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# THE NELCHINA-SUSITNA REGION ALASKA

BY

THEODORE CHAPIN

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# PREFACE.

By Alfred H. Brooks.

The Nelchina-Susitna region, described in this bulletin, though much more accessible than many parts of Alaska which are far better known, had up to 1913 been relatively little visited. It had, however, been traversed in 1898 by a party under the leadership of Capt. (now Gen.) E. F. Glenn, United States Army, and had been penetrated by a few trappers and prospectors. As has so frequently happened in Alaska, however, these conditions were quickly changed by the reported discovery in 1913 of placer gold in the region. The usual exaggeration of the richness and extent of these deposits created enough excitement to bring into the region several hundred men. Some systematic prospecting was done, but most of the miners left after they had learned the actual conditions.

As shown in this report, there has been but little productive mining in the region, and its geology does not encourage the hope of finding extensive placers, yet the wide distribution of alluvial gold indicates considerable mineralization. Moreover, the presence of a large number of intrusive igneous rocks also encourages the hope of finding local mineralization of the bedrocks. During the relatively recent profound glaciation of the area most of the preglacial gravels have been eroded. This process would lead to the removal of any placers formed in preglacial time and the dissipation of their gold contents. It is not impossible, however, that in favored localities some of the preglacial gravels may remain, and such deposits, if they exist, may contain workable deposits. Such placers are likely to be deeply buried and would have to be rich to warrant exploitation in this isolated region, where operating costs are necessarily high. The region will, however, be readily accessible when the Government railroad is completed to the Matanuska coal field. Under the improved economic conditions which will then exist systematic prospecting would appear to be justified. Furthermore, the fact that some of the bedrock is mineralized makes it at least possible that auriferous lodes may be found, though none has yet been discovered.

# THE NELCHINA-SUSITNA REGION, ALASKA.

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By Theodore Chapin.

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## INTRODUCTION.

### LOCATION AND AREA.

This bulletin deals with parts of the drainage basins of Copper and Susitna rivers. The topographic map accompanying the report (Pl. I, in pocket) shows an area of about 10,000 square miles, which is included between parallels 61° 35′ and 63° 05′ and meridians 145° 20′ and 148° 40′. The relation of this region to the southern part of Alaska is shown in figure 1.

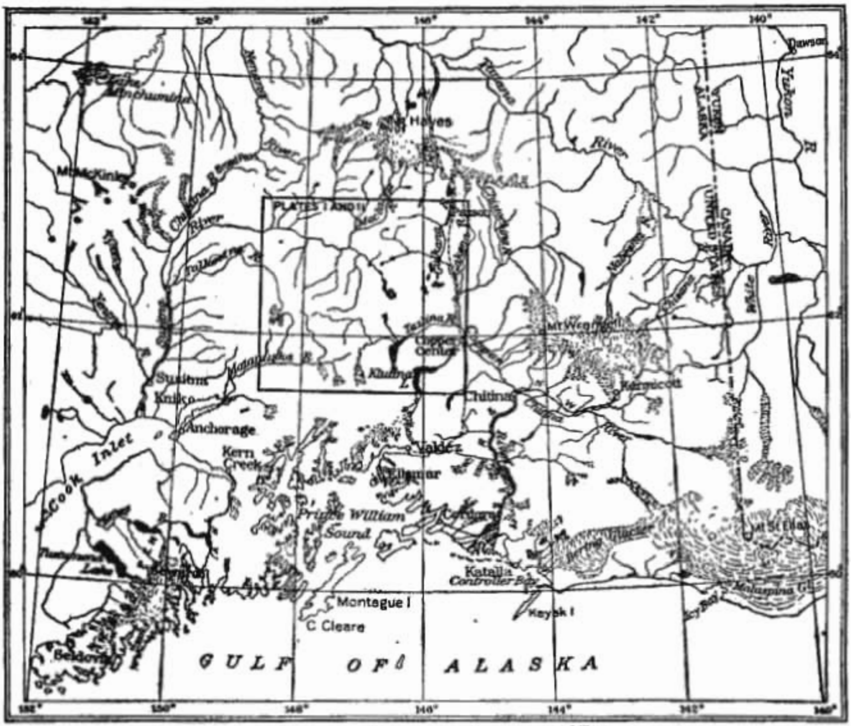

Figure 1.—Index map of part of southern Alaska, showing area represented on Plates I and II.

The part of the region that was examined geologically and that is discussed in this paper extends diagonally from the southeast to the northwest corner of the area mapped. (See Pl. II, in pocket.)

### EARLY EXPLORATIONS AND PREVIOUS WORK.

In 1848 Rufus Serëberinikoff, a Creole, a graduate of a school of commercial navigation in Petrograd, explored Tazlina Lake. He ascended Copper River to Tazlina River and traveled thence to Tazlina Lake, which he called Lake Pleveznie. He spent two days exploring the lake and noted two western tributaries, one of which leads to a portage to Cook Inlet. He evidently referred to Nelchina River and the route to the coast by way of Matanuska Valley.[1] Lieut. H. T. Allen[1] skirted the border of this region in a military reconnaissance made along Copper River in 1885.

Aside from the meager information obtained by these two expeditions, the first definite knowledge of this region was gained from the reports of Government exploration parties in 1898. In that year the eastern border of this region was visited by F. C. Schrader,[2] who, as geologist to a military expedition under Capt. W. R. Abercrombie, made a geologic reconnaissance from Valdez over Valdez Glacier and down Klutina River to Copper Center and beyond. The same year W. C. Mendenhall,[3] acting in a similar capacity to another military expedition under Capt. Edwin F. Glenn, crossed this region on a reconnaissance from Resurrection Bay to Tanana River. His route was along Matanuska River, Hicks Creek, and Billy Creek to the headwaters of Little Nelchina River (Bubb Creek and Nelchina River of former publications), down Flat Creek and Little Nelchina River to the sharp bend in the river 4 miles below the mouth of Crooked Creek, and thence northwestward to Lake Louise and on to Delta River. His route across the region here considered, except for a short distance along Flat Creek and Little Nelchina River, therefore lay for the most part across gravel flats, so that his investigations added little to our knowledge of the geology of the hard rocks. Both these exploratory expeditions, however, were of great value in outlining the general features of the physiography, drainage, and geology of a larger area, of which this region forms a part. Mendenhall[4] and Gerdine continued the study

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[1] Allen, H. T., Report of an expedition to the Copper, Tanana, and Koyukuk rivers, in the Territory of Alaska, in the year 1885, p. 21, Washington, 1887.

[2] Schrader, F. C., A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 341–423, 1900.

[3] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 265–340, 1900.

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

of the Copper River region in 1902 and mapped the south and west slopes of Wrangell Mountains and parts of the Alaska Range that are drained by tributaries of Copper River.

In 1906 T. G. Gerdine and Adolph Knopf[1] carried reconnaissance topographic and geologic surveys up Matanuska River and Hicks Creek across to the headwaters of Little Nelchina River and down to Tahneta Pass. The same year R. H. Sargent and Sidney Paige, members of the same party, ascended Chickaloon River to its head, went down Talkeetna River to its mouth, and continued along the west flank of the Talkeetna Mountains to Knik. J. W. Bagley, D. C. Witherspoon, and C. E. Giffin mapped the headwater regions of Gulkana and Susitna rivers, and F. H. Moffit and B. L. Johnson studied the geology of the same region.[2] Two years later Mr. Moffit and J. E. Pogue extended the geologic surveys to Broad Pass and J. W. Bagley carried the topographic mapping over the same area.[3] The same year G. C. Martin and J. B. Mertie, jr., studied the geology of the upper Matanuska Valley and the headwater region of Little Nelchina River.[4]

## PRESENT INVESTIGATION.

The purpose of the work on which the present report is based was to connect these former surveys and continue the work westward. A party organized for this purpose was placed in charge of J. W. Bagley, who has prepared the following statement regarding the topographic survey of the region:

> The topographic survey of the region was started from a base 10,973 feet long, which was laid out near Nelchina village, on the low ridge lying between Crooked Creek and Little Nelchina River. This base lay at the edge of the region included in a topographic survey by T. G. Gerdine in 1906, and at the outset a tie was obtained with several of his stations, which supplied the temporary vertical datum. The base was expanded by theodolite at the same time the topographic work was being carried forward by plane-table and panoramic camera.[5] The survey took a general northwesterly course, extending across Susitna River to points only 15 miles from Broad Pass, and in this region it was joined to surveys of three former years. On the return trip to Nelchina additional stations were occupied to embrace as much of the country adjacent to the route as the short time permitted. The later part of the season was employed in extending the survey from Nelchina to

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

[2] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska, with accounts of the Valdez Creek and Christochina placer districts: U. S. Geol. Survey Bull. 498, 1912.

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

[4] Martin, G. C., and Mertie, J. B., jr., Mineral resources of the upper Matanuska and Nelchina valleys: U. S. Geol. Survey Bull. 592, pp. 273–299, 1914; Geology of the upper Matanuska Valley, Alaska: U. S. Geol. Survey Bull. — (in preparation).

[5] Bagley, J. W., The panoramic camera in topographic surveying: U. S. Geol. Survey Bull. 657, 1917.

Copper Center. Over this route ties were made with the latitude-longitude station at Copper Center, determined astronomically by the Coast and Geodetic Survey in 1911, with the land survey lines laid out by the General Land Office in the vicinity of Copper Center in 1904–5, with the topographic work of the Geological Survey by T. G. Gerdine in 1902, and with the railroad reconnaissance of the route from Chitina to the lower Matanuska, made by Henry Deyo,[1] of the Alaskan Engineering Commission, in 1914. The accurate line of levels carried over the railroad survey from tidewater to tidewater supplied a vertical datum to which the survey was adjusted before the compilation of the map was commenced. The last few days of the season were spent in recovering the initial east and west base line of the land survey near Willow Creek and expanding it to the stations occupied in that locality

The party of 7 men and 15 pack horses left Knik June 7 and arrived at Nelchina June 24 by way of Matanuska Valley, Squaw Creek, and Crooked Creek. Provisions for the season were brought in from Valdez during the winter, and a cache had been left at Nelchina and another one at the mouth of Maclaren River. Actual field work was started June 15 at Albert Creek and extended northwestward along the foothills of Talkeetna Mountains to Kosina Creek. The party crossed Susitna River at the mouth of Maclaren River on August 1 and spent a month mapping the region north of the river. The return trip from the mouth of Maclaren River was by way of Susitna River, Tyone Creek, Sanona Creek, and Little Tyone to Nelchina and thence to Copper Center by way of Tazlina Lake. The party spent a few days in the vicinity of Klutina Lake and left Copper Center October 10 for Valdez by the Government road. To the writer was assigned the investigation of the geology and mineral resources of the region mapped. He is indebted to Mr. Bagley for many courtesies rendered and also to Messrs. J. E. Clark and G. J. Chamberlain for assistance in collecting specimens. A preliminary report of this district was published in 1915.[2]

Although the party was the recipient of many courtesies during the season, special mention should be made of those extended by L. F. Shaw, commissioner of Nelchina recording precinct; Messrs. Tolson and Sellick, of Fourth of July Creek; Camille McGown, of Nelchina; J. L. Simpson and Ringwald Blitz, of Copper Center; and F. J. Bingham, of Willow Creek.

## GEOGRAPHY.

### SURFACE FEATURES.

The dominant topographic forms bear evidence of the intense glaciation to which the region has been subjected. Three distinct

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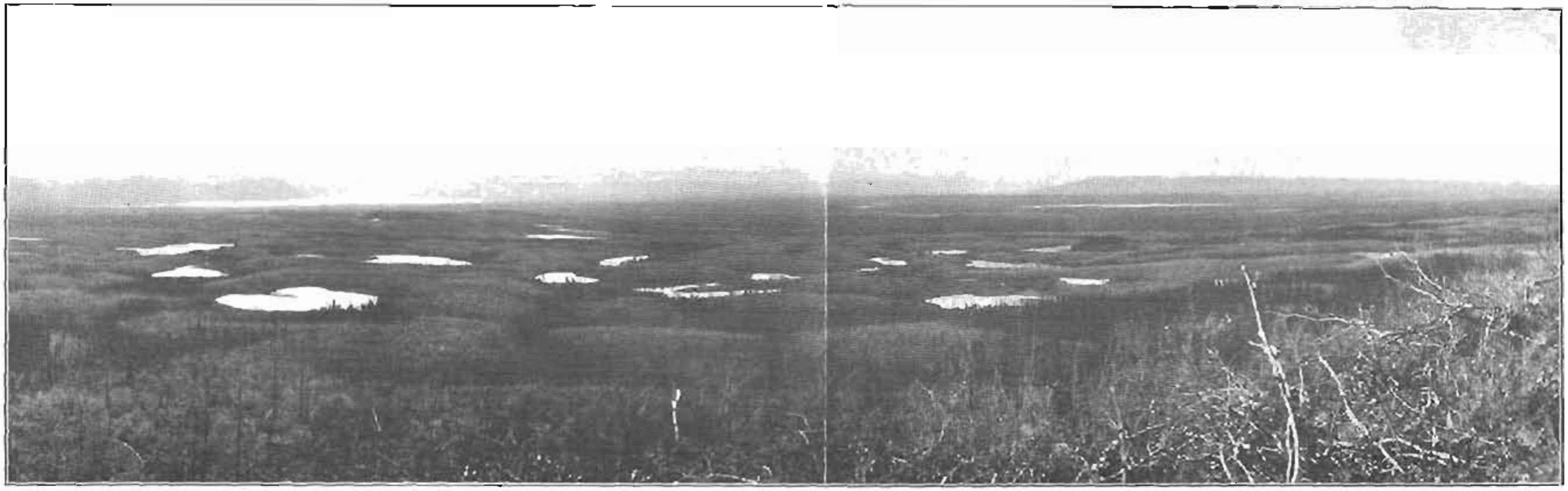
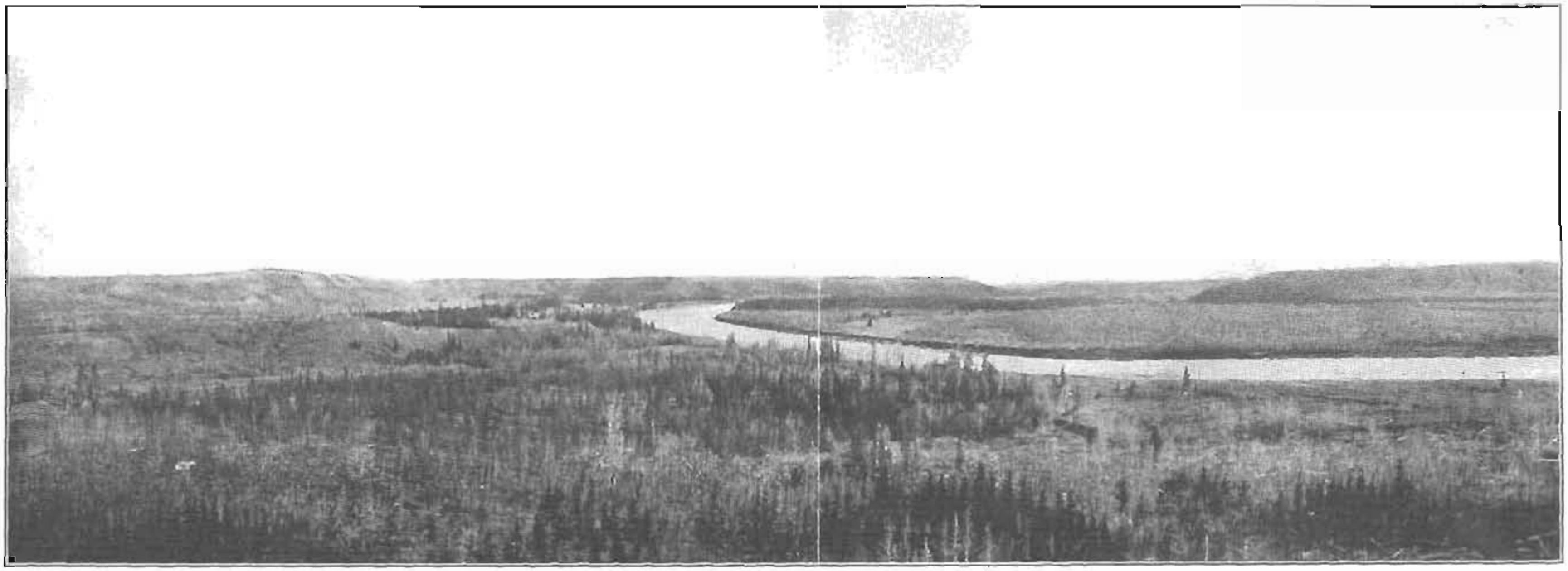
[1] Alaskan Eng. Comm. Rept. for 1914–15: 64th Cong., 1st sess., H. Doc. 610, pts. 1 and 2, 1916.

[2] Chapin, Theodore, Auriferous gravels of the Nelchina-Susitna region: U. S. Geol. Survey Bull. 622, pp. 118–130, 1915.



*A.* LAKE-DOTTED MORAINE, COPPER-SUSITNA BASIN.

View looking southwest from Mendeltna River; Tazlina Lake and Chugach Mountains in the background.



*B.* TAZLINA RIVER AT THE MOUTH OF MOOSE CREEK.

View showing dissected gravel plain of Copper-Susitna basin.

types of topography are represented by the débris-filled lowland, in which the relief is slight; the rounded foothills, which include ice-scoured knobs and ridges; and the rugged mountains, in which there are numerous cirques. These types, although diverse, are all the inheritance of a profoundly glaciated region and are varied expressions of glacial action. Although divisible into smaller topographic units, this region falls naturally into four physical divisions—an extensive lowland and three bordering well-defined mountain provinces of diverse character--parts of the Talkeetna and Chugach mountains and the rugged ranges lying between Susitna River and the Alaska Range.

The largest of these divisions is the lowland province, a broad basin extending the length of the area mapped and including parts of the valleys of Susitna and Copper rivers and the almost imperceptible low divide that separates them. This province is floored with glacial silts and gravels that form part of an extensive gravel sheet reaching from Mentasta Pass and the headwaters of Chitina River to Cook Inlet. It is of late geologic age, and its glacial origin is evident from its poorly drained, lake-dotted surface and the character of its deposits. (See Pl. III, *A*.) It has a rolling, nearly level surface, broken by gravel ridges and sharp canyon-like stream valleys. The drainage is young and poorly developed. The streams have cut into the gravels in V-shaped troughs, and the interstream areas contain ponds and swamps that have no apparent outlets.

