GOLD LODE MINING IN THE WILLOW CREEK DISTRICT.

By Stephen R. Capps.

INTRODUCTION.

Gold mining in the Willow Creek district in 1917 was confined to the exploitation of the quartz lodes, from which almost the entire production has been won for several years. Although the first gold recovered from this area was gained by placer mining, the workable placers were soon exhausted, and of recent years their output has been negligible. The production from this camp in 1917 was made by four mines. Two of these mines, the Gold Bullion and the Alaska Free Gold, have been in operation for many years and have produced the bulk of the output of the district. The Independence mine, which has for years been a producer, was idle in 1917, though the mill was used to crush some ore from a near-by property. In 1916 a mill was erected and put into operation on the Mabel, and in 1917 a mill was completed on the property of the Talkeetna Gold Mining Co. To summarize these conditions, in 1917 there were five quartz mills in the district, of which three were operated steadily and two at intervals, and another small prospecting mill was ready to be set up. A report on the Willow Creek district, comprising a description of the geology and an account of the mining developments through 1913, has been published.[1] A later summary of the progress of mining through 1915 has also been issued.[2] The following notes on the properties are incomplete but are intended to supplement the previously published reports by carrying forward the account of the progress of mining to the fall of 1917.

In the accompanying table the production of the district is given by years. The large production of 1914 is due to the fact that during that year the cyanidation of accumulated tailings was begun, and the gold so recovered came in part from ores previously mined. In 1915 and 1916 the two cyanide plants were operated principally on the current tailings. In 1917, as a result of the high price of potassium cyanide, considerable quantities of tailings were ponded for storage, to await a time of more favorable operating costs.

[1] Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, 1915.

[2] Capps, S. R., Gold mining in the Willow Creek district: U. S. Geol. Survey Bull. 642, pp. 195–200, 1916.

Gold and silver produced at lode mines in Willow Creek district, 1908–1917.

Year.	Gold.		Silver.[a]	
	Quantity (ounces).	Value.	Quantity (ounces).	Commercial value.
1908	87.08	$1,800	6.28	$3.64
1909	1,015.87	21,000	80.25	41.73
1910	1,320.15	27,290	104.29	56.31
1911	2,505.82	51,800	197.95	109.91
1912	4,673.02	96,600	369.07	226.97
1913	4,883.94	100,960	385.83	233.42
1914	14,376.28	297,184	1,330.00	735.00
1915	11,961.55	247,267	811.00	421.00
1916	14,473.46	299,193	1,468.00	967.00
1917	9,466.17	195,662	713.00	586.00

[a] The silver content recovered from the gold bullion is estimated.

GOLD BULLION MINING CO.

The Gold Bullion mine was operated throughout the open season of 1917. Milling was begun on June 1, and the 12-stamp mill was operated at different proportions of its capacity, the rate depending upon the water supply. During the month of June the ore was supplied from the old No. 2 tunnel, but from July 1 to the end of the season all ore milled was taken from the Gold Dust tunnels 8, 9, 11, and 12. About 65 men were employed, of whom 50 were at the mine and 15 at the mill and camp. At the mine no mechanical power is used, and hand drilling is still relied upon. Hydraulic power is obtained for the mill and to operate a part of the cable tram. The water supply, however, has always been inadequate, and the quantity of ore crushed in any year has been determined in large part by the amount of power available. In 1916 five 1,050-pound stamps were added to the mill, making a total of 12 stamps, and a pipe line and small Pelton wheel were installed, using water brought from a small stream on the mountain to the south of the mill under a head of 425 feet, thus adding notably to the milling capacity.

The cyanide plant for the treatment of the sands was installed in 1914 and has operated satisfactorily. The sands accumulated before the installation of the cyanide plant have now been leached and the current mill product is being handled systematically. The plant has six leaching tanks, one of 37 and five of 30 tons capacity, and three other tanks for solutions. The product treated is coarser than that formerly handled, and an extraction of about 78 per cent is reported; the slimes are stored for possible future treatment. The concentrates from the mill are now also cyanided on the ground and the precipitates are all retorted, so that the only product shipped is bullion.

Several faults that add difficulty to the recovery of ore have recently been encountered in mining. One of these faults is exposed in Gold

Dust tunnels No. 8 and No. 10 and in the No. 3 raise in tunnel No. 8, and no ore has been found beyond it. Another fault in the old No. 2 tunnel cuts off the ore in several drifts and is said to show a displacement of 50 feet.

Exploratory work was done in 1917 on a surface showing of rich quartz in a saddle of the Craigie-Willow Creek divide, near the east end of the Gold Bullion claims, in the hope of locating the vein in place. About 20 tons of loose ore was picked up at this locality and taken by pack horses to a chute in the Gold Dust workings.

The progress of underground mining on this property to September, 1917, may be briefly summarized as follows: The old No. 2 tunnel has now over 3,300 feet of workings in addition to the stopes. Gold Dust tunnel No. 11, started in 1916, extends over 200 feet in a southerly direction and has three southwest drifts of an aggregate length of 550 feet. Gold Dust tunnel No. 12 lies approximately 180 feet west of No. 11 and is about 150 feet long, with a southwest drift 60 feet long. Gold Dust tunnels 11, 10, and 8 are now connected. No. 10 is 215 feet long, and much ground between it and No. 11 is stoped out. Old tunnel No. 9 is now caved and a new No. 9 has been driven to a length of 90 feet. The ground between the old and the new No. 9 tunnels is worked out. The main No. 8 tunnel is 225 feet long and has four southeast drifts that aggregate 430 feet of tunnel in addition to stopes.

Plans are under way to connect the Gold Dust No. 12 tunnel underground with the main No. 2 adit, thus making it possible to haul all ore from the Gold Dust workings by an underground tram to the head of the wire tram at the mouth of No. 2. This work would make it possible to eliminate one cable tramway and a surface tram line, both of which can be operated only during the open season from July 1 to October 1 and would lengthen the possible mining season. It was also proposed to drive the south drift of No. 2 tunnel through to the Willow Creek side of the mountain, to make accessible certain ores there that can not now be economically taken to the mill.

ALASKA FREE GOLD MINING CO.

Milling was commenced at the mine of the Alaska Free Gold Mining Co. on May 20, 1917, and was continued throughout the summer and fall, except for one month when operations were suspended on account of labor trouble. Before the strike both of the two Lane mills were operated for 24 hours a day for about a month, but since the resumption of operations only one mill has been turning. About 25 men have been employed on an average, and the mill has worked three shifts, but the mine has run only a single day shift. Considerable improvements have been made on the property since 1915.

A comfortable bunk house and a mess house have been built on the mountain near the workings, thus eliminating a high climb daily of the entire mining force. All the men now live at the mine except the mill crew of five men. A 16-horsepower Fairbanks-Morse gasoline engine and an Ingersoll-Rand compressor have also been installed at the upper camp to supply power for an Ingersoll-Rand jack hammer. One man now does all the drilling and blasting and is said to replace 12 hand drillers. The cyanide plant was idle in 1917, as the increased cost of chemicals had greatly increased operating expenses. The sands are ponded for future treatment. In September, 1917, the No. 8 tunnel was 225 feet long, the No. 9 tunnel 100 feet long, and the crosscut 175 feet long. A new 150-foot tunnel has also been driven, and new stopes have been made in all these workings. At the time of the visit the ore was being taken from surface workings on the outcrop of the main vein south of the open cut that was made in 1915.

INDEPENDENCE GOLD MINES CO.

As a result of increased operating costs no mining was done in 1917 on the property of the Independence mine. In 1916 an adit was driven below the old working tunnel to intercept the vein at a lower level. The vein was reached at a distance of 278 feet from the portal and was followed for 28 feet, but although its average thickness was 2 feet the gold content of the portion mined was less than that required to pay costs of mining and treatment. In 1916 a No. 2 Denver Chilean mill, which has a proved milling capacity of 36 tons of ore crushed to 40 mesh, was installed. In 1917 the pipe line that supplies the Pelton wheel was extended to a total length of about 1,100 feet, giving a head of 210 feet at the wheel. A temporary arrangement was made with the owners of the Gold Cord prospect for the use of the mill, a tramway was erected to the Gold Cord workings, and a few hundred tons of ore was milled.

Considerable prospecting, including several open cuts and a 33-foot tunnel on the east bank of Fishhook Creek, has been done in the endeavor to locate new ore bodies. The northward strike of the Gold Cord vein indicates that the extension of the vein may cross the Independence property, and this possibility has stimulated prospecting.

GOLD CORD MINING, MILLING & POWER CO.

The Gold Cord Mining, Milling & Power Co. has nine claims on upper Fishhook Creek, located on a quartz vein discovered in the fall of 1915 by Byron and Charles Bartholf. Developments in September, 1917, included cook and bunk tents, 245 feet of underground workings, and a wire-cable tram with two buckets of 500 pounds capacity, supported by four towers, that connects the workings with the quartz mill of the Independence mine, at a distance of 2,400 feet. The slope from the mine to the mill is insufficient for gravity operation of the tram, and power for the tram is supplied from the mill.

The Gold Cord ore body consists of a main vein, the so-called "blue lode," of blue-gray to greenish quartz mottled with white, which strikes in a general north-south direction and dips 40°–44° W. The vein ranges in width from 2 to 9 feet or more and cuts the diorite, that is, the country rock, for all the mines of this district. The quartz contains scattered specks and bunches of arsenopyrite and pyrite and some visible free gold. Near the portal of the tunnel the "blue lode" is apparently crossed, at an acute angle, by a vein of white quartz that strikes west of north and dips west. At the time of visit this portion of the tunnel was partly covered by timbers and lagging, and the conditions could not be satisfactorily determined.

The ore from this mine is said to carry encouraging amounts of gold, but a mill test of a few hundred tons is said to have yielded only a part of the gold content upon the amalgamation plates, the remainder being so entangled with sulphides that further treatment will be necessary for its recovery.

MABEL MINING, MILLING & POWER CO.

The Mabel mine and mill were operated throughout the open season of 1917, beginning May 23, and about 18 men were employed, of whom 14 were working in the mine and 4 at the mill. This property was equipped in the winter of 1915–16 with a 2-bucket wire-cable tramway 3,500 feet in length, which has a vertical drop of about 1,500 feet, connecting the mine with the mill, in which a Denver Chilean mill and crusher of about 15 tons capacity were installed. Power is obtained from a 13-inch turbine wheel that is operated by water procured from Archangel Creek through a ditch half a mile long and supplied to the wheel under a 30-foot head. After leaving the amalgamation tables the tailings are ponded for future chemical treatment. The underground workings in September, 1917, consisted of an upper tunnel 200 feet long, not including stopes, and a lower tunnel 260 feet long. From a hasty examination it appears that the workings show two distinct veins, generally parallel and about 70 feet apart, which strike northeast and dip about 30° NW., and a third vein that is quite flat and connects the other two. This flat vein has not been followed beyond its intersection with the two northwestward-dipping veins. The underground work has demonstrated a marked tendency of the veins to pinch and swell within short distances. Gold is also irregularly distributed in the veins, but for the last two years the mill has been supplied to capacity with ore of good grade. Near the surface cropping of the main vein and above the upper tunnel a small stringer of very high grade ore has been exploited. This stringer consists of banded white to rusty quartz that contains patches of sulphides, stains of copper carbonate, and abundant visible free gold. It is generally reported in this district that this high-grade ore contains gold tellurides, but samples selected by the owners as their typical "telluride ore" upon analysis in the chemical laboratory of the United States Geological Survey failed to show any trace of tellurium.

TALKEETNA GOLD MINING CO.

The property of the old Matanuska Gold Mining Co., in the upper basin of Fairangel Creek, was purchased in the fall of 1915 by the Talkeetna Gold Mining Co. The property was equipped in 1917 with a Denver Chilean mill of about 12½ tons crushing capacity, operated by a Pelton wheel working under an 85-foot head. The present water supply is inadequate during part of the season, but it is planned to extend the intake pipe line to give a head of 125 feet or more at the mill. Ore is brought to the mill from the mine by a wire-cable tramway composed of two sections. The upper section, carried by ⅝-inch cable, with one supporting tower, is 1,500 feet long and runs from the mine to an angle station. The lower section carries the ore from the angle station to the mill, a distance of 600 feet. Comfortable quarters for the men have been erected both at the mill and at the mine, and an average of 15 men were employed in 1917. In September, 1917, the main tunnel had a length of 60 feet. The tunnel was driven on a vein which near the surface showed a width of 1 to 3 feet but which in the breast of the tunnel was only 2 to 6 inches wide. Another tunnel, on a second vein, had a length of over 100 feet. The veins on this property, as elsewhere in the district, show a tendency to pinch and swell within short distances.

KELLY-WILLOW CREEK PROSPECT.

The Kelly-Willow Creek ground comprises five full claims and three fractional claims that lie north of the Independence Gold Mines property and adjoin it. The owners report five distinct quartz veins, all showing a tendency to lie in parallel planes. Two of these veins are near the summit of Independence Mountain, one is considered to be the extension of the Independence vein, and of the two others one lies 300 feet above and the other 200 feet below the Independence vein. Development work has been directed, in large part, toward proving the continuity of the Independence vein and toward the location in it of pay shoots. The workings consist of a number of open cuts and two short tunnels 20 and 25 feet long. The open cuts seem to prove that the Independence vein is continuous northward for many hundred feet beyond the boundaries of the Independence property, and according to reports it carries gold throughout its length, locally in encouraging amounts. The general strike of the vein is N. 23° W. and the dip 35° SW.

RAY-WALLACE MINING CO.

The Ray-Wallace Mining Co. has acquired a lease on the old Rosenthal property that lies on the high ridge which borders the basin of Fishhook Creek on the east. The old tunnel on the property is reported to have reached a length of 330 feet in 1917, and a new tunnel, on the Trickster claim, had been driven a distance of 30 feet to intersect a vein that crops out above, but it had not yet cut the vein. A new vein, on the Morning Star claim, has been uncovered by several open cuts. It strikes nearly due east and dips about 55° S. and shows a maximum of 6 inches of quartz and a foot or more of crushed and oxidized vein matter. The quartz contains some pyrite and arsenopyrite and some dark material in spots which is said to contain tellurides but which upon chemical analysis failed to give a trace of tellurium. The owners of this property plan to install a cable tram and a mill in the winter of 1917–18.

MOHAWK MINING CO.

The Mohawk Mining Co., which is incorporated as a stock company, has eight claims in the upper basin of Sidney Creek, a tributary of Archangel Creek from the south. The main vein has been developed by two tunnels, one about 70 feet above the other. The lower tunnel, 30 feet long, failed to penetrate through the loose detrital material. The upper tunnel, which is 160 feet long, is now partly caved in. It follows a band of decayed diorite and gouge in which is some white banded quartz that shows arsenopyrite. The vein pinches and swells and is said to show a maximum thickness of 30 inches of quartz, though at the breast the quartz vein was only 6 to 8 inches wide. The vein strikes N. 35° W. and dips 45° SW. Average assays of the vein matter are said to have given promising returns in gold, but the percentage of the gold content that can be recovered by amalgamation can be determined only by mill tests on a considerable amount of ore. It is said that milling equipment for this property had been purchased, but it was not installed in 1917.

NORTHWESTERN MINE.

A group of 13 claims, called the Northwestern mine, has been located on the west side of Moose Creek, about 3 miles above the canyon through which that stream emerges from the mountains. The ore body lies on a high mountain ridge, about 1,600 feet above Moose Creek, at an elevation of about 3,800 feet. A horse trail leads up Moose Creek from its mouth, through the canyon, and from the valley bottom below the ore body a steep switchback foot trail leads to the prospect.

The country rock in this vicinity exhibits a gneissic phase of the diorite mass that forms a large part of the Talkeetna Mountains. Near the south ridge of this mass, from Moose Creek westward across the basin of Little Susitna River, the intrusive rock has a more or less well-developed gneissic structure and locally shows a pronounced banding. Certain phases are also highly hornblendic. A short distance south of the property here described Tertiary arkoses overlap and conceal the gneissic and granitic rocks. The ore body, which is conspicuous on account of a rusty red gossan, has been developed by open cuts, strippings, and a 33-foot tunnel. It has been formed through the replacement of the gneissic rock by sulphides, chiefly pyrrhotite, pyrite, and chalcopyrite. Sphalerite is also reported. The banding of the gneiss, although somewhat wavy and twisted, has a general strike of N. 60°–75° W. and a dip of 65° S. to vertical, and the ore body lies parallel to the gneissic structure. As shown by the workings, the area of heavy mineralization appears to have a thickness of 25 to 30 feet, and disseminated sulphides occur for considerable distances on either side. The body of massive sulphides has been exposed by open cuts along the strike for at least 80 feet, and gossan shows beyond the cuts in both directions. Within this ore body the sulphides range in abundance from scattered specks disseminated without any marked arrangement in rather massive diorite to bands of sulphides that follow the banding of gneissic materials and to massive sulphide masses in which no gangue or country rock appears. Each of the three principal sulphides—pyrite, pyrrhotite, and chalcopyrite—occurs in places in large, nearly pure aggregates, but more commonly the three are intermingled. The tunnel penetrates through the gossan into sulphides that are unoxidized, except along joints and cracks down which surface waters have circulated. No one was resident on this property at the time of visit but assay certificates supplied by the principal owner showed from 0.04 to 0.08 ounce of gold and 0.8 to 1.2 ounces of silver to the ton, and from a trace to 5.6 per cent of copper. One assay also showed the presence of 0.03 per cent of nickel.

OTHER PROSPECTS.

In addition to the properties described above, there are many prospects in this region on which some work has been done. Some of these prospects were visited by the writer in 1917. Concerning others that he could not examine within the time available, information from sources that were believed to be reliable was obtained. The following notes include such information as seems worth publishing.

The so-called Jap claims, on upper Willow Creek, have been leased, and work was continued on two tunnels. On the Eagle claim

No. 2 the tunnel in the fall of 1917 was 200 feet long, with a 25-foot crosscut and a 50-foot winze. The vein is said to be 6 feet wide between walls, and the quartz vein matter averages 12 inches wide and is said to carry gold in commercial quantities. On the Mary claim is a tunnel 100 feet long on a quartz vein that is reported to average 2 feet wide but to be of rather low grade. Near the portal of this tunnel a winze has been started on a quartz stringer that is said to be rich in gold.

The Bluebird claim, south of the Gold Cord, has been developed by numerous open cuts and a 30-foot shaft. The shaft is reported to show a large body of quartz that contains visible free gold.

A group of four claims, also known as the Gold Cord, for the owners believe them to contain the northward extension of the Gold Cord vein opened in the head of Fishhook Creek valley, has been staked in the upper basin of Sidney Creek. Open cuts show a few inches of white quartz that contains stains of copper carbonate and is said to carry visible free gold.

Smith & Sutherland hold four claims in the southeastern portion of the Sidney Creek basin. It is reported that a 40-foot tunnel driven on this property has now caved in.

Little work was done in 1917 on the Arch group. The old inclined tunnel is caved, and another 80-foot tunnel driven at a lower point on the same vein has now caved 50 feet from the portal and is inaccessible.

The Webbfoot group of two claims, lying on the south side of Archangel Creek and west of Sydney Creek, has been developed by a large amount of stripping along the outcrop of the vein. The vein is said to show an average width of several feet of quartz and to carry encouraging amounts in gold.

The Alaska Quartz group of two claims, on the mountain ridge between Archangel and Reed creeks, has been prospected by two tunnels 20 feet and 212 feet long. In the longer tunnel the vein carries 16 inches of quartz at the portal, but the quartz pinches out about 40 feet from the portal, and beyond that point the tunnel was driven along a slip zone that contains gouge.

The Babcock-McCoy claims, on Reed Creek, are developed by open cuts and by a 100-foot tunnel. The open cuts are said to show a vein that ranges from a few inches to 9 feet in thickness and that is said to carry promising amounts of gold. The tunnel, driven to intersect the vein at some distance below the cropping, has not yet reached the vein.

The Little Gem group of three claims lies on the east side of upper Archangel Creek. Two tunnels, the upper 25 feet and the lower 60 feet long, have been driven on the vein, which in the workings shows a maximum width of 8 inches. The vein carries a very rich streak of ore, from half an inch to 2 inches wide, in which visible gold is abundantly present. The owners have on the ground a 5-ton Buster Brown mill and a 4-horsepower Moline gasoline engine, with hemp rope for a tramway, although none of this equipment was installed in September, 1917.

The Hillis group of three claims, commonly known as the Fern-Goodell property, is situated in the upper basin of Archangel Creek. An adit tunnel that has a total length of 96 feet was driven 40 feet to the vein, which was followed for 56 feet in an attempt to find an ore shoot that crops out on the surface. The vein in the tunnel is reported to have a maximum width of 5½ feet and to carry some gold throughout, with a particularly rich streak a few inches wide on the hanging wall. The vein quartz is white and shows arsenopyrite and some gold, and the richest ore is mottled with bluish spots. Tellurides have been reported from this property, but their presence has not yet been conclusively proved.

Vein quartz, carrying considerable molybdenite, has been found in at least two localities in the Archangel Creek basin. One of these localities is in the upper basin of Fairangel Creek, and the other is on the divide between Archangel and Purches creeks. Neither locality was visited by the writer, and the extent of the deposits has not been determined.

The Good Hope lode, on the east side of lower Reed Creek, was staked in 1916. It has been exposed in two large open cuts and is said to show a strong vein, several feet wide, from which a few colors of free gold may be panned.

The Galena-Gold group of three claims was staked in 1917 on the head of Purches Creek. Little development work has been done, and neither the width nor the length of the ore body has been determined, but it is said that at least 1 foot of good ore, containing chalcopyrite, pyrite, galena, and free gold, shows on the surface.

The Jessie B group of two claims lies in the upper basin of Peters Creek. The vein is reported to be from 2 to 5 feet wide, and specimens of ore show quartz stained with copper carbonates and iron oxide. The vein matter is said to show free gold upon panning, and a considerable amount of ore is said to have been mined and stacked during the progress of development work.

MINERAL RESOURCES OF THE WESTERN TALKEETNA MOUNTAINS.

By Stephen R. Capps.

INTRODUCTION.

The limits of the region here called the western Talkeetna Mountains are somewhat arbitrarily drawn. It includes that portion of the Talkeetna mountain mass that lies west of a sinuous line extending from the head of Little Susitna River northward along the rugged crest of the mountains and embraces the basins of a number of westward-flowing tributaries of Susitna River and the basins of Sheep River and Iron Creek, two tributaries of Talkeetna River.

Although the Willow Creek gold mining district is geologically and topographically a part of this region, it is excluded from the area here treated, as a separate account of its mining activities is given elsewhere. (See pp. 177–186.)

Systematic surveys were begun in this part of Alaska in 1898, when G. H. Eldridge[1] and Robert Muldrow, of the United States Geological Survey, ascended the Susitna basin to Broad Pass and obtained the first accurate information concerning the geography of that great river system. During that same year W. C. Mendenhall,[2] while attached to a War Department expedition in charge of Capt. F. W. Glenn, ascended Matanuska River to its head and proceeded northeastward to Delta River, thus skirting the Talkeetna Mountains on the south and east. The next notable survey in the region here discussed was carried out in 1906, when R. H. Sargent and Sidney Paige,[3] of the United States Geological Survey, ascended Matanuska River and Chickaloon Creek, ascended Talkeetna River to Sheep River, and thence followed the west flank of the mountains southward to Knik Arm. Their topographic and geologic surveys thus completely surrounded the western Talkeetna Mountains but left inclosed within their route of travel a large unmapped area. In 1910 F. J. Katz[4] spent a few days in the Willow Creek district, and in 1913 S. R. Capps[5] made a detailed study of that area.

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

[2] Mendenhall, W. C., A reconnaissance from Resurrection Bay to Tanana River, Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 31–264, 1900.

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

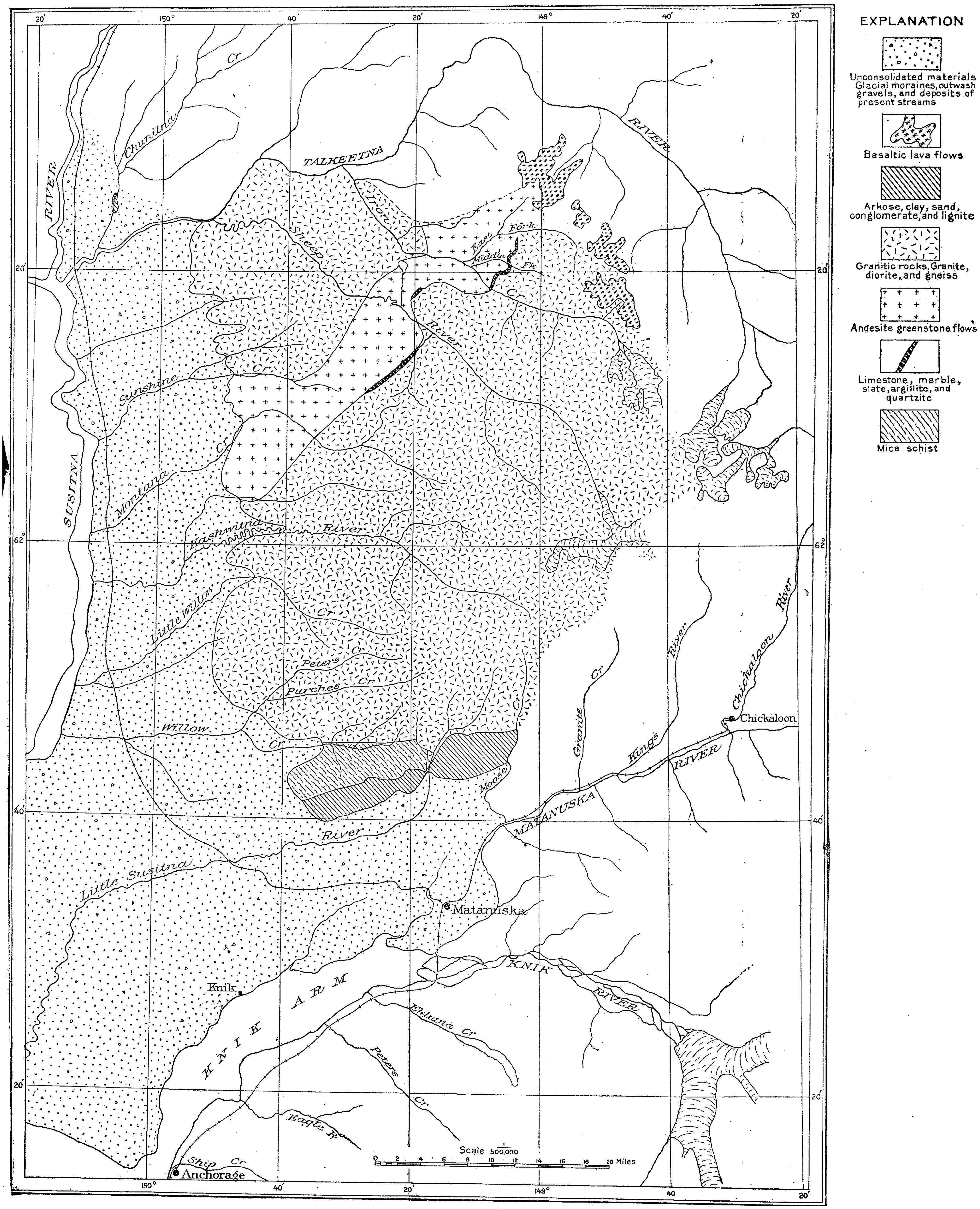
[4] Katz, F. J., A reconnaissance of the Willow Creek gold region: U. S. Geol. Survey Bull. 480, pp. 139–152, 1911.

[5] Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, 1915.

On the Government railroad in progress of construction from Seward to Tanana River, rails were laid by the fall of 1917 from Turnagain Arm northward as far as Montana Creek, and the branch line up Matanuska Valley was in operation to the Chickaloon coal field. Upon the laying of a stretch of track along the north shore of Turnagain Arm, now rapidly approaching completion, rail transportation will be available from Seward to points well up Susitna Valley, and the area thus supplied will expand as construction proceeds northward.

The western Talkeetna Mountains have long been considered to offer a promising field for the prospector. In 1897 the first gold-placer claims were staked on Willow Creek, and although the workable ground proved to be of small area, considerable gold was produced. In 1906 gold quartz was discovered in the Willow Creek district, and since that time the production of lode gold has steadily increased. From time to time prospectors attempted to extend the productive area of the Willow Creek district northward, and some encouraging quartz veins were found, but the cost in time and money of getting supplies into that area grew prohibitive as the distance from the water increased, and no serious attempts were made to develop mines north of the basins of Willow Creek and Little Susitna River.

The passage of a bill by Congress authorizing a Government railroad up Susitna Valley and the progress of construction on this project greatly encouraged both prospectors and those seeking agricultural lands in this hitherto remote area, and it became desirable to complete topographic and geologic surveys along the route to be served by the railroad. Accordingly, in 1915, J. W. Bagley, of the United States Geological Survey, carried out a reconnaissance topographic survey in the western Talkeetna Mountains, covering an area of 835 square miles previously unsurveyed. In 1917 the writer, in addition to other duties, was assigned to the task of studying the more important mineral resources of that area and of mapping the areal geology in so far as time for that work was available. After returning from a few weeks' visit to the upper Chulitna basin, the field party, consisting of the geologist, a cook, and two packers, with seven pack horses, left Talkeetna on July 29 and ascended the valley of Talkeetna River and of Iron Creek to the vicinity of the numerous lode prospects in that basin. Two weeks was spent in a study of the prospects and of the geologic conditions of that vicinity, after which the party proceeded southward through the mountains. Only 16 days was available for the areal geologic mapping of several hundred square miles of rugged mountains, but much of that area is occupied by a single geologic unit, and it is believed that the general distribution of formations, as shown on the map (Pl. IV), is approximately correct in its larger features.



GEOLOGIC SKETCH MAP OF THE WESTERN TALKEETNA MOUNTAINS.

The conclusions reached in this paper are based on a preliminary study of the data gathered and are subject to modifications in the more complete report now in preparation.

GENERAL FEATURES OF THE REGION.

GEOGRAPHY.

