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MINERAL DEPOSITS OF THE RUBY-KUSKOKWIM REGION ALASKA

BY

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By J. B. Mertie, Jr.

ABSTRACT

The Ruby-Kuskokwim region lies in west-central Alaska, between the Yukon and Kuskokwim Rivers. Gold was discovered in this region in 1906, and in the following 10 or 12 years several gold placer-mining camps were located, most of which are still producing gold. These mining districts, named from north to south, are the Ruby, Cripple, Ophir, Tolstoi, Nixon Fork, McGrath, Iditarod, and Georgetown districts. Valuable gold lodes were located in the Nixon Fork district in 1918, and these have been mined continuously since that date. Other gold lodes have been located in the Ophir and Iditarod districts, and silver-lead ores have been prospected in the Ruby district, but none of these lodes have been commercially successful. In the Georgetown district, however, cinnabar ores have been known for many years and have been mined intermittently since 1906.

The following report is essentially a description of the mineral deposits that have been found in this region and of the status of mining in 1933.

The geologic features of this region have been described in some detail in earlier reports, and here only a generalized statement of the general geology is presented, adequate for an understanding of the history and character of mineralization in this region. Gold mineralization is believed to have occurred both in the Mesozoic era and during the Tertiary period, but the ores of cinnabar are believed to have originated only during the Tertiary. The age of the silver-lead ores has not been determined. The gold placers, derived from such preexisting lodes, range in age from early Pleistocene to Recent.

During the season of 1933 a total of 65 placer-mining plants were operated in the Ruby-Kuskokwim district, of which 20 were located in the Iditarod district, 19 in the Ophir district, 14 in the Ruby district, and the remainder in the 4 smaller districts above named. Of these plants, five were dredges, of which three were operated in the Ophir district and two in the Iditarod district. The largest production of placer gold came from the Iditarod district. Two gold lodes were also operated in the Nixon Fork district. The production of placer and lode gold in this region in 1933 was about $400,000.

INTRODUCTION

LOCATION AND EXTENT

The Ruby-Kuskokwim region lies in west-central Alaska between the Yukon and Kuskokwim Rivers. The geographic limits of this region are approximately latitude 61°40′ and 64°50′ N., and longitude 154°30′ and 158°20′ W. (See fig. 5.) Only certain parts of

this great area have so far been proved to contain commercial mineral deposits, and these have been designated locally as mining districts. In order to avoid the presentation of a single large and unwieldy map with this report, three smaller maps have been prepared, which show only the country contiguous to the mining districts. These three maps (pls. 2, 4, and 6) have a north-south continuity but jog progressively westward from Ruby to Iditarod, thus omitting parts of the region which are not known at present to contain workable mineral deposits.

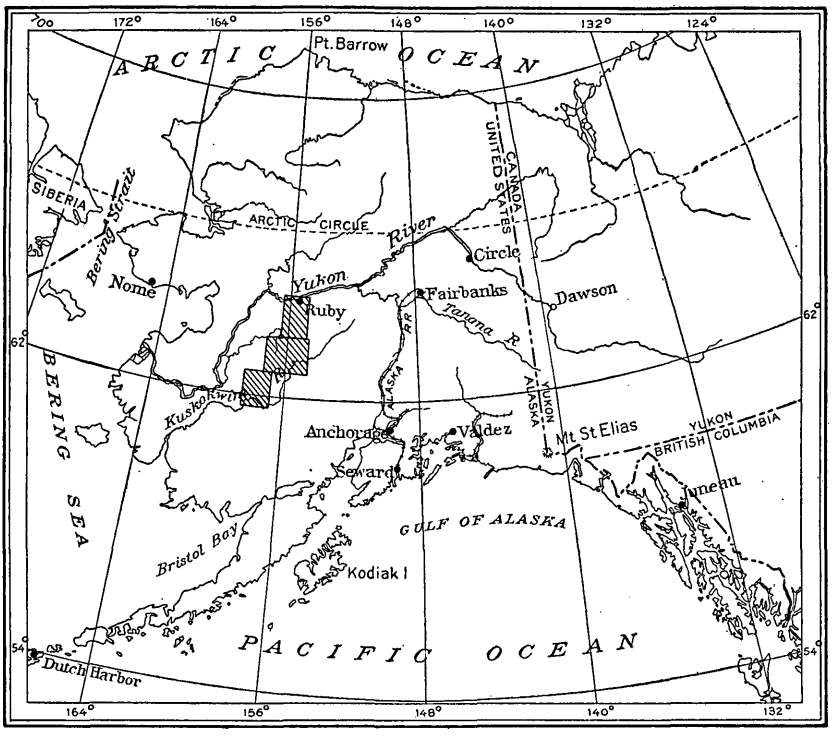

FIGURE 5.—Index map showing location of Ruby-Kuskokwim region, Alaska.

The northern area, shown on plate 2, lies between parallels 63°40′ and 64°50′ and meridians 154°40′ and 156°20′ and includes the Ruby and Poorman placer-mining districts. The Ruby district comprises a narrow belt that extends from Ruby southward for a distance of about 35 miles. Within this belt gold placers have been found on several streams, of which Long Creek and other nearby tributaries of the Sulatna River are the most productive. Still farther south and somewhat west of the Ruby district is the Poorman district, which comprises several streams, most of them draining to the Innoko River. The gold placers of the Poorman district lie mainly in the valleys of Poorman Creek and its tributaries.

The central area, shown on plate 4, includes that part of the region lying between parallels 62°40′ and 63°40′ and meridians 154°30′ and 157°10′. The Cripple, Tolstoi, Ophir, Nixon Fork, and McGrath mining districts are included in this central area. The Cripple, Tolstoi, Ophir, and McGrath districts are the sites of placer mining, but the Nixon Fork district has both lode and placer mines. The Cripple district comprises the headwater tributaries of Colorado Creek, in the Cripple Creek Mountains. The Tolstoi district includes Madison and Mastodon Creeks and their tributaries, which debouch into Tolstoi Creek about 25 miles northwest of Ophir. The Ophir district includes many creeks in the upper basin of the Innoko River and is the largest placer-mining district in this central area. The McGrath district centers at present on Candle Creek, about 10 miles southwest of McGrath. The Nixon Fork district lies in the headwaters of several tributaries of the Nixon Fork, about 35 miles northeast of McGrath.

The southwestern area, shown on plate 6, includes that part of the region lying between parallels 61°40′ and 62°40′ and meridians 156°40′ and 158°20′. In the northwestern part of this area is the Iditarod mining district, which at present is the largest producer of placer gold in the Ruby-Kuskokwim region. South and somewhat east of the Iditarod district, extending to the Kuskokwim River, is the Georgetown district, which includes several tributaries of the Kuskokwim where placer mining is now in progress. Several quicksilver lodes are also known in this district, and one of these, along the Kuskokwim River about 15 miles above Georgetown, is a small producer of this metal.

DISCOVERY AND EARLIER SURVEYS

The first geologic explorations in this region were made by Spurr [1] in the course of a trip down the Yukon River in 1896 and another trip down the Kuskokwim River in 1898. The Geological Survey has also in its files some unpublished notes made by Collier regarding the river bluffs at Ruby, made in 1902 in connection with his study of the coal resources of the Yukon.[2] The data presented in these early reports antedate by several years the first discoveries of valuable minerals in this region and may have served in some measure to focus attention upon this southwestern part of Alaska as a potential mineral area.

[1] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey 18th Ann. Rept., pt. 3, pp. 87–392, 1898; A reconnaissance in southwestern Alaska: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 31–264, 1900.

[2] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, 1903.

In the summer of 1906 placer gold was found on Ganes Creek, in the Ophir district, by four prospectors, Thomas Gane, F. C. J. Spencer, Mike Roke, and John Maki. So far as known to the writer, this was the initial discovery of gold in the Ruby-Kuskokwim region. Late in the summer of 1907 prospectors reported that gold had been found on Ruby Creek, a small tributary of the Yukon River, opposite the mouth of the Melozitna River. Later in the same year many men stampeded to the new discovery and prospecting was begun on nearby streams, but it was not until 1910 that the really productive placers were found on Long Creek and its tributaries. The discovery on Long Creek was made in July 1910 by N. P. Johnson and C. W. Fornander. In the meanwhile, as the Ophir camp was developing, many men were engaged in prospecting in that part of the region, and on Christmas day 1908, the original discovery in the Iditarod district was made on Otter Creek by W. A. Dikeman and John Beaton.

In the 7 or 8 years following 1910 most of the other camps that are now producing were located. Placer gold was found in the Cripple Creek Mountains in the spring of 1912, and the Poorman placers were discovered about the same time, though mining did not begin in the Poorman district until 1913. Candle Creek, in the McGrath district, was opened up in 1914, and development of the Tolstoi placers was begun in 1915, though gold had been known to exist in that district for several years before mining was actually started. In the Nixon Fork district the original discovery of gold placers was made by F. E. Matthew on Hidden Creek in June 1917, and the high-grade gold lodes of the present Nixon Fork mines were located by J. O. Pearson and J. O. Strand in the fall of 1918.

The presence of quicksilver along the Kuskokwim River had been known for many years prior to the first explorations of the Geological Survey, for in a report written in 1881 Petrof[3] mentions the occurrence of well-defined series of cinnabar, stibnite, and silver-bearing quartz in the Kuskokwim region. The cinnabar lode above Georgetown, however, was not discovered until 1906.

Concurrently with these mineral discoveries, investigations of geological and mineral resources have been carried on by the Geological Survey since 1908. This work was begun by A. G. Maddren, who spent the season of 1908 in the Ruby and Ophir districts. In 1910 Maddren devoted another season's work to an investigation of the Ophir and Iditarod districts and the country intervening between these two camps; and in the same year C. G. Anderson made a preliminary topographic map of a narrow belt between Ruby and

[3] Petrof, Ivan, Report on the population, industries, and resources of Alaska: 10th Census, vol. 8, pp. 13, 77, 90, 1884.

Ophir and of a wider belt between Ophir and Iditarod. In 1912 H. M. Eakin continued the investigations of the country between Ruby and Iditarod and completed the regional report that had been begun by Maddren in 1910. Eakin again visited the Ruby district for 10 days in 1913, at the end of his regular season's work north of the Yukon River. In 1914 the country between Iditarod and Georgetown was mapped geologically by Philip S. Smith and topographically by R. H. Sargent, in the course of a reconnaissance survey of the region between Cook Inlet and the Kuskokwim Basin, and the region between Iditarod and the Kuskokwim River was visited by A. G. Maddren on his way to the gold placer camps of the lower Kuskokwim. The results of their independent investigations were embodied in a report prepared jointly by Smith and Maddren on the quicksilver deposits of that area.

In 1915 a new study of the area between Ruby and Iditarod was undertaken, with the idea of covering a larger area than had been included in the older report by Eakin. The geologic mapping was entrusted to the writer and G. L. Harrington, and the topographic mapping to R. H. Sargent and C. E. Giffin. Sargent and the writer covered the country between Poorman and Iditarod, and Giffin and Harrington the area between Ruby and Poorman. In connection with the investigations of the occurrence of tin and tungsten in Alaska, the Ruby district was again visited by Theodore Chapin in 1917, and in the same year G. L. Harrington made a study of the gold placers of the Tolstoi district.

The subsequent discovery of the placers and lodes of the Nixon Fork district made further work in that area desirable, and in 1920 G. C. Martin visited the Nixon Fork district and made a preliminary report on the conditions of mineralization in that area. In 1924, a survey was undertaken of the region between Ruby and the Nixon Fork, in the course of which R. H. Sargent amplified considerably his earlier topographic map of the Ruby-Kuskokwim region and J. S. Brown prepared a geologic map of the Nixon Fork country.

REPORTS AND MAPS

A list of the publications of the Geological Survey that treat of the geology and mineral resources of the Ruby-Kuskokwim region and nearby areas is given below.

Spurr, J. E., Geology of the Yukon gold district: U. S. Geol. Survey 18th Ann. Rept., pt. 3, pp. 87–392, 1898.

Spurr, J. E., A reconnaissance in southwestern Alaska: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 31–264, 1900.

Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, 1903.

Maddren, A. G., Gold placers of the Ruby Creek district, Alaska; Gold placers of the Innoko district, Alaska: U. S. Geol. Survey Bull. 379, pp. 229–233, 238–266, 1909.

Maddren, A. G., Gold placer mining developments in the Innoko-Iditarod region, Alaska: U. S. Geol. Survey Bull. 480, pp. 236–270, 1911.

Maddren, A. G., The Ruby placer district, Alaska: U. S. Geol. Survey Bull. 520, pp. 271–296, 1912.

Eakin, H. M., Gold placers of the Ruby district, Alaska; Gold placers of the Innoko-Iditarod region, Alaska: U. S. Geol. Survey Bull. 542, pp. 279–303, 1913.

Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, 1914.

Eakin, H. M., Placer mining in the Ruby district, Alaska: U. S. Geol. Survey Bull. 592, pp. 363–369, 1914.

Smith, P. S., Mineral resources of the Lake Clark-Iditarod region, Alaska: U. S. Geol. Survey Bull. 622, pp. 247–271, 1915.

Smith, P. S., and Maddren, A. G., Quicksilver deposits of the Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 622, pp. 272–291, 1915.

Mertie, J. B., Jr., and Harrington, G. L., Mineral resources of the Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 642, pp. 223–266, 1916.

Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, 1917.

Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, 1918.

Chapin, Theodore, Tin deposits of the Ruby district, Alaska: U. S. Geol. Survey Bull. 692, p. 337, 1919.

Harrington, G. L., The gold and platinum placers of the Tolstoi district, Alaska: U. S. Geol. Survey Bull. 692, pp. 339–351, 1919.

Martin, G. C., Gold lodes in the upper Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 722, pp. 149–161, 1922.

Mertie, J. B., Jr., The occurrence of metalliferous deposits in the Yukon and Kuskokwim regions, Alaska: U. S. Geol. Survey Bull. 739, pp. 149–165, 1923.

Mertie, J. B., Jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, 1924.

Brown, J. S., The Nixon Fork country and Silver-lead prospects near Ruby, Alaska: U. S. Geol. Survey Bull. 783, pp. 97–150, 1926.

Topographic maps of the Ruby-Kuskokwim region have been published in Bulletins 578, 655, 667, and 754; those in Bulletin 754 are the latest and most comprehensive. A preliminary edition of a topographic map of the Nixon Fork district and vicinity was printed in 1926 in a two-color photolithographic edition but has not been issued in its final engraved form.

PRESENT INVESTIGATION

During the period 1925–32 no further work was done in the Ruby-Kuskokwim region by the Geological Survey. In 1933, however, it was considered desirable to visit this region again, in order to learn at first hand what mining developments had taken place since 1924, and this work was undertaken by the writer. Owing to a severe curtailment of the appropriation of the Geological Survey, it was

not possible to place a pack-train outfit in the field; instead, the writer worked alone, utilizing whatever transportation facilities were available in the country and back-packing his own supplies and equipment where no other transportation was obtainable. The region between Poorman, Cripple, Ophir, and Takotna was visited in this way. The time available for this work was very short, only 43 days being spent in the field.

For the foregoing reasons, it was not possible to undertake any exhaustive new geologic studies in this great area, and the present report does not completely supplant either the writer's report of 1915 or Brown's report of 1924. Only hurried visits were made to most of the mining plants, and this report is mainly a statement of the present status of mining developments in the Ruby-Kuskokwim region.

ACKNOWLEDGMENTS

The hospitality of the miners and prospectors of Alaska is well known. Realizing the difficulties under which this trip was undertaken, the people of this region made a special effort to aid the writer; they not only gave their usual cooperation and hospitality but also aided materially in other ways. In this connection, the writer wishes particularly to thank Mr. Martin Webories, who accompanied him on the trip from Poorman to Ophir and helped as a guide both in the Ruby and Poorman districts; Mr. Dan McFadden for voluntary services at Long; and Mr. Charles Smith for free transportation between Takotna and McGrath. The writer also wishes to express his appreciation of helpful cooperation and other courtesies from Messrs. T. J. De Vane and Albert Verhonik in the Ruby district; Jim Wilson and Harold Strandberg in the Cripple district; Eric Hard, W. E. Puntila, and P. W. Carlson in the Ophir district; C. C. Mespelt in the Nixon Fork district; Harry Donnelley, John Beaton, Alex Mathieson, the Olson brothers, Arnold Kobler, and W. F. Duffy in the Iditarod district; and Mr. and Mrs. C. P. Gerhart, of Holy Cross.

GEOGRAPHY

DRAINAGE

The Ruby-Kuskokwim region is a country of diversified drainage and relief. It lies between the Yukon and Kuskokwim Rivers, but most of the part so far mapped drains to the Yukon. The divide trends about northeast. The Yukon drainage system, northwest of this divide, consists of two large streams that head against each other and flow in opposite directions—the Nowitna River, which drains northeastward, and the Innoko River, the larger one, which drains southwestward. South of the divide are two smaller streams, which

likewise flow in opposite directions but toward each other—the Takotna River, flowing northeast, and the Nixon Fork of the Takotna, flowing southwest. Their confluence is only a little more than 5 miles in an air line from the Kuskokwim River. Southeast of the Nixon Fork is the North Fork of the Kuskokwim River, which flows southwestward to the main Kuskokwim, and heading against the Takotna River is the George River, which also flows southwestward to the Kuskokwim. The striking feature of the main drainage systems of this region, therefore, is their general parallelism along a northeast-southwest line, although the parallelism is more pronounced southeast of the Yukon-Kuskokwim divide. The courses of these streams are probably controlled mainly by the structure of the country rock.

The Nowitna River discharges into the Yukon about 35 miles in an air line upstream from Ruby. Three principal streams constitute the headwaters of the Nowitna. The northwesternmost of these is the Susulatna River, known locally as the Agate Fork. The central stream is the upper Nowitna. The southeasternmost is the Sulukna River. All three flow northeastward, following closely the regional structure of the country rock. In the northern part of its valley the Nowitna receives two other tributaries from the southwest, which in order downstream are the Lost and Sulatna Rivers. In this lower stretch the Nowitna flows in a tortuous course over a silt-filled valley floor, across the regional strike, to join the Yukon.

The Sulatna River and its tributaries drain the Ruby minig district. The upper valley of the Sulatna is carved in crystalline rocks and, unlike the other forks of the Nowitna, trends east of south until it reaches the Mesozoic rocks, where it turns northeastward to follow the regional strike of these later rocks. In the headward part of its valley the Sulatna receives a large northern tributary, Long Creek, which is flanked on the east and also headed by other tributaries of the Sulatna. Long Creek and these flanking streams to the east are the principal streams of the Ruby mining district.

The Innoko River has a large drainage basin, of which only the headwater valleys, near the Yukon-Kuskokwim divide, have yet been mapped. As most of the lower Innoko Valley lies outside the area under present consideration, it may suffice to state that the four principal tributaries that drain the Ruby-Kuskokwim region, named from northeast to southwest, are the North Fork of the Innoko River, the main Innoko, the Dishna, and the Iditarod. The smaller headwater tributaries of these streams are noticeably controlled by regional structure, but the main streams flow generally northward to join the Innoko River, which beyond the junction with its North Fork flows generally southwestward to the Yukon. The main Innoko Valley and the lower valleys of its four principal tributaries are wide silt-filled

plains. The region northwest of the Innoko, between the Innoko and the Yukon, is part of a distinctly different geomorphic province, the Kaiyuh Hills.

The North Fork of the Innoko River heads in the hills between Poorman and the Cripple Creek Mountains. Poorman Creek, a smaller tributary of the North Fork, drains most of the Poorman mining district. Heading against Poorman Creek, however, are several smaller streams that drain to the Sulatna River but are nevertheless considered to be a part of the Poorman district.

The main Innoko River drains the hills in the area from the Cripple Creek Mountains southwestward to the Beaver Mountains, including also the country around Cloudy and Twin Mountains. The Cripple Creek Mountains are drained by Colorado Creek, a tributary of the Innoko. Between Colorado Creek and the headwaters of the main Innoko is another large tributary, Folger Creek. The main Innoko River heads against the valley of the Takotna River; it flows southwestward from Twin and Cloudy Mountains, turns northwestward through the Innoko district, and then northward, receiving at this turn a large tributary from the south, Beaver Creek, which drains the east side of the Beaver Mountains.

The Dishna River, third of the large tributaries of the Innoko, heads against the headwaters of the Takotna River and drains the area from that point northeastward to the Beaver Mountains. Tolstoi Creek, a large tributary of the Dishna, drains the north flanks of the Beaver Mountains and the west side of Mount Hurst. The Tolstoi mining district is in the lower valley of Tolstoi Creek.

The Iditarod River heads against the George River and some smaller tributaries of the Kuskokwim River and, like the main Innoko, has a general northerly course, though its headwater tributaries lie mainly in valleys that trend northeast, parallel to the regional strike of the rocks. One of the principal of these headwater tributaries is Otter Creek, which heads against the Dishna River and flows southwestward to the Iditarod. In the western part of the valley of Otter Creek several tributaries enter from the south, of which the most important to the miner is Flat Creek. The western part of the valley of Otter Creek, together with the valleys of Flat Creek and several other nearby streams, constitutes the Iditarod mining district.

The general distribution of the streams southeast of the Yukon-Kuskokwim divide has already been sketched. The Nixon Fork of the Takotna River flows generally southwestward but in its lower part meanders extensively in a silt-filled valley. At the west end of its headwater section several small tributaries enter from the southeast; of these the one on which the most placer mining has been

done is Hidden Creek. The area adjacent to these streams constitutes the Nixon Fork mining district. Another stream, the Tatalina River, flows parallel to the Takotna on the southeast and enters the Takotna a short distance above its confluence with the Kuskokwim at McGrath. Candle Creek, one of the lower tributaries of the Tatalina from the southwest, is the only site of mining operations in the McGrath district.

RELIEF

As a whole, the Ruby-Kuskokwim region is rather low and rolling, but it includes several groups of mountains, which, however, are isolated and do not form any continuous ranges. Between the mountain groups are low ridges from which long flat-topped spurs extend laterally into the stream valleys.

The northern part of this region, from Ruby to Poorman, has a rather distinct topographic aspect in that the ridges are lower, the ridge tops are flatter, the slopes of the spurs are longer, and the tributary streams are more widely spaced. Its rather sharp demarkation from the country to the southwest is apparent both in the field and from an inspection of the topographic map. Within this lower area between Ruby and Poorman the average elevation of the ridges is about 1,500 feet. The highest point is Yuko Mountain, with an elevation of about 2,300 feet. Another landmark is Twin Buttes, with an elevation of only 1,800 feet. As the Yukon at Ruby is about 275 feet above sea level the maximum relief in this part of the district is only about 2,000 feet.

South of the Poorman district the relief is considerably greater; here the isolated mountain groups rise to a considerable height above the ridge levels. The highest is the Cloudy Mountain massif, at the head of the Innoko River, which rises to an elevation of 4,400 feet or more. Other high groups are the Sunshine Mountains, between the Nixon Fork and the Nowitna River, with a maximum elevation of 4,000 feet; the Beaver Mountains, at the head of Beaver and Tolstoi Creeks, 3,800 feet; and the Cripple Creek Mountains, at the head of Colorado Creek, 3,600 feet. There are several other mountains or groups of mountains that have elevations of 2,500 to 3,500 feet. The average ridge level in this central and southern part of the region is close to 2,000 feet. Iditarod, on the Iditarod River, is about 300 feet above sea level, and McGrath, on the Kuskokwim, about 375 feet. The maximum relief in the central and southern parts of this region is thus about 4,000 feet, or twice that in the Ruby and Poorman mining districts.

CLIMATIC CONDITIONS

The climate of the Ruby-Kuskokwim region is typically subarctic, with long, cold winters and short but rather warm summers. Climatic records, particularly regarding the amount of precipitation, are of value to placer miners, especially to those interested in new placer-mining projects. No complete climatic records have been kept at stations within the Ruby-Kuskokwim region, but partial records have been kept at Ruby for the years 1917–20 and at Sleitmut from 1929 to the present time. A fairly complete record, however, has been kept at Holy Cross for 40 years, and this station lies in a contiguous area where climatic conditions are not markedly dissimilar to those in the southern part of this region. The 50-year record at Tanana is similarly applicable to the northern part of the Ruby-Kuskokwim region.

From these records it appears that the mean annual precipitation increases from about 13 inches at Tanana to about 20 inches at Holy Cross. The partial record at Ruby suggests an annual precipitation at that point of about 15 inches. The precipitation at Sleitmut, on the Kuskokwim, seems to be more nearly comparable with that at Holy Cross. The mean annual temperature is about 23° at Tanana and 26° at Holy Cross. In the hilly region southeast of the Yukon River the temperature is somewhat different from that which prevails along the river, probably lower; and, similarly, the precipitation back from the river is doubtless different, probably greater. In general, therefore, the northern part of the Ruby-Kuskokwim region is drier and probably somewhat cooler than the southern part; and the region as a whole is wetter and warmer than the country farther east in the Yukon Valley—for example, the Yukon-Tanana region.

TIMBER, FORAGE, AND GAME

Spruce is the most common type of timber in this country, but with it at certain localities are more or less poplar and birch, and a small amount of tamarack. The poplars, commonly called "cottonwood", are more prevalent along the valley floors and lower slopes, and the birch thrives best on well-drained slopes and ridges. Along the banks of streams and in upland gulches, and at damp places near timber line willows and alders grow in great profusion; and above timber line dwarf black-birch brush is also common. In the vicinity of Ruby and Long timber line is about 1,800 feet above sea level, but in the southern part of the region little timber grows above the 1,500-foot line. Locally, however, where conditions are favorable, as in the limestone country of the Nixon Fork district, spruce grows well above 2,000 feet.

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The stand of timber in this region is nowhere very heavy, and the trees are usually small, but along the valley floors trees as large as 24 inches in diameter are not uncommon. This timber in the past has sufficed locally for lumber and firewood, but among the larger mining camps the supply has now become scant, so that its use for fuel is rather costly. Great forest fires have repeatedly swept over the country, destroying a great deal of the timber. During the summer of 1933 the whole area between Poorman and the Cripple Creek Mountains was burned over, and extensive fires also occurred in and about the Nixon Fork district.

Forage for stock is fairly plentiful along the valley floors of some of the larger streams, such as the Sulatna, Nowitna, and Takotna Rivers; but on the upland slopes grass is scarce, particularly where the country rock is ultrabasic, and in general these upland areas are not good grazing ground for packhorses in summer.

Game is by no means plentiful. In the higher groups of mountains small scattered bands of caribou may be seen, though not comparable in numbers to the great herds of the Yukon-Tanana region. Bears are likewise not plentiful. Some moose live in the broad valley lowlands, such as that of the Nowitna. Small game, such as ptarmigan, grouse, and rabbits, are more plentiful now than when this country was visited by the writer in 1915, but the fires of 1933 undoubtedly destroyed or drove out much of the smaller game from the northern part of the region. Salmon run up the Yukon and Kuskokwim Rivers and are depended upon to a considerable extent for dog feed as well as for human consumption. Whitefish and pike are also found in the larger streams, and the smaller streams are well stocked with grayling.

SETTLEMENTS AND COMMUNICATION

Ruby is a small town on the south bank of the Yukon River, about 110 miles in an air line below the confluence of the Yukon and Tanana. It is the principal settlement and distribution point for the northern part of this region and according to the census of 1930 had a population of 132. In summer passengers, freight, and mail for Ruby are handled by steamboats operated by the Alaska Railroad, which ply on the Tanana and Yukon Rivers between Nenana and Marshall. Ruby also has an airplane landing field and can also be reached by hydroplane; many passengers now use these flying services rather than the river boats. In winter mail and passenger traffic is handled largely by airplanes equipped with skis. Until the fall of 1933 Ruby had a wireless telegraph station, operated by the United States Signal Corps, but this has now been discontinued and is replaced by a commercial telegraph and radiophone station.

The two other settlements in the northern part of this region are Long and Poorman, respectively 30 and 58 miles south of Ruby, with which they are connected by a road. This road serves for automotive transport in summer and for sledding in winter. Another means of freighting supplies, particularly into the Poorman district, is by launch up the Sulatna River to Tamarack Landing and thence either north or south by the road, but this route is no longer used. There is a commercial radiophone at Poorman. Long has no means of transmitting messages but by the use of broadcast receivers is able to receive messages transmitted by the radiophones operating at Ruby and Poorman.

The village of Cripple is the source of supplies and equipment for the Cripple district. This settlement is on the Innoko River about 5 or 6 miles above the mouth of Colorado Creek and is connected with Graham and Cripple Creeks by both winter and summer trails, the distance being about 9 or 10 miles. The winter and summer trails continue from Cripple Creek eastward to the head of Colorado Creek, and another winter trail follows down Colorado Creek. A summer trail connects Cripple Creek with Ophir. During the summer of 1933, when low water in the Innoko River made it impossible to land freight at Cripple, some supplies were delivered at Cripple Creek by airplanes from Anchorage. For this service no landing field was available, but the planes, flying low, successfully dropped supplies along a line of ground targets.

Ophir, the distributing point for the Ophir district, is a small village on the upper Innoko River about 72 miles in an air line S. 25° W. of Poorman. Ophir is credited in the census of 1930 with a population of 19 persons, but in summer two-thirds of these are out on the creeks engaged in mining, and if all others on the nearby creeks are counted, the population of the Ophir district is considerably greater. Ophir has no telegraphic communication but has four routes by means of which passengers, freight, and mail can enter. First, a good automobile road connects Ophir with Takotna, which in turn obtains its supplies from Bethel by way of the Kuskokwim and Takotna Rivers; most of the supplies and equipment consigned to Ophir from the States now come by this route. Second, the Innoko River may be navigated in its lower course by launches and in its upper course by poling boats and horse-drawn scows; it was by this route that supplies were formerly brought into the country, but at present the river is used more as a summer mail route than as a freighting route. Third, a winter trail comes into Ophir from Poorman by way of Cripple, a distance of about 90 miles; up to the winter of 1933–34 the winter mail to Ophir was carried by this route, but the service is now discontinued, and Ophir will receive its winter

mail in future by airplane. Fourth, most passengers for Ophir now enter by means of airplanes, but because the aviation field at Ophir is not in good condition, passengers usually fly to Takotna and then continue by automobile to Ophir; some mail was brought in by this route during the summer of 1933.

Takotna is a supply point for the Ophir district and nearby places. In 1930 it had a population of 65 persons. It is on the north side of the Takotna River at the head of launch navigation. About 5 or 6 miles west of Takotna a branch goes off from the Takotna-Ophir road to the headwaters of Yankee and Ganes Creeks, so that the mining activities at the heads of these creeks are in reality tributary to Takotna rather than to Ophir.

McGrath is the main distributing point for the central part of the Ruby-Kuskokwim region, and in 1930 its population was 112. It is on the northwest bank of the Kuskokwim River at the mouth of the Takotna River, about 325 miles by river from Bethel. McGrath is the point of disembarkation for passengers and freight coming up the Kuskokwim River by steamboat, though it is not the extreme head of steamboat navigation. Ocean-going vessels discharge their cargoes at Bethel, on the lower Kuskokwim, and the steamboat *Tana* makes two trips every summer from Bethel to McGrath. From McGrath suplies go by launch up the Takotna River to Takotna and up the Kuskokwim River to Medfra. The average freight rate from Seattle to McGrath is about $75 a ton and from McGrath to Takotna about $25 a ton. From Takotna supplies are moved by autotruck to Ophir and vicinity for $25 a ton and from Takotna to the head of Ganes Creek for $30 a ton.

In addition to its importance as a distributing point for freight, McGrath in recent years has also become an aviation center for the Ruby-Kuskokwim region. It has a landing field for airplanes, and when the Kuskokwim River is low it also has a good natural landing field on the river bar. McGrath is likewise well situated for hydroplane traffic, as the quiet water at the mouth of the Takotna River affords an ideal landing place. As a result of these conditions and of its central location, airplanes are coming and going nearly every day from McGrath to Fairbanks, Anchorage, Takotna, Flat, and points on the lower Kuskokwim and Yukon Rivers. Under emergency conditions—as for example, if freight is delayed by low water or if perishables are needed—there is also considerable airplane freighting in and out of McGrath. For this service the rate from Anchorage to McGrath is 22 cents a pound, from Anchorage to Takotna 25 cents a pound, and from McGrath to Takotna 4 cents a pound. During the summer of 1933, when the water in the Takotna River was abnormally low, considerable airplane freighting was

done between McGrath and Takotna. To obviate the difficulties of low-water transportation between McGrath and Takotna the construction of an automobile road between these points is being urged by the people of this district.