The lowland province is bordered on the southwest by the Chugach and Talkeetna Mountains. The Chugach Mountains form a belt 50 to 60 miles wide that extends from Mount St. Elias to Kenai Peninsula in a course roughly parallel to the coast. They form a complex mass whose peaks reach elevations of 8,000 to 10,000 feet.[1] East of Tahneta Pass the bold front of the Chugach Mountains rises abruptly from the gravel lowland but is flanked in places by foothills, the only part of the Chugach Mountains included within the region here mapped.

The Talkeetna Mountains are separated from the Chugach Mountains by Tahneta Pass and Matanuska Valley. They form a rudely circular mass, which has no definite trend. They are rugged in outline and range in elevation from 5,000 to 6,000 feet, though individual peaks are 8,000 to 9,000 feet high. On the south they rise abruptly from the floor of Matanuska Valley. On the north the low rounded, flat-topped foothills of this range are carved from an extensive peneplain that lies along the northern base of the Talkeetna Mountains. This peneplain dips gently to the north and is abruptly terminated by the depressed trough that is now covered by the gravels of

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[1] Brooks, A. H., Geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 30, 1906.

1898 a glacier discharged bergs into the upper end of the lake. As the lake and glacier are now separated by a gravel-filled flat it is evident that the glacier has recently receded or that the upper end of the lake has been filled with silt.

The upper end of the lake is confined within rock walls in an extension of the valley occupied by Tazlina Glacier, but most of the lake lies in a depression in glacial deposits near the contact of the gravel sheet and the Chugach Mountains. At its lower end the lake contracts to a narrow stretch of water from which Tazlina River issues over rapids and flows in a canyon-like gorge in the glacial deposits. The Tazlina enters Copper River 9 miles above the Klutina. (See Pl. III, *B.*) A rather large tributary, locally known as Tolsona Creek, enters the river from the north about 10 miles below Tazlina Lake.

Nelchina River, which is tributary to Tazlina Lake, receives its water from the Chugach and Talkeetna mountains. Its south fork, which is generally regarded as the main fork, heads in Nelchina Glacier[1] and receives several tributaries from the Chugach Mountains. Little Nelchina River, which has two main branches, Crooked and Flat creeks, is larger and longer than the Nelchina. It rises in the Talkeetna Mountains. Mendeltna Creek, the outlet of Mendeswinas, Old Man, and other lakes, enters Tazlina Lake half a mile below the mouth of Nelchina River.

Susitna River, the master stream of the western part of the region, is formed by the melting of the ice of several large glaciers in the Alaska Range. From its source it flows southward and southeastward for 70 miles to a point where it makes an abrupt bend to the west, locally known as the "big bend." Above this bend the river flows over gravel flats in a channel that becomes deeper downstream. From the mouth of Maclaren River to the "big bend" the river flows in a meandering course in a channel cut in a flat gravel plain. At some places it is confined between steep walls; at others it is flanked by terraces that extend back from the river and indicate its former positions. West of the mouth of Oshetna River the character of Susitna Valley changes considerably. The valley is inclosed by low buttes and rock crops out along the river, which flows in rapids through narrow gorges separated by long stretches of quiet water. A view of Susitna River near the mouth of Maclaren River is shown in Plate V, *A.*

The watershed between the drainage basins of Susitna and Copper rivers is ill defined. It lies on a broad flat area that is dotted with swamps and lakes, and the direction in which many of these drain is doubtful. The largest of these lakes are Lake Louise, Susitna

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[1] Nelchina River and Nelchina Glacier have erroneously been mapped as Tazlina River and Tazlina Glacier on earlier Survey maps.

Lake, and Tyone Lake, whose exact position and extent are still in doubt. These three appear to be connected, so that they form a continuous body of water nearly 20 miles long. They are the source of Tyone River, a large stream that enters the Susitna near the point where it bends abruptly to the west. Throughout its course Tyone River meanders through glacial deposits. Near its mouth it is sluggish and deep. Its water, like that of many streams which head in lakes and drain swampy regions, is highly colored with vegetable stain. Its principal tributaries are Tyone Creek, locally known as Little Tyone, and Sanona Creek, streams that head in the Talkeetna Mountains. Sanona Creek is formed by the confluence of Joe Creek and Yacko Creek. Near Tyone Lake there are a number of smaller lakes which discharge into the tributaries of Tyone Creek.

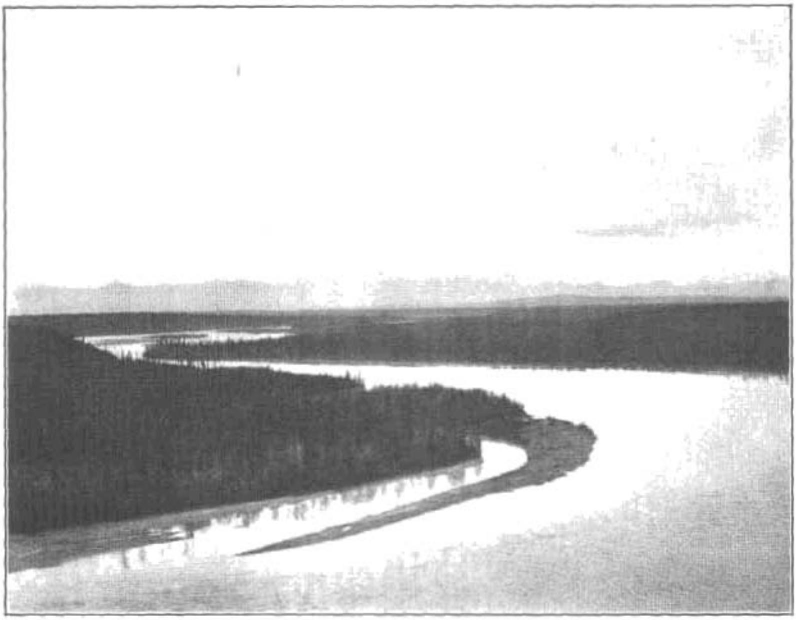
Oshetna River and its confluents drain a large area in the Talkeetna Mountains. Its two main tributaries are Little Oshetna and Black rivers. Little Oshetna River rises near the head of Little Nelchina River and flows northward for 20 miles to its confluence with Oshetna River, the main fork of which issues from glaciers in Talkeetna Mountains but receives other small tributaries. In its upper course it spreads over a broad, flat bottom in a braided channel and offers an easy route of travel, but at its mouth it is confined in a single channel and is difficult to cross. Black River is a glacial tributary that enters the Oshetna from the west. It flows in a straight glaciated valley, which is overdeepened in its upper part and bordered by immense lateral moraines. For some distance it flows parallel to Oshetna River, which it enters about 4 miles west of Lone Butte.

West of Black River is another glacial stream, known to the natives as Kosina River. It carries less water than Black River but has many similar characteristics. Its valley is bordered by glacial moraines and shows profound glacial erosion. Tsisi and Terrace creeks, tributaries of this stream, are similar to it. Each occupies a gorgelike basin that shows strong glacial erosion and is covered with glacial deposits in its lower part. Each contains lakes that occupy rock depressions caused by glacial scour and lakes formed by obstructions composed of glacial débris.

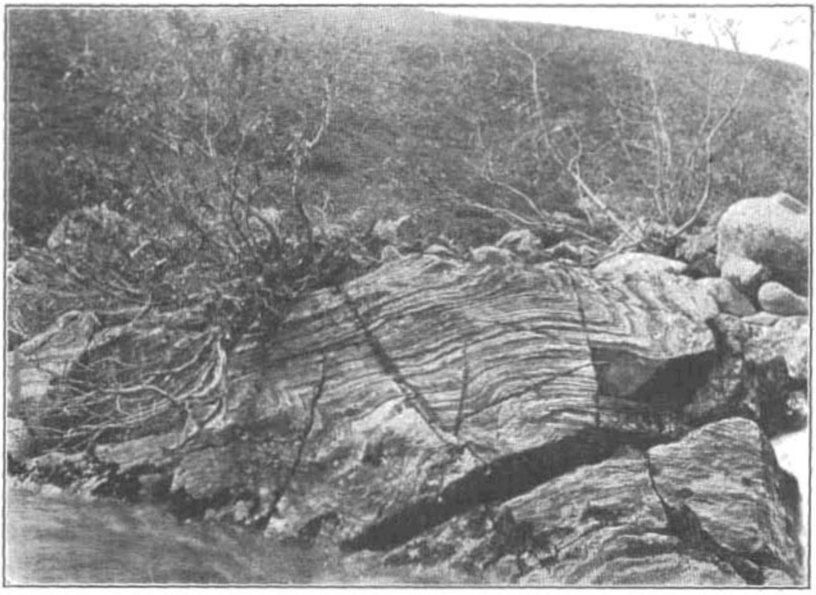
The tributaries that enter Susitna River from the north, named in order from west to east, are Tsusena, Deadman, Watana, Jay, and Coal creeks. These are all clear-water streams that head in the mountainous region north of Susitna River.

## CLIMATE.

In the absence of weather records a knowledge of the weather and climate in the region must be derived principally from personal ob-



*A.* SUSITNA RIVER NEAR THE MOUTH OF MACLAREN RIVER.



*B.* CONTORTED GNEISS ON TSUSENA CREEK.

servations made during one season, supplemented by such information as could be gathered from others.

For the purposes of the prospector and traveler the year may be divided into an open and closed season which may be called summer and winter. The climate is that of the district behind the coastal barriers and is marked by warm summers and long, cold winters. The rainfall is a medium between the excessive precipitation of the coast and the semiaridity of the interior. A personal record kept for 102 days, from July 1 to October 10, showed that 42 days were free from storm, 29 of which were fair and 13 cloudy. On 31 days it rained or snowed for a considerable part of the day, and on 29 other days there were light showers. The summers are warm, but sudden changes of temperatures are not uncommon and may be accompanied by a heavy frost or a light fall of snow. On one day late in July snow fell heavily for several hours but stayed on the ground for only a short time. A little snow fell also in each of the remaining months of the summer. The winter snowfall is not heavy, but the weather is cold.

The open season for placer mining lasts from May until October, varying somewhat from year to year and depending on the elevation of the region. Ice suitable for winter sledding usually forms in November and lasts until March or April.

## VEGETATION.

Spruce is the principal timber in the region. It covers the lowland areas to an elevation governed somewhat by local conditions but ranging from 2,500 to more than 3,000 feet. The quality of the timber varies greatly. Considerable areas of swampy and poorly drained gravel flats maintain a growth of scrubby spruce trees only a few feet in height and 2 or 3 inches in diameter. At some places, however, the trees grow much larger. On Tsusena and Watana creeks, northern tributaries of the Susitna, exceptionally good timber was seen, many of the trees measuring over 2½ feet in diameter at the base. Most of the timber along the Susitna is not so large but is ample in size and quantity for use in mining and building. Good timber also grows along Little Nelchina, Tazlina, Oshetna, and Klutina rivers. The general distribution of spruce timber is shown in figure 2.

Birch, of which there are several species, is less abundant than spruce. One dwarf variety, commonly known as "buck brush," is a bush that averages 3 or 4 feet in height and at some places grows larger. It grows chiefly on relatively dry, gravelly ground and not on swampy areas. Quaking asp and willow grow along stream courses and on well-watered hillsides at a slightly higher elevation than spruce and at many places furnish the only available firewood. Alder also grows above timber line but is not abundant except in a few localities. A few cottonwood trees grow along stream courses.

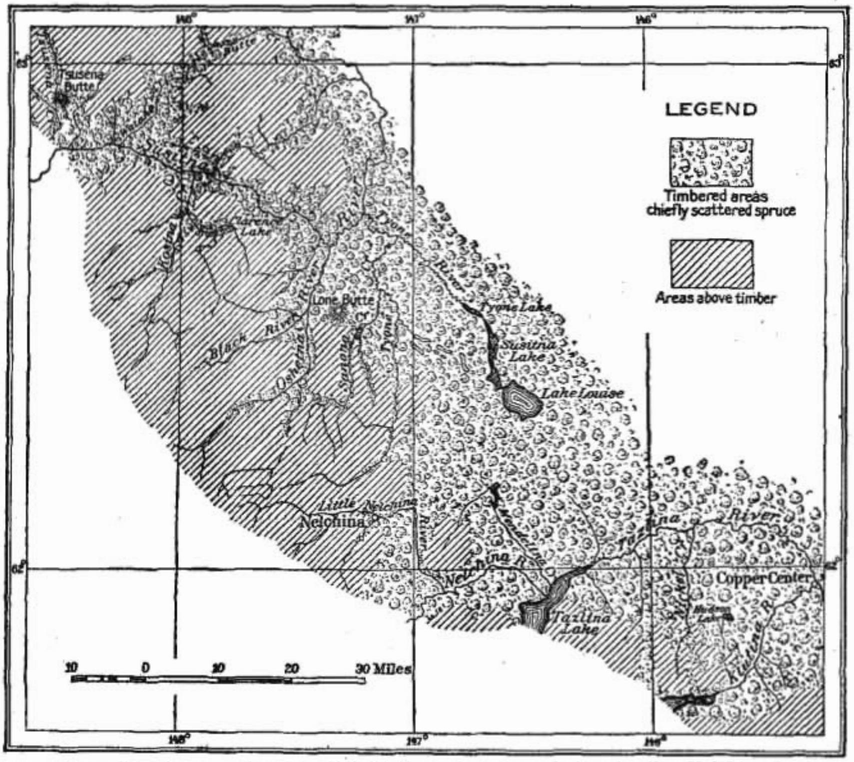


FIGURE 2.—Sketch map showing distribution of spruce timber in the Nelchina-Susitna region.

Several varieties of grass are available for horse feed. The most useful are bunch grass and redtop. These grasses grow luxuriantly in places but are not abundant, so that it is not always easy for the traveler to find forage. A substitute for these grasses is a rank black-seeded swamp grass, which horses will eat, though they do not relish it. A little grass appears about the 1st of June, but grass can not be depended upon for forage until the middle of June. Horse feed lasts from mid-June until the time of the heavy frosts, which varies from early in September to the 1st of October, depending on the season and the location. After the other grasses are gone a "pea vine," which grows along river bars and dry benches, is sometimes available for grazing.

## GAME.

The most plentiful large game animal of the Susitna region is the caribou. These animals, which are found on both sides of Susitna River, are tame and are easily taken. They range from the river to the high ridges and are often seen in large herds. Moose also may be found in the Susitna region but are more abundant in the low country to the east and around Klutina and Tazlina lakes. A few sheep live in the Talkeetna Mountains and in the mountains north of Susitna River. Brown bears are plentiful but are not desirable game. Other fur-bearing animals are foxes, rabbits, squirrels, marmots, martens, wolverines, muskrats, and weasles. Ptarmigan are plentiful throughout the region, and spruce hens are found at some places. Ducks, geese, and other waterfowl spend the summer in the streams and lakes but leave in the fall. The clear-water streams in the Susitna basin abound in grayling and contain also several kinds of trout. A very large trout is found in some of the lakes. Salmon are plentiful along Copper River but are not found in the upper Susitna.

## ROUTES OF TRAVEL.

The Nelchina region may be reached either by way of Knik or from Cordova or Valdez by way of Copper Center. The route from Copper Center follows the wagon road for 10 miles to a point half a mile north of Simpson's road house, and thence goes by a trail along the north bank of Tazlina River and Tazlina Lake to the mouth of Mendeltna Creek. From this point the trail takes a northwesterly direction to Little Nelchina River and thence follows that stream to Nelchina, at the mouth of Crooked Creek. This is a winter trail and has been laid out in a winding course in order to cross the ice of several large lakes. It is in places very swampy for use in summer, but with caution it may then be traveled by pack horses. The distance from Copper Center to Nelchina is about 90 miles.

The Knik route goes by trail up the Matanuska Valley to Chickaloon, from which several possible routes lead to the Nelchina-Susitna region. One route follows the Matanuska around the east end of Sheep Mountain, goes up Squaw Creek, and crosses a low divide to the head of Crooked Creek. Another route is the Hicks Creek trail, by way of Billy Creek to the head of Little Nelchina River, or by way of Alfred Creek to the head of Albert Creek. Susitna River may be reached by way of Chickaloon and Talkeetna rivers through low passes at the headwaters of Kosina Creek, a tributary to the Susitna.

Supplies for this region are taken in during the winter from both Knik and Copper Center, but as Knik is not an open port during the winter, freight from the outside usually goes by way of Copper Center from either Chitina or Valdez. The distance from Albert Creek to Knik is about 106 miles.

Before the Valdez-Fairbanks wagon road was built this region was crossed by the winter trail from Valdez to Valdez Creek by way of Valdez, Glacier, Klutina Lake, St. Anne River, Tazlina Lake, Tyone Lake, Tyone Creek, and Susitna River. The region will be more accessible when the Government railroad is constructed along Susitna River through Broad Pass to the Tanana and the branch line is built up the Matanuska to the coal field. When the coal-field branch is built to Chickaloon, Albert Creek may be reached by an overland journey of 50 miles.

### POPULATION.

Copper Center, the principal settlement of this region, stands at the confluence of Copper and Klutina rivers, 101 miles north of Valdez, on the Fairbanks-Valdez Government road, and may be reached from Cordova by rail to Chitina, a distance of 131 miles, and thence by wagon for 50 miles, or by wagon road direct from Valdez. Copper Center is a distributing point for the Nelchina, Upper Susitna, Gulkana, and Chistochina regions. A post office, United States commissioner, Government telegraph station, and a Government school for the natives are located here.

Nelchina is a small village at the mouth of Crooked Creek. It is the seat of the Nelchina recording precinct and the general headquarters of the neighboring region. Aside from these two settlements the white population is confined to the road houses along the Government road and the transient prospectors and miners.

The Indian population is small. Cabins and camps on Klutina and Tazlina lakes, on Susitna River, and at other places are used temporarily by natives on hunting and fishing expeditions, but aside from a few natives scattered over the region the permanent Indian population is confined to Copper Center.

## DESCRIPTIVE GEOLOGY.

### GENERAL FEATURES.

The general distribution and probable extension of the geologic formations of the Nelchina-Susitna region are shown on the geologic map (Pl. II, in pocket). They represent a variety of types, including rocks of sedimentary and of igneous origin and their metamorphic derivatives.