The region here described as the western Talkeetna Mountains is, as its name implies, predominantly an area of high relief. On its eastern border the summit peaks of the mountain mass reach elevations of 7,000 to 8,800 feet and nourish many glaciers, the largest of which has a length of 12 miles. Farther west the mountains decrease somewhat in height but are extremely rugged and steep for an average distance of 20 miles from the divide. Within that area the land forms are characteristically those of a severely glaciated mountain mass in crystalline rocks with multitudes of cirque basins and relatively straight, troughlike trunk valleys.

As the Susitna lowlands are approached the mountain topography undergoes a sharp change of type. The ragged sky line of the higher mountains disappears, and the interstream ridges on the western mountain flank have rounded contours and plateau-like surfaces up to an elevation of 3,000 feet or more. Many facts prove that this series of plateaus, which may be regarded as a high beach now dissected, was once overridden by the northward-moving ice of the great Susitna glacier, and its subdued topography and rounded forms are due, at least in part, to the erosive effects of that ice mass.

On their western flank the Talkeetna Mountains merge gradually into the Susitna lowlands. Susitna River flows southward through a broad structural basin that is bordered on the east by the Talkeetna Mountains and their northward extension and on the west by the Alaska Range and its foothills.

Between these two mountain masses this lowland has a width of about 50 miles in the latitude of Kashwitna River but narrows to a width of 20 miles at Talkeetna. From it irregular projections extend up the valleys of the larger tributary streams. Along the axis of this basin the relief is slight, and the gradient southward to tidewater is gentle. Talkeetna, at the mouth of Talkeetna River, is 80 miles from the head of Cook Inlet, yet its elevation above sea level is only 350 feet. The flatness of the valley floor is relieved only by rolling morainic hills and by the comparatively shallow trenches of the streams that cross it. Toward its borders the relief increases, the stream trenches are of greater depth, and the rolling lowland merges into the flanks of the foothills and the mountain ranges.

The area here treated contributes all its drainage to Susitna River. More than half of the region is drained directly to the Susitna by Willow and Little Willow creeks, Kashwitna River, and Montana and Sunshine creeks, all of which head in the mountains and flow westward to emerge into the lowlands through which they flow to join the Susitna. Sheep River and Iron Creek both head in glaciers at the summit of the range and flow in parallel courses northwestward to join Talkeetna River 16 and 30 miles, respectively, above its mouth.

GLACIATION.

The higher parts of the Talkeetna Mountains reach above the level of perpetual snow and nourish a large number of glaciers. A considerable portion of the waters of Kashwitna and Sheep rivers and Iron Creek is supplied by the melting ice fields, and Montana Creek receives enough glacial drainage to cloud its waters in summer. As measured by the standards of the neighboring Chugach and Alaska ranges all the glaciers in the Talkeetna Mountains are of small size, occupy only the extreme heads of the cirques, and are of simple form. Of those on the west slope of the mountains only three of four are of the type that comprises a somewhat extended main lobe fed by numerous tributaries.

The largest glacier in the Talkeetna Mountains is that in which Sheep River heads. The upper basin of Sheep River is encircled by the highest peaks of the range, and the northern slopes are protected from solar radiation, so that conditions are especially favorable for the accumulation of glacial ice. In addition to the main glacier there are more than thirty smaller ice fields over half a mile long that send their water to Sheep River. The Kashwitna and Iron Creek basins also contain numerous glaciers.

Although glaciers are so numerous in the range, the present glaciers are altogether insignificant as compared with the great ice fields that once covered this area. During the earlier period of glaciation all the mountain valleys were filled to the brim with glacial ice, so that only the highest peaks and ridges projected above its surface. This ice moved slowly down the valleys to join the enormous glaciers that occupied Susitna Valley. Some idea of the volume of the former Susitna glacier may be gained from the statement that at the mouth of Kashwitna River the glacier at one time reached a thickness of close to 4,000 feet and had a width of over 50 miles.

ROUTES OF TRAVEL.

Although not far distant from tidewater, the western Talkeetna Mountains have always been rather difficult of access, and few white men had traveled in them until the beginning of construction on the railroad gave promise of improved transportation to the region. Two routes of approach to the mountains have been followed, one by boat or sled up Susitna River and its tributaries and the other along the flank of the mountains northward from Willow Creek, the route chosen by any particular party being determined by the time of year when the trip was to be made and the means of transportation available. Most prospectors and trappers in interior Alaska prefer to travel in winter by dog sled, when the frozen streams and the mantle of snow make it possible to haul heavy loads with the least effort and equipment. Trading stations and stores have long been maintained at Knik, on Knik Arm, and at Susitna station, on Susitna River near the mouth of the Yentna. A trading station was also operated for some years at the mouth of Talkeetna River but was abandoned in 1911. Winter travelers obtained supplies from one of these places and sledded them up the valleys to the chosen prospecting or trapping ground. In summer Susitna River is navigable for high-powered, shallow-draft boats as far north as the mouth of Indian River, and construction camps have been established at intervals along the line of the railroad by the Alaskan Engineering Commission. Talkeetna, a considerable village, including, in addition to the buildings of the commission, several stores and many dwellings, has sprung up at the mouth of Talkeetna River, and transportation by boat was obtainable in 1917 to the mouth of Indian River. The tributaries of Susitna River from the east, however, are not navigable for power boats. Kashwitna and Talkeetna rivers may be ascended for some distance by poling boat, but the swift current and shoal waters of these streams make navigation by small boat difficult and dangerous.

The only feasible land route for summer travel up the east side of Susitna Valley has been along the flank of the mountain pass. The Susitna lowlands contain much swampy ground and dense thickets of brush, so that very great difficulties were encountered in endeavoring to travel through them with horses. The higher parts of the mountains are much too rugged to permit taking horses across them from one east-west valley to another, so that a route between these two extremes must be chosen. Two such routes have been followed with pack trains in 1906, 1916, and 1917 by Geological Survey parties and present no insurmountable difficulties. Between the east-west valleys the broad, timberless benches afford good footing, and trails have been cut across the brushy valley slopes.

In 1917 construction work on the Government railroad was pushed rapidly, and by the fall of that year rails were laid to Montana Creek and the grade was practically complete to Talkeetna. Trails and wagon roads that roughly followed the railroad survey through the lowlands had been built, and thus a route of great natural difficulty became the main highway of travel. Completion of the railroad to Talkeetna, and the consequent building of trails and wagon roads up the main valleys leading into the mountains, should within a few years make the whole of this region easy of access.

VEGETATION.

A sharp contrast exists between the thick timber and brush of parts of the lowland areas of this region and the barren slopes of the higher mountains. The Susitna lowland is thickly wooded with trees wherever the ground is fairly well drained. Thus there is a heavy growth of cottonwood and spruce along the banks of all the streams, and of spruce and birch on the rolling hills of the lowland and the slopes of the mountain flanks. Groves of cottonwood trees, many of which reach a diameter of 3 or 4 feet, grow in favorable localities in the stream flats, and birch and spruce trees attain 2 feet in diameter on the slopes. Within the lowland area, however, there are many places in which drainage is sluggish and which are characterized by marshes, entirely barren of trees or containing only stunted, scrubby spruce trees. The same distribution of thick timber interspersed with areas of scattered stunted trees and barren marshes is found in the valleys of the tributary streams. Timber line has, in general, an elevation of about 2,000 feet; below that elevation well-drained lands are timbered, but above it few trees grow. Although, locally, cottonwood and spruce trees of sufficient size to furnish saw logs are found, the timber is for the most part too small and of too poor quality to supply lumber for any but local uses, and no lumber industry of magnitude is likely to be developed. There is a possibility, however, that considerable areas of cottonwood and spruce that lie near the largest streams will sometime furnish materials for a wood-pulp industry.

Within the timber of the lowlands there is commonly a thick growth of willow and alder brush, and these bushes grow at a considerably greater elevation than the trees, so that there is generally a belt of thick brush above timber line. The brush affords fuel for the camper at many places where trees are lacking, but the dense growth greatly impedes travel, and the man traveling with horses who leaves the few poorly defined trails must do much trail chopping to penetrate the thickets.

Grass for forage for horses is abundant throughout the region, and camping grounds can nearly everywhere be found where horses will obtain sufficient grass for their needs. A variety of grass locally known as red top is particularly abundant near timber line, and over large areas it grows in thick stands to a height of 5 or 6 feet. While green it furnishes good forage for stock, but upon freezing in the fall it loses its nourishing qualities. An even better forage grass known as bunch grass occurs in places, usually above timber line.

GAME.

The big-game animals of this region include moose, caribou, sheep, and bear. Moose are generally distributed throughout the lowlands and range wherever trees and brush grow. Caribou range in the areas above timber line, particularly in the northeast part of this region, although they are nowhere abundant. The white bighorn sheep is found in the highest mountains, particularly in the headward basins of Sheep River and Iron Creek. Black bears live in and near timbered areas, and brown and grizzly bears may be seen almost anywhere, as they range the higher mountains and also visit the stream valleys during the salmon run.

Rabbits and ptarmigan are very abundant during some years, but their numbers vary greatly from season to season, and in 1917 few were seen. Some fur-bearing animals, including fox, lynx, mink, and marten, are captured each winter. Salmon run up Susitna River and most of its tributaries to spawn, and practically all streams not clouded with glacial silt are stocked with grayling and trout.

POPULATION.

There are settlements of natives at Knik, Susitna station, and Talkeetna, and from these villages hunters and trappers have long made expeditions into the mountains for fur and meat, yet the visible evidences of their occupancy are meager. The Indian transports his few belongings by dog sled in winter, following the frozen streams, and in summer uses a boat or loads his effects upon his dogs, himself, and his family. He chops no trail but makes detours around obstructions, and his trails are of little use to the white man who travels with horses.

Only within the last year or two have there been any permanent white inhabitants in the mountainous portions of this region. A single group of claims was staked on Iron Creek in 1910 and has been visited yearly by the owners since that time, but no permanent buildings were constructed, and the only white visitors to the mountains were a few prospectors and trappers. Within the last few years, however, many mining claims have been located in the Iron Creek basin, and some prospects are known in Montana, Kashwitna, Peters, and Purches basins. Some log cabins have been constructed, and the number of permanent residents will increase as railroad construction stimulates prospecting and mining.

Susitna station has long been a permanent settlement of whites and natives. Talkeetna has had white inhabitants at intervals and is now an established village.

Since 1915, the development of an agricultural population around Knik Arm and in Matanuska Valley has proceeded rapidly, and in 1917 a large quantity of agricultural produce was raised there. Undoubtedly this development will extend up Susitna Valley, where much land has farming possibilities, and a gradually increasing agricultural population may be expected in this region.

GENERAL GEOLOGY.

CHARACTER OF THE ROCKS.

The striking feature that at once becomes apparent on inspection of the geologic map of the western Talkeetna Mountains is the great predominance of igneous materials over sedimentary rocks. Great areas of deep-seated granitic intrusives, older deformed lava flows, and little-disturbed Tertiary lavas occupy almost all the region in which the hard rocks are exposed, and the granitic rocks and older lavas doubtless extend westward beneath the mantle of unconsolidated materials. Except for a narrow and interrupted belt of sediments that crosses the basins of Sheep River and Iron Creek and a few isolated outliers of this group of sediments, with some materials of sedimentary origin intimately intruded by granitic rocks in the area between lower Sheep River and Iron Creek, the entire western Talkeetna Mountains are composed of igneous materials. As has already been stated, the areal geologic mapping of this whole region was done hastily, for the prime object of the writer's visit to the Susitna basin was the investigation of the mineral resources of several widely separated localities. Time was therefore lacking for a careful tracing of the contacts between the formations, and more careful and painstaking work probably will make considerable modifications in the geologic boundaries as here given. It is believed, however, that the general outlines of the areas occupied by the different rock types are shown in approximately their proper position.

In many areas sedimentary rocks that contain determinable fossils give the geologist certain tie points from which he can draw conclusions as to the age of the rock formations with which he deals. In this region, however, no fossils have been found. The few sedimentary rocks examined are highly metamorphic, and this metamorphism included deformation and recrystallization, so that any fossils which the rocks may have once contained have been largely or completely destroyed. By their very nature the igneous rocks are unlikely to contain recognizable organic remains, so the age determination of the rocks in this area must be inferred from their correlation, upon lithologic or structural grounds, with other formations in surrounding regions where more satisfactory age determinations have been made.

MICA SCHIST.

The oldest rocks known within the Talkeetna Mountain area are the mica schists that occur on the south flank of the Willow Creek basin. These schists have been described elsewhere[1] and are not

[1] Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, pp. 26-30, 1915.

known to occur in the region here discussed, but it is of interest to note that they are of pre-Jurassic age and constitute one of the formations into which the granitic materials were intruded.

LIMESTONES, MARBLES, SHALES, SLATES, AND QUARTZITIC SEDIMENTS.

As shown on the geologic map (Pl. IV) a narrow and interrupted belt of sediments occurs at the contact of the granitic rocks with the andesite-greenstones in the basins of Iron Creek and Sheep River. Small outlying patches of these sediments also occur both in the granitic rocks and in the andesite. The most conspicuous member of the group of sediments is a heavy bed of blue-gray limestone that forms prominent cliffs on the north side of Iron Creek, on the Middle Fork of Iron Creek, and at the head of Prospect Creek. It has in places a thickness of at least 600 feet and from a distance appears to be massive. Close examination, however, shows that the rock has been greatly sheared and in part recrystallized. Upon weathering it breaks down into small prismatic bits and is seamed with thin films of calcite along the lines of cleavage. Within the limestone there are local masses of completely recrystallized material that now appears as beautiful pure-white marble. Associated with the limestone and overlying it there is in places a considerable thickness of shales, slates, and quartzitic beds that represent metamorphosed clastic materials.

A few miles south of Sheep River this group of sediments occurs in a narrow northeast-southwest belt. There the limestones have been completely altered to white and green contorted and banded marble, and the clastic beds to siliceous schists and quartzites. Fossils have nowhere been found in these sediments, and their age is not definitely known, but from a somewhat similar association of limestones, shales, and lava flows in the upper Chulitna region, where the limestones are of Triassic age, it is suggested that the sediments here described may prove to be Triassic.

ANDESITE-GREENSTONES.

A considerable belt of territory, extending from the basin of Iron Creek southward to the basins of Montana Creek and Kashwitna River, is occupied mainly by lava flows that are dominantly andesite-greenstones. These rocks are bordered on the southeast in part by the series of limestones, marbles, and associated sediments and in part by an intrusive contact with the granitic rocks. The northwest border of the andesite-greenstones has not been carefully traced out but is believed to be an intrusive contact with granitic materials. The characteristic phase of this material consists of a medium-grained blue-gray or greenish-gray rock full of amygdules filled with greenish-yellow epidote. The epidote commonly displays a radial, spherulitic structure. Associated with the amygdaloidal rocks that were poured out as lava flows are local bodies of somewhat coarser grained dark-gray or black greenstones that probably represent an intrusive phase of the same period of igneous activity and may mark the location of vents through which the lavas reached the surface. The andesite-greenstones are of especial economic importance in the Iron Creek district, for it is in those rocks that the copper prospects of that basin have been found. Structurally the andesite-greenstones overlie the limestones, marbles, and associated sediments. Paige[1] has described similar rocks, associated with abundant dacites, rhyolites, and tuffs, that occupy a large area in the upper Talkeetna basin. The area here shown (Pl. IV) as occupied by andesite-greenstones is directly connected both to the northeast and southwest with the areas mapped by Paige. No definite evidence of the age of the greenstones was procured by the writer in 1917, but in the extensions of this area, in the upper Talkeetna basin, Paige obtained evidence that led him to classify the rocks as lower Middle Jurassic, and that age determination was later modified to Lower Jurassic.

GRANITIC ROCKS.

The dominant geologic feature of the Talkeetna Mountains is the great mass of granitic intrusive rocks that occupies a large portion of this region. These rocks form a main roughly circular area, measuring about 50 miles in diameter, and some smaller areas around the periphery of the central mass. The largest of these smaller areas lies for the most part in the lower Talkeetna basin and measures at least 12 by 15 miles. As shown on the map (Pl. IV), the higher portions of this mountain mass are composed exclusively of granitic materials, and the rugged character of the mountain peaks, with their multitudes of ragged pinnacles and serrate ridges, is due to the influence that this rock type has exerted upon the forms produced by erosion.

The granitic rocks are in general coarse-grained gray to pink diorites and granites and show a considerable range in texture and composition. Throughout most of the area in which they occur they are massive, little altered, and free from the effects of metamorphism. In some localities, however, they have been metamorphosed and show all gradations from unaltered massive materials through banded gneisses to hornblende schists. Within those areas in which metamorphism has occurred there is a larger proportion of dark hornblendic rocks.

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 16–19, 1907.

Structurally the granitic materials are found in intrusive contact with the mica schists of the Willow Creek district, with the limestones and shales of Sheep River and Iron Creek basins, and with the andesite-greenstones of those areas. They are therefore younger than all those formations. They are unconformably overlain by the Tertiary lavas of upper Iron Creek and by the early Tertiary sediments of the lower Matanuska basin and so are known to be pre-Tertiary. The evidence is still insufficient to prove their exact age, but there seems to be little doubt that they are Mesozoic, and although they have generally been referred to the Middle Jurassic are now believed to be of Lower Jurassic age.

TERTIARY SEDIMENTS.

Tertiary sediments, including arkoses, conglomerates, sands, shales, and lignitic coal, occur at many localities around the borders of the Susitna basin. In general the outcrops occur along the flanks of the surrounding mountains or as isolated areas in which the Tertiary beds are surrounded by later unconsolidated materials and for the most part covered by them. The area of Tertiary deposits shown on the map (Pl. IV) is small, but the economic value of the formation is disproportionate to its area, for the lignitic coal beds that are present in many places offer possibilities of the development of a valuable fuel supply. The best-known occurrence of this formation is in the Matanuska Valley, where a considerable area is underlain by workable coal beds. Farther west and north the beds are less conspicuous, and their distribution is not so well known. On the south flank of the Bald Mountain ridge, which separates the Willow Creek basin from the eastward-trending portion of Little Susitna River valley, there is a large area of arkoses and conglomerates of Tertiary age which contains no lignite beds that are known to be extensive. An excavation on the railroad line, in the spring of 1917, 2 miles west of the Little Susitna bridge, showed Tertiary beds, and in the summer of that year it was reported that a lignite bed was uncovered there. Lignite-bearing Tertiary beds are reported on the west flank of the Talkeetna Mountains in the basins of Willow Creek and Kashwitna River, but these localities were not visited, and the area and thickness of the formation are not known.

Similarly unconsolidated Tertiary sands and shales, which contain a thick lignite bed, are reported on lower Chunilna Creek, a southward-flowing tributary of Talkeetna River, 4 miles above its mouth. What is probably the western extension of that same field lies along the east bank of Susitna River, from 7 to 12 miles above the mouth of the Talkeetna, and was briefly examined. In that locality, a distance of several miles, the river flows against a bluff composed of blue-gray sands, blue clays, a little sandstone, and some lignite. Good exposures of undisturbed material are scarce, and above the bluff the surface is covered by younger unconsolidated deposits. A 2-foot bed of fairly good lignite was seen, and scattered detrital materials indicate that other lignite beds occur in the same section. It is reported that at one locality a 4-foot bed is exposed, and the coal-bearing area is said to extend to the west side of the river. The coal-bearing beds are believed to be of Eocene age.

TERTIARY LAVAS.

The deposition of the Tertiary sediments was interrupted from time to time by the ejection of basaltic lavas, and a large volume of this material was poured out after the last of the Tertiary sediments were laid down. Thus, in the Willow Creek district thin basal flows are conformably interbedded with Tertiary arkoses. The greatest development of these lavas, however, took place somewhat later, when large areas, including most of the earlier formations, were buried beneath extensive flows of basalt. These lavas reach their greatest development, in the area here discussed, in the upper basin of Iron Creek, where they form a nearly horizontal capping over many ridges and lie upon an erosion surface that was developed on both granitic rocks and greenstones. The basalt flows are of Tertiary age. Some are apparently Eocene, but for the most part they are believed to be post-Eocene.

UNCONSOLIDATED DEPOSITS.

The unconsolidated deposits include glacial morainal materials, glacial outwash gravels of both present and past glaciers, and the detrital materials of the present stream flats. As the earlier glaciers reached so great a development in this region, filling the Susitna basin to a height of over 4,000 feet and completely covering all the lower slopes of the mountains, the deposits left by them cover a large area and have a considerable vertical range. On the map (Pl. IV) the distribution of those materials is shown only in the localities where they are present in sufficient thickness to conceal the identity of the underlying formations. Glacial materials have been recognized over a much wider area, but in places where the area and thickness of the material are small and where the character of the underlying rocks could be determined with little uncertainty the glacial materials were not shown on the map. During the withdrawal of the old glaciers large volumes of outwash gravels and sands were deposited over the lowlands, and these materials are still present in the form of gravel plains, locally dissected by the streams to form benches or terraces. The gravels along the flood plains of the present streams are composed both of the outwash from the present glaciers and of the products of normal weathering and erosion by streams.

ECONOMIC GEOLOGY.

GENERAL FEATURES.

The first discovery of valuable mineral deposits in this general region was made in 1897, when gold placer gravels were found in the Willow Creek basin. The area of workable gold placer deposits proved to be small, but their discovery led to prospecting for the lodes from which the gold came, which resulted in the finding, in 1906, of the lode on which the Alaska Free Gold mine is located. This discovery was soon followed by others, and a permanent gold lode camp, which had produced over $1,000,000 by the end of 1916, was established. All the producing mines in this district are confined within a small area, but there has been more or less consistent prospecting in the mountains north of the producing area, and some promising gold lodes have been discovered but await improved transportation for further development.

In 1910 claims were staked on the Copper Queen lode, on Iron Creek, and assessment work has been done on that property each year since. By 1916 it became apparent that rail transportation up Susitna Valley was soon to be realized, and a number of men went into the basin of Iron Creek, and many claims were staked on copper and gold bearing lodes, and the activity was continued in 1917. More or less work was done on 15 or 20 groups of claims, and a large number of additional claims were staked. In August, 1917, about 20 men were prospecting or carrying on development work in the Iron Creek basin.

At the time of the writer's visit, in August, 1917, the Iron Creek district could be reached only by a poor trail that offered difficulties even for a pack horse. Supplies for the prospectors were therefore limited to articles that had been brought in by sled during the preceding winter or to such materials as could be transported during the summer by pack horse. As a consequence of the remoteness of the district only the simplest forms of prospecting were carried out and even a small amount of development work demanded a large outlay of time and money. The ore bodies are opened only by rather shallow open cuts, and no attempt has been made to sink shafts or drive tunnels. In many places, too, the undisturbed bedrock near the ore outcrops is covered with vegetation or loose surficial material, so that it was difficult or impossible to determine either the size or the geologic relations of the ore bodies. No property in the district had at that time any mass of ore which a conservative mining engineer would consider as being blocked out.

The prospects examined were believed to be valuable for their content of copper or of copper and gold. Most of the ore bodies are due to the replacement, along zones of faulting and shearing, of andesite-greenstone by metallic minerals, but one or two have some of the aspects of contact-metamorphic deposits, though they lie at some distance from the contact of the diorite and greenstone. So far as is known the content of the ores in free gold is not sufficient to justify the installation of crushing and amalgamating machinery on the ground. The base character of the ore will necessitate smelting for the recovery of the copper and gold. Furthermore, the ores contain large amounts of metallic minerals in addition to those which carry the copper and gold, so that concentration, to reduce the weight and bulk of the ores shipped, is likely to offer difficulties. Locally there are bodies of nearly pure copper sulphides that need little concentration, but no large bodies of ore of this type have been developed, and the properties that develop into mines will probably prove to contain large bodies of ore of moderate richness. The imperative need of a mining camp of this type is therefore cheap transportation, and that can be obtained for this camp only by the construction of a branch line of the Government railroad either up Talkeetna River and Iron Creek, or up the Talkeetna to Sheep River and up that stream to and through the divide at Rainbow Lake and thence to the vicinity of the junction of the main forks of Iron Creek.

PROSPECTS.

The following descriptions of prospects are based on observations made in August, 1917. An attempt was made to visit all those properties on which any considerable amount of development work had been done or on which the owners were at work at the time of the writer's visit. The properties visited are described in order, from west to east. A large number of claims have been staked in the district on which little work has been done, and time was not available to visit all of these.

COPPER QUEEN GROUP.

The Copper Queen group includes two claims that lie on the north side of Iron Creek, 2 miles below the mouth of East Fork. These claims were staked in 1910 by A. O. Wells, Frank Wells, and John Coffee and cover the first lode discovery in the Iron Creek district. The ore body lies in a rock bluff on the bank of Iron Creek, and all the work done on it is in the valley bottom. Developments have been confined to stripping the vegetation from the ore body and to the excavation of a shallow open cut. The country rock is an amygdaloidal andesite-greenstone, in which the amygdules are filled with greenish-yellow epidote. The ore body, which lies along a zone of shearing and crushing that strikes N. 10° E. and stands nearly vertical, has been formed by the replacement of the sheared andesite. In the open cut this sheared zone is heavily mineralized throughout a width of 21 feet across the strike, though within that distance there are many large lenticular horses of nearly barren country rock. Pyrite, arsenopyrite, and chalcopyrite are the common metallic minerals and occur as nearly pure masses of one or the other of these sulphides or intimately intergrown with one another. The ore is generally banded parallel to the direction of the shear zone and in places consists of parallel alternating bands of country rock, pyrite, and chalcopyrite. Some quartz is present in the ore as gangue but is not abundant. Scattered specks and blotches of sulphides occur both in the horses within the ore body and in the wall rock for some distance back from the zone of shearing. The owners report that this ore body is valuable for its gold as well as its copper content, picked samples having shown upon assay several dollars a ton in gold, in addition to the copper.

COPPER KING GROUP.

The Copper King group comprises six claims that lie on the south valley wall of Iron Creek opposite the mouth of East Fork. The principal workings lie at an elevation of about 3,300 feet, 1,500 feet above the valley bottom. Development work on the property has been directed to the excavation of a large number of trenches and open cuts in the attempt to demonstrate the presence of a long continuous ore body. These open cuts show that the andesite-greenstone country rock is cut by a shear zone that strikes northeast and dips about 60° E., in which the sheared material has been replaced in part by metallic minerals and some quartz. The shear ranges from 6 to 20 feet in width, and the degree of replacement of the sheared andesite-greenstone differs greatly from place to place. The best showing of ore was in a large open cut that had been excavated down to undisturbed bedrock. In this cut, through a width of 9 feet across the strike of the shear zone, abundant chalcopyrite and specular hematite with some pyrite and a little quartz were exposed. The ore is banded parallel to the direction of the shear zone and consists of alternating bands of nearly pure chalcopyrite, specular hematite intergrown with quartz, and pyrite. The individual bands are more or less discontinuous, and the characteristic mineral of one band may be present in small amounts in the other bands. Another cut near by shows several feet of nearly pure hematite with only small amounts of sulphides. Locally some quartz is present in the shear zone in small distinct veins. The ore from this group of claims is said to carry only small amounts of gold and silver.

COPPER WONDER GROUP.

The Copper Wonder group comprises seven claims that lie on the south slope of the Iron Creek valley, south of the mouth of Middle Fork. These claims were first staked in June, 1917, and the only development work done by August of that year was the excavation of three open cuts in the bluffs of Alder Gulch, at an elevation of about 2,500 feet. These cuts show a zone of strong shearing in andesite-greenstone country rock, but the ground has been much disturbed, and in the shallow excavation the strike and dip of the shear zone could not be definitely determined. In the larger open cut the andesite-greenstone is seen to be much altered along the shear zone, in which there is a heavy deposit of specular hematite, together with some pyrite and bunches of chalcopyrite as large as one's fist. A little quartz was also noted as a gangue mineral. The hematite has a thickness of 2 to 3 feet through an exposed vertical distance of 20 feet, and there is considerable copper carbonate stain in the altered shear-zone material. Scattered specks of sulphides were seen in the andesite country rock outside of the shear zone.

PHOENIX GROUP.

The Phoenix group includes three claims on Hyphen Gulch, a small tributary of Iron Creek from the northeast, a little more than a mile above the mouth of Middle Fork. The only locality at which any noteworthy excavation had been made was at an elevation of 3,600 feet, where an open cut showed a small shear zone, 2 to 3 inches wide, in andesite-greenstone. This shear zone, or line of faulting, strikes S. 30° W. and dips 65° NW. and contains gouge and decomposed materials with a little quartz and some copper carbonate stains. The andesite-greenstone wall rock is, however, much stained with copper carbonate and has locally been partly replaced by chalcopyrite, bornite, specular hematite, and quartz. The bornite is closely associated with chalcopyrite and is apparently a surface occurrence only, for a shallow excavation made at the best showing of bornite showed little bornite at a depth of a few feet below the surface but an increasing abundance of chalcopyrite. A number of narrow veins of nearly pure hematite with little associated sulphides have been found on this property.

BLUE LODE GROUP.

The Blue Lode group of five claims lies on the south side of the valley of Middle Fork of Iron Creek, about 2½ miles above the mouth of that stream and 1 mile northeast of the Phoenix group. The principal excavation is at an elevation of 4,200 feet, where a large open cut has been made along a fault or shear zone about 2 feet wide that strikes N. 16° E. and dips 80° W. This zone is filled with gouge, fine crushed and decomposed material, and some quartz that contains chalcopyrite. The wall rock of this shear zone is andesite-greenstone, which has locally been replaced by specks and bunches of bornite and chalcopyrite. An andesite-greenstone cliff above the excavation shows abundant stains of azurite and malachite. Broken surfaces of the surface wall rock show bornite and chalcopyrite intimately intermingled, but a few feet below the surface the bornite becomes relatively scarce and chalcopyrite predominates, suggesting that the bornite occupies only a shallow zone of enrichment and that at greater depth the chalcopyrite will prove to be the prevailing sulphide. Another open cut farther down the mountain shows chalcopyrite but no bornite. This property was staked only a few weeks before it was visited, and too little development work had been done to determine either the size of the ore body or its character at depth.

EASTVIEW GROUP.

The Eastview group of two claims lies in the basin of Middle Fork of Iron Creek half a mile southeast of the Blue Lode group and about the same distance northeast of the Phoenix, at an elevation of 4,500 feet. The country rock is andesite-greenstone, and the workings include three open cuts, from which have been taken large lumps of banded quartz, hematite, and chalcopyrite. In these lumps of ore chalcopyrite is locally abundant, but as none of the cuts had been carried down to undisturbed bedrock at the time of the writer's visit, no ore in place was seen, and nothing is definitely known about the size or position of the ore body.

