from its head to the main river valley and affords abundant evidence that this region was at one time thickly covered by ice.

Placer-mining operations are conducted on a bench on the north side of Lime Creek, well above the stream and about 1½ or 2 miles east of the divide between Lime Creek and Chisna River. The gravels here are evidently largely of glacial origin. The section exposed in mining shows about 6 feet of heavy bowlder wash resting on blue glacier clay or mud containing small angular rock fragments, which is in turn overlain by more of the heavy bowlder wash, the whole section having a thickness of 30 to 40 feet. A large amount of greenstone, associated with slate, limestone, conglomerate, and granite, is present in the deposit. The richest gold deposit is contained in a rusty gravel seam on the blue-clay bedrock. Copper nuggets ranging in size from shot to pieces of several pounds are caught in the sluice boxes. They resemble those of Chititu and Dan creeks in the Nizina district and like them are probably derived from copper deposits in basalts or greenstones, such as are exposed in the mountain northwest of Lime Creek.

ORIGIN OF THE GOLD.

From his study of the placer deposits of the Chistochina district, Mendenhall reached the conclusion that the gold was derived from an area of local metamorphism in the slates of the Mankomen formation, and gave the following account of its origin and the conditions governing its disposition:

> The coarsest gold of the Chistochina field is found in Miller Gulch, in Slate Creek, and at the head of the Chisna. That taken from the lower Chisna is finer in grain and has a higher assay value, although in other respects it resembles the product of the headwaters. It is therefore considered probable that all of the gold of the field has been distributed from the region about the sources of the producing streams, but there is a lack of unanimity as to the manner of its occurrence there.
>
> Many operators plausibly maintain that it is derived from the "round wash," which is particularly heavy about the head of Miller Gulch and Slate Creek. This deposit of cobbles is also present on the divide between Ruby Gulch and the stream next east, so that the advocates of this theory are able to prove that each stream at present worked to a profit drains an area in which the "round wash" is found. They likewise regard the smooth surface of the gold as evidence that it is water worn and has therefore been brought, like the "round wash," from some extraneous source.
>
> Some facts, however, are distinctly opposed to this hypothesis. Others seem to admit of as ready explanation on another basis.

A small stream on which a group of claims known as the "Big Four" has been staked heads opposite Miller Gulch and flows down to Chistochina Glacier. The heaviest deposit of the "round wash" known in the region occurs on the slopes drained by this brook, which seems, therefore, to be more favorably situated than Miller Gulch relative to this deposit as a source of gold; but the Big Four claims yield fine gold in moderate amount and are not to be compared in richness to Miller Gulch. Furthermore, Ruby Gulch and the creek next east of it seem to be equally favorably situated in relation to the deposit of the "wash," which occupies the divide between them, yet one has yielded operators a handsome return and the other is not profitable.

It is even more significant that the sources of the gold-bearing creeks are all within an area whose extent coincides with a region of local metamorphism in the Permian shales, and that no other metamorphosed areas of these beds and no other gold districts within them are known. Where they have been metamorphosed an incipient cleavage is developed and the shales carry a few narrow quartz stringers. It is believed that the flat, smooth character of much of the gold is sufficiently accounted for by its origin in these shales and by its purity and consequent softness, which lead to a rapid smoothing and polishing with but little transportation.

It is therefore concluded that the gold is derived from these Permian rocks and that in its genesis it is related to the local metamorphism which they have suffered. It is evidently post-Permian in age, and since Eocene beds deposited unconformably upon the Permian are but little folded and wholly unmetamorphosed, it is probably also pre-Eocene.

INFLUENCE OF GLACIATION.

Ice has been an important and often disturbing agent in the distribution of the gold within the district. To this agent must be attributed the irregularities in depth of bedrock, the potholes which occasionally exist in the stream bed, and the changes in drainage which are to be inferred in many instances. The coarseness of the gold now found in the lower Chisna, if, as believed, it has been derived from the district at the heads of the Chisna and of Slate Creek, is probably due in part to the action of the ice as a carrier. Furthermore, the canyon on the lower Chisna, with the short stretches above and below it within which bedrock is accessible, is no doubt due to the superposition of the stream, in the process of readjustment during the withdrawal of the ice from the lower Chisna Valley, upon the granite ridge through which the canyon is cut. To this agent again must be attributed the heterogeneous filling of the middle Chisna Valley and the burial of bedrock there beyond the reach of the miner.