Medfra, known also as "Berry's Landing", is the supply point for the Nixon Fork district. It is on the north bank of the Kuskokwim River about 32 miles in an air line upstream from McGrath, though probably two or three times that distance by river. From Medfra a wagon road has been constructed northward for 11½ miles to the Nixon Fork mining district, and this road is now being improved for automotive traffic. Airplanes land on the river bar opposite Medfra at stages of low water.

The Iditarod mining district, though mainly on Flat and Otter Creeks, had for its original distributing point the incorporated town of Iditarod, on the Iditarod River about 7 miles in an air line north of the mouth of Otter Creek. Supplies for this district still come up the Iditarod River to Iditarod, but the town itself is now almost abandoned and is mainly the site of warehouses for the storage of supplies pending their further transportation to the mines. Another settlement, called "Flat", was early established at the junction of Flat and Otter Creeks, merely as a subsidiary distributing point, but in recent years it has come to be the principal town in this district, and in 1930 it had a population of 124 persons. Iditarod is connected with Flat by an automobile road. From Flat a similar road leads up Otter Creek as far as Slate Creek and another up Flat Creek, branching at its head to go to Willow, Happy, and Chicken Creeks.

The present town of Flat has two general stores, a hotel, and a bank. All the supplies landed at Flat are transported up the Iditarod River from Holy Cross. Part of these supplies arrive at Holy Cross by way of the Alaska Railroad and its river steamboats, and nearly half are brought up the Yukon River from St. Michael. The Iditarod district like the Ophir district, is handicapped at times by low water in the Iditarod River, which prevents the prompt delivery of supplies and equipment at Iditarod. This was particularly true during the abnormally dry summer of 1933. To remedy this difficulty, the people of this district are urging the construction of a road from some point on the Kuskokwim River at or near Georgetown across the hills to Flat, so that all supplies can be brought in by way of Bethel. The airline distance between Georgetown and Flat is 37 miles, but a road following as much as possible the solid ground of the sinuous ridge tops would be considerably longer.

In recent years airplanes have become an important element in the transportation system of the Iditarod district. Two landing fields have been built—one on the valley floor of Otter Creek close to Flat and the other on top of the ridge north of Flat. Hydroplanes also land on the river at Iditarod. This air service has entirely revolutionized the transportation of passengers to and from the Iditarod district. In the early years of this camp all passenger traffic was carried by small steamboats or launches from Iditarod to Holy Cross and thence by river steamboat up or down the Yukon River. Now most passengers enter and leave Flat by airplanes, which fly on a regular schedule to Anchorage and at less frequent intervals to other Alaskan points. The mail is delivered at Flat by air service, and a certain amount of air freighting is also done. Thus fresh vegetables are brought to Flat from Holy Cross at a rate of 10 cents a pound, and occasional trips are made to outlying points, such as Julian Creek, where supplies are dropped along a line of targets, as on Cripple Creek. Airplane transportation to similar remote parts of Alaska is destined to play an increasingly important part in the Territorial transportation system.

GENERAL GEOLOGY

The geologic column of the Ruby-Kuskokwim region includes many types of rocks of diverse origin and age. Local descriptions of the geologic formations have been given in the various reports listed on pages 119–120, and a more general statement of the regional geology has also been presented.[4] In the hasty trip which the writer made through this region during the summer of 1933 no additional comprehensive geologic studies were attempted, and for the purpose of the present paper a synopsis of the prior geologic information seems adequate.

The sedimentary sequence consists of early Paleozoic or pre-Cambrian metamorphic rocks, later Paleozoic rocks of less altered character, early Mesozoic rocks, and a group of late Mesozoic and Eocene rocks that form the country rock over a large part of the region. The igneous sequence comprises early Paleozoic greenstone and related rocks, late Paleozoic or early Mesozoic lava flows, Mesozoic (?) granitic rocks, and a diversified assemblage of Cenozoic intrusive and extrusive rocks that show wide variations in chemical composition. Overlying all these hard rocks is a mantle of residual debris that covers the valley slopes and most of the lower ridges, and also thick alluvial deposits of Quaternary age that form the present valley floors.

[4] Mertie, J. B., Jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, 1924.

SEDIMENTARY ROCKS

UNDIFFERENTIATED METAMORPHIC ROCKS

In the geologic mapping so far done a considerable variety of nonfossiliferous rocks, in different stages of metamorphism and recrystallization, have been grouped together as a single cartographic unit, but this unit probably includes rocks of diverse age. The type locality for the undifferentiated metamorphic rocks is in the area between Ruby and Poorman, where they form a large part of the country rock. These rocks also are present in the country between the head of the Nixon Fork and the Nowitna River. Similar rocks are known in contiguous areas east of the Ruby district, in the lower Nowitna Valley; north of the Ruby district, in the valley of the Melozitna River; and along the southwest end of the Kaiyuh Hills.

In the Ruby-Poorman area most of the country rock consists of slate and phyllite, though locally quartz-mica schist, in part garnetiferous or tourmaline-bearing, quartzite, quartzite schist, and other totally recrystallized rocks are found. Where well exposed the slate and phyllite show cleavage, crenulation, and usually fracturing or shattering, with a subsequent filling of quartz as veinlets, veins, and irregular lenses. There is no evidence to indicate that this generation of quartz is gold-bearing. The structure of these undifferentiated rocks is complex, and on account of scarcity of bedrock exposures in the Ruby-Poorman area their history is particularly hard to decipher. The dominant cleavage is about N. 30° E., with local variations of 20° to 30° to the east or west. The available evidence indicates that the general structure is that of an anticline with the major axis pitching toward the southwest, though, of course, the structural detail is much more complex than that of a simple arch. Associated with the altered sedimentary rocks are several varieties of altered igneous rocks, of which the most noteworthy is a formation of lavas and tuffs of greenstone habit, together with a small proportion of altered intrusive rocks. The extrusive greenstones are largely altered basalt and diabase but include also some andesitic rocks. The intrusive greenstones consist mainly of metagabbro, with a small amount of altered dioritic rocks. The older sedimentary members of these undifferentiated metamorphic rocks are considered to be of pre-Ordovician age, but the presence of infolded Devonian limestone suggests that rocks ranging in age from Ordovician to Devonian are also included. The age of the igneous members is not definitely known, but from comparative studies made in other parts of interior Alaska, it is believed that the extrusive greenstones are in part of Ordovician age and in part of Carboniferous age.

In the area at the head of the Nixon Fork this group of rocks, according to Brown,[5] embraces a considerable variety of schistose rocks of sedimentary origin but also includes some altered igneous members. The rocks of this area seem to be more universally metamorphosed and to have a more complex structure than those of the Ruby-Poorman area. The sedimentary members consist mainly of quartzite, quartz-sericite schist, mica schist, phyllite, and crystalline limestone, of which quartz-sericite schist and phyllite are perhaps the most common. The greenstones are distinctly schistose and are considered to represent original basic lava flows. Gneissoid hornblende diorite is also well represented among the altered igneous rocks. Quartz venation, which tends to follow the cleavage, is common, but apparently here, as in the Ruby district, this quartz was not associated with any mineralization of economic value. The dominant structural feature is cleavage that trends about north, with marked variations to the east and west. The dip of the cleavage is erratic. In this area the metamorphic rocks are considered to be mainly of pre-Ordovician age.

EARLY PALEOZOIC LIMESTONES

In the Ruby-Kuskokwim region, as in other parts of interior Alaska, great deposits of limestone were formed during the Ordovician and Silurian periods. This statement is not intended to imply that Cambrian or Devonian limestones are not represented in this region; nor does it mean that all the rocks of the Ordovician and Silurian systems are calcareous. It is true, however, that the only fossiliferous rocks of Ordovician and Silurian age so far recognized in this region are limestones. The largest body of limestone is found along the southeast side of the Nixon Fork, where such rock is exposed in a belt 7 to 8 miles wide and more than 30 miles long. A smaller belt of limestone, about 2 miles wide, extends northeastward from Tamarack Landing, on the Sulatna River, for 7 miles. Smaller bodies of limestone are exposed along the banks of the Yukon River both above and below Ruby; and still smaller masses occur on the ridge between the heads of Poorman and Timber Creeks and at other isolated localities.

The limestone formation of the Nixon Fork district, according to Brown,[6] consists of several lithologic types, which are differentiated mainly on the basis of color and the thickness of beds. Most of this limestone, though apparently massive when viewed from a distance in the higher hills, is essentially thin-bedded, but a few beds from

[5] Brown, J. S., The Nixon Fork country, Alaska: U. S. Geol. Survey Bull. 783, pp. 101–102, 1926.

[6] Idem, pp. 102–105.

20 to 200 feet thick occur. The massive and moderately thin bedded varieties are blue-gray, gray, or white on fresh fracture but weather to a dull white or gray. The very thin-bedded varieties, however, though dark gray or black on fresh fracture, tend to weather to tones of buff, yellow, and brown. These thinner-bedded rocks are also impure, containing layers and beds of calcareous sandstone, shale, and chert. The structure of this great mass of limestone is evidently complex, for the beds appear to be compressed into sharp folds, anticlinal, isoclinal, and overturned. With a liberal allowance for duplication of beds due to close folding, the minimum thickness of 5,000 to 7,000 feet of limestone, suggested by Brown, is conservative and reasonable. Brown made 15 collections of fossils from this limestone, most of which were found along the northwestern border of the mass. Of these collections eight were determined as Ordovician, five as Silurian, and two were indeterminate. The Ordovician faunas are principally of Richmond (Upper Ordovician) age, and the Silurian faunas appear to be late Silurian, so that similar limestones of widely different age are evidently closely associated, making their differentiation a difficult matter. This condition may perhaps be similar to that noted by the writer [7] in the White Mountains, of the Yukon-Tanana region, where Silurian limestone has been found resting without angular discordance upon calcareous tuffs and lavas of Ordovician age.

The limestone northeast of Tamarack Landing on the Sulatna River consists mainly of massive blocks, which show neither bedding nor banding. The structure and age of this mass of limestone are indeterminate, but it is probably of either Ordovician or Silurian age.

The limestone exposed along the banks of the Yukon River below Ruby is a highly metamorphosed crystalline variety, in which the original bedding is indeterminate, though in places there is a decided banding, which is more likely to be a secondary structural feature. This limestone ranges in color from white to dark gray but weathers white. About 4½ miles upstream from Ruby are two beds of limestone, separated by a body of schist that in part is garnetiferous. Garnetiferous schist has likewise been found south of the limestone below Ruby, so that there appears to be a close association between rocks of these two types. These bodies of limestone conform with the generally southwest regional trend of the undifferentiated metamorphic rocks, but their local relation to the schists is obscure. As no fossils have been found in these crystalline limestones their age is unknown, but they are believed to be not younger than Ordovician.

[7] Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872 (in press).

DEVONIAN ROCKS

Devonian rocks are typically developed along the Kuskokwim River from a point not far below Medfra downstream as far as Vinasale. These rocks were first seen and mapped by Spurr,[8] by whom they were designated the "Tachatna series" (now Takotna). The "Takotna series" was defined as a series of "gray limestones (generally thin-bedded and fissile), limy, carbonaceous, and chloritic slates, and occasional generally fine-grained arkoses." No further work has been done in areas of these rocks since 1898, and the lithologic description therefore stands as given. Between Medfra and McGrath these rocks, though much folded, have a dominant strike to the northeast and dip usually southeast. This structure accords well with the presence of Ordovician and Silurian limestones farther north, along the divide between the Nixon Fork and the Kuskokwim River. From fossils collected by Spurr along the north bank of the Kuskokwim about 13 miles in an air line above McGrath, the age of these rocks has been determined to be Middle Devonian.

Three other small areas of Devonian rocks are known in the Ruby district—two of them along the automobile road not far north of the old Hub roadhouse and the other at the head of the south branch of Main Creek. These isolated patches of Devonian rocks are infolded with the metamorphic rocks that surround them and have a common regional structure. They consist of much sheared and partly recrystallized limestone that contains fragments of determinable invertebrates.

CARBONIFEROUS ROCKS

Few Carboniferous rocks have yet been definitely recognized in the Ruby-Kuskokwim region. Harrington[9] described briefly a formation in the vicinity of Mount Hurst, in the Tolstoi district, which he regarded as probably Carboniferous. These rocks lie west of Mount Hurst and extend from Tolstoi Creek intermittently northward for nearly 20 miles. They are described as schistose limestones, with which are associated small areas of phyllite and schistose argillitic rocks. Most of the Carboniferous rocks of Alaska, particularly the limestones, are abundantly fossiliferous, but no fossils were found in the supposed Carboniferous rocks near Mount Hurst. It is possible that this limestone is of pre-Carboniferous age.

A body of Permian limestone 5 miles in length is exposed in the upper valley of Meadow Creek about 30 miles north and a little east of the Nixon Fork lode mines. The trend of these rocks is northwest.

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[8] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 157–159, 1900.

[9] Harrington, G. L., The gold and platimum placers of the Tolstoi district, Alaska: U. S. Geol. Survey Bull. 692, p. 342, 1919.

According to Brown,[10] the stratigraphic sequence of rocks at this locality comprises a few hundred feet of soft yellowish sandstone and sandy limestone, overlain by 1,000 feet of slate, in turn overlain by quartzite and more soft sandstone. Both the upper and lower members of the sequence are fossiliferous. These rocks trend northwest, dip southwest, and appear to overlie unconformably undifferentiated metamorphic rocks to the north.

LATE PALEOZOIC OR EARLY MESOZOIC ROCKS

A group of rocks whose age is not closely determined form the ridge country for some distance south of Poorman, extending from the heads of Glacier and Timber Creeks southward to the North Fork of the Innoko River. Similar rocks have been mapped by Harrington north and south of Mount Hurst, in the Tolstoi district. These rocks consist essentially of chert, argillite, and slate, with which are interbedded more or less lava and tuff. The chert ranges in color from light to dark green, with white, blue-gray, and horn-colored varieties. The argillaceous members of this sequence are well-indurated dark-gray rocks, usually without a slaty cleavage. The interbedded lavas and tuffs appear to be the same as similar lavas and tuffs that constitute a contiguous geologic formation, and it is presumed that the cherts and argillites grade, either upward or downward, into a volcanic series. Most of the cherts and argillites are closely folded, and their regional trend ranges from northeast in the area south of Poorman to north-northeast in the vicinity of Mount Hurst. The dip is inconstant, both in direction and in degree. These rocks are younger than Devonian and older than Cretaceous, but no closer assignment of age can be made. They are therefore regarded, until better information can be obtained, as of late Paleozoic or early Mesozoic age.

UPPER CRETACEOUS AND EOCENE ROCKS

The bedrock over a large part of the Ruby-Kuskokwim region is believed to be mainly of Upper Cretaceous age. The northeasternmost exposure of this belt of rocks in this region is in the headward portion of the valley of the Susulatna River (locally called "Agate Fork"), from which point the rocks extend southwestward for 150 miles to Georgetown. Similar rocks also extend from the Innoko-Iditarod flats for 50 miles southeastward to the Kuskokwim River.

These rocks consist mainly of sandstone and shale, with many intermediate rocks, such as sandy shale and shaly sandstone, to-

[10] Brown, J. S., op. cit., pp. 105–107.

gether with a minor proportion of conglomerate. Small seams of coal also occur in these rocks. So far as known, no large bodies of chert or limestone occur in this series, and their absence affords one method of distinguishing the Cretaceous rocks of this region from earlier Mesozoic and Paleozoic rocks. The proportion of sandstone to shale has not been determined, but the sandstone, because it forms the ridge tops where rocks crop out, appears to be more plentiful than it really is. At many localities the sandstone and shale, particularly the shale, show the effects of thermal metamorphism, a result of their intrusion by igneous rocks. Several different types of conglomerate have been recognized. A basal conglomerate, according to Spurr,[11] is exposed along the Kuskokwim River about 10 miles below Vinasale, where these rocks first appear in a trip downstream. Intraformational conglomerate has been observed at many places. The upper conglomeratic beds, which appear to grade upward into Eocene rocks, occur mainly along the divide at the heads of the Susulatna River and Folger Creek, where they form a small synclinal basin.

The Upper Cretaceous rocks in general are deformed into a system of broad open folds, whose axial planes strike northeast. The rocks dip both northwest and southeast, and it is evident that beds at the same stratigraphic horizons are repeated many times across the strike. No detailed stratigraphic sections have been measured, and the thickness is therefore at present undetermined, though probably aggregating thousands of feet. Locally, in the neighborhood of the Tertiary intrusives, these rocks have been closely folded and faulted into complex structure, and close to the intrusive contacts they have been baked and silicified. A structural feature of special interest is a conspicuous system of linear drainage channels that trend N. 50° E. across the country. The longest and most marked of these form a line 150 miles or more in length, along which lie the valleys of Bonanza and Fourth of July Creeks, the Takotna River, and the Nixon Fork. This line is believed to be the site of an extensive fault or zone of faulting.

Most of these rocks are known from their contained fossils to be of Upper Cretaceous age, but it is possible that some Lower Cretaceous rocks are also present, in large measure buried by the Upper Cretaceous rocks. From the synclinal basin at the heads of the Susulatna River and Folger Creek, however, the writer in 1915 collected Tertiary plants and also invertebrates that could be either Upper Cretaceous or Tertiary. It is therefore fairly well established that this sequence of rocks also contains beds of post-Cretaceous age, and the relation of these younger beds to the

[11] Spurr, J. E., op. cit., p. 159.

monzonitic rocks of the region is the principal evidence for the Tertiary age of the latter.

LATE TERTIARY ROCKS

After the deposition of the Eocene rocks exemplified by those at the heads of the Susulatna River and Folger Creek, this region was uplifted and has remained a positive element in the earth's crust to the present day. With such terrestrial conditions, erosion rather than sedimentation became the dominant geomorphic process, but some continental deposits were formed which have persisted. Thus, in the area west of Cloudy Mountain tuff, tuffaceous sandstone, and shale are interbedded with the Tertiary lavas. Small remnants of beds of conglomerate have been found at several widely separated localities, suggesting that considerable areas of such rocks may once have existed. The rocks interbedded with the Tertiary lavas are probably of post-Miocene age, but the age of the conglomerate is entirely indeterminate.

QUATERNARY DEPOSITS

The Quaternary deposits consist of unconsolidated alluvial material of diverse character, ranging in age from early Pleistocene to Recent. Ever since the ice age these deposits have been continuously in process of formation by various agencies of degradation, transportation, and deposition; and their history is complex and not thoroughly understood. Most of these deposits are of fluviatile character, but glacial, lacustrine, eluvial, residual, eolian, and other types of deposits are also present. A description of the distribution, character, origin, and age of all these deposits is beyond the scope of the present paper, but some details regarding the character of the fluviatile deposits are given in the account of the gold placers.

Only the high mountains in the Ruby-Kuskokwim region have supported glaciers in the past, but some of these have been rather deeply scoured by the alpine glaciers that extended from the mountain summits for some miles down the valleys. In general, the country above an elevation of 4,000 feet was occupied by glaciers, but such areas constitute only a very small part of the region. Some of the more strongly glaciated areas are the Beaver Mountains, Cloudy Mountain, and the Sunshine Mountains, but slight glaciation has also occurred in some of the lower groups of mountains. In the more strongly glaciated areas valley glaciers moved down the slopes, particularly the north slopes, and developed such topographic forms as cirques, hanging valleys, and U-shaped valleys, which are characteristic of glacial erosion. In the subsequent melting of these ice streams morainal deposits were left in the valleys. Some of these deposits

remain undisturbed in their original form, but most of them have been extensively reworked by later streams, which have converted them to a greater or less degree into apparently normal fluviatile deposits.

Throughout the Pleistocene epoch, in the country that was too low to be glaciated, a variety of other alluvial material was being deposited. These deposits are in general of two types—fluviatile and lacustrine. The oldest of these Pleistocene deposits is the deeply buried gravel that lies on bedrock in the ancient stream channels. The gravel was deposited by active streams, which functioned under climatic conditions not greatly dissimilar to those existing at the present time. The thickness of the older gravel appears in general to be closely related to the size of the stream that formed the deposits and ranges from a few feet to 20 or 30 feet. The channels in which the gravel lies, though determined by the antecedents of the present streams, are in general dissimilar to the present stream channels, as they follow down one side of a valley or perhaps cross back and forth without regard to the present channels. Some of the richest gold placers of the region have been found in these ancient deposits of buried gravel, of which those of Long and Poorman Creeks are excellent examples.

With the advent of the ice age, or perhaps as a result of conditions induced by the ice age, this type of active fluviatile erosion and deposition largely ceased, and the older gravel was gradually buried by deposits of silt. These silt deposits are much thicker in the Ruby district than they are farther south in the Ruby-Kuskokwim region, and no completely satisfactory explanation of their origin has been evolved. Some of them, as in the valleys of the Yuko and Nowitna Rivers, have a thickness of 100 feet or more above the present stream levels and an undetermined thickness below. Similar deposits of silt occur as surficial veneers in the valley of the Nowitna River and its tributaries up to an elevation of at least 1,200 feet above sea level, but whether these deposits remain in essentially their original form or whether they are the relics of very deep valley deposits that extended up to this elevation has not been determined. It seems probable that some of the thicker deposits of silt, particularly in the Ruby district, are of lacustrine origin, but this interpretation is more difficult of application farther south. Some of the silt has been extensively moved by the action of winds, though this statement does not necessarily imply original eolian origin. The dune topography in the valley floor of the upper Nowitna Valley, northwest of the Sunshine Mountains, exemplifies this condition.

The deposition of silt, regardless of its origin was probably brought about through some marked changes in local climatic conditions.

Whatever these changes were, they exerted a profound effect upon the fauna of the region. Many types of animals that existed at the beginning of the silt sedimentation became extinct; others were modified, with the resulting development of new species more fit to cope with the new conditions. The silt therefore became the burial place of many ancient animals, and in it are commonly found the bones of ancient species of mammoth, buffalo, horse, musk ox, moose, bear, beaver, and other vertebrates.

In addition to the ancient buried gravel and the silt, numerous small deposits of high gravel occur in the Ruby district. Many of these are unrelated to the present streams, and the rounded forms of the cobbles and boulders indicate that such deposits do not consist of ordinary weathered or residual material. Skookum Bar, near the divide between Boston and Big Creeks, is an example. Such patches of high gravel may be interpreted either as remnants of pre-Pleistocene fluviatile deposits, comparable with the gravel of Idaho Bar, in the Rampart district, or as late Pleistocene delta or beach deposits laid down at various stages in the lowering of Pleistocene lake basins. The terraces of this district are likewise susceptible of several interpretations.

After the dispersal of the alpine glaciers and the termination of silt sedimentation in this region, the more usual types of erosion and sedimentation were again established, and normal fluviatile processes again became dominant. Apparently much of the silt was rapidly removed, and the modern stream gravel began to form. At some localities, particularly in the northern part of the region, the gravel was laid down on beds of silt; but at other places, particularly in the southern part of the region, where the silt deposits either were thinner and were more completely removed or else were not deposited, the recent gravel was laid down on bedrock surfaces, and some of these modern deposits have been the source of valuable gold placers. The placers of the Cripple district are examples of gold deposits in recent gravel.

Rock debris must first be produced before it can be transported by the streams and deposited as alluvial material. Rock comminution is accomplished by different processes, partly chemical and partly mechanical. In cold climates mechanical disintegration of the bedrock, as a result of alternate thawing and freezing, is a more active factor than in warmer climates, and considerable subsequent movement of the rock debris is also accomplished by frost heaving and by processes of soil flowage peculiar to subarctic regions. A mantle of residual and semiresidual material thus accumulates on the surfaces of ridges and moves gradually down the

slopes into the valleys. If the bedrock is mineralized, a considerable concentration of gold may occur in these processes, such that the resultant debris may be worked as a commercial placer. The placers at the heads of Flat, Happy, and Chicken Creeks, in the Iditarod district, exemplify such residual deposits that constitute commercial placers.

IGNEOUS ROCKS

PALEOZOIC GREENSTONE AND TUFF

In the Ruby district lava, tuff, and intrusive rocks of greenstone habit crop out intermittently from the head of Big Creek southwestward to Yuko Mountain and occur also at Twin Buttes and in the headwater portions of the valleys of Long Creek and the Sulatna River. These rocks include gabbro, diabase, basalt, diorite, and andesite, but the three basic varieties are the most plentiful. Most of these rocks have been greatly altered from their original state by chemical and dynamic metamorphism, and some of them are completely recrystallized. They are rather closely associated at some localities with beds of chert. Little information is available regarding the structure of these rocks, but in general they appear to have much the same trend as the underlying metamorphic rocks—that is, about N. 25° E.—with the lavas dipping both to the northwest and southeast. The age of these rocks is indeterminate, but they probably represent more than one period of Paleozoic igneous activity, ranging possibly from the Ordovician to the Carboniferous.

PALEOZOIC OR MESOZOIC LAVAS

Lava flows and tuffs of late Paleozoic or early Mesozoic age are known definitely only at one locality—in the headwaters of the South Fork of the Sulatna River, extending south into the valley of the Susulatna River. Certain rocks of similar character in the vicinity of Mount Hurst, which have been mapped as of Tertiary age, may also belong to this sequence.

These lavas are fine-grained to aphanitic rocks, which range from cream-colored and buff into yellowish and reddish-brown rocks. Most of them are porphyritic, with phenocrysts of plagioclase, ranging from oligoclase to labradorite, and rarely biotite. The ground mass consists mainly of quartz and oligoclase-albite, with some biotite and a few scattered grains of iron oxides. These rocks are essentially soda rhyolite and oligoclase dacite. In general their component minerals are considerably altered to secondary products. The feldspar is more or less sericitized, and the biotite and iron minerals are altered to iron hydroxides. In addition, however, much silicification has occurred, particularly in the tuffaceous members of

this group. The field relations indicate that a part of these rocks are interbedded with the upper part of the chert and argillite rocks of late Paleozoic or Mesozoic age, and the volcanic activity that produced them is believed to have begun at or near the end of the period of sedimentation represented by these cherts and argillites.

MESOZOIC (?) GRANITE

Three bodies of true granite occur in the Ruby district—one at the head of Flint Creek, another along the ridge east of Birch Creek, and a third on the east side of the lower Sulatna River. These rocks are composed of quartz, orthoclase or microcline, anorthoclase, biotite, muscovite, and a subordinate amount of plagioclase feldspar. A chemical analysis of the granite from the head of Flint Creek indicates that quartz forms about one-third and feldspar about one-half of the rock. These rocks are therefore highly alkalic and siliceous, and have not the common petrographic characteristics of the Tertiary monzonitic rocks, nor of their granitic variants. No critical stratigraphic evidence as to the age of these granites is available, but as only two periods of granitic intrusion later than the pre-Cambrian are now known in interior Alaska, and these rocks do not appear to be related petrographically to the Tertiary monzonitic rocks, it has been assumed as a working hypothesis that they belong to the earlier, or Mesozoic, type of granitic rocks. These Mesozoic (?) granites are believed to be the source of the mineralization in the valley of Long Creek and perhaps also at Poorman, but, as in the Fairbanks district, the genetic connection between the intrusive rocks and the placers is an indirect one, in that the granite produced mineralization at some distance from its contact with the country rock.

TERTIARY INTRUSIVES AND EXTRUSIVES

In an earlier report the writer[12] differentiated and mapped four groups of Tertiary igneous rocks, which occur at many localities in the central and southern part of the Ruby-Kuskokwim region. These four groups of rocks included the following:

1. Pyroxene andesite and basalt (flows and tuffs).
2. Pyroxene diorite, gabbro, pyroxene andesite, diabase, and basalt (intrusives).
3. Monzonite and quartz monzonite (intrusives).
4. Oligoclase-quartz diorite, soda granite, oligoclase dacite, and soda rhyolite (intrusives and extrusives).

[12] Mertie, J. B., Jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pp. 62–74, 1924.

It is not practicable in the present paper to enumerate the various localities at which these rocks occur nor to describe their petrographic characteristics. The monzonitic rocks, however, are of most significance because they are the source of much of the mineralization of this region, and for that reason some further details regarding them are given below.

So far, 24 localities are known where monzonite, quartz monzonite, or closely related rocks occur in the central and southern parts of the Ruby-Kuskokwim region. These are as follows:

1. Cripple Creek Mountains.
2. Mount Hurst.
3. Twin Mountain.
4. Beaver Mountains.
5–11. Localities in the Nixon Fork district.
12. Takotna Mountain.
13. Head of Candle Creek.
14, 15. Mount Joaquin and another mountain about 10 miles south of it.
16. Head of Moore Creek.
17. Camelback (Bonanza) Mountain.
18–21. Localities in the Iditarod district.
22. Locality 7 miles east of Georgetown.
23, 24. Barometer Mountain, south of the Kuskokwim River, and another locality about 10 miles to the west.

In the Cripple Creek and Beaver Mountains the monzonitic intrusives are associated with a variety of other Tertiary igneous rocks and have not been separately mapped. Prospectors, to whom these rocks are of prime importance, should also remember, however, that such rocks doubtless exist at many other localities in this region, and that the smaller and less conspicuous intrusive bodies, which are least likely to be seen in reconnaissance geologic work, may be of more economic significance than the larger bodies.

The monzonite and quartz monzonite are coarsely crystalline light- to dark-gray intrusive rocks, that are as a rule uniformly granular and nonporphyritic. Normally they consist of orthoclase, plagioclase, biotite, augite, hornblende, and more or less quartz, together with small amounts of iron ores, apatite, zircon, and titanite. The orthoclase and plagioclase occur in about equal amounts and in some rocks occur as graphic intergrowths. Taken together the feldspars constitute from 60 to 70 percent of these rocks. Quartz is scarce or absent in the monzonites, but ranges in amount up to 18 percent in some of the quartz monzonites. Biotite and augite are the usual dark minerals; hornblende is less common; and olivine occurs in some of the monzonites. These four dark minerals constitute from 10 to 35 percent of these rocks. The iron ores, magnetite and ilme-

nite, form from 1 to 4 percent. Many variants of these monzonitic rocks also exist as dikes.

Most of the monzonitic and associated intrusive rocks of the Ruby-Kuskokwim region invade Upper Cretaceous rocks at many different localities and are therefore not older than Upper Cretaceous and probably younger. In the vicinity of the Cripple Creek Mountains these rocks invade a country rock that is probably of Eocene age, and on this stratigraphic evidence they are considered to be not older than Eocene. It is probable that they are of mid-Tertiary age. Insufficient work has yet been done in the Ruby-Kuskokwim region to prove that all the monzonitic rocks are of Tertiary age, but most of them have petrographic features that suggest a common origin and age.

ECONOMIC GEOLOGY

Gold is the principal mineral product of the Ruby-Kuskokwim region, but smaller amounts of other minerals have also been produced commercially. Placer gold is mined on many different creeks in the Ruby, Cripple, Ophir, Tolstoi, Nixon Fork, McGrath, Iditarod, and Georgetown districts; and lode gold is produced in the Nixon Fork district. In a country where placer gold is so widespread, it may seem strange that so few gold lodes have been located, but in this region the spurs and even the main ridges are deeply covered with a mantle of residual debris, overlain by moss, so that prospecting for lodes is difficult and costly. However, it is likely that in the coming years, even this handicap will be overcome, and the bedrock sources of some of this gold will be found.

Other minerals besides gold have been found in the placer concentrates, showing their presence in the region, but for the most part their bedrock sources are likewise unknown. Such minerals include cassiterite, scheelite, galena, cinnabar, stibnite, and bismuth, or, in other words, ores of tin, tungsten, lead, mercury, antimony, and bismuth. A mercury lode mine on the Kuskokwim River about 15 miles above Georgetown has been worked on a small scale for many years. Other lodes have also been found, but few of them have been brought to the stage of production.

Coal beds have also been found and prospected at several localities, but so far coal has not been an economic factor in the development of this region. Wood appears to be an adequate fuel for heating and for small power plants, but where larger or more economical power is required, the great advantages of internal-combustion engines have led to the importation of gasoline and fuel oil.

PLACERS

RUBY DISTRICT

The gold placers of the Ruby district are, in general, deeply buried, discontinuous bodies of gravel, which lie on bedrock beneath a cover of silt, in rather wide, open valleys. As a rule the placers do not follow the present courses of the streams but lie on one side or the other, on so-called benches. These are not true bench placers, however, because the surface of the bedrock below the placers is not much higher than that of the bedrock below the streams and at some localities may be lower. These deposits are therefore classified as buried placers; they were undoubtedly formed by the ancient streams that carved the valleys and not by the streams that now occupy these valleys.