The oldest rocks of the region include gneisses, greenstones, and associated limestones, tuff, schist, and other altered sediments, evidently of Paleozoic age. The Mesozoic rocks are widely distributed. Formations regarded as Triassic include an extensive series of basaltic and andesitic lavas and a sedimentary formation composed of slate and graywacke, with which are associated limestone and schist. Jurassic stratified rocks include a group of andesitic and rhyolitic lavas and associated tuffaceous sediments, in part altered to greenstone, and a number of sedimentary formations consisting of conglomerate, sandstone, and shale.

Granular intrusive rocks, including diorites, quartz diorites, monzonites, and granites, are widely distributed in the Talkeetna Mountains and in the unnamed mountains north of Susitna River. These fall naturally into two groups, which differ greatly in composition and apparently in age, although they may be two phases of rock that were formed during a long period of igneous activity. The older igneous rocks are dominantly diorite and quartz diorite; the younger ones are granites and quartz monzonites, with which are associated various lavas, including andesite and basalt. The unaltered igneous rocks range in age from Jurassic to late Tertiary. Gneissic rocks are associated with the quartz diorite.

All the hard-rock formations are covered in part by unconsolidated deposits of glacial gravel and débris. The stratigraphic succession is summarized below:

*Stratigraphic sequence in the Nelchina-Susitna region.*

| Age. | Formation. | Lithologic character. |
|---|---|---|
| Quaternary. | | Stream gravels.<br>Glacial gravels, sands, and silts.<br>Morainal deposits. |
| | —Unconformity— | |
| Tertiary. | | Flows of basaltic, andesitic, and rhyolitic lavas. |
| | Unconformity— | |
| Upper Jurassic. | Naknek formation. | Shale and sandstone. |
| | | Conglomerate with lenses of sandstone and shale. Possibly equivalent of Chisik conglomerate. |
| | —Unconformity— | |
| Middle Jurassic. | Chinitna formation. | Concretionary sandy shale and sandstone. |
| | Tuxedni sandstone. | Sandstone and sandy shale and arkose. |
| | —Unconformity (?)— | |
| Lower Jurassic. | | Volcanic rocks, consisting of andesites, rhyolites, dacites, breccias, and tuffaceous sediments. |
| | —Unconformity (?)— | |
| Upper Triassic (?). | | Slate and graywacke with intercalated beds of limestone and schist. |
| Triassic (?). | | Basic lava flows. |
| Carboniferous or older. | | Greenstone schist and limestone with basic and dioritic intrusives. |
| | Klutina group. | Quartz and mica schist, limestone, and argillite. |

## CARBONIFEROUS OR PRE-CARBONIFEROUS ROCKS.

### KLUTINA GROUP.

#### DISTRIBUTION AND CHARACTER.

The mountains that form the north barrier of Klutina Lake from St. Anne Creek eastward are composed of altered sediments and intrusions of quartz diorite and basic igneous rocks. The sediments were provisionally called the Klutina "series" by Schrader,[1] who described them as "mica schists, quartz schists, sometimes cherty or jaspery in character, and crystalline limestone or marble." Only the section east of Chultikana Creek was examined in 1914. The dominant rocks in that section are fine-grained black slates and argillites. Interbedded with the argillaceous sediments are beds of dark-gray crystalline limestone, ranging in thickness from a few inches to 20 feet. The argillaceous rocks are fractured and seamed with quartz, which form an intricate network of tiny stringers, and in places the rock is largely replaced by silica. The limestone throughout is more or less altered and veined with calcite. Silicification of the limestone has formed irregular masses and beds of white cherty rocks, a product of the complete replacement of limestone by silica.

The Klutina group is bounded on the north, south, and west by gravel. On the east the beds of the group are separated from greenstone by a mass of intrusive quartz diorite, and the group at some places includes small bodies of intrusive gabbro.

#### STRUCTURE.

In the region studied the Klutina beds have a nearly constant strike of about N. 60° W. The general dip is toward the northeast but is interrupted at some places by variations caused by sharp folds.

#### AGE AND CORRELATION.

The age of the Klutina group is not certainly known. Schrader[1] states that the Klutina may be pre-Silurian, this tentative determination having been based on a seeming similarity of the rocks of the group to those of the Fortymile "series" of Yukon Valley. The Fortymile "series" is regarded by Brooks[2] as a calcareous member of the Birch Creek schist or a higher member of the metamorphic series, none of which is known to occur south of the Alaska Range. The

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[1] Schrader, F. C., op. cit., p. 410.

[2] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 59, 1911.

Klutina rocks are less deformed than those of the typical Fortymile "series," and if degree of metamorphism may furnish a means of comparison the Klutina rocks are younger. Even by lithologic similarity, however, the Klutina group can not with confidence be correlated with any near-by formations.

The beds are intruded by quartz diorite of Jurassic or later age. Northeast of the intrusives there are flows and breccias of andesitic greenstone and interbedded slates, which on lithologic and mineralogic similarity are doubtfully correlated with the lower Jurassic volcanic rocks. The Klutina slates appear to dip beneath the greenstone and are therefore probably older.

## GREENSTONE, LIMESTONE, AND SCHIST.

### DISTRIBUTION AND CHARACTER.

*General features.*—The low rounded buttes within the big bend of Susitna River are made up of greenstones and schists, local beds of limestone, slate, and quartzose rocks, and dioritic and diabasic intrusives. Similar rocks occur east of Susitna River.

Though the rocks that form this group differ widely in composition and character they are more or less related and are therefore treated as a cartographic unit and represented on the map by a single symbol. More detailed work, however, will doubtless show that the group comprises several formations. A distinction which was noted in the field but which could not be shown on the map, owing to the reconnaissance nature of the survey, was made between greenstone that is schistose in part and a series of sediments and basaltic flows that are also somewhat altered but that do not look so old as the typical greenstone. No unconformity was noted between the younger and older rocks, but one is suggested by the apparent difference in the degree of alteration.

With the possible exception of masses of the ancient greenstone, whose relation to the less-altered rocks is uncertain, the lower part of this group is dominantly sedimentary and the upper part igneous. The exposed base is the massive limestone, which in its upper part becomes thin-bedded and contains intercalations of schist and quartzose sediments, which in turn are interlayered with greenstone flows. In the upper part of the group the greenstone predominates and grades insensibly into the overlying series, composed of augite andesite lavas of probable Triassic age.

*Greenstone.*—The predominant rock of the group is greenstone, which includes several types of altered effusive and intrusive rocks. The typical greenstones of the effusive type are dark-green fine-grained rocks that contain a few small crystals of hornblende and pyroxene. Under the microscope the rocks are seen to be altered augite andesites and basalts. The groundmass is composed of a finely granular ophitic aggregate of pyroxene and plagioclase ranging from andesine to labradorite. Large phenocrysts of pyroxene and feldspar which occurred in the original rock are in large part altered to hornblende, epidote, chlorite, serpentine, and calcite. The calcite replaces the feldspar of both the groundmass and phenocrysts and in places is so abundant that the rock effervesces freely with acid. Altered diabases also occur.

The most conspicuous greenstone of the intrusive type is a fine-grained green rock that includes irregular white areas of feldspar and flashing needles of hornblende. The original rock was a diorite composed essentially of hornblende and oligoclase. Secondary epidote, chlorite, and a little quartz have formed at the expense of the original minerals and in places have entirely replaced them.

*Limestone.*—Limestone occurs only in a small area between Watana and Jay creeks, but at this place it is conspicuous. Its base is concealed beneath gravels. The lowest strata exposed are massive beds. Where observed the general strike is northwest and the dip ranges from 30° to 60° NE. The beds are folded and twisted, so that its thickness can not be determined but is estimated to be 500 feet. In its upper part the limestone becomes thinner bedded and contains intercalated sheets of greenstone and metamorphosed sediments.

The rock is crystalline and for the most part white but is marked by black and green bands, which give it a variegated appearance.

*Schist.*—Interbedded with the limestone and greenstone are thin beds of black slate and quartzites, fine-grained quartz schists, and phyllites, evidently of sedimentary origin. Schists derived from igneous rock also occur. One such rock exposed on Jay Creek is a greenish-gray schist with large quartz crystals set in a fine-grained matrix of quartz, feldspar, sericite, and epidote. More basic schists composed of hornblende and feldspar occur but are not common.

*Intrusive rocks.*—Dioritic and other intrusive rocks are also associated with the greenstones and schists. Among these intrusives are unaltered diorite and quartz diorite rocks similar to the rocks composing the large batholith south of Susitna River and evidently to be correlated with them. They are in large part altered, however, and appear to grade into the typical greenstone.

### AGE AND CORRELATION.

The age of this group of rocks is uncertain. As has been stated, it probably contains a number of formations of widely differing ages. In part at least it is the continuation of a wide belt of greenstone and schist east of Susitna River, but it contains also limestone and quartzose sediments, apparently conformable. The greenstone and schist east of Susitna River are regarded by Moffit as pre-Carboniferous.[1] He bases his opinion, which he states is little more than speculation, on the relative amount of metamorphism, which indicates that the schists are older than the nearest Carboniferous sedimentary formation.

If the pre-Carboniferous age of the greenstone and schist is accepted it may be well to consider other formations with which members of the group may be correlated. Carboniferous rocks with which these may possibly be correlated are the sedimentary rocks at the base of the Nikolai greenstone, the Chisna formation, and the Carboniferous (?) rocks of Hanagita Valley. The rocks of the Hanagita Valley that are tentatively referred to the Carboniferous consist essentially of schist and slate but include also limestone and a great amount of associated greenstone.[2] In their relations with one another the rocks of Hanagita Valley bear a striking resemblance to the lower part of the greenstone, limestone, and schist group of the Susitna Valley.

The Chisna formation is a group of rocks that extends from the headwaters of Chistochina River westward to the source of Eureka Creek.[3] It consists of conglomerates, slates, gneisses, quartzitic sediments, tuffaceous beds, and limestone associated with diabasic and dioritic rocks. The beds are folded and are in part schistose. No striking resemblance was noted between the Chisna formation and the greenstone and schist group of the Susitna Valley as a whole. No conglomerate was seen on Susitna River and no quartzite except thin schistose beds. Such members, however, may be concealed. The base of the series in Susitna Valley is not exposed, a fact that may account for the absence of these members.

On the whole the Chisna formation has suffered less metamorphism than the greenstone and schist group of Susitna River, yet the similar relation in both regions of limestone beds with altered sediments and associated diabasic and dioritic rocks is at least suggestive of a possible correlation. The Chisna formation was temporarily assigned by Mendenhall to the lower Carboniferous or Devonian and by Moffit with reasonable but not absolute certainty to the Carboniferous. Moffit regards the Chisna as younger than the greenstone and schist of the Gulkana region, his view being in harmony with that which regards the lower part of the greenstone and schist formation

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[1] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska: U. S. Geol. Survey Bull. 498, p. 26, 1912.

[2] Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, p. 18, 1914.

[3] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, pp. 33–36, 1905. Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska: U. S. Geol. Survey Bull. 498, pp. 27–29, 1912.

in the Susitna Valley as the equivalent of the greenstone and schist east of Susitna River and the upper part of the group as the equivalent of the Chisna.

The Nikolai formation is made up of massive amygdaloidal basaltic lava flows similar to the lavas of this region.[1] At the base it has a great thickness of conglomerate, slate, limestone, and tuff, with intercalated flows. The resemblance of the sedimentary portion of the Nikolai to the greenstone and schist formation in Susitna Valley and the apparent conformable relation of each to similar overlying lava formations is also suggestive. The Nikolai greenstone was formerly regarded as Triassic, but recent collections of fossils made by Moffit, Chapin, and Mertie from the sedimentary beds intercalated into the lower portion of the lava flows prove that a portion of it is Carboniferous and probably lower Carboniferous.[2]

## TRIASSIC (?) ROCKS.

### TRIASSIC (?) LAVAS AND TUFFS.

#### DISTRIBUTION AND CHARACTER.

Watana Creek and its main tributary, Fox Creek, flow through a broad belt of heavy dark-colored volcanic rock, which extends from the main forks of the creek northeastward to Susitna River. The lavas form the end of a range of rugged mountains, which beyond Susitna River stretch in a broad crescentic belt roughly parallel to the Alaska Range. These mountains are made up principally of basaltic and andesitic lava flows and beds of water-laid tuffaceous material.[3]

The Watana Creek lavas are composed essentially of dark basalts and andesites, in part amygdaloidal, and beds of tuffaceous material and breccia. They show conspicuous bedding and consist chiefly of lava flows and beds of tuff and breccias, indicating a long period of volcanic outflow and intervals of explosive activity and sedimentation. The beds dip dominant at a low angle to the north, but at the northeast end of the ridge they dip gently to the southeast. At some places the lava beds show more deformation, indicated by sharp folds and steep dips.

The dominant members of this series are dark-green rocks of fine grain and even texture. Amygdaloidal phases are common, in which

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[1] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 60–63, 1911.

[2] Moffit, F. H., The Kotsina-Kuskulana region, Alaska: U. S. Geol. Survey Bull. — (In preparation).

[3] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska: U. S. Geol. Survey Bull. 498, pp. 29–30, 1912.

irregular cavities, the largest half an inch in diameter, are filled with calcite, chloritic material, and quartz. The groundmass of the typical rocks is composed of a fine-grained aggregate of feldspar and highly refracting minerals. Phenocrysts of plagioclase feldspar and pyroxene are more or less altered to epidote and chloritic material, which are plentiful enough to give the rock a greenish cast. In the lower part of the exposed section much light-colored tuffaceous material and local beds of coarse angular breccia are intercalated with the flows. The lava flows contain beds of both andesite and basalt.

The thickness of the beds south of Butte Creek is calculated to be 3,500 feet.[1] The maximum thickness of the beds exposed in the high range between Butte and Watana creeks is evidently greater.

#### AGE AND CORRELATION.

The only available evidence of the age of the Watana Creek lavas is seen in their relations to other rocks. The lavas appear to overlie conformably the group of greenstones and schists that are exposed along Susitna River, but as the age of this group is not known, the apparent relation does not indicate the geologic age of the lavas, which must be determined by observations made in other regions, principally by Moffit in regions north and east of that here considered. Moffit[2] states that the lava flows between Clearwater Creek and Susitna River were probably poured out either in late Carboniferous or in early or Middle Triassic time, and in a later report[3] he notes that the Butte Creek lavas closely resemble the Nikolai greenstone of Chitina Valley and the greenstones that are exposed in some other parts of the Wrangell Mountains. In a still later report, now in preparation, Moffit[4] presents evidence that the Nikolai greenstone is Triassic rather than earlier.

### UPPER TRIASSIC (?) ROCKS.

#### DISTRIBUTION AND CHARACTER.

Rocks referred tentatively to the Upper Triassic consist of limestone, slate, argillite, and related coarser sediments, as well as dioritic and other intrusives. A small area of these rocks is exposed along the northwest side of Tsisi Creek for an unknown distance.

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[1] Moffit, F. H., The Broad Pass region, Alaska, with sections on Quaternary deposits, igneous rocks, and glaciation by J. E. Pogue: U. S. Geol. Survey Bull. 608, p. 27, 1915.

[2] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska: U. S. Geol. Survey Bull. 498, p. 30, 1912.

[3] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, p. 28, 1915.

[4] Moffit, F. H., The Kotsina-Kuskulana region, Alaska: U. S. Geol. Survey Bull. — (in preparation).

The most prominent members are dark-blue and black slate and argillites and greenish-gray graywacke. The graywacke is made up of grains of quartz and feldspar and fragments of rock. The beds are closely folded and in places have suffered considerable metamorphism, which has resulted in the formation of talc and mica schists and intermediate schistose rocks. Intercalated with the slate, graywacke, and schist are thin beds of crystalline limestone, veined with calcite, and in part silicified. The beds of slate and graywacke have been invaded by masses of quartz diorite and in places extensively mineralized with quartz veins.

### STRUCTURE AND THICKNESS.

The slate and graywacke group is composed of a series of closely folded beds that have steep dips. The general strike of the beds is N. 45° E., parallel to the direction of Tsisi Creek, along which the beds dip steeply to the northwest, standing nearly vertical. The close folding and disturbance due to intrusions of quartz diorite make any estimate of thickness difficult and doubtful, and the slaty cleavage and schistosity add to the difficulty, for they may be easily mistaken for bedding. Hasty measurements made on a section exposed along a tributary of Tsisi Creek indicate that the group is at least 2,000 feet thick, but it may be much thicker, for neither the top nor the base of the section was seen.

### AGE AND CORRELATION.

No fossils were found in these rocks. They are referred to the Upper Triassic by correlation with Upper Triassic rocks that form a belt extending from Gulkana Glacier past Valdez Creek to Watana Creek. These rocks are described as dark-blue or black slate, interbedded graywacke and arkose, and limestone, schists, and granular intrusives.[1] By reason of their lithologic resemblance to and apparent structural continuity with the rocks on Watana Creek the rocks of the slate-graywacke series are doubtfully referred to the Upper Triassic.

The Upper Triassic rocks on Valdez Creek are the equivalent of the Chitistone limestone and McCarthy formation of Chitina Valley and the Triassic limestone of the Nabesna River region.[2] Thick Upper Triassic formations are found on Cook Inlet and Kenai Peninsula.[3]

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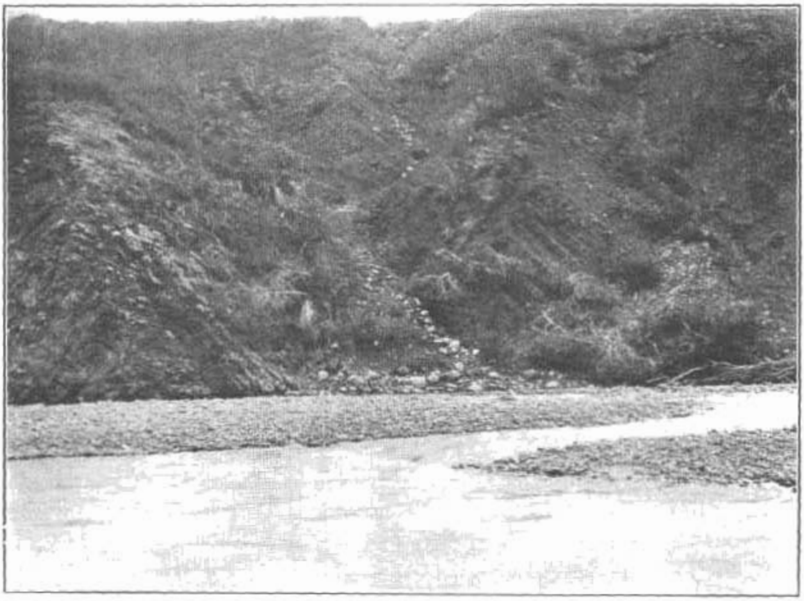
[1] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska: U. S. Geol. Survey Bull. 498, pp. 31–33, 1912.