TALKEETNA GROUP.

The Talkeetna group of nine claims lies in the valley of Prospect Creek, about 2 miles above the mouth of that stream. The claims were staked in the spring of 1916, and their exploration and development have been limited to strippings and open cuts made in the endeavor to show the character of the ore in place. At the time of the writer's visit eight men were employed on this property. The main ore body is on the claim known as Talkeetna No. 2, where an extensive gossan on the steep mountain slope, at an elevation of 4,200 feet, renders the ore deposit conspicuous from a distance. A number of trenches and open cuts have been excavated through this gossan, but these have been made for the purpose of ascertaining the character of the unoxidized ore body, and no consistent effort has been made to outline the area of mineralization or to determine its structure and relations. The country rock is an amygdaloidal andesite-greenstone, and the amygdules are filled with epidote. This greenstone is cut by a shear zone that strikes approximately east and west and dips 75° N. The shear zone has acted as a channel for the circulation of mineralizing solutions, and the sheared material, as well as the massive wall rocks, have been in part replaced by specular hematite, chalcopyrite, pyrite, and quartz. The area of heavy mineralization, as well as could be determined from the workings, is several hundred feet long and is locally at least 30 feet thick. Its long dimension is parallel to the strike of the shear zone, which itself lies almost parallel to the steep mountain face, so that the ore is exposed on the surface through a vertical distance of at least 50 feet. The gossan is only a few feet thick and is abundantly stained with copper carbonate.

Specular hematite is by far the most abundant metallic mineral and occurs in massive aggregates many feet thick, in which the only other conspicuous mineral is granular quartz that is intimately intergrown with the hematite. Another abundant type of ore consists of an intergrown aggregate of hematite, chalcopyrite, and quartz that forms the matrix of a breccia and surrounds angular fragments of andesite-greenstone, themselves partly replaced by iron and copper minerals. Elsewhere the ore consists of sheared and schistose andesite-greenstone largely replaced by metallic minerals, which is banded with small quartz veinlets that include the same minerals—pyrite, chalcopyrite, and hematite. Veinlets of ore shoot off from the main ore body into the country rock, and sulphides and hematite are widely disseminated in the country rock for some distance on both sides of the shear zone. These claims are being prospected as a source of copper, and a large amount of work must be done before a proper estimate can be made of the amount of copper ore of any particular grade that is available. The principal copper mineral, chalcopyrite, differs greatly in abundance from place to place within the ore body. Locally hematite is present to the almost complete exclusion of the sulphides. Elsewhere chalcopyrite forms the bulk of the ore. In some places the chalcopyrite crystals are surrounded by a thin zone of hematite and that by quartz. It is reported that assays show from less than 1 per cent to 8 per cent of copper and small amounts of gold and silver. Underground exploration alone can determine the character and metallic content of this ore body with depth, but the great size of the deposit may make possible the development of a mine even with a comparatively low grade of ore.

Shallow excavations have been made on croppings of metallic minerals on claims No. 3 and No. 7 of this same group, on the north side of Prospect Creek, where a number of open cuts, for the most part shallow and in disturbed ground, show similar ores, which have the same association of pyrite, hematite, and chalcopyrite.

OTHER PROSPECTS.

A number of claims, or groups of claims, in addition to those described above, have been staked in the basin of Iron Creek, but on most of them little development work had been done, and the restrictions of time imposed upon the writer made it possible to visit only those properties that had been furthest developed. The location of many of these groups is shown on the accompanying map (Pl. IV).

Vigorous prospecting in this district has been carried on only since the spring of 1916, and many of the claims were staked in 1917, so that the amount of work which has been done on any property is not necessarily an index of the value of the ore deposit, and some of the properties not visited and not described specifically may be of greater merit than some of those that are more fully described here. The possibilities for the discovery of still other ore deposits in this area have by no means been exhausted, and it is likely that other ore bodies more valuable than any yet discovered may be found. A large area in the basins of Sheep River, Montana Creek, and Kashwitna River has received scant attention. Hand specimens of rich copper and gold ores have been brought out from this area by prospectors, but the localities from which they came could not be learned, and the deposits were not visited by the writer. Late in the summer of 1917 reports were circulated of the discovery, on a northward-flowing tributary of Talkeetna River opposite the upper basin of Iron Creek, of a large dike the surface croppings of which yielded gold upon panning, and which was said to show an encouraging gold content upon assay. A considerable number of prospectors visited the locality, and many claims were staked, but the lateness of the season prevented a thorough prospecting of the deposit, and its commercial value is yet to be demonstrated. The next few years will probably witness increasing activity in prospecting in the western Talkeetna Mountains, and there is every promise that some producing mines will be developed.

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MINERAL RESOURCES OF THE UPPER CHULITNA REGION.

By Stephen R. Capps.

INTRODUCTION.

The area here referred to as the upper Chulitna region includes what has generally been called the Broad Pass mining district. The prospects that have attracted considerable attention to this part of Alaska lie 15 to 30 miles southwest of Broad Pass, and that pass can be seen only in the distance. Furthermore, the term "Broad Pass region"[1] has already been used to describe an area including the headwaters of Nenana River and a part of the upper Susitna basin. In order to avoid confusion, therefore, the area here discussed is termed the upper Chulitna region. It lies on the southeast slope of the Alaska Range between meridians 149° and 150° west longitude and parallels 62° 45′ and 63° 15′ north latitude.

Although a few prospectors and explorers had penetrated to this part of Alaska, no systematic surveys had been extended to it until 1898, when, through the discovery of the rich gold placers in the Canadian Klondike, interest in Alaska was stimulated and a number of surveying expeditions were dispatched by the United States Army and the Geological Survey to different parts of the Territory. One of these expeditions, a Geological Survey party in charge of G. H. Eldridge and Robert Muldrow, ascended Susitna River to Indian River and proceeded thence northeastward through the upper Chulitna basin to the headwaters of Nenana River. The map published as a result of their expedition[2] gave the first authentic geographic information about a large area on the upper Susitna basin. In 1902 A. H. Brooks, of the Geological Survey, explored the west and north flank of the Alaska Range from the head of Skwentna River to the Nenana, and between that year and 1912 several mountaineering, exploring, and railroad survey parties reached some part of this district but left no records that were available for the public. Among the more noteworthy of these explorations was that conducted by F. A. Cook, who in 1903 pushed southward across the range with pack horses through a pass lying somewhere between Muldrow

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

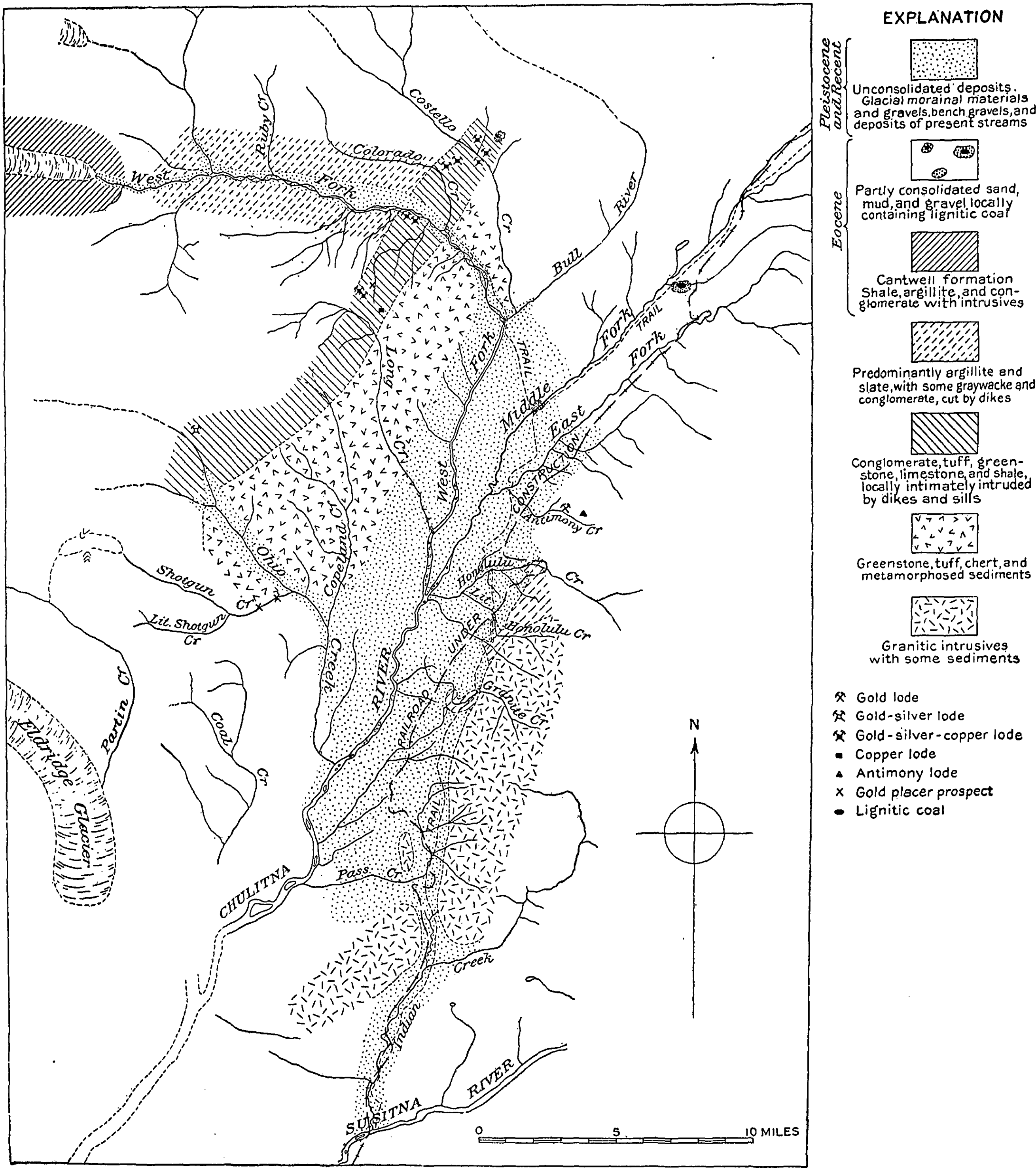
[2] Eldridge, G. H., A reconnaissance in the Susitna basin and adjacent territory, Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, map 3, 1900.

Glacier and Nenana River. His account of the journey is not clear, and he made no accurate survey, but as nearly as can be determined he crossed an ice-filled pass at the head of Teklanika River and descended Bull River to the Chulitna. It is reported that the first discovery of placer gold in this district was made by John Coffee in 1907 on Bryn Mawr Creek, and many lode claims were staked in the basin of West Fork of Chulitna River in 1909. In 1912 a mountaineering expedition, conducted by Herschel C. Parker and Belmore Browne, ascended Susitna and Chulitna rivers and what is now called Ohio Creek by dog sled, crossed a high, glacier-filled pass to the West Fork of Chulitna Glacier, and from the head of that glacier penetrated across another divide to the north slope of the Alaska Range. The sketch map of their route constitutes the first published record of the drainage along their line of travel through the range. In 1913 F. H. Moffit [1] and J. W. Bagley, of the Geological Survey, mapped both the geology and topography of an area extending from Broad Pass eastward to the West Fork of Susitna Glacier, and in 1914 D. L. Reaburn, of the Alaskan Engineering Commission,[2] mapped the topography along the line of the Government railroad survey between the mouth of Indian River and Broad Pass.

For several years development work has been done on a number of lode claims in the upper Chulitna basin, and encouraging reports have been circulated concerning large bodies of gold ore there. This area, at present so remote, will become readily accessible upon the completion of the Government railroad now in progress of construction between Seward, on the coast, and Fairbanks, on Tanana River. It was therefore deemed advisable to make at least a hasty geologic investigation of the area, to determine the geologic conditions of the ore bodies and the probabilities of the development in this area of producing mines. Upon the entrance of the United States into the European war, a large number of the topographers of the Geological Survey were called upon for military work, and no topographer was available for making a topographic survey of the region, but the maps of the Alaskan Engineering Commission along the main Chulitna Valley furnished control from which foot traverse and compass sketching could be carried westward. Plans were therefore made for a geologic party to visit this area during the summer of 1917, and the writer was assigned to carry them into effect. The season's work was to include investigations in other parts of the Susitna basin as well, so that only a short time could be spent in this area. The party, consisting of the geologist and three camp hands, with seven pack horses, left Anchorage by railroad on June 18 for Matanuska, from which the horses were driven over the

[1] Moffit, F. H., op. cit., Pls. I and II.

[2] Reports of the Alaskan Engineering Commission for the period from Mar. 12, 1914, to Dec. 31, 1915: 64th Cong., 1st sess., H. Doc. 610, pt. 2, map 6, 1916.



GEOLOGIC SKETCH MAP OF THE UPPER CHULITNA REGION.

trail to the terminus of the rails, at that time at Little Susitna River. From that point the pack train followed the construction road and trails along the general route of the railroad survey up Susitna and Chulitna valleys to Middle Fork of Chulitna River, where a trail branching off to the northwest leads up West Fork of Chulitna River to the vicinity of the lode prospects. In all a period of only 24 days was spent between the time of departure from Indian River and the return to that place. During this time all the prospects in West Fork of Chulitna and Ohio Creek basins on which any considerable development work has been done were visited and the larger features of the geology of the area were mapped. The southeastward-flowing tributaries of Chulitna River have not yet been accurately surveyed, and the position of the drainage lines, shown on the accompanying sketch map (Pl. V), as determined by foot and compass traverse, can be considered as only approximate.

As already stated, the information on which this report is based was procured in the course of a hasty visit to the region, and during practically the whole time the weather conditions were very bad. The areas of the different geologic formations, as shown on the map (Pl. V), are therefore subject to revision when more detailed field work is done.

GENERAL FEATURES OF THE REGION.

GEOGRAPHY.

The upper Chulitna region consists essentially of the valley of Chulitna River, a broad northeast-southwest basin, which is bordered on both sides by rugged mountains. At a point just west of Chulitna Pass Chulitna River flows at an elevation of 1,200 feet, and at Broad Pass the basin floor rises to a height of about 2,400 feet. The southeast margin of the Chulitna basin lies only a few miles away from the river and is formed by a ridge of sharp and rugged peaks that rise to heights of 5,000 to 6,000 feet. The streams that drain this ridge are all of moderate size, and their water is clear, indicating the absence of any large glaciers in those mountains. To the northwest the Chulitna basin is of a different character, for it includes a long section of the southeast slope of the Alaska Range. There the lateral spurs of the main range begin only a short distance back from Chulitna River and become constantly higher and more inaccessible toward the crest of the range, 20 to 35 miles from the river. All the larger tributary streams from the Alaska Range, including Ohio Creek, West Fork of Chulitna River, Bull River, and their principal tributaries, carry glacial waters, and large areas in the valley heads are occupied by glacial ice. In the rugged ice-filled portion of the range travel is difficult and hazardous, and a large area is still entirely unexplored.

GLACIATION.

The portion of the Alaska Range that drains to Chulitna River is characterized by the number and large size of its existing glaciers and by the pronounced manner in which the surface forms have been modeled by the greater glaciers of earlier times, of which the present ice tongues are the remnants. The southeast side of the Alaska Range nourishes some of the largest alpine glaciers of the continent. Two of these glaciers, tributaries of Chulitna River though lying south of the area here discussed, are several miles wide and probably over 30 miles long. In the region with which this report is concerned the larger streams that drain from the Alaska Range, including Ohio and Copeland creeks and West Fork of Chulitna and Bull rivers, as well as their larger tributaries, are glacier-fed. The size of the glaciers is determined by the altitude of the surrounding mountains and the area of the catchment basins.

There can be no doubt that the present glaciers are small compared with those that occupied this region in times past. At the time of greatest glaciation, ice from the Alaska Range moved southward down Chulitna and Susitna valleys, was augmented by other glaciers from the Talkeetna and Kenai mountains, and pushed down the Cook Inlet depression at least as far as the Forelands. Thus the entire Susitna basin was a great ice field and was connected to the east by way of the upper Susitna basin with a similar ice field that filled the Copper River basin. In order to drain southward, as it did, this glacier must have had a surface slope to the south of steeper gradient than that of the present valley floor, so that in the area here discussed the glacial ice must have reached a great thickness, and this conclusion is verified by evidence of ice sculpture high on the flanks of Chulitna Valley. The divide between West Fork of Chulitna River and Long Creek was overridden by glacial ice to an elevation of at least 4,500 feet, 2,300 feet above the valley of West Fork, directly to the north. The east wall of Chulitna Valley near Antimony Creek also shows erosion by a southward-moving glacier to a height of much more than 4,000 feet. In the lack of an accurate topographic map of this region as a whole it is not yet possible to outline the area reached by the glaciers at the time of their greatest extension, but it is certain that at that time only the high peaks and ridges of the mountains projected above the ice and that from the crest of the Alaska Range to the Pacific Ocean the area of land above the ice was very much less than the area of the glaciers.

ROUTES OF TRAVEL.

The upper Chulitna region has always been difficult of access, and those who have visited it have done so only at the cost of much time and effort. The Alaskan prospector knows no barriers of distance or bad trail if he is convinced that his chosen field offers a fair chance for the discovery of valuable minerals, but the time consumed in going to and from a remote area must be subtracted from the total season available for prospecting, and the actual time spent in the search for valuable ground is short when the trail to it is long and arduous. Heretofore two distinct methods of transportation, or a combination of the two, have been chiefly employed by those who have visited the region. The most favored has been the use of dog sleds up the frozen streams in winter. Supplies were procured from Talkeetna, where a store was maintained for some years, from Susitna station, or from Knik. A considerable part of the prospecting was done by a group of men who brought their supplies in during the fall, trapped for fur in the winter, and spent the summer in prospecting. Summer traveling was done for the most part by launch or poling boat up Susitna River to the mouth of Indian River, and thence by trail up Indian River through Chulitna Pass and up Chulitna Valley, crossing East and Middle forks to West Fork near the mouth of Bull River. A few parties came in by pack train from Knik Arm, following the west flank of the Talkeetna Mountains to Talkeetna River and crossing that stream to ascend Susitna Valley to Indian River. This method of travel was slow and costly and was used for the most part by surveying parties, whose work was a study of the entire route rather than an effort to reach the upper Chulitna by the easiest means.

In the spring of 1915 active construction on the Government railroad, which is planned to extend from Seward to Fairbanks, was commenced, and the town of Anchorage was established as a base of supplies. During that year the work was for the most part confined to the areas bordering Knik and Turnagain arms and to the construction of a branch line to the coal fields of Matanuska Valley, but in 1916 and 1917 construction was carried on along the main line, up Susitna Valley, and power boats were operated for transporting passengers and freight up Susitna River to the mouth of Indian River. In June, 1917, the rails extended to the railroad crossing of Little Susitna River 174 miles from Seward, and stretches of wagon road, connected by trail, followed the railroad route as far north as Talkeetna River. Above the Talkeetna a passable trail for pack horses was available all the way to West Fork of Chulitna River. By the end of 1917 it was reported that the rails were in place as far north as Montana Creek, 210 miles from Seward, and much of the railroad grade was completed as far as Dead Horse, about halfway between Talkeetna and Indian rivers. As soon as construction is completed to Broad Pass, the upper Chulitna district will become easily accessible, and the improved transportation will greatly stimulate mining and prospecting.

A favorable pass across the Alaska Range at the head of West Fork of Chulitna River has been used for sledding supplies across the range in winter and has been crossed by pack trains in summer. It is necessary to ascend the glacier at the head of West Fork of Chulitna River for a distance of 10 or 12 miles to a low pass, which leads perhaps 2 miles down another small glacier to the edge of Muldrow Glacier, which is followed northward for about 10 miles to the north base of the Alaska Range. The route presents no insurmountable difficulties late in summer, though travel would be difficult until the soft snow has disappeared from the surface of the glacier. The distance from the last spruce timber on West Fork of Chulitna River to the first brush near Muldrow Glacier is about 20 miles, and under favorable conditions the trip may be made by pack train in one day.

The completion of the railroad will make the region easily accessible from points on Tanana River by way of Nenana River.

VEGETATION.

In the upper Chulitna region timber is confined to the valleys of the principal streams. The valley of Chulitna River has a growth of trees, mainly spruce, but including some cottonwood and birch, up to an average altitude of 2,000 feet above sea level, though locally trees grow above that altitude and considerable areas below 2,000 feet are untimbered. In the valleys tributary to the Chulitna through from the northwest a fringe of trees extends along the lower valley walls to an elevation of perhaps 2,500 feet. Thus spruce groves composed of trees reaching a foot or more in diameter are present on West Fork of Chulitna River to a point within 2 miles of the glacier in which the stream heads, and Ohio Creek has patches of good cottonwood and spruce trees for about 2 miles above the mouth of Christy Creek, whereas Copeland, Long, Colorado, and Costello creeks, with steeper gradients, follow timberless valleys in their upper courses, and even brush of sufficient size to supply the moderate needs of the camper is lacking.

There is little timber in the Chulitna basin that is fit for other than local uses. Patches of cottonwood trees, in the bottoms of the larger streams, will supply logs as much as 4 feet in diameter, and these will furnish a small number of saw logs. The spruce and birch trees are generally small, few attaining a diameter of more than 2 feet, and although they will furnish cabin logs, mining timbers, cordwood, and an inferior grade of lumber, the products of the forests will be used only locally.

Grass sufficient for forage can generally be found throughout the region. There are considerable areas of marshy bench lands and of spruce-covered bottoms in which the prevailing ground cover is sphagnum moss and low brush and in which grass for horses is not abundant, but within those areas there are scattered well-drained spots in which horses will find sufficient food for a short time. The two principal varieties of forage grass are locally known as "red top," which grows to a height of several feet, and as "bunch grass," which affords a less heavy growth but exceeds the "red top" in nutritive value. At a few localities a vetch, known to the prospectors as the "pea vine," is abundant on the stream gravel bars and affords excellent forage.

GAME.

Although big game is not particularly abundant in the upper Chulitna basin, the prospector is occasionally able to furnish his larder with fresh meat. Caribou range over most of the area, and although usually found in small bands or as scattered individuals, when once seen they are easily procured by the hunter and so are the most useful animals for food. Moose are present in the timbered areas, though in small numbers, and on rare occasions the white mountain sheep are seen in the areas of rugged relief. Black bears are not uncommon, especially in the timbered and brushy tracts, and brown and grizzly bears are sometimes encountered. The relative scarcity of big game on this side of the Alaska Range is especially striking, for on the north slope of the range, not many miles away, is one of the most prolific game fields of North America. There sheep, caribou, and moose graze in great numbers, and their preference for the north slope of the range, rather than the south slope, is due directly or indirectly to climatic differences. The Chulitna slope of the mountains has a heavy precipitation, both in summer and in winter. The heavy winter's snows impede free travel and cover the herbage on which the animals feed, whereas the small snowfall on the north slope leaves wide areas of bare, wind-swept pasture upon which the game herds graze. In summer, too, the drier, sunny climate of the north slope and the abundant pasturage there are preferred by the wild animals.

Of the smaller wild animals rabbits and ptarmigan are perhaps most useful, for they furnish a valuable supply of fresh meat. At times both are extremely abundant, but in 1916 and 1917 they had almost completely disappeared. Trout and grayling may be caught in most of the clear-water streams, but as most of the rivers are glacier-fed and turbid, the opportunities for the traveler to get fish are infrequent. Each winter numerous fur-bearing animals are taken, including lynx, fox, mink, and marten.

NATIVES.

There are no established settlements of natives in the area discussed in this report. The nearest settlement is at the mouth of Talkeetna River, where a few families spend part of each year catching salmon. Without doubt the natives at times ascend the tributaries of Chulitna River on hunting or trapping expeditions, but they have left little evidence of their visits. During the summer of 1917 no natives were encountered by the Geological Survey party north of Talkeetna River.

GENERAL GEOLOGY.

CHARACTER OF THE ROCKS.

The rocks of the upper Chulitna region consist of a wide range of materials that have undergone different degrees of metamorphism. They include cherts, slates, and highly metamorphosed tuffs; less altered shales, graywackes, limestones, and tuffs; closely folded shales and graywackes; a thick series of shales and conglomerates; partly consolidated sands and clays with associated lignite; and several types of unconsolidated glacial and stream deposits. Igneous rocks are also present as basic lava flows, as dikes and sills, and as large intrusive masses. As shown on the map (Pl. V), the largest bodies of intrusive rock within the area visited lie between Chulitna and Susitna rivers. Northwest of Chulitna River the Alaska Range proper shows on its flank a considerable amount of fragmental volcanic material in the form of tuffs, associated with normal sediments. Farther to the northwest the main range is composed predominantly of sedimentary beds.

The distribution of the geologic formations, as they have now been differentiated, is shown on the map (Pl. V). The mapping, however, was done in the course of a hasty trip of only three weeks, the principal object of which was the visiting of the numerous mining claims. During the mapping it rained almost constantly. In this area the geology is by no means simple, and the grouping together of certain lithologic units and the areas assigned to them can be considered as only tentative and will be considerably modified when more detailed studies are made. A base map was available only along the main Chulitna Valley. The main portion of the Alaska Range, from Chulitna River to the crest, is unmapped, and much of it is still unexplored. The drainage lines shown on the map as solid lines were taken from the surveys of the Alaskan Engineering Commission. The drainage shown in broken lines was mapped by foot traverse during the progress of the geologic work in 1917.

STRUCTURE.

The dominant structural trend of the rocks on the southeast flank of the Alaska Range is north-northeast, parallel to the axis of the range and to the broad trough of the Chulitna. A part of this structure was developed during the growth of the present mountain range, and the structural features of the little-consolidated Tertiary lignite beds may be attributed entirely to those mountain-building movements. The growth of the present range, however, took place in post-Mesozoic time. The Mesozoic and older rocks are more strongly metamorphosed than the Tertiary lignite-bearing beds, and their structure must therefore be in part ascribed to movements that antedated the last mountain-forming processes. Indeed, in examining the formations it is seen that each is more severely metamorphosed than the one succeeding it. It is therefore evident that the site of the Alaska Range has long been a zone of weakness along which folding has taken place from time to time, and the present mountains are but the topographic expression of the latest of the earth movements. Folding and faulting have both been operative in forming this massive range, and severe earthquakes in recent years suggest that even now the same slow forces are at work and that mountain growth still continues.

SEDIMENTARY AND METAMORPHIC ROCKS.

GREENSTONE TUFFS, SLATES, AND CHERTS.

What appears to be the oldest group of rocks in the area here described comprises greenstone tuffs, cherts, and slates that form the front of the mountain range northwest of Chulitna River. These rocks crop out at intervals along the valley of West Fork of Chulitna River below the mouth of Colorado Creek and appear also on Long, Copeland, and Ohio creeks in the areas indicated on the map (Pl. V). These rocks are prevailingly so metamorphosed and altered that their original character is difficult to determine in the hand specimens. At many places in which comparatively fresh and unaltered material can be obtained the characteristic rock consists of a multitude of fragments of basic dull-green to faint-purple lavas inclosed in a matrix of finer material of the same sort. The fragments are generally angular and of irregular shape and range in size from microscopic grains to pieces several inches in diameter. These rocks are composed of fragmental material that was ejected violently from volcanic vents and accumulated in thick deposits, presumably in bodies of standing water. Their water-laid character is inferred not from any characteristic of the tuffs themselves, for they are free from any evidence of assortment of the materials, but from the association with the tuff beds of large amounts of chert and slate or argillite. At places the cherts and slates are notable members of the group, preponderating over the tuffs. Elsewhere they occur as thinner layers or lenses in areas where the tuffs are the prevailing rock. It is apparent that the normal processes of sedimentation, which resulted in the formation of the slates and cherts, were interrupted from time to time by volcanic outbursts, during which large quantities of fragmental volcanic material were ejected and accumulated rapidly in the near-by waters.

Between these periods of volcanic activity the normal sediments were laid down. The dark-gray to black slates occur in thin beds, alternating with light-green, gray, or blue-gray cherts.

No fossils were found in this group of tuffs, slates, and cherts, and their age is not definitely known. As will be shown later, however, they are known to be overlain by other materials from which Triassic fossils were obtained. The structural relation between this group and the Triassic rocks has not been fully determined, but they are believed to be unconformable. If that conclusion is correct, the tuffs and associated slates and cherts are pre-Triassic and probably Paleozoic. No closer age determination is justifiable on the basis of our present knowledge.

TRIASSIC TUFFS, LIMESTONES AND SHALES, AND LAVA FLOWS.

Economically the most important group of rocks in the district is a series of Triassic tuffs, limestones, shales, and basic lava flows with minor amounts of conglomerate and graywacke, which apparently lies unconformably upon the beds already described. Most of the mineralized lodes so far discovered occur in these rocks. The approximate position of the contact between this group and the underlying group composed of greenstone, tuff, slate, and chert (see Pl. V) crosses West Fork of Chulitna River a short distance below the mouth of Colorado and Bryn Mawr creeks, runs southwestward across the valleys of Long and Copeland creeks, and crosses Ohio Creek just above the mouth of Christy Creek. Between Costello and Long creeks the relations between the two groups of rocks are not clear, for the surface is generally covered with vegetation, and intrusive dikes and sills are unusually abundant. Farther south better exposures are available, and on Ohio Creek an excellent section is exhibited. There the older group of tuffs, slates, and cherts forms the walls of the lower valley as far northwest as Christy Creek, where it appears to lie unconformably beneath a heavy bed of conspicuous red tuff and agglomerate. This red tuff is the basal member of a group of rocks that has an aggregate thickness of several thousand feet and includes tuffs, agglomerates, conglomerates, amygdaloidal greenstone flows, and massive limestone beds. The tuffs range in texture from fine-grained rocks that resemble red sandstone, through coarser rocks composed of angular fragments from one-eighth to 1 inch in diameter, to coarse agglomerates containing fragments of volcanic débris several inches across. They range in color from vivid red, in which the composing fragments are chiefly jaspilite, through green and purple shades. In some of the tuffs the fragments all appear to be sharply angular in outline; in others some fragments are angular and others partly rounded. These tuffs grade, by scarcely perceptible variations, into rocks composed largely of beautifully rounded quartz pebbles the size of a pea, so that characteristic tuffs and typical conglomerates are apparently connected by a series of intermediate rocks. On upper Ohio Creek five distinct and massive limestone beds form conspicuous features of the landscape. One of these beds yielded fossils that were determined by T. W. Stanton to be of Triassic age, and several other collections of fossils, taken from boulders in the bed of Copeland Creek, all appear to be of the same age. The tuff beds, so abundant in the lower portions of this group of rocks, give place to amygdaloidal lava flows in the higher parts of the group, and on Ohio Creek a considerable thickness of lava flows appears above the uppermost limestone bed.