ECONOMIC CONDITIONS.

The high cost of labor and supplies, due to the remoteness of the district from the coast and to the difficulties of freighting, has already been spoken of and need not be repeated, but it should be said that there has been improvement in these respects since the early days of mining here. The other important conditions affecting mining are thus summarized by Mendenhall:

> Another condition which tends to raise the cost of production in the region is the absence of wood on the upper Chisna and on Slate Creek and Miller Gulch. These streams lie well above timber line, and wood, for whatever purpose desired, must be hauled from the nearest timber, 5 or 10 miles distant.

This work is accomplished in the early spring over the snow, before it is possible to begin mining operations, but with the high wages that prevail this increases considerably the cost of living. On the lower Chisna there is sufficient timber for all present needs.

The length of the working season is rather short on the upper creeks, where the water freezes in the sluice boxes usually by September 15 or 20, and it is sometimes as late as July before the snow is melted from the upper portions of gulches, so that a working period of not more than three months is to be counted upon for this part of the district. Here again the lower Chisna is more favorably situated, since the fall freezing is delayed for two or three weeks and the snow melts away earlier in the spring.

INDEX.

A.

Page.

Acknowledgments to those aiding............ 9, 11
Alaska, southern part of, outline map of..... 11
Alaska Range, structure of, features of......... 45–47
  structure of, figures showing............. 46
  topography of, plate showing............ 52

B.

Basalt Mountains, on Windy Creek, plate showing.......................... 40
Basic lavas and tuffs, character, age, and distribution of...................... 29–30
Bench gravels, of Valdez Creek, character of. 60–62
Big Four claims, gold placers of.............. 74–75
Big Rusty Creek, rock glacier on, plate showing.............................. 44
  upper valley of, plate showing........... 40
Birch Creek schist, character and distribution of.............................. 24–26
Brooks, A. H., preface by.................... 7–8

C.

Carboniferous rocks, character and distribution of............................ 27–30
Chisna River, gold placers of................. 75–77
Chistochina district, drainage, topography, and history of.................... 70–71
  economic conditions in................... 79–80
  glaciation in............................. 79
  gold placers of........................... 72–79
  transportation and communication in.... 71–72
Chistochina River, structure of Alaska Range near, figure showing............. 46
Climate, general features of.................. 15–16
Coal, occurrence and value of................ 69
Conglomerate with Triassic sediments, plate showing.......................... 32
Copper River, section of Pleistocene on...... 43
Copper River region, central part of, geologic map of..................... In pocket.
Copper River valley, former and present land surfaces of, figure showing........ 50
Creek gravels of Valdez Creek, character of.... 58–60

D.

Delta River, structure of Alaska Range near, figure showing..................... 46
Delta River district, gold placers of........... 65–66
Diorite intrusive, in Jurassic rocks, age of..... 35
Drainage, of Chistochina district, general features of.......................... 70–71
  of Gulkana-Susitna region, general features of............................ 13–14

E.

Page.

Economic geology, account of................ 53–69
Eocene land surface, figure showing.......... 50
Eureka Creek, landslide on tributary of...... 32
Explorations, in Gulkana-Susitna region, account of.......................... 9–10

F.

Fish, abundance of........................... 68
Fossils, Triassic, identifications of........... 33
Freighting, cost of............................ 20

G.

Game, abundance of.......................... 67–68
Geography, of Chistochina district, general features of......................... 70–71
  of Gulkana-Susitna region, general features of........................... 11–21
Geologic work, in Gulkana-Susitna region, account of......................... 9–10
Geology. *See* Stratigraphy; Structure; Historical geology; Economic geology; *also particular periods and formations.*
Giffin, C. E., work of......................... 9
Glacial deposits, character and distribution of. 39–41
Glaciation, in Chistochina district, effect of... 79
  in Gulkana-Susitna region, effect of....... 51–53
Gold, conditions affecting mining of.......... 66–68
  in Valdez Creek district, distribution and values of......................... 53–65
    history and production of............ 53–54
    lode deposits of, character and distribution of......................... 56–57
    placer deposits of, character and distribution of....................... 57–65
    source of............................. 55–56
  suggestions regarding mining of.......... 68–69
Gold placers, of Chistochina district, character and distribution of........... 72–79
  origin of gold of.......................... 79
  output of................................. 72
Grass, character and distribution of.......... 17–18
Gulkana Glacier, plate showing.............. 52
Gulkana-Susitna region, geologic map of. In pocket.
  location of................................ 11–12
    figure showing........................ 11
  topographic map of................ In pocket.