[2] Idem, p. 33.

[3] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Bull. Geol. Soc. America, vol. 16, pp. 393–396, 1905. Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 41–50, 1912.

*A.* JOINTED ANDESITE, OSHETNA RIVER.



*B.* INTERBEDDED TUFF AND ANDESITE, OSHETNA RIVER.

## JURASSIC ROCKS.

### LOWER JURASSIC ROCKS.

#### DISTRIBUTION AND CHARACTER.

A belt of volcanic rocks, consisting essentially of andesites, rhyolites, dacites, breccias, and associated tuffaceous sediments, extends from Tyone Creek westward to the high divide between Oshetna and Black rivers. These rocks are bounded on the north and east by deposits of gravel and on the west by the batholith of quartz diorite. On the south they are overlain unconformably by Upper Jurassic sediments. To this group is referred an isolated area of similar rock on Crooked and Albert creeks and also the andesitic lavas and tuffs of Stuck Mountain. This group might by detailed mapping be broken up into a number of units, and it may include areas of Tertiary lavas similar to those that are exposed north of Susitna River.

In the region studied the rocks of this group are dominantly andesitic and rhyolitic in composition but exhibit wide variation in texture. Along Oshetna River a short distance above the mouth of Little Oshetna River there are flat-lying beds of fine-grained tuffaceous shale, which appear to occupy the lowest position in the rocks of this group. Farther up the river the shales are overlain by andesitic and dacitic flows and intercalated beds of tuff. (See Pl. VI, *A*, *B*.) On the double butte between Black and Oshetna rivers there are rhyolite and rhyolitic tuffs with beds of chert, which are cut by diorite and basic intrusives.

In the upper part of the group as exposed in this region andesitic tuffs and tuffaceous sandstones predominate and are best developed in the vicinity of Albert Creek. Gold Hill is composed of a fine-grained reddish-brown scoriaceous rock, which under the microscope is seen to be a tuff with a glassy base inclosing feldspar crystals that are in large part altered to calcite. Stratified water-laid tuffs are conspicuous in this locality. They are coarse-grained rocks composed of angular fragments of plagioclase feldspar and ferromagnesian minerals, small rounded pebbles, and chloritic material, which in places colors the rock bright green. In the more explosive type the chloritized areas occur as bright bluish-green angular fragments inclosed in a fine-grained brown matrix.

#### STRUCTURE AND THICKNESS.

Folding is prominent. Compression and subsequent tilting have thrown the beds into a series of eastward-trending folds, more or less compressed, but with few sharp flexures. The dominant dip is southward, at angles ranging from nearly horizontal to 60°.

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#### STRUCTURE AND THICKNESS.

Folding is prominent. Compression and subsequent tilting have thrown the beds into a series of eastward-trending folds, more or less compressed, but with few sharp flexures. The dominant dip is southward, at angles ranging from nearly horizontal to 60°.

Faulting on a small scale is conspicuous throughout the group, but evidence of extensive movement was not observed.

The estimated thickness of the dominantly igneous part of the group is over 1,200 feet, and above and below this igneous rock there are several hundred feet of tuffs and tuffaceous sandstone and shale.

### AGE AND CORRELATION.

No fossils were collected from this group of volcanic rocks in the Nelchina region, so the determination of its age rests upon its correlation with near-by rocks of known age. The field evidence is not conclusive, but it indicates that the rocks constitute a part of a series of bedded volcanics of Lower Jurassic age that are extensively developed in the Talkeetna Mountains. This group consists of breccias, agglomerates, and andesitic and rhyolitic lavas and tuffaceous shales, sandstones, and conglomerates. The rocks of this group are widely distributed in the Talkeetna Mountains, and from place to place the members differ in character.

North of Doone Creek Martin and Katz[1] noted creamy-white and drab felsites, brownish-green narrow-banded tuffs of fine angular clastic texture, dark fine-grained fragmental rock, banded fossiliferous tuffs composed of angular bits of feldspar and dark fragments, stratified breccias containing angular fragments of porphyritic or felsitic rocks, and black aphanitic vesicular basalts. The development of secondary minerals is indicated by the prevalent green color, which is more pronounced where the rocks are crushed and shattered.

Features of the stratigraphy and structure of the group also indicate its correlation with the Lower Jurassic rocks of the Talkeetna Mountains. The volcanic rocks exposed along the tributaries of Oshetna River and Tyone Creek bear the same unconformable relation to the overlying Upper Jurassic rocks as the Lower Jurassic volcanic rocks of the Talkeetna Mountains, and a westward projection along their strike would carry them toward the Lower Jurassic rocks of the Talkeetna Mountains, with which they were probably continuous before the intrusion of the quartz diorite.

The Lower Jurassic rocks of the Talkeetna Mountains were first studied by Paige and Knopf and on the basis of a small collection of fossils found in interstratified tuffs from Sheep Mountain were assigned to the lower Middle Jurassic. The fossils were submitted to T. W. Stanton, who reported as follows:[2]

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[1] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, p. 30, 1912.

[2] Paige, Sidney, and Knopf, Adolph, Geological reconnaissance in the Matanuska and Talkeetna basins: U. S. Geol. Survey Bull. 327, p. 18, 1907.

6708. Creek entering Chickaloon River from west 1 mile above Government Bridge. Float above falls.

Pecten sp.

Several undetermined small pelecypods.

Possibly Jurassic.

6709. On same creek as 6708 at elevation 2,200 feet. From talus.

Cardinia? sp.

Jurassic.

The lots numbered 6693, 6697, 6706-6709 are referred to the Jurassic and are probably Lower Jurassic, though the paleontologic evidence for the latter reference is not so full as is desirable. The fossils are almost certainly from the same beds from which Mr. Knopf collected his lot No. 201, at the head of Matanuska River, in 1906. Mr. Knopf's collection was at that time doubtfully referred to the "Enochkin formation," but I am now inclined to regard the beds from which he collected as equivalent to the supposed Lower Jurassic near Seldovia and to regard them as Lower Jurassic. It is true that not more than two or three species are common to the different localities from which these fossils have been collected, but the general character of the fauna from each suggests the Lower Jurassic, and probably more systematic collecting would prove that the different lots really belong to a single fauna.

Further collections by Martin and Mertie[1] from Boulder Creek and from Sheep Mountain furnish faunal and floral evidence of the Lower Jurassic age of the rocks of this group.

Brooks[2] provisionally mapped these rocks with the Skwentna, with which he suggests their possible correlation.

## MIDDLE JURASSIC ROCKS.

### TUXEDNI SANDSTONE.

#### DISTRIBUTION AND CHARACTER.

The Tuxedni sandstone extends from a line passing through the forks of Alfred Creek and Tahneta Pass northward to Flat Creek and Willow Creek, inclosing a small area of Lower Jurassic and Tertiary volcanic rocks. The base of the formation was not observed. The only locality at which fossil-bearing rocks were noted is on a small tributary of Crooked Creek a mile north of the mouth of Albert Creek. The beds are composed essentially of buff sandstone, soft sandy shale, and a smaller amount of dark-brown arkosic sandstone that contains black minerals. On weathering the light sandstone becomes red and yellow.

#### AGE AND CORRELATION.

A collection of fossils found in this formation was submitted to T. W. Stanton, who reported as follows:

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[1] Martin, G. C., and Mertie, J. B., jr., Geology of upper Matanuska Valley: U. S. Geol. Survey Bull. — (in preparation).

[2] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 86, 1911.

8951. No. 17. Small gulch tributary to Crooked Creek. north of Albert Creek.
Pecten sp. a.
Pecten sp. b.
Inoceramus sp.
Grammatodon sp.
Trigonia sp.
Protocardia sp.
Cyprina? sp.
Trigonia sp. cf. T. dawsoni Whiteaves.
Stephanoceras? sp.
Middle Jurassic, Tuxedni fauna.

The relation of the Tuxedni formation to older rocks is not evident. Associated with the purely volcanic portion of the Lower Jurassic volcanic rocks on Albert Creek are beds of tuffaceous shale and sandstone, which from their dominantly tuffaceous character are evidently members of the volcanic series and were so regarded in mapping. They may, however, represent a transition stage from volcanic activity to a period of sedimentation, and mark an unconformity between the Lower Jurassic and Middle Jurassic rocks. Apparent conformity exists between Lower Jurassic lavas and the overlying sediments with associated volcanic beds, which are exposed in the Matanuska region.[1] The relation, however, of the small patch of Lower Jurassic rocks inclosed within the area of Tuxedni sandstone on Albert Creek indicates an unconformity. This relation is in accord with that at the type locality on Cook Inlet, where an unconformity separates Lower and Middle Jurassic rocks.[2]

The Tuxedni sandstone is widely distributed on Cook Inlet, and its type section on Tuxedni Bay is the most complete known section of these rocks. In this section, where neither the base nor the top is exposed, Stanton and Martin[3] measured 1,128 feet of Tuxedni rocks. At Tuxedni Bay and other places on Cook Inlet fossil plants are interbedded with marine sediments.

Rocks of about the same age occur in the Tordrillo formation in the Alaska Range,[4] at several places in Matanuska Valley,[5] and on Chitina River.[6]

### CHINITNA FORMATION.

#### DISTRIBUTION AND CHARACTER.

Upon the Tuxedni sandstone, and in apparent conformity, lies a series consisting essentially of concretionary sandy shale and some

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[1] Paige, Sidney, and Knopf, Adolph, op. cit., p. 23.

[2] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, p. 60, 1912.

[3] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Bull. Geol. Soc. America, vol. 16, pp. 399–400, 1905.

[4] Brooks, A. H., op. cit., p. 90.

[5] Paige, Sidney, and Knopf, Adolph, op. cit., pp. 16–19.

[6] Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, p. 26, 1914.

sandstone. The sandstone is in places conglomeratic and contains angular fragments of shale and black minerals. It extends from the area covered by the Tuxedni sandstone northward for an undetermined distance toward Little Nelchina River and Flat Creek and is bounded on the east by gravel.

### STRUCTURE.

The Middle Jurassic sandstone and shale formations exhibit considerable folding and maintain a general dip toward the north. Their general structural relations to the other Jurassic rocks are shown in figure 3. They apparently dip beneath the Upper Jurassic beds and with them are involved in a broad synclinal fold.

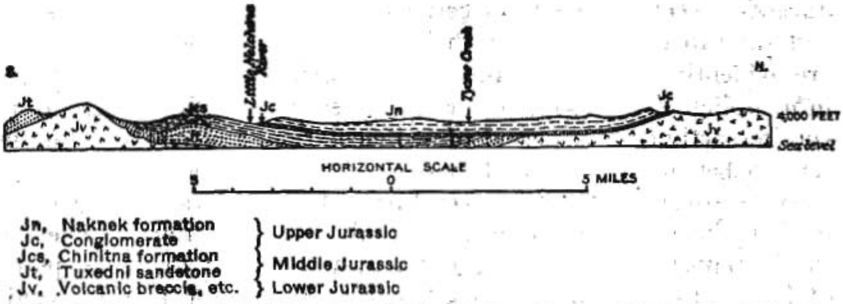

FIGURE 3.—Diagrammatic section across Little Nelchina River and Tyone Creek, showing relations of Jurassic sedimentary rocks.

### AGE AND CORRELATION.

No fossils were found in the Chinitna formation, so its age was determined only by stratigraphic correlation. It apparently overlies the Tuxedni sandstone conformably and dips beneath the massive conglomerate that is considered the base of the Upper Jurassic rocks. It is thus regarded as the equivalent of the Chinitna shale and is doubtfully referred to that formation, which it resembles lithologically.

Exposures of Chinitna shale are found near by at the head of Little Nelchina River and at several places in the upper Matanuska Valley.[1] It also occurs on Cold and Dry bays[2] on Alaska Peninsula and on Tuxedni, Chinitna, and Iniskin bays, on Cook Inlet.[3]

Formerly the Tuxedni sandstone and Chinitna shale were grouped together as the "Enochkin formation." The Chinitna shale is described as resting with apparent conformity upon the Tuxedni sandstone, from which it differs by being argillaceous rather than arenaceous and by possessing distinctive faunas and floras.[3]

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[1] Martin, G. C., and Mertie, J. B., jr., op. cit. Paige, Sidney, and Knopf, Adolph, op. cit., pp. 20–22.

[2] Martin, G. C., The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: U. S. Geol. Survey Bull. 250, pp. 52–53, 1905.

[3] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, p. 65, 1912.

## UPPER JURASSIC ROCKS.

### CONGLOMERATE.

#### DISTRIBUTION AND CHARACTER.

The Upper Jurassic formations in the Nelchina region are marked by massive beds of conglomerate. In areal distribution these rocks occupy two parallel westward-trending bands along the north and south borders of the known areas of the Naknek formation. The larger of these bands extends from Tyone Creek across Daisy, Fourth of July, Walker, Yacko, Red, and Joe creeks to Little Oshetna River and is probably continuous with the conglomerate on Oshetna River. A parallel belt of conglomerate extends from a point near the mouth of Crooked Creek up Little Nelchina River to the mouth of Flat Creek and an unknown distance beyond. The conglomerate exposed at these places is similar in general appearance and composition. It is composed of massive plates made up essentially of dioritic and volcanic rocks set in a gritty matrix containing abundant fragments of mica and shale. Along its base it is predominantly coarse and contains essentially material derived from the Lower Jurassic volcanic rocks, upon which it lies in places. In its upper part there are lenses of fine yellow sandstone and beds of conglomerate made up of small well-rounded pebbles, and with these beds thin beds of shale are intercalated. This alternation of coarse and fine sediments was noted along Little Nelchina River near the mouth of Idaho Creek. At this place a cliff over 400 feet high is built up of lenticular beds of sandstone and conglomerate.

The conglomerate extending from Tyone Creek to Little Oshetna River, and the conglomerate on Oshetna River are with little doubt the Chisik conglomerate. The conglomerate on Little Nelchina River and Idaho Creek is with less confidence also regarded as Chisik. Its lower contact is concealed, but it is believed to lie next above the Chinitna formation, which is of Middle Jurassic age. It is known by its fossils to be Upper Jurassic. It is overlain with apparent conformity by Upper Jurassic shales and sandstone of the Naknek formation. This conglomerate may be a member of the Naknek formation and may thus occupy a higher position among the Upper Jurassic rocks than the Chisik conglomerate, but probably not, for to assume that it occupies such a position is to assume also that the beds were brought to their present position by faulting, no evidences of which were seen at this place. By reason of their similar stratigraphic relation to the known Naknek rocks, their lithologic similarity, and absence of proof to the contrary the conglomerate on Little Nelchina River and the Chisik conglomerate that extends from Tyone Creek to Little Oshetna River are believed to be the same.

### STRUCTURE AND THICKNESS.

If the conglomerate on Little Nelchina River and Idaho Creek and the conglomerate that extends from Tyone Creek to Little Oshetna River are the same, the conglomerate and the overlying Naknek sandstone and shale occupy a broad syncline that brings the conglomerate to the surface in two parallel belts—one on Little Nelchina River and the other on tributaries of the Little Oshetna and Tyone Creek. The conglomerate is undeformed and but little disturbed. On Little Nelchina River the beds are nearly level, but in places on the northern limb of the syncline they are tilted to about 20°. Their entire thickness was not determined. The cliff on Little Nelchina River shows a thickness of over 400 feet. On Yacko Creek there is a measured thickness of 450 feet besides concealed portions at the top and at the base of the formation. The relations on Yacko Creek are shown in figure 4.

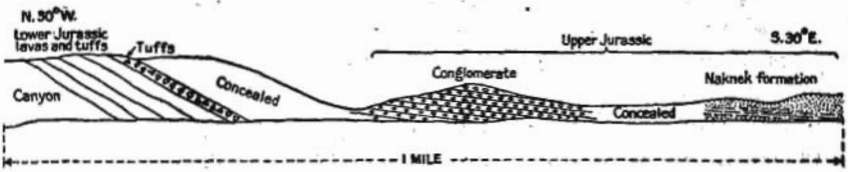

FIGURE 4.—Section exposed along Yacko Creek above canyon.

### AGE AND CORRELATION.

A small collection of fossils gathered from the interstratified sandstone beds was submitted to T. W. Stanton, who reported as follows:

8952. No. 18. North bank of Little Nelchina River, just above Idaho Creek.
  Aucella sp.
  Turbo sp.
Upper Jurassic.

The conglomerate forms the basal member of the Upper Jurassic rocks and lies unconformably on older rocks. Along the northern belt its contact is with the Lower Jurassic volcanic rocks. On Little Nelchina River its lower contact is concealed, but it is believed to overlie the Chinitna formation, which is of Middle Jurassic age. It is overlain with apparent conformity by Upper Jurassic shale and sandstone assigned to the Naknek formation. Its correlation with the Chisik conglomerate rests upon its lithologic similarity and its basal position among Upper Jurassic rocks.

## NAKNEK FORMATION.

### DISTRIBUTION AND CHARACTER.

A great thickness of shale and sandstone referred to the Naknek formation overlies the Upper Jurassic conglomerate with apparent conformity. It extends westward from Tyone Creek to Oshetna River in a broad belt and is bounded on the north by conglomerate believed to be the Chisik conglomerate and on the south, in part at least, by conglomerate regarded as the same formation.

The lower part of the Naknek formation is composed of sandstone and sandy shale resembling members of the Chisik conglomerate. In its upper part the formation becomes argillaceous. The arenaceous members are overlain by dark-blue fissile shale containing beds of hard white sandstone. Fossils are not widely distributed in the Naknek formation but are locally very abundant. In places thin beds of conglomeratic arkose are conspicuous on account of the abundant fragments of aucellae which make up a large part of the rock.

### STRUCTURE.

The Naknek formation occupies the trough of the syncline in which the Upper Jurassic conglomerate is involved. The beds are more deformed than the conglomerate and show many minor gentle folds. The beds are not known to be faulted extensively, though they show some small displacements.