On West Fork of Chulitna River the section, though presenting certain features in common with that on Ohio Creek, is greatly different in detail. The red and green tuffs are present at the base and appear at the Riverside claims along Bryn Mawr Creek and on the claims of the Golden Zone group. The abundant intrusive material, in dikes and sills, has altered the surrounding rocks by contact metamorphism, and as a result the limestones, here inconspicuous, are generally changed to marble, and white, cream, and bluish cherts appear. The amygdaloidal greenstones, so abundant on upper Ohio Creek, are relatively scarce on West Fork of Chulitna River, where the group is overlain by a heavy body of black argillites, slates, and graywackes.

ARGILLITES, SLATES, AND GRAYWACKES.

A conspicuous group of rocks that crop out along the valley of West Fork of Chulitna River and forms a large element of the Alaska Range is composed predominantly of black argillite, together with minor amounts of graywacke and some fine conglomerate. Its extent along the strike, from northeast to southwest, has not been determined, but from the width of the belt across the strike, as exposed on West Fork of Chulitna River for a distance of over 7 miles, it seems certain that these rocks are of wide distribution. Their thickness as measured across the strike can not, however, be regarded as the normal thickness of the group, for there is abundant evidence of close folding and faulting. The general structural trend is northeast, and the dips average 45° or more and are prevailingly to the northwest. Intrusive dikes and sills are present throughout this group of sediments. Apparently this group of rocks lies structurally above the group of Triassic tuffs, limestones, shales, and lavas, though the relations between the two groups were not observed. Neither was it possible in the brief time available for the study to determine the relations of this group of rocks to the overlying formation, which, as will be shown, is probably of early Tertiary age. The only conclusion that can now be drawn is that these beds are younger than that portion of the Triassic represented by the fossiliferous limestones and older than Eocene.

Certain other black argillites, slates, and graywackes occur on the east side of Chulitna River and were observed from Granite Creek to Antimony Creek. These rocks are in general more highly metamorphic than the rocks of West Fork of Chulitna River, just described, but are here included with that group, though the correlation is only tentative.

Eldridge [1] described a group of slates exposed along Susitna River for a distance of 50 miles, which he termed the Susitna slates, but he made no statement as to their probable age. Brooks [2] described a similar belt of rocks in Kichatna Valley that he believed to be "of unknown age, but probably chiefly Paleozoic." Capps [3] found the same belt of rocks to be continuous from the Kichatna locality of Brooks northeastward and traced it almost to the area described by Eldridge. He classified the rocks as probably of Paleozoic or Mesozoic age. Throughout that distance the slates, argillites, and graywackes of this group are perhaps the most abundant single element in the flank of the Alaska Range. The present investigation has disclosed the fact that a similar formation is prominent in the headwaters of Chulitna River, and although the correlation is by no means certain, it seems probable that the rocks there are a continuation of series of similar rocks mapped farther south. The evidence that the beds of the upper Chulitna are of Mesozoic age indicates a similar age for the great belt of rocks extending to the southwest, if future studies prove the stratigraphic continuity between the two localities.

CANTWELL FORMATION.

In the upper valley of West Fork of Chulitna River the valley walls for some distance above and below the terminus of the glacier in which that stream heads are composed of conglomerates, impure sandstones, grits, and shales. The beds are gray to black. Conglomerates, in unusual abundance, occur throughout the formation. Among the included pebbles argillites, graywackes, and slates are most conspicuous, but pebbles of other rocks and of quartz are also present. Much of the conglomerate is fine, the pebbles averaging only a small fraction of an inch in diameter, but some coarser beds, inclosing boulders as much as a foot in diameter, were seen. The matrix consists of an impure gray sand or grit. All gradations are apparent in coarseness of bed, from coarse conglomerate through fine conglomerates and grits to sandstones and shales.

In the general make-up of this group of sediments there is an unmistakable resemblance to the Cantwell formation in the headwater

[1] Eldridge, G. H., A reconnaissance in Susitna basin and adjacent territory, Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 15-16, 1900.

[2] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 67-68, 1911.

[3] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, pp. 24-28, 1913.

region of Nenana River, as described by Moffit,[1] and in the upper Toklat basin as described by Capps.[2] In those localities the beds have been determined, on the basis of fossil plant remains, to be of Eocene age, and as the area here described is directly along the strike and only a few miles away from the Toklat locality, and as the lithologic aspect of the rocks, although unusual, is the same at these localities, the beds of upper West Fork of Chulitna River are referred with little hesitancy to the Cantwell formation. The Cantwell formation is generally folded, tilted, and faulted and is cut by intrusive rocks. In places lava flows are interbedded with the sediments. The stratigraphic and structural evidence and the degree of induration seem to indicate that these beds may be older than the Eocene.

COAL-BEARING TERTIARY BEDS.

The next succeeding formation that has been recognized in this region comprises the Tertiary coal-bearing deposits that occur at scattered localities throughout the Susitna basin. These beds include unconsolidated or slightly consolidated shales or clays, sands, gravels, conglomerates, and some lignitic coal. With the area here described the coal-bearing formation was seen at only two localities, and at these its exposures are small, but the presence of pieces of lignite on the gravel bars of both East and Middle forks of Chulitna River indicates that the formation occurs on both of those streams and that it may be of considerable extent beneath the deposits of younger gravels. The coal-bearing formation crops out as a bluff of fairly firm conglomerate at the trail crossing of Middle Fork of Chulitna River, but no lignite was seen there. On Coal Creek, a small tributary of Costello Creek, shales and sands, with lignitic coal, occur. They are described below (pp. 231–232).

The age of the lignite-bearing formation throughout the Susitna basin has generally been regarded as Eocene. Some uncertainty, however, has arisen during the last few years, for on the evidence of the fossil plant remains obtained from the Cantwell formation that also has been classified as Eocene. Throughout the area in which it has been recognized the Cantwell formation consists of dark, completely indurated rocks, which, though carrying a small amount of carbonaceous material, have nowhere been found to contain valuable coal beds. The Cantwell beds are also generally much tilted and deformed. The coal-bearing Tertiary beds, by contrast, are everywhere light in color and are generally little consolidated and only mildly deformed. In both lithologic character and structure they differ greatly from the Cantwell formation and are certainly younger

[1] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 40–49, 1915.
[2] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 37–44, 1919.

than the Cantwell. There can be but little doubt, however, that the lignite-bearing beds of the upper Chulitna basin are to be correlated with similar deposits that occur at intervals throughout that basin and that have been classed as of Eocene age.

UNCONSOLIDATED DEPOSITS.

The unconsolidated deposits include a variety of relatively young sediments, including the morainal materials dropped directly by glaciers; bench or high-level gravels, mainly laid down by the streams that carried the outwash from the ancient greater glaciers; and the gravels of the present stream flats, composed in part of the outwash from existing glaciers and in part of the products of normal stream erosion. All these deposits are undeformed. Recognizable moraines were seen only near the lower ends of the glaciers in which the tributaries from the Alaska Range head, but a layer of unassorted glacial till, composed of blue clay studded with boulders and angular fragments of rock, was seen at many places and may be expected generally throughout those parts of the lowlands that have escaped vigorous stream erosion. The bench gravels are strongly developed along the main Chulitna and in the lower valleys of its large tributaries and are especially conspicuous from the trail where it crosses Little Honolulu and Honolulu creeks and East Fork of Chulitna River. At all these places the bench gravels are yellowish from oxidation and are capped by bluish, unoxidized glacial till. The present stream gravels, composed in part of glacial outwash and the reworked bench gravels and glacial materials, include also the products of present-day rock weathering and erosion.

IGNEOUS ROCKS.

The only mass of intrusive rock of sufficient size to map separately, in an investigation such as that on which the present report is based, is a large body of granitic material that lies on the east side of Chulitna Valley and extends from a point below the mouth of Indian River northward to the vicinity of Honolulu Creek. It is composed of gray to pink diorite and granite, of medium to coarse grain, and is bordered on the east by black slates and by unconsolidated materials. The area shown on the map (Pl. V) as occupied by granitic intrusive rocks includes also some large bodies of slate that were caught up and inclosed by the molten rock when it was injected, but time was not available for tracing out the outlines of these slate bodies. Dikes of granite and diorite also radiate from this central mass in all directions and ramify through the neighboring formations. Indeed, acidic dike rocks that may be related to this large intrusive mass cut all the formations already described except the Tertiary coal-bearing formation and the younger unconsolidated materials. The granitic intrusive rocks of the Alaska Range and of the Talkeetna Mountains have generally been referred to a period of extensive intrusion in Lower Jurassic time, and the rocks here described are of similar character and possibly of the same age. This age determination is not considered final, however, for if the dike rocks that cut the Cantwell are referable to the same period of intrusion as the large granitic bodies east of Chulitna River, and the Eocene age of the Cantwell is accepted, the date of the intrusion must be post-Eocene. At present the evidence is not sufficiently conclusive to justify a definite age determination for the granitic intrusives as a whole.

The group of tuffs and sediments from which Triassic fossils were collected contains large amounts of basic lavas, already referred to, and some basic dikes that were observed may be related to the same period of igneous activity as the lavas.

ECONOMIC GEOLOGY.

HISTORY OF MINING AND PROSPECTING.

Little information has been published concerning the early history of prospecting in the upper Chulitna region, and the date of the arrival of the first prospectors there is not known to the writer. Certainly the discovery of workable gold placer gravels on Valdez Creek, a headward tributary of Susitna River, in 1903, stimulated prospecting in the upper basin of the Susitna, and it is likely that in the following years some adventurous pioneers made their way into the Chulitna basin, but no valuable discoveries of gold were made, and the region remained generally unknown. So far as could be learned, the first claim was staked in this region by John Coffee on Bryn Mawr Creek in 1907, and that claim was worked by the owner in 1909. It is also reported that the first lode claim, the Golden Zone, was staked in 1909, although the present owners date their holding from 1912. The Northern Light lode was discovered in 1911, and during the years 1911 and 1912 practically all the claims that are now held and many other claims later relinquished were first staked. The only valuable mineral actually recovered from this region has been a small amount of placer gold, which was taken from the head of Bryn Mawr Creek. Most of the interest in the region centers on the lodes, which contain gold, copper, and antimony in encouraging amounts. The ores are not free milling, however, and the prospective value of the lodes is in their possibility of producing a large tonnage of ore of moderate richness rather than small quantities of high-grade ore. For the development of properties of this kind good transportation is a prime essential, both for the bringing in of supplies and equipment and for the shipment of the mined ore or concentrates to a smelter. The remoteness and difficulty of access of the upper Chulitna region has so far effectually prevented any lode mining, but the transportation to be furnished by the Government railroad should make it possible to produce metal from those properties that carry ores of sufficient richness to pay charges for mining, transportation, and smelting.

LODE DEPOSITS.

GENERAL FEATURES.

No ore from the lode deposits of the upper Chulitna region has yet been reduced, and as a consequence no commercial production of metals has been made, so that all the lode properties are still to be classified as prospects. Active development work has been carried out on eight or ten groups of claims, however, and a lesser amount of prospecting has been done on several other properties. The fact that no producing mines have yet been developed in no way reflects upon the character of the ore deposits or upon the industry and initiative of the prospectors, for the lack of anything more than the crudest and most expensive means of transportation would have prevented the mining of all but the richest bonanza deposits. The real test of the merits of the properties will come when the Government railroad is finished and the best transportation that can be hoped for is available. Then, if the richness of the ore bodies justifies it, mines will be opened.

Most of the claims in this region were staked and are held by men of small means, who have been compelled to finance their prospecting ventures in the summer by their earnings during the rest of the year. As the simplest mining supplies have been brought to this remote country only at great cost of money, time, and effort, the amount of work accomplished in opening up the ore deposits is small, yet it represents the utmost zeal and enthusiasm on the part of men who have worked under discouraging conditions.

The accompanying sketch map (Pl. V) shows that with the exception of a single prospect on Antimony Creek, east of Chulitna River, all the lode prospects in the upper Chulitna region lie along a nearly straight line, near the contact between the older greenstone tuffs, cherts, and metamorphic sediments on the east and the Triassic tuffs, limestones, and shales on the west, and all lie within the Triassic materials. Aside from the lode claims on Ohio Creek, which are of somewhat different character, the claims that have received most attention lie in a narrow northeast-southwest belt about 7 miles long, cut across almost centrally by West Fork of Chulitna River.

It is a significant fact that in that part of the group of Triassic tuffs and sediments in which the ore bodies occur calcareous rocks are present, either as limestone, marble, or limy shale. Furthermore, in the vicinity of the ore bodies there is an unusual amount of igneous material, injected as dikes into the tuffs, limestones, and shales. The ore bodies themselves, as imperfectly exposed in the scanty workings, are not sharply outlined and have not generally a definite veinlike character. They appear to be irregular masses in which the mineralization is heavy in places but fades out into less mineralized country rock in all directions. Indeed, scattered specks of sulphides can be found in these rocks over wide areas. The principal metallic minerals recognized include arsenopyrite, pyrite, sphalerite, chalcopyrite, pyrrhotite, stibnite, and galena, and assay returns show the presence of gold. Some small, distinct veins cut the ore bodies, and these carry sulphides in a gangue of calcite or quartz, or both, but most of the ore seems to consist of sulphides that have replaced limy rocks, or else it occurs as disseminated sulphides in different types of material, including tuffs, cherts, limestones, and the dike rocks themselves. The information at hand, therefore, indicates that as the result of the intrusion of acidic dikes the intruded rocks suffered some contact metamorphism. Mineralized solutions from the igneous mass penetrated the neighboring rocks and replaced certain of the limy beds. The calcareous beds were not alone affected, however, for sulphide-bearing solutions also penetrated certain tuff and chert beds and replaced portions of these with sulphides, but the larger ore bodies, as at present exposed, seem to represent the replacement of calcareous sediments by metallic sulphides.

One great disadvantage under which the prospectors in the upper Chulitna region have labored is the difficulty of obtaining assay returns with sufficient promptness to guide the progress of development work. In ore of this character the gold content, upon which the value of the ore largely depends, can not be determined without assaying, and the difficulty of travel to and from the region has usually resulted in compelling the prospector to have only a single group of assays made at the end of his season's development work. Such assays are too often made of picked samples of ore, rather than of average samples across an entire ore body, and the prospector is thus in danger of deceiving himself in regard to the average tenor of the ore.

In the following notes those lode prospects on which any considerable amount of development work has been done are described in the order in which they lie from northeast to southwest.

LODE PROSPECTS.

Northern Light group.—The Northern Light group consists of three claims on the northeast side of Costello Creek, a short distance below the mouth of Camp Creek. These claims were first staked by A. O. Wells, Frank Wells, and Joe Focket in 1911 and are still held by these men together with some additional partners, who later bought interest in the ground. The mineralized area first attracted attention on account of the rusty red discoloration of the outcrops. The country rock comprises a confused assemblage of volcanic tuffs, impure limestones, and shales, cut by dike rocks. Much of the rock is so badly altered that its original character is obscure, but tuffs, sediments, and ore are highly calcareous, and even the dike rocks contain calcium carbonate. The area of strongest mineralization is irregular in outline and has a greatest width of about 30 feet. The mineralized rock strikes about N. 65° W. and dips 70° SE. It is apparently the result of the replacement of a limy bed by sulphides and contains veins and bunches of quartz. This limy bed appears to lie between metamorphic tuffs, which the owners term the hanging wall, and a finely granular dike rock that forms the footwall. A tunnel 64 feet long has been driven into the highly stained bluff of Costello Creek through material that everywhere contains finely disseminated sulphides. At the time of the writer's visit, in July, 1917, the breast of the tunnel showed a quartz vein 6 inches to 1 foot thick, highly mineralized. Within the mineralized zone there are many horses of the footwall rock that are comparatively lean in sulphides, though gold and silver have been found in assays of the country rock on both sides the area of heaviest mineralization, which has been traced along the surface for a distance of about 800 feet. The metallic minerals that have been recognized include arsenopyrite, pyrite, chalcopyrite, sphalerite, and a little stibnite, and assays are said to show the presence of gold and silver in encouraging amounts.

Lucrative group.—The Lucrative group, consisting of five claims, lies on Costello Creek near the mouth of Camp Creek. The only development work that was seen consists of a tunnel 15 feet long that is driven into a bluff on the west side of Camp Creek, about 1,500 feet above its mouth. The tunnel, which runs S. 70° W., follows the strike of a rusty, mineralized, vertically dipping quartz stockwork in a mass of intrusive rock. The stockwork, as shown in the tunnel, is 15 to 18 inches wide, is much fractured and broken, and is bordered on each side by a sharply defined wall, along which movement has taken place, as shown by slickensides and gouge. The principal mineralization consisted in the formation of abundant arsenopyrite in bluish banded quartz, with some specks of chalcopyrite. The owners were not on this property at the time of the writer's visit, and no information was obtained concerning the content of the ore in gold or silver.

Silver King group.—The Silver King group, consisting of two claims—the Silver King and Silver King Extension—lies on the northeast side of Colorado Creek about 1½ miles above the mouth of that stream. This ground had been located in previous years, but the title had lapsed, and it was staked by the present owner in March, 1917. At the time of the writer's visit development work on this ground had been confined to the excavation of a number of open cuts. These cuts nowhere penetrated to solid, undisturbed ground, so that the geologic structure of the ore deposit could not be determined with accuracy. As shown by the shallow excavations the center of mineralization appears to be in a dike that is highly altered. The dike probably cuts calcareous sediments, for it contains much calcite, and both the dike rock and the ore effervesce freely upon the application of dilute hydrochloric acid. The outlines of the ore body had not been determined, but there is apparently a large mass of material that contains abundant sulphides. The sulphides that were recognized include arsenopyrite, pyrite, chalcopyrite, pyrrhotite, and stibnite, both in massive aggregates and finely disseminated throughout the country rock. Small calcite veinlets were observed, and in one cut a body of massive stibnite from 6 inches to 1 foot thick that strikes about east and west and dips 23° S. is exposed. No assays were available, and the content of the ore in gold and silver was not known.

Riverside group.—The Riverside group comprises several claims that adjoin West Fork of Chulitna River on its southwest side, about a mile above the mouth of Bryn Mawr Creek. Developments in 1917 included half a dozen large open cuts, a shaft 15 feet deep, and two tunnels, one 10 feet long and the other of unknown length, now caved in. All these workings are at the base of a steep rock bluff, at the edge of the broad gravel flat of West Fork of Chulitna River. The rocks exposed consist predominantly of steeply dipping green to red tuffs, with which are associated pale-pink, green, and blue-gray cherts, locally banded; rusty gray and white marble; and abundant dikes of medium-grained acidic intrusive rocks. The tuffs are hard and dense and range in texture from fine-grained to very coarse. The marbles and cherts are less abundant but are visible in several of the open cuts. Tuffs, cherts, and calcareous beds are all more or less altered by contact metamorphism, as a result of their intimate intrusion by the dike rocks.

The openings that have been made on these claims are unconnected, and the surface between them is covered by vegetation and by loose glacial deposits and talus, so that little can now be said in regard to the geologic relations and extent of the mineralized area. Such data as could be obtained, however, indicate that here, as at other places in the district, the mineralization is the result of the replacement of calcareous beds by quartz and metallic sulphides, introduced by mineralizing solutions that were related to the intruded dike rocks. The ore examined consists of a rusty quartz gangue full of vugs into which project quartz prisms terminated by rhombohedrons.

Abundant sulphides, including arsenopyrite, pyrite, chalcopyrite, galena, and probably sphalerite are inclosed by the quartz gangue, and specks of these sulphides occur without quartz gangue in marble, tuffs, and dike rocks. A little green copper carbonate stain was noted. It is reported that average assays taken over a zone in the marble 12 feet wide yielded several dollars a ton in gold and silver.

Lindfors group.—The Lindfors group includes three claims, known as the Hill Top, Morning Glory, and Lucky Strike, all lying at the head of Bryn Mawr Creek and adjoining the Golden Zone group. This ground was staked in 1913, and the developments consist of a number of open cuts and strippings along both bluffs of Bryn Mawr Creek. No underground work had been done on these claims in July, 1917. The country rock, as exposed in the creek bluffs and the open cuts, consists of a group of altered materials, the original character of some of which is obscure. Tuffs, marbles, and dike rocks in different stages of alteration were noted, and all contain some disseminated sulphides. It is evident that on these claims the mineralization was due to the replacement of calcareous sediments by quartz and sulphides and to the impregnation of different types of country rock with sulphides introduced in connection with the intrusion of acidic dikes. Apparently the intrusion was followed by a period of pneumatolytic alteration of both the dikes and the rock into which they were intruded, and some metallic minerals may have been introduced at that time. One open cut shows a vein of massive arsenopyrite from 4 to 20 inches thick that lies between a much decomposed dike and some altered tuffs. Another cut showed a considerable area in which disseminated sulphides and some small sulphide-bearing quartz veinlets, containing also a brown-weathering carbonate that is probably ankerite, cut through much altered calcareous materials. Arsenopyrite, pyrite, chalcopyrite, and sphalerite were recognized, and it is reported that some rich assays have been obtained and that large quantities of materials carry encouraging amounts of gold.

Golden Zone group.—The Golden Zone group includes three claims in the upper basin of Bryn Mawr Creek, adjoining the Lindfors group on the northwest. The claims were staked in 1912, attention having been attracted to this locality by the presence of a large hill, the rock of which is oxidized to a rusty red and is conspicuous for a long distance. This hill on examination proves to be composed of a body of acidic rock that is intruded into an assemblage of materials including tuff, marble, and shale. The intrusive mass is generally impregnated with scattered specks of sulphides, but locally the mineralization is heavy, and the rock is cut by many small quartz veinlets. In places the intrusive material is massive and appears fresh in hand specimens, but in the more heavily mineralized portion it is much altered and broken into slabs 3 to 8 inches thick, separated by layers of pulverulent material stained by iron oxide and copper carbonate. The developments include many small open cuts, one large cut 120 feet long, and 221 feet of underground workings. The large open cut shows altered and rusty intrusive material that contains disseminated sulphides and a little quartz, and an average sample through the whole cut is said to have yielded an encouraging amount of gold and silver. The tunnel, which was driven in a northwest direction on the slope of the hill toward Bryn Mawr Creek is straight for 137 feet and at a point 82 feet from the portal has a crosscut to the southwest 84 feet long. The main tunnel was driven through an altered and generally decomposed mass of dike rock in which iron and copper sulphides are generally disseminated and are especially abundant along cracks, joints, and slip zones. Some bunches and stringers of quartz are present in the dike rock. The crosscut follows a slip zone which contains gouge. Some white to buff soft calcareous material was also excavated from the tunnel. The metallic minerals that have been recognized on this property include arsenopyrite, pyrite, sphalerite, chalcopyrite, galena, malachite, and probably stibnite. It is reported that assays of the average material removed from the tunnel show several dollars a ton in gold and silver, and some rather high assays were procured. No one was resident on this property when it was visited in July, 1917.

Hector group.—The Hector group includes two claims that lie on the Long Creek side of the divide between Long Creek and West Fork of Chulitna River, opposite the head of Bryn Mawr Creek. The ground was staked in 1914, and the developments include only a number of shallow open cuts. These cuts were made on small rock exposures that projected through a covering of vegetation and of surficial materials, so that no large surface of bedrock was available for examination, either for deciphering the geologic relations or for determining the extent of the ore bodies. The rocks examined include more or less altered materials that are probably the metamorphic equivalents of siliceous shales, graywackes, and tuffs. The finer beds are banded white, brown, and green cherts, interbedded with dense graywackes and argillites. The beds strike S. 75°–80° W. and have steep dips, generally to the northwest. The whole assemblage has been intimately cut by acidic intrusive rocks, which form dikes of considerable size and are locally interleaved in thin layers with the sediments. The cherts are highly siliceous, but all the other materials have an appreciable content of calcium carbonate, and both the graywackes and the dike rocks effervesce freely with dilute hydrochloric acid.

The principal ore body, as exposed in a shallow trench, consists of chalcopyrite and pyrrhotite, intimately mixed, disseminated through the coarser sediments and the dike rocks. A trench shows mineralization over a distance of 30 feet across the bedding, and other openings along the strike show abundant sulphides 250 feet from the principal opening. The sulphides replace certain beds and occur in the dike rocks themselves. Chert beds that cut through the mineralized area are almost free from sulphides. The sulphides range in abundance from scattered small specks of chalcopyrite and pyrrhotite to masses of sulphides in which little rock is visible. Some small quartz and calcite veinlets cut the ore, but the degree of mineralization seems to be independent of their presence. Assays of the best ore are said to have yielded 17 per cent of copper, but development has not yet proceeded far enough to determine the probable size of the ore body or the influence of depth upon the character and degree of mineralization.

Ready Cash group.—The Ready Cash group, which is reported to include nine claims, lies on the northeast side of Ohio Creek about 3 miles above the mouth of Christy Creek. At the time of the writer's visit, in July, 1917, no one was resident on these claims, and none of the owners were seen in the country, so that the only information gathered was that procured in a brief study of the workings that could be found by following trails from the camp site. The country rock in the vicinity of the workings consists of interbedded argillites, graywackes, and greenstone tuffs, all more or less metamorphosed. The local structure is generally difficult to determine, but the prevailing larger structural features strike somewhat east of north and in general dip rather steeply eastward. Apparently the attention of the prospectors was attracted to this locality by a quartz vein that crops out conspicuously on the east wall of a small gulch that is tributary to Ohio Creek from the north. This vein, which cuts altered slates, graywackes, and tuffs, is 8 to 10 feet wide, strikes N. 15° E., and dips vertically. It is rusty and shows some stains of copper carbonate. A short distance down the mountain an adit tunnel 170 feet long was driven in a direction S. 80° E., apparently for the purpose of cutting the quartz vein at depth. The breast of the tunnel had not yet reached the vein exposed on the surface, but in the tunnel a few small quartz veins from 1 to 3 inches wide were intersected. No data were obtained concerning the assay values of the ores at this property.

It is reported that another tunnel 75 feet long has been driven on this property a short distance downstream from the tunnel already mentioned and on the same vein as that which the 170-foot tunnel was meant to cut. The vein is said to be from 12 to 15 inches wide, to carry abundant galena, and to show high assays in silver. Pieces of ore which were found at the entrance to the long tunnel but which presumably come from the other tunnel show quartz with some calcite that carries abundant arsenopyrite, pyrite, chalcopyrite, and galena.

North Carolina group.—The North Carolina group includes several claims that lie in the upper basin of Antimony Creek, a small tributary of East Fork of Chulitna River that joins that stream from the east at the trail crossing, 1 mile above the mouth of East Fork. Mining developments include a log cabin, in the highest patch of timber on the creek, two tunnels, 40 and 10 feet long, and a number of open cuts and strippings.

The mouth of Antimony Creek has an elevation of approximately 1,625 feet above sea level. About 3 miles above the mouth of the stream, at an elevation of 2,700 feet, a 40-foot tunnel has been driven into the steep north bluff of the valley, about 75 feet above the creek, on a claim called North Carolina No. 3. The tunnel follows the footwall contact of a 3-foot basic dike with the shale, impure limestone, and graywacke country rock. The dike strikes S. 65° W. and dips 60° SE., and the sediments have about the same strike but dip more gently. The tunnel is timbered and lagged and is caved at the breast, so that no opportunity was afforded to study the conditions of structure and mineralization in it. It is reported that at the breast there is a gouge-filled slip zone, in which are scattered cubes and bunches of pyrite in the gouge. Pieces of ore found on the dump show abundant pyrite, which occurs as veins or streaks in the altered shales or argillites. The sulphide streaks are highly calcareous, and where the shales that carry the sulphides are more siliceous they contain tiny films and veinlets of calcite. Some secondary crystalline calcite also occurs surrounded by pyrite. The pyrite is probably due to the replacement of limy sediments by mineralized solutions that circulated along a fault zone. Assays are said to show the presence of small amounts of gold.

Farther up Antimony Creek, on the top of the bordering ridge on the north, at an elevation of about 4,000 feet, a 10-foot tunnel has been driven on a claim known as North Carolina No. 5. This tunnel penetrates black argillites, slates, and graywackes that on the surface are so weathered and disturbed that their structure is not determinable. The tunnel is timbered and is caved at the breast, so that the geologic conditions encountered in driving it could not be determined. An ore pile at the mouth of the tunnel contains several tons of massive stibnite ore that includes both finely granular stibnite and a mixture of the granular sulphide with acicular crystals. In some specimens there is a considerable admixture of granular quartz through the stibnite, but other pieces show massive sulphide with no visible gangue. Small amounts of yellow and reddish secondary oxidation products, probably stibiconite and kermesite, were noted on weathered surfaces and in fractures in the ore, and some rusty quartz is associated with it. The owners report that the stibnite occurs in lenses or kidneys that have a maximum thickness of 2 feet and are only a few feet long and that lie parallel in the vein. They report also that the stibnite carries some gold.

Other prospects.—In addition to the prospects already described, on which a considerable amount of systematic development work has been done, there are within the upper Chulitna region a number of claims or groups of claims that show different degrees of mineralization and on which the annual assessment work has been done for some years. On most of these claims too little work has been done to outline the ore bodies or to reveal the conditions or extent of the mineralization. The following notes mention those properties in this class to which the writer's attention was directed:

The Center Star group of two claims lies northeast of the Silver King group and on a line between it and the Northern Light property. The openings, which include several small open cuts and strippings, show a bluish dike rock in which disseminated arsenopyrite, pyrite, and chalcopyrite were recognized.

The Flaurier group of five claims adjoins the Riverside group on the west. The country rock includes the same group of cherts, argillites, tuffs; and possibly limestone cut by dikes that have already been described as occurring at the Riverside group. Open cuts show altered, rusty materials that locally contain considerable quantities of sulphides, which seem to be scattered through the rock by impregnation rather than to occur as a segregated replacement deposit. Assays taken over a considerable area of this material are said to show a few dollars in gold and silver to the ton.