Gold-bearing gravel is widely distributed throughout the Ruby district, but the commercial placers are localized in three general areas, which may be designated the Ruby, Long, and Poorman areas. (See pl. 2.)

RUBY AREA

The Ruby area includes several creeks close to the present town of Ruby, chiefly Ruby Creek and various headwater tributaries of Big Creek. No placer mining is now in progress in this area, but the placers of Ruby Creek have some interest because they are the site of the original gold discovery in this district.

Ruby Creek is a stream about 2 miles in length that empties directly into the Yukon River at Ruby. Gold was discovered on Ruby Creek about a quarter of a mile above its mouth in the summer of 1907, and the gold-bearing gravel was worked in a small way for many years thereafter. The gold placers were found on a small bench along the east side of the creek. According to early reports the overburden was from 12 to 15 feet thick and consisted of sandy loam and fine gravel at the bottom, covered with carbonaceous silt or muck. The loam and gravel were interbedded, and the gravel consisted of fine pebbles of schist and slate, together with some well-rounded boulders of dioritic rocks and vein quartz, the largest of which were 18 inches in diameter. On Discovery claim the bedrock is mainly a blocky limestone, the crevices in which are filled with the overlying loam. The gold was in very small particles, and most of it occurred in the sand and fine gravel just above bedrock, though some lay directly on and in bedrock. The placers of Ruby Creek were found to be localized and of low tenor, so that the total production probably never exceeded a few thousand dollars.

During the winter following the discovery of gold on Ruby Creek several men prospected in the headwaters of Big Creek, and accord-

ing to Maddren[13] at least 15 shafts were sunk to bedrock. This work showed a depth to bedrock of 15 to 60 feet and a stratum of 1 to 7 feet of gravel overlain by silt and clay. Colors of gold and considerable pyrite were found in all these holes, but no pay streak was located. In later years considerable additional prospecting has been done in the headwater tributaries of Big Creek, and some gold has been found on Glacier Creek, but no rich placers have been located. The same may be said of the headwater tributaries of Boston and Beaver Creeks.

LONG AREA

The Long area comprises essentially all the headwater tributaries of the Sulatna River on which gold placers have been found. These streams include Long Creek and its tributaries; several tributaries of the Sulatna that enter a short distance below the mouth of Long Creek; and the headwater tributaries of Flint and Trail Creeks, which head against Long Creek and flow eastward to the Sulatna. Numerous rich gold placer deposits have been found in the Long area, but the richest and most continuous of these is the pay streak on Long Creek, which has been worked since 1910.

LONG CREEK AND BEAR GULCH

Long Creek is a stream about 20 miles in length that heads against Beaver and Main Creeks and flows generally southward to the Sulatna River. There are several abrupt changes in its course, one of which occurs at the townsite of Long, where the stream, flowing about S. 60° E., turns abruptly to flow S. 40° W. Bear Gulch (locally caller "Bear Pup"), a small tributary of Long Creek, enters directly at this turn and, having a general course of S. 50° W., appears to be the real head of Long Creek. Another equally well marked change in direction is at the mouth of Ptarmigan Creek, a tributary from the northwest, where Long Creek veers abruptly from a course of S. 50° W. to S. 30° E. These changes in the course of Long Creek were probably induced by variations in the structure of the bedrock and were doubtless established at an early stage in the development of the valley.

On its west side Long Creek has one small tributary, Last Chance Creek, which enters about 2½ miles above Long, and two large tributaries, called Basin and Ptarmigan Creeks, which enter several miles below Long. Some low-grade placers have been found in Swift and Willow Creeks, headwater tributaries of Basin Creek, but no placers are known to have been found on Ptarmigan Creek or its

[13] Maddren, A. G., Gold placers of the Ruby district, Alaska: U. S. Geol. Survey Bull. 379, pp. 232–233, 1909.

tributaries. On its east side Long Creek has a considerable number of small tributaries, many of which contain gold. These eastern tributaries, named in order downstream, are Bear Gulch, Fourth of July Creek, Snow Gulch, Fifth of July Creek, Short Creek, Flat Creek, Midnight Creek, Greenstone Creek, and Andrew Gulch. Bear Gulch and Midnight and Greenstone Creeks have produced considerable amounts of placer gold.

The valley of Long Creek is asymmetric, having a fairly steep slope on its west side and a gentle slope on its east side. This asymmetry is noticeable throughout the valley but is much more pronounced in the headwater part, above the town of Long. The depth of the valley below the ridges on both sides is about 1,000 feet. The valley floor above Long is rather narrow, but below Long it widens rapidly, and at the lower end of the productive portion it becomes a broad, flat, swampy muskeg plain. The gradient of Long Creek within the productive area is about 1¾ percent, but the gradient of the bedrock is appreciably higher. The gradient of Bear Gulch is about 2 percent. In cross section the bedrock floor of lower Long Creek is nearly flat for a considerable distance, indicating a considerable lateral widening by the ancient stream before the valley was alluviated. The present stream does not in general flow on bedrock, even at times of flood; but a little below Snow Gulch, where it is superposed on the west wall of the old valley, it flows for a short distance over a bedrock riffle.

The pay streak on Long Creek is formed at its upper end by the junction of two lesser pay streaks, one from Bear Gulch and another from upper Long Creek; and from this junction, which marks the townsite of Long, the pay streak extends downstream for a known distance of about 3½ miles. The pay streak extends up Bear Gulch about four claim lengths and up Long Creek above the mouth of Bear Gulch, for six or eight claim lengths. The original discovery of gold on Long Creek was made on upper Long Creek, just above the present site of Long; and this Discovery claim serves as a starting point from which not only the claims of upper and lower Long Creek but also those of Bear Gulch, are numbered. Plate 3, though not accurate in orientation and scale, shows the general position of the placer-mining claims on Long Creek.

The present course of Long Creek bears no close relation to the configuration of the bedrock floor of the valley, and the pay streak is essentially independent of the course of the stream. On upper Long Creek the pay streak lies along the east side of the creek. This pay streak is dissected by Bear Gulch and continues again on the Mascot claim east of Long Creek but swings away from the creek, so that on the Windy claim it is about 250 yards from the creek. On the Novika-

kat association the pay streak is decidedly sinuous, but from the middle of this association it veers toward the creek, and at the junction of the Lone Pine and Keystone claims it approaches close to Long Creek. Still farther downstream, on the Buckeye claim, the pay streak again veers to the east of the creek. As a result of these conditions the configuration of the valley floor and that of the underlying bedrock are not closely accordant, and the depth of the pay streak below the surface is variable, ranging from 20 to 80 feet. Thus, some of the deepest mining was done close to Long on the Mascot claim, where the pay streak lies below a sharply rising valley floor. On the other hand, at the lower end of the Novikakat association the pay streak was less than half as deep, although the bedrock gradient down the valley is greater than the stream gradient.

The pay streak on Long Creek is neither continuous nor uniformly of high grade. It is rather a succession of high-grade placers connected by low-grade or nearly barren gravel deposits, all of which, however, have a fairly well defined directional trend. Even at the sites of the higher-grade deposits the gravel that was mined was found to be decidedly "spotted"—that is, the gold was very irregularly distributed. In fact, much of the gold was found in pockets on or in crevices in the bedrock. The mineralized belt that produced the gold on Long Creek evidently lay east of the creek, and the pay streak was apparently enriched locally by an accretion of gold from the small eastern tributaries of Long Creek or perhaps by residual erosion and creep from mineralized zones along the ridge to the east. No average value of the pay streak can be stated, but, in order to pay, most of the ground that has been worked by underground methods had to yield 85 cents or more to the square foot of bedrock. Some of the pay streak barely afforded wages; some of the ground that was worked yielded from $1.50 to $3 a square foot; and at one place on the Mascot claim some of the ground averaged $15 a square foot over a considerable area. The Mascot claim has been the richest on the pay streak, having produced more than $750,000.

The stratigraphic section from the surface to bedrock, along the pay streak, has been found to be rather variable. On the Mascot claim, at the time of the writer's first visit, in 1915, a shaft 75 feet deep showed at the top 30 feet of muck, followed downward by 30 feet of a mixture of muck and slide rock and 15 feet of gravel. The gold was found at the base of the gravel and in the underlying 2 to 3 feet of decomposed bedrock. At some places clay seams or false bedrock was found 2 to 3 feet above the bedrock, but where gold was found on such clay beds little or no gold was found on the true bedrock below. The bedrock was a cherty or siliceous rock, with talcose bands. It was much jointed and had weathered into splintery and fibrous

pieces, which were easily picked in mining. It is evident from conditions underground that much residual alteration had taken place in the bedrock prior to the deposition of the overlying gravel. On the Novikakat association the pay streak has been found to lie from 20 to 70 feet below the surface, averaging perhaps 40 feet, with a thickness of gravel on bedrock ranging from 4 to 16 feet. On the Lone Pine claim the depth to bedrock was 50 feet, with gravel at the base averaging 10 to 15 feet in thickness. The pay streak at different localities is also variable in width, but it has been worked at places up to a width of 100 feet.

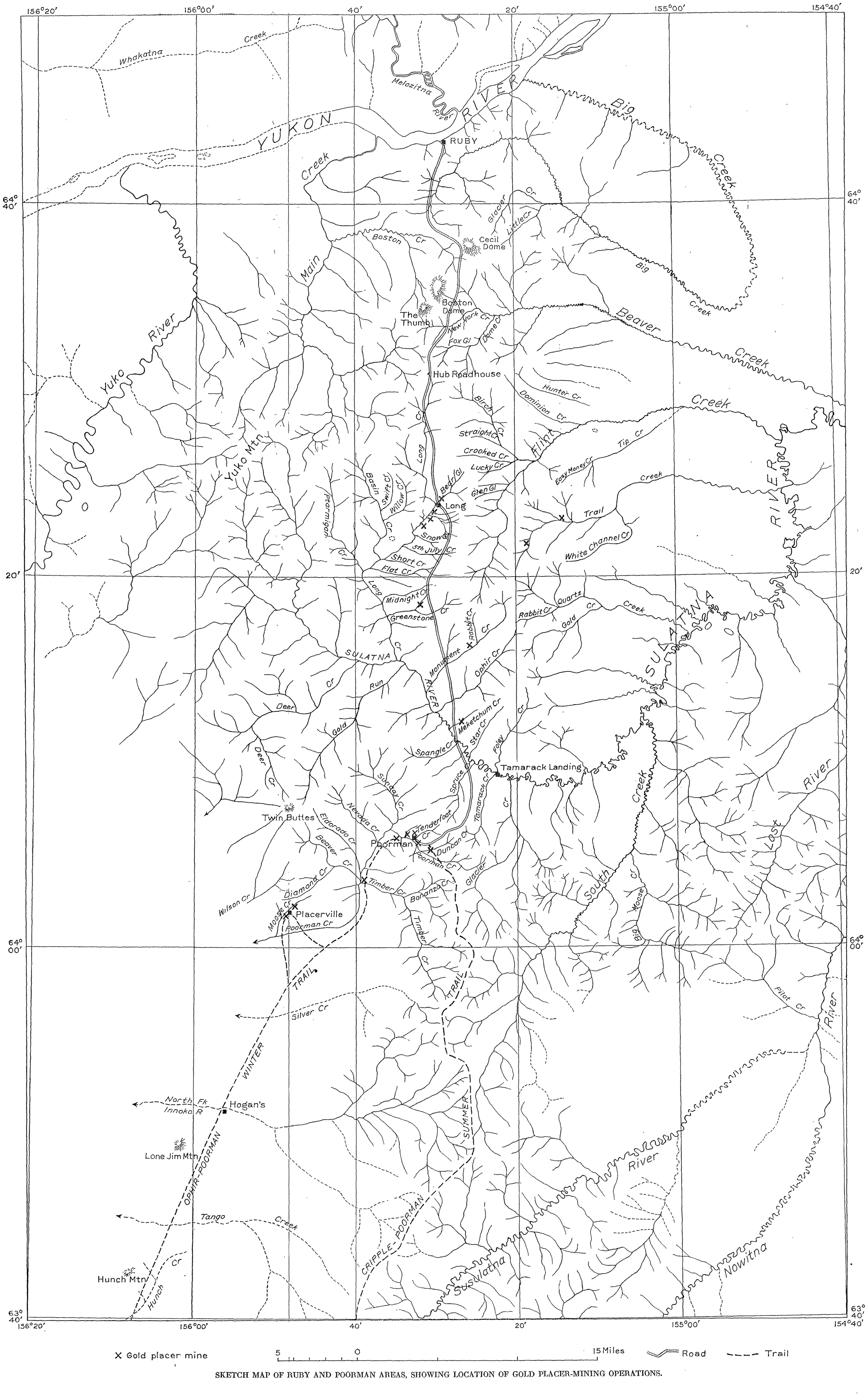
The gold, whether it occurs on or just above bedrock, is rather closely associated with gravel that is tightly cemented in a clayey matrix, so that it is necessary to wash the material thoroughly to separate the gold as it passes through the sluice boxes. Much brecciated but little-worn vein quartz is also found with the placer gold. The gold itself varies considerably in appearance, some of it being spongy and some dense, but most of it is not thoroughly rounded and gives the impression that it has not traveled far from its bedrock sources. Both coarse and fine gold occur in the pay streak, but the gold from the Mascot claim was particularly coarse and in the earliest operations at that site was recovered largely in the form of nuggets. One of these nuggets, at the then current price of $20.67 an ounce for pure gold, was valued at $1,961; and another, which is said to have been stolen and later cut into two parts, is reported to have had a value of $2,700. Farther down Long Creek the gold in the pay streak becomes progressively smaller in size, with fewer nuggets and more fine gold. The following assays of the gold from Bear Gulch and Long Creek, representing about 1,500 ounces, were supplied mainly by Robert Deacon, of Long:

Fineness of gold from Long Creek and Bear Gulch

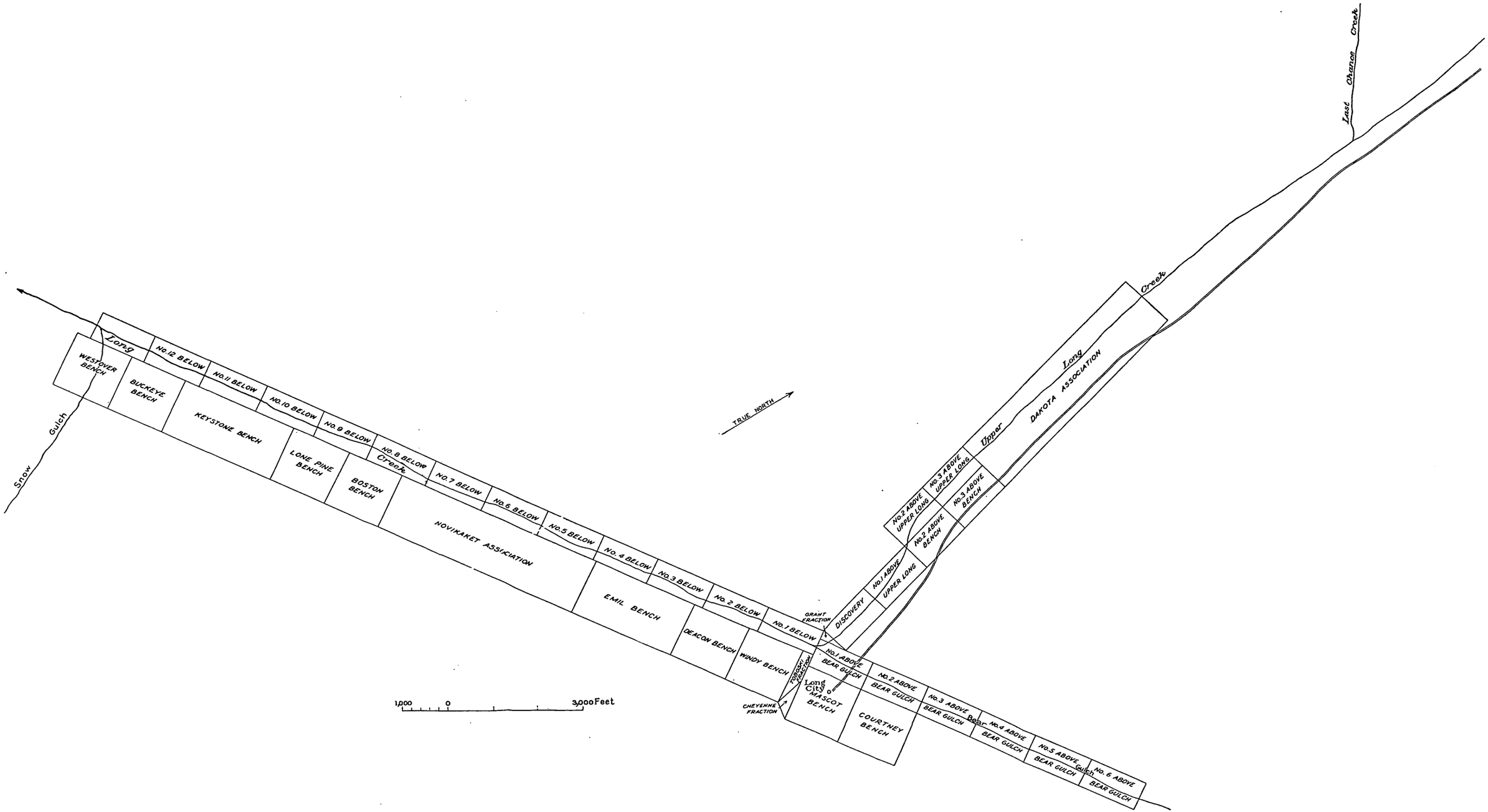
[Parts in a thousand]

Year	Gold	Silver	Year	Gold	Silver
1914	860	132	1918	854	137
1915	856½	135	1924	855½	135
	859¼	132	1926	859	138
	859½	133	1929	852½	145
1916	857½	137	1931	855	139
	856½	137			
	861¼	128	Average	857	135
1917	858¾	134			

No consistent difference is apparent in the fineness of the gold from one end of the pay streak to the other. Considerable amorphous cassiterite, or wood tin, occurs in the concentrates recovered with the gold, not only on Long Creek but also on all its eastern tributaries where gold placers have been worked. Cassiterite is also



SKETCH MAP OF RUBY AND POORMAN AREAS, SHOWING LOCATION OF GOLD PLACER-MINING OPERATIONS.



SKETCH SHOWING LOCATION OF PLACER-MINING CLAIMS ON LONG CREEK, IN THE RUBY DISTRICT.

found in the headwater tributaries of Flint and Trail Creeks, which head against Long Creek.

Little is known by the writer regarding the character and depth of the pay streak and of the overburden on upper Long Creek, above the mouth of Bear Gulch. Gold has not been mined above the Dakota association. Apparently the bench claims on the east side of the creek, opposite claims 2 and 3 above Discovery, have been the best claims, and these two claims together have produced about half as much gold as the Mascot claim. The Dakota association, Discovery claim, and claim 1 above Discovery have each produced only about $10,000. The depth of bedrock on these five claims is reported to have ranged from 20 to 50 feet, and the gravel on bedrock is said to have ranged in thickness from 4 to 10 feet.

The productive claims on Bear Gulch consist of six creek claims and a bench claim opposite claim 2 above Discovery, which adjoins the Mascot claim on its upstream side. The principal pay streak on Bear Gulch was found on a low terrace along the southeast side of the creek, where it followed close to the creek, rarely passing to the northwest side; but open-cut mining operations have so diverted the creek from its original channel that the relation of the pay streak to the present creek is not entirely clear. Claims 2 and 3 above Discovery were the best of these creek claims, producing together probably between $500,000 and $600,000. The pay streak on these creek claims of Bear Gulch ranged from 20 to 30 feet below the surface, with a thickness of gravel of 6 to 8 feet. The average width of the pay streak up to the upper end of claim 3 above Discovery was from 75 to 100 feet.

In addition to the main pay streak along Bear Gulch, there is another pay streak of lower tenor that branches off from the main pay streak at the upper end of claim 2 above Discovery and extends southward onto the bench southeast of the creek. This appears to be a true bench channel, for the bedrock here is 20 to 35 feet above the level of the present creek. The overburden is about 25 feet thick and is nearly all muck or silt, with little or no gravel. The bedrock on this bench is a brown-stained, greatly weathered greenstone, and the gravel includes the various types of country rock and vein quartz. At the south end of this cut several feet of gravel lies on bedrock, but this is unusual. This side or bench pay streak has been worked for a length of 400 feet and a width of 125 feet. In general, conditions on Bear Gulch are essentially similar to those on lower Long Creek. The main pay streak follows the southeast side of the valley and is not closely related to the course of the present creek. The gold has come into the valley from the southeast side, and this is particularly evident in the local enrichment of the

pay streak at the mouths of gulches entering from that side. The bench channel that starts at claim 2 above Discovery merely represents a preserved remnant of an older erosion surface, and similar terraces carrying lower-grade gold placers may later be located on Long Creek, east of the main creek.

Most parts of the pay streak of Long Creek and Bear Gulch have been worked by underground methods, though the shallower pay streak on Bear Gulch was worked mainly by open cuts. The method of mining that was and still is used is to sink a shaft to bedrock, drive drifts north and south from the shaft, and open up crosscuts in the drifts, retreating gradually with the workings toward the shaft. All this ground is frozen, and therefore steam points were utilized for thawing. The pay dirt is wheeled to the shaft in barrows, dumped into a bucket, and elevated to the surface, whence the bucket is conveyed by an overhead tram to a gin pole, where the bucket is automatically tipped and the gravel dumped. Although the deposits on the upper bench claims, such as the Mascot, Windy, Deacon, and Emil, were in general frozen, some water was encountered, so that pumping was necessary at some plants, thus increasing the cost of operation. From the Novikakat association downstream, however, considerable thawed ground was found, and both timbering and pumping became increasingly necessary, except in the blocks of frozen ground. These mining operations have been carried on both in summer and in winter. Steam generated by a boiler using wood as fuel is used for power. The gravel is washed when water is available, but water in sufficient volume for sluicing has been hard to get at some plants, particularly during dry summers. Thus, when the Mascot claim was first opened up, the sluice water was impounded and used repeatedly in a short line of sluice boxes. Naturally, with the gold held in sticky clay, much of it was not saved, and the tailings from these operations were so rich that they subsequently were reworked by a scraper plant and yielded a handsome profit.

During the summer of 1933 only two plants were being operated on Long Creek and Bear Gulch. One of these plants was on the upper end of the Novikakat association and consisted of the usual shaft and drift mining operations. This work was being done in a block of frozen ground. The shaft was 45 feet deep, and the gravel on bedrock had a thickness of 5 feet. The other plant was engaged in open-cut mining operations on the first tier bench, opposite the upper end of claim 2 above Discovery. This mining was being done in the bench pay streak and at the lower end of the 400-foot cut described on page 149. The work was done by means of a 2½-inch giant, fed by water from a flume 600 feet long, which obtained its water from a small gulch farther upstream on the southeast side of

the valley. This water was delivered under a head of 30 feet, but water is ordinarily scarce, so that little mining can be accomplished except in the spring and during rainy periods.

Long Creek, as a whole, constitutes a favorable project for unified large-scale mining operations. By the underground methods so far used only the high-grade parts of the pay streak could be worked at a profit. In the areas so far worked, much of the poorer material has been left, and some of the richer deposits have doubtless not been discovered. In addition, however, there is much virgin ground, some of which may be of good tenor, that has not been worked and cannot be worked profitably by underground methods, because it is thawed, and the flow of water cannot be easily controlled. The lack of sufficient water above the level of the pay streak, either on Long Creek or in any nearby streams within a reasonable distance, renders impracticable large-scale hydraulic mining operations by the use of water supplied by ditch lines; and some of the ground is rather deep to be worked by ordinary dredges, without the prior removal of some of the overburden. At the present stage of development of placer mining, two possible methods might be feasible. If the ground warrants the cost, large-scale hydraulic methods might be applied, using a large volume of water pumped upstream from the Sulatna River or over the divide from the Yukon. Otherwise a smaller volume of water might be pumped to supply sluice water for the use of dragline excavators of the type now being used in the Iditarod district.

FIFTH OF JULY AND SHORT CREEKS

The pay streak on Long Creek has not been explored below Snow Gulch. Still farther down the valley, but farther from Long Creek than the main pay streak, some work was done years ago between the tributary gulches Fifth of July and Short Creeks, at a place 3 miles below Long and about a third of a mile from Long Creek. A shaft 75 feet deep was sunk to bedrock and showed 40 feet of muck underlain by 35 feet of gravel and slide rock. The bedrock is a white clay, and the gold lay either on or close to this material. The ground is very spotted. The gold that was found was in small particles, with only a few small nuggets.

Some mining operations were also carried on in earlier years in the valley of Short Creek. Here the pay streak was not deeply buried, for the overburden consisted of but 6 to 8 feet of muck lying above 4 to 6 feet of well-worn gravel and sand containing numerous well-rounded boulders of quartz and cobbles of greenstone. The gold was found within a foot of bedrock, but the tenor of the gravel was low, and the pay streak poorly defined and irregular. This work was done by open-cut mining methods.

MIDNIGHT CREEK

No mining is now in progress on Midnight Creek, but this stream had gold placers that were formerly worked by underground methods. In 1915 placer mining was in progress about a mile above the winter trail to the Sulatna River and about three-quarters of a mile west of the present automobile road. The overburden here consisted of 14 feet of muck overlying 4 feet of auriferous gravel, which rested upon a false bedrock of clay-cemented material. The gold was in very small particles. Farther downstream, near the winter trail, a hole was sunk 80 feet to true bedrock, but no mining was done, so far as known.

On Midnight Creek, as on the other eastern tributaries of Long Creek, considerable cassiterite was found in the concentrates recovered with the gold. During the progress of mining on Midnight Creek, either in or prior to 1918, 14 sacks of concentrates were shipped to Singapore for smelting.[14] This shipment consisted of 1,037 pounds of ore, which was found to contain 537 pounds, or about 52 percent, of metallic tin. These concentrates were recovered in working 6,000 square feet of bedrock, and the net return to the operators was $156.22, or about 2½ cents to the square foot of bedrock. At 87 cents a pound for tin, the current price in 1918, the value of this shipment was about $467; but the cost of shipment and smelting, together with penalties imposed by the smelting company on account of admixed ores, doubtless accounts for the small returns to the shipper. As this shipment, however, probably represents the average character of the cassiterite ores recovered from the placers of the Long area, it appears that the tin adds little to the over-all value of the ground.

GREENSTONE CREEK

Greenstone Creek, the next tributary of Long Creek from the east below Midnight Creek, has a length of about 5 miles. It has been the site of considerable mining activity in past years and is still being worked. Greenstone Creek is formed by the confluence of two headwater gulches, of which the northern one is known as Greenstone Gulch. The mouth of this gulch is about 2 miles above the mouth of the creek. The original discovery of gold on Greenstone Creek was probably made near the lower end of Greenstone Gulch, but no discovery claim was ever formally staked. From a point on Greenstone Gulch about 800 feet upstream from its mouth the placers of Greenstone Gulch and Greenstone Creek were worked downstream for a distance of about 2 miles by a dredge that was built in 1916 and oper-

[14] Chapin, Theodore, Tin deposits of the Ruby district, Alaska: U. S. Geol. Survey Bull. 692, p. 337, 1919.

ated for 2 years. The pay streak followed the general course of the creek and was from 60 to 100 feet in width. At the lower end of the area dredged the overburden above bedrock was 25 feet thick, but at the upper end it was only 5 to 8 feet thick. The overburden is said to have been almost entirely gravel, with only a surficial covering of muck, and was everywhere frozen. The ground worked by the dredge is believed to have had a value of 30 to 40 cents a square foot, and the total production is reported to have been about $500,000.

A short distance above the upper workings of the dredge the creek pay streak ends, but at a higher elevation along the northwest valley wall another pay streak begins and continues upstream. This is made up of several narrow transverse pay streaks that trend southeast toward the main creek, each a few feet wide and about 50 feet in length. These parallel pay streaks are about 300 to 400 feet from the creek and about 20 to 40 feet higher. The overburden is mostly gravel from 6 to 10 feet deep. These little pay streaks were mined by open cut and shoveling into boxes some years ago.

About 2,000 feet upstream from the mouth of Greenstone Gulch and 1,200 feet from the uppermost dredge tailings there appears another pay streak in the creek bed, which might be considered an upstream continuation of the lower pay streak worked by the dredge. This pay streak also was worked but is now being reworked along the margins of the old diggings. The overburden at the present open cut is unfrozen ground and consists of 2 feet of silt overlying 4 feet of gravel. The gravel is poorly sorted angular to subangular material, composed mainly of gabbroic greenstone with a little vein quartz. Numerous angular greenstone boulders, the largest as much as 30 inches in diameter, occur in the gravel. The bedrock is also greenstone. Practically all the gold occurs on bedrock. It is said to be fine-grained, some of it angular, and some well worn. One assay shows a fineness of 865¾ parts of gold and 129 parts of silver in a thousand. Water for sluicing is obtained from a ditch about 1½ miles in length that goes around the point of the spur between Greenstone Gulch and Greenstone Creek and taps the creek. At the time of the writer's visit water was scarce and only enough was available for two splashes a day, or about 3 hours of sluicing. The pay gravel is shoveled into 6 sluice boxes, but 18 additional boxes are used as a flume line to lead water from the ditch.

MONUMENT CREEK

Monument Creek, an eastern tributary of the Sulatna River, is a stream about 9 miles in length that occupies one of the broad, open valleys so characteristic of the Ruby district. Gold was discovered on Monument Creek during the winter of 1912–13, but though now

known for more than 20 years, this creek has produced only about $30,000. Discovery claim was located at the mouth of Rabbit Creek, a tributary from the north, about 4½ miles from the mouth. The main pay streak on Monument Creek is very irregular, both horizontally and vertically, but has been traced from a point half a mile above Rabbit Creek downstream for about a mile. As seen at its lower end the pay streak lies about 100 feet northwest of and parallel to the creek and is said to be from 20 to 50 feet wide, with a tenor in places of 60 to 75 cents a square foot. The best ground so far worked was on Discovery claim.

On the Eagle association, about a quarter of a mile below Rabbit Creek, the section to bedrock comprises 25 feet of muck underlain by 15 feet of gravel, all solidly frozen. The gravel averages 5 to 6 inches in diameter, but near bedrock there are some boulders as much as 2 feet in diameter. The fragments are subangular to rounded, showing fair water action, and consist of a variety of Paleozoic semimetamorphic rocks, such as quartzite, chert, slate, and a little limestone, and several varieties of basic greenstone. The gold occurs in streaks of fine gravel 3 to 6 inches thick in the main body of gravel, and these streaks are irregularly distributed, both laterally and vertically. Little or no gold is found on bedrock. Both coarse and fine gold are present, but the largest piece so far found weighed a little over an ounce. Three assays of the gold, furnished by Dan McFadden and based on production in 1924, 1927, and 1931, show an average fineness of 853 parts of gold and 139 parts of silver in a thousand.

The gold placers of Monument Creek were worked during the winter of 1931–32, when a winter dump was taken out on the upper end of the pay streak, above Rabbit Creek. This work was done by underground mining, the gravel being thawed by steam points and hoisted to the surface by a hand windlass. A small prospecting boiler was used for furnishing power.

SWIFT AND WILLOW CREEKS

Swift and Willow Creeks are two small tributaries of Basin Creek near its head. They head against Last Chance Creek, a tributary of Long Creek. Some prospecting was done on Willow Creek in earlier years in an effort to locate shallow placers that could be worked at a profit by open-cut methods, but the results have not been generally favorable. About a mile above the mouth of Willow Creek holes ranging in depth from 35 to 70 feet were sunk to bedrock, and a little mining was done on shallow ground above a false bedrock of clayey gravel. The gold is said to have

been fine-grained, bright, and only slightly rounded. No work is in progress on this creek at present.

The upper part of Swift Creek has been the site of open-cut mining for some years, both on Discovery claim and on claims below Discovery. At present, one operator is engaged in small-scale open-cut mining on Discovery claim. The pay streak is in the bed of the creek and is about 10 feet wide, and the ground is said to have a tenor of about 25 to 30 cents a square foot of bedrock. The overburden consists of 5 to 9 feet of gravel, though at the upper end of the cut some silt overlies the gravel. This overburden is unfrozen. The gravel is largely sheared chert and greenstone, with a small proportion of sandy phyllite and a little schist. More or less vein quartz also occurs in the gravel. The gold is found in the lower foot of gravel and in the upper foot of bedrock.