### AGE AND CORRELATION.

T. W. Stanton made the following report on a collection submitted to him for identification:

8953. No. 19. Idaho Creek, 1½ miles above its mouth.
    Serpula? sp.
  Jurassic or Cretaceous.
8954. No. 20. Ridge between Little Nelchina River and Tyone Creek, 2 miles north of Idaho Creek.
    Aucella sp.
  Upper Jurassic.
8955. No. 21. Yacko Creek on claim No. 10 below, near base of Upper Jurassic overlying conglomerate.
    Inoceramus sp.
    Tancredia? sp.
  The fossils are not sufficient to distinguish between Jurassic and Cretaceous.

The name Naknek was first used by Spurr[1] to describe a series of arkoses and conglomerates with beds of limestone and associated volcanic rocks that occurs in the vicinity of Naknek Lake on the Alaska Peninsula. He estimated that a thickness of at least 1,500 feet of Naknek beds is exposed near Katmai. The Naknek formation is also extensively exposed on Cook Inlet. On the north shore of Chinitna Bay Stanton and Martin[2] measured a section comprising

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[1] Spurr, J. E., A reconnaissance in southwestern Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 169–171 1900.

[2] Stanton, T. W., and Martin, G. C., op. cit., pp. 403–405.

over 5,000 feet. Other exposures of the Naknek formation occur on Cook Inlet,[1] on the Alaska Peninsula,[2] and at several places in Matanuska Valley.[3]

## CRETACEOUS ROCKS.

The Lower Cretaceous limestone and Upper Cretaceous shale and sandstone described below occur only in an area embracing the drainage basins of the upper parts of Squaw Creek, Alfred Creek, and Billy Creek. The geology of this region was not studied by the writer and information regarding it was obtained from others.

Rocks of Lower Cretaceous age are represented by a massively bedded limestone that overlies Upper Jurassic rocks at the head of Nelchina River and Billy Creek.[4]

Upper Cretaceous shale and sandstone occur at the headwaters of Squaw, Alfred, and Billy creeks.

## TERTIARY ROCKS.

### CONGLOMERATE.

Conglomerate of Tertiary age has a wide distribution on the tributaries of Caribou and Billy creeks, an area which, although included in the accompanying geologic map, was not visited by the writer. The following description is taken from a report by Paige and Knopf:[5]

> Occasional thin layers of sandstone show that the conglomerate is lying in horizontal attitude. It is almost exclusively composed of large well-rounded boulders of augite andesite and quartz monzonite embedded in a tuffaceous matrix. In the upper horizons the boulders of andesite preponderate. The boulders of the conglomerate are ellipsoidal in shape, and many of them are as much as 2 feet in diameter. The conglomerate is lithified firmly enough to form large boulders in the present stream wash. Sheets of lava are occasionally intercalated in the conglomerate.

This conglomerate was at that time correlated with the Upper Jurassic sediments of the Nelchina River region, but since then has been studied in greater detail by Martin, who regards it as Tertiary.

### ACIDIC LAVAS.

#### DISTRIBUTION AND CHARACTER.

On the upper part of Tsusena Creek there are several large surface lava flows, including dacite, rhyolite, and andesite. These rocks,

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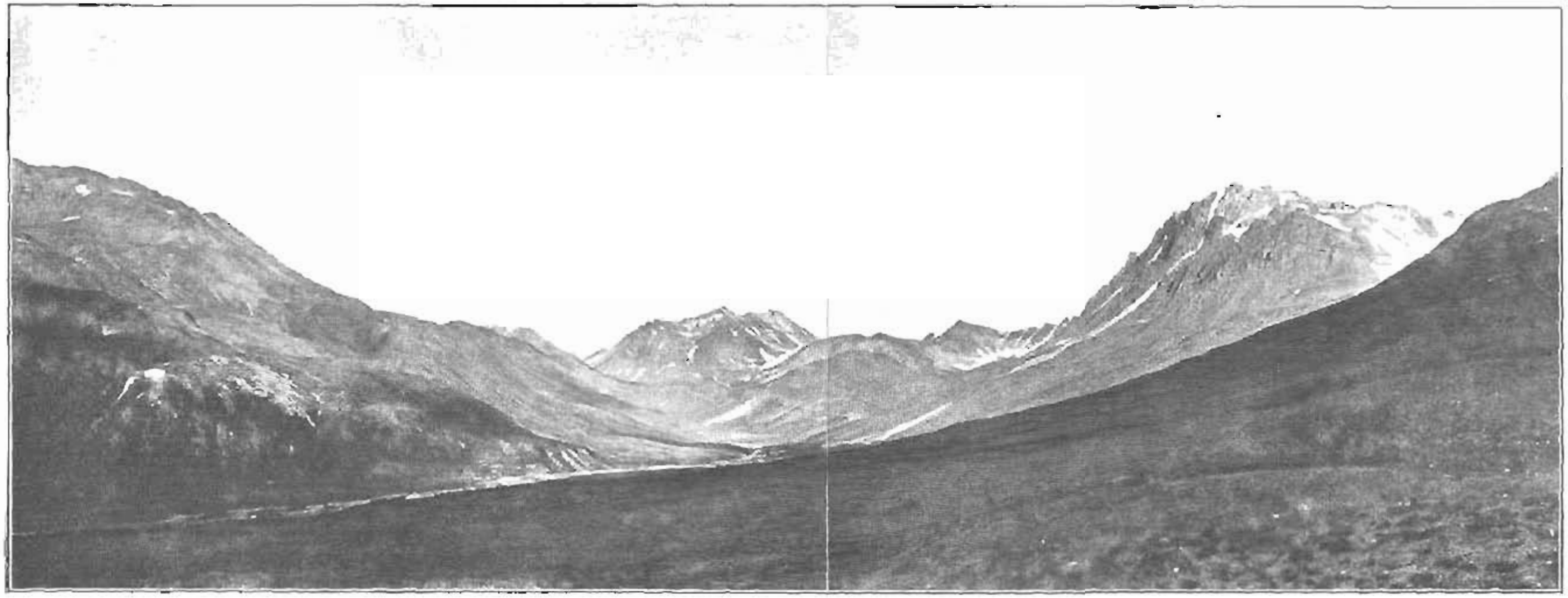
[1] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 69–74, 1912.

[2] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 33–38, 1911.

[3] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins: U. S. Geol. Survey Bull. 327, pp. 20–23, 1907.

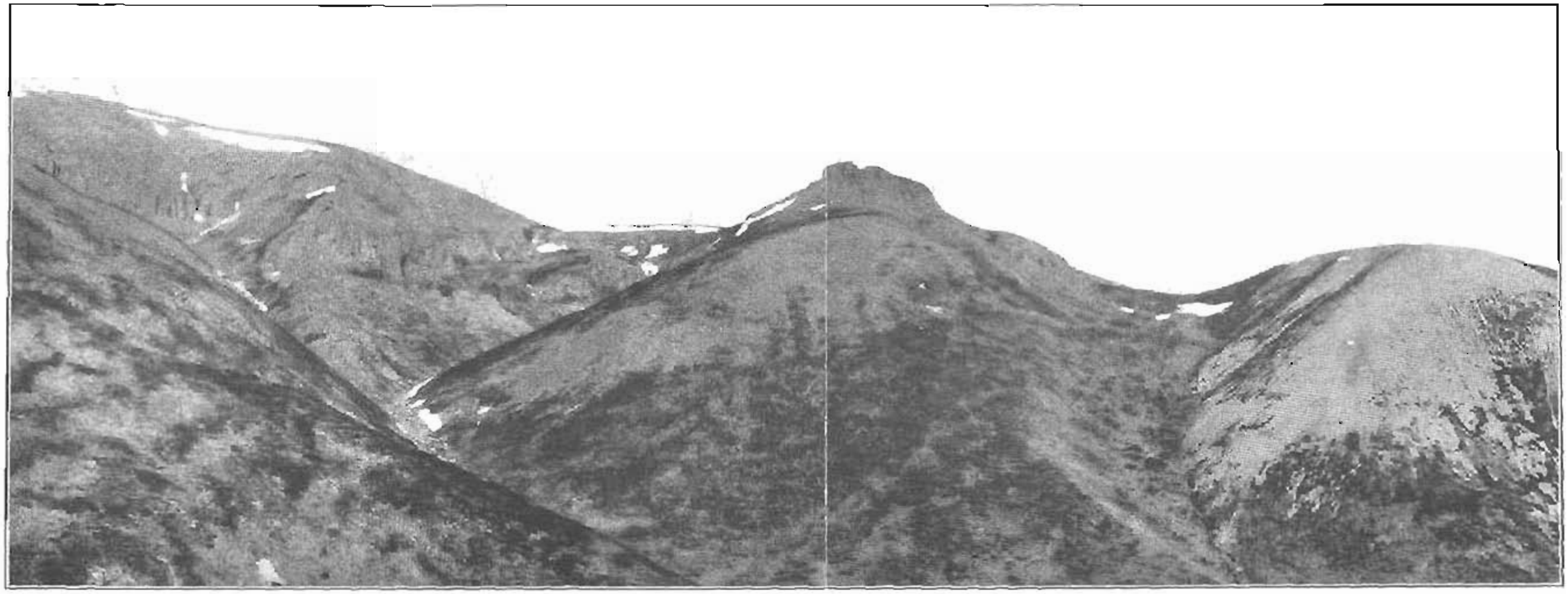
[4] Idem, p. 24.

[5] Idem, p. 21.



A. TERTIARY LAVAS NEAR THE HEAD OF TSUSENA CREEK.

Mount Chulitna in middle background, elevation 6,700 feet.



B. VOLCANIC ROCKS AT THE HEAD OF ALFRED CREEK.

*Tertiary basalt unconformably overlying Lower Jurassic tuff beds (white rock at right of picture).*

which are more or less associated in the field, are grouped together under the name of acidic lavas and on the geologic map are represented with a single symbol. (See Pl. VII, *A*.)

The oldest of these lava flows is dacite, a fine-grained porphyritic rock that ranges in color from gray to dark brown. It contains crystals of striated feldspar set in a fine-grained groundmass of biotite, feldspar, and quartz. Mineralogically it corresponds to quartz diorite, but its texture and field relations indicate that it is a surface flow. The area that contains the dacite was invaded by large bodies of granite, and in zones of deformation small areas of garnet schist and sillimanite schist have been formed.

These rocks include rhyolite and rhyolite tuffs. One type is a dense rock with typical flow bands of white and green material inclosing prominent phenocrysts of orthoclase feldspar. The microscope shows that the rock has a dense groundmass, mainly glass, containing many spherulites and phenocrysts of feldspar. Orthoclase predominates, and plagioclase is subordinate. Associated with this typical flow rock is considerable fragmental material ranging from fine-grained tuffs that are not easily distinguished from flow rocks to coarse angular breccias. Another type of rhyolite is a buff-colored dense rock set with small angular crystals of quartz.

Amygdaloidal andesite occurs on the divide between the head of Jack River and the east fork of Tsusena Creek, just north of the area mapped. Microscopically it is a fine dark-green dense rock containing numerous round amygdules of white quartz. Altered portions of the rock are purplish gray and are pitted with irregular amygdules consisting of an outer shell of quartz and an interior of dark-green serpentine and chloritic material. The groundmass is a granular network of lath-shaped crystals of andesine and a little chloritic material.

### AGE AND CORRELATION.

The age of these lavas is uncertain. They appear to correspond, in part, at least, to a series of lava flows that occur in the Broad Pass region and that are regarded by Pogue[1] as Tertiary. Although treated as a unit, these lavas appear to include flows of different ages. The dacite is evidently the oldest. It is intruded by large bodies of granite and has suffered metamorphism, which was not noted in the other lavas. The amygdaloidal andesite lies upon the eroded surfaces of the granite and is the youngest lava noted. The rhyolite appears to be intermediate in age between the dacite and amygdaloidal andesite. The amygdaloidal andesite may be the equivalent of simi-

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[1] Pogue, J. E., Igneous rocks [of the Broad Pass region, Alaska]: U. S. Geol. Survey Bull. 608, pp. 60–62, 1915.

lar rocks in the Broad Pass region which overlie Eocene sediments and consequently are regarded as Tertiary.[1]

This group of lava flows is thus probably Tertiary, except possibly the dacite, which, on account of its relation to the Tertiary granite and of its greater deformation, may be considered Mesozoic.

### BASALTIC LAVAS AND TUFFS.

#### DISTRIBUTION AND CHARACTER.

The rocks that form the summit of the high peaks at the head of Albert Creek are basalt, comprising flows and interbedded white tuffs. (See Pl. VII, *B*.) The typical flow is porphyritic, having a dense black groundmass studded with many crystals of feldspar and pyroxene. The groundmass is a fine-grained aggregate of feldspar needles, pyroxene, and magnetite dust, and the phenocrysts are augite and labradorite. Mingled with the flow rock are beds of white, yellow-weathering tuffs. The basalt flows lie nearly horizontal and rest unconformably on Lower Jurassic volcanic beds.

#### AGE AND CORRELATION.

The basalt is probably the equivalent of a series of basaltic flows that are widely distributed in the Talkeetna Mountains. These flows are well exposed on the summit of Castle Mountain, in Matanuska Valley, where the following section was studied by the writer in 1910:

*Section in summit of Castle Mountain, Matanuska Valley, Alaska.*

| | Feet. |
|---|---|
| Dense basalt | 130 |
| Tuffs, breccias, and vesicular lavas | 170 |
| Dense basalt, in part columnar at the bottom and vesicular at the top | 250 |
| Tuffs, breccias, shale, sandstone, and conglomerate | 90 |
| Dense and amygdaloidal basalts | 210 |
| Unconformity. | — |
| Eska conglomerate. | 850 |

The basalt rests unconformably upon the Eska conglomerate, which is regarded by Martin as Tertiary and possibly Miocene.[2]

### QUATERNARY DEPOSITS

Quaternary deposits are widely distributed in the Nelchina-Susitna region. They mantle all the lowland and reach their greatest development in the broad Copper-Susitna basin, from which apophyses

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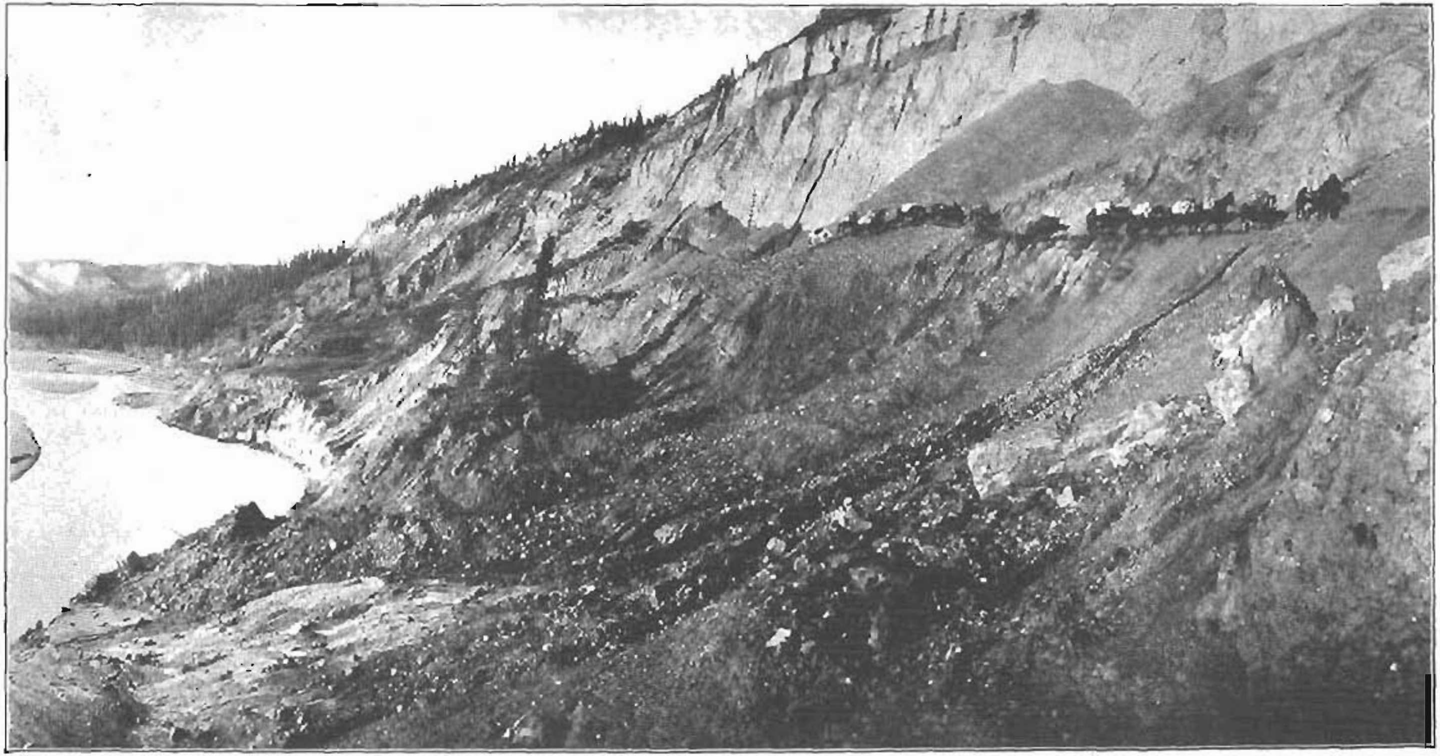
[1] Pogue, J. E., op. cit., p. 63.

[2] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 54–55, 1912.



SAND AND SILT BLUFFS ALONG TAZLINA RIVER NEAR THE MOUTH OF TOLSONA CREEK.

of them extend up the valleys and depressions. They are thickest in the interior of the broad valleys and thin out up stream valleys and on the slopes of the bordering mountains. The surface of this Quaternary terrane is gently rolling. (See Pl. III, *A*.) At some localities the place of the contact of the deposits with the bedrock is nearly concordant with a contour line, but over a broad area it varies greatly yet slopes gently southeastward in conformity with the slope of the basin. The maximum thickness of the glacial deposits is not known. The thickest measurable section observed is along the Susitna at a place where the stream flows in a gravel channel, 500 feet below the surface of the plain, so the maximum thickness must exceed this figure. Copper, Tazlina, and Klutina rivers expose sections over 500 feet thick.