The Jumbo is a fractional claim adjoining the Riverside and lying 2,000 feet southwest of West Fork of Chulitna River. On this claim a large open cut shows a fine-grained conglomerate in which are bunches and specks of sulphides, mainly pyrrhotite but with some pyrite and chalcopyrite.

The Golden Zone Extension group includes some claims that lie adjacent to the Golden Zone group on the southwest. Prospecting has been carried on by the opening of a number of long, shallow trenches, which for the most part fail to penetrate through the loose surficial material to undisturbed bedrock. The underlying rock apparently consists of altered tuff, chert, and argillites cut by dike rocks, in which there is locally some disseminated arsenopyrite.

It is reported that a large number of claims have been staked on the main northern branch of West Fork of Chulitna River for manganese. The manganese is said to occur in seams in slate and serpentine. The surface ores are all soft and decomposed, and no excavations have been made that show the character of the manganese ore at depth.

GOLD PLACER MINES AND PROSPECTS.

In the upper Chulitna region, as in most other unexplored countries, the efforts of the earliest prospectors were directed to the search for easily mined gold placer deposits, and in 1907 the first claims located in this region were staked for placer gold, on upper Bryn Mawr Creek. In 1909 some mining was done on this ground, and a small amount of gold was recovered. Prospecting for gold placer gravels has continued since that time, and although gold has been found at many places, it has nowhere been found in sufficient amount to warrant mining under the conditions imposed by the remoteness and difficulty of access of the region.

In 1917 some prospecting for gold was done on West Fork of Chulitna River, but no workable deposits were found. Two men continued the attempt to discover a pay streak on lower Shotgun Creek, a tributary of lower Ohio Creek from the west. Encouraging amounts of gold have been found at that locality, and several persons have at one time or another attempted to mine there, but so far without success.

The gravels of Gold Creek, a tributary that joins Susitna River from the east 2 miles below the mouth of Indian River, have long been known to be auriferous, and attempts to mine them have been made at intervals by different men. A small amount of gold has been recovered, but no ground rich enough to yield a profit to the miners has yet been found.

Some gold has from time to time been won from the bars of Susitna River near the mouth of Gold Creek and a short distance below Deadhorse Hill. This gold was all fine and occurred near the top of the stream-gravel deposits. Deeper holes sunk through the gold-bearing gravels failed to show any increase in the amount of gold with depth but rather a decrease.

COAL.

As has already been stated, coal-bearing Tertiary beds are widely distributed throughout the basin of Susitna River and are known to occur at two localities in the upper Chulitna region. The only one of these localities that was visited in 1917 lies near the head of Coal Creek, a small stream that flows into Camp Creek, which in turn is tributary to Costello Creek from the northeast. There the bluffs show a section of Tertiary shale and lignite. At the time of the writer's visit, in July, 1917, a snow bank covered much of the outcrop, and the surface of the beds was partly masked by detritus, but in a vertical section of 24 feet three lignite beds, 6, 5, and 9 feet thick, separated by shale beds, were seen. A 15-foot tunnel, driven on one coal bed, shows a 6-foot face of bright black lignite of fair quality.

Neither the top nor the bottom of this bed was seen in the tunnel, so the thickness certainly exceeds 6 feet. The coal beds dip about 14° E. The area of the coal field is not known, for exposures are few, but the coal is apparently limited on the west by Camp Creek and is said to crop out at least 1,200 feet east of the tunnel. This lignite has had a small local use by the prospectors for fuel for camps and as forge coal.

It is reported that Tertiary deposits containing a lignite bed several feet thick crop out in the valley of a tributary of Middle Fork of Chulitna River, about 11 miles above the junction of East and Middle forks, between the trail and the line of the railroad survey, and coal-bearing beds are said to crop out on Coal Creek, a southeastward-flowing tributary of the Chulitna, south of Ohio Creek.

PLATINUM-BEARING GOLD PLACERS OF THE KAHILTNA VALLEY.

By J. B. MERTIE, Jr.

INTRODUCTION.

The valley of Kahiltna River includes an area about 80 miles long and from 5 to 20 miles wide, which begins at the confluence of Kahiltna and Yentna rivers and extends somewhat west of north to the crest of the Alaska Range. This strip of territory, aggregating about 1,000 square miles, forms the central part of the Yentna district. Cache Creek and its tributaries and the headwater tributaries of Peters Creek constitute the present center of mining activity in the Kahiltna Valley.

The exploratory expeditions of Spurr [1] and Eldridge [2] in 1898 and of Brooks [3] in 1902 yielded the first geographic and geologic knowledge of Yentna and Susitna rivers, but Kahiltna River and its tributaries were not visited by these earlier workers. The first authentic geographic knowledge of the Kahiltna Valley was obtained in 1906, when the area now known as the Yentna district was mapped topographically by R. W. Porter, working independently of the Geological Survey. In 1911 Capps [4] visited the Yentna district, including the valley of Kahiltna River, and made numerous corrections and additions to the topographic mapping of Porter, and two years later his reconnaissance topographic and geologic map of the region was published.

Placer mining began in the Cache Creek and Peters Creek basins in 1905 and has continued to the present time. Capps, in addition to his geologic work in this district, also studied the gold placers and reported on their occurrence, origin, and value.

The Kahiltna Valley, including Cache and Peters creeks, was visited by the writer in September, 1917, with two objects in view. First, platinum had been recently reported from gold placers at several localities along the lower part of Kahiltna River, and the

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 31–264, 1900.

[2] Eldridge, G. H., A reconnaissance in the Susitna basin and adjacent territory, Alaska, in 1898: Idem, pp. 1–30.

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

[4] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, 1913.

United States Geological Survey desired to investigate these occurrences of platinum and determine, if possible, their significance and value, as well as to search for other platinum-bearing gravels; second, it was desirable to learn the amount of mining development which had taken place during the preceding six years and thus to bring up to date the record of the placer-mining industry in this district. These objectives were accomplished in a trip of 27 days, starting from and returning to Anchorage.

The writer takes this opportunity to acknowledge gratefully the hospitality and cordial cooperation of the mining men in the Cache Creek district. Special thanks are due to Messrs. Harris and Murray, of the Cache Creek Dredging Co. and the Cache Creek Mining Co., respectively, for many favors received.

GEOGRAPHY.

The geographic features of the Yentna district have already been stated in some detail by Capps,[1] and the following notes are written only as a summary of the data for Kahiltna Valley. Kahiltna River has its source in Kahiltna Glacier, from which a number of glacial streams emerge and flow for miles as a system of anastomosing channels over an aggraded flood plain of sand and gravel but gradually unite downstream to form the main river. A main channel may be said to begin at the mouth of Treasure Creek, about 7 miles in an air line from the foot of the glacier, but even from this point downstream to the flats the river flows through many sloughs over a wide flood plain. At the Kahiltna Flats the main channel and sloughs unite and spread out across the valley bottom to form a wide expanse of shallow water and shifting sand bars, through which a shallow-draft poling boat in many places has difficulty in finding a channel. Below the flats the main channel is well defined, though in places sloughs cause islands in the river. At a point 20 miles in an air line below the glacier, at Camp 2, the river enters a canyon and cuts through the Eocene coal-bearing formation for several miles in a series of rapids. Below the mouth of Peters Creek the river is incised in the coal-bearing rocks at many places and is a swift stream, which here and there flows in a gorge. A stretch of several miles of this character at the lower end of the Kahiltna is sometimes referred to as the lower canyon of the Kahiltna. The length of Kahiltna River, from Kahiltna Glacier to its junction with Yentna River, is about 42 miles in an air line, though much more than that by the windings of the stream.

All the larger tributaries of Kahiltna River, with the exception of Treasure Creek, enter from the east side of the valley and drain

[1] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, pp. 11-22, 1913.

the Dutch, Peters, and Little Peters hills. Named in order downstream, they are Granite, Cache, Hungryman, Bear, and Peters creeks, of which Cache and Peters creeks are the largest. These eastern tributaries of Kahiltna River emerge from the hills in gorges, of which the lower canyon of Cache Creek is typical, and flow over the Kahiltna flood plain to join the main river. The east side of the Dutch and Peters hills is drained by Tokichitna River and its tributaries, which head against the headwater tributaries of Peters and Granite creeks.

The Dutch, Peters, and Little Peters hills form a kite-shaped area that is bounded on the northeast by the valley floor of Tokichitna River, on the southeast by the wide alluvial flats of Chulitna and Susitna rivers, on the southwest by the Kahiltna flood plain and Kahiltna Glacier, and on the northwest by Dutch Creek, a tributary of Granite Creek, and the upper Tokichitna tributaries. These three groups of hills, which include the Cache Creek mining district, cover an area of about 300 square miles adjoining what may be termed the upper Kahiltna basin. The lower Kahiltna Valley may be said to begin at the mouth of Peters Creek and to extend to Yentna River. The Dutch Hills rise to an elevation of over 4,000 feet, the Peters Hills between 3,000 and 4,000 feet, and the Little Peters Hills only 2,000 feet. A wide trough-shaped depression of glacial origin, occupied by Cache Creek and the headwater tributaries of Peters Creek and lying for the most part between elevations of 2,000 to 2,400 feet, separates the Dutch Hills from the Peters Hills to the south. The Peters Hills are separated from the Little Peters Hills by a wide, high, level flat at the heads of Hungryman and Bear creeks.

The valley floor of Kahiltna River and its eastward continuation into the Susitna Flats constitute the lowland area of Kahiltna Valley. These lowlands consist of wide stretches of level alluvium, with some low rolling hills, separated usually from one another by lakes, swamps, or sluggish meandering streams. The lower Kahiltna Valley ranges in elevation from 200 to 500 feet; the elevation at the foot of Kahiltna Glacier is about 800 feet. In general, the lowland areas are timbered and densely overgrown by low brush.

The only settlement in the lower Kahiltna Valley is McDougall, on the north bank of Yentna River about 8 miles above the mouth of the Kahiltna. The nearest post office is at Susitna, on the east bank of Susitna River at the mouth of the Yentna, 29 miles in an air line from McDougall. About 100 men are engaged in mining in the Kahiltna Valley, chiefly in the valleys of Cache and Peters creeks.

GEOLOGY.

SLATE AND GRAYWACKE SERIES.

The larger geologic units of Kahiltna Valley have already been described and mapped by Capps [1] and are shown on the geologic sketch map in this report (Pl. VI). The oldest rock formation known in the valley is a series of slates and graywackes, with certain phyllitic and quartzitic phases, which forms the predominating country rock of the Dutch, Peters, and Little Peters hills and extends to the northeast and southeast along the south flank of the Alaska Range. With regard to the lithologic character of these rocks, particularly in the Dutch and Peters hills, Capps [2] writes as follows:

They consist chiefly of black to gray slates and phyllites, in many places carbonaceous, and beds of graywacke, which range from fine-grained to coarse gritty rocks. In some places the rocks are massive, with argillites instead of slates, but the foliated types are much more widespread than the massive types. It is difficult to estimate just what proportion of the whole series is formed by the graywacke beds. Many sections show great thicknesses of the slaty phases, with very little graywacke present. At other localities the graywackes preponderate, occurring in thick, massive beds that show little foliation or schistosity and that are often mistaken by the miners for fine-grained dike rocks, which they closely resemble. The whole series is much jointed, the graywackes less closely than the slates, which are in many places broken into long prismatic pieces by sets of intersecting joints.

Of the slates in general Capps [2] further says:

Evidences of mineralization are widespread in these rocks. A characteristic phase of the slates in many places throughout the region contains small cubical cavities, the largest a quarter of an inch in diameter, formed by the leaching out of cubes of iron pyrite, the rock being discolored for some distance around each cavity. Some of the graywacke beds also show the presence of much finely disseminated pyrite.

The slate and graywacke series is greatly folded and faulted and exhibits great variation in strike and dip. The average strike, however, is about N. 60° E., and the general dip is at a high angle to the south. On account of the irregularity of structure and the lack of knowledge of these rocks over a large area, no reliable estimate of thickness can be made other than the statement, as given by Capps,[3] that the series is several thousand feet thick.

This slate and graywacke series was correlated by Capps [3] with a similar series of rocks observed by Brooks [4] in the valley of Kichatna River and with the Susitna slate described by Eldridge,[5] and for lack of conclusive evidence it was assigned provisionally to the Paleozoic or Mesozoic. During the season of 1917 two fossil shells

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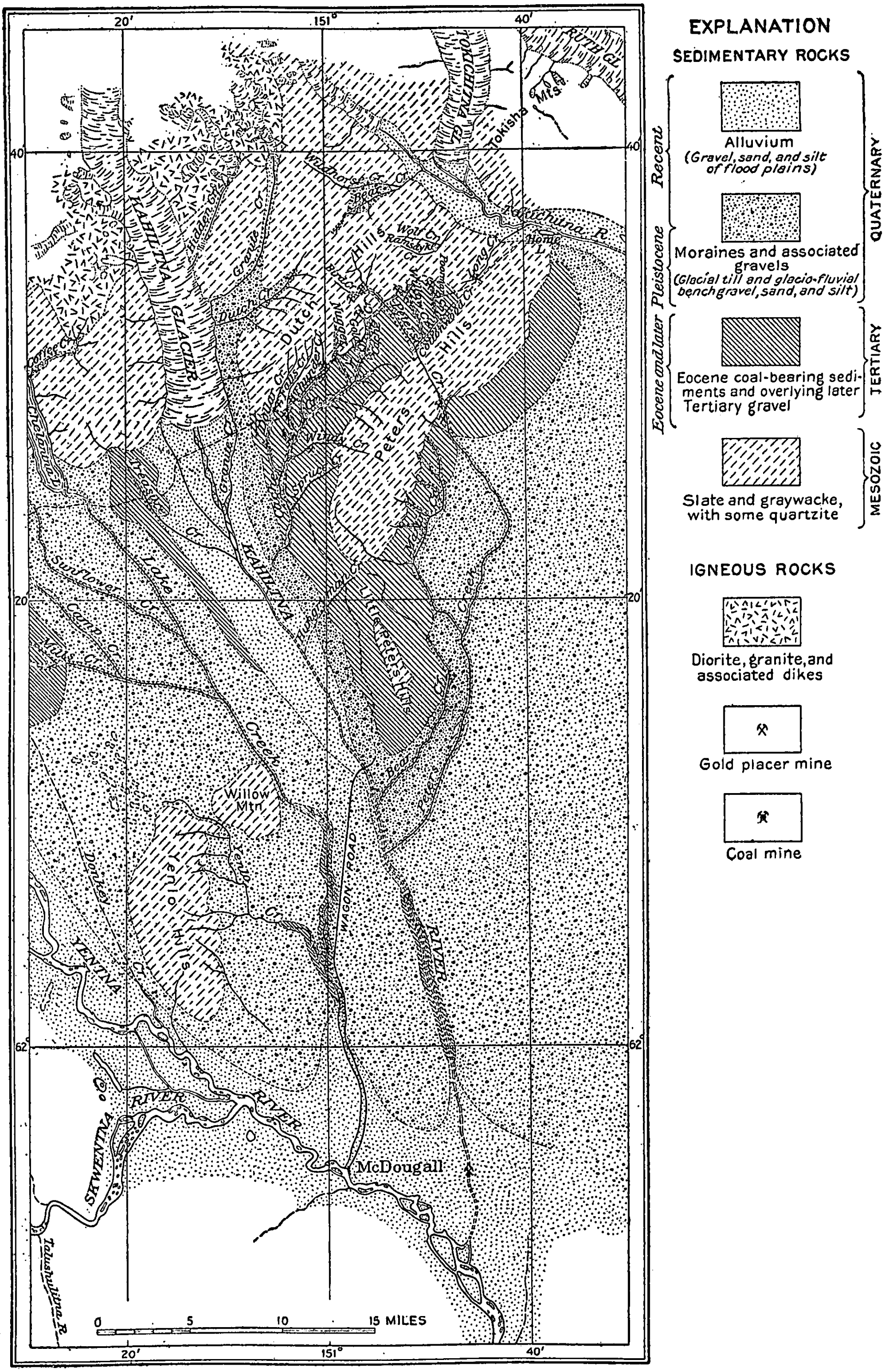
[1] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, pp. 22–47, 1913.

[2] Idem, p. 25.

[3] Idem, p. 27.

[4] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 67–68, 1911.

[5] Eldridge, G. H., A reconnaissance in the Susitna basin and adjacent territory, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 15–16, 1900.



GEOLOGIC SKETCH MAP OF THE KAHILTNA VALLEY.

were found by the writer on Long Creek, in the Tokichitna Basin. The localities and the determinations made by T. W. Stanton are as follows:

10124. No. 4. Angular wash, half a mile from head of Long Creek, tributary of Tokichitna River. Elevation, 2,500 feet.

10125. No. 5. In place, a quarter of a mile from head of same creek. Elevation, 2,600 feet.

These two specimens are fragmentary imprints in slate and probably represent a single species, which in my opinion is referable to a broad form of *Inoceramus* more like some of the Alaskan Upper Cretaceous types of *Inoceramus* than those known from the Jurassic. It is probably worthy of mention that the lithology of the matrix suggests the Yakutat rocks of Woody Island and that the fossils themselves have some resemblance to *Inoceramya concentrica* Ulrich from that locality, though they do not belong to that species. Though other fossils are needed to make the identification positive, I think that these fossils are probably of Upper Cretaceous age.

Other fossil fragments were observed in the slate and graywacke series on Long Creek, and a careful search in this vicinity might reveal other forms or better-preserved specimens of the same one. It is evident, at all events, that this slate and graywacke series is Mesozoic in age and not Paleozoic, and it seems probable that it represents some horizon in the Cretaceous system.

TERTIARY SYSTEM.

Two formations, which make up the Tertiary system, overlie unconformably the slate and graywacke series. The older of these is the Eocene coal-bearing formation correlated with the Kenai, and the younger is a gravel deposit which lies conformably on the coal-bearing rocks.

In the valley of Kahiltna River the coal-bearing rocks crop out in the valley of Treasure Creek, in the basin between the Dutch and Peters hills, along the east side of the Kahiltna Valley from the Little Peters Hills to Kahiltna Glacier, along the southeast flank of the Peters Hills, and in the lower Kahiltna Valley. Later alluvial deposits probably conceal large areas of these rocks in the Kahiltna and Susitna flats. The overlying gravels are best exposed west of Kahiltna Valley, at the head of Camp and Mills creeks, but are also said by Capps [1] to occur at the mouth of the canyon of Nugget Creek and on Cache Creek at the mouth of Windy Creek. They were noticed also by the writer on Gopher Creek, a headwater tributary of Willow Creek.

The Eocene coal-bearing rocks are described by Capps [2] as follows:

The character of the Eocene beds is more or less uniform in the many outcrops examined, even in widely separated localities. Most of the exposures show only a small part of the total thickness of the series, but even where the outcrops are small

[1] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, p. 34, 1913.
[2] Idem, p. 30.

little difficulty is encountered in identifying them. The beds consist predominantly of unconsolidated or loosely consolidated clays and sands, containing layers of fine pebbles, and commonly some lignitic coal. Even where the surface is covered with vegetation pieces of lignite in the stream beds often serve to indicate the presence of these deposits. At the few localities where the relation between the Eocene sediments and the underlying slates could be studied, the slates and graywackes have been deeply weathered and decayed, the slates having broken down to a bluish-white kaolinic clay and the graywackes changed to a soft gritty sandstone before the overlying materials were deposited. It is often difficult to determine the point at which the clay shales of the Tertiary succeed the residual clays of the slate series. The coal-bearing sediments consist of alternating clays, sands, and fine gravels, the beds in most places being little consolidated, though here and there a coarser layer has been cemented into a rather fine conglomerate or grit. At a bluff on the east bank of Susitna River at Susitna station there is an outcrop of a coarse-grained conglomerate which Spurr refers provisionally to the Kenai formation, of Eocene age, but nothing similar to this rock was seen in the Yentna region.

Lignitic coal occurs in the Tertiary rocks in many places. All of the coal examined was rather fibrous and woody, of a brown to black color, and is of little value except as a source of local fuel supply. The beds examined are from a few inches to 12 feet in thickness.

Structurally, the coal-bearing rocks are distinct from the slate and graywacke series in that they are only loosely consolidated and, although folded, show only to a small degree the effects of metamorphism. Only exceptionally are the coal-bearing beds inclined at high angles, as for instance about 2½ miles below the canyon on Peters Creek, where these rocks and their included coal beds dip 70° NW. and strike N. 45° E. The folding is, in general, of the broad, open type, and the rocks are only imperfectly indurated. Their thickness is not definitely known but is believed to exceed 1,000 feet.

The overlying gravel has been described by Capps [1] as follows:

The gravels are rudely stratified, as though by streams, the largest boulders being about 1 foot in diameter, but most of the pebbles measure from 2 to 4 inches through and are mixed with much sandy material. A large variety of rocks is represented by the pebbles—slates, graywackes, black and gray conglomerates, and quartz are present as well as diorites and many other types of igneous rocks. The deposit throughout its thickness shows a yellowish color due to oxidation, but the yellow color is evidently only a coating on the pebbles, for it has disappeared from the materials that have been rehandled by streams. The great age of these gravels is attested by their decayed condition, many of the pebbles being so rotten that they crumble and fall to pieces when disturbed, although they must have been hard and firm when they were rounded and deposited by the streams.

The gravels, where seen by the writer on Gopher Creek, formed a rotten conglomerate made up in the main of greatly decayed pebbles a few inches in diameter, though cobbles as large as 18 inches were also seen. This conglomerate formed the bedrock underlying the stream placers at the upper end of Gopher Creek. The total thickness of the gravel is unknown, but at least 600 feet of such rock was seen by Capps [2] in the upper part of Treasure Creek.

[1] Capps, S. R., op. cit., p. 34.

[1] Idem, p. 35.

QUATERNARY SYSTEM.

With the advent of Quaternary time there came a gradual change in climatic conditions, which resulted in the development of glaciers in this area on a large scale. The glaciers gradually extended from the Alaska Range southward to Cook Inlet, filling the valleys and covering all the prominent hills in Kahiltna Valley. The Peters and Dutch hills, if not actually overridden by ice, were covered by a névé of snow and ice which contributed to the surrounding ice sheet. This ice advance, which occurred during Pleistocene time and perhaps extended into Recent time, was finally stopped by further climatic changes, and the ice fields began to disappear. It is probable that the retreat of the ice was rhythmic in character—that is, the glacier alternately retreated and advanced—with a cumulative net loss that resulted eventually in the entire disappearance of the ice fields and the restriction of the ice to the present valley glaciers.

During the glacial epoch great physiographic changes took place. The details of the pre-Quaternary topography were entirely obliterated by the action of the ice and topography characteristic of a glaciated area was developed. Old stream valleys were scoured out and broadened into wide U-shaped valleys, and the hills were smoothed and rounded by overriding ice. The Alaska Range, the accumulating ground of the snow and ice, was rendered more rugged and precipitous than before, owing to "bergschrund" sapping on the high ridges. When the ice fields finally disappeared normal stream erosion again became effective, with the result that the glacial topography is now in the process of retransformation to the pre-Quaternary type. The gorges and canyons in Kahiltna River and its tributaries are an index of the degree to which normal stream erosion has been reestablished. Such gorges, though conspicuous, are relatively minor features of the present topography, and the old glaciated outlines still remain the dominating topographic features.

These erosional processes have resulted necessarily in the development of several types of detrital deposits. During the period of glacial action and in the subsequent retreat of the glaciers the débris eroded by the action of the ice was deposited in moraines of different kinds, of which the ground moraines that were formed under the lower reaches of the ice field are best preserved. Terminal moraines at the ends of the glaciers appear for the most part to have been removed, either as they formed or shortly afterward, by glacial streams that issued from beneath the ice. The morainal material removed by the glacial streams was distributed over a wide area adjacent to the glaciers and subsequently, as the streams entrenched themselves in it, formed the bench gravels contiguous to the present streams. These bench gravels, which consist of reworked glaciofluviatile deposits, are essentially similar to the morainal material except that the detritus is more or less rounded and much of the finer silt, or glacial mud, has been carried away by the transporting streams. The lower portions of the bench deposits carry the larger boulders and the upper portions the smaller boulders, cobbles, and pebbles. On Cache Creek a short distance above the mouth of Nugget Creek the bench gravels have an average size of about 5 inches, but some of those at the base of the deposits are as much as 3 feet in diameter.

As the glaciers retreated and the streams began to adjust themselves in the vacated valleys, the irregular glacial gradients were gradually transformed by alluviation at some places and stream erosion at others into normal or approximately normal stream gradients, with the characteristic water grades and headward steepening. This process has resulted in the development of the present alluvial deposits in the overdeepened glacial troughs and of canyons in the valley protuberances. There is little difference between the bench and stream gravels except that the process of stream sorting has been carried still further in the stream gravels. The coarser parts of the bench gravels, which the streams have been unable to handle, remain in the headwater alluvial deposits, and the finer materials have been deposited progressively downstream. In the lower courses of the large rivers the present alluvium is largely silt and fine sand.

MINERAL RESOURCES.

VALUABLE MINERALS PRESENT.

Placer gold is the only mineral that has been exploited on a commercial scale in the valley of Kahiltna River up to the present time. Other minerals of value, however, including principally platinum, cassiterite (tin oxide), and scheelite (calcium tungstate), have been found in the placer sands, and it is possible that some of these may later be produced in commercial amounts. Provision should be made for the recovery of platinum in the gold placers, where it is found in any considerable amount, and the district should be further prospected for workable deposits of placer platinum. Heavy concentrates of cassiterite from the placer sands were noted at certain localities, and search should be made for their bedrock sources. The presence of scheelite in the placers, although it is not plentiful, indicates the presence of tungsten ore south of the Alaska Range and should be remembered when prospecting for lode deposits. The Eocene coal deposits have already been used locally as a source of fuel and power.

ECONOMIC CONDITIONS.

The central supply for Kahiltna Valley and vicinity is the town of Anchorage, at the head of Cook Inlet. From that point passengers and freight are transported by launches across the inlet and up Susitna River to the mouth of the Yentna, where the trading station of Susitna is located. On account of present construction work on the Government railroad up Susitna Valley a small steamboat owned by the Government plies regularly between Anchorage and up-river points on the Susitna, stopping at Susitna station. Light-draft launches navigate Yentna River to a point above the mouth of the Kichatna but seldom go above the trading station of McDougall, at the mouth of Lake Creek, which is the supply depot for Kahiltna Valley. A wagon road begins at McDougall, follows up the east side of the Lake Creek valley for about 15 miles, and then leads across into Kahiltna Valley, reaching Kahiltna River at Camp 2, about 26 miles in an air line above its mouth. A bridge spans the river at this point. Camp 2 is connected with the Cache Creek district by a soft, difficult trail. During the summer of 1917 the Cache Creek Dredging Co. operated a small boat, fitted with a gasoline engine, on Kahiltna River, transporting freight from Camp 2 to the mouth of Cache Creek, where it was conveyed by wagon up the canyon to the dredge, a distance of about 7 miles. A new wagon road, which has been surveyed from Talkeetna on the Government railroad to Cache Creek and vicinity, will when completed greatly facilitate communication with Kahiltna Valley.

The transportation of supplies into Kahiltna Valley is at present slow, laborious, and costly. The freight rate by water from Anchorage to McDougall was $15 a ton in 1917, and the commercial charge for winter dog-sled freighting from McDougall to Cache Creek is 8 to 10 cents a pound, though by the use of bobsleds and horses this may be reduced to 4 cents a pound. An extra charge of 2 to 5 cents a pound is made for taking supplies to the headwater tributaries of Cache and Peters creeks. The commercial freight rate in summer from McDougall to Cache Creek is 35 cents a pound, of which about 25 cents represents the actual cost. The minimum cost of freighting, therefore, from Anchorage to Cache Creek is $95 a ton. The new wagon road to Cache Creek used in conjunction with rail transportation from Anchorage to Talkeetna should materially reduce the cost of supplies and will also make the district more accessible than heretofore.

Timber for use in mining is not in great demand in Kahiltna Valley, for little underground work is done, and most of the placer mining is accomplished by hydraulic plants. The dredge on Cache Creek uses coal to generate power. Wood is used chiefly as fuel for heating, and for this as well as for lumber and other necessities there is an abundance of timber. Spruce 24 inches in diameter and cottonwood as large as 5 feet in diameter are available[1] in the lowlands, but little timber grows above an elevation of 2,000 feet. The Cache Creek mining district, on account of its general elevation above 2,000 feet, is at a disadvantage because the wood needed must be brought up from the timbered valleys below.

Water for hydraulicking is taken from the streams at some distance above the placer ground and led by ditches to the hydraulic pipes. The rainfall and stream flow are adequate to supply plenty of water with the required pressure at most of the mining plants. Numerous good power sites for hydroelectric plants are available in the canyons of different streams and particularly in the lower valley of Cache Creek below the mouth of Spruce Creek, where a large and unfailing flow of water falls about 500 feet within a mile and a half or less.

The standard wage in the Cache Creek district in 1917 was $5 a day and board for eight hours of labor, and winchmen, cooks, and other specialized workmen were paid $6 a day and board. On the basis of a charge of $1.50 a day for each man for the cost and preparation of food, the total cost of unskilled labor amounted to 81 cents an hour and for skilled labor 94 cents an hour.

PLACER DEPOSITS.

CACHE CREEK BASIN.

GENERAL FEATURES.

Cache Creek and its tributaries drain the western part of the glacial trough which separates the Peters Hills from the Dutch Hills. The main creek rises in the Dutch Hills, flows in a general southwesterly direction for 18 miles, and empties into Kahiltna River about 13 miles below the glacier. Cache Creek has a number of tributaries, of which those entering from the northwest are the larger and the more important as producers of placer gold. The largest of those named in order downstream are Nugget, Thunder, Falls, and Dollar creeks. The southwestward-flowing tributaries in order downstream are Trout, Long, Windy, and Spruce creeks, of which only Windy and Spruce creeks have gold placers worthy of attention. The basin of Cache Creek embraces an area of about 75 square miles.

In the upper part the basin of Cache Creek is a wide, open U-shaped glaciated valley, with a floor of soft coal-bearing rocks of Kenai age, into which Cache Creek has incised a V-shaped gorge that ranges from 250 to 300 feet in depth throughout its length. The tributaries of Cache Creek, including also upper Cache Creek, lie in the hard slate and graywacke that form the sides of the valley and have not been incised so deeply. For this reason canyons have developed

[1] Capps, S. R., op. cit., p. 18.

on the lower courses of the tributaries, in order to join the slate and graywacke valleys with the more deeply incised valley of Cache Creek. Cache Creek also has cut a canyon in its lower valley in order to reach on a water grade the more deeply scoured valley of Kahiltna River.