Below Discovery claim old tailing piles show the site of earlier work. There the overburden is thicker, at one place 16 to 20 feet, consisting of 6 to 8 feet of gravel overlain by 10 to 12 feet of muck. This ground was worked by drifting and produced some coarse gold, with a record of one nugget valued at $50.

MEKETCHUM CREEK

Meketchum Creek is a short eastern tributary of the Sulatna River that enters about 3 miles below the mouth of Monument Creek. Gold was discovered on Meketchum Creek in 1917, at a site named the Red Dog claim. The pay streak was located in the present valley floor, along the south side of the creek but close to it and at places reaching it. On the Red Dog claim the pay streak is 40 feet wide and is reported to have been traced 3,000 feet above the present workings, though it narrows somewhat upstream. Downstream from the present workings the pay streak veers away from the creek to the south. The overburden at the Red Dog claim is 80 feet thick and consists of 60 to 70 feet of muck, overlying 10 to 20 feet of gravel in which the gold is more or less evenly distributed. Farther upstream the gravel thins to 2 or 3 feet, and the gold occurs mainly on or near bedrock. All this ground is solidly frozen and in underground work requires little timbering. The gravel is subangular greenstone, of an average size of 4 to 6 inches, and the bedrock is also greenstone. The gold is of high purity, as the mean of two assays shows 918 parts of gold and 76 parts of silver in a thousand. Considerable coarse gold is recovered.

This ground is worked mainly in winter by the usual underground methods. During the summer of 1933 two men were prospecting, in preparation for operating during the winter of 1933–34.

TRAIL CREEK

Trail Creek is one of the longer of the lower tributaries of the Sulatna River from the west. The upper valley of Trail Creek is connected with Long by a trail that crosses Flint Creek, which lies between Long Creek and the headwaters of Trail Creek. Trail Creek has been worked and prospected for several miles from its headwaters, and colors of gold are said to have been found for 17 miles downstream. No Discovery claim was originally staked on Trail Creek, but the older workings are in the upper valley not far below the confluence of the two headwater gulches that form the head of the creek. About a quarter of a mile below this confluence and for some distance downstream gold was found along the northwest side of the creek, but no well-defined pay streak was located; the gold occurred in small spots, which, though they ranged in tenor from 75 cents to $2.25 a square foot of bedrock, were found to be discontinuous and erratically distributed. These spots occurred 50 to 150 feet from the creek. The overburden, which is about 35 feet thick, consists at some places almost entirely of muck but at other places includes a basal stratum of gravel 2 to 5 feet thick. Some of this gravel is frozen and some is unfrozen, with no apparent relation to its proximity to the creek. The gravel is subangular, and the cobbles average 5 to 6 inches in diameter and consist mainly of greenstone, fine-grained quartzite (in part banded), more or less carbonaceous shale, chert, and considerable vein quartz, which occurs here and there in boulders as large as 2 feet in diameter. The bedrock is shale, probably altered by weathering from slate. Most of the gold lies on or in bedrock.

About half a mile below the confluence of the headwater gulches, on the northwest side, a rich spot was discovered and mined that was said to have yielded $2.25 in gold to the square foot of bedrock. Here the bedrock was highly mineralized with pyrite, and a pan taken from the old tailings showed several good-sized pieces of pyrite and gold to the value of about 3 cents. Of the gold mined about 10 percent was in nuggets worth $5 or more apiece, and one nugget worth $300 was found. Some of this gold was spongy and little rounded, but some was well rounded, suggesting both near and remote bedrock sources. The ratio of gold to silver was said to be 5.5 to 1, which, if 1 percent is allowed for dross, gives a fineness of 838 parts of gold and 152 parts of silver in a thousand. Many other shafts have been sunk in this upper part of the valley, on both sides of the creek, as the pay streak goes from one side to the other, and some of these shafts have struck good spots that were worked at a profit, but a continuous workable paystreak has not been located.

About 3½ miles below the head of Trail Creek two miners were preparing during the early summer of 1933 to begin mining with a hydraulic plant. These men hold three association claims with a total length of about 4,000 feet along the creek and with water rights upstream, and in July they had just completed the building of a ditch 6,000 feet in length along the south side of the valley, which will give them a head of 70 feet at the lower end of their ground. Hydraulic operations had not yet begun at the time of the writer's visit, but the overburden to be worked appeared to have a thickness of about 25 feet, with only about 2 feet of gravel at the base. The operators plan to use two giants, with 1½- and 2-inch nozzles, one for washing down the overburden and one for stacking tailings. Some of this ground has prospected as high as $1 a square foot of bedrock, but the operators, well knowing the irregular distribution of the gold on this creek, are not expecting much more than a third of that value.

Still farther downstream on Trail Creek a large tributary, White Channel Creek, enters from the south. Some prospecting was done on White Channel Creek during the winter of 1914–15, and holes were sunk 150 feet to bedrock. A stratum of white quartz gravel was located, but apparently no workable pay streak could be found.

FLINT CREEK AND TRIBUTARIES

Flint Creek is the next large tributary of the Sulatna River from the west, north of Trail Creek. Unlike Trail Creek, however, it has a considerable number of good-sized headwater tributaries, which include Dominion, Birch, and Crooked Creeks, as well as the main head of Flint Creek itself. With the exception of Dominion Creek, all these upper tributaries of Flint Creek head against Long Creek.

Birch Creek was staked and prospected in 1914, and considerable mining was done on this creek in subsequent years. The principal mining operations were carried on along the southwest side of the valley, for about 2 miles above the mouth of Crooked Creek. Here the bedrock is said to have been covered by 70 to 90 feet of overburden. The bedrock is composed of Mesozoic (?) granite, but this is succeeded downstream by pyritiferous slate. The gold occurs mainly on or in the granite bedrock and is fairly coarse, but much of it is greatly tarnished. Three recent assays show 872 parts of gold and 120 parts of silver in a thousand. Pyrite, cassiterite, and native bismuth occur in the concentrates.

Crooked Creek is a tributary of Birch Creek. Along the south side of Crooked Creek there is a poorly defined silt terrace, in which were sunk shafts that showed 40 to 50 feet of silt, overlying several

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feet of gravel with clayey layers, but so far as known little gold was found at this locality. During the summer of 1933 two men were engaged in prospecting on Lucky Creek, a tributary of Crooked Creek.

Glen Gulch is a west tributary of Flint Creek that enters about 2 miles above the mouth of Birch Creek. The gravel on Glen Gulch was found to be gold-bearing throughout the length of the creek, and considerable mining, both underground and open cut, has been done. According to earlier records, the depth to bedrock ranged from 10 to 15 feet in the upper valley and was as much as 35 feet or more in the lower valley. In the upper valley the overburden was mostly gravel, but in the lower valley the gravel ranged in thickness from 1 to 7 feet. The ground in the lower valley was frozen and required thawing. No mining is now in progress on Glen Gulch.

Above Glen Gulch there are several western tributaries of Flint Creek that have been prospected, but no extensive mining has been done. These small tributaries, named in order upstream, include Gold Run, Eldorado Creek, Root Creek, and Granite Creek. Prospecting has also been done on Tip Creek, a lower tributary of Flint Creek, and on Easy Money Creek, the head of Tip Creek. Shafts seen along the northwest side of upper Flint Creek, where the trail from Long to Trail Creek crosses, were said to have been sunk 40 feet to bedrock, through frozen ground. The bedrock at these shafts is a porous quartzite, but the most interesting feature here was the considerable variety of rocks represented in the gravel, which, however, included very few cobbles of granite, though Flint Creek heads in a body of granite. The extremely decayed condition of these few granite cobbles suggests that prolonged residual weathering was widespread in this region prior to the formation of the gold placers. Evidently, the granitic rocks were so badly weathered that few of them were able to withstand the abrasion attendant upon transportation downstream.

POORMAN AREA

Poorman Creek and its tributaries are the sites of various gold placers. Poorman Creek is a tributary of the North Fork of the Innoko River and is separated from the Sulatna drainage basin by a broad, flat ridge about 1,100 feet above sea level. Three small streams, known as Tamarack, Spruce, and Spangle Creeks, that flow northeastward to the Sulatna from this broad divide, are also included as a part of the Poorman area, mainly because of their proximity to it. Poorman, in the upper valley of Poorman Creek, is the distributing point for the Poorman area and is connected with Ruby by a truck road 58 miles in length.

The Poorman placer area included originally the upper valley of Poorman Creek, the lower tributaries of Poorman Creek from the southeast, and the nearby Sulatna tributaries mentioned above. Subsequently gold placers were found farther down the valley of Poorman Creek, in tributary streams that enter from the northwest. These include the placers found on Beaver Creek and the group on Moose Creek designated locally Placerville. All these placers are here included as part of the Poorman area.

POORMAN CREEK

Poorman Creek heads against Glacier Creek, a tributary of the Sulatna River, and flows N. 60° W. for about 6 miles, then turns abruptly and flows in a general southwesterly direction to the North Fork of the Innoko River. The northwestward-trending part is here referred to as upper Poorman Creek. In this upper part of its valley Poorman Creek receives two tributaries from the northeast, in order downstream Duncan and Tenderfoot Creeks. Little Gulch, known locally as Little Pup, enters Poorman Creek from the opposite side of the valley about halfway between Duncan and Tenderfoot Creeks. The first tributary of Poorman Creek from the east, below the bend, is Solomon Creek, another site of placer mining. Below Solomon Creek, on the same side of the valley, is Timber Creek, which with its tributaries Flat and Bonanza Creeks also contains gold placers. The next two tributaries of Poorman Creek from the southeast, below Timber Creek, are Gentian and Cache Creeks, but these are not known to have gold placers. Spruce and Tamarack Creeks are the two principal tributaries of the Sulatna River that contain gold placers and are included as part of the Poorman area.

The first discovery of gold in the Poorman area was made on upper Poorman Creek by a Mr. Hermann in 1912, and mining began the following year. The valley of upper Poorman Creek is wide and open but is asymmetrical in cross section, for the north slope is longer and gentler than the south slope. No well-defined benches occur on either side of the valley. The auriferous gravel on Poorman Creek extends from a point near the mouth of Duncan Creek, following generally along the north side of the creek, to a point a short distance above Tenderfoot Creek, where it becomes a workable pay streak that begins to veer northward away from the creek, and continues down along the north bench of Poorman Creek. The richest placers have been found along this north wall of the valley at a distance of 600 to 1,000 feet from the creek. Farther down the valley, however, the pay streak crosses to the south side, where it is now being mined. It is apparent that the old course of Poorman Creek bears no close relation to its present channel; and

here, as on Long Creek, the pay streak occurs as a typical buried placer, which, after its formation, was covered by silt and has not since been denuded, except where subsequent superposed streams have dissected the silt and bared the ancient gravel to erosion. The same is true of the tributaries of Poorman Creek.

The gold of the placers on Poorman Creek and vicinity originated in quartz veins in the country rock, but apparently this mineralization of the bedrock was sharply restricted on at least two sides. Little gold is found on Poorman Creek above the mouth of Duncan Creek nor on Timber Creek above the mouth of Flat Creek. Accordingly, Tamarack, Duncan, and Flat Creeks appear to mark the eastern limit of mineralization, and the lower valley of Poorman Creek seems to mark the western limit. It seems probable that this mineralized belt is underlain by granitic rocks, which were the source of the quartz veins, but of this there is no direct surficial evidence. The manner of concentration of the gold in this area is noteworthy. Everywhere the gravel of the gold placers includes a large proportion of vein quartz, and among the other rocks represented chert is next in abundance. This condition can have been produced only by a long period of residual rock decay prior to the formation of the placers, whereby, through selective disintegration, the highly resistant siliceous rocks became the prevalent rock debris. Probably most of the old quartz veins in the country rock had a low tenor in gold, but the prolonged disintegration must ultimately have freed a large quantity of gold, which was subsequently washed down into the valleys to form the gold placers.

The mining plants in the Poorman area, particularly on Poorman Creek, were seriously handicapped by the drought of 1933, and for that reason mining operations were sharply restricted. Moreover, the two largest plants now operating on Poorman Creek were in litigation, and the owners were not on the premises, so that little first-hand information could be obtained regarding conditions underground. In the valley of Poorman Creek, a short distance above Tenderfoot Creek and about 150 feet north of Poorman Creek, a prospecting shaft 50 feet deep was sunk during July, which exposed 48 feet of muck overlying 2½ feet of gravel, with a bedrock of crenulated phyllite. This shaft is about at the point where the pay streak, in its extension downstream, veers toward the bench. Little gold has been found in the gravel for three claim lengths above this shaft.

Where Tenderfoot Creek enters Poorman Valley the pay streak is interrupted, but just below Tenderfoot Creek, along this north side of the valley, the richest placers have been found. At the time of the writer's first visit to Poorman Creek, in 1915, six plants were being

operated along this bench, and these operations showed a stratigraphic section to bedrock, in general, as follows: From the surface downward was a thickness of 18 to 68 feet of muck, averaging 44 feet; below this was fine gravel or "chicken feed", ranging in thickness from 1 to 14 feet and averaging 5 feet; and still lower, lying upon bedrock, coarser gravel, ranging in thickness from 2 to 12 feet and averaging 6 feet. The bedrock was partly a crenulated phyllite, approaching a schist, and partly mica rhyolite porphyry probably belonging to the Paleozoic or Mesozoic lavas. The gravel consisted largely of boulders of vein quartz and rusty quartz breccia, with varying amounts of igneous rocks, quartzite, phyllite, slate, and chert. Most of the gold lay on bedrock, but in places it extended down into the bedrock for 2 or 3 feet. The gold was characteristically fine-grained, the pieces having an average value of perhaps 3 to 5 cents each; nuggets were uncommon and not of large size, the largest up to that time having a value of $12. The gold was rather rough, and pieces of vein quartz were attached to some of the larger pieces. Some of this placer ground ran as high as $5 to the square foot of bedrock, but ground was worked that averaged an eighth of that value.

The principal recent development has been the discovery of other pay channels still farther north on this bench of Poorman Creek, and these are the placers that are now being worked. West of Tenderfoot five groups of claims are now being held and partly worked. The second of these groups, consisting of several claims owned by Teobaldo Forno, is the site of one of the larger plants now operating on Poorman Creek. The working shaft is 1,000 feet from Poorman Creek, and its top is perhaps 40 to 50 feet above the level of the creek. The depth to bedrock is 80 feet, but the depth to bedrock under Poorman Creek directly to the south is 40 feet; therefore bedrock at this plant is little, if any, higher than under the creek, 1,000 feet distant. This shows the great width of the bedrock floor of Poorman Creek. The upper 75 feet of the overburden is largely muck, overlying 5 feet of gravel. The pay streak, both here and on the next claims to the west, is said to be from 200 to 300 feet wide, and present operations are along its north side. The gravel is angular to subangular and is nearly 50 percent vein quartz, with phyllite constituting most of the remainder, though a little chert, cherty grit, and both gabbroic and basaltic greenstone also occur. The bedrock is the dark-colored phyllite so common elsewhere along this pay streak. Most of the gold is fine-grained, and the largest nugget so far found at this plant had a value of only $10. One assay of the gold produced in 1932 showed a fineness of 840¾ parts of gold and 154 parts of silver in a thousand. The concentrates showed much barite and pyrite, as well as other minerals.

West of Forno's ground are the Washington and Gold claims, owned by Dennis Coyle, where a second large plant is being operated. No one was at this plant at the time of visit, and no first-hand information could be obtained regarding conditions underground, but presumably they are much the same as on the claims to the east. Still farther west, on the Knoll claim of the fourth group, a prospect shaft was being sunk late in July, which at a depth of 75 feet had penetrated through the muck and into the gravel. The gravel here, as to the east, was subangular and contained much vein quartz. Small particles of gold were found in the upper part of the gravel stratum, but bedrock had not yet been reached.

Considerably farther down Poorman Creek, where the pay streak crosses to the north side, a third large plant was operated by Harry Jensen during the winter of 1932–33. A recent assay of the gold at this site shows 853¼ parts gold in a thousand. The shaft at this plant was said to be only 40 feet deep, but no other information regarding the mine was obtained.

All these mining plants along the "benches" of Poorman Creek are worked by underground methods, either in summer or in winter. The ground, in general, is frozen, but here and there thawed streaks are encountered. Thus in the ground now being worked west of Tenderfoot Creek the southern or more valuable side of the pay streak was frozen solid, but thawed ground is found along the north side, so that some pumping has to be done. The bedrock also "swells" when the gravel is removed; therefore it is seldom that more than 10,000 square feet of bedrock is cleaned from any one shaft. Mining is carried on by the usual drifting methods, which include wheelbarrowing the gravel to the shaft; elevation to the surface in an iron bucket by means of a steam hoist; and overhead tramming to the gin pole, where the bucket is automatically tipped. On the "bench" at Poorman water for sluicing is obtained from Tenderfoot Creek, but here, as at other plants in the vicinity, the low gradients of the streams make it impossible to obtain water under sufficient head to wash the auriferous gravel after it is dumped at the surface. The sticky character of the gravel, due to an admixture with clay, renders a stream of water still less effective. To overcome this difficulty duplex force pumps are extensively used to create the necessary pressure for the giants. The increased recovery of gold from the gravel more than pays for the installation and operation of such pumps. All these plants are operated by steam power, generated by wood-burning boilers. Examples of the power required in such plants are as follows: Forno uses a 35-horsepower Pennsylvania-type boiler; Coyle, a 30-horsepower Scotch marine boiler; and Jensen (at the lower plant), a 16-horsepower Scotch marine boiler. These three drift-mining plants employ about 20 men.

HEADWATER TRIBUTARIES OF POORMAN CREEK

Duncan Creek, one of the tributaries of upper Poorman Creek from the north, has been worked since 1913. At the time of the writer's visit in 1915 the principal work was being done on claims 1 and 2 below Discovery, in a valley that projects into the valley floor of Poorman Creek. The section on these lower claims showed 43 feet of muck, overlying 2 to 5 feet of gravel, which rested on a bedrock of schist. The gravel was subangular and included a considerable amount of a porous quartz breccia that looked like a weathered quartzite containing angular quartz pebbles. The gold was in small particles and rather angular, and the largest nugget that had been found had a value of $25. The pay streak was said to have a tenor of about 75 cents to the square foot of bedrock.

At present two men are prospecting on the lower end of Discovery claim, where conditions are somewhat similar to those on the lower claim. A shaft 56 feet deep had penetrated through about 54 feet of muck and had uncovered 2½ feet of gravel, lying upon a bedrock of schist. The gravel is subangular and consists of schist, vein quartz, and a minor proportion of other rocks. The pay streak, so far as known, is in the central part of the valley, on the southeast side of the creek but close to it. The gold lies mostly in bedrock, of which 2 feet must be removed in order to get a good recovery. Upstream, shafts have shown a general increase in depth to bedrock; but about 1,500 feet upstream, two shafts disclosed shallow ground on the northwest side of the creek and deep ground at some distance from the creek to the southeast. The old channel, therefore, bears no close relation to the present course of Duncan Creek.

Little Gulch (locally called "Little Pup") is a small gulch with gently sloping walls that opens into Poorman Creek from the southwest, about midway between Duncan and Tenderfoot Creeks. Years ago a small pay streak, about 3,000 feet long, was located on Little Gulch but was soon worked out. This pay streak is said to have been 5 to 14 feet wide, and the best part of it had a tenor of $2.25 to the square foot of bedrock. The ground was worked for about 150 yards along the creek and is said to have produced $4,800. About 200 yards downstream this pay streak was prospected by a shaft, and showed gravel with a tenor of 65 cents to the square foot, but this gravel was not worked. About 100 yards above the upper end of the old pay streak another shaft was sunk to a depth of 62 feet, but this uncovered no pay gravel. In these two shafts, and in fact everywhere on Little Gulch, very little gravel is present, and the entire overburden is muck. The bedrock is a closely folded phyllite. One man is now engaged in prospecting farther up on Little Gulch and is sinking a shaft about 1,400 feet upstream from the old pay streak.

SOLOMON CREEK

Solomon Creek, a stream about 3 miles in length, enters Poorman Creek from the east about 3 miles below the bend. The headwater part of the valley of Solomon Creek is narrow and rather steep-walled, but farther downstream the valley becomes wide and open and gradually merges into the still wider valley floor of Poorman Creek. The original discovery of gold on Solomon Creek was made in the upper valley during the winter of 1913–14.

Two men are now operating a drift mining plant in the upper valley of Solomon Creek, on the Hard Times and Lucky claims. The pay streak here lies in the present valley floor, and the shaft is about 80 feet south of the creek bed. The pay streak is about 40 feet wide and consists of 4 to 5 feet of angular wash, bound together by clay and overlain by about 22 feet of muck. This angular gravel consists of phyllite and vein quartz, in about equal proportions, and ranges in size from small fragments to boulders 18 inches in diameter. The bedrock is phyllite. At the property the gold is rather evenly distributed through the angular wash, and practically none is found on or in bedrock. The gold is angular, and much of it has inclusions of quartz. No coarse gold is found, the largest nugget being valued at only $1. The fineness of the gold dust from this creek is reported to be 830 parts of gold and 165 parts of silver in a thousand.

Mining is accomplished by drifting, both in summer and in winter. The pay dirt is hoisted and dumped in the usual way. A 300-foot ditch from Solomon Creek supplies water for sluicing, but the pressure obtainable is insufficient for washing the sticky mixture of clay and gravel, and a Worthington duplex force pump is used to deliver the water to a giant under the required pressure. For power, a wood-burning upright boiler rated at 10 horsepower is utilized.

About a mile downstream from the plant just described other drift mining plants have operated on Solomon Creek, but no mining was in progress at the time of the writer's visit. Two working shafts were seen, one 400 feet downstream from the other; drift mining was done at the upper one in 1929–30 and at the lower one in 1932. Both shafts are on the north side of Solomon Creek and about 200 feet from it. At the downstream shaft a thickness of 7 to 8 feet of gravel was found on bedrock, overlain by about 52 feet of muck, but the pay streak was only 15 feet wide. The ground, however, had a tenor of about $1.50 to the square foot of bedrock. The gravel is angular and includes about 75 percent of vein quartz, together with considerable chert and other rocks. The average size is 6 to 8 inches, but boulders as large as 2 feet in diameter were found. The bedrock is slate. Most of the gold is angular, and it occurs in a stratum about 1 foot thick, immediately above bedrock. The largest nugget recovered at this

plant weighed about half an ounce. At the upstream shaft the depth to bedrock was also about 60 feet, and gravel of the same character and thickness was found on bedrock. The pay streak, however, consisted of several high-grade narrow streaks distributed over a width of 80 feet, so that the pay streak as a whole was of rather low grade, averaging perhaps 35 cents to the square foot of bedrock. About 50 percent of the gravel is vein quartz. The bedrock is a lustrous black slate, tending toward a phyllite. The gold has the same character as at the downstream shaft. All this ground is thoroughly frozen and may be worked either in summer or in winter. Mining is done by the usual underground methods, a steam hoist and a 20-horsepower wood-burning boiler for power being used. The gravel pile, dumped at the gin pole, is washed with a ¾-inch nozzle coupled to a 2-inch pipe, which in turn is joined to a Worthington duplex force pump. Water for nozzling and sluicing is delivered by a ditch with an intake 850 feet upstream from the upper shaft.

Another plant, which was operated throughout the summer of 1933, is a short distance below the mouth of Solomon Creek. This work was being done on the Ferres association and the Bluebell association, which consist of four claims that lie in the valley floor of Poorman Creek. The pay streak here was discovered in 1930 and has been worked continuously since that time. Gold is found over a width of 100 feet, but the pay streak is only 30 feet wide, and the richest part of it is confined to 15 feet. The section shown in the shaft comprises 10 feet of muck underlain by 60 feet of gravel containing thin streaks of muck. This gravel, unlike most of the pay gravel of the Poorman area, is well rounded and averages perhaps 3 inches in size. No large boulders are present, and the largest cobble seen had a diameter of only 8 inches. About 90 percent of the gravel is vein quartz, and the remainder is largely chert. The bedrock is deeply weathered, and its true character is therefore hard to determine, but apparently it is a chert grit. The surface of the bedrock is very irregular, and for this reason 5 feet or more of bedrock has to be removed at some places, in order to hold an even grade in the drifts. Most of the gold occurs in the upper 12 to 18 inches of bedrock, particularly where many small quartz pebbles occur in the disintegrated bedrock. The gold is fairly well worn and of moderately fine grain, but much of it has a black coating. The largest nugget so far found weighed about three-quarters of an ounce. Stevens & Lohr, operators of this plant, supplied 5 assays of the gold that they recovered in 1932; the average shows that the fineness is 835 parts of gold and 159 parts of silver in a thousand.

This plant is operated by underground mining methods, both summer and winter. The equipment includes the usual bucket, steam

hoist, overhead tram, automatic tipple, and gin pole. The dump pile is sluiced at this plant without the aid of a force pump, as a ½-mile ditch from Solomon Creek brings an adequate supply of water with the required head, so that sluicing can be done not only in spring but throughout the summer. The gravel is entirely frozen, and no timbering is required underground except along the main haulageway. The gravel is thawed by means of 12-foot steam points, and each set of thaws takes 6 to 7 hours. No water occurs in the drifts except that caused by thawing the gravel, which collects in the sump at the bottom of the shaft and is elevated to the surface by a steam injector. Ordinarily, from 12,000 to 15,000 square feet of bedrock is mined from a single shaft. A 30-horsepower boiler is used for furnishing power. The wood for this boiler is cut during the winter and floated downstream to the plant in the spring. The operating costs at this property are high, because the Ruby-Poorman truck road has not yet been extended south of Poorman and the cost of freighting supplies from Ruby is about 30 cents a pound. Six men were engaged in operating this plant.

FLAT CREEK

Flat Creek, which is about 2 miles in length, heads against Little Gulch and flows southwest to Timber Creek. Gold was first discovered on Flat Creek during the winter of 1913–14, and its placers have been worked intermittently since that time. This stream has a gentle gradient, except at the very head, where the gradient steepens abruptly. The uppermost workings lie about a quarter of a mile from the head of the creek and extend from that point downstream for about 1½ miles. The richest claim on the creek has proved to be claim 2 above Discovery. At the upper workings the depth to bedrock is 50 feet, of which the lower 2 feet is gravel. Farther downstream the thickness of the overburden increases somewhat, but the thickness of the gravel increases much more, becoming 20 feet near Timber Creek. The pay streak is said to have shown a tenor of 50 cents to $5 to the square foot of bedrock.

One plant was being operated on Flat Creek during the summer of 1933. W. D. Vuicich, the owner of this plant, holds claims 1 and 2 above Discovery and a first-tier bench claim on the southeast side of the creek, opposite claim 1 above Discovery. He has been mining at this site for 5 or 6 years. Gold is very irregularly distributed in Flat Creek over a width of 1,000 feet, and this may therefore be called the width of the pay streak, though the gold occurs in narrow and irregular streaks and patches, with much intervening barren ground. The old workings on claim 2 above Discovery were along the northwest side of the creek, where the ground was said to have

been worked over a width of 30 feet and to have yielded $5 to the square foot of bedrock. Present operations are on the southeast side of the creek. The shaft at which operations in the winter of 1932–33 were centered showed a depth of 55 feet to bedrock, of which the upper 37 feet was muck and the lower 18 feet gravel. The gravel is subangular and rather fine, averaging perhaps 3 inches in diameter, with no large boulders and few cobbles. Much of the gravel is chert, but there is considerable vein quartz and some phyllite. The bedrock is also phyllite. The gold occurs almost entirely in the upper 6 inches of bedrock, or on its surface, and is uniformly rough. The larger grains are usually intermixed with vein quartz, and the concentrates contain some cassiterite. Three assays of the gold produced in 1933 show an average fineness of 786 parts of gold and 207 parts of silver in a thousand. The largest nugget so far found weighed a little more than half an ounce.

The ground at this plant is solidly frozen, and in the underground workings no timbering is required away from the main drift. The usual drift-mining methods are employed. A 16-horsepower wood-burning boiler is used as the power plant. The gravel in the mine is thawed by 10-foot steam points, set in the face 3 feet apart. Twelve points are set at a time, so that the gravel overlying 360 square feet of bedrock is thawed with one setting. During the summer of 1932 about 17,000 square feet of bedrock was mined from one shaft. The gravel in the dump pile is washed with a jet of water and sluiced in the manner customary in this district, but no force pump is required, as the operator has the use of a 1,000-foot ditch from Flat Creek and a ditch 1 mile long that supplies water from Timber Creek. Four or five men are employed at this plant.

SPRUCE AND TAMARACK CREEKS

Spruce and Tamarack Creeks were the sites of gold-placer mining in earlier years, but no mining was in progress on these creeks in 1933, and they were not visited by the writer. Because of the increased price of gold, however, the placers on these two streams are again being worked. No details of these recent mining operations are available, but it is known that the bullion recovered in 1935 from Spruce Creek had an average fineness of 854 parts of gold and 140 parts of silver in a thousand, and that the bullion from Tamarack Creek contained 871 parts of gold and 124 parts of silver in a thousand.

MOOSE AND BEAVER CREEKS

Northwest of Poorman Creek another mineralized zone is known where gold placers have been found and mined. This apparently is

a narrower belt of mineralization, but it appears to be roughly parallel to the main Poorman belt. Gold placers have been found in this belt on Moose and Beaver Creeks.

Moose Creek is 3 or 4 miles in length and runs southwestward, emptying into Poorman Creek about 9 miles below the mouth of Timber Creek. The valley of Moose Creek is broad and open, and the divides on sides of the valley are low, probably not rising more than a few hundred feet above the valley floor. The valley is asymmetric in cross section, as the stream follows the northwest side. Mining operations, however, have shown that there are old bedrock channels under the southeast valley slope that are not closely related genetically to the present stream. Mystery Creek, a small tributary, enters Moose Creek about a mile above the mouth. Although no settlement or distributing point has been established on Moose Creek, the several mining plants in this vicinity are collectively known as Placerville and are so referred to locally.

Gold was first discovered on Moose Creek by John Wolf in 1920, but it was not until 1931 that the pay streak was located and mining was begun. Discovery claim is in the lower part of the valley, and mining and prospecting are in progress on this claim and on the four adjoining claims upstream. At the present time two drift mines and one open-cut project are established, but owing to the drought of 1933 only one of the drift mines was able to obtain sufficient water to operate a boiler, and sluicing and all other operations that required water were at a standstill.

The drift mine that was operating is on claim 2 above Discovery, along the southwest side of the valley about 300 feet from Moose Creek. The depth to bedrock is 55 feet. As the top of the shaft is about 30 feet above the creek level and the depth to bedrock under the creek is 35 feet, there is evidently a broad bedrock floor under this southeast side of the valley. Other shafts have shown a still deeper channel in this old bedrock surface between the present shaft and the creek, but little or no gold was found in this channel. The pay streak on claim 2 above Discovery is 50 to 60 feet wide and, as a whole, will run about 40 cents to the square foot of bedrock, though here and there the ground will have a tenor of $3 to $5 a square foot. The operating shaft is 55 feet deep, and the section in the shaft is almost entirely muck in which vegetal material and the bones of extinct vertebrates are not uncommon. Northeast of the shaft the muck has numerous lenses of ice and no gravel is present on bedrock. South of the shaft 5 to 6 feet of gravel is found on bedrock. The gravel, where present, is largely basaltic greenstone but also includes considerable vein quartz. The pebbles average 3 to 4 inches in diameter,

but some large boulders also occur. The bedrock is a deeply decomposed basaltic greenstone. The gold is found in the uppermost 12 to 18 inches of decomposed bedrock, particularly where overlying gravel is either scarce or absent. The gold is fairly fine-grained and well rounded, but one nugget weighing almost 7 ounces has been recovered. One assay showed a fineness of 842½ parts of gold and 152 parts of silver in a thousand.

Mining at this claim is accomplished with a steam hoist, bucket, overhead tram, gin pole, and automatic tipple. The ground is solidly frozen, and drift mining offers no special difficulties. No water occurs in the drifts, and pumping is necessary only after a block of ground has been thawed. The pay dirt is rather sticky and needs to be washed with a jet of water under pressure before sluicing, in order to recover a high proportion of the gold. Water is obtained from a ditch 500 feet in length, which taps Moose Creek above the plant, but here as at many other plants in this area a Worthington duplex force pump is used for giving the required hydraulic pressure to a ¾-inch nozzle.