The beds are composed of unconsolidated material and exhibit considerable variation in character, ranging from coarse morainal heaps to finely laminated silts. (See Pl. VIII.) The character of the deposits shows no definite relation to their distribution. They consist of fine silts surrounded by coarser deposits and are overlain by till, indicating rapidly changing conditions of sedimentation. On the whole their character indicates that they were deposited through the agency of ice and water and in time were closely connected with the ice invasion and more distinctly with its retreat. The extent of the ice transgression is discussed in detail under the heading "Glaciation" (pp. 54–58). As the glaciers melted material suspended within the ice or carried on its surface was deposited in morainal heaps. Such deposits are widely distributed and in places they are thick, but on the higher slopes they consist only of a thin covering of morainal material or erratic boulders. Morainal deposits were attacked by the streams that flowed from the melting ice, so that as the glaciers receded the material they bore was in large part redistributed and mingled with that carried by the débris-laden streams. The finer material was carried farthest from its source and deposited as silts, clays, and fine sands. In this region much of it found lodgment in lakes and ponds, where it was perfectly sorted. The coarser material was spread out by the shifting overburdened streams in sheets and lenses of sand and gravel.

Morainic deposits are conspicuous in the western part of the region. On both sides of Susitna River there are prominent moraines, with characteristic lake-dotted hummocky surfaces. A number of streams south of Susitna River are bordered by high lateral moraines that extend below the points where the valleys leave the uplands and deploy into spatulate lobes, which unite to form a nearly continuous moraine from Oshetna River to Kosina Creek and possibly beyond. On Kosina Creek and Black River the lateral moraines from conspicuous ridges 500 feet above the valley bottoms

An extensive moraine reaches from Deadman Creek to Watana Creek, and a larger one extends southward from Coal Creek for 15 miles. It rises in an abrupt scarp above the lowland plain, to which it stands in marked relief.

## INTRUSIVE ROCKS.

### QUARTZ DIORITE.

#### DISTRIBUTION AND CHARACTER.

Quartz diorite and related dioritic rocks are widely distributed in the Talkeetna Mountains and the mountains north of Susitna River. A large boss of quartz diorite, covering several hundred square miles, makes up the mountainous area that is drained by the upper part of Kosina Creek and its tributaries. From a point on Susitna River about 7 miles west of the mouth of Oshetna River dioritic rocks extend southwestward for an unknown distance into the Talkeetna Mountains.

The rocks making up this mass are dominantly quartz diorites—even-grained black and white rocks composed essentially of plagioclase feldspar and hornblende in about equal amounts, together with a little quartz. Hornblende is invariably present and in places forms a large proportion of the rock. In the hand specimen it appears black, but under the microscope it is seen to be dark green and strongly pleochroic. The feldspar is dominantly andesine and oligoclase-andesine. Quartz is not abundant and does not occur in the dioritic phases of the rock. Biotite occurs very sparingly; other accessories are titanite and zircon.

From place to place the quartz diorite shows considerable variation in texture. Of very common occurrence is a gneissoid appearance caused by a local foliation of the rock and a parallel arrangement of the hornblende minerals. Rocks exhibiting this slight gneissoid texture are regarded as cataclastic phases of the massive quartz diorite and should not be confused with the typical gneisses in which there has been a recrystallization of the rock with the development of metamorphic minerals.

In the area north of Susitna River diorites are not widely distributed. A small intrusive mass occurs between Tsusena and Deadman creeks, and unmapped areas of dioritic intrusives were noted in the greenstone area inclosed within the "big bend" of Susitna River. Small areas of dioritic rocks occur on Twin Hills and Lone Butte and in the vicinity of Stuck Mountain and Klutina River.

#### AGE AND CORRELATION.

The diorite and quartz diorite differ only in their content of quartz and are regarded as phases of a single mass. The isolated masses of dioritic rock are correlated with the Talkeetna batholith only because of lithologic similarity. Their age is determined by the relation the quartz diorite bears to the Jurassic sediments in the Talkeetna Mountains, where it invades the Lower Jurassic volcanic rocks and so is later. The Upper Jurassic conglomerate contains numerous boulders of quartz diorite, whose source is believed to be the quartz diorite batholith of the Talkeetna Mountains. The direct relation of the quartz diorite to the Middle Jurassic formations was not seen, but the absence of quartz diorite detritus in the Middle Jurassic rocks and its abundance in the Upper Jurassic conglomerate lead to the belief that the quartz diorite was intruded following the deposition of the Middle Jurassic rocks and previous to the Upper Jurassic sedimentation. It is thus regarded as Middle Jurassic, and it may have accompanied the uplift that marked the close of Middle Jurassic sedimentation.

## GNEISS.

### DISTRIBUTION AND CHARACTER.

Small areas of gneiss occur on Tsusena and Deadman creeks. The most abundant type is granular gneiss of medium to coarse grain, composed essentially of quartz, plagioclase feldspar, and biotite. The rock is black and white on a fresh break but weathers quickly to rusty brown, a color which is characteristic of the exposed surfaces. It has a marked foliation, caused by the parallel arrangement and lenticular aggregates of the biotite minerals.

Associated with the most abundant type are gneisses of somewhat different character—very fine grained rocks that are composed essentially of quartz, feldspar, and biotite in narrow alternating bands of dark and light minerals and that contain many red garnets. Under the microscope the rock is seen to contain also considerable pyroxene and epidote, with accessory magnetite and zircon. In places this rock is closely folded and contorted. (See Pl. V, *B*, p. 16.)

The association of the biotite gneiss with the quartz diorite is evident. In areal distribution it borders the quartz diorite, into which it grades by decrease in the amount of metamorphism.

Associated with the typical gneisses are crystalline schists derived from dacite lava flows. They are fine-grained bluish-gray rocks and contain large flakes of biotite. Large red garnets are locally developed, and sheaf-like aggregates of fibrolite occur. The fine-grained base of the rock is composed of an aggregate of quartz and feldspar. These rocks might be called garnet schist or sillimanite schist according to the dominant metamorphic mineral which they contain. The derivation of these schists from the dacite lava flows is indicated by the field evidence. The schists border an area of dacite lava flows, from which they are separated by a zone of partly recrystallized rock intermediate in metamorphism between the dacite and the crystalline schist.

#### AGE AND CORRELATION.

The biotite gneiss was, in large part at least, derived from the quartz diorite, of Middle Jurassic age; the gneiss is invaded by Tertiary granite and its gneissic character is therefore regarded as of late Mesozoic or possibly early Tertiary age. It is probably the equivalent of gneiss occurring near by in the Broad Pass region.[1]

### GRANITE.

#### DISTRIBUTION AND CHARACTER.

Granite occurs only in the northwestern part of the region. It occupies several areas, which are separated by deposits of glacial and stream gravels but are evidently parts of a single batholith that occupies much of the drainage basins of Tsusena and Deadman creeks. Between these two streams granite is the dominant rock of the prominent ridges that form the southeastern end of the mountainous area north of Susitna River. (See Pl. IV.) The granite is intimately associated with the lavas that make up a large part of this range. It invades the oldest member of the lava group and is apparently covered by later flows. It also invades the gneiss and quartz diorite.

The typical granite is a granular rock of medium grain which contains quartz and feldspar and much biotite but shows considerable variation from place to place in texture and mineral composition. Porphyritic phases occur, in which large crystals of orthoclase an inch or more in diameter are set in a granular groundmass of quartz, feldspar, biotite, and accessory hornblende. Another variety is a light-colored granular rock of even texture, composed essentially of quartz and feldspar with a liberal sprinkling of red garnets. In all the granitic rocks quartz is abundant. The feldspar is essentially orthoclase and subordinate plagioclase. Increase of plagioclase forms varieties that approach quartz monzonites.

#### AGE AND CORRELATION.

The granite of the Chulitna Mountains appears to be continuous with large bodies of granite that occur at the headwaters of Brushkana Creek and is correlated with these and bodies of similar rock on other tributaries of Nenana River.[2] From evidence obtained in

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[1] Pogue, J. E., Igneous rocks [of the Broad Pass region, Alaska]: U. S. Geol. Survey Bull. 608, p. 55, 1915.

[2] U. S. Geol. Survey Bull. 608, pl. 2, 1915.

the Broad Pass region Pogue regards the granites as post-Eocene.[1] The granite in the Susitna region is distinctly later than the quartz diorite and was probably not formed during the same general period of eruptive activity.

### DIKE ROCKS.

Dike rocks are not conspicuous in the Nelchina-Susitna region but represent great extremes in composition. Diabase dikes in the vicinity of Tsusena Creek occupy narrow fissures that invade the granite. The diabase is a dark-green fine-grained rock that contains small flashing crystals of pyroxene and lath-shaped automorphic crystals of labradorite surrounded by augite, which produce an ophitic texture. Magnetite is an abundant accessory. Basaltic dikes are found also on Albert Creek in the vicinity of the Tertiary basalt flows. Tongues of alaskite that occur near the granite and that are probably genetically connected with it cut the diorite and gneiss. Dikes of rhyolite and granite porphyry are found also on Tsusena Creek. Small intrusive bodies of serpentine occur in the Klutina beds near Klutina Lake. The original character of this rock is not evident. Specimens studied are composed almost entirely of serpentine and veins of magnetite.

## GEOLOGIC HISTORY.

Owing to the imperfection of the geologic record it is not possible to decipher, except in a general way, the geologic changes in the region and the conditions that accompanied them. The distribution of land and water at different geologic periods is indicated by the nature and the present relations of the sedimentary formations; the periods of volcanism and intrusion are shown by the relation of the igneous rocks to the sedimentary and to the other igneous rocks; and the periods of deformation are indicated by the structural relations.

### PALEOZOIC TIME.

The earliest legible record in the Nelchina-Susitna region indicates that part of the land now occupied by the Copper-Susitna valley was covered in Carboniferous or earlier time by a shallow sea in which were deposited limestone and clastic sediments. The diversity of the sediments indicates many changes in the position of the seashore in Paleozoic time. The Paleozoic was also an era of volcanic activity, as is shown by the association of lava flows and pyroclastic rocks with the marine sediments.

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[1] U. S. Geol. Survey Bull. 608, p. 59, 1915.

## MESOZOIC TIME.

The earliest record of events in the Mesozoic era is found in the massive lava flow of Watana and Butte creeks. These flows are believed to have been poured out in Triassic time during a long period of volcanism that possibly began in the Paleozoic era. During this period several thousand feet of lava flows accumulated. These lavas are believed to be the equivalent of the Nikolai greenstone of the Copper River valley. If this correlation is correct the extent of the area covered by lava emitted during this period of volcanism is very great.

An invasion of the sea in Mesozoic time is recorded in the small area of slate, graywacke, and limestone on Tsisi Creek, in the Susitna Valley. The exact time of the deposition of these sediments is in doubt, but on account of their seeming structural continuity with Upper Triassic sediments on Deadman and Valdez creeks, which they resemble, they are regarded as Upper Triassic. After their deposition the rocks of Tsisi Creek were deeply buried, folded, and injected by igneous magmas and were afterward exposed to erosion.

A period of marine sedimentation was followed in Lower Jurassic time by another period of volcanism, in which a great thickness of andesitic and rhyolitic lavas and associated breccias and tuffs were deposited in the Talkeetna Mountains. After a period of erosion the region was again submerged in Middle Jurassic time, and beds of the Tuxedni sandstone and Chinitna shale were deposited.

During or just after Middle Jurassic time there was a general period of diastrophism. Magmas that formed the batholithic masses of quartz diorite in the Talkeetna Mountains were injected into the rocks, and Middle Jurassic marine sedimentation in this region was brought to a close by a general uplift of the land, which was followed by vigorous denudation, which uncovered large masses of quartz diorite and Lower Jurassic volcanic rocks.

In Upper Jurassic time the Talkeetna region was again invaded by the sea, in which was deposited a great thickness of conglomerate, sandstone, and shale, forming in whole or in part the Naknek formation. Marine conditions apparently continued into Lower Cretaceous time, resulting in the deposition of massive beds of limestone. The ensuing changes are not recorded in this region, but the record in adjacent regions indicates that Lower Cretaceous sedimentation was closed by a gentle uplift of the land.[1] After this uplift in Upper Cretaceous time the land was again invaded by the sea, and shale and sandstone were then deposited. Upper Cretaceous sediments are not known to occur in this area north of Alfred Creek, which, how-

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[1] Paige, Sidney, and Knopf, Adolph, op. cit., p. 33.

ever, does not necessarily mark the northern limit of the Upper Cretaceous sea, for deposits of this age may have been removed by erosion.

## TERTIARY TIME.

Marine sedimentation in neighboring regions was closed in late Cretaceous or early Eocene time by a general uplift of the land, which finally brought the entire province above the sea. The Nelchina-Susitna region was doubtless involved in this general uplift and, in part at least, in the following period of crustal deformation, which resulted in folding and uplift along the Alaska Range and a general uplift of the entire region. The disturbance in the Chulitna Mountains found expression in a general outpouring of lava and in igneous intrusion. A long stage of erosion followed, marked by a series of differential uplifts attended by periods of active erosion and intervals of quiescence.

This Tertiary period of erosion, in which the major depressions were formed, was brought to a close by an uplift that shifted drainage lines and brought about a general change of climate.

## QUATERNARY TIME.

### GLACIATION.

When the climate became favorable for the continuous accumulation of snow the glacial epoch began. The higher parts of the mountains became gathering places for glacial ice, which moved along stream courses as valley glaciers and as these glaciers descended to the lowlands they deployed to form piedmont ice sheets and finally coalesced into a great intermontane glacier, which at the time of its maximum intensity spread from the Alaska Range to the Talkeetna and the Chugach mountains. It extended far up Chitina Valley and included parts of the Chulitna and the Wrangell mountains in its ice-covered basin.

Unmistakable evidence of the extent of this ice transgression is seen in the mantle of glacial débris now found in the lowland areas, in the marks of glacial erosion manifest in scratches on rocks, rounded hilltops, and straightened and oversteepened valleys, and in the numerous cirques in the mountains, which still maintain a few active glaciers.

### RETREAT OF THE ICE.

When the conditions became unfavorable for the continued accumulation of ice, so that the waste became greater than the supply, a general retreat of the glaciers began, which has continued intermittently to the present and is still in progress. During this period of glacial retreat the great gravel sheet of the Copper-Susitna basin was laid down. As the ice melted great quantities of unsorted material were deposited in morainal heaps, and on the farther retreat of the glaciers this material was in part reworked and covered with coarser material by streams.

The retreat of the ice has not been continuous but has been marked by recessions and advances and possibly by an uplift and a period of interglacial erosion. Ponded areas received silts and fine sands and interbedded coarser material. When the lowlands were freed from ice the isolated glaciers gave rise to silt-laden streams, which continued to furnish material that built up the gravel plain. This glaciofluvial action still continues below every active glacier. A general uplift that followed or accompanied the glacial retreat has rejuvenated the streams, which are now rapidly cutting deep channels in the gravel deposits.

## GEOMORPHOLOGY.

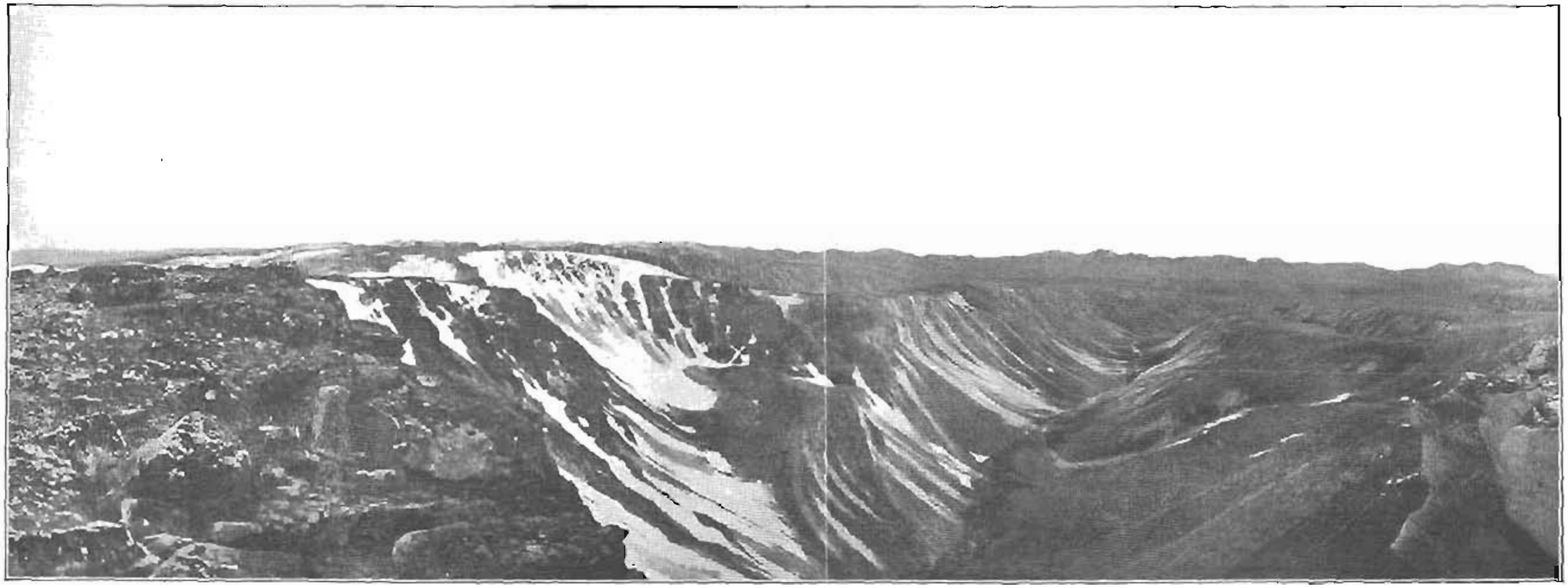
### LAND FORMS.

#### LOWLANDS.

The term Copper-Susitna lowland is applied to the broad gravel-filled depression that includes much of the Copper River basin and a part of the Susitna basin. The Copper River part has usually been called the Copper River plateau. The term lowland is used here in preference to plateau, as it is really an extensive depression filled with a thick deposit of glacial gravel into which the streams have cut deep trenches. The bedrock is exposed at only a few places, but it is believed to conform in its broader features to the surface of the gravel which is undulating and warped, sloping toward the center of the basin and also toward the southeast. Along Susitna River the surface of the lowland in the center of the valley stands at an elevation of 2,500 feet. At Copper Center and Stuck Mountain, near the eastern border of the area mapped, its elevation is 1,000 feet and at Chitina only about 800 feet.