The glacial trough that forms the upper basin of Cache Creek has an elevation of nearly 2,400 feet in the upper valley. Cache Creek at its mouth has an elevation of about 600 feet, thus showing a fall of 100 feet to the mile for the length of the stream. The fall in the upper valley is considerably less than this but is counterbalanced by a heavy fall in the lower valley or canyon of Cache Creek.

The location of the gold placer mines under operation in the Kahiltna Valley, including also those on Cache and Peters creeks, is shown on the map (Pl. VI).

CACHE CREEK.

CREEK PLACERS.

There are two sources of placer gold in the valley of Cache Creek—one in the glacial till and gravel that overlie the Eocene coal-bearing rocks in the broad valley and form the benches along the creek, and the other in the present stream gravels, which have been derived in large measure from the erosion of the glacial débris of the benches.

Little is known concerning the distribution, number, and character of pay streaks in the reworked glacial débris. This material, though largely till, has also zones of washed gravel and boulders, showing that stream as well as glacial action has effected its present distribution. The glacial till is composed of unsorted rocks and boulders of all sizes, showing usually little or no water action, together with a great amount of fine clay or glacial mud. Gold is distributed throughout the glacial material in greater or less amount, but true pay streaks are lacking on account of the paucity of the action of water, with its consequent sorting of material and concentration of the heavy metals and minerals. At some localities, more particularly where the action of water has played a more important part in the formation of the deposits, there is a slight concentration of the gold, so that the deposits may be mined at a profit on a small scale. There seems to be no regularity, however, in the distribution of the placers in the bench deposits, and no method is known whereby they may be located by physiographic deduction. At some places in the Cache Creek district quite unsorted glacial till has been mined by placer-mining methods and yielded a profit, but such occurrences must be regarded as altogether fortuitous—that is, as deposits of till which happened to be derived from rich gold lodes and suffered little distribution prior to their final deposition. It is estimated that the content of gold in the more favored localities on the benches may average 10 cents a cubic yard. The future of the Cache Creek district as a mining center is dependent on the mining of these low-grade bench deposits by large-scale hydraulic methods. By large-scale operation and economic management it may be possible to mine such placers for as little as 4 or 5 cents a cubic yard, particularly after communication has been established with the Government railroad and the district becomes more accessible.

The present stream gravels have so far formed the more attractive field for placer mining on Cache Creek. Gold was first discovered in 1906 on Discovery claim in the upper canyon of Cache Creek, and placer-mining operations have been carried on intermittently since that time in the creek placers. The creek placers at the canyon were examined in 1911 by Capps,[1] who reported as follows on their distribution and character:

> The ground worked was that of the present stream flat, and the gravels moved range from 4 to 7 feet in depth and lie on slate bedrock. There are some large boulders present, but most of them can be handled by one man. A short distance below the canyon the slate bedrock gives place to the materials of the coal-bearing series, which change character within short distances, ranging from a fairly firm, gritty sandstone to soft clay shales. The pay streak is said to be rather well defined in the canyon and for a short distance below it but soon spreads out in the wider valley below and is difficult to trace. The gold is rather unevenly distributed, for, though most of it is found on bedrock, the degree of its concentration depends somewhat on the character of the bedrock, the harder strata having retained it better than the softer. No records have been kept which would show the gold content of the gravels to the cubic yard or to the square yard of bedrock, but it is reported that the returns have averaged about $10 a day for each man employed. The sluice boxes, 14 inches wide, are set on a grade of 5 inches to the box length. The gravels are ground-sluiced to a depth within a foot or so of bedrock by the aid of canvas hose and water under pressure from the bench to the southwest, the rest of the gravel being shoveled in and bedrock cleaned by hand. The stream at Discovery claim can be depended upon to run a sluice head of water for the boxes used throughout the season, and most of the time it flows two sluice heads. The gold is coarse, bright, and somewhat worn, though many pieces are rough, and some cubes of crystalline gold have been found. Pieces worth $20 have been taken from this claim, and only about one-third of the gold recovered will pass through a 16-mesh screen.
>
> The coarseness of the gold and the roughness of some of it indicate that it has traveled no great distance from its bedrock source. It must originally have come from the quartz veinlets of the slate and graywacke series in the upper part of the Cache Creek valley or at the head of Bird Creek, for the upper valley at one time contained a vigorous glacier, and ice also came into it from the head of Bird Creek across a low divide. This glacier eroded its basin and doubtless scattered and removed any preglacial gold which may have been concentrated in its upper portion. No ground carrying paying quantities of gold has been discovered above the canyon of Cache Creek. Toward the mouth of the slate valley the ice scour was less severe, as the glacier joined a large sluggish ice sheet in the broad basin between Dutch and Peters hills. Here the valley deepening was not pronounced, and a part of the material

[1] Capps, S R., op. cit., pp. 54-55.

picked up by the ice in the upper valley was dropped. It may be that the glacial deposits here covered up portions of the preglacial channel of Cache Creek without disturbing them. When the glacier melted away, the stream cut through the glacial deposits and at and below the canyon intrenched itself into the slates and the softer beds to the east. In the rehandling of the glacier material any gold that it contained was concentrated in the stream bed, and if the valley was cut through any undisturbed portions of the old preglacial channel these too would have contributed to the richness of the present placer deposits.

In 1916 the Cache Creek Dredging Co., operating under a lease from the Cache Creek Mining Co., built a dredge and began work on Cache Creek in the placer ground owned by the latter company. Beginning at the mouth of Windy Creek, the dredge had worked upstream three-quarters of a mile by the fall of 1917. The pay streak is from 150 to 300 feet wide and is believed to extend upstream for several miles. The depth of the gravels ranges from 3 to 7 feet, averaging perhaps 4½ feet, and the bedrock is the soft, loosely consolidated Eocene sand, clay, and gravel. Practically all the gold is taken from the gravels, but it is necessary for the dredge to remove bedrock in shallow ground in order to excavate a channel sufficiently deep in which to float. The problem of working in shallow ground will probably be accentuated as the work continues upstream and may ultimately render necessary the reconstruction of the dredge or the purchase of a new one of lighter draft.

The gold recovered by the Cache Creek dredge is a composite of the gold from various tributaries and can not be said to belong to any definite type. The assay value ranges from $17.60 to $17.80 an ounce. Though more waterworn than the gold in streams like Thunder Creek, owing to its further transportation, the Cache Creek gold nevertheless shows in its lack of well-rounded edges the fact that it has undergone comparatively little transportation. Some very angular gold recovered is doubtless derived from the weathering of near-by gravel banks of glacio-fluviatile origin, and the generally small proportion of well-rounded gold indicates that little of the gold has traveled very far. The gravel banks of the Cache Creek basin must be considered the source of most of the gold, as far as the present stream is concerned, though there are good reasons for believing that some of the gold has entered the placers from bedrock subsequent to the retreat of the glaciers. The ultimate or bedrock source of the gold, however, is harder to decipher on account of glacial action, which has laid down a mantle of detrital material that conceals most of the original bedrock and is itself by no means so susceptible to physiographic interpretation as stream detritus would be. It is believed both by Capps [1] and the writer that the bedrock source of the Cache Creek gold is confined mainly to the near-by hills—first, because the Cache Creek glacial trough appears to have been filled with a sluggish ice sheet, which favored a minimum of glacial transportation, and, second, because the slate and graywacke bedrock in the basins of Cache and Peters creeks, particularly in the Dutch Hills, yields positive evidence of gold mineralization at several localities.

A small amount of platinum metals, about 0.003 per cent of the gold by weight and less than 0.02 per cent of the gold in value, is also recovered. The platinum grains are small, few of them exceeding 1 millimeter in size, and most of them are thin and flaky. Two kinds of platinum metals appear to be present. The more common type is a dark-gray to bronzy metal, which carries probably the main content of platinum. The second variety consists of bright silvery grains and commonly shows what appear to be crystalline outlines. This variety is believed to be mainly iridosmium. On page 258 is given an analysis of the platinum metals received from Poorman Creek, in the Peters Creek basin, and it is most likely that this analysis is also a fair index of the character of the platinum metals on Cache Creek. On account of the flaky character of the platinum it is probable that the recovery made by the dredge in the sluice line does not fairly represent the platinum content of the placers; but, on the other hand, it is unlikely that enough platinum is present in the placers to make the installation of more refined methods for its recovery worth while.

As an indication of possible minerals of value in the territory drained by Cache Creek the concentrates or heavy minerals caught with the precious metals are also of interest. Examination of the concentrates from Cache Creek has revealed ilmenite, magnetite, cassiterite (tin oxide), zircon, quartz, garnet, limonite, pyrite, and scheelite (calcium tungstate). The presence of cassiterite and scheelite is worthy of particular mention, for the ores of tin and tungsten have heretofore been found chiefly north of the Alaska Range, in interior Alaska.

The dredge operating on Cache Creek is one of the flume type, with buckets of 7½ cubic feet and a daily capacity of 2,000 cubic yards. Power is supplied by a steam boiler, under which coal is used for fuel. The coal is mined on Cache Creek at the mouth of Short Creek and is hauled by teams to the point where the dredge is operating and lightered on board to the boiler. A steam electric or hydroelectric plant is contemplated, and either should materially lessen the ultimate cost of mining. Prospecting is carried ahead of the dredge by means of an 8-horsepower gasoline drill. The dredge in 1917 was handicapped by a short season and by two heavy floods in Cache Creek, both of which did much damage and caused the loss of considerable time. The second period of high water, which occurred in

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[1] Capps, S. R., op. cit., p. 54, 1913.

September, was particularly disastrous on Cache Creek and its tributaries, and the highest known water marks for Kahiltna and Yentna rivers were surpassed.

BENCH PLACERS.

On upper Cache Creek, just above the mouth of Gold Creek, the bench gravels on the left bank of the creek, at an elevation of 2,300 feet, were being worked in 1917 by hydraulicking. The bedrock at this locality is composed of Eocene coal-bearing sediments and consists mainly of sandstone, with some clay shale and conglomerate and coal seams. The bedrock surface is decidedly irregular, and good-sized "pot-holes" are exposed as the surface is uncovered. A lens of conglomerate covered by a seam of brown to black iron hydroxide forms the bedrock surface at one place, and on this irregular surface coarse gold is found. Much of the gold, particularly the coarse gold, occurs on such iron-stained bedrock surfaces, as well as in similar unstained gravel beds higher up in the placer body. Some gold, however, is distributed throughout the gravels.

Most of the gravel is well rounded, with comparatively little subangular material. The average size of the gravel is about 4 or 5 inches, though boulders a foot in diameter are common, and others as large as 3 feet were seen. A body of heavier gravel wash, about 7 feet thick, lies next to bedrock. It is apparent that such bench gravels have undergone a high degree of stream sorting and are clearly to be distinguished from the glacio-fluviatile bench gravels at other localities in this vicinity, as, for instance, on Bird Creek.

A clay seam which has some interest is exposed in the cut at this property. This seam is about three-fourths of an inch thick, strikes N. 22° W. and dips 78° W., and cuts through both the bench gravels and the underlying bedrock. To the east of this seam the gravels are well rounded, as above described, but to the west the detritus is comparatively unsorted and bears more resemblance to till than to a fluviatile deposit. It seems certain that this seam of clay is a fault gouge and indicates that fault movements have taken place subsequent to the deposition of the bench gravels.

The gold at this property is bright and little worn, and the largest piece so far recovered was worth $1.40. The assay value is about $17.50 an ounce. Considerable heavy sand is recovered with the gold, and samples of this sand contain ilmenite, magnetite, garnet, zircon, quartz, and pyrite.

About 1,500 cubic yards of gravel had been hydraulicked and sluiced at this locality by the early part of September, 1917. Water is taken from Cache Creek and Columbia Gulch. One man was at work at this property.

Still farther upstream, where the old pack trail along the south side of the Dutch Hills crosses Cache Creek, hydraulicking of the bench deposits was in progress. This deposit, though showing plainly the effect of water action, is not nearly so well assorted as the one just described. It may be considered to be intermediate in character between the glacio-fluviatile material and the well-washed bench gravels. The deposit is about 35 feet thick, and the lower 12 feet is subangular wash. Overlying this wash is 12 feet of blue glacial mud containing angular unsorted boulders, above which lies 8 feet of the same material stained brown by surface oxidation. The bedrock is slate, which continued downstream for several hundred feet before the Eocene coal-bearing formation begins. The gold is said to be distributed in the lower 12 feet of washed gravel, but little gold is present on the slate bedrock.

The gold is coarse and rather angular. The coarsest piece so far found is valued at $9. The concentrates are composed chiefly of pyrite, with subordinate amounts of magnetite, arsenopyrite, quartz, and scheelite.

One man was working this placer. Farther downstream preparations were being made to open another bench deposit, and for this purpose a ditch 1,000 feet long had been dug, giving a head of 40 feet.

NUGGET CREEK.

Nugget Creek has been described by Capps[1] as follows:

> Nugget Creek is the uppermost large tributary of Cache Creek, joining it a few miles below its head. Its source is in the Dutch Hills, through which it flows in a wide, straight, U-shaped valley, which shows strongly the erosive action of the great glacier that once occupied it. In the hills the basin of Nugget Creek is composed of the rocks of the slate and graywacke series, and the stream flows in a postglacial canyon, which is shallow toward the valley head but narrower and deeper downstream. At the point where it leaves the slate hills the creek occupies a canyon cut 200 feet into the rocks, but at the base of the hills the slates give place to the softer rocks of the coal-bearing series, and through these the stream has widened its gorge, though the valley walls are high and steep throughout the remainder of its course to Cache Creek.

During the summer of 1917 one plant was engaged in working the creek placers below the mouth of the canyon, on claim No. 4 below Discovery, about 1,000 feet below the mouth of the canyon, along the west side of the creek. The bedrock is the coal-bearing formation, chiefly conglomerate composed of pebbles, cobbles, and boulders of a graywacke, made up of fragments of flint, chert, and slate. Overlying the bedrock is a thickness of 7 to 8 feet of gravel, in the lower part of which and on the bedrock itself is found most of the gold. The gold is coarse and is neither angular nor well rounded. The minerals collected with the gold in the sluice boxes include quartz, magnetite, cassiterite, pyrite, garnet, and zircon.

[1] Capps, S. R., op. cit., p. 58.

This deposit is mined by hydraulicking. Two nozzles are used, one for hydraulicking the gravels and the other for stacking the tailings. Water is taken from Nugget Creek at a point some distance above the canyon, and a pressure of 200 feet is thus obtained. The gravel is washed toward shear boards and thence into a line of sluice boxes. Six men were at work on this property. The owners intend to work out the creek placers on both the east and west sides of the creek and then to turn their attention to the benches on the west side. In spite of floods and adverse mining conditions, 5,000 square feet of bedrock was cleaned at this property in 1917.

One man was also at work on a bench on the east side of Nugget Creek, about 200 feet above the creek. A cut about 300 feet long and 12 feet wide had been made, and 9 feet of gravels removed. The lower 4 feet consists of heavy, well-washed boulders. Most of the gold is moderately coarse, though some of it is fine, and is rather rough. The concentrates recovered with the gold consist mainly of pyrite, with some magnetite, arsenopyrite, quartz, and a few grains of scheelite. This gravel was hydraulicked by a nozzle under a head of 50 feet, with water taken from a ditch 3 miles long.

THUNDER CREEK.

Capps[1] thus describes Thunder Creek:

> Thunder Creek heads in the slates and graywackes of the Dutch Hills, near Nugget Creek. On leaving the hills it bends to the south, following the general direction of the Cache Creek valley, and joins Cache Creek 3½ miles below the mouth of Nugget Creek. In its course below the hills it is intrenched below the level of the surrounding plateau, its valley lying for the most part in the beds of the coal-bearing series. For a portion of its length, however, it has cut through the softer sediments into a ridge of underlying slates. The bedrock, therefore, varies in different portions of the stream's course.

During the summer of 1917 one large hydraulic plant was operating on Thunder Creek, on the Battle-Axe Association ground, about 1½ miles below Discovery claim. A number of low benches along the west side of the creek have been worked out, and present operations are confined to a high bench on the east side, about 150 feet above the creek level.

The gravel deposit at this locality is 80 feet thick and resembles considerably the gravel bank on Cache Creek, above the mouth of Gold Creek, in that the gravel shows the effect of much water action. The lower 40 feet is much iron-stained, and layers of hard iron hydroxide cement near the bottom render this part of the deposit more resistant to the nozzle. Overlying the lower 40 feet is a body of fine, well-washed gravel 8 feet thick in a dark-blue clay cement, overlain in turn by a yellow gravel deposit much like the lower part.

[1] Capps, S. R., op. cit., p. 61.

This placer body is most remarkable, however, on account of the peculiar character of the underlying bedrock. The coal-bearing formation is considered to be the bedrock, though hydraulic operations have cut through it in places, exposing a much weathered phase of the slate and graywacke series, which projects upward as reefs. It is evident, therefore, that the coal-bearing formation forms only a thin mantle upon the slate and graywacke series. This mantle of soft bedrock constitutes the puzzling feature. In general, the rock at this locality is a brown clay, locally carrying thin streaks of coal, which strikes N. 40° E. and dips 35° NW., or toward Thunder Creek. Two well-defined beds of quartzose material, however, interbedded with the clay rock, and these beds carry coarse angular gold. The giant has little effect on this material, but on exposure to the air it slacks and flows away in a muddy ooze. These quartzose seams are composed largely of angular fragments of a much weathered and disintegrated gold quartz and a minor amount of well-rounded quartz pebbles, cemented in a white clayey material, which on close examination proves also to consist largely of fine fragments of quartz—that is, it is a siliceous clay. Thin seams of coal also are found in these siliceous seams, together with fine fragments of coal in all orientations, resembling washed material. A considerable proportion of the gold recovered at this plant comes from this siliceous clay, and even the adjoining brown clay contains a little gold. Two such siliceous deposits, each averaging about 12 feet in thickness, are exposed in the cut, about 50 feet apart stratigraphically. Both these deposits can be traced downstream, and in that direction they appear to lie farther apart. Seams of clay gouge that strike N. 80° W. and dip 85° N. cut these seams, as well as the other coal-bearing sediments, showing the presence of later faulting.

It is difficult to formulate a satisfactory genetic interpretation of these siliceous beds. The angular shape of the quartz fragments and particularly the lack of admixture with other detrital material point unmistakably to a minimum of transportation in the formation of these deposits. On the other hand, the presence of even a small percentage of rounded quartz pebbles indicates that the action of water was certainly a factor in their formation, and the presence of coal seams also relates them to the detrital Eocene sediments. One fact that must have an important bearing is the evidence of deep residual weathering at this locality during the deposition of the coal-bearing sediments. The slate and graywacke under these coal-bearing beds are extremely decayed, being altered almost to the condition of a clay. Some of the quartz pebbles in the quartzose seams were also found to be badly disintegrated and ready to fall apart into angular fragments when separated from the clay matrix. Moreover, the matrix, when viewed under the microscope, is seen to be composed of subangular to rounded grains of decayed cloudy quartz. All the evidence indicates that these quartzose seams are the result of deep residual weathering, with a minimum of water transportation, and the only logical inference is that some large gold-bearing quartz veins are present in the slate and graywacke series under the Eocene coal-bearing mantle at no great distance from this locality. It is not safe, however, to say that such quartz veins will be uncovered by following the quartzose beds in any particular direction, for too little is known of the conditions of deposition or of the direction from which the detrital material came. Neither is it safe to infer that the quartz veins when uncovered will prove to be comparable in content of gold with the derived detrital material, for much surface enrichment must have occurred in such deep weathering. If representative samples of the quartz fragments and pebbles could be obtained, quite free of the matrix, assays of the material might yield an approximate indication of the gold content of the original vein material.

The gold recovered at this plant is coarse and bright, and most of it is angular, only about 2 per cent being rounded. The assays range from $17.50 to $18.15 an ounce and average perhaps $18. The largest pieces of gold recovered from the gravel banks were valued at about $10 or $12, but a nugget worth $100 has been taken from the Eocene quartzose seams. The concentrates recovered with the gold are composed of quartz, ilmenite, magnetite, garnet, zircon, pyrite, arsenopyrite, cassiterite, and a few grains of scheelite.

Twelve men were employed at this plant early in the summer of 1917, but some of them left toward the end of the season. Three other operators were placer mining in a small way on the Battle-Axe Association ground—two below this plant, working low benches along Thunder Creek, and one upstream, working in the creek placers. Considerable native copper has been found in the bed of Thunder Creek at the upper plant.

FALLS CREEK.

Falls Creek is described by Capps[1] as follows:

> Falls Creek is the next important tributary of Cache Creek south of Thunder Creek. It heads in the slates and graywackes of the Dutch Hills, flows in a course roughly parallel to that of Thunder Creek, and joins Cache Creek about three-fourths mile south of it. At the point where it passes from the slates to the beds of the coal-bearing series it has developed a narrow canyon and a waterfall, which suggested its name. Gold was first mined on Falls Creek in 1905, in the canyon cut through the slates, and the stream afforded considerable production for a few years. In the narrower portion of the canyon the difficulties of diverting the creek prevented mining except for a short time in the spring when the volume of the stream was small.

[1] Capps, S. R., op. cit., p. 62.

Two small placer plants were in operation on Falls Creek in 1917. One of these plants was mining a bench placer deposit on claim No. 2 above Discovery, about 35 feet above the creek level. A hydraulic nozzle, with a head of 90 feet, was used to remove 3 feet of gravel from a slate bedrock. Water was being taken from a tributary of Falls Creek that enters from the east side. The gold is moderately coarse but contains no exceptionally large pieces. Earlier in the summer the same operator worked on an association of six claims that lie downstream from claim No. 1 below Discovery. This work was done in the creek placers by the hydraulic nozzle under a head of 125 feet. The tailings also were stacked by means of the nozzle. The gold recovered was rather fine. Four men were employed.

One other man was at work on Discovery claim on Falls Creek, just at the mouth of the canyon.

DOLLAR CREEK.

Capps [1] describes the general character of Dollar Creek as follows:

> Dollar Creek, the lowest large tributary of Cache Creek from the west, joins Cache Creek 2 miles below the mouth of Falls Creek. The geologic and topographic conditions in its basin are much like those on Thunder and Falls creeks. Dollar Creek flows from the slate hills at its head out onto the Cache Creek plateau in a sharply incised valley, which gradually becomes deeper downstream until at the mouth of the creek the valley bottom lies over 300 feet below the general level of the surrounding country. Even below the border of Dutch Hills the slate bedrock is exposed by the stream cut for some distance out upon the plateau, showing that the old slate surface on which the soft bedrock sediments were laid down was uneven.

In 1917 placer mining was being carried on at the Anna Bub mine, a group of claims extending about 6 miles along Dollar Creek. The chief work was done on claim No. 1 above Discovery.

The conditions at this property are essentially similar to those on Thunder Creek—that is, a hard bedrock composed of slate and graywacke is overlain by a gold-bearing quartzose stratum of Kenai age, which in turn is overlain by a body of gravel and glacial mud. At the site of present mining operations, on the east end of the creek, the bedrock is a deeply weathered green graywacke, which strikes N. 25° E. and dips from 70° E. to 90°. In the creek bed the bedrock consists of slate in a similar state of alteration, but more crushed and folded, and therefore with a less uniform trend.

The quartzose stratum is estimated to be 60 feet thick in the middle of the cut and contains about an equal number of fragments of quartz and graywacke which are imperfectly rounded to angular, thus showing the small amount of water transportation. The graywacke, which is more susceptible to weathering than the quartz, is the more rounded, but even the quartz at this locality shows somewhat more the effect of the action of water than the quartz on

[1] Capps, S. R., op. cit., p. 62.

Thunder Creek. A bed of lignite was seen on this deposit and others were reported. At one place in the cut a body of green graywacke, about 75 feet long and 30 feet thick, lies in and takes the place of the quartzose bed, about 10 feet of which lies both above and below the graywacke. This body may be either an exceptionally large detrital boulder lying in the quartzose formation, or a reef projecting upward from the underlying bedrock, undercut on the west side and filled with placer material, or possibly a block of graywacke faulted upward from the underlying bedrock. The first hypothesis seems more probable.

Overlying the quartzose beds is a bed of gravel, from a few inches to several feet in thickness, and ranging from fine "chicken feed" to coarse boulders. This gravel, particularly in its coarser phases, carries considerable gold, though not so much to the cubic yard as the underlying quartzose deposit. Above the gravel lies 85 feet of blue reworked glacial mud, which contains many washed boulders from 6 inches to 3 feet in diameter and carries only a little gold. The uppermost 10 feet of the placer is composed of sandy wash with some gravel, which also pans a little fine gold.

Most of the gold is recovered from the quartzose deposit and from the surface of the underlying graywacke. Within the quartzose body itself gold seems to be localized at the upper surface of thin bands of fine siliceous mud and also upon the lignite beds, both of which appear to have acted as false bedrock. It seems certain that this deposit has been acted upon by water to a greater degree than the Thunder Creek deposit, though the two deposits had essentially the same origin.

The gold recovered is both coarse and fine, and only a little of it is worn. The largest nugget so far recovered is worth $90 and is believed to have come from the gravel bed above the quartzose deposit. An $18 nugget, with well-rounded outline, was found on the surface of the graywacke bedrock. The gold ranges from $17.56 to $17.60 an ounce in value.

An unusually large amount of pyrite is recovered in the concentrates. This mineral occurs in both crystalline and massive form, ranging from minute crystals up to balls of pyrite 2½ inches in diameter. This pyrite was assayed, at the suggestion of the writer, and was found to contain 4.03 ounces of gold or about $71 to the ton. The other heavy minerals of the concentrates include magnetite, ilmenite, quartz, zircon, garnet, and cassiterite.

This property has been worked for seven years, during the last four years of which work has been done largely on the quartzose deposit. Eight men were employed in 1917. Seventy-five sluice boxes, each about 6½ feet in length, are used in the sluice line, and some fine gold is found in the very last of these. Hydraulicking is done under a head of 200 feet, and when conditions are favorable about 1,000 cubic yards of material can be put through the boxes in a day.

WINDY CREEK.

Windy Creek rises in the Peters Hills and flows in a general westerly course to join Cache Creek between Falls and Dollar creeks. It is the only tributary of Cache Creek from the southeast side of the valley that has been found to carry placer gold in economic amounts.

The placer is a bench deposit about 80 feet above the creek level, on the left side, consisting of 160 to 180 feet of glacio-fluviatile material. The lower 40 to 60 feet consists of gravel, of which the lower 6 feet is iron-stained and firmly cemented. This body of gravel is overlain by 100 feet of blue mud containing large angular boulders, and this in turn is covered by 20 feet of gravel which extends to the surface. The gravel in general averages 5 inches in diameter, though boulders from 1 to 3 feet in diameter are uncovered. The bedrock is clay and sandrock of the coal-bearing formation. Most of the gold occurs in the lower 6 feet of the deposit and is fine and flaky, the largest piece recovered being valued at $1.85. The concentrates are composed of pyrite, quartz, ilmenite, magnetite, garnet, limonite, arsenopyrite, zircon, and a little cassiterite. Pyrite is particularly abundant in the upper gravel bed. Native copper in small amount and scheelite are also reported from the concentrates.

This great bank of gravel and mud is washed down by two nozzles, of 4 and 5 inches diameter respectively, with a head of 225 feet. High and low line ditches from Windy, Little Windy (a fork of Windy), and Fox creeks supply the necessary water. Between 300,000 and 400,000 cubic yards of material was hydraulicked at this property in 1917. Four men were employed.

PETERS CREEK BASIN.

PETERS CREEK.

Peters Creek rises in the Dutch Hills, flows for 17 miles to the southeast, cuts through the Peters Hills in a narrow gorge, and then flows in a direction south of west for about 19 miles to join Kahiltna River about 5 miles below Camp 2. That part of Peters Creek which drains the Dutch and Peters hills—that is, the upper 12 miles—is the scene of placer mining in this drainage basin and is the subject of discussion in this paper. Peters Creek in its lower valley flows in a flat, open-timbered country, over the outwash of glacio-fluviatile deposits.

The chief headwater tributaries of Peters Creek are Cottonwood Creek, which enters from the northeast, and Bird Creek, which enters from the west 4 miles upstream. Poorman and Willow creeks are important tributaries of Cottonwood Creek and enter from the northwest side of the valley. Cottonwood, Willow, and Poorman creeks really drain the northeastward extension of the Cache Creek glaciated trough, whereas Bird Creek and the extreme headwater tributaries of Peters Creek cut back into the Dutch Hills. A low saddle west of the mouth of Cottonwood Creek separates Peters Creek from the headwaters of Cache Creek, and a similar low saddle separates the head of Cottonwood Creek from Long Creek, a tributary of Tokichitna River.

Capps [1] describes the physiographic features of Peters Creek as follows:

Peters Creek occupies a valley intermediate between Kahiltna and Tokichitna rivers and in its upper portion is roughly parallel to these two streams. It heads in a broad, severely glaciated, U-shaped valley in the Dutch Hills, turns at a right angle to cross the Cache Creek plateau, crosses the Peters Hills through a deep transverse trough, and enters the broad lowland of the Susitna Valley, the west edge of which it follows to its junction with Kahiltna River. Its total length is more than 35 miles. In its course through the higher parts of the Dutch Hills it flows in the bottom of the glacial trough in a channel which has been notched little or not at all into the slates and graywackes of the hills. In the more easily eroded coal-bearing beds of the Cache Creek plateau it has intrenched itself deeply in a canyon-like valley that extends headward into the slates for some distance above the mouth of Bird Creek, and a similar canyon extends for more than a mile up Bird Creek. The downward slope of the Cache Creek plateau toward Peters Hills causes the stream valley to become shallower and wider in that direction, but on entering the valley through these hills the creek again flows through a rock canyon. This second slate canyon terminates at the east border of the Peters Hills, the stream once more flowing between valley walls of the coal-bearing series and the banks gradually becoming lower downstream through the little-known area of the Susitna lowland to the south and east.

No placer mining was being done on Peters Creek in 1917, but prospecting was in progress along the benches and in the stream gravels at the lower end of the Peters Hills canyon, and below this locality. About 2 miles of claims in this vicinity have been leased by one operator, and it is expected that these placers will be thoroughly prospected in 1918.