A similar drift-mining plant is located on Discovery claim, but owing to lack of water this plant was not being operated at the time of the writer's visit, and nothing was learned of the conditions underground. Another mining project in this vicinity is a long open cut on the northwest side of Moose Creek, between its mouth and Mystery Creek. This cut, however, has not yet been opened up to bedrock and is not on a producing basis.

About eight men are engaged in the mining operations on Moose Creek.

In January 1930 gold was discovered on Beaver Creek, about 1½ miles above the mouth of Diamond Creek and 5 miles northeast of the present mining operations on Moose Creek. This discovery was made by three men, who sank a 60-foot shaft on the northeast side of Beaver Creek and about 250 feet from it. They found about 5 ounces of gold at the bottom of their shaft, and this discovery naturally started a stampede. The later comers, however, were unable to find a continuation of the pay streak, and interest in this locality soon died out. According to current reports, the original discoverers took out $5,000 in gold during the summer of 1930 and $1,500 during the winter of 1931–32, but they also were unable to locate any contination of the pay streak. At present no one is known to be mining on Beaver Creek. The sequence is reported to have been essentially similar to that at the upper end of the pay streak on Moose Creek—that is, an overburden composed largely of muck, with little or no gravel, on bedrock.

CRIPPLE DISTRICT

The Cripple district (see pl. 4) consists of the Cripple Creek Mountains and the adjoining foothills. The Cripple Creek Mountains form an isolated mountainous mass that lies about 40 miles S. 20° W. from Poorman. This group of mountains is drained on the east by the Susulatna River and on the north, west, and south by tributaries of the Innoko River. Gold placers have been discovered on the southwestern slopes of the Cripple Creek Mountains. All the valleys containing these placers are tributary to the drainage system of Colorado Creek.

Colorado Creek has two main headwater forks—Colorado Creek proper, on the east, and Graham Creek, on the west. The confluence of these two streams is about 6 miles north of the crest of the Cripple Creek Mountains. Cripple Creek is the headwater part of Graham Creek, but the name "Graham" is applied to this stream only from the mouth of Bear Creek, a western tributary, to the confluence with Colorado Creek, a distance of about 4 miles. The present placer-mining operations are being carried on in the valley of Cripple Creek and in the corresponding upper valley of Colorado Creek.

In the part of Cripple Creek where mining is in progress, the stream gradient is about 2¾ percent; the valley floor has a width of 150 yards or more, and the walls of the valley are fairly steep, rising more than 1,000 feet to the interstream divides. At the mouth of Bear Creek and for some distance below, along Graham Creek, the valley narrows, but still farther down it widens considerably, and below the mouth of Graham Creek the valley of Colorado Creek becomes a wide expanse of niggerheads, moss, and undrained lakes. In this lower part of Colorado Creek the stream follows the east wall of the valley, along which the spurs are sharply truncated. The valley of upper Colorado Creek, from the mouth of Graham Creek upstream for several miles, is a wide alluvial flat quite different from the valley of Graham Creek, but near the site of the mining operations on Colorado Creek it narrows rapidly to a valley essentially similar to that of Cripple Creek.

The Cripple Creek Mountains are a complex mass of Tertiary intrusive rocks, which include not only monzonitic rocks but various products of magmatic differentiation. The country rock intruded by these igneous rocks probably includes several geologic formations, for on Cripple Creek the bedrock at the lower mining plant is greenstone; at the upper plant it is soft sandstone and shale of Cretaceous or Eocene age; and farther upstream and in the hills between upper Cripple and Colorado Creeks much banded red, green, and gray chert is exposed, of the type elsewhere assigned to the late Paleozoic

or early Mesozoic. No detailed geologic mapping has been done in the Cripple Creek Mountains, and the distribution and structure of these various rocks are not known.

CRIPPLE CREEK

The lower mining plant on Cripple Creek, owned and operated by Wilson & Hard, comprises four adjoining claims, of which the two lower ones constitute the Horseshoe association and the two upper ones the White Mule association. An adjoining fraction called the Goodluck fraction, which is contiguous to the White Mule association at its upper end, is also held by these operators. The pay streak is now being worked on the lower end of the Horseshoe association, along the west side of the creek. This pay streak is about 200 feet wide and is said to have a tenor of 20 to 30 cents to the square foot. The overburden consists of 2 to 12 feet of muck, overlying 5 to 6 feet of gravel. The muck increases in thickness from the east to the west side of the cut, or away from the creek. The thickness of the gravel is rather uniform. The ground is unfrozen. The pebbles in the gravel are fairly well rounded and of rather uniform size, averaging 4 to 5 inches in diameter, and consist largely of chert, greenstone, andesite, and basalt porphyries, with a smaller proportion of granitic rocks and some soft sandstone and shale. The bedrock is a serpentinous greenstone. The gold is found in the lower 2½ feet of gravel and on bedrock and is moderately fine grained. The largest nugget so far recovered weighed about 0.6 ounce. One assay of gold mined here in 1932 was supplied by P. W. Carlson, of Ophir, and another of gold mined in 1933 was given by the operators. The average of these two assays shows a fineness of 910¼ parts of gold and 86 parts of silver in a thousand, with only 3¾ parts of dross.

Open-cut mining at the Wilson & Hard plant is accomplished with the aid of a slack-line scraper. The muck is first ground-sluiced off, and then most of the gravel is stripped off with the scraper and dumped along the west side of the cut. When the auriferous gravel is exposed, as determined by panning, a dump box is built on the elevated dump pile, and sluice boxes are connected to the dump box. The pay gravel is then scraped up, dumped into the dump box, and sluiced. Water for the sluicing operations is obtained from a ditch along the west side of the valley, which taps Cripple Creek about three-quarters of a mile upstream and furnishes a head of 70 feet in the cut. In the scraping operations a gin pole is erected along the west side of the cut, where the gravel is to be dumped, and the boiler house is set up on the valey floor. The slack-line scraper is so called because the bucket returns to the east side of the cut with

a slack line, under the action of gravity alone. The capacity of the scraping bucket is about 1¼ cubic yards. A 50-horsepower wood-burning boiler is used for the power plant. A cut 1,400 feet long and 200 feet wide had been ground-sluiced off at the time of the writer's visit early in August 1933, and it was expected that the lower 300 feet of this cut, or about 60,000 square feet of bedrock area, would be worked before the end of the summer. The shortage of water during the late summer may have greatly curtailed this work. Eight men are employed at this plant.

Above the ground held by Wilson & Hard are several association claims, followed in turn by claims 2 and 1 below Discovery and Discovery. The original discovery of gold on Cripple Creek was made in 1912 at the site of the present Discovery claim, at the mouth of Fox Gulch, which enters the main valley from the west. The claims upstream from the ground now held by Wilson & Hard, as far as Discovery claim, have recently been consolidated into a single group, now held by Strandberg & Co. During the summer of 1933 preparations were being made to install a drag-line scraper plant, but, unfortunately, low water in the Innoko River rendered it impossible to land the machinery at Cripple, and the plant could not be installed in time to operate during the summer. The valley floor at the site of this plant is estimated to be about 100 yards in width, and in preparation for the plant two cuts had been ground-sluiced off, one 375 by 80 feet and an adjoining cut upstream 300 by 200 feet. Another activity at this plant was the construction during the summer of a new ditch 6,000 feet long, which will deliver the water from upper Cripple Creek under a head of about 175 feet at the present cuts.

The pay streak is the width of the upper cut, but some of this ground had been partly worked by earlier operators, a fact which explains the narrower width of the lower cut. The character and thickness of the overburden are much the same as at the Wilson & Hard plant, farther downstream, but the bedrock is sandstone and slate, presumably of Upper Cretaceous age. Two assays of the gold mined at this site by earlier open-cut operations were furnished to the writer by P. W. Carlson, of Ophir. The average of these two assays shows a fineness of 888 parts of gold and 111 parts of silver in a thousand. This gold, like that at the Wilson & Hard plant, contains remarkably little dross.

COLORADO CREEK

The mining plant on Colorado Creek is about east of the upper workings on Cripple Creek. The valley floor at this point is narrower than at the mining plants on Cripple Creek, and both the stream and the underlying bedrock have higher gradients. The width of the pay streak on Colorado Creek has not been determined

X Gold placer mine o Gold lode mine 5 0 15 Miles Road Trail

SKETCH MAP OF CRIPPLE, TOLSTOI, OPHIR, NIXON FORK, AND McGRATH DISTRICTS, SHOWING LOCATIONS OF GOLD PLACER- AND LODE-MINING OPERATIONS.

by prospecting, but at the present site of mining a cut 150 feet wide by 200 feet long is being worked. The tenor of this pay streak is variable but probably has averaged close to 30 cents to the square foot, although the ground now being worked may be somewhat poorer than that. No Discovery claim has been located on Colorado Creek. The present operator, who has been working on this creek for 7 years, holds 13 claims and has gradually been working upstream. In the present cut the overburden consists of 3 feet of muck underlain by 8 feet of gravel, but farther downstream, where mining was done some years ago, the depth to bedrock was as much as 20 feet. The overburden is frozen, but the gravel thaws naturally after the muck is ground-sluiced off. The gravel is coarse and includes many large boulders; it consists mostly of granitic rocks and chert but smaller amounts of basaltic rocks, greenstone, and sandstone are also present. The bedrock is a soft, iron-stained sandstone, probably of Upper Cretaceous or Eocene age. Into this bedrock the layers of smaller gravel and also, at places, the gold extend several feet, requiring the removal of that amount of bedrock to obtain a high recovery of gold. At some places the lower 2 feet of gravel also contains some gold. The gold is moderately fine and well worn. Four assays based upon production in 1932 and 1933 were supplied by P. W. Carlson, of Ophir, and from these the average fineness is found to be 873 parts of gold and 121 parts of silver in a thousand.

Mining is being done by means of a hydraulic plant and elevator. Water for these operations is obtained by a ditch with an intake about a mile upstream on Colorado Creek, which follows down the east side of the valley and discharges into the gulch near the camp. A lower ditch picks up the water from this gulch and delivers it to the penstock under a head of 156 feet. The total length of ditch line is 6,200 feet. The water is fed to a 23-inch pipe which is gradually reduced to 14 inches. Most of the water is used by the hydraulic elevator, which has a 3-inch nozzle and a 10-inch throat, but some of it is used by a hydraulic giant with a 2½-inch nozzle. The elevator conveys the gravel to an elevated dump box, whence it goes to a line of three sluice boxes. The operator formerly used an ordinary hydraulic plant and piped his tailings, but the large amount of heavy sands clogged up his bedrock drain, necessitating the change to a hydraulic elevator. A scraper plant might possibly be used to advantage on this ground instead of a hydraulic elevator. Water was scarce here, as elsewhere, during the summer of 1933, and a good part of the season was therefore spent in clearing off 50,000 square feet of ground above the present cut, preparatory to ground sluicing. The operator and one other man were working at this plant.

OPHIR DISTRICT

The Ophir district is the oldest mining community in the Ruby-Kuskokwim region. The original discovery of gold was made in 1906 on the bars of the Innoko River a short distance below the mouth of a stream which the four discoverers named Ganes Creek after one of their number. Later in 1906 these four men, Gane, Spencer, Roke, and Maki, ascended Ganes Creek and located workable gold placers about 10 miles above its mouth. In the following year a large number of people stampeded to the new diggings from Fairbanks, Nome, and other points, and the nearby streams, including Little, Spruce, and Ophir Creeks, were also staked. A recording office, called Moore City, was established on Ganes Creek opposite claim 6 above Discovery. In January 1908, however, rich placers were found on Ophir Creek, and a second stampede ensued, with the result that Moore City was abandoned and a new sttlement called Ophir was established that spring on the Innoko River opposite the mouth of Ophir Creek. Ophir has remained the distributing point for this district.

The country rock of the Ophir district belongs to the Cretaceous sequence that forms the bedrock over so much of this region. In the valleys of the producing creeks of the Ophir district these rocks are largely slate, with a cleavage that strikes from N. 45° E. to east and is nearly vertical. The bedding is seldom determinable. It does not follow, however, that all the country rock is slate, for though the valleys are carved largely in slate, the ridges may be sandstone. The character of the gravel that constitutes the placers suggests that this is true, but insufficient geologic work has been done in this district to settle the question. The country rock is cut by many dikes of dacite, andesite, and related rocks, which follow closely the cleavage of the slate. These intrusive rocks have been observed and collected mainly in the valleys in the vicinity of placer-mining operations, and at such places they occur in a greatly weathered condition. They consist of kaolinized feldspar, in large part originally plagioclase, and of quartz, chloritized biotite, and hornblende, apatite, and various secondary minerals, including much calcite. It has been stated by earlier workers [15] that these dikes are mineralized with pyrite and that they are associated with and in places cut by veins and stockworks of gold-bearing quartz. On these grounds, therefore, the dikes have been considered to be the principal channels which ore-bearing solutions followed in their upward migration. The writer, in a cursory examination of this district,

[15] Maddren, A. G., Gold placers of the Innoko district, Alaska: U. S. Geol. Survey Bull. 379, p. 266, 1909. Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pp. 28–29, 1914.

was unable either to verify or to refute this interpretation but nevertheless gained an impression that the intrusion of the dikes and the mineralization of the country rock were less closely related than above stated. Quartz veins and quartz cobbles are by no means common in the placers in this district, in contrast to the conditions recorded in the Ruby district; and even allowing for the higher degree of residual weathering in the Ruby district it seems rather doubtful if all the gold of the Ophir district could have come from quartz veins. On the other hand, the granitic magma from which this gold originally came did not approach close enough to the surface to have been exposed yet to erosion, so that a direct source of the gold from granitic rocks cannot be demonstrated. It is possible that the country rock of the Ophir district is widely and diffusely mineralized, both by small gold-bearing quartz veins and in mineralized zones where little or no quartz is present.

The placers of the Ophir district differ in several important respects from those of the Ruby district. First, it is evident from the condition of bedrock under the placers that the country rock of the Ophir district, though subjected to considerable residual erosion prior to the accumulation of the oldest placers, was not nearly so greatly decomposed as in the Ruby district. Second, the placers of of the Ophir district are not essentially ancient buried placers, as in the Ruby district; instead, they are in part recent placers occupying the beds of the present streams and in part true bench placers situated on bedrock terraces well above the bedrock floors of the present streams. This is not to say that the bench placers of the Ophir district are not as old as the buried placers of the Ruby district, for the animal remains found in both show that they are closely related chronologically. The geomorphic histories, however, are different. The placers of the Ophir district lie for the most part in or alongside valley floors which are about 1,000 feet above sea level, whereas those of the Ruby district lie about 400 feet lower. But the lower valley of the Innoko River appears to be as deeply alluviated as the open valleys near Ruby. Therefore, it is concluded that the placers of the Ophir district were formed in higher country and were not subsequently subjected to the general process of valley alluviation that appears to have been so effective and widespread in the Yukon Basin up to elevations of 600 to 700 feet. The streams of the Ophir district, though doubtless affected by the general alluviation farther downstream, continued to degrade the headwater portions of their valleys while the Pleistocene alluviation was in progress farther downstream, so that the ancient placers were isolated as bench deposits. At the present time gold placers are being worked in the Ophir district on Ophir, Spruce, Little, Ganes, and

Yankee Creeks; on Anvil Creek, a small tributary of the Innoko, lying between Ophir and Spruce Creeks; on Victor Gulch, which lies between Anvil and Spruce Creeks; and on Ester Creek, a small stream that heads against Little Creek and flows westward to Beaver Creek. (See pl. 4.) A total of 19 placer-mining plants are in operation on these creeks, of which 3 are dredges, 1 is a scraper plant, 7 are hydraulic plants, and 7 are shoveling-in operations. These plants are described in the following pages, starting with Ophir Creek and proceeding southeastward.

OPHIR CREEK

Ophir Creek is about 6 miles in length; it heads against Beaver Creek, flows about N. 25° E., and empties into the Innoko River opposite the settlement of Ophir. The valley of Ophir Creek is rather symmetrical, with gently sloping walls in its lower part and steeper walls farther upstream. Bedrock benches are present, as shown by the mining operations, but these are not prominently reflected in the present surface configuration. Near the mouth the valley floor is about 150 yards wide, but in the vicinity of Upper Discovery claim the valley floor is hardly more than 200 feet wide. Two Discovery claims have been located on this creek. The Lower Discovery claim is about six claim lengths above the mouth of the valley. Claim 12 above Lower Discovery is called "Upper Discovery", and from this point upstream the claims are numbered with reference to the Upper Discovery claim. Ophir Creek has been the largest producer of placer gold in the Ophir district, and is locally said to have yielded close to a million dollars. On claim 3 below Lower Discovery, which was the richest claim on Ophir Creek, some of the ground along the pay streak yielded from $7 to $8 to the square foot of bedrock.

The pay streak in Ophir Creek is mainly of recent formation, though undoubtedly enriched by the erosion of older bench placers. These stream placers were essentially shallow deposits, few exceeding 35 feet in depth, and varied in width from 20 to 200 feet. The pay streak was by no means continuous nor of uniform richness but was worked in earlier days by underground methods from its mouth to a point about a mile above Upper Discovery. Most of this ground was frozen, but there was a thawed streak in the middle of the pay streak at many places where the ground could not be worked by the methods then in vogue. In this early work the pay streak was seldom mined for a width of more than 70 feet. But the presence of lower-grade ground on both sides of the high-grade central part of the pay streak, together with the unworked high-grade ground that was thawed, have rendered it feasible to rework much of these

placers to the lateral limits of the pay streak by means of hydraulic and scraper plants. The overburden consists largely of muck in the lower valley but is mainly gravel in the upper valley. The gold occurs mainly on or in the fractured slaty bedrock. At the present time two small hydraulic plants are mining the bench deposits of the lower valley, and one large scraper plant is working the stream placers of the upper valley.

A small hydraulic plant is set up on the Stayton claim, on the northwest side of Ophir Creek opposite claim 5 below Lower Discovery. The operator formerly worked on the opposite side of the valley but has been mining at the present site for 2 or 3 years. The depth to bedrock in the creek opposite the Stayton claim is 28 feet. About 120 feet northwest of the creek the bedrock rises abruptly to a level 10 feet above the bed of the creek, and therefore 38 feet above the level of bedrock under the creek. A little farther northwest the surface of bedrock is a little lower, and it is in this bedrock bench channel where mining is now being done. The pay streak here has a tenor of 5 to 20 cents a square foot of bedrock. The overburden consists of 6 to 14 feet of gravel, overlain by 1 to 2 feet of muck, and is frozen throughout. The largest cobbles in the gravel do not exceed 9 inches in diameter, and the pebbles as a whole probably average 3 to 4 inches in diameter. They are well rounded and are mainly sandstone and slate, with several varieties of basaltic and diabasic rocks, some dacitic and related rocks, some vein quartz, and a little chert. The bedrock is a sandy slate, whose cleavage strikes N. 70° E. and dips about 80° N., and it is little altered. The gold particles differ much in size, some being small and others coarse. The largest piece so far found weighed a little less than 2¼ ounces. Three assays of the gold, based on production in 1929, 1931, and 1932, were furnished by the operator of this property. One of these represented gold from the southeast side of the creek, and two represented gold from the present site. The average fineness of the material recovered at the present plant is 874 parts of gold and 119 parts of silver in a thousand, but that from earlier operations on the southeast side of the creek had a fineness of 895½ parts of gold and 90 parts of silver.

This ground is mined by a hydraulic plant consisting of a single giant with a 2-inch nozzle. A ditch nearly a mile long delivers water to the giant under a head of 30 to 35 feet. At the time of the writer's visit no mining was in progress, owing to the scarcity of water. The operator of this plant works alone.

A second plant on Ophir Creek is on another bench along the southeast side of the valley, opposite the upper end of claim 5 below Lower Discovery. The cut is about 300 feet southeast of the creek,

and the bedrock level at the cut is about 6 feet above the stream bed, or about 34 feet above the level of bedrock below the creek. At this site, however, the bedrock slopes gently toward the creek. This carried gold to the value of 20 to 25 cents to the square foot of bedrock. The stratigraphic section at this plant shows an overburden of 30 to 40 feet, of which the lower 5 to 6 feet is gravel. The muck has large masses and wedges of ice and contains the fossil remains of extinct vertebrates. The contact between the muck and the gravel is marked by a well-cemented iron-stained layer of muck and gravel that is hard to remove. The main mass of underlying gravel is rather fine; few of the pebbles in it exceed 4 to 5 inches in size, and the average is perhaps 2 to 3 inches. It is moderately well rounded and of the same general character as that on the opposite bank. The bedrock in the cut was not exposed to view, but nearby it consists of sandy shale and sandstone. The gold is fine-grained and flaky, but some larger pieces have been found, which commonly have more or less quartz adhering to and intergrown with them. The largest nugget reported at this site weighed nearly 3 ounces. The average fineness, based on two assays, is 898 parts of gold and 98 parts of silver in a thousand. This checks closely with the returns from Stayton's earlier operations on the southeast bench.

This property is worked by hydraulic methods. Water is obtained from a ditch along the southeast side of the valley, about 8,500 feet in length, which delivers it under a head of 60 feet. This ditch was built in 1932. The operator uses a giant with a 2-inch nozzle but has to shovel the gravel into the sluice boxes at the lower end of the cut because of too low a gradient for the disposal of tailings. The operator hires an extra man.

The third and largest plant now being operated on Ophir Creek is located on claim 12 above Lower Discovery—that is, on Upper Discovery claim. This is a hydraulic slack-line scraper plant, owned by Collins & Hard, and has gradually been working upstream from claim 7 above Lower Discovery during the last 15 years. The pay streak in this part of the valley is from 150 to 200 feet wide, though at the site of present mining operations the cut is only 150 feet wide. The cut mined in 1932 was 190 feet wide in places. The overburden is about 15 feet thick but thins upstream. It is practically all gravel with little or no muck. The gravel is small, the individual pebbles averaging perhaps 3 inches in diameter, and there are no large boulders. It consists largely of sandstone, shale, and a variety of fine-grained igneous rocks, ranging in composition from basalt to rhyolite. The bedrock is a black slate, which is cut here and there by narrow dikes. The gold occurs almost entirely on and in bedrock, of which the upper 4 feet must at places be removed in order to

obtain a high recovery of the gold. The largest piece of gold found in recent years by these operators weighed 14 ounces. Four assays, based upon production in 1930, 1931, and 1932, show an average fineness of 913 parts of gold and 83 parts of silver in a thousand. This fineness is slightly higher than that at the Wilson & Hard property on Cripple Creek, and the percentage of dross is about as low.

The Collins & Hard plant is worked by means of a slack-line scraper similar to the one on Cripple Creek. The gin pole for the tram is on the southeast side of the valley, and the sluice boxes lead from the dump pile downstream. The sluice line consists of 2 boxes 3 feet wide with pole riffles, followed by 2 similar boxes with iron rails, which in turn are succeeded by 10 boxes 20 inches wide with iron rails. All are set to a grade of 13 inches to the box length. The scraper bucket has a rated capacity of 1 cubic yard and an actual capacity of 25 cubic feet, and if sufficient water is available for sluicing, it will deliver 35 buckets an hour to the sluice line. The water is obtained from a ditch about half a mile long, and though most of it is used for sluicing, some is used in a giant with a 2-inch nozzle for washing the pay dirt prior to sluicing, and some for general work in the cut, as well as ground sluicing. A 50-horsepower wood-burning boiler is used for power, but wood now has to be hauled 5 miles downstream. For this and other services a tractor is used. At the time of the writer's visit in August 1933 mining was at a standstill, owing to lack of water. Besides the two partners, five other persons were at work, but more are doubtless employed when ample water is available.

SPRUCE CREEK

Spruce Creek is of about the same length as Ophir Creek and flows parallel to it, about 1½ miles to the southeast. The valley of Spruce Creek, however, differs materially from that of Ophir Creek. The upper valley, downstream to a point about 3 miles from the mouth, is a sharp gorge with a narrow valley floor. From this point downstream the valley becomes wider and decidedly asymmetric in cross section, and the creek follows close to the northwest or steep wall of the valley. The southwest side, in this lower part of the valley, is a gently rising slope, which extends back from the creek for a quarter of a mile or more before the abrupt rise to the hills begins.

Discovery claim on Spruce Creek is about 2 miles from the mouth. On claim 3 above Discovery a tributary, Maiden Creek, enters from the southeast, and about half a mile farther downstream another tributary, Tamarack Creek, also enters from the southeast. The creek bed or valley floor of Spruce Creek has not been found to have a workable pay streak, but mining has been done along the gently rising southeast terrace from a point a short distance above Maiden

Creek downstream to Tamarack Creek and below. A pay streak has also been mined in Tamarack Creek and yielded good returns. The pay streak along the southeast side of Spruce Creek is not continuous but has been mined at several places for a width of 80 feet, at a distance of 50 to 100 yards from the creek. This bench pay streak has nowhere been of the bonanza type, but it has been worked intermittently since 1909. At the present time two small hydraulic plants are at work.

The plant farther upstream is along the first-tier bench, opposite claim 3 above Discovery. The cut is about 250 feet from the original position of the creek, but owing to the diversion of the creek toward the northwest wall by tailing the cut is about 300 feet from the present position of the stream. The bedrock in the cut slopes gently toward the old site of the creek, where it drops abruptly but not to any considerable depth, as the creek was cutting bedrock before its channel was filled with tailings. At the site of the cut an area of placer ground aggregating 14,000 square feet was opened and worked in 1933. The overburden consists of about 6 feet of gravel, with little or no overlying muck. The pebbles are fairly well rounded and small, averaging only a few inches in diameter, but some good-sized cobbles also occur. The bedrock is a black slate cut by numerous fine-grained dikes, probably of dacitic character but in general too much altered for accurate petrographic determination. The gold lies mainly on bedrock. Water for a single giant and for sluicing is obtained from a ditch 1½ miles in length, which takes water from both Spruce and Maiden Creeks. This ditch supplies water at the cut under a head of 30 feet, but the season of 1933 was so extraordinarily dry that little was available. The two partners at the plant used the water 16 hours a day, leaving 8 hours of water for use by the plant downstream.

The downstream plant is on claim 2 above Discovery and on the first-tier bench claim opposite claim 2 above Discovery. The cut is at about the same distance from the creek as that at the upper plant, and other conditions are about the same. The surface of bedrock is said to be about 20 feet above the present level of the creek, and about 3 feet of gravel is present. The bedrock is a slate that has several structural planes, of which one, the cleavage, strikes N. 60° E. and dips 60° SE.; another, which appears to be the bedding, strikes N. 20° W. and is about vertical. No gold assays were seen from either of these two plants, but four assays of the gold from Spruce Creek were furnished by P. W. Carlson, of Ophir. The average of these indicates a fineness of 884 parts of gold and 110 parts of silver in a thousand. Some rather coarse gold is found along this bench of Spruce Creek, and the operators at the lower plant

report finding one nugget that weighed about 16 ounces. About 3,000 square feet of bedrock was cleaned at this plant during the season of 1933.

LITTLE CREEK

Little Creek is southeast of Spruce Creek, runs parallel to both Spruce and Ophir Creeks, and is about 7 miles in length. At its lower end it veers abruptly eastward and empties into Ganes Creek about half a mile from the Innoko River, instead of flowing directly to the river.

The claims on Little Creek are staked in such a manner that a special description of their lay-out seems desirable. Just above the automobile road is a claim whose designation is not known to the writer. This is succeeded upstream by the Bonanza association of five claims, laid out end to end. Next is the Fothergill association of eight claims, laid out end to end in pairs, so that this association has a length of a mile. Above this is Discovery claim.

Upstream from Discovery is another group of 8 claims, called the "Gold Run Association", laid out like the Fothergill association, so as to have a length of a mile. Above the Gold Run association the claims are numbered 1 above, 2 above, 3 above, and so on upstream, but these claims are staked across the creek. The automobile road up Little Creek goes up the west side of the valley to the lower end of Discovery claim, then crosses to the east side, and near the middle of the Gold Run association crosses back to the west side.

The gold placers of Little Creek have been mined since 1908. In its lower 3 miles the valley is fairly open, but above this stretch it becomes markedly constricted for about half a mile and then opens out again farther upstream. The constricted part of the valley occurs in the upper half of the Gold Run association; in this part the stream gravel of Little Creek contains many large boulders and little pay and has never been worked. Above this constricted zone the creek placers have been worked for several claim lengths, and prospects have been found as far upstream as claim 14 above Discovery. The placers of Little Creek include both creek and bench placers, but in general there is no sharp drop in the bedrock surface from the terraces to the creek, so that the creek and bench deposits grade into one another. From the lower end of the gorge to the lower end of Discovery claim the pay streak appears to lie mainly, though not entirely, along the west side of the creek, but below this point it appears to cross to the east side. Three plants are now being operated on Little Creek.

A dredge is now being operated on Little Creek on claim 3 above Discovery. This dredge was built by the Flume Dredge Co. on the Fothergill association in 1924, where it worked until 1926. In

1927 it was dismantled and rebuilt on claim 3 above Discovery, and since that time it has continued to operate in this upper part of the valley. This dredge is now operated by Waino F. Puntila. Beginning work on the "bench" of claim 3 above Discovery, the dredge worked downstream for 1,000 feet and then, swinging out into the creek bed, began working upstream, taking the whole pay streak and reworking the old tailings. This method was used because there was a narrow streak of thawed ground along the "bench", which could thus be worked while the creek placers were being stripped and thawed. At present the dredge is near the place where it originally started and will continue to work upstream. The pay streak at this place is said to be nearly 300 feet wide, and the dredge is working over a width of 240 feet. The dredge is now digging 20 feet below the level of its pond and is taking 3 to 4 feet of gravel that lies on bedrock. On the west side of the cut it is digging into old tailings, which are 8 to 10 feet above water line.

This is a flume-type dredge, driven by a single-cylinder Fairbanks-Morse Diesel engine, rated at 60 horsepower, which drives a central power shaft from which power is taken by belt drive to operate the digger, winch, and pump for the sluice line. The digger takes about 50 percent of the power, the pump about 30 percent, and the winch about 20 percent. The engine burns about 75 gallons of oil in a 24-hour day. A 12-inch pump is used for the sluice line, but a small pitcher pump is also used occasionally for pumping water from the hull. The dredge is lighted by a small direct-current 120-volt generator. A boiler is also used for thawing the pond in the late fall. The dredge is operated by two spuds amidships. It has a bucket line of 34 buckets, each of a capacity of 2½ cubic feet, and digs at the rate of 15 buckets a minute.

Operation of the dredge was curtailed during the late summer and fall of 1933 by the extreme dryness of the season, as a result of which the water was so low in the Takotna River that it was not possible to obtain an adequate supply of fuel oil from McGrath. The average mining season is from the later part of May until the first of November, but sometimes the dredge operates until the middle of November. This plant employs 13 men, including 7 men on the dredge, a cook, and 5 men who are working upstream from the dredge in stripping and ground sluicing.

The second plant on Little Creek is a hydraulic plant operating below the constricted zone on the Gold Run association. The owner and operator of this plant has been working this and adjoining ground for many years. In the early years of mining on Little Creek Discovery claim and the lower half of Gold Run were worked by underground methods. In more recent years the present operator has reworked the same ground by open cuts made with a scraper

plant from the lower end of Discovery claim upstream for 3,000 feet. Discovery claim is said to have been the richest, yielding so far about $200,000. The pay streak in these operations was about 150 feet wide and lay partly in the present valley floor and partly along the first tier of "bench" claims. At most places the bedrock rises very gradually from the floor of the valley to its slopes, but at a few places abruptly. The overburden on the main pay streak is said to have been 14 to 18 feet thick and to have consisted mainly of gravel with only a thin cover of muck. The fragments are not large, the largest cobble being perhaps 10 to 12 inches in diameter, but they are decidedly subangular to angular, and those nearest the top of the overburden are most angular. The bedrock is mainly slate, but at one place a coarse conglomerate, 20 to 30 feet thick, is interbedded with the slate.

The work during 1933 consisted in opening four small cuts in the deep gravel along the east edge of the pay streak, almost under the automobile road. These cuts are just downstream from the conglomerate bedrock. Later in the summer, at the time of the writer's visit, the operator was hydraulicking and sluicing an old tailing pile about 250 feet west of the creek and 40 feet above it. About 4 to 5 feet of low-grade ground below the tailings was being worked at the same time. The gold, both here and in the main pay streak, is found almost entirely on and in bedrock and is rather shotty and fairly uniform in size. Few nuggets are found, but one that was recovered on Discovery claim weighed 10 ounces. Four assays of this gold are available, one of which was contributed by the present operator, and three by P. W. Carlson, of Ophir. The average of these shows a fineness of 828 parts of gold and 167 parts of silver in a thousand. Another assay of the gold from the Fothergill association, where the dredge worked in 1926, showed a fineness there of 830¾ parts of gold and 164 parts of silver.