The divide between the drainage systems of Susitna and Copper rivers is low and imperceptible. It is simply an unreduced portion of the gravel plain in which the present streams are incised—an undrained swampy area, from which project a few buttes but no rock barriers. There is no topographic break between the drainage area of the Copper and that of the Susitna, the topographic continuity indicating that the present drainage basins form parts of a single former valley and that the master stream of this region, which drained the upper basin of Copper River, once flowed westward through this old Copper-Susitna valley.

A. DISSECTED PENEPLAIN OF TALKEETNA MOUNTAINS AND VALLEY OF KOSINA CREEK.



B. TALKEETNA PENEPLAIN AND TALKEETNA MOUNTAINS.

Mendenhall[1] regards the Copper River valley as a sunken block between two uplifted areas—the Chugach and the Alaska ranges. If, as has been suggested, the Copper-Susitna valley is topographically continuous, the Copper River valley may have been formed in the same way as that part of the Susitna Valley here considered.

### MOUNTAINS.

This lowland province is bordered on the southwest by the Talkeetna Mountains, a rugged mass that ranges in general height from 5,000 to 6,000 feet but includes peaks 8,000 to 9,000 feet high. The low rounded, flat-topped foothills of this range in the area studied are carved out of an extensive peneplain that lies along the northern base of the Talkeetna Mountains, which rise gently from this old land surface. This peneplain dips gently to the north and is abruptly terminated by the depressed trough now covered by the gravels of the lowland province.

The peneplain has been modified by glacial and stream erosion and by volcanic outpourings. (See Pls. VII, *B*, and IX, *A*, *B*.) It has been grooved and rounded by the overriding sheet of ice that covered the region and bears many minor irregularities caused by the plucking and grinding of the ice. The streams that traverse it flow through steep-walled gorges produced by stream erosion and altered by a valley glacier of a later stage than that of the piedmont ice sheet that covered the peneplain. Small masses of Tertiary lavas on Alfred and Albert creeks overlie the beveled surface of the peneplain. The Talkeetna Mountains are regarded by Paige and Knopf[2] as carved from a mass elevated by a domal uplift that was accompanied by normal faulting.

Between the Alaska Range and Susitna River is a tract of rugged mountains, the crest of whose ridges, ranging in elevation from 5,000 to 7,000 feet, forms the divide between the Susitna, the Chulitna, and the southern tributaries of Nenana River. These mountains are composed essentially of granitic and effusive rocks, with which are associated metamorphosed sediments. The varied composition of the rocks has given rise to a varied topographic expression. The basalt hills, though sharp and rugged, are more subdued in outline; they do not show the extreme angularity seen in the granite mountains. (See Pls. IV and VII, *A*.) The present rugged aspect of these mountains is due in large part to glacial erosion, which was con-

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[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, pp. 84–86, 1905.

[2] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 38–39, 1907.

trolled essentially by the existing drainage channels. This small isolated mountain mass is evidently a link in the crescent-shaped chain of mountains that extends from the vicinity of Gulkana Lake to the junction of Susitna and Chulitna rivers. These mountains are roughly parallel to the Alaska Range but are much lower and less imposing.

## DRAINAGE.

The Nelchina-Susitna region is all drained into two master streams, Copper and Susitna rivers, which empty respectively into the Gulf of Alaska and Cook Inlet. The parts of Copper River and its tributaries that are included in the lowland are incised in steep-walled gorges cut in the glacial deposits and differ in position and arrangement from the drainage lines that existed before the region had been glaciated.

Susitna River issues from several large glaciers in the Alaska Range and flows southward and southeastward for 70 miles to the "big bend," where it enters the old Copper-Susitna valley and turns abruptly to the west. From the mouth of Maclaren River it flows for 25 miles in a meandering course in a steep-walled channel cut in the gravel deposits. Below the mouth of Oshetna River the character of the valley changes considerably. The river is flanked by low buttes, and at one place the rock bed of the river emerges from the gravel covering, revealing a narrow channel incised in the rocky floor of the old valley. This inner trench was cut during either a preglacial or an interglacial epoch, for this old channel is filled in part with glacial gravel. The river at this place has in part cleaned out the old channel and in part cut a new course.

Nearly all the large tributaries of Susitna River that come from the Talkeetna Mountains are of glacial origin. In their upper courses, where they flow in broad valleys that have been widened and smoothed by glacial erosion, they are overloaded with glacial débris, are rapidly building up their bottoms, and are spread out in braided channels. (See Pl. IX, *A*.) This deposition tends to increase the stream gradient below, so that erosion is very active in the lower parts of the streams, where it has produced sharp V-shaped channels. These features are characteristic of the glacial streams that head in the high mountains and enter the lowlands.

The tributaries that enter the Susitna from the north and west are not glacial streams, although each may draw a small part of its water from glaciers. These streams have clear water and are not overladen with glacial débris. Like the glacial streams, however, each occupies a sharp trough where it enters the gravel lowland. These troughs may be regarded as products of extinct glacial streams.

## TERTIARY DEVELOPMENT.

The present surface had its origin in early Tertiary time, when the land was lifted from the sea and when active erosion began which has continued intermittently to the present time. The lack of Tertiary sediments makes it difficult to trace in detail the Tertiary history of this region and the formation of the present topography. In the main the Tertiary was a period of differential uplift and degradation. The salient features of the present surface were then developed, but they have been greatly modified by glaciation, one of the most potent agents in giving the surface its present configuration.

### EOCENE PENEPLANATION.

The general uplift in early Tertiary time marked the beginning of a period of erosion in which parts of this region at least were reduced to a peneplain. Portions of this old land surface are well preserved south of Susitna River and remnants of it appear between Tsusena and Watana creeks. (See Pl. IX, *A*, *B*.) This planation occurred in early Tertiary time, probably in the Eocene epoch. The region is evidently a part of the Eocene peneplain that was formed in the Talkeetna region.[1] The record of its existence north of Susitna River is obscured by later events. It is possible that parts of the region north of Susitna River that are now covered by the Tertiary lava flows were also reduced to a peneplain.

Eocene planation was accompanied in adjacent regions by extensive fluviatile deposition. In the Broad Pass region Eocene deposits attain a thickness of 2,700 feet.[2] In Matanuska Valley deposits of Eocene sandstone, shale, and conglomerate aggregate over 4,000 feet in thickness.[3] Deposits of this age are not found in the Nelchina-Susitna region, and if they once existed they have been removed by erosion.

### EOCENE DIASTROPHISM.

Eocene sedimentation in adjacent regions was brought to a close by diastrophism that involved uplift. Marked orogenic movements were localized. The intense crustal deformation that occurred along the Alaska Range is not recorded in the Nelchina-Susitna region. The greatest disturbance was in the mountains near Tsusena, Butte, and Watana creeks. The uplift was accompanied by folding and igneous intrusion and a general outpouring of lava. In the

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[1] Paige, Sidney, and Knopf, Adolph, op. cit., p. 38.

[2] Moffit, F. H., The Broad Pass region, Alaska, with sections on Quaternary deposits, igneous rocks, and glaciation, by J. E. Pogue: U. S. Geol. Survey Bull. 608, p. 47, 1915.

[3] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 39-54, 1912.

Talkeetna Mountains the entire region was uplifted but not greatly deformed. Even the Upper Jurassic formations stand at low angles and are but gently folded. Faulting is conspicuous but not extensive. More extensive deformation is recorded in the higher parts of the Talkeetna Mountains and on their southern slopes along Matanuska River.[1]

### POST-EOCENE EROSION.

The uplift in Eocene time was followed by another cycle of erosion in which the major features of the present surface were outlined. The Talkeetna Mountains and the mountains north of Susitna River were carved from uplifted masses and the larger stream valleys were formed.

The problem of determining the preglacial course of Copper River has been of special interest since the first geologic work was done in this region. Mendenhall[2] and Schrader[3] suggested that the old Susitna received its waters from the region that is now drained by the Copper at a time when the Copper flowed northward, in a direction opposite to its present course, and that later the Copper was captured through headward erosion by a small stream that occupied the present valley of lower Copper River.

It has recently been held by Moffit[4] and by Martin[5] and is generally accepted as a fact by all who are familiar with the region that Copper River cut its present channel through the Chugach Mountains since or during the Pleistocene or glacial epoch. Thus the old Copper River, which drew its waters from Chitina River and the headwaters of the present Copper River, probably had an outlet to the Yukon through one of the low passes in the Alaska Range or, more likely, to Cook Inlet through either Susitna or Matanuska River, or the Chulitna and Susitna.

In addition to the pass through the Chugach Mountains that is now occupied by Copper River (which need not here be considered, for prior to the glacial epoch it was not occupied by Copper River) the low passes from the Copper Valley are Delta Pass, through the Alaska Range; Tahneta Pass, to Matanuska Valley; and the low, flat divide between the Copper and Susitna basins. Through one of

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[1] Paige, Sidney, and Knopf, Adolph, op. cit., p. 39.

[2] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 334, 1900.

[3] Schrader, F. C., A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 412, 1900.

[4] Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, pp. 41–42, 1914.

[5] Tarr, R. S., and Martin, Lawrence, Alaskan glacier studies of the National Geographic Society in the Yakutat Bay, Prince William Sound, and lower Copper River regions, p. 454, 1914.

these gaps the water of Copper Basin evidently flowed. These passes range in elevation from 2,600 to 3,000 feet. Copper River is only 600 feet above the sea at the mouth of the Chitina, and the bedrock there, which is concealed by glacial gravels, is evidently lower. The bedrock in each of these passes also is covered with gravel, which may conceal deep channels, but even if stripped of its detrital covering no one of them would probably be reduced sufficiently in elevation to bring it to the present level of Copper River at Chitina. In a consideration of the altitude of the preglacial land surface the amount of deepening by ice erosion and the subsequent glacial deposition should be taken into account. In this region neither is accurately known, and as the effect of each process is to offset that of the other both are disregarded. It is thus evident that there must have been a crustal movement by which the western part of the region was raised relative to the eastern part.

The waters of part of the area that belongs geographically to the Copper River drainage basin are now diverted through low passes in the Alaska Range northward to the Yukon system. One of these passes is now occupied by Delta River, which receives its waters from the Tangle Lakes, Gulkana Glacier, and Eureka and Phelan creeks. Delta Pass, although a possible outlet for the waters of the old Copper River, need not receive extended consideration. Moffit[1] has suggested that a low divide in the Alaska Range where the Delta now flows was modified to some extent by moving ice and that during the latter part of the glacial epoch the Delta reached the Tanana by crossing this divide instead of following its natural course to the south. Furthermore, the Delta Valley is not a mature stream-developed valley, such as might have been occupied by the old Copper River.

Tahneta Pass, a broad opening between the head of Matanuska Valley and the Copper River basin, is also a possible outlet for the old Copper River. The river might have flowed through it into Matanuska Valley either directly or by way of Squaw and Caribou creeks. The progressive thinning of the glacial deposits toward Matanuska Valley indicates a northward movement of the ice, and from its position and the constriction of its rock basin toward the south Tahneta Pass is regarded as a tributary of the old Copper River rather than the valley of the river itself.

From its junction with a stream entering from Tahneta Pass the old Copper evidently flowed northwestward along the present course of Tyone River to the big bend of Susitna River. The apparent continuity of the rock basins of this part of Susitna Valley and the Copper Valley suggests that the old Copper may have found a pregla-

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[1] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska: U. S. Geol. Survey Bull. 498, pp. 50–51, 1912.

cial outlet through the present Susitna Valley, either westward along the present course of the river or northwestward along the present upper course of Susitna River, Monahan Flat, and Nenana River to the upper end of the box canyon above the mouth of Jack River, and thence southwestward through Broad Pass and Chulitna River valley, which is regarded by Moffit[1] as the preglacial course of Nenana River.

While the Copper-Susitna basin was being formed the land was in a mature state of topographic development and stood much lower than at present. The larger streams no doubt flowed in broad, flat valleys, and the tributaries in winding courses in V-shaped valleys inclosed between sinuous, flat-topped ridges and interlocking spurs—the products of normal stream erosion and weathering. The uplift that brought this period of erosion to a close also marked the beginning of the glacial epoch.

## GLACIATION.

The extensive ice sheet that once occupied the Copper-Susitna basin has left a most unmistakable impress on the entire region. The rounded knobs of the ice-covered area, the glaciated valleys, the cirque topography of the highland regions, and the extensive sheets of gravel, with their superimposed drainage, all testify to the profound influence of the ice on the configuration of the surface.

### GLACIAL EROSION.

The degradation effected by glaciation is very marked and in large part has given rise to the varied configuration of the surface in all the region; even the drift covering doubtless lies on an ice-sculptured bedrock. The most conspicuous features are the broad, straight valleys, with typical U-shaped cross section and the truncated spurs, with characteristic triangular shape. These features have been produced by the removal of a great amount of material. The deepening alone has been great, as is indicated by hanging valleys that stand several hundred feet above the main valleys. As the hanging valleys were doubtless also deepened, the degradation was great, and to this erosion must be added the removal of projecting spurs and the changing of a youthful stream-developed valley to a broader and straighter U-shaped trough. Above the surface of the ice the destructive effect of cirque development has proceeded to different degrees and has given a characteristic form to the topography. The region covered by the ice flood shows different erosional effects. Knobs and ridges that project from the

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[1] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pl. 2, and p. 15, 1915.

gravel plain are rounded and smoothed as though overridden by ice that was incompetent to reduce them to the level of the basin on which they stand.

### SOURCES OF THE ICE AND DIRECTION OF MOVEMENT.

The Copper-Susitna Glacier drew its ice from different sources. Its main discharge appears to have been westward through Susitna Valley, but it had other outlets, which at the time of its greatest extent may have acted as spillways. The Alaska Range contributed large ice streams, which moved down Susitna Valley and its tributaries. The mountains north of Susitna River were local centers of glaciation from which ice moved in all directions. A part of the ice moved northwestward and joined an ice stream that at some time moved westward through Broad Pass. The highest parts of these mountains were not overflowed but projected as islands from the surface of the ice. The Chugach and Talkeetna mountains were also important sources of considerable ice. The upper part of Klutina Lake lies in a depression through which a large glacier that drew its supply from the crest of Chugach Mountains moved northward to the lowland ice sheet. Nelchina and Tazlina glaciers were other sources of southward-moving ice bodies from the Chugach Mountains.

Two of the largest tributaries of the Copper-Susitna Glacier were Chitina Glacier and the glacier that occupied the upper part of the present Copper River. These glaciers were fed in large part by ice drawn from the Wrangell Mountains, a local center of glaciation from which the ice moved in all directions. Chitina Valley was buried under ice, which overflowed into Hanagita Valley. The pass through Chugach Mountains now occupied by Copper River was covered with ice, some of which moved northward to join the Chitina Glacier. At a later time, when the ice sheet of Copper River valley stood at a higher level, this pass became a southern outlet for ice and water.

Moffit and Pogue[1] state that ice moved northward through Delta Pass and southwestward through Broad Pass. Tahneta Pass was also covered with ice, which apparently moved northward, as is indicated by the thick deposits at the margin of the Copper River basin, which thin progressively toward the Matanuska Valley. It is not unlikely, however, that at some stage in the glaciation of the region ice overflowed from Copper basin into the Matanuska valley through this pass.

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[1] Moffit, F. H., The Broad Pass region, Alaska, with sections on Quaternary deposits, igneous rocks, and glaciation by J. E. Pogue: U. S. Geol. Survey Bull. 608, pp. 66–73, 1915.

The valley of Susitna River, however, is considered the main outlet of the Copper-Susitna Glacier. For a time it was able to accommodate all the outflow, but on the accumulation of ice, influenced no doubt by differential elevation, it became blocked and the ice rose until it overflowed through different spillways.

### EPOCHS OF GLACIATION.

It has been suggested that the ice of Copper River valley moved westward to Cook Inlet by way of Susitna Valley, along the old course of Copper River. The ice movement, however, was not so simple as this suggestion would imply and, in the Susitna Valley at least, it included recessions and advances, and possibly there was an interglacial epoch of erosion. The discrimination of the different epochs of glaciation and the interglacial epochs is of special interest. Capps[1] has recently shown that the glacial deposits in the White River region unconformably overlie tillite, a rock derived from glacial deposits. The tillite is oxidized and the beds are tilted at a high angle and overlain by lava flows, indicating an earlier glacial epoch separated from a later glacial epoch by interglacial deformation, volcanism, and erosion.

The fact that there was more than one great advance of the ice and a long interglacial epoch in Copper River valley has not been well established but is strongly suggested. At many places lava flows and bombs lie between glacial deposits. Schrader and Spencer[2] note that at one such place there was an advance of the ice subsequent to the flow of lava, which they consider recent. The lava flows, however, in their areal distribution show no recognizable relation to the present topography, whereas they would show some such relation unless their outpouring was followed by a long period of glaciation. Furthermore, since they were poured out they have been deeply furrowed, as if they had been subjected to considerable erosion. It therefore seems that the relation of the lavas to the glacial deposits may indicate the occurrence of a long period of glaciation rather than the recency of the lava outflow, which may mark an interglacial epoch synchronous with that which existed in the White River region, an epoch marked also by volcanic activity. The character and the relations of the sediments, which consist of deposits of till intercalated with beds of outwash gravel, indicate that there were minor oscillations of the ice doubtless with variations and reversals in the direction of its movement.

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

[2] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska: Spec. Pub. U. S. Geol. Survey, pp. 59–60, 1901.

It is believed that the recession of the ice in parts of Susitna Valley was followed by an interglacial epoch and subsequent advance of the ice. An indication of this retreat and advance is found in the character of certain stream valleys that cut parts of the old peneplain, which was submerged while the piedmont ice flooding was at its maximum stage. Among the upper tributaries of Kosina and Tsisi creeks there are a number that occupy sharply incised rock-walled channels. These channels have been occupied by valley glaciers, which evidently widened and straightened them, but they shown no indications of erosion by the piedmont ice sheet, and in this respect they present a marked contrast to the valleys that existed prior to the piedmont glaciation.

The form and relation of the valleys of these tributaries of Kosina and similar creeks are most plausibly explained by assuming that they were not subject to erosion by the piedmont ice sheet and that since its recession they were formed by stream erosion and subsequently altered by valley glaciation. If this assumption is correct these valleys were cut during a long interglacial epoch. It is possible, however, that they were filled with ice at the time of the piedmont ice flooding and ran transverse to the direction of the main glacial movement and thus escaped erosion by the piedmont ice sheet or that the erosional effect of the valley glaciation was so intense that it obliterated all traces of earlier glaciation. In Susitna Valley, especially along the base of the Talkeetna Mountains, these two types of glacial erosions, one caused by the overriding of an extensive area by the piedmont ice sheet and the other by the later occupation of depressions by ice tongues, are very pronounced. Whether these two intervals of the ice occupation are distinct periods of glaciation separated by an interglacial interval of erosion or whether they are only phases of the same general period of glaciation is not certain.