With regard to the discovery of gold on Peters Creek and particularly with reference to the earlier work done in and near this canyon, Capps [2] writes as follows:

Gold was discovered at a number of places on Peters Creek and its affluents in 1905, and mining has been done on that creek each summer since that time. In 1911 work was in progress at two places on the main stream. At the mouth of the canyon, through Peters Hills, a short distance above the point at which the stream passes from the slates onto the soft bedrock, two men were mining on a bench about 30 feet above the stream level, where a few feet of gravel lie on a slate bedrock. Water under a pressure of 70 feet, brought by ditch and canvas hose, was used for piping the gravels into the sluice boxes. The gravels contain rather abundant boulders. At the time

[1] Capps, S. R., op. cit., pp. 63–64. [2] Idem, pp. 64–65.

the place was visited some of the ground was still frozen. The gold, which is for the most part concentrated on bedrock, is coarse, flat, worn, and somewhat rusty, and gives evidence of having traveled some distance from its source. The largest nugget found weighed 9 pennyweights, and the gold assays about $17.75 to the ounce. The ground worked in 1910 was a short distance downstream from that worked in 1911, on a bench only a few feet above the stream. The bedrock at this place is a hard, rusty dike intruded into the slates. Prospect holes in the creek gravels below the canyon show placer gold on a soft bedrock, but the gradient of the creek is too low and the ground too deep to permit mining by pick and shovel methods.

The bedrock source of the gold in lower Peters Creek is still open to queston, but this gold, like that in the other parts of this district, was doubtless derived from the quartz stringers in the slates and graywackes. In lower Peters Creek some of the gold may have come directly from the rocks of Peters Hills, through which the valley is cut, but as gold is found in the stream gravels above Peters Hills and up to the head of the stream it seems probable that the present placers are in large part the product of reconcentration of gold that was scoured from the upper tributaries of the streams by glacial ice, scattered throughout the valley, and again reconcentrated by postglacial erosion.

About three-fourths mile below the mouth of Bird Creek, at the lower end of the upper rock canyon of Peters Creek, two men were mining in 1911 near the contact of the slates with the soft bedrock. A dike of a crystalline intrusive rock crosses Peters Creek at this place. The creek gravels average about 6 feet in depth and the gold values are concentrated on or near bedrock. At the time the creek was visited in 1911 little ground had been mined, but the claims between the mouth of the canyon and Bird Creek are said to have produced a few thousand dollars altogether.

In 1916 the creek gravels on a bar west of the creek itself, about 2,000 feet below the mouth of the canyon, were mined by two men. A cut 700 feet long and 48 feet wide was worked by open-cut methods, and the material was shoveled into sluice boxes in three 16-foot cuts. The depth to bedrock was 4 feet but increased rather abruptly on each side of the cut. This cut is an old watercourse of Peters Creek. The ground is reported to have yielded $1 a cubic yard of gravel mined. Downstream from this cut a number of prospect holes have been begun, but at a depth of 5 or 6 feet water was encountered and the work ceased. The bedrock, however, is known to be composed of the Eocene coal-bearing formation, consisting of sandstone, shale, and lignitic coal beds. If the drill shows that this lower ground is favorable, it may perhaps be worked profitably by dredging. About three-quarters of a mile below the canyon the valley floor that is suitable for dredging is about 1,200 feet wide, and the canyon is a fine power site.

At the lower end of the canyon, at an elevation of 1,880 feet on the west side, the contact between the slate and graywacke series and the coal-bearing formation is exposed. The slate and graywacke formation at this locality strikes N. 70° W. and dips 30° N., though the original strike for this vicinity is probably more nearly N. 55° E., and the dip is steep to the northwest, as seen farther up in the canyon. Numerous diabase dikes cut the slate and graywacke and weather out conchoidally as "niggerheads." Quartz veinlets and stringers are also numerous.

In this vicinity—that is, at the lower end of the canyon—a small bench placer about 15 feet above the creek and embracing about 5,000 square feet was hydraulicked in 1915 or 1916. The overburden comprises 3 feet of gravel and 3 feet of overlying soil. Farther from the stream the overburden is heavier, and the work was discontinued. A similar bench about 50 to 80 feet above the creek bed was worked in 1916, and about 20,000 feet of bedrock was cleaned. It is possible that a larger hydraulic plant could be installed here and could work the deeper and heavier bench gravels at a profit.

POORMAN CREEK.

The headwaters of Poorman Creek rise in and cut through the rock of the slate and graywacke series, but the coal-bearing formation begins a short distance downstream and continues to the mouth. Discovery claim lies at the contact between the slate and graywacke series and the coal-bearing formation. Twenty-four claims, covering practically the whole creek, are now owned by two men, who are working this ground every year. In 1917 most of the work was done on claim No. 1 below Discovery and a smaller amount on Discovery and claim No. 1 above Discovery.

On claim No. 1 below Discovery a bench deposit was worked. This deposit consisted of 25 feet of gravel, lying upon a bedrock composed of Eocene conglomerate and clay shale. The lower part of the gravel is a heavier wash than the upper part and contains boulders 1 foot in diameter and some as large as 4 feet. It is also much iron stained. The upper part is made up of finer gravel and contains a number of beds of peat several inches thick. Much of the gold is found in the lower part of the gravel and on bedrock. About 2,500 square feet of bedrock, aggregating about 2,300 cubic yards of gravel, was hydraulicked on this bench in 1917. Water is usually scarce, and the hydraulicking has to be done intermittently, when the dam upstream fills with water.

Also on claim No. 1 below Discovery, but upstream from the bench deposit just described, at the mouth of Dandy Creek, a tributary of Poorman Creek, two men worked the creek gravels by hydraulicking. The bedrock is composed of Eocene conglomerate, and the overburden is about 10 feet thick. The pay streak, which ranges in width on Poorman Creek from 6 to 150 feet, is here at its widest. Some hydraulic mining also was done on Poorman Creek above the mouth of Dandy Creek.

The gold recovered from the upper end of Discovery claim and from claim No. 1 above Discovery is coarse, shotty, and rather dark in color, and some of it is much iron stained. The bench gold is similar but a little coarser. The gold from Poorman Creek at the mouth of Dandy Creek is brighter, finer, and more flaky. The bright gold is valued at $17.70 to $17.78 an ounce before melting, and the dark gold is worth somewhat more.

The concentrates taken with Poorman Creek gold are of special interest on account of their content of platinum and tin. A mixed sample of the concentrates taken from bench and creek placers showed the presence of garnet, cassiterite, zircon, magnetite, ilmenite, pyrite, quartz, and platinum. This sample, after examination by the writer, was submitted to Ledoux & Co., of New York, who report the presence of 36.54 per cent of tin—that is, the sample must have contained about 46 per cent of cassiterite. The cassiterite is present as small crystals, none of which in the sample examined exceeded a quarter of an inch in diameter. Another sample of concentrates, which weighed 647 grains and which was the very heaviest of the pannings and represented perhaps a five-hundredth concentration of the first sample, was found to have a considerable amount of platinum metals, perhaps 100 grains.

The platinum metals from Poorman Creek are essentially similar to those from Cache Creek. Two kinds were obtained—the dark-gray to bronze flat, flaky pieces, which presumably are largely platinum, and the bright, silvery, commonly crystalline variety, which is supposed to be chiefly iridium and osmium. A sample weighing 41.6 grains was picked by hand from the heavy concentrates above mentioned and was submitted to the chemical laboratory of the United States Geological Survey for complete analysis. R. C. Wells, the analyst, reports as follows:

Analysis of sample of platinum metals from Poorman Creek.

Silica, etc	1.0
Iridosmium	32.0
Iridium	11.3
Rhodium	1.4
Platinum	47.3
Iron	5.2
Gold	1.5
Palladium	Trace.
Copper	.1
Nickel	.03
Zinc and silver	Trace.
	99.83

Specific gravity of sample, 18.1.

More platinum was seen on Poorman Creek than at any other place in the Kahiltna Valley, yet even at this locality it is doubtful whether enough platinum is available to make its recovery on a commercial scale worth while.

Poorman Creek shows evidence of intensive mineralization. On Discovery claim, at the contact of the slate and graywacke series with the coal-bearing formation, the slate strikes N. 35° E. and dips 55° NW. A dike of soda rhyolite porphyry cuts the slate just above the contact, and others crop out farther upstream. The porphyry consists of phenocrysts of quartz and albite in a fine-grained, much altered groundmass of the same material, and both phenocrysts and groundmass show the result of later sericitization (replacement by sericite). Mineralized quartz veins and stringers commonly accompany these dikes. In claim No. 1 above Discovery the slate bedrock is soft, decomposed, and much mineralized by pyrite. This zone of mineralization in upper Poorman Creek appears to extend into the Willow Creek and Long Creek basins and must have had a strong influence on the placers at those localities. It can not be doubted that some of the placer gold on Poorman Creek has been concentrated directly from sources in mineralized bedrock subsequent to the retreat of the ice, although concentration from the glacio-fluviatile deposits certainly took a major part in the process. One fact that bears on the localized origin of the gold on Poorman Creek is the recent discovery of a gold-bearing gravel channel in the coal-bearing sediments just above their contact with the slate and graywacke series. The value and extent of this channel have not been investigated, but the very fact of its existence indicates that some of the gold was localized in this drainage basin, for no means of transportation other than water was effective in the coal-forming epoch. The origin of the platinum metals is not known.

WILLOW CREEK.

On Willow Creek placer mining was carried on by one operator at two different localities—on Ruby Creek, a headwater tributary of Willow Creek that enters from the east side, and on the main Willow Creek some distance downstream.

On Ruby Creek, where most of the summer's work was done, the present stream gravels were being worked in a pay channel at least 30 feet wide, in which 4 feet of gravel lies upon Eocene coal-bearing bedrock. The gold is found largely on the bedrock. About 400 feet of the creek bed, or about 12,000 feet of bedrock, was worked by the hydraulic nozzle in 1917. On Willow Creek the gravel was shoveled into boxes.

The gold is rather fine, flaky, and bright. It resembles very much the gold from Poorman Creek at the mouth of Dandy Creek, though it is a little finer. Platinum in small amount was noticed with the gold, though it may be considered negligible as a commercial product. The concentrates collected with the gold in the sluice boxes are made up of garnet, magnetite, ilmenite, zircon, cassiterite, pyrite, and quartz. A sample of these concentrates was submitted to Ledoux & Co., of New York, who report the presence of 20.03 per cent of tin, hence the concentrates must consist of about 25 per cent cassiterite. The cassiterite is of the same character as that found on Poorman Creek—that is, it consists of small crystalline grains.

On Gopher Creek, another headwater tributary of Willow Creek, which enters from the west side, another man was hydraulicking the creek gravels. A cut 1,200 feet long and 40 feet wide had been worked, exposing Eocene bedrock in the lower part of the cut and slate bedrock in the upper part. At the upper end of the cut two subsidiary pay channels that cross the main channel were discovered, and plans for future work involve the working of a left-side bench in the hope of finding a continuation of these channels. The overburden in the cut is about 4 feet thick, and the gold lies chiefly on bedrock. A preglacial conglomerate, composed of greatly decayed pebbles of all kinds, the largest 18 inches in diameter, was observed at the upper end of the cut. The gold is rather fine, the largest nugget so far recovered being valued at $4. An interesting exhibit from this placer consisted of a specimen in which native gold and lead were intimately intergrown.

BIRD CREEK.

At the lower end of Bird Creek, about two claim lengths from the mouth of the creek, one man was engaged in 1917 in working a bench deposit on the north side of the creek and about 50 feet above it. The bedrock is composed of slate and is overlain by a gravel deposit which is 8 feet thick at the north side of the cut and decreases to a few inches toward the creek. The bedrock is very uneven, owing partly to the high tilt of the slate and partly to erosional potholes. The best paying material is found mainly on the bedrock. The gold is coarse, dark, and iron stained. The largest nugget so far recovered weighed 1 ounce. A soda rhyolite porphyry dike crosses Bird Creek just above the bench, and numerous quartz stringers occur in the slate bedrock. Mining is done by means of a hydraulic nozzle, but the bedrock is picked, cleaned, and shoveled into the boxes by hand.

One claim length farther upstream on Bird Creek another man was at work on the St. Louis bench, on the south side of the creek. The bench is 50 feet above the creek level, and a 40-foot head is used in hydraulicking the deposit.

The gold placer body on the St. Louis bench is quite different from any in the Peters Creek basin previously described, and so far as any workable placer in the Cache Creek district is concerned it is correlatable only with the glacio-fluviatile auriferous deposit on Windy Creek, in the Cache Creek basin. This deposit seems to be purely of glacio-fluviatile origin and consists of 50 to 75 feet of glacial mud and angular to subangular boulders of all sizes, resting upon a much broken, decayed, and uneven-surfaced slate. The upper 10 feet is stained yellowish brown from the effect of surface oxidation. Gold is distributed rather evenly throughout the placer body, with no particular concentration at or near bedrock.

The gold is both coarse and fine but is almost universally angular, only about 1 or 2 per cent being worn. One pretty specimen of dendritic gold and others of wire gold, all quite unworn, have been recovered. As a rule the gold is dark in color, and the largest nuggets are deeply iron stained. A piece of gold worth $12 is the largest so far found.

The concentrates contain about 95 per cent of pyrite, both in cubical and massive form. The few remaining constituents include arsenopyrite, magnetite, and a very little scheelite. A little native copper is also found occasionally in the concentrates.

TOKICHITNA BASIN.

LONG CREEK.

Long Creek heads against Cottonwood and Poorman creeks and flows northeastward for about 6 miles to join the Tokichitna a short distance above Home Lake. Its drainage basin lies entirely within the area of the slate and graywacke series. In 1917 one man was engaged in placer mining on Canyon Creek, a small headwater tributary of Long Creek that enters from the west. Both Canyon Creek and Long Creek above the mouth of Canyon Creek cut through the slate in gorges.

The valley floor of Canyon Creek in the gorge is from 8 to 30 feet wide, and the pay channel has a greatest width of 7 to 15 feet, averaging perhaps 6 feet but narrowing in places to 1 foot. A cut 600 feet long in this channel was mined in 1917, the placer being shoveled into sluice boxes. At the upper end of the cut the gravel is only 2 feet thick, but it increases to 8 feet at the lower end. Most of the gravels are in the form of cobbles averaging 6 inches in diameter, though boulders as large as 2 feet are present. The gold, which is coarse, lies for the most part on or near bedrock, and much of it is iron stained. The largest nugget found was worth $34, but pieces worth from $1 to $3 are common. A few small grains of platinum were observed with the gold and in the heavy sands.

The concentrates include magnetite, ilmenite, garnet, zircon, cassiterite, specularite, quartz, and occasionally a little platinum. In a sample of the heaviest of these minerals, panned from the general run of concentrates, some fine specimens of crystalline cassiterite, with quite unworn edges, were noticed.

At the lower end of the cut on Canyon Creek a zone of soft, clayey decomposed slate about 50 feet wide is exposed, which is cut by quartz stringers and visibly mineralized by pyrite. This zone trends N. 15° E., the general trend of the slaty cleavage at this locality. At the head of Long Creek acidic dikes and numerous quartz stringers cut the slate. It is believed that much of the Long Creek gold in the present creek placers has been concentrated directly from mineralized bedrock in this vicinity, rather than from the glacio-fluviatile deposits.

KAHILTNA RIVER.

In 1917 prospecting for gold and platinum placers was carried on at two localities on Kahiltna River—one about 3 miles by stream below the mouth of Peters Creek, where five men were at work; the other 30 miles downstream, where seven men were employed.

The bedrock at the upper camp is the coal-bearing formation, composed of iron-stained sandrock, blue clay with included woody material, and numerous lenses of fine iron-stained conglomerate. This formation is exposed above and below the camp in the bluffs along the river. Beds of lignitic coal are also present in this vicinity. The extreme width of the gravel channel is several hundred yards, but the boundaries of a definite pay channel had not yet been determined at the time of the writer's visit. Along the east side of the river, near the water's edge, the gravel is 6 feet thick, but farther back, in the timber, it is 9 feet to bedrock. Seven drill holes had been sunk to bedrock, and the gravels were found to range from a few inches to 2 feet in diameter. There is said to be a heavy concentration of black sand in the gravel. The gold is very fine, as the coarsest pieces are worth 1 or 2 cents, and it is said to be worth a trifle over $18 an ounce after melting. Platinum is also reported in these gravels.

Mining on a very small scale has been carried on intermittently for a number of years along the bars of Kahiltna River, and some fairly rich spots have been found, particularly on the bars projecting into the river at sharp turns. Sholan Bar at this upper camp contains some surficial placer of this character. Thirty pans of gravel, panned for the writer, contained considerable fine gold and a few grains of platinum. The concentrates taken in these 30 pans consisted of garnet, magnetite, ilmenite, zircon, and quartz. It is believed by the present prospectors that a good chance exists of finding similar amounts of gold, but more particularly platinum, in the deeper gravels extending to bedrock. The content of free platinum, however, appears to be small, and the writer finds no evidence to support the idea that platinum is present in chemical combination with other minerals of the concentrates.

At the lower camp on Kahiltna River seven men were engaged in prospecting and related work. Forty-five claims are owned and options are held on 36 others in the vicinity of this lower camp by the same owners as at the upper camp. Prospecting has been done chiefly at the bars along the river by hand methods and by means of two gasoline drills of 4 and 8 horsepower. Thirteen drill holes had been sunk by September, 1917.

The lower camp is on the west side of Kahiltna River just above the mouth of Beaver Creek, a small tributary entering the river about 8 miles above the Yentna. At Round Bend Bar, on the east side of the Kahiltna about 8 miles above the camp, about $1,500 in gold was rocked out by two men from about 100 cubic yards of gravel taken from the bar in 1908. Some platinum was found with the gold. The concentrates included magnetite, ilmenite, hematite, limonite, quartz, garnet, zircon, and a little platinum. Each cubic yard of gravel is said to have contained 3 pounds of black sand. About 0.1 cubic yard of gravel from the water's edge was panned for the writer and found to contain some fine gold and a few grains of platinum. Four claims are held at Round Bend Bar and vicinity, and seven drill holes have been sunk, but none of them have reached bedrock.

At Boulder Bench, on the same side of the river and downstream from Round Bend Bar, a small open cut about 600 square feet in extent has been made in the gravel bank about 15 feet above the river's edge. This has been prospected at different times since 1907. The gold-bearing bedrock is exposed at a height of about 6 feet above the river, but a layer of hardened gravel and clay about 9 feet above the river has been used as a false bedrock. The average amount of gold to the cubic yard from this cut indicates a commercial gold placer, but the extent of the pay gravel is not known. A little platinum also was found here in pieces as much as one-eighth inch in diameter. No drill holes have been sunk at Boulder Bench.

Other bars along the Kahiltna also carry some gold. At Leslies Bar, about 2 miles above the camp, on the west side of the river, four men working in 1907 made $13 a day for each man, and another bar near by produced $500 in 1906. At both these localities, however, the pay gravel was within 1 foot of the surface. One drill hole was put down 9 feet on Leslies Bar in 1916 and is said to have shown favorable conditions. Five drill holes were sunk in 1917 on the Red Hill Bar, across the river from the Round Bend claims.

COAL DEPOSITS.

The coal-bearing formation, as shown on the accompanying map (Pl. VI), includes many beds of lignitic coal, which crop out at numerous localities in Kahiltna Valley. These coal beds range in size from mere stringers a few inches thick up to beds 14 feet thick. The coal is classed as lignite, though it varies somewhat in grade. There is little promise that such fuel will ever have a market, even in the near-by Cook Inlet district, because of the presence of better coal in the Matanuska Valley which can be more easily procured. Yet a good opportunity exists to use this coal locally for fuel and power, and this is now being done by the Cache Creek Mining Co.

A number of coal beds are exposed on Short Creek, a tributary to Cache Creek. Probably the best one is a bed of high-grade lignite about 8 feet thick, without partings, near the head of the creek. An entry 100 feet long was driven into this coal seam, and it was mined for a period by the Cache Creek Dredging Co., but the upkeep of the wagon road up the canyon of Short Creek was found to be too costly and the work was abandoned.

At present the company is mining another coal bed at the mouth of Short Creek, about half a mile below the mouth of Falls Creek. About 1,000 tons a month was mined during the summer of 1917, most of which was used for generating power on the dredge. Some of it, however, was used for heating in the camp. Ten men, including a foreman, were employed. This coal bed strikes about west, or perhaps N. 80° W., and dips about 10° S. An entry 475 feet long, with a height of 6 feet in the clear, has been driven on the strike of the seam, and rooms have been turned off at regular intervals to the northwest, at an acute angle with the tunnel, in order to avoid working directly up the dip. So far eight rooms have been turned off, the largest of which, No. 8, is 200 feet long. Gravity haulage is employed in the rooms. A tipple with a capacity of 50 tons has been built at the mine entry, and from this tipple coal is dumped into wagons and then hauled downstream to the dredge on Cache Creek.

The coal seam is rather uniform in thickness, averaging 5 feet 2 inches. About 14 inches of coal is left in the roof to support the overlying clay, and the rooms are therefore 4 feet high. No clay partings are present, but a streak about 4 inches thick in the upper half of the seam is of noticeably lower grade.

Another promising bed of coal is exposed along the east bank of Peters Creek about 2½ miles below the mouth of the canyon. This bed contains a fairly high grade coal, which is reported to do fairly well for blacksmithing. The strike of the bed is about N. 45° E. and the dip about 70° NW. The shale footwall is exposed, but the hanging wall is covered by slide. About 10 feet of coal is exposed, but the total thickness of the bed is probably 12 or 14 feet.

CHROMITE DEPOSITS IN ALASKA.

By J. B. Mertie, Jr.

Deposits of chromite have been known in Alaska for a number of years, but they became of economic interest only in 1917, when the relatively high price of the ore recalled them to the attention of mining men, with the result that ore is commercially mined at one property.

The chromite deposits of present economic interest are at the southwest end of Kenai Peninsula, in two areas, one along the north shore of Port Chatham and the other at Red Mountain, about 16 miles to the northeast. (See fig. 3.) Both deposits occur in bodies of altered peridotite, and, so far as known, these are the only bodies of peridotite in this vicinity, but exploration farther from the coast, in the mountains, may reveal others.

Peridotite of the same kind also occurs in large and small masses at several other places in the area between Yukon and Tanana rivers, and at Livengood, in that area, there is a deposit of chromite, but the ore in the interior of Alaska could not be mined profitably except when prices are very high.

The chromite of southwestern Kenai Peninsula occurs in lens-shaped bodies that range in thickness from a few inches to 20 feet and that lie in attitudes ranging from horizontal to vertical. None of the lenses appear to be more than 150 feet long, and most of them measure considerably less. The ore is not of uniform grade. Some of it averages 50 per cent of chromic oxide, and some is a mixture of chromite and peridotite, the leanest part of which may yield only 5 to 10 per cent of chromic oxide. All gradations between these extremes are found.

The deposit now being mined is on a spit at the southeast end of a peninsula known as Claim Point, which projects southeastward into Port Chatham. This peninsula measures about 4,000 feet from east to west and about 2,200 feet from north to south, and is joined to the mainland by a neck of land about 200 feet wide. The rock of Claim Point is entirely peridotite, which crops out also on the mainland to the north and continues southward into Port Chatham for an unknown distance. The known area of peridotite here covers about three-fifths of a square mile.

The ore body is almost completely covered by water at high tide, so that mining must be done between low and half tide. The deposit is in a vertically placed lens, which has a length of about 100 feet and a maximum width of 20 feet.

About 800 tons of ore containing from 46 to 49 per cent of chromic oxide was mined in 1917, and about as much more remains in sight

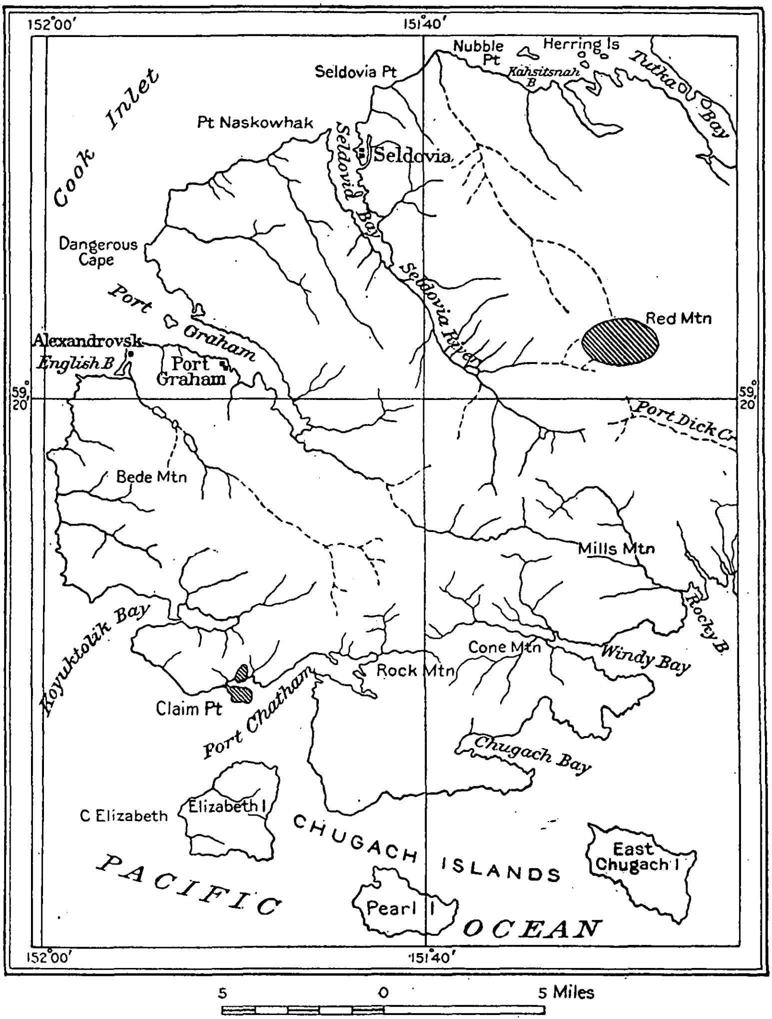

FIGURE 3.—Map of the Seldovia district. Shaded areas show location of chromite deposits.

above half tide. Ultimately it will be necessary to work from a shaft or cofferdam and hoist ore to the surface, a method that will increase materially the cost of mining.

Probably the upper half of the deposit has been removed by erosion. If so, and if the deposit becomes thinner downward for 50 feet and the ore has a specific gravity of 3.9, only 4,000 or at most 5,000 tons remains below the level of half tide.

Several other lenses of high-grade ore, none more than 3 feet thick, occur in this vicinity, as well as a number of bodies of low-grade ore that range in thickness from 5 to 20 feet and in content of chromic oxide from 5 to 15 per cent. At one place on the north side of Claim Point, near the crest of the peninsula, there are four lodes that stand nearly vertical, and the owners are considering the feasibility of driving a tunnel from a lower point on the hillside to crosscut them. These four bodies should produce, when concentrated, about 3,000 tons of 50 per cent ore, but it is likely that the tunnel contemplated might also reveal other deposits. There should be available at Claim Point at least 15,000 tons of chromite ore of a grade containing 50 per cent of chromic oxide.

The freight rate on ore from Port Chatham to Seattle is $3.50 a ton, and from Seattle to an eastern smelter is about $12 a ton, to which must be added the cost of lighterage to the steamship anchorage in Port Chatham or lighterage to the wharf at Port Graham.

The body of peridotite at Red Mountain is much larger than that at Claim Point but is more difficult of access, and the grade of the ore there is not so well known. The peridotite covers about 3 square miles and contains many stringers and lenses of chromite ore, of both high and low grade. The largest deposit observed was a lenticular body of high-grade ore not more than 75 feet long, that had a maximum thickness of 8 feet at the center and contained probably not over 1,000 tons. At this place there are many other smaller deposits and perhaps some as large or larger, all of which should yield at least as much chrome ore and possibly several times as much as the body at Claim Point. On the other hand, these ores occur at an elevation of about 3,000 feet and at a minimum distance of 6 miles from tidewater, from which much of the route lies through a precipitous and densely vegetated country. In winter the ore might be sledded out to tidewater, but in summer it would have to be carried by a tram.

GEOLOGIC PROBLEMS AT THE MATANUSKA COAL MINES.

By G. C. Martin.

INTRODUCTION.

A brief visit was made to the Matanuska coal fields from August 26 to 31, 1917, for the purpose of reviewing the mining developments that have been undertaken since the detailed geologic survey[1] of that field was made and of conferring with Mr. Sumner S. Smith, the engineer in charge of the coal-mining operations of the Alaskan Engineering Commission, in regard to structural and other geologic problems that had come up in connection with mining.

MINES ON ESKA CREEK.

GENERAL GEOLOGY.

The mines on Eska Creek are in the NE. ¼ NE. ¼ sec. 16, T. 19 N., R. 3 W., which is part of leasing block No. 7. At the time that the field work was done the workings included nine openings, all of which are drifts from natural exposures of coal beds near the level of the creek. Three of these openings were productive mines, and the others included prospect openings, abandoned mines, and mines that had not yet become productive. (See fig. 4.)