Water for these hydraulic operations is obtained from a ditch three-quarters of a mile long, and at the present site of mining two giants were being used—a 3-inch giant for hydraulicking and a 2-inch giant for disposal of the tailings. The hydraulic head at the upper giant was 25 feet and at the lower one 50 feet, but water was scarce, and the work was being done by splashes. Three men were engaged in this work.

The third plant on Little Creek is about half a mile above the Takotna-Ophir automobile road on the Bonanza association, but this plant was not being operated at the time of the writer's visit, owing to the scarcity of water. This plant is on the east side of Little Creek. About 200 feet from the creek is a line of cuts, each about 100 by 40 feet, which together mark a "bench" pay streak about 100 feet wide. Adjoining these on the east is another line of cuts,

and still farther east is a third line. In the creek the depth to bedrock is about 18 feet, but a short distance from the creek the surface of bedrock rises abruptly and then slopes gently upward under the open cuts. At the middle line of cuts the depth to bedrock is 8 feet, and the gravel is subangular, overlying a slate bedrock. At the upper line of cuts the ground is still shallower and everywhere there is little muck above the gravel. About a mile above the Takotna-Ophir road a small stream, Goldbottom Creek, enters Little Creek from the east. Just below this creek 33,000 square feet of "bench" ground was worked years ago that had a tenor of 60 to 70 cents to the square foot of bedrock, but the ground downstream from this is of lower grade and is rather spotted in the distribution of gold. Five assays of this "bench" gold from the Bonanza association, based on production in 1931 and 1932, were supplied to the writer by P. W. Carlson, of Ophir. These show an average fineness of 826 parts of gold and 167 parts of silver in a thousand.

GANES CREEK

Ganes Creek is a much larger stream than any of the other producing creeks of the Innoko district and is one of the principal heads of the Innoko River. It has a length of more than 30 miles, and two of its headwater tributaries head in glacial cirques in the Beaver Mountains. Leaving the mountains, Ganes Creek flows across a broad basin that was formerly the upper valley of Beaver Creek. Southeast of Ganes Creek is a headwater tributary, Last Chance Creek, which heads near Crater Mountain and flows across the same broad basin, joining Ganes Creek at the east side. This basin is filled with alluvial material, in part of morainal character, which shows particularly well along the low ridge between Ganes and Last Chance Creeks. Below the confluence of Ganes and Last Chance Creeks, at the east side of this old valley of Beaver Creek, Ganes Creek goes into a box canyon several hundred feet deep, through which it flows, cutting slate bedrock, for about 6 miles. Below this canyon Ganes Creek has a flat valley floor, which, however, is sharply entrenched in rock walls that rise abruptly to a well-marked terrace. The valley floor ranges in width from 200 yards at the mouth of the canyon to a mile at the confluence with the Innoko River. The terrace, which is rock-cut but gravel-covered, ranges in height from 100 feet above the creek level at the lower end of the canyon to 60 feet farther downstream. Apparently, the lower end of this canyon was the upper limit of the preglacial valley of Ganes Creek, and by the postglacial obstruction of the lower valley of Beaver Creek its headwater streams were diverted southeastward across a bedrock divide into the head of Ganes Creek and gradually carved a gorge

through these hills. In this manner the upper drainage of Beaver Creek was beheaded by the old Ganes Creek, producing the present valley, which is twice as long as the preglacial valley.

Gold occurs in the basin of Ganes Creek, both in the present stream valleys and in the gravel that lies on the rock-cut terrace. This terrace was the floor of the preglacial valley of Ganes Creek and therefore antedates the headwater extension of the Ganes Creek Valley westward into the Beaver Mountains. Hence, the gold on the terrace must have come from the preglacial valley, but the general absence of gold placers above the canyon shows that most of the gold in those deposits also must have come from bedrock within the hills traversed by the preglacial valley. The present stream placers of Ganes Creek are therefore derived in part directly from mineralized bedrock in and below the canyon and in part from the concentration of the preglacial stream gravel, of which remnants are still preserved on the terraces.

When Ganes Creek was first discovered it was staked from source to mouth, as the barrenness of the gravel above the canyon was not then realized. Discovery claim was located about 10 miles above the mouth, at the mouth of a gulch formerly called Last Chance Gulch but now designated "Six Gulch." The present automobile road from Takotna to upper Ganes Creek comes down the valley of Six Gulch. The claims on Ganes Creek were numbered from 83 above Discovery to 58 below Discovery; claim 40 above Discovery was at the head of the canyon. Gold placer mining has been done on Ganes Creek from claim 17 above Discovery downstream at intermittent localities for several miles. A great deal of prospecting has been done, and considerable is still in progress. The entire history of these mining activities is not known to the writer, except for the operations of the dredges. At present two dredges are located on Ganes Creek, of which only one was being operated during the season of 1933. One man was working on the bench opposite claim 4 above Discovery, 1 was mining on Discovery claim, 2 were prospecting on claim 5 below Discovery, and 1 man was prospecting on claim 12 below Discovery. Most of the claims from 12 above Discovery downstream to the Takotna-Ophir road are now held by one man, who is doing considerable prospecting in this region. A prospecting party from Chicago was working farther downstream during the summer of 1933.

The uppermost mining plant on Ganes Creek at the present time is a dredge operated by Waino F. Puntila. This is the old Guinan & Ames dredge that formerly operated on Glacier Creek, in Seward Peninsula. It was transported to Ganes Creek and rebuilt there in 1925 and operated during the seasons of 1926, 1927, 1929, 1930, and 1933. Starting work on claim 13 above Discovery, this dredge worked

up the west side of the pay streak to claim 17 above Discovery and returned downstream along the east side. At present it is on claim 14 above Discovery, working downstream. All the creek placers in this zone, except those on claim 17 above Discovery, were found to be thawed.

The pay streak in this upper part of the valley ranges from 100 to 300 feet in width, but the dredge at the present site is taking a cut 85 feet wide. The dredge is able to dig 16 feet below the water line but is digging to a depth of only 8 to 10 feet deep below the water, which includes from 6 inches to 2 feet of bedrock. The pebbles of the gravel are sandstone, slate, and volcanic rock and are well-rounded. The bedrock is slate, and practically all the gold lies on or in bedrock. The largest nugget recovered during 1933 weighed half an ounce, but a 2-ounce nugget was found farther upstream some years ago. Most of the gold is in fine particles and inclined to be flaky. It is accompanied by large amounts of black sand. The fineness of this gold is not known.

The dredge is of the flume type, with one spud and two headlines. The power plant consists of a 2-cylinder Scandia Diesel engine, with 12-inch cylinders rated at 60 horsepower, which burns 85 gallons of fuel oil in 24 hours. The engine drives a central shaft, from which belts transmit power to operate the digger, a 6-drum winch, pump, and generator. An 8-inch centrifugal pump is used for the sluice water, and the lights are run by a 2½-horsepower 110-volt direct-current generator. A small gasoline engine is also used for the lights and, when the main engine is not running, for other purposes. A 14-horsepower boiler is used for thawing the pond in the late fall, and a hand pump is used for removing water from the hull. The digging ladder has 27 buckets of a capacity of 2 cubic feet, and digs at the rate of 16 buckets a minute. The dredge is operated by seven men, in two shifts, and also employs a cook. The operators aim to work the dredge during a season of about 150 days, from the middle of May to the middle of November, but delays in the spring and early fall sometimes shorten that period materially. The season was shortened in 1933 by low water in the Takotna River, which prevented the delivery of an adequate supply of fuel oil from McGrath.

On claim 6 above Discovery is another dredge, which was not operated during the season of 1933. This is the dredge that formerly operated on Greenstone Creek, in the Ruby district. It was moved to Ganes Creek by the Innoko Dredging Co. in 1923 and was rebuilt there on claim 5 above Discovery. Under the management of this company and others it worked during the seasons of 1924, 1925, and 1927 to 1930. In 1933 it was controlled by Frank Speljack, Peter Messick, Mike Mynttic, and John Repo, who expected to oper-

ate in 1934. Beginning on claim 5 above Discovery the dredge worked upstream along one side of the pay streak to claim 11 above Discovery and then returned to its present position on claim 6 above Discovery. The present owners hold 11 claims on Ganes Creek and hope to operate the dredge downstream as far as Discovery.

The pay streak from claims 5 to 11 above Discovery is probably 500 feet wide, for the two cuts of the dredge are not contiguous but are separated by an unworked zone. It is expected that the pay streak will be found to narrow farther downstream to a width of perhaps 200 feet. The depth to bedrock is 8 to 20 feet but is said to average about 14 feet, and the average gold content of the ground so far worked is said to have been about 25 cents to the square foot of bedrock. No gold from this part of Ganes Creek was seen by the writer, but an assay supplied by P. W. Carlson, of Ophir, of the gold recovered from claim 7 above Discovery in 1932 showed a fineness of 888¼ parts of gold and 107 parts of silver in a thousand.

This dredge is of the stacker type, with a 30-inch flume on each side of the stacker belt, and operates from 2 spuds. It has two Pennsylvania-type wood-burning boilers, one on each side of the boat, each of which is rated at 80 horsepower. The dredge burns 9 cords of wood a day, and inasmuch as wood costs about $25 a cord landed at the dredge, this is a heavy operating cost. The present operators hope later to install a Diesel engine. For the flume and sluice boxes 8- and 12- inch pumps are used, operated by a steam turbine. The digging ladder, the 7-drum winch, trommel, and stacker are driven by a compound steam engine, with one 20-inch and two 10-inch cylinders. A small gasoline engine is used for pumping water from the hull and for other purposes. A condenser and pump are utilized to supply water for the boiler. The dredge is also equipped with a 5-kilowatt 110-volt direct-current generator for lighting. The trommel is about 30 feet long, with 1½-inch holes in the upper two-thirds and 3-inch holes in the lower third. At present the digging ladder has 55 buckets, each with a capacity of 3 cubic feet, but as this dredge can dig only 16 feet below the water line and 1 to 2 feet of bedrock has to be taken up to obtain a good recovery of gold, it has been handicapped in working the deeper ground. The present owners hope to overcome this difficulty by adding a 6-foot extension to the digging ladder.

East of Ganes Creek one man was working on the terrace opposite claim 4 above Discovery. This site, the French Hill claim, is about 80 feet above the level of Ganes Creek, from which it is separated by a precipitous bedrock cliff. Owing to lack of water no active mining was in progress at the time of the writer's visit, but the operator was on the ground. The overburden is said to be 6 feet in depth, of

which the lower 4 feet is gravel. The bedrock, seen in some old cuts, is slate with a cleavage that is about vertical and strikes northeast. This is open-cut work, and the water, when available, is obtained from a ditch 1,500 feet long, with an intake on Potosi Creek, a small tributary of Ganes Creek that enters from the east just below the French Hill claim.

Farther downstream one operator was working a small open cut on Mackie Creek near its mouth, on Discovery claim. This cut was in the stream bed of Mackie Creek and was about 16 by 46 feet in size. The overburden here consisted of 5 feet of gravel overlain by 1 to 2 feet of moss and clay. The bedrock is a sandy slate, and all the gold is found in bedrock. Sluice water was being obtained in small amounts through a ditch about 1,000 feet in length. The prospecting operations still farther downstream on Ganes Creek were not visited by the writer.

YANKEE CREEK

Yankee Creek is about 12 miles long, runs in general parallel to Ganes Creek, and empties into the Innoko River 5 or 6 miles above the mouth of Ganes Creek. Although it was first staked when the other creeks of the Ophir district were staked, gold in paying quantity was not found in its valley until 1909. The valley is rather broadly open, and both the valley floor and the underlying bedrock slope gently upward to the valley walls. The gravel deposits are shallow and in large part unfrozen. The entire record of mining on Yankee Creek is not known to the writer, as many of those who formerly worked on this creek have now gone elsewhere. The creek is known, however, to have been worked from claim 11 below Discovery at least as far upstream as claim 14 above Discovery. The claims from 8 above to 5 below Discovery are said to be patented ground. At the present time one dredge is operating on Yankee Creek and three open cuts are being worked, of which two are upstream from the dredge and one below.

The dredge on Yankee Creek, known as the Higgins dredge, is the property of the Flume Dredge Co. but is now under option and operation by Higgins, Felder & Gale. This is an old dredge that was formerly operated on the Solomon River, in Seward Peninsula. It was moved to Yankee Creek in 1921 and was operated in 1921 to 1929. During this period it worked downstream as far as claim 3 above Discovery and then upstream as far as claim 14 above Discovery. In 1930 it was dismantled and rebuilt on claim 2 above Discovery, worked downstream to claim 5 below Discovery, and is now back on claim 2 below Discovery, working upstream. This dredge has therefore worked every year since 1921, including part of the season of 1930.

At the present site of the Higgins dredge the pay streak is not well defined but ranges in width from 300 to 400 feet, and the ground is said to have a value of 4 to 5 cents to the square foot of bedrock. Farther downstream the pay streak is 400 feet wide and of still lower grade, but on claims 7 and 8 above Discovery the pay streak was 200 feet wide and of much higher grade. The dredge, at its present site, is taking a cut about 80 feet wide. The overburden is from 7 to 8 feet thick and consists mainly of gravel, but 1 to 2 feet of the slate bedrock is also removed. The fineness of the gold now being recovered is given as 878½ parts of gold and 112¾ parts of silver in a thousand, but the average fineness of the gold based on this assay and 5 others reported by the Flume Dredge Co. in earlier years is 886 parts of gold and 105 parts of silver. Considering the range covered by the dredge up and down Yankee Creek, this is probably a fair average for the creek.

This dredge is of the flume type, operated with two spuds and two headlines. Its power plant consists of a single-cylinder Fairbanks-Morse Diesel engine, rated at 60 horsepower, which burns 52 gallons of fuel oil in 24 hours. It has a digging ladder, a 5-drum winch, a pump for the sluice line, and a 2½-kilowatt 110-volt direct-current generator for lighting. A small gasoline engine is also used for power when the main engine is not running. A 14-inch centrifugal pump is used for the sluice water. The digging ladder consists of 26 buckets each of a capacity of 3½ cubic feet. This dredge is not equipped with a boiler for thawing the pond in the late fall, and the operating season is therefore somewhat short, seldom lasting beyond the middle of October. Like the other dredges in the Ophir district, the Higgins dredge was handicapped in 1933 by a shortage of fuel oil. This plant employs six men, working in two shifts, and a cook.

On the lower end of claim 3, above Discovery, two men were shoveling in an open cut about 25 by 100 feet, in virgin ground between two cuts made by the dredge. The gravel here is 5 to 8 feet thick, and the bedrock is a decomposed intrusive rock. The gravel consists of well-rounded cobbles of sandstone, shale, and volcanic rocks. The gold lies entirely in the upper part of the bedrock, and the method of working was to remove the overburden in barrows and shovel the decomposed bedrock into sluice boxes.

Below the dredge on Yankee Creek two men were working another open cut on claim 11 below Discovery. This cut lay along the east side of the creek and about 400 feet from it. The operators had groundsluiced off a tract 800 feet long and had built a bedrock drain about 1,200 feet long from the end of this tract to the creek. This is rather deep ground for open-cut shoveling-in operations, as

the depth to bedrock is 20 feet, of which the upper 10 to 12 feet is muck and the lower 6 to 8 feet gravel. The gold occurs on and in a sandstone bedrock, of which a thickness of 18 inches has to be removed to obtain a good recovery of gold. The ground worked in 1933 was a cut 15 feet wide by 30 feet long at the upper end of the tract. Water for sluicing is obtained from a ditch 1,000 to 1,500 feet long, which taps Yankee Creek.

On the upper end of Yankee Creek two men were prospecting and open cutting on claims 9 and 10 above Discovery. This work was being done on the west side of Yankee Creek, along the edge of the creek pay streak, where the dredge formerly worked. About 500 square feet of bedrock was cleaned in these operations. The fineness of the gold dust recovered was 866¼ parts of gold and 121½ parts of silver in a thousand.

OTHER CREEKS

About midway between Ophir and Spruce Creeks is Anvil Creek, a short parallel creek about 2 miles in length. Gold was discovered on Anvil Creek in 1917, and the creek has been worked intermittently in a small way since that time. The first work was in the creek channel, where some high-grade placers were located. The depth to bedrock is said to have been about 30 feet, and the narrow pay streak was worked by drifting. The present work consists of an open cut along the northwest side of the stream, about 300 yards upstream from the Takotna-Ophir automobile road, where the gold-bearing gravel is being shoveled into sluice boxes by two operators. This open cut is about 150 feet from the creek, and the surface of bedrock is said to slope gently southeastward to a point within 25 to 50 feet of the creek, where it drops abruptly to the level of the creek pay streak. No regular pay streak occurs along this northwest bench of Anvil Creek, but there is said to be a zone about 100 feet wide and parallel to the creek in which good spots are found. On the southeast side of the creek, also, small spots have been found that could be worked at a profit. The overburden at the present cut consists of 6 feet of muck, underlain by 4 to 8 feet of well-rounded gravel, which averages 4 to 5 inches in size. No large boulders are present, and few of the cobbles exceed 9 inches in diameter. The gold is found either on bedrock or in the upper 6 inches of rock. The gold is rather shotty, and there are many nuggets, of which the largest recovered by the present operators weighed nearly 6 ounces. Four assays of the gold were furnished by the operators, and one by P. W. Carlson, of Ophir. The average of these assays indicates that the fineness is 878 parts of gold and 117 parts of silver in a thousand. Considerable cinnabar occurs in the concen-

trates recovered with the gold. A ditch half a mile long leads creek water to the cut, but little was available during the season of 1933.

Between Spruce and Anvil Creeks is Victor Gulch, a small gulch that cuts back a short distance into the hills. A small hydraulic plant is located in this gulch about a quarter of a mile upstream from the automobile road. The operator of this plant has been working at this site since 1920 and holds several claims, known as No. 1 association. The pay streak lies along the northwest side of the gulch, close to the creek, and a cut about 450 feet long has been worked along the pay streak. The width of the workable ground has been variable and irregular but ranged in general from 6 to 80 feet. The bedrock drops off abruptly at the east side of the cut, near the creek, but as the creek bed is well incised the depth to bedrock in the creek does not increase materially. The overburden along the cut has averaged about 25 feet in thickness, but at the upper end of the cut, where mining is now in progress, it is 20 feet thick on the west side, and nearly twice as thick at the east side of the face. Most of the overburden is muck, in which the remains of ancient vertebrates are not uncommon. A bone found in this muck was determined by C. W. Gilmore, of the United States National Museum, as the basicranial portion of the skull of a Pleistocene horse. About 6 to 8 feet of angular gravel and fractured bedrock underlies the muck. The bedrock is slate, whose cleavage strikes N. 60° E. and stands about vertical. The slate is cut by numerous dikes of fine-grained and greatly altered dacitic and andesitic rocks. Some of the fractured debris is notably pyritized. The gold occurs both in and on the bedrock and is said to be coarse and shotty, with numerous good-sized nuggets, of which one weighed about 5½ ounces. More or less quartz occurs with the gold, and one piece of vein quartz containing free gold was seen by the writer. The concentrates contain cinnabar. Five assays of the gold show an average fineness of 882 parts of gold and 115 parts of silver in a thousand.

Water for this work is obtained in part from a ditch 2 miles in length, with an intake on lower Spruce Creek, but the water does not have sufficient head for hydraulicking and can be used only for sluicing. A short ditch brings water from the upper part of Victor Gulch for use in a small giant, but the catchment basin of the gulch is so small that the giant can be used only during periods of rainy weather. The trend of the present pay streak is toward the creek, as it is traced upstream, and the operator is now prospecting farther up the gulch along the bench on the opposite side of the creek to determine if the upstream continuation of the pay streak lies on that side.

Heading against Little Creek and running southwest is Ester Creek, a small stream flowing into Dollar Creek, which in turn is one of the headwater tributaries of Beaver Creek. One man was operating a small hydraulic plant on Ester Creek in 1933, but this property was not seen by the writer. Two assays of the gold dust were furnished by P. W. Carlson, of Ophir, and the average of these shows a fineness of 836 parts of gold and 156 parts of silver in a thousand.

TOLSTOI DISTRICT

The Tolstoi district is a small area that consists mainly of the drainage basins of Mastodon and Madison Creeks, which are eastern tributaries of Tolstoi Creek, one of the large tributaries of the Dishna River. (See pl. 4.) The mouth of Mastodon Creek is about 22 miles northwest of Ophir, and the mouth of Madison Creek is about 5 miles farther northwest, down Tolstoi Creek. The headwaters of Mastodon and Madison Creeks are about 12 miles east of their mouths. The settlement of Tolstoi was located at the mouth of Mastodon Creek.

The geology and placers of the Tolstoi district have been described by Harrington,[16] who visited this area in 1917. The writer has not visited the Tolstoi district. According to Harrington's data, the country rock of this district is more diversified than that of the Ophir district, in that late Paleozoic and early Mesozoic sedimentary and volcanic rocks form a part of the stratigraphic sequence, though Cretaceous sediments and a series of Tertiary igneous rocks are also present. Mastodon and Madison Creeks have low gradients and flow at lower elevations than the producing creeks of the Ophir district. Apparently, these two streams lie at or below the level that marks the upper limit of regional silt alluviation, and the placers are therefore of the buried type, similar in that respect to those in the Ruby district.

Gold was found on these eastern tributaries of Tolstoi Creek as early as 1907, but little attention was paid to this district until the winter of 1915–16, when commercial gold placers were located on Boob Creek, one of the lower tributaries of Mastodon Creek from the south. This discovery was followed by a stampede in the summer of 1916 and a second gold rush during the winter of 1916–17. During these rushes the district was rather thoroughly prospected, but no other high-grade placers were found, though some that could be worked were found on other creeks. In 1917 five plants operating on Boob Creek produced $50,000, but these placers were soon worked

[16] *Harrington, G. L.*, The gold and platinum placers of the Tolstoi district, Alaska: U. S. Geol. Survey Bull. 692, pp. 339–351, 1919.

out. The later history of mining in the Tolstoi district is not known to the writer, but it is reported that one man was still working on claim 4 above Discovery on Esperanto Creek, a headwater tributary of Madison Creek, during the summer of 1933. This work was evidently done in shallow ground, for according to the operator's report about 1,200 square feet of bedrock was cleaned. The auriferous gravel is said to have averaged 1 foot in thickness, but the thickness of the overlying alluvial material was not stated.

NIXON FORK DISTRICT

The Nixon Fork district lies about 30 miles northeast of McGrath and comprises the area drained by several of the streams near the head of the Nixon Fork, a tributary of the Takotna River from the northeast. (See pl. 4.) These tributaries of the Nixon Fork, which enter from the southeast side of its valley, are, named in order downstream, Submarine, Mystery, Ruby, and Hidden Creeks. Heading against these four creeks are Medicine and Crooked Creeks, which flow southeastward to the Kuskokwim River. The placers of the Nixon Fork district lie mainly in the streams that drain into the Nixon Fork, but some placers have also been found in Crooked Creek. The lode deposits of this district, which are described on pages 229–242, lie along the divide between the four creeks that drain to the Nixon Fork and the two that flow to the Kuskokwim.

The country rock in the vicinity of the lode and placer deposits consists of early Paleozoic limestone and Cretaceous sandstone and shale, all of which are intruded by monzonitic rocks that are probably of Tertiary age. These intrusions were unquestionably the source of the mineral-bearing solutions that have produced the gold lodes of this area, from which in turn the gold placers have been derived. (See pl. 5.)

HIDDEN CREEK

Gold placers were first discovered on Hidden Creek in 1917, and the other placer deposits were found soon thereafter. These placers have been worked since their discovery, and some of them were still being worked during the summer of 1933. The most productive of the placer deposits are those of Hidden Creek.

Hidden Creek has a total length of about 10 miles. The stream flows southwest for about 4 miles in its upper valley and then turns abruptly and flows north of west for 6 miles to the Nixon Fork. The valley above the bend is asymmetrically placed with regard to the intrusive rocks, in that these rocks lie almost entirely in the heads of the tributaries from the north, which therefore contain gold placers.

These tributaries, named in order downstream, are Riddle, Birch, and Holmes Gulches. The extreme head of Hidden Creek, above the mouth of Riddle Gulch, also contains some placers, which, however, are of rather low grade. Discovery claim, on Hidden Creek, is about opposite the mouth of Whistling Gulch, a tributary from the south, which enters Hidden Creek about midway between Riddle and Birch Gulches. The grade of Hidden Creek from the mouth of Riddle Gulch to claim 2 below Discovery averages about 4¾ percent, though the gradient at the upper end of this stretch is naturally higher than the average.

The pay streak that has been mined on Hidden Creek extends down Riddle Gulch to Hidden Creek and continues down that stream for about a mile. At the lower end of claim 1 below Discovery the depth to bedrock is only 12 feet, but a short distance below this point the depth to bedrock abruptly increases to 200 feet, and three-quarters of a mile farther downstream it is 135 feet to bedrock. In this deeper ground the overburden has been found to be 45 feet of angular gravel, overlain by a great thickness of sticky mud, which acts as a false bedrock. The high-grade pay streak ends where this deep alluvium begins, though some low-grade placers have been found to lie above the muddy false bedrock. This abrupt deepening of the overburden occurs at or just below the point where, in going downstream, the bedrock changes from quartz monzonite to limestone, and it is probable that the change of level is due to underground solution of the limestone and the subsequent collapse of the roof of a cavern thus produced.

The pay streak from claim 1 above Discovery to the mouth of Riddle Gulch ranges in width from 100 feet at the lower end to 40 feet at the upper end and averages perhaps 60 feet. The average tenor of the pay streak has been about 25 cents to the square foot. At the lower end of this pay streak the thickness of the overburden was 12 feet, but it diminished gradually to 10 feet at the mouth of Riddle Gulch. The gravel of these placers from claim 1 below to 2 above Discovery is angular to subangular and poorly sorted. As the bedrock in this part of Hidden Creek is quartz monzonite, the gravel is of the same rock. As a rule, the fragments are not large, except in the upper part of the overburden, where there are many boulders 2 to 3 feet in diameter and some as large as 6 feet. The gold occurs in the lower few inches of the gravel and on but not in bedrock. It is angular and rough, and the largest pieces contain much attached or intergrown vein quartz. The largest nugget so far found weighed about 4¾ ounces. This gold is of remarkably high grade, as will be seen from the 14 subjoined assays, which were kindly furnished by F. E. Matthew.

Fineness of gold dust from Hidden Creek

[Parts in a thousand]

Year	Gold	Silver	Year	Gold	Silver
1925	923¼	68	1927	952¾	38
	911½	74		961¾	30
	922	66		892½	67
	928	62		927½	64
1926	921	64	1928	919¼	68
	922½	65	1929	930½	62
	958¼	33	1932	923	67
			Average	928	59

The concentrates recovered with the gold include much native bismuth, as well as scheelite, barite, and other minerals. The bismuth occurs as nuggets as much as 3 or 4 inches in diameter, and some of these are reported to have been intergrown with gold. A sample of the bismuth analyzed in the laboratory of the United States Geological Survey, however, showed no traces of either gold, silver, or copper.

The operator on Hidden Creek in 1933 was F. E. Matthew, the original discoverer, who has mined from the lower end of claim 1 below Discovery to claim 2 above Discovery. A Leclaire scraper is used in this work, by means of which most of the upper part of the overburden is scraped over to the north side of the valley, above and beyond the workable pay streak. Most of the boulders can be moved by the scraper, but some of the larger ones have to be blasted. The remaining gravel and loose bedrock is moved with a hydraulic giant and driven down the cut against shear boards and on into a line of four sluice boxes. The giant uses a 3-inch nozzle, and a ditch three-quarters of a mile in length supplies water with a head of 95 feet at the uppermost workings. Water is scarce, however, and the hydraulicking had to be done by splashes, except during periods of heavy rainfall. To operate the scraper a triple-drum hoist is used, and power for this is supplied by a 30-horsepower wood-burning boiler. One extra man is employed.

BIRCH GULCH

One man was operating a small open cut on Birch Gulch during the summer of 1933, about 1,500 feet downstream from the contact between the quartz monzonite and the Paleozoic limestone. The pay streak here appears to be about 50 feet wide, and 2 cuts are visible, which have been shoveled in during earlier years. The present operator is shoveling in a small open cut about 15 feet wide along the east side of the older workings. The overburden here consists of 3 feet of angular wash overlain by 8 feet of muck. The gold oc-

curs mainly on bedrock, but some gold is found in the gravel as much as 12 inches above its base. The bedrock is a limestone heavily impregnated with iron hydroxides. An assay of this gold shows a fineness of 961¾ parts of gold and 33 parts of silver in a thousand. Bismuth nuggets occur in the concentrates. For this work a ditch with a length of 1¼ miles has been constructed to take water from the head of Hidden Creek, but during the dry summer of 1933 little water was available, and at the time of the writer's visit work was at a standstill. Some of this ground is reported to carry gold to the value of 75 cents to the square foot of bedrock.

HOLMES GULCH

On Holmes Gulch another open cut was being shoveled in during 1933, when sluice water was available. This ground is held by E. M. Whalen, the owner of the Whalen lode, at the head of Holmes Gulch. The placer claims consist of two associations, aggregating nine claims, which are staked from the head of Holmes Gulch downstream.

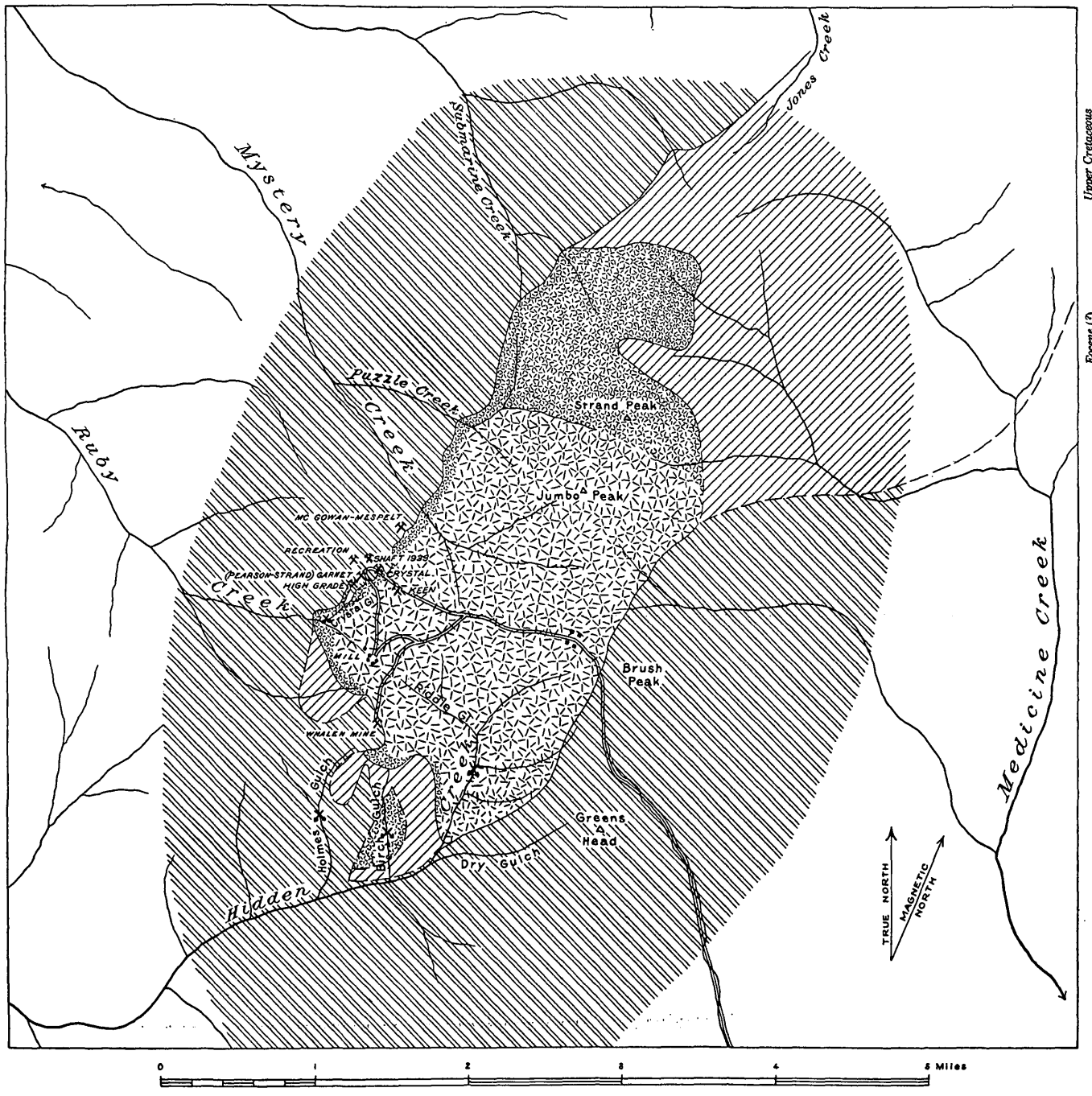
The pay streak on Holmes Gulch has been traced from the present open cut upstream and bearing off in the direction of the Whalen lode for a distance of 4,000 feet, though straight up the main valley the quartz monzonite is only 2,000 feet distant, and to the east only about 600 feet. The overburden at this cut consists of about 11 feet of angular gravel, mostly 4 to 5 inches in diameter, with a few boulders as large as 4 feet in diameter. The bedrock is a greatly decayed and iron-stained limestone, and it is said to be intersected in places by porphyritic dikes. The gold is rather fine-grained but contains some larger nuggets, to which considerable quartz is attached, and its outline is extremely rough and angular. This gold has a fineness as high as that on Hidden Creek and Birch Gulch.