Corroborative evidence of a later ice transgression is found in the relation of the morainal deposits that border the lower parts of Kosina Creek. These moraines and similar ones on adjacent streams and across Susitna River stand well above the outwash gravels, which they evidently overlie. They mark the limit of a glacial readvance, conclusive evidence of the extent and duration of which is lacking.

### THICKNESS OF THE ICE.

The maximum thickness of the ice is not known but may be inferred from the greatest height at which glacial scratches are found and from the altitude of glacial deposits and erratic boulders. Near the mouth of Oshetna River the ice overflowed buttes that rise 2,600 feet above the valley bottom. This figure represents the minimum thickness of the ice, for the position of neither the top nor the bottom of the ice is evident. Many other buttes, the highest about 3,000 feet above the valley floors, are believed to have been completely submerged by the ice.

## POSTGLACIAL EVENTS.

### DEPOSITION.

The gravel sheet of the Copper-Susitna basin and of the valleys of the tributary streams that form conspicuous features of the configuration of the present surface was built up of materials furnished from the streams that issued from the ice while it was retreating. At that time, too, moraines were no doubt reworked in part and covered with glaciofluvial deposits. In the Susitna Valley, however, extensive moraines that overlie the glaciofluvial gravels are conspicuous topographic features. This alluviation of the valley floor continued until a sheet of gravel 1,000 feet thick was laid down. This process is still in operation along the fronts of the present glaciers, which are building up their valley floors, but its effects are now relatively insignificant.

### UPLIFT AND EROSION.

After the glacial gravels were laid down and in part coincident with their deposition, an uplift of the region rejuvenated the streams and initiated the present cycle of erosion. That this uplift was differential is shown by the present slope of the basin toward the southeast and the relative heights of the glacial deposits along its borders.

The amount of glacial erosion, however, is in marked contrast to that accomplished since the withdrawal of the ice. The upper valley of Lake Creek supports two streams which flow parallel to each other in ice-cut troughs for 3 miles before they come together. In the lower part of this creek, as in many other localities, lakes connected with no other water stand at discordant levels and are separated by narrow gravel banks. These conditions indicate that the postglacial erosion has been insignificant. Apparent exceptions to these conditions are found in the deep channels cut in the gravels by the large streams, but even here no ramifying system has dissected the plain. The drainage is young and is confined to large streams that have few tributaries.

Disturbed preglacial drainage and apparent lack of postglacial erosion are notably illustrated by the formation and the present outlets of Deadman Lakes. These lakes occupy a depression in a valley the stream in the upper part of which is now called Deadman Creek and that in the lower part Delusion Creek, an appropriate name, for though the valley is prominent it carries little water. Before this region was glaciated lower Deadman Creek and its west fork were one stream and upper Deadman Creek flowed through the present site of the lakes down Delusion Valley. When the ice that filled Deadman and Delusions creeks and their upper tributaries melted a large moraine dammed the valley so effectually that the waters of the upper part of Deadman overflowed the basin and found outlets, one through a low divide to the main channel of Deadman Creek and the other to Watana Creek. The waters are now ponded by a narrow gravel barrier, which if actively attacked by erosion would be easily reduced, and the waters of the upper part of Deadman Creek that now flow through the upper lake might be reclaimed by their preglacial channel.

Rock glaciers, which are locally important agencies of postglacial denudation, are long, narrow rock flows generally confined in cirque-like valleys.[1] They appear to occur only in the more recently glaciated regions and are believed to be descendants of true glaciers. Several occur on the tributaries of Tsusena Creek, but none were noted elsewhere.

## MINERAL RESOURCES.

### GENERAL FEATURES.

Placer gold is the only mineral resource that is attracting attention in the Nelchina-Susitna region. It is widely distributed and may be washed from nearly any stream. Although this fact has been known to prospectors for some time gold had not until recently been found in quantity sufficient to mine profitably or even to encourage prospecting. A fresh impetus, however, was given to prospecting in the Nelchina region by the report of a rich find on Albert Creek, one of the branches of Crooked Creek, a tributary of Little Nelchina River, and during the open season of 1914 about 400 men were prospecting on the tributaries of Little Nelchina and Oshetna rivers. Gold was found on a number of the near-by creeks, but for the most part the results of the season's work were discouraging, and few men stayed in the district during the winter. Prospecting, however, had not been thorough enough to determine adequately the value of the region as a source of placer gold.

Gold has been found in encouraging amount only in a small area on the tributaries of Little Nelchina River, Tyone Creek, and Oshetna River, and has not yet become of economic importance. The placer gold is widespread but is concentrated sufficiently to justify mining only on Albert Creek. Fine gold occurs in the glacial gravel which covers the region, and colors may be found even on the hilltops, where no concentration has taken place. The gold occurs from the grass roots to bedrock. Even the stream gravels show no definite

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[1] Capps, S. R., Rock glaciers in Alaska: Jour. Geology, vol. 18, pp. 359-375, 1910. Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 52-59, 1911.

pay streaks, as though there had been but little lateral or vertical concentration since their deposition.

### SOURCE OF THE GOLD.

The features just mentioned indicate a glacial origin for most of the gold. The glacial source of the gravels has been pointed out, and the widespread distribution of the gold through the gravels and its lack of concentration show that it also was glacially transported. Its bedrock source is not known. The glacially transported débris was derived from many sources and contains an abundance of rocks foreign to this region, which were evidently moved a great distance. The stream gravels are largely of glaciofluvial origin and except for a narrow strip along each stream course have not been reworked. These conditions account in part for the failure to find workable deposits in a region where gold is so widely distributed. The extensive deposits of glacial gravel evidently contain a wealth of disseminated gold, but owing to lack of sufficient reconcentration give little promise of yielding valuable deposits.

Although most of the gold was probably derived from the glacial gravels, some placers may have been enriched from other sources. Paige and Knopf[1] suggest that the gold in the stream beds was derived from the Upper Jurassic conglomerates by reconcentration. These rocks, however, can not now be regarded as even a contributing source, for the beds of eroding streams show no gold enrichment where they cross the conglomerate formation. Small veins in the bedrock are regarded by Martin and Mertie[2] as a possible source of the gold, but the veins in this region are not conspicuous and are probably not a general source of the gold although they may have contributed a part of it.

The geologic formations of this region in which gold lodes are most likely to be found are the greenstone, limestones and schists, the Triassic schist and slate, and the Lower Jurassic lavas. These formations are all more or less mineralized, although they are not known to contain gold in this region.

## GOLD PLACERS.

### CROOKED CREEK.

#### MAIN STREAM.

Crooked Creek is tributary to Little Nelchina River. It flows in a meandering course through a broad, flat gravel-filled valley that is bordered by low glaciated hills. Throughout its course the stream

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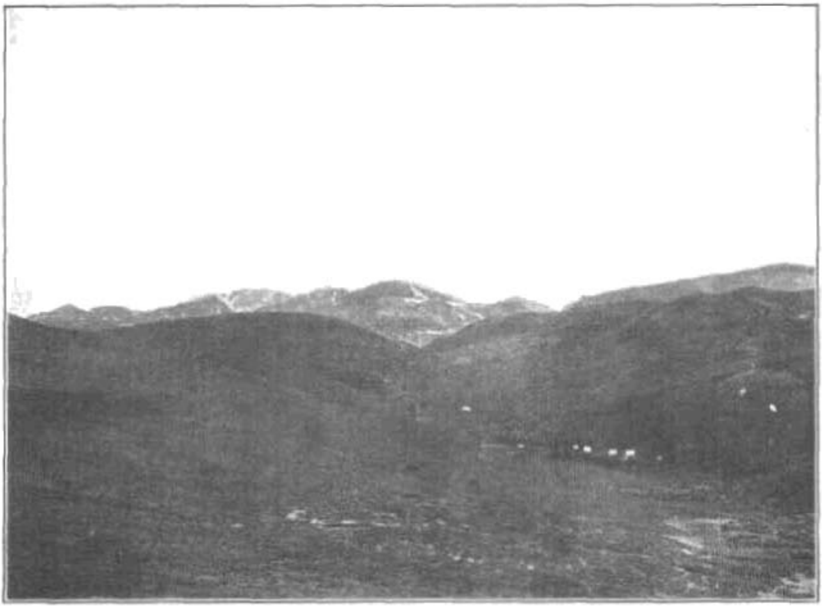
[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, p. 67, 1907.

[2] Martin, G. C., and Mertie, J. B., jr., Mineral resources of the upper Matanuska and Nelchina valleys: U. S. Geol. Survey Bull. 592, pp. 280–281, 1914.



*A.* ALBERT CREEK.

*B.* GROUNDSLUICING ON OLSEN AND GETCHEL CLAIMS ON ALBERT CREEK.

has been covered by locations, but little actual work has been done except on its tributaries.

One claim, however, "No. 19 below," is being vigorously prospected. A shaft was sunk during the summer to a depth of 180 feet, and winter work was planned to drive the hole to bedrock if possible. The following log, which was furnished by the operators, shows the character of a part of the section:

*Section exposed in shaft on claim "19 below," Crooked Creek, Nelchina drainage basin, Alaska.*

| | Feet. |
|---|---|
| Glacial capping, muck, and wash | 85 |
| Wash gravel | 2 |
| Silt | 10 |
| Gravel, blue-gray, composed of quartz and basaltic lava and carrying no sediment; contains a few colors of gold to the pan | 9 |
| Vegetable muck with willow twigs | 12 |
| Clay seam. | |
| Gravel | 2 |
| Vegetable muck,[1] gas bearing | 15 |
| Gravel, blue-gray | 8 |
| Gravel, yellow | 6 |
| Clean wash, containing no sediment | 10 |

### ALBERT CREEK.

Albert Creek, a small stream about 3 miles long, which enters Crooked Creek 9 miles from its mouth (see Pl. X), is the only stream in the Nelchina region that has produced any gold. The placers were discovered in 1912, and in the following spring 10 claims were staked by Odin Olson, Fred Getchell, Joe Palmer, and Duncan McCormick. During the season of 1913 much of the time was spent on dead work, but a cut 34 by 39 feet was opened and yielded about 60 ounces of gold. The gravel averaged over $10 a cubic yard. Development work was continued in 1914 under a new lease. In June over half a mile of ditch was completed, and a strip was being groundsluiced preparatory to sluicing. Work was suspended early in the fall. It is reported that 150 ounces of gold was recovered. Prospecting was done by a number of other men on the creek with indifferent success.

The three main tributaries of Albert Creek are locally known as Money Gulch, Porphyry Gulch, and Noon Gulch. The bedrock on Albert Creek is tuffaceous sandstone and shale, which are associated with volcanic rocks. The bedrock is overlain by about 5 feet of poorly stratified coarse gravel containing many flat and angular boulders of graywacke. Through this gravel the alluvial gold is disseminated with little or no concentration on the bedrock. Upon

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[1] The gas escaping from this stratum was sufficient to ignite and to cause a slight explosion.

the coarse gravel lies 2½ feet of finer gravel and clay and lenses of ice, and upon this lies 2 feet of silt and clay. The pay streak does not appear to be continuous, but prospecting has not yet been adequate to prove or disprove its extent or value. Timber for cabins and mining use was brought from Startup, a camp at the head of Squaw Creek, 6 miles south.

### OTHER TRIBUTARIES OF CROOKED CREEK.

Prospecting was being done in 1914 on other tributaries of Crooked Creek. Six men were at work on Poorman Creek and early in the summer had ground sluiced 350 feet of ground and had boxes ready to set up. Bedrock on the lower part of the creek consists of conglomerate, shale, and sandstone, and on the upper part of vesicular red andesitic lava with beds of white tuff. Bedrock at the workings is about 6 feet deep. The gold is rather flaky but contains small nuggets. It is reported that a small production was made. A little work was done on Cottonwood Creek, but bedrock was not reached. Prospecting was done also on Bonanza Creek, South Creek, Willow Creek, and other small streams.

### CARIBOU CREEK.

Prospects on Alfred and Mazuma creeks, tributaries of Caribou Creek, were not visited by the writer. The following is taken from a published report by Martin and Mertie:[1]

> *Alfred Creek.*—Alfred Creek is a large stream tributary to Caribou Creek from the east about 13 miles above its mouth. The upper part of the valley is open and lies among rounded hills, but the lower part is deeply incised, the creek passing through several canyons, of which the lowest one, which is about half a mile long, terminates about half or three-quarters of a mile above the mouth of the creek in a broad flat. The trail follows the creek except at this lower canyon, which it avoids by passing over the bench to the north. A moderately dense growth of small spruce extends along the lower half of the stream. In the upper part of the valley there is no vegetation larger than willows and small cottonwoods along the stream course. There are numerous patches of good grass on the hillsides.
>
> The rocks exposed along the upper half of Alfred Creek consist of Jurassic sandstones and shales cut by small dikes. Along the lower half of the creek the only rocks exposed are Upper Cretaceous shales, except at the lower end of the lowest canyon, where there is a large dike of coarse diabase. The rocks exposed on the tributaries are probably in large part the same as those on the main creek, except that the high ridge north of the creek is known to be capped by Tertiary volcanic rocks. These may be here, as they are at so many places in this district, underlain by Tertiary conglomerate. If so, this conglomerate is a likely source of the placer gold.

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[1] Martin, G. C., and Mertie, J. B., jr., Mineral resources of the upper Matanuska and Nelchina valleys: U. S. Geol. Survey Bull. 592, pp. 278–280, 1914.

Alfred Creek has apparently been staked throughout the greater part of its length, but on only a few claims has more than technical assessment work been done. The discovery was made in 1911. A total of about $1,500 of gold is said to have been recovered from this creek.

*Mazuma Creek.*—Mazuma Creek is tributary to Caribou Creek from the northeast at an altitude of about 3,300 feet. The lower part of its course is in an inaccessible canyon, but the upper open part of its valley may be reached by a trail leading across the hills from the mouth of the stream entering Caribou Creek next below Mazuma Creek. The entire valley is above timber line and contains no vegetation larger than moderate-sized willows and small cottonwoods. The nearest timber is on Caribou Creek about 2 miles below Mazuma Creek, where there is a sparse growth of small spruce. Grass is abundant along the trail leading into the upper Mazuma Valley.

The rocks on Mazuma Creek are basaltic lavas and tuffs, underlain along the upper part of the creek by coarse conglomerate. An exposure at an altitude of about 4,600 feet shows coarse, poorly consolidated conglomerate overlain by angular blocks of lava which were probably transported from the hillsides above. The conglomerate is well consolidated near creek level, but looser above. This difference may be either the result of local cementation, local leaching, or reworking. It is probably due to reworking, for the looser part is decidedly coarser than the well-consolidated conglomerate at the creek level. The well-consolidated conglomerate consists of boulders, in general not over 6 inches in diameter, and contains lenses of shale and sandstone, while the looser conglomerate has numerous boulders from 1 to 2 feet long. The boulders are chiefly granitic and fine-grained igneous rocks with some sandstone, shale, and porphyry. The conglomerate, both above and below the contact of the better and the less consolidated part, is thoroughly indurated along vertical fissures which stand out like dikes. The creek gravels, so far as noted, contain only material which might be derived from the conglomerate or the overlying volcanic rocks and include numerous large boulders.

Claims have been staked from 3 to 5 miles above the mouth of the creek. The discovery was made in 1906. Nuggets up to 16 or 18 cents in value are said to have been found. It is reported that a large number of them have "cement" sticking to them. There has apparently been little or no production from this creek. The improvements consist of a wing dam, several prospect holes, and a ditch which will deliver water from a tributary stream under moderate head.

Whatever gold occurs in the gravels of Mazuma Creek was probably derived by reconcentration from a more disseminated deposit in the conglomerate. If there is, as there appears to be, a loose reworked conglomerate lying upon and derived from an older and more thoroughly indurated conglomerate, the contact of the two is possibly gold bearing.

### LITTLE NELCHINA RIVER.

A number of claims have been staked on Little Nelchina River, but little work has been done. The nature and depth of the gravels of the Little Nelchina are not known, as bedrock is not exposed. Sections of the gravels have not been exposed by mining and only slightly by erosion, as the stream is not actively deepening its channel. Low benches along its border are composed of coarse glacial material. From the depth of the gravel on Crooked Creek it is assumed that the bedrock of the Little Nelchina is also deep.

### TYONE CREEK.

#### YACKO CREEK.

Yacko and Joe creeks unite to form Sanona Creek, one of the tributaries of Tyone Creek. Several men were prospecting on Yacko Creek in 1914. Bedrock was not reached, but enough gold was found in the overlying gravel to encourage further work. The gold is coarse and flat. The contact between the volcanic rocks and the Mesozoic sediments crosses this stream. Above this contact the stream flows over a wide, flat valley bounded by rounded hills, but where it enters the volcanic rock the valley narrows into a canyon and the hills are much more rugged.

#### FOURTH OF JULY CREEK.

Gold has been found on Fourth of July Creek, but development work in 1914 met with little success.

The dominant rock on Fourth of July Creek is basic lava of Lower Jurassic age. Near the head of the creek the lavas are overlain by coarse conglomerate, sandstone, and shale.

#### DAISY CREEK.

Daisy Creek has been worked at several places and fair prospects have been found. Bedrock on the lower part of the creek is lava and on the upper part sandstone and conglomerate. The upper valley is wide and flat, but where the stream enters the volcanic rock the valley narrows to a canyon, below which it widens out considerably. The gravel is shallow, ranging in depth from 5 to 12 feet, but considerable trouble with ground water was met. In the fall of 1914 a drill was taken in to prospect the ground during the following winter.

### OSHETNA RIVER.

Several prospects were located on tributaries of Oshetna River in 1914. Alluvial gold occurs in the gravels of Little Oshetna River but is at few places concentrated in pay streaks on the bedrock. Prospectors on Gold Creek found coarse gold but had difficulty in getting to bedrock on account of the ground water. Gold enough to encourage further prospecting has been found also on Granite and Roaring creeks, small tributaries of the Oshetna that enter at 11 and 13 miles, respectively, above the mouth of Little Oshetna River.

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