H.

Historical geology, account of................ 47–53
History, of Chistochina district, account of... 71

J. Page.

Johnson, B. L., work of.................... 9
Jurassic rocks, character and distribution of.. 33-35

K.

Klawasi River, section of Pleistocene on..... 42
Klutina River, section of Pleistocene on..... 43

L.

Labor, cost of.............................. 67
Lake gravels, character and distribution of.. 41-45
Landslide, plate showing.................... 32
Land surfaces, condition of, in Eocene epoch and at present, figure showing... 50
Lavas, character and distribution of......... 29-30
Lime Creek, gold placers of.................. 78-79
Lode deposits, of gold, on Valdez Creek, character and distribution of......... 56-57
Lucky Gulch, gold nuggets from, plate showing.............................. 62
gold placers of........................... 63

M.

Mail facilities, of Chistochina district, character of.......................... 72
of Valdez Creek district, character of..... 67
Mendenhall, W. C., on Chistochina district.. 70-71, 72-74, 76-80
on stream and lake gravels.............. 42-43
Miller Gulch, gold placers of................ 72-73
Mining, conditions affecting................. 66-68
suggestions regarding.................... 68-69
Mining development, on Valdez Creek, data on.............................. 58
Monahan tunnel, plate showing............. 60
Moraines, character and distribution of...... 39-41

P.

Phelan Creek, Tertiary conglomerate on tributary of, plate showing.......... 60
Placer deposits, character and distribution of. 57-65
Pleistocene deposits, sections of, figures showing.............................. 42, 43
Population, estimate of..................... 18-19
Pre-Carboniferous (?) rocks, distribution, character, and age of............ 26-27
Pre-Ordovician (?) rocks, character, age, and distribution of.................. 24-26

Q.

Quaternary deposits, deposition, character, and distribution of.............. 39-45

R.

Relief, character of......................... 12-13
Rock glacier, occur ence and nature of....... 41
Ruby Creek, gold placers of.................. 75
Rusty Creek, boomer and dam on, plate showing.. 62
gold placers of........................... 64-65

S.

Slate Creek, gold placers of.................. 72-73
Stanton, T. W., fossil determinations by.... 33

Page.

Stratigraphy, detailed account of............ 21-45
general outline of, in Chistochina district. 23-24
in Gulkana-Susitna region.......... 21-22
geologic column representing............. 22
Stream gravels, character and distribution of. 41-45
figures showing sections of............... 42, 43
Structure, general features of................ 45-47
of Alaska Range, figures showing......... 46
Supplies, sources of......................... 67
Surveys, in Gulkana-Susitna region, account of.............................. 9-10
Susitna River, headwaters of, topographic map of .... In pocket.
region near headwaters of, geologic map of.......................... In pocket.

T.

Tammany bench claim, relation of to Valdez Creek, figure showing............ 61
Tertiary conglomerate, plate showing........ 60
Tertiary rocks, character, distribution, age, and correlation of................. 35-38
Timber, availability of, for mining.......... 67
character and distribution of............ 16-17
Timberline Creek, gold placers of............ 65
Topographic development, account of....... 49-51
Topography, general features of............. 12-14
Trails, in Chistochina district, character of... 71
in Gulkana-Susitna region, character and number of........................ 19-21
Transportation, facilities for................. 19-21
Triassic rocks, character, distribution, age, and correlation of............... 31-33
Triassic sediments, conglomerate associated with, plate showing............. 32
Tuffs, character and distribution of.......... 29-30

V.

Valdez Creek, bowlder deposits on, plate showing.......................... 58
claims along, figure showing............. 59
geology of and mining development on... 57-62
lower part of, plate showing............. 52
relation of, to Tammany bench claim, figure showing.................... 61
"soil flows" near head of, plate showing.. 44
tunnel and claim on, plate showing...... 60
wing dam in canyon of, plate showing... 58
Valdez Creek district, conditions affecting mining in 66-68
gold placers of 57-62
Vegetation, character and distribution of.... 16-18

W.

Water, availability of, for mining........... 66-67
White Creek, gold placers of................. 64-65
upper valley of, plate showing........... 40
Windy Creek, basalt mountains on, plate showing.......................... 40
Wing dam in canyon of Valdez Creek, plate showing.......................... 58
Witherspoon, D. C., work of................. 9

O