For the work on Holmes Gulch two small ditches have been constructed along the hillside above the cut, but usually water is available only in the spring or during periods of rainy weather. The operator ground sluices off some of the overburden and shovels the remainder into a line of eight sluice boxes. Good tailing room is available, as the gradient of the gulch is very steep. A cut about 15 feet wide is now being opened up, and the ground is said to have a tenor of about 75 cents to the square foot of bedrock.

OTHER CREEKS

Other placers have been worked on Ruby Creek[17] and on one of its tributaries, Crystal Gulch. This gulch heads at the site of several gold lodes that have been worked for several years, but only a small

[17] Not to be confused with the Ruby Creek that empties into the Yukon. (See p. 144.)



EXPLANATION

SEDIMENTARY ROCKS

Upper Cretaceous — CRETACEOUS

Fine-grained sandstone and shale, with blocky metamorphosed slate at places near igneous contacts

PALEOZOIC

Blue and white limestone, recrystallized at places near igneous contact

IGNEOUS ROCKS

Eocene (?) — TERTIARY

Quartz monzonite with fine-grained porphyritic border facies

Placer mine.

Lode mine.

GEOLOGIC SKETCH MAP OF NIXON FORK DISTRICT IN THE VICINITY OF THE GOLD LODES AND PLACERS.

amount of high-grade placer ground was found, and most of this has now been worked out. One man was working on an open cut in Ruby Creek during a part of the summer of 1933, when water was available, but this cut was not seen by the writer. The fineness of the gold on Ruby Creek, averaged from production in 1929, is 807¾ parts of gold and 107 parts of silver in a thousand. This gold is notably lower in grade than that found in the valley of Hidden Creek and its tributaries.

Another man worked an open cut on claim 1 above Discovery on Eagle Creek, a headwater tributary of Crooked Creek, during the summer of 1933. About 5,800 square feet of bedrock was cleaned during the season.

McGRATH DISTRICT

The only mining now in progress in the McGrath district is on Candle Creek, a tributary of the Tatalina River. (See pl. 4.) Candle Creek heads in a group of low hills southwest of McGrath and flows northeast for 10 miles, joining the Tatalina River a few miles above the confluence of the Tatalina and Takotna Rivers. The valley of Candle Creek is straight and narrow in the upper part, but it widens downstream and in its lower course merges with the flats of the Tatalina River. A well-defined bench begins in the upper valley and continues downstream for about 5 miles. The creek is sharply incised in this terrace.

Candle Creek is an excellent example of the influence of bodies of granitic rocks in producing gold mineralization. The walls of the creek valley are composed largely of Cretaceous sandstone and shale, and the bedrock on the divide at the head of the creek is a dense basalt. Just downstream from this divide, however, the bedrock changes to quartz monzonite, which crops out as a ham-shaped body that extends downstream in diminishing size for about 3 miles and terminates along the northwest side of the creek, about three or four claim lengths above Discovery. The gold is derived from small quartz veins in the quartz monzonite and in mineralized country rock adjacent to the quartz monzonite.

The gold placers on Candle Creek, according to local reports, were discovered by Louis Blackburn and Bert Eldridge in 1913, and mining was already well established in 1915. Discovery claim is about 4 miles from the head of the creek, and the other claims are numbered in order below and above Discovery, except that the four claims that lie upstream from claim 10 above Discovery are known collectively as the Red Devil association. At the upper end of the Red Devil association the pay streak was rather narrow and the overburden consisted of 9 to 15 feet of gravel, which contained some large boul-

ders. At this point the gold was irregularly distributed through the gravel. Downstream the width of the pay streak and the thickness of the overburden progressively increases; thus at the lower end of claim 7 above Discovery it was 16 feet to bedrock, at the lower end of claim 6 above Discovery it was 25 feet to bedrock, and at the upper end of claim 3 above Discovery it was 35 feet to bedrock.

Open-cut mining was done in the upper part of Candle Creek during the first 3 years after its discovery, but in 1917 a dredge was installed, which, however, did not begin operations until 1918 and did not begin to produce steadily until 1919. This dredge, owned by the Kuskokwim Dredging Co., was then operated each year, through 1926. The dredging in 1922 was done at or near claim 9 above Discovery, and at that place the pay streak was 252 feet wide and the average depth to bedrock was 14½ feet. From some of the older records eight assays of this gold have been averaged, showing a fineness of 914 parts of gold and 78 parts of silver. The concentrates contain considerable cinnabar.

Candle Creek was not visited by the writer in 1933, but one operator was reported to be making open cuts along the margin of the ground earlier worked by the dredge.

IDITAROD DISTRICT

The Iditarod district, as considered in this report, is an area of about 50 square miles that lies in and between the lower valleys of Otter and Bonanza Creeks, two of the upper tributaries of the Iditarod River. (See pl. 6.) As the term is sometimes used, however, the district includes several outlying creeks that are producers of placer gold, such as Moore Creek to the northeast and Donlin and Julian Creeks to the south. The placers of the Iditarod district center in two areas that are sites of igneous intrusion. One of these sites is the west end of the ridge between Otter and Bonanza Creeks. All the streams that radiate from this site have been producers of placer gold; these streams are Flat, Willow, Chicken, Prince, Slate, and Black Creeks. The other site is in the valley of Otter Creek, about 2½ miles above Flat Creek, whence the auriferous gravel of Otter Creek continues downstream. Some small tributaries that enter Otter Creek 2 to 3 miles east of Flat Creek, have also been producers of placer gold; the principal ones are Glen Gulch, on the south side of Otter Creek, and Granite Creek and Malamute Gulch on the north side.

The country rock of the Iditarod district consists of sandstone, argillite, and slate, with various intergradations. In general, these rocks resemble the country rock in the region surrounding the district, except that here, as in the Ophir district, they are more indu-

rated and many of the argillaceous rocks have a slaty cleavage. Locally, along the borders of the monzonitic intrusives, partial recrystallization has taken place, with the development of quartzitic rocks from the sandstones and of hornfels from the argillite and slate. Similarly, the structure of the rocks differs from that in the surrounding area, for in addition to the regional open folding, the rocks of the Iditarod district have been acted upon by compressive stresses attendant upon their invasion by igneous intrusives. All the sedimentary rocks of the Iditarod district and of the surrounding area are believed to be of Upper Cretaceous age.

Sometime during the Tertiary period the country rocks of the Iditarod district were intruded by bodies of monzonite, of which the two most prominent are the mass at the head of Flat Creek and that in the valley of Otter Creek. The mass at the head of Flat Creek is roughly elliptical, with its major axis trending northwest, and the lengths of the major and minor axes are about 3 and 1½ miles. The intrusive body in the valley of Otter Creek probably has a surficial area only about 15 percent as great as the other mass. Still other bodies of such rocks are known in this vicinity, and it seems probable that much of the district is underlain by a larger body of intrusive rocks, of which the surficial masses represent merely apophyses. The bodies of monzonite are cut by veinlets and small veins of quartz, which contain free gold and metallic sulphides, but numerous iron-stained joint planes and fractures that have little or no quartz are also believed to be sites of considerable gold deposition. The metalliferous deposits are believed to have been formed at a late stage in the general process of magmatic cooling of hot ore-bearing aqueous solutions. The component minerals of the monzonite also show the effects of saturation by such solutions. Similarly, the country rock has been intensively mineralized at places along the margins of these intrusive masses, but it is characteristic of such mineralization that it did not extend any considerable distance from the contacts, and the veins in the country rock are irregular and discontinuous.

The gold placers of the Iditarod district have been derived directly from the erosion of the mineralized parts of thin bodies of monzonite and of the adjacent country rock. The manner of accumulation of the gold placers, however, was not uniformly the same, so that various types of placers resulted. The monzonite, both at the head of Flat Creek and in the valley of Otter Creek, is deeply weathered, at some places to a depth of 10 feet or more. If the monzonite happens to be gold-bearing, such disintegration frees some of the gold, which then tends to sink lower in the rock debris. Continued weathering of this material and the removal of a part

of it by ground water produce an enrichment in gold, which under favorable circumstances may produce a workable residual placer. More commonly, however, the weathered rubble is subjected to movement, produced by hillside creep, which in this region is accentuated to a marked degree by frost heaving and related processes. Under such conditions most of the gold is gradually freed from its hard-rock binder, and as the mass of arkosic sand moves slowly down the hill slopes the gold tends not only to sink to the base of the moving mass but also to be retarded with respect to the overriding debris. Hence the arkosic material gradually works downhill, leaving a part of its contained gold farther up the slopes, and in this manner, even before the debris gets to well-established watercourses, there thus occurs a pronounced concentration of gold, which may produce workable placers. Such semiresidual or eluvial placers are particularly well developed at the heads of Flat and Chicken Creeks.

Where the weathered material has migrated down the hill slopes to established watercourses, it is then transported down the valleys by normal stream action, and the gold is still further concentrated as stream placers. Such placers are well developed in the valleys of Flat and Willow Creeks. In an attempt to classify the stream placers of the Iditarod district into ancient and recent stream placers, certain difficulties arise. Elsewhere in the Yukon Basin, below elevations of about 600 feet above sea level, the ancient placers are almost universally "buried placers"—that is, placers like those on Long and Poorman Creeks, where the bedrock level below the placers has about the same elevation as the bedrock under the present stream gravel and where, on account of silt alluviation and the subsequent superposition of stream channels on the silt surface, the recent and the ancient stream channels are essentially unrelated. In the Iditarod district the stream placers lie about 500 feet above sea level on Otter Creek, but in the valleys of Flat, Willow, and Slate Creeks they extend upstream to elevations of 600 to 800 feet. Although some muck overlies most of these placers, no great thickness is present, particularly in Otter Creek, where it might be expected most. Where the placers continue up the tributaries of Otter Creek above the 600-foot level, low bedrock benches begin to appear, though they have no surficial expression. The placers of Flat Creek lie both above and below this critical elevation, and the bedrock bench in the upper valley is low and was either imperfectly developed or has subsequently been materially dissected. In the valley of Willow Creek the placers have about the same vertical range as in Flat Creek, but, in addition to the creek placers, bench placers are well developed on a bedrock terrace considerably above the level of bedrock under the creek. On Otter Creek, however, the

surface of bedrock rises gradually from the center of the valley to the valley slopes, and shallow placers occur in the present valley floor in such a way that no well-defined or unrelated ancient and recent channels can be discriminated. Ancient pre-Pleistocene or early Pleistocene gravel deposits were probably formed in the valley of Otter Creek, as elsewhere in this region, but they must have been entirely reworked by the present stream, as the gravel of this part of Otter Creek shows every evidence of recent origin. It is also possible that the ancient gravel of Otter Creek was not gold-bearing, for the small body of monzonite that is now exposed to erosion in the valley of Otter Creek and the neighboring country rock, which together are considered to be the sources of the placer gold, may not have been denuded in early Pleistocene time. In fact, other evidence regarding the distribution of various grades of gold in these placers (see p. 199) renders it even probable that gold-bearing bedrock has only in recent time been exposed to erosion. These considerations lead to the belief that "buried" placers of the type found in the Ruby and Poorman areas do not exist at the same levels in the Iditarod district; drill records in the lower valleys of Otter and Bonanza Creeks show ancient buried gravel but at lower elevations than farther up the Yukon Valley.

At the present time the Iditarod district is the largest producer of placer gold in the Ruby-Kuskokwim region. About 20 plants were operated during the season of 1933, of which 2 were dredges, 3 were drag-line excavators, 1 was a drag-line scraper plant, 9 were hydraulic plants, and the remainder were small open-cut operations. The dredges operated on Flat and Otter Creeks; drag-line excavators were used on Flat, Willow, Happy, and Slate Creeks; a drag-line scraper operated on Flat Creek; and hydraulic plants operated on Willow, Chicken, Prince, Flat, Otter, and Granite Creeks. The information graphically represented by plate 7, which shows the location of the mining claims on Flat and Otter Creeks, was supplied to the writer by John Beaton and Alex Mathieson, of Flat.

FLAT CREEK

Flat Creek is a southern tributary of Otter Creek, about 4 miles long, that heads in the intrusive mass of monzonite at the west end of the ridge between Otter and Bonanza Creeks. The settlement of Flat is at the mouth of Flat Creek, about 500 feet above sea level. The valley of Flat Creek is rather open, but it is asymmetric in cross section, as the stream flows against a fairly steep west wall throughout most of its course. The east side of the valley has a gently rising slope toward the hills. Both sides are devoid of any marked terraces, though, as noted on page 200, buried bedrock channels that

lie above the present level of the stream have been found along the "bench" on the east side.

The longitudinal profile of Flat Creek is worthy of special mention. At the head of the creek is a wide semicircular, steep-sided basin, in which there is an abrupt descent from an elevation of 1,600 feet above sea level to the creek. At the foot of this amphitheater-like slope there is an abrupt change to a wide valley floor that has a gradient of only 3 or 4 percent, which gradually diminishes to less than 2 percent at Flat. There is thus no gradual transition between the upper basin of Flat Creek and its valley proper; instead, a steep headwater hill slope is joined directly to a mature open valley. This wide upper catchment basin, however, has the effect of producing a greater run-off in Flat Creek than usually is found in a stream of this size.

The southernmost placers of the Flat Creek Valley are the residual and semiresidual deposits in this upper catchment basin, and those farther north are succeeded downstream to the mouth of the creek by normal stream placers. The gold-bearing deposits in the creek are from 10 to 25 feet deep and are composed largely of gravel and sand, with a surficial cover of silt. Large monzonitic boulders of residual origin occur in the upper part of the valley, but the gravel becomes progressively finer downstream, as the monzonitic material disintegrates rapidly and does not stand stream transportation, and below the granitic contact the stream has too low a gradient to transport large boulders of the country rock. The richest of the gold placers have been found on the Marietta claim, just below the steep-walled head of the valley. Farther downstream the pay streak becomes wider and of lower tenor, though the whole creek may be regarded as a placer of bonanza type.

The uppermost placer-mining plants on Flat Creek are operating in the semiresidual placers at its extreme head. Upstream from the uppermost claims shown in plate 7 are two additional associations of claims, whose position is not sufficiently well known by the writer to be plotted. The upper of these is the Idaho association, consisting of six claims and two fractional claims. Two partners are operating a hydraulic plant on the Idaho association. The main placer channel of Flat Creek connects upstream with this property, and most of the intervening ground has been worked in earlier years. Two cuts were being opened up. One of these, considered to be in the main pay channel, is 165 feet wide and 365 feet long. At the upper end of this cut the overburden is 20 feet thick, and at its lower end from 4 to 12 feet thick. The other cut, 150 feet west of this one, is 150 feet wide and 365 feet long. Here the depth to bedrock is only about 8 feet. The overburden in these two cuts, from bedrock to surface, consists

of angular wash, with a matrix of granitic sand. Here and there, but particularly near bedrock, is some small, partly rounded gravel, but most of the wash consists of angular fragments of unsorted monzonite, together with fine-grained equivalents and variants of the monzonitic magma. The bedrock is a deeply weathered monzonite, and the surface of bedrock in these cuts has a gradient of about 25 percent. This ground has an average tenor of 30 cents to the square foot of bedrock, and the gold is said to be fairly evenly distributed through the gravel. The gold is so fine-grained that 15 percent of it is saved in the matting below the undercurrents in the three lowest sluice boxes. Charles Yost, one of the operators, supplied five assays of the gold, based on production in 1931 and 1932; the average of these shows a fineness of 856 parts of gold and 125 parts of silver in a thousand. The concentrates contain cinnabar, but this mineral is not plentiful.

This ground is worked by open cuts with the aid of a hydraulic giant, but water is scarce at all times, and special methods have to be used to make the work profitable. The present operators have evolved the plan of working two sets of cuts simultaneously, in order that the available water may do double duty. Accordingly, two cuts will be opened about 1,000 feet down the slope from the upper cuts, and the water, after being used in the upper cuts, will be impounded and used in the lower cuts. Water is obtained from two ditches, one extending 1½ miles to the east and the other a quarter of a mile to the south. These ditches pick up a good supply of water from melting snow in the spring or during rainy periods later in the summer, but at other times they are almost dry, so that the work has to be done at irregular intervals. The nozzle on the giant is likewise varied from 2½ to 4 inches, the size used depending on the amount of water available. A line of eight or nine sluice boxes 24 inches wide is set to grades of 14 to 16 inches to the box length, and the three lower boxes have undercurrents and matting for retaining the fine gold. Mercury is also used in the boxes to obtain a higher recovery of gold. When water is available the two operators of this plant employ two extra men.

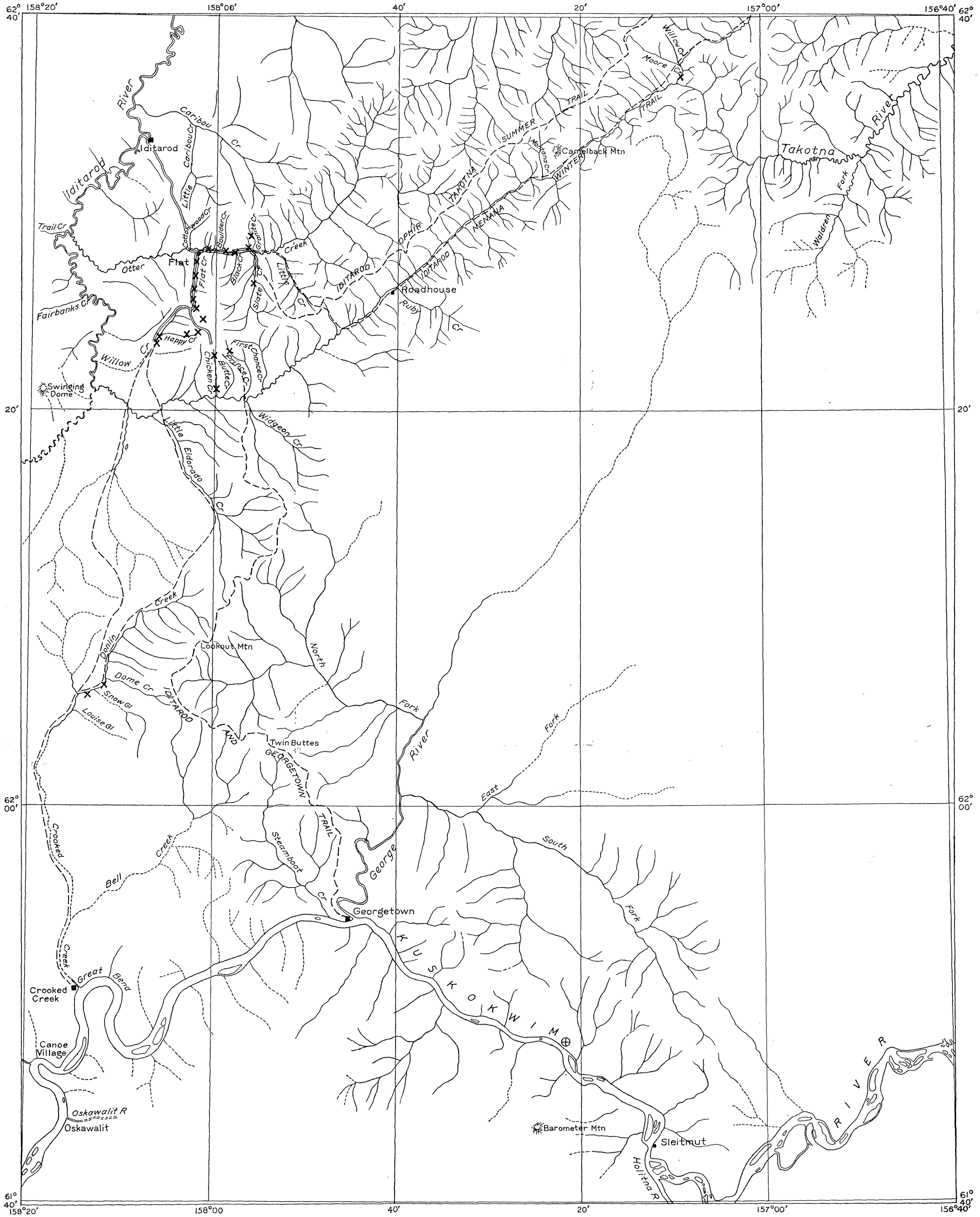
About 1,000 feet below the lower cuts of the plant just described two other operators are working a similar plant on the Hillside association. Here a side channel enters the main channel from the east, and it is in this side channel that the mining is being done. This plant was not in operation at the time of the writer's visit, but a cut 100 by 200 feet and apparently about 30 feet deep was seen. The bedrock was not everywhere uncovered, but at the lower end of the cut it showed as an almost vertical cliff 30 feet in height. Another striking sight on the west side of the cut is a large slab of false bed-

rock, below which was 10 feet of washed gravel. Except for these irregularities in the surface configuration of bedrock, the conditions are about the same as at the upper plant.

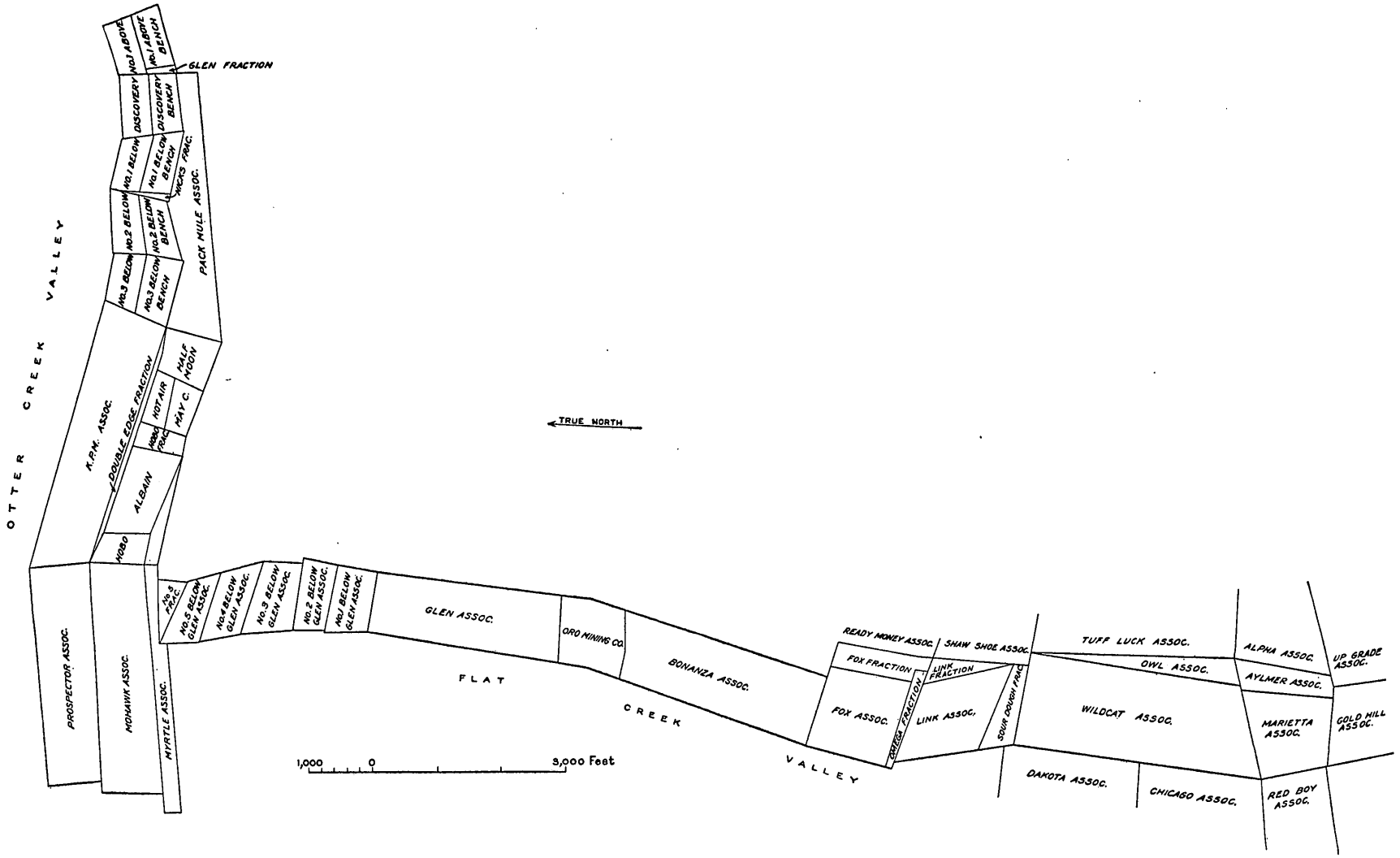
Another open-cut mine was operated on the Hilltop association during a part of the summer. This plant, which was worked by two men, was not seen by the writer. According to a report by the operators, a cut aggregating 1,500 square feet was worked, in angular material about 6 feet thick. The fineness of the gold from this cut was stated to be 853 parts of gold and 140 parts of silver in a thousand, and this agrees closely with the records of the fineness of the gold on the Idaho association.

Below the semiresidual placers on Flat Creek are the stream placers. These stream placers were worked by a dredge owned by the Yukon Gold Co. in 1912–18. The dredge was built on the west side of the Marietta claim and, after working upstream to the upper limit of that claim, turned and worked downstream for the entire length of Flat Creek. Much of the ground worked by this dredge was virgin ground, and as the placers of Flat Creek were unusually rich, the dredge recovered large amounts of gold. It failed, however, to recover all of the gold, partly because it did not dig deeply enough into bedrock and partly because the gravel was not thoroughly separated and washed. As a result, both the bedrock below the placers and the old tailings of this dredge have yielded large returns to later operators, and Flat Creek is still a large producer of placer gold.

The uppermost plant that was operated in the stream placers of Flat Creek during the summer of 1933 was a drag-line scraper plant on the Wildcat association, a group of six claims held by Strandberg & Co. In the early part of the summer a cut 70 by 100 feet had been worked on the east branch of Flat Creek, about 500 feet from the creek. The bedrock in this cut is about 30 feet higher than the bedrock under the present creek and consists of sandstone and slate. The cleavage of the slate strikes N. 60° E. and dips steeply south. This cut, which was located in old dredge tailings, was completed early in the summer. At the time of the writer's visit a cut 100 by 100 feet was being worked directly adjacent to the creek along the east side. This cut included a part of the ground earlier worked by dredging and some virgin ground. The ground has been so much disturbed here and elsewhere on Flat Creek by the earlier dredging operations that it is difficult to learn the exact nature of the original overburden. At this place, however, the original overburden is said to have been about 6 feet of muck, with little or no underlying gravel. Most of the gold occurred in bedrock, of which the present scraper plant is now removing from 3 to 5 feet. This bedrock is a blocky



SKETCH MAP OF IDITAROD AND GEORGETOWN DISTRICTS, SHOWING LOCATION OF GOLD PLACER MINES AND CINNABAR LODE.



SKETCH SHOWING LOCATION OF PLACER-MINING CLAIMS ON FLAT AND OTTER CREEKS, IN THE IDITAROD DISTRICT.

argillite and sandstone, with joints and fractures into which the gold has penetrated deeply. The surface of bedrock at this site has a gradient of about 3 percent. The operator at this plant furnished a record of five assays of the gold from earlier operations on claims of the Upgrade association and nine assays from those of the Wildcat association. The average fineness of the gold from the Upgrade association is 844 parts of gold and 134 parts of silver in a thousand, and that from the Wildcat association is 885 parts of gold and 108 parts of silver. The highest assays of gold from the Upgrade association are lower than the lowest assays from the Wildcat association, and the gold recovered far up the slope on the Idaho association is intermediate in grade between that found on the Upgrade and Wildcat associations. It is therefore probable that the observed difference between the gold on the Upgrade and Wildcat associations is due more to original differences in the quality of the gold or to other unknown factors than to the usual loss of silver, as placer gold is transported downstream.

The scraper plant on the Wildcat association uses a bucket with a capacity of 1½ cubic yards, and the power plant consists of a 40-horsepower wood-burning boiler. The usual winch equipment is used. A string of sluice boxes is employed, and the last few boxes utilize undercurrents and matting to recover the fine gold, of which there is considerable. When water is available this plant employs three men.

About 3,000 feet downstream from the lower end of the Wildcat association is the Bonanza association, which extends downstream for another 3,000 feet and consists of two claims, staked end to end, up and down the creek. (See pl. 7.) A drag-line excavator plant was operated on the Bonanza association claims during the summer of 1933. The pay streak here is from 300 to 400 feet wide, and most of it was worked years ago by the dredge of the Yukon Gold Co., but the pay streak still yields good returns. The Northland Development Co., which is operating the excavator, worked four cuts during the season. Two of these were in the old dredge tailings, in the original site of the creek. These two cuts were 125 feet in width and had an aggregate area of 75,000 square feet. The old tailings were 10 to 12 feet deep. A third cut was worked along the west side of the old dredge tailings and was in a lower-grade lateral extension of the pay streak, which was not worked by the dredge. This cut was 60 feet wide and aggregated 45,000 square feet. The depth to bedrock was 16 to 20 feet, but in places the operators also removed 6 to 7 feet of bedrock, in order to obtain a high recovery of the gold. At the time of the writer's visit, late in August, the operators had

just removed their equipment over to the east side of the creek and were opening up a fourth cut along the east side of the dredge tailings, opposite the third cut and in a similar eastward lateral extension of the pay streak. This cut was 75 feet wide at its upper end and 150 feet wide at its lower end, was 1,500 feet long, and aggregated about 128,000 square feet. Here the overburden is 10 to 11 feet deep, and the bedrock is about 10 feet higher than in the creek channel. The gravel on this bench ground is subangular and fairly small. There were very few boulders seen in the tailings, and the largest of these was about 18 inches in diameter. The surface of bedrock, in this part of Flat Creek, has a gradient of about 2 percent. The gold is in small, fine particles and occurs in the lower 3 to 4 feet of gravel and in bedrock. The operators kindly furnished 10 assays of the gold recovered from this work, from which it appears that the average fineness is 879 parts of gold and 110 parts of silver in a thousand. This gold, it will be noted, is slightly lower in grade than that found a mile farther upstream on the Wildcat association. This is further evidence indicating that Flat Creek is an exception to the usual rule that placer gold increases continuously in fineness downstream.

The plant on the Bonanza association consists of a Bucyrus-Erie dragline scraper, built on a caterpillar base. The boom is 55 feet long, so that with a few additional feet to the center of the turntable this machine can easily work a cut 100 feet wide at its base if the sluice boxes are on one side of the cut, and it can work a cut 200 feet wide if the sluice boxes are in the middle of the cut. The bucket of the scraper has a capacity of 1½ cubic yards and can handle about 2,000 cubic yards in a 24-hour day. As water is often scarce on Flat Creek, the sluice water is impounded and pumped back to the head of the sluice line. For this purpose a 65-horsepower 4-cylinder Diesel engine is used, which, because it works constantly, consumes about as much oil as the main engine, which works only intermittently. In operation, the gravel is dumped by the bucket into a dump box at the upper end of the sluice line, where it is separated and cleaned by a small giant. Water for this giant is supplied by a ditch along the east side of the creek, with an intake of about 2,000 feet upstream from the plant. The water is supplied under a head of 30 feet. One of the interesting and economical features of this plant is the fact that the dump and sluice boxes are built as a rigid unit that can be moved on skids when changing from operation at one cut to another. Nine sluice boxes are used, set at grades of 12 to 14 inches to the box length, and in the last 3 boxes undercurrents and matting are provided, in which fine gold aggregating 10 percent of the total output is recov-

cred. On account of the presence of late winter frost in the ground on Flat Creek this plant can seldom begin operations before June 1 and usually quits about October 1, though in 1933 it operated until October 17. Day and night shifts are worked, and the total number of men employed is 15.