The coal beds that are being mined and prospected on Eska Creek are exposed in a discontinuous series of low cliffs that extend intermittently along one or the other bank of the creek but generally not on both of them. Between these cliffs are covered slopes, and back from them are gravel terraces and gently sloping areas covered with glacial drift and containing few if any exposures of rock. The outcrops on Eska Creek show that the creek cuts across two eastward-trending belts of gently dipping coal-bearing rocks—a southern or northward-dipping belt, in which the Emery, David, and Kelly drifts are situated, and a northern or southward-dipping belt, in which the Maitland, East Eska, Shaw, Martin, and West Eska drifts are situated. The southern belt lies north of and is separated by a concealed interval from Cretaceous rocks that are older than the coal. The northern belt lies south of and merges into or is separated by a fault from a belt of intensely deformed coal measures

[1] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley: U. S. Geol. Survey Bull, 500, 98 pp., 19 pls., 1912.

that probably is practically barren of workable coal and that extends northward into the great zone of faulting on the southern border of the high mountains. For immediate practical purposes only the

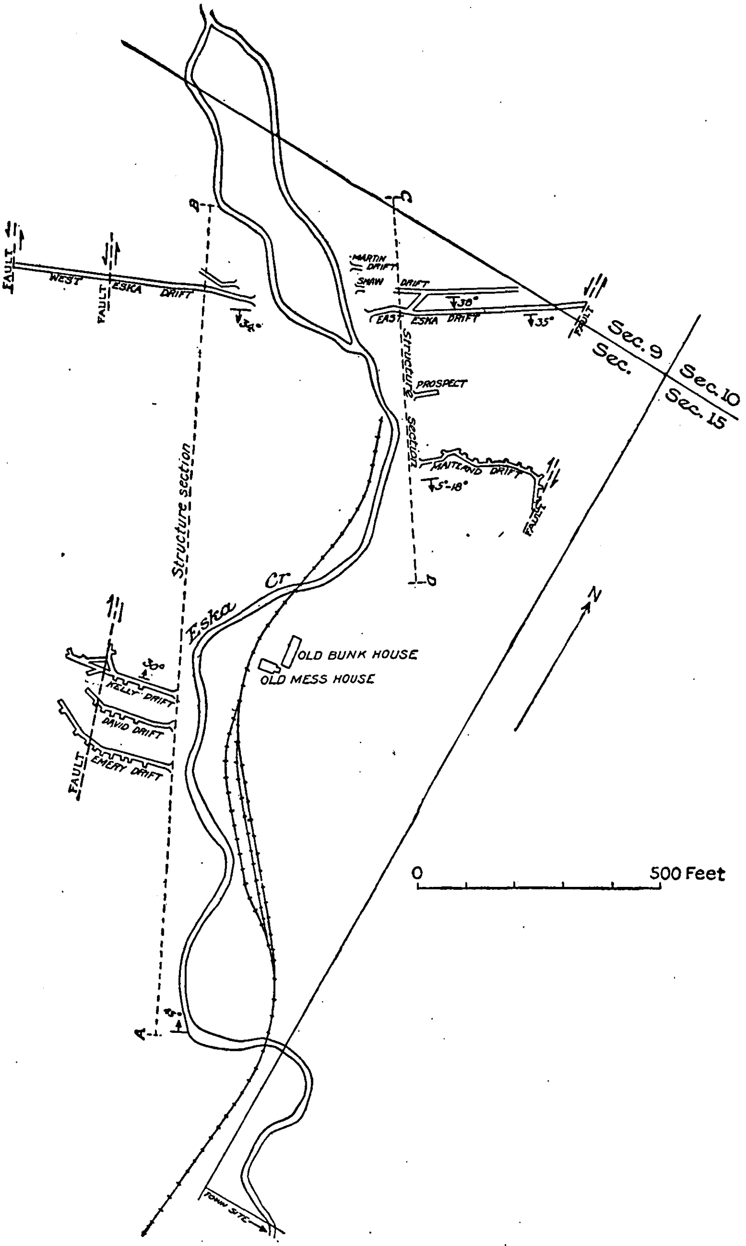

FIGURE 4.—Map of the Eska Creek coal mines.

two gently dipping belts of coal measures need to be considered in further detail. As shown below (p. 273), these belts may be fault blocks or may be the opposite flanks of a syncline. The rocks of each belt are cut by faults, some of which show at the surface, whereas others have been encountered in mining. Nowhere has the magnitude of any of the faults been determined.

The southern or northward-dipping belt of coal-bearing rocks extends from a point near the northwest corner of Eska town site to a point between the Kelly drift and the upper railroad bridge just above the old mine camp. The strike is in general N. 60°–75° E., and the dip 30°–40° NW. Near the northern edge of this belt the following section is exposed:

Section on west bank of Eska Creek opposite old mine camp.

		Ft.	in.
Sandstone.			
Coal (Kelly seam)	Coal	2–2½	
	"Clod"	4–6	
	Coal (average)	3	
Concealed		10±	
Shale (partly concealed)		6	
Sandstone		5	
Gray shale with some ironstone		4	
Shale		5	
Coal (David seam)	Coal	2	6
	Yellow shale		1½
	Coal		10
Carbonaceous shale		6	
Ironstone			4
Gray shale		5	
Ironstone			6
Gray shale		2	
Ironstone			6
Gray shale		3	
Ironstone		½–2	
Gray shale		4	
Ironstone		½–1	
Gray shale		2	
Ironstone concretions			6
Gray shale		5	
Sandstone lens (grades into shale)		5	
Shale with a few ironstone nodules		12	
Shale with a little coal		3	
Shale and coal		2	
Coal (Emery seam)	Bone		6
	Coal	2	3
	Soft shale		1
	Coal		4
	Soft shale		2
	Coal		10

These beds strike about N. 80° E. and dip 30° N. Their relations are shown graphically in figure 5.

Beneath this section the rocks are mostly concealed. Near the bridge at the lower end of the railroad yards is an outcrop which shows about 4 feet of impure coal that strikes N. 60° E. and dips

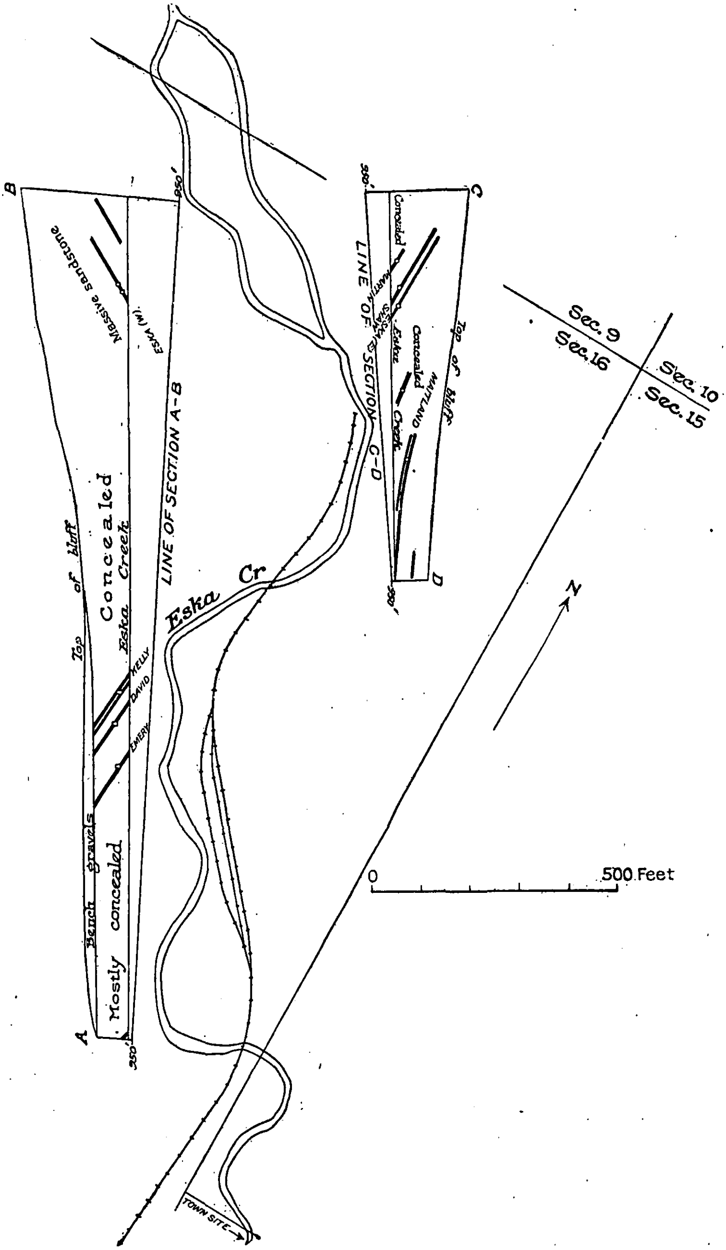

FIGURE 5.—Structure sections at the Eska Creek coal mines.

45° N. This bed should be about 300 or 400 feet below the Emery seam, if there is no fault in the concealed interval. On the east bank of the creek near the northwest corner of Eska town site is an outcrop of shale, in part coaly, that should be several hundred feet lower than the coal last described.

The next known outcrops, down the creek, are of Cretaceous sandstone in the bluff near the northeast corner of sec. 21. The intervening gap, about half a mile wide, would contain the contact of the coal measures with the underlying formation. There are reasons for suspecting that this contact is locally along a fault. The base of the coal-bearing formation is certainly not exposed along the creek, and apparently it is not exposed in the near-by hills. Consequently it is not possible to estimate the position of the coal beds just described relative to the base of the coal-bearing formation, or to state whether there are other coal beds beneath them.

The northern or southward-dipping belt of coal-bearing rocks extends from the upper railroad bridge to the vicinity of the main forks of Eska Creek near the northeast corner of the SE. ¼ SW. ¼ sec. 9. The general strike is N. 60°–90° E., and the dip 5°–35° S. The discontinuity of the exposures, the presence of faults, and the presence of disturbances that may be caused either by faulting or by slumping and tilting of blocks of strata on the steep hillsides make it impossible to describe a complete section or to determine the thickness of strata and the number and position of the coal beds. The exposed strata are at least 300 feet thick and include four or more coal beds, among which are those opened at the Maitland, Eska, Shaw, and Martin drifts. Detailed measurements and discussions of the several incomplete local sections are given on pages 274-275. The base of the coal measures is not exposed in this belt, and there is no information available in regard to the total thickness of the coal measures or the number of the coal beds beneath the surface.

The contact of the two belts of gently dipping coal-bearing rocks lies in a concealed interval near the upper bridge in the railroad yards. Because of this concealment it is impossible to state whether these belts lie on opposite flanks of a syncline or are fault blocks. As their contact lies approximately in line with the synclinal axis of Wishbone Hill, it might be assumed that the synclinal relation is the more probable. However, the synclinal structure of Wishbone Hill is shown only in exposures of the Eska conglomerate, which is less disturbed than the coal measures and overlies them possibly in unconformable relation, and consequently an unfaulted syncline in the conglomerate need not necessarily extend east to Eska Creek or down into the coal measures. Furthermore, the locality here discussed is nearer in line with the possible fault that marks the southern boundary of the conglomerate mass of Wishbone Hill than it is with the synclinal axis of the hill itself. The strata exposed on the opposite sides of the concealed interval are not sufficiently characteristic (see p. 274) to furnish reliable evidence as to whether they are identical. It must be concluded, therefore, that either a fault or a synclinal axis is possible at this locality. The writer believes that the fault is more probable, but the actual relations can be determined with absolute certainty only by following the coal underground through the concealed interval.

The northern or southward-dipping belt of coal-bearing rocks appears in a discontinuous series of exposures that extends along the east bank of the creek for about 600 feet, beginning near the railroad bridge, or about 400 feet above the Kelly drift. (See fig. 5.) The southernmost and presumably the highest (stratigraphically) of these exposures is the following:

Section on east bank of Eska Creek near upper railroad bridge.

		Feet.
Shale.		
Coal, with shale partings		4
Sandstone and shale		20
Sandstone		7
Shale		3
Coal (Maitland seam)	Coal	3
	Shale	3–6
	Coal	3

It is possible that the Maitland seam is the same as the Kelly seam. This correlation is suggested by the general similarity in section of the coal seams themselves and by the presence of a massive sandstone above the Maitland seam like that above the Kelly seam. The writer believes that this correlation should be considered as probable, though not proved.

The strata are mostly concealed for a distance of about 300 feet up the creek from the Maitland drift. About 150 feet above the Maitland drift is an old prospect opening that shows about 3 feet of coal. This coal bed and the strata in the concealed intervals on each side of it should lie below the Maitland seam and have a thickness of 50 to 150 feet unless they have been faulted. The probable presence of at least one fault in this interval is indicated by the fact that the Eska coal, which has been opened (see section below) near the northern end or at the stratigraphic base of this concealed interval, is not overlain by the massive cliff-making sandstone and other strata which overlie the Eska coal on the west bank of the creek, nor is there room for these strata in the concealed interval. (See section, p. 275.)

At the upper end of this concealed interval is an exposure in which the East Eska, Shaw, and Martin drifts have been driven. The section at this locality is as follows:

Section on east bank of Eska Creek at upper end of railroad spur.

	Ft.	in.
Sandstone	20	
Shale	5	
Coal (Eska seam)	2	6

		Ft.	in.	Ft.	in.
Shale				9	
Coal (Shaw seam)	Coal	1	1		
	Shale		1		
	Coal		10½		
	Shale		1½		
	Coal	2	0		
				4	2
Concealed (partly shale and sandstone)				25±	
Coal (Martin seam)				3±	

Above this point the best exposures are on the west bank of Eska Creek, where there is a discontinuous series of exposures that extends north from a point opposite the upper end of the preceding section. There are no exposures on the west bank of the creek between this point and the Kelly drift, a distance of about 800 feet. At the southern end of these exposures a drift (West Eska) has been driven on the Eska seam. The following section is exposed at this locality:

Section in cliff on west side of Eska Creek opposite upper end of railroad spur.

		Ft.	in.	Ft.	in.
Sandstone (cliff)				75±	
Soft sandstone				9	
Shale with a little coal				2	
Concealed (shale and sandstone)				64	
Shale				16	
Coal (Eska seam)				3	
Shale with coal streaks				5	
Shale				14	
Carbonaceous shale				2	
Shale and coal				5	
Coal (Shaw? seam)	Coal		11		
	Shale		3		
	Coal		10		
	Shale		3		
	Coal		10		
	Shale		1		
	Coal	1	9		
				4	11
Shale				5	
Ironstone				1	
Shale				5	
Coal (shaly)				2	6
Coal				2	
Shale				5	
Coal				2	2
Shale with ironstone concretions				23	
Coal				1	
Shale				6	
Coal				1	
Shale				10	

The thick sandstone at the top of this section forms a cliff that extends continuously westward along the top of the bluff west of Eska Creek from the West Eska drift to a point near the northwest corner of the NE. ¼ sec. 16. Beneath this sandstone cliff are gentler slopes, generally covered with talus and soil, in which reliable exposures are by no means numerous or extensive. Some of the exposures

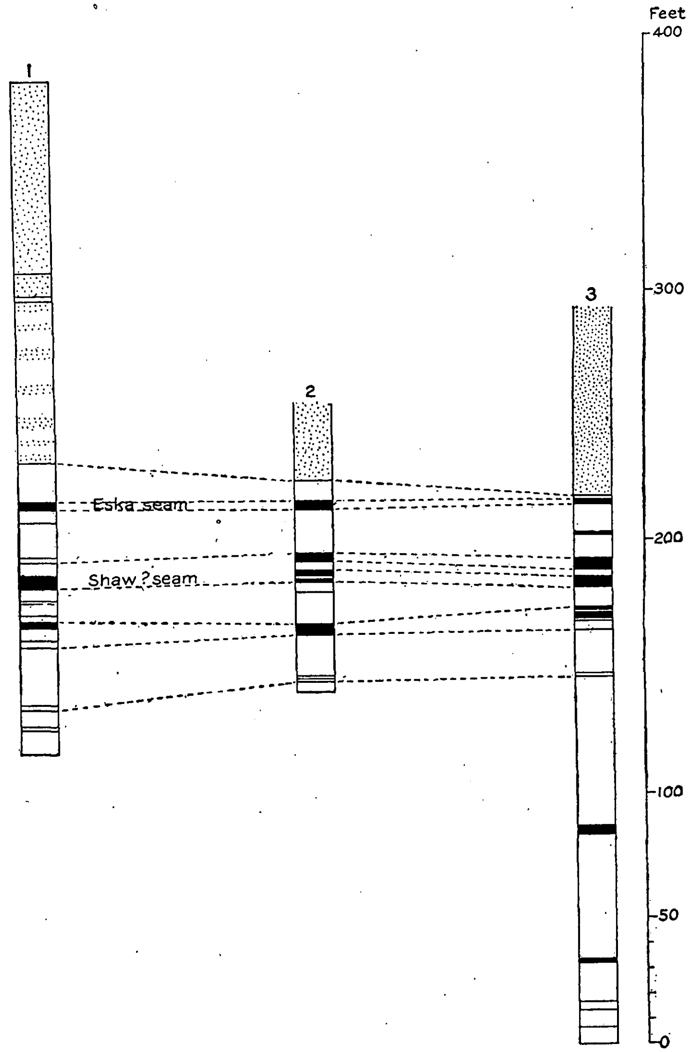

FIGURE 6.—Hypothetical correlation of coal beds on west bank of Eska Creek, in the N. ½ NW. ¼ sec. 16, T. 19 N., R. 3 E. 1, Cliff near West Eska drift; 2, about 1,250 feet below forks; 3, about 1,100 feet below forks.

at the base of the bluff apparently indicate faults and local folds that were not seen in the sandstone of the cliff. Some of the exposures are certainly blocks that have been tilted or have fallen on the steep hillside. A larger number of the exposures may either be rocks in place or tilted or fallen blocks. If they are rocks in place the soft shales and coal beds may have yielded more than the massive sandstone under the forces that caused the folding and faulting, or the sandstone may overlie the coal-bearing shales with an undetected unconformity and for that reason does not partake of all their structural complexity, or it may be that there is an undetected fault along the base of the sandstone cliff.

The writer has published elsewhere[1] a section which shows the strata beneath the massive sandstone at a locality about 1,200 feet above the West Eska drift. In another section[2] he shows the strata including and underlying the same sandstone at a locality about 1,350 feet above the West Eska drift.

It will be assumed, in the absence of evidence to the contrary, that there is neither an unconformity or a fault at the base of the sandstone. Therefore, if the coal beds are persistent the coal beds in section 36 and those in the upper half of section 37 may possibly be correlated with the coal beds exposed in the cliff near the West Eska drift, as is indicated in figure 6.

A short distance above the placé where section 37 was measured several faults are exposed in the west bank of the creek. One of these faults shows considerable displacement. This fault possibly marks the northern edge of the block of rock that forms Wishbone Hill. Just north of this fault several northward-dipping coal beds are exposed, of which the following section was measured:

Section on west bank of Eska Creek 1,450 feet above West Eska drift.

	Ft.	in.
Sandstone.		
Coal (lenticular)	4	
Shale	14	
Coal	2	6
Shale	2	
Coal	2	6
Shale	8	
Coal		4
Shale		8
Coal	2	
Shale	1	
Coal	1	
Shale	20	
Coal (with some shale)	2	
Shale	5	

The northward dip at this locality is believed to be a local feature caused by drag on the fault plane. The next exposures up the creek are of southward-dipping strata and do not show coal beds.

The exposures on the west fork of Eska Creek, above the main forks in the SE. ¼ SW. ¼ sec. 9, are of closely folded and much-

[1] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 84-85, section 36, 1912.

[2] Idem, pp. 85-87, section 37.

disturbed rocks, in which several thin coal beds and stringers of coal were noted. The thickest coal seen is near the northern boundary of sec. 9 and is recorded in section 38.[1] This exposure is possibly the same as that of which Mr. Sumner S. Smith has furnished the following measurement:

Coal bed on west bank of Eska Creek near the north boundary of sec. 9, T. 19 N., R. 3 E.

	Ft.	in.
Dark-brown shale that contains ironstone nodules.		
Mixed sandstone and shale	1	10
Intrusive (?)	2	6
Dark-brown shale that contains petrified wood and nodules	6	
Dirty coal that carries bands of sulphur	1	4
Dark shale	1	4
Very hard black coal	2	2
Shale		1
Very hard black coal		3
Shale		1½
Very hard black coal	2	10
Shale that contains concretions		10
Strike, N. 70° E.; dip, 73° S.		

The writer believes that any coal beds that may occur in this belt of intensely deformed rocks on the border of the high mountains are so inaccessible and probably are so lenticular that they have no immediate value.

PROGRESS OF MINING.

The workings on Eska Creek consisted, in the summer of 1917, of nine openings, three of which (the Kelly, David, and Shaw drifts) are in the northward-dipping belt of coal measures, and the others (the Maitland, East Eska, Shaw, Martin, and West Eska drifts, and the unnamed prospect opening between the Maitland and East Eska drifts) are in the southward-dipping belt of coal measures. Some of these mines (the Kelly, David, Emery, and Maitland drifts and perhaps some of the others) were formerly worked by lessees. The Kelly, David, and Emery drifts had been abandoned, because the coal had been cut off by a fault, up to which it had been worked out above drainage. In the West Eska and Martin drifts main entries were being driven preparatory to mining. The Maitland, East Eska, and Shaw drifts were producing coal in an aggregate average amount of about 100 tons a day. In addition to the fault that cut off the coal in the Kelly, David, and Emery drifts, a fault cuts off the coal in the Maitland drift, and since the writer left the field faults have been encountered in the East Eska, Shaw, and West Eska drifts. None of these faults show at the surface. The position of each of these faults in the mines is indicated in figure 4. The extent of the faults beyond the present workings is not known.

[1] Martin, G. C., and Katz, F. J., op. cit., p. 87.

CHICKALOON RIVER.

The coal outcrops on Chickaloon River are situated in the S. ½ NE. ¼ sec. 25, T. 20 N., R. 5 E., and in the SW. ¼ NW. ¼ sec. 30, T. 20 N., R. 6 E., which constitute part of leasing block No. 12.

Chickaloon River enters the general area of the Matanuska coal field (the Matanuska Valley proper) in the northern part of T. 20 N., R. 6 E. After flowing through a gorge cut in the Eska conglomerate in sec. 5, it comes out into a more open valley, where there are discontinuous exposures, first on one bank and then on the other. These exposures, from the lower end of the conglomerate gorge in sec. 5 to the point where the river turns west in the SW. ¼ NW. ¼ sec. 30, consist of steeply folded rocks that belong to the Chickaloon formation and of several intrusive masses. The Chickaloon formation underlies the Eska conglomerate and includes the coal beds of the Matanuska field. However, it is not everywhere coal bearing, and none of the exposures just mentioned contain any coal. The outcrops on the north or west bank of Chickaloon River in its east-west course from the eastern boundary of the SW. ¼ NW. ¼ sec. 30, T. 20 N., R. 6 E., to the bend just above the west boundary of the NE. ¼ sec. 25, T. 20 N., R. 5 E., contain numerous exposures of coal. These outcrops will be discussed more fully below. The south or east bank of the river in this interval contains no known outcrops of coal. From this locality to its mouth Chickaloon River flows past almost continuous exposures of steeply but somewhat irregularly folded rocks that belong to the Chickaloon formation and of numerous intrusive masses. These exposures contain no coal. Throughout the series of exposures along Chickaloon River, from the point where it comes out of the high mountains into the general area of the Matanuska coal field to its mouth, the general dip is northward. The structure, however, is not a simple monocline, for the rocks are probably repeated by faults as well as by partly overturned folds. The discontinuity of the exposures, the presence of faults of undeterminable throw, the possibility of unseen faults and folds in the concealed intervals, and the lack of characteristic horizon markers make it impossible to describe the structure except in general terms.

The area back from the river is mostly covered with terrace or glacial gravels. Exposures are in fact practically confined to the banks of the larger streams and to knobs of intrusive rocks. The only exposures of coal known to the writer in the area between Chickaloon and Kings rivers are an 18 or 20 inch bed of impure coal about 200 feet above the mouth of the creek that enters Chickaloon River in the SW. ¼ NW. ¼ sec. 25, a 15-inch bed of impure coal in the NW. ¼ NW. ¼ sec. 22, and a 3 or 4 foot bed of coke where a creek crosses the west line of the SW. ¼ sec. 15.

The coal exposures on Chickaloon River are in the face of the bluff that extends for a little more than half a mile along the north or west side of the river in its east-west course through the S. ½ NE. ¼ sec. 25, T. 20 N., R. 5 E., and the SW. ¼ NW. ¼ sec. 30, T. 20 N., R. 6 E. This bluff, which is about 100 feet high, rises from the alluvial flat on the river's edge to a gravel terrace that is about a quarter of a mile wide. The upper part of the bluff is composed of terrace gravels, and the lower part is composed of steeply dipping coal-bearing rocks that are partly concealed by gravels that have slid down over them. Several coal beds are exposed in outcrops on this bluff, but more complete exposures are afforded by 11 tunnels that have been driven into the face of the bluff. Detailed measurements of the coal beds and other strata in these tunnels, as they were exposed in 1910, are given elsewhere.[1] Additional measurements were doubtless made by the engineers of the Bureau of Mines in the course of their mining operations of 1913, but these have not been published.

The attitude of the coal beds differs somewhat in different parts of the exposures. The tunnels on Chickaloon River are situated in four groups between which the rocks are more or less concealed. This grouping is indicated in the following list, in which the tunnels are arranged in sequence from east to west:

Coal tunnels on Chickaloon River.

1. Bend of river in east part of SW. ¼ NW. ¼ sec. 30, T. 20 N., R. 6 E.
A, B, 2. E. ½ SE. ¼ NE. ¼ sec. 25, T. 20 N., R. 5 E.
3, C. W. ½ SE. ¼ NE. ¼ sec. 25, T. 20 N., R. 5 E.
D, 4, 5, E, F. SW. ¼ NE. ¼ sec. 25, T. 20 N., R. 5 E.

The five western tunnels (Nos. D, 4, 5, E, and F) and the easternmost tunnel (No. 1) are situated farther north than the others. At all of these tunnels the strike is approximately east and the dip is 50°–70° N. In the southernmost tunnels (Nos. A, B, and 2) and probably also in the near-by intermediate group (Nos. 3 and C) the strike is northwest and the dip is 65°–85° S. In tunnel No. 2, the presence of what seems to be a typical underclay on top of one of the coal beds indicates that the rocks are locally overturned.

The attitude of the coal beds as described above, and the restriction of the known coal outcrops to this eastward course of the river, can not be definitely explained at present. There are several possible theories concerning the local structure that may explain the known facts, but none of them can be proved or disproved without further knowledge of underground conditions. These theories are thus outlined:

(1) That the coal outcrops lie on a monoclinal northward-dipping block of coal-bearing rocks, in the southern part of which (as in tunnels A, B, and 2) the rocks are folded beyond the vertical.

[1] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 78-81, 1912. Regulations governing coal-land leases in the Territory of Alaska, 86 pp., maps, U. S. Dept. Interior, 1916.

If this theory holds, the coal lies only north of the river. The rocks south of the outcrops are barren of coal unless another block of coal or another horizon at which coal is present passes under them from the south. Eastern and western extensions of the coal belt may lie concealed beneath the terrace gravels, or these extensions may be cut off by transverse faults.

(2) That the coal outcrops lie in an anticline, of which the coal beds of tunnels A, B, and 2 are on the southern limb.

According to this theory, the coal may be present in depth both north and south of the river. Such an anticline may extend east and west beneath the terrace gravels, it may plunge in either or both directions, or it may be cut off at one or both ends by a transverse fault. The exposure at tunnel No. 1 seems to indicate anticlinal folding. The northward-dipping rocks along the river below the tunnels indicate that the anticline, and possibly the coal beds also, are cut off by a fault and do not extend west of the bend of the river in the SW. ¼ NE. ¼ sec. 25, T. 20 N., R. 5 E.

(3) That the coal outcrops lie in two monoclinal blocks separated by a fault.

Under this theory the coal may underlie at considerable depth an area both north and south of the river. The coal-bearing strata may extend east and west beneath the terrace gravels or they may be cut off by transverse faults.

The actual structure at the Chickaloon coal outcrops and consequently the extent of the coal in depth can obviously be determined with certainty only by underground exploration. Because of this condition, and because there is very little coal above drainage at this locality, it is intended to sink a slope for 600 or 800 feet on one of the coal beds and then explore in depth with the purpose of blocking out, if possible, an area of workable coal.

MINES AND PROSPECTS ON MOOSE CREEK.

The Doherty mine, operated by the Doherty Coal Co. under a 10-acre mining permit, is situated on the west bank of Moose Creek in the NW. ¼ sec. 2, T. 18 N., R. 2 E. This mine was opened in 1916. The section of the coal bed is as follows:

Section of coal in Doherty mine.

	Ft.	in.
Sandstone (roof).		
Bone ("cap rock")	1	1
Coal	1	11
Bone		1
Coal	1	3
Carbonaceous shale ("black dirt")		3
Shale (floor).		

Strike N. 67° E., dip 45° SE.

The coal is mined by the room and pillar system and is hoisted on a slope from the entry on the 400-foot level. On reaching the surface it is screened and handpicked to remove the pieces of "cap rock" that come down in mining. The coal that goes through the screens is mixed with that which goes past the pickers and is hauled by a steam locomotive over a narrow-gage railroad, 3,000 feet long, to bunkers on a railroad spur one-fourth of a mile west of the mouth of Moose Creek. The output, about 50 tons a day, was sold in part to the Alaskan Engineering Commission and in part to the public in Anchorage. It is reported that the mine has been abandoned.

The coal shipped from this mine is high in ash. A cleaning plant was being installed, which should result in a better product. If the operators of this mine are able to compete with other producers they will probably be able to find a moderately large area of workable coal in the vicinity of their mine. No structural disturbances have thus far been discovered. The mine is situated on the north flank of a small local basin or else on a southward-dipping fault block. If mining operations are extended at this point the slope should be continued either to the axis of the basin or to the lower edge of the fault block.

A prospecting tunnel was being driven into the hill from the east bank of Moose Creek in the NW. ¼ sec. 27, T. 19 N., R. 2 E., by prospective lessees of leasing blocks 2 and 3. The coal beds at this locality [1] lie near the supposed zone of faulting that apparently forms the northern boundary of the structural mass of Wishbone Hill. They are badly disturbed and have also been burned. The tunnel was being driven in an attempt to get into an area of workable coal beyond the disturbed and burned zone. At the time the locality was visited the driving of the tunnel was still in progress.

LITTLE SUSITNA RIVER.

A brief visit was made also to a locality on Little Susitna River, where a bed of lignite has been found in a "trap" from which ballast was being taken for the railroad. The locality is in sec. 21, T. 18 N., R. 3 W., near mile 175 from Seward. The bed is reported to have the following section:

Section of lignite near Houston.

	Ft.	in.
Sand.		
Lignite	2	8
Shale and bone	2	
Clay.		

At the time the locality was visited by the writer the coal was not exposed, the pit which had been dug into it being filled with water. The beds exposed in the trap are semi-indurated sand and clay like those of the Kenai formation of Cook Inlet. The lignite was found at the level of the swamp and is said to dip about 6° N. The bed consequently does not extend above drainage level.

[1] Martin, G. C., and Katz, F. J., op. cit., p. 87 (sections 40–42).