At the lower end of Flat Creek a dredge is being operated by the North American Dredging Co. This dredge was built by the Yukon Gold Co. in 1916 on Black Creek, where it operated for one season. In 1917 it was moved to Otter Creek, where it operated through the year 1931. In 1932 it began work on the Mohawk association, at Flat, and worked up Flat Creek for three-quarters of a mile along the west side of the old tailings of the earlier dredge, passing across the Myrtle association and claims 5, 4, 3, and 2 below the Glen association. All this work in 1932 was therefore in virgin ground. In 1933 this dredge worked downstream again through the older dredge tailings and by September 1 had arrived at claim 5 below the Glen association. The operators expected to take another cut in 1934, going upstream parallel with but east of the cut made in 1932. On claim 5 below the Glen association the pay streak has a width of about 1,200 feet, but a quarter of a mile farther downstream it is 2,000 feet wide. On claim 5 below the Glen association the original depth to bedrock is said by the present operators to have averaged 15 or 16 feet.

This dredge is of the stacker type, driven by an Ingersoll-Rand 3-cylinder Diesel engine, rated at 125 horsepower. The engine uses about 115 gallons of fuel oil in 24 hours. The power equipment also includes a 5-kilowatt, 110-volt, direct-current generator for lighting and an accessory 3-kilowatt generator, operated by a small gasoline engine, for emergency lighting. A 20-horsepower boiler is used for thawing the pond in the late fall. The dredge is equipped with a 7-drum hoist and operates from one spud and headlines. The trommel is 20 feet in length, perforated with 2-inch holes. The digging ladder has 54 buckets, each with a capacity of 3 cubic feet, and digs at the rate of 25 buckets a minute. The dredge handles about half the rated load, or about 2,000 cubic yards a day. The dredge can dig about 15 feet below water level and at the time of the writer's visit was taking a cut from 65 to 140 feet wide.

Beaton & Mathieson kindly supplied the writer with a number of assays of the gold recovered by this dredge, both on Otter Creek and in the lower valley of Flat Creek. These assays, on the various claims on Flat Creek, are given herewith:

Fineness of gold in lower valley of Flat Creek

[Parts in a thousand]

	Gold	Silver
1932		
Mohawk association	875	115
	870	119
	880	115
Myrtle association	875½	118
	880	112
Claim 5 below Glen association	880½	115
	882	111
Claims 5 and 4 below Glen association	883	110
Claim 4 below Glen association	878	114
	881	114
Claim 3 below Glen association	887½	115
Claims 3 and 2 below Glen association	878	114
1933		
Claims 2 to 5 below Glen association	878	115
	872	116
	878	114
Average	878	114

From these assays it will be seen that the gold in this part of the Flat Creek Valley shows little variation from the mean. It also appears that the fineness of the gold does not increase from the Bonanza association downstream—in fact, a slight lowering in grade is perceptible. Considering Flat Creek as a unit, the assays already given show that the gold increases in fineness from the semiresidual placers at the head downstream to the Wildcat association and gradually decreases in fineness from that association downstream. This mode of variation suggests not only that marked variations existed in the grade of the gold in its original bedrock but also that gold from diverse sources was mixed together in the development of the pay streak in the lower valley of Flat Creek, and it seems to be a further indication that most of the ancient placers of Flat Creek have been reworked to form the recent placers.

WILLOW AND HAPPY CREEKS

Like Flat Creek, Willow Creek and its tributaries head in the mass of monzonite at the west end of the ridge between Otter and Bonanza Creeks. Willow Creek flows in a general southwesterly direction for 5 miles and then turns west for 2 miles to join the Iditarod River. In its upper 5 miles the valley of Willow Creek is decidedly asymmetric in cross section, as the stream flows along a steep northwest wall. The southeast side of this upper valley is a wide flat, which extends half a mile from the creek to the slope that rises sharply to the hills. Several small tributaries enter along the southeast side, of which Happy Creek is one of the largest and economically the most important. Another tributary, Gold Creek, enters from the same side about 1¼ miles below Happy Creek.

The three principal groups of claims on Willow Creek, in succession downstream, are the Wildcat association, the White Star fraction,

and the Fine Gold association. The White Star fraction and the Fine Gold association are owned by the Manley estate. Gold Run enters Willow Creek near the upper end of the Fine Gold association. The Wildcat association consists of eight claims, staked crosswise of the creek, and is the site of the original discovery on Willow Creek. One hydraulic plant worked during the summer of 1933 on the upper end of the Wildcat association, and another hydraulic plant, aided by a dragline excavator, operated farther downstream. A dragline excavator plant was also in operation on Happy Creek.

The hydraulic plant on the upper end of the Wildcat association was operated by four partners. The present work is being done along the southeast side of the creek and about 250 feet from it. The pay streak here is 300 feet wide and is reported to have an average tenor of 20 to 25 cents to the square foot of bedrock. The overburden has a thickness of 12 feet, of which the upper 7 feet is muck and the lower 5 feet subangular gravel that has an average diameter of 3 or 4 inches but includes boulders as much as 1 foot in diameter. The gravel consists mainly of sandstone and slate, with practically no monzonite, although Happy Creek and other tributaries of Willow Creek head in such rock. A little brecciated vein quartz also occurs in the gravel. The bedrock is slate, whose cleavage strikes N. 40° E. and dips steeply southeast; but at one place along the southeast side of the cut a dike of vesicular basalt follows the cleavage of the slate. The surface of bedrock along these bench workings is about 8 feet higher than the bedrock under the creek, but the slope from the bench to the creek is gradual and continuous at about 3 or 4 percent. The downstream slope of both the bench and creek bedrock is about 2 percent. The gold at this cut lies mainly on bedrock but at some places occurs in the lower several feet of the gravel, and a little gold has been found at the base of the muck. The gold is said to be very fine grained, and the largest nugget so far reported weighed only about 25 grains. Four assays of this gold show an average fineness of 877½ parts of gold and 115 parts of silver in a thousand.

The present operators have been working at or near the present site since 1919 and have mined both the creek and the bench placers, but the creek placers are now about worked out. The mining is done by hydraulic methods, using three giants with 2½-inch nozzles. Two giants are used in moving the gravel toward the sluice boxes, and one is used for stacking tailings. The gravel is moved down against shear boards that converge to the lower end of the cut and is there picked up by a hydraulic elevator and lifted 5 feet to an elevated dump box. The throat of the elevator is 8 inches in diameter. The dump box is followed by three elevated sluice boxes. Water for this work is obtained from a ditch that taps Willow Creek 2 miles upstream and also picks up some water from Happy Creek.

The water is delivered at the cut under a head of 80 feet. The penstock is 300 yards from the cut, and the water, leaving the penstock in a 24-inch pipe, is gradually reduced to an 8-inch stream at the cut. All this ground is frozen, but by stripping in the fall it will usually thaw sufficiently for mining during the following summer. Two cuts, aggregating about 34,000 square feet, were worked during the season of 1933.

At the lower end of the Wildcat association and also on the adjoining claims of the Manley estate downstream a hydraulic plant, aided by a dragline excavator, operated during the summer of 1933. Both bench and creek ground are being worked at this site, but the present operations are on bench ground. Two well-defined pay streaks are recognized. The pay streak in the present creek bottom is 200 to 400 feet wide, with an overburden 16 to 18 feet thick, of which the lower 10 to 12 feet consists of well-rounded gravel and the upper part is muck. The pay streak along the southeast bench is about 500 feet wide, and its northwest edge is 1,100 feet from the creek. The overburden is 15 to 24 feet thick, of which the lower 3 to 10 feet is subangular to angular gravel and the rest is muck. The gravel in general averages about 3 inches in diameter and does not exceed 10 inches; and it is almost entirely sandstone and slate, with only a little vein quartz and practically no monzonite. The gravel of the bench placers contrasts sharply with that of the creek placers, which is fairly well rounded. The bedrock is a slate, which strikes N. 35° E. and dips steeply southeast. The surface of bedrock on this bench ground is 35 to 40 feet higher than the bedrock under the creek placers and has an average gradient toward the creek of 3½ percent, but the descent to the creek bedrock is discontinuous, in small steps. The gold occurs mainly on but not in bedrock and at some places also lies in the lower foot of gravel. It is rather fine-grained, and the largest nugget so far found weighed less than half an ounce. The creek gold, as a whole, is no coarser than the bench gold, but some larger nuggets have been found in the creek placers. Two assays show an average fineness for the bench gold of 871 parts of gold and 124½ parts of silver in a thousand; this is somewhat lower than the bench gold found farther upstream on the upper end of the Wildcat association.

Mining at this lower plant is done by hydraulic methods, but a caterpillar drag-line excavator is used for stacking tailings. Water is obtained from two ditches; one of these is 2 miles long and delivers the water from Gold Creek at the cut under a head of 170 feet; the other ditch is 2½ miles long, takes water from Willow and Happy Creeks and delivers it at a head of 50 feet on the bench workings. A third ditch was built higher on the southeast hill

slope and was to be used for working ground farther downstream on Willow Creek, but this ditch is in poor condition and is not being used. Giants with 2½- or 3-inch nozzles are used, the size depending upon the supply of water, and the gravel is washed to shear boards that converge toward a line of three sluice boxes. As the grade is insufficient to dispose of tailings, a Bucyrus drag-line excavator is utilized for this purpose. This machine has a beam 55 feet in length, but the distance from the center of the turntable to the end of the beam is about 80 feet. It has a bucket with a capacity of 1½ cubic yards. Power for the excavator is furnished by a 60-horsepower steam boiler, which uses from 1 to 1½ cords of wood in 10 hours. In addition to the owner of the Wildcat association and a representative of the Manley estate four other men are employed at this plant.

Happy Creek is a short headwater tributary of Willow Creek and heads in the same body of monzonite that forms the basin of the head of Flat Creek. Its upper valley is narrow and devoid of benches. At the lower workings the gradient of Happy Creek is about 3 percent, at the site of the present operations it is 5 percent, and a short distance upstream 7 percent. Above this, as on Flat Creek, the gradient rises abruptly.

On Happy Creek the claims have been restaked since the original discovery and are now staked upstream and downstream from the Ray fraction. Years ago the placers of Happy Creek were partly worked by drifting operations, but this work was never very successful, because 80 percent of the placers were unfrozen. Olson & Co., the present operators, began open-cut work on Happy Creek in 1930 and have continued to the present time. The creek has been worked upstream, and the plant is now operated on claim 1 above Ray fraction.

The pay streak farther down Happy Creek was 100 to 110 feet wide, but at the present site it is between 400 and 500 feet wide, extending onto the north bench. This north bench is now being prospected with a Keystone drill, and placers have been located 400 feet from the creek. Here the depth to bedrock is 50 feet, but this increase in the thickness of the overburden is due to a surface slope that rises gently from the creek; the bedrock appears to be no higher than at the creek. The placers along this north side of the creek seem to be at least as rich as those in the creek bed. Upstream from the present plant gold placers are known to continue for about 2,000 feet, to a point where the gulch rises abruptly to the headwater hill slope. At the very head of Happy Creek, almost on the mountain top, are residual placers that yielded good returns and are still worked on a small scale. It will probably be

found that a continuous body of semiresidual placers connects those on the mountain top with the present stream placers on Happy Creek, just as at the head of Flat Creek.

Throughout the lower workings on Happy Creek the overburden is about 12 feet deep, but its thickness increases gradually upstream and at the site of the present plant is 18 feet. Nearly all of this material is angular to subangular debris, with an average size of 4 to 6 inches, though good-sized boulders are common, some of them as much as 2 feet in diameter. These boulders increase in number and size upstream. In the present cut at the head of Happy Creek some were as much as 4 feet in diameter, and prospecting has disclosed others as large as 30 feet. Here, as on Hidden Creek, in the Nixon Fork district, most of the boulders occur in the upper part of the gravel. All this debris is poorly sorted, gravel and finer material occurring together everywhere. At many places there is a thin stratum of monzonitic sand, rather than gravel, directly on top of bedrock, and this usually contains considerable gold. The gravel is composed of sandstone, argillite, and slate, together with monzonite and its magmatic variants, but the monzonitic rocks increase upstream and become dominant in the upper part of the creek. The bedrock at the present cut consists of dark-colored sandstone and sandy argillite, both intricately fractured, so that the gold has sunk deeply into them. In working the deposit only the lower 2 to 3 feet of gravel is sluiced, but at many places 6 to 7 feet of the blocky bedrock is also removed and sluiced. At the present cut several monzonitic dikes 20 to 50 feet thick cut the bedrock. These dikes are completely decomposed at the surface to an arkosic sand. Some of the gold from Happy Creek is well worn, and some is rough, but in general it is coarser than the gold of Willow Creek. One nugget weighing about 1⅔ ounces is about the largest piece so far found. Andrew Olson supplied the writer with 8 assays of the gold, based on production in 1930, 1931, and 1933. The average of these shows that the fineness is 864 parts of gold and 126 parts of silver in a thousand, but the gold had a range from 856 to 876 parts. Much cinnabar occurs in the concentrates, and in the pannings from the drill on the north bench, where prospecting is now being done, a curious sectile metallic substance was noticed. This was analyzed in the laboratory of the United States Geological Survey and found to be lead antimonide.

Mining at this plant is done by means of a caterpillar dragline excavator similar to the one on Flat Creek, except that gasoline instead of fuel oil is used for power. The scraper has a bucket with a capacity of 1 cubic yard and a beam 55 feet in length. With an additional 20 feet to the center of the turntable the maximum reach is 75 feet. The gasoline engine that furnishes the power is rated at 85 horsepower. A 1½-kilowatt 110-volt direct-current generator is

also used for electric lighting. In addition to the main scraper plant a caterpillar shovel with a half a cubic yard bucket is used for making vertical cuts along the edges of the pay streak. This was formerly the main digging equipment but is now used merely as an accessory. As water is scarce in Happy Creek the sluice water is impounded and pumped back to the dump when necessary. For this purpose a 65-horsepower Diesel engine is used, and at the present site of the plant water is being pumped 1,400 feet upstream and raised to a head of 80 feet. Water had to be pumped throughout the summer of 1933.

The washing plant is similar to the one used by the Northern Development Co. on Flat Creek. An elevated dump box and sluice boxes are built as a rigid unit, and this unit is placed on the bank above the south side of the cut. The dump box is 7 feet wide, and the sluice boxes, which have a width of 30 inches, are set to a grade of 12 inches to the box length. Six main sluice boxes are used, but an extra box, which leads sidewise from the lowest box, is equipped with undercurrents and matting, and in this box fine gold aggregating 8 to 10 percent of the output is recovered.

Two small open-cut plants where the gold-bearing gravel is shoveled into sluice boxes were also worked at the extreme head of Happy Creek, in the residual deposits. At this place the original pay streak was 200 feet wide and is said to have yielded about $1 to the square foot of bedrock. The present work is being done along the margins of the old high-grade pay streak, and the ground now being worked probably has a tenor of about 20 cents to the square foot. One cut 100 feet long and 36 feet wide had been blocked out, but owing to scarcity of water the work was progressing rather slowly. The overburden consists of 2 to 4 feet of residual monzonitic sand, some fine gravel near bedrock, and numerous large boulders. The gold is fine-grained, and no large nuggets are found. About 1,000 feet farther up the slope a similar cut was blocked out.

CHICKEN CREEK

Chicken Creek heads in the same mass of monzonite as Flat and Happy Creeks, but flows south to Bonanza Creek. It has a length of about 3 miles, and its upper valley is a narrow gorge. At the head of Chicken Creek, where mining is now in progress, the gradient of the creek is from 10 to 15 percent, but a little farther downstream the slope is almost precipitous for a short distance, then gradually decreases downstream, and in the lower part of the valley it becomes rather low.

Chicken Creek has been mined since 1913, and old tailings are visible from the head of the creek for a mile downstream. Below

the precipitous part of the valley old shafts are visible, and still farther downstream more tailings show that considerable mining has been done there. Two mining plants are now being operated on Chicken Creek. One of these is a hydraulic plant, which is located at the head of the creek and is working the semiresidual placers at that site. The other plant consists of open-cut shoveling-in operations at the extreme lower end of the creek.

The operators of the upper plant on Chicken Creek have been mining at this site since 1924. The pay streak, as now exposed, is at least 500 feet wide, and the highest-grade placers were found in the bed of the creek, where two cuts had earlier been worked. A third cut is now being worked along the west side of these, and a fourth cut is being prepared still farther west. In the center of the valley the depth to bedrock is said to have been about 47 feet, but at the present bench workings the overburden averages about 18 feet in thickness. The bedrock, moreover, is 25 to 30 feet above the level of bedrock in the center of the valley. The overburden along this west bench is a mixture of monzonitic sand and angular monzonitic wash, with many large boulders. Though some of the boulders are scattered from top to bottom of the overburden, most of them occur in the upper part. Most of the gold is found in the lower 4 to 5 feet of sand and angular gravel, but some gold occurs throughout the overburden, and roughly the value of the ground is proportional to the thickness of the overburden. The bedrock is a greatly decomposed monzonite into which the gold has hardly penetrated at all, but in places where the monzonite is hard and blocky some gold has penetrated deeply, though even at such places the amount of gold in the bedrock is relatively so small that removal of the bedrock to obtain it does not pay. As everywhere else on the flanks of this monzonitic dome, the semiresidual placers in this locality are unfrozen. The gold is rather fine, angular, and equidimensional. Nuggets are uncommon, and the largest so far found weighed less than half an ounce. Five assays of the gold based upon production in 1929 were supplied by the operators, and the average of these shows a fineness of 862 parts of gold and 128 parts of silver in a thousand.

A hydraulic plant is used in working these placers. Several giants are used, with nozzles of 2 to 3 inches, depending upon the supply of water. The main difficulty in this work is the removal of the large boulders, and to accomplish this two gin poles have been installed, one in the cut and one high on the west bench, with a high-line cable between them. A wire net, with a trolley, is then used to move the boulders, and by this method boulders as large as 3 feet in diameter

are lifted out of the cut. For power a 40-horsepower wood-burning boiler is used. Water for hydraulicking and sluicing is obtained from several miles of ditches at the head of Chicken Creek, which converge to two main lines, one of which delivers water at a head of 150 feet and the other at 100 feet. Little water was available at the time of the writer's visit in late August, but a small crew was engaged in cleaning bedrock by pick and shovel. When water is available this plant employs 10 to 20 men.

On the lower end of Chicken Creek, about half a mile above its mouth, a long open cut was being prepared for subsequent shoveling-in operations. A dam has been built about 2,200 feet above the mouth of Chicken Creek, and the operators have opened up a cut and bedrock drain along the east bench of the creek, in which they expect to work for a distance of 1,800 feet downstream from the dam. Below this the surface of bedrock dips steeply below the level of the watercourse that constitutes the lower end of the bedrock drain. At the mouth of Chicken Creek, in the valley of Bonanza Creek, the depth to bedrock is said to be 90 feet. In order to facilitate the disposal of tailings at the end of this drain the operators have straightened the course of Bonanza Creek by cutting byways across several of its loops, so that the current at the mouth of their drain will be materially increased.

The present cut is about 100 feet east of Chicken Creek and is 15 to 40 feet wide and 12 to 40 feet deep. The lower 10 to 30 feet consists of gravel, the smaller pebbles of which are fairly well rounded, brown, and iron-stained, but the larger cobbles, 1 or 2 feet in diameter, are subangular. In the upper part of the cut these larger cobbles occur mainly in or near the overlying muck, but in the lower part they are also in the lower gravel. The gravel is mainly sandstone and argillite, with very little of the monzonite that forms the bedrock at the head of Chicken Creek. The bedrock, also, is sandstone and argillite.

In this work an automatic dam is used, with a gate 6 feet square, and even under the conditions of drought during the summer of 1933 the operators were getting 10 splashes of 5 minutes duration in 24 hours. Each splash was estimated to give 36 sluice heads of water. No shoveling in had yet been done at this cut, as it was still in course of preparation, but a similar cut with a length of 800 feet, which branches from the present cut 1,000 feet from Bonanza Creek, was worked in earlier years. This cut was 20 feet wide at its upper end, 30 feet wide at its lower end, and 30 feet deep; and one man, working alone at this site, shoveled in a cut 15 by 200 feet in 1930–32. The present work is being done by three men.

PRINCE CREEK

Prince Creek lies east of Chicken Creek, but it heads in the monzonite dome at the heads of Flat, Happy, and Chicken Creeks and flows in a general southerly direction to Bonanza Creek. There are two principal headwater forks of Prince Creek, of which the western one is the site of present mining operations. Discovery claim is located in the west fork, but no part of the valley of Prince Creek has been a large producer of placer gold.

The present mining is being done at a small hydraulic plant on Discovery claim, operated by one man. During the season of 1932 this operator worked a cut 150 feet long and 50 feet wide, in which the overburden ranged from 22 feet in thickness at the lower end to 30 feet at the upper end. Near bedrock there is about 5 feet of monzonitic sand, with some fine gravel and a few large boulders. Above this the gravel is coarse, angular, and unsorted, with a sandy matrix, and appears to be the product of creep. It contains many large boulders, the largest as much as 4 feet in diameter. The gravel consists of argillite, sandstone, and monzonitic rocks. The bedrock is a banded argillite. Upstream from the cut of 1932 and adjoining it another similar cut was being opened in 1933, but little progress had been made because so little water was available. In this cut a clay streak acts as a false bedrock, and the ground is not being opened up to the true bedrock.

Water for the hydraulic operations is obtained from two ditches, which tap both forks of Prince Creek; the available head at the present cut is 100 feet. For removing boulders from the cut a gin pole, boom, and hand hoist have been constructed, with which boulders weighing as much as 10 tons can be lifted and removed. The present operator has been working at this site for 4 years.

OTTER CREEK

Otter Creek heads against the Dishna River and flows in a general southwesterly course for 13 miles to the mouth of Little Creek, one of its tributaries from the south; thence it has a westerly course for 10 miles to the point where it debouches onto the flats of the Iditarod River; and then for 3 miles it crosses these flats flowing northwest. The distances given are reckoned in an air line and take no account of the meanders of Otter Creek, which below the mouth of Little Creek become increasingly numerous. Throughout its course the valley of Otter Creek is asymmetric in cross section, as the stream flows close to the north wall for the entire distance. Bonanza Creek shows to a still greater degree the asymmetric profile and similar though less marked changes in direction in its lower valley.

About 2 miles above the mouth of Flat Creek a small intrusive mass of monzonite forms the bedrock in the valley of Otter Creek. Discovery claim and claim 1 above Discovery, together with the two corresponding first-tier bench claims to the south, are all located on this intrusive body, but the monzonite extends upstream almost to the mouth of Slate Creek and downstream about three claim lengths below Discovery claim. Glen Gulch, a small tributary of Otter Creek, enters just above Black Creek, and in this direction the monzonite extends well into the head of Glen Gulch. Downstream from the monzonite the bedrock on Otter Creek consists of Cretaceous sandstone and shale, which strike N. 70° E. and dip steeply north.

The placers of Otter Creek begin toward the upper end of the body of monzonite and extend downstream to a point below the mouth of Flat Creek. (See pls. 6 and 7.) The productive ground is confined to a tract from a quarter to half a mile wide, which lies in the valley bottom, south of the present channel of Otter Creek. In the center of the valley the overburden ranges in thickness from 10 to 18 feet, but on the bench claims to the south it is considerably thinner. This overburden consists of 2 to 6 feet of gravel and semi-residual debris overlain by 4 to 12 feet of muck, and much of it is frozen. The gravel consists of monzonitic and basaltic material, with considerable sandstone and shale. The bedrock in the upper part of the pay streak is a greatly decomposed monzonite, the upper part of which is in places a residual arkosic sand in which cobbles and boulders of monzonitic material are numerous. The gold occurs in this residual bedrock material, but where the monzonite is blocky and has resisted alteration the gold has pentrated for a considerable distance into bedrock cracks. In general, the placers of Otter Creek are shallow stream placers, but the placers on the bench claims grade so imperceptibly into those on the valley floor that both ancient and recent placers may be present.

Assays of the gold in Otter Creek bring to light some interesting features.

Fineness of gold on Otter Creek

[Parts in a thousand]

	Gold	Silver	Dross
Claim 1 above Discovery	854	134	12
Discovery claim	843	140	17
K. P. M. association	838	141	21
Prospector and Mohawk associations	824	133	43

The records are summarized as follows:

These assays show a progressive lowering in the fineness of the gold from the upstream to the downstream end of the pay streak.

It also appears that the decrease in the fineness of the gold is not accompanied by a corresponding increase in the proportion of silver but instead is due to a progressive increase in the dross. It is believed that there are two general grades of gold on Otter Creek. The higher grade gold is derived from crevices and quartz stringers that occur mainly in or near the body of monzonite. The lower-grade gold is associated with ores of stibnite and mercury, which occur as larger veins, more commonly in the country rock at some distance from the intrusive mass. The available assays show the predominance of the higher grade of gold on claim 1 above Discovery, but one assay of a small sample shows that even at this site the lower-grade gold is also present, though not in sufficient quantity to change materially the high average fineness. It is believed that farther downstream, however, the lower grade of gold becomes progressively more prevalent, thus producing the lower averages above recorded. This hypothesis not only explains the progressive lowering of the grade of the gold downstream but also suggests that little reworking of the gold placers has taken place on Otter Creek and that the gold has not migrated downstream any considerable distance from its original bedrock sources.

The uppermost mining plant now operating on Otter Creek is a hydraulic plant on the first tier of bench claims, south of claim 1 above Discovery. Glen Gulch crosses this claim before entering Otter Creek, and the material now being worked may perhaps better be considered a bench deposit of Glen Gulch, as it lies along the east side of Glen Gulch and was probably concentrated by the action of water in that gulch. In the center of Glen Gulch the pay streak probably averaged $1 to the square foot of bedrock, and the overburden was 27 feet thick. This true Glen Gulch pay streak was about the length of a placer claim and was first worked by drifting and later reworked by open-cut hydraulic methods. This claim length is reported to have produced gold valued at about $200,000. Along the east side of Glen Gulch the pay streak is of lower grade but is wide and is continuous with the pay streak of Otter Creek. The present hydraulic plant is about 150 feet east of Glen Gulch, and the cut has an area of about 16,000 square feet. Another cut, perhaps 7,000 square feet in area, was worked farther up Glen Gulch earlier in the season. The overburden at the larger cut consists of 5 to 7 feet of subangular gravel, overlain in general by an equal thickness of muck. The gold occurs mainly on bedrock, but at some places the monzonite is blocky, and there the gold penetrates to a depth of 2 or 3 feet. Some gold also occurs in the lower 3 feet of gravel. This gold is coarse, and one nugget weighing over 6 ounces has been found. Peter Miscovich, the operator of this plant, kindly furnished four assays of the gold, with

the corresponding weight in ounces of each sample, so that a weighted mean fineness could be computed. This fineness is 854 parts of gold and 134 parts of silver in a thousand.

When adequate water is available this deposit is worked by three giants, with a hydraulic lift that elevates the gravel 12 feet from the bottom of the cut to the top of the dump box. The throat of this lift has a diameter of 8¾ inches. Water is obtained from a ditch 1¾ miles in length, which taps Slate Creek below its forks, but the Riley Investment Co., operating farther down Otter Creek, has a prior right to this water, and so the operator at this plant was using the water only during the night, when it was not needed downstream. The penstock is connected with the cut by 2,600 feet of hydraulic pipe, and the available pressure in the cut is that produced by a head of 70 feet.

A second hydraulic plant is being operated on Discovery bench, about 700 feet downstream from Black Creek and about the same distance from the position of Otter Creek, before it was deflected by mining operations in the valley floor. The owner of this plant has been operating at this site for several years and during the season of 1933 worked a cut 125 by 115 feet, or about 14,000 square feet in area. The overburden here consists of 5 feet of gravel overlain by about 5 feet of quartzose sand, but in earlier cuts, farther upstream, the gravel was overlain by as much as 15 feet of muck. The gravel at this cut is well rounded and consists mainly of sandstone, slate, and argillite. The largest boulder seen had a diameter of 18 inches, but such boulders in general are scarce. The bedrock is monzonite, but about 100 feet downstream from the present cut a quartz-stibnite vein about 3 feet thick, striking about N. 45° E., cuts the bedrock. The wall rock of this vein is a minette. Other evidence of nearby mineralization is afforded by a cobble derived from a quartz-cinnabar vein, which was seen in the present cut. The gold recovered at this plant is fine-grained. Sixteen assays of the gold, based on production in the years 1927 to 1932, were furnished by Martin Roslund, operator of this plant. These show an average fineness of 843 parts of gold and 140 parts of silver in a thousand, which is about 1 percent lower in grade than the gold on the next claim upstream. This decrease in quality downstream is also evident from the individual assays, which show that the highest-grade gold occurred in the cuts farthest upstream and that the lowest-grade gold came from the present cuts.

The third plant on Otter Creek is a dredge operated by the Riley Investment Co. This dredge was built on Discovery claim in 1914, and has operated on Otter Creek every year since, working up and down Otter Creek several times. The dredge is now in the middle

of the valley about half a mile above Flat and is working downstream while a crew of men are engaged in thawing the ground in this half-mile stretch. At Discovery claim the pay streak was about 1,200 feet wide, but at the present site of the dredge the pay streak is about half a mile wide. The overburden in general is between 8 and 10 feet thick, but the dredge also digs 3 to 5 feet of bedrock. The gravel is subangular to rounded, and there are few boulders. At the present site the bedrock is sandstone and slate, but streaks of monzonitic bedrock are reported by the operators, showing that monzonitic dikes also occur. The fineness of the gold in the lower part of this pay streak was determined from the assays of the gold produced by the dredge of Beaton & Mathieson, which operated on Otter Creek in the years 1917 to 1931. Thirty assays of the gold from the K. P. M. association, at the upper end of the half-mile stretch, showed an average fineness of 838 parts of gold and 141 parts of silver in a thousand. Downstream from the K. P. M. are the Prospector and Mohawk associations, and 37 assays of the gold from these associations showed an average fineness of 824 parts of gold and 133 parts of silver.

The dredge is a stacker type, operated from two spuds and two headlines and driven by an Enterprise 125-horsepower 3-cylinder Diesel engine. About half the power is used in operating the digging ladder and the other half in operating the trommel, stacker belt, and pumps. Two centrifugal pumps are used, one with an 8-inch intake, and the other 10-inch. The former is used for producing a stream of water under pressure for washing the gravel in the trommel; the latter is a low-pressure pump for bywater for the sluice line. The dredge also has an auxiliary Atlas engine for driving the generator and other emergency uses when the main power plant is not running. The dredge is lighted by a 5-kilowatt 110-volt direct-current generator. Another source of power is a 40-horsepower boiler, which is used for heating and thawing in the late fall. The dredge uses a 7-drum hoist and is equipped with a 20-foot trommel screen, with 2-inch holes in its lower end and smaller holes forward. The digging ladder has 53 buckets, each with a capacity of 3½ cubic feet, and digs at the rate of 22 buckets a minute. Sixteen men are employed at this plant, of whom four are engaged in cold-water thawing downstream from the dredge. The operating season is from 5 to 5½ months, ending usually about November 10.

GRANITE CREEK AND MALAMUTE GULCH

Granite Creek enters Otter Creek from the north side of its valley just below the mouth of Slate Creek, and a short distance downstream from the mouth of Granite Creek is Malamute Gulch, a small gulch

locally called Malamute Pup. Granite Creek and Malamute Gulch are the sites of gold placers that are related to the monzonite in the valley of Otter Creek.

Granite Creek is not particularly well named, as its valley is carved mainly in a bedrock of sandstone and argillite, though some dikes of granite rock are said to cross the valley in its upper part. The stream placers of Granite Creek have been worked from the mouth upstream to the present cut, on claim 2 above Discovery, and a cut aggregating 10,000 square feet along the east bench of Granite Creek was also worked some years ago. The pay streak in the creek placers of Granite Creek, at the site of present operations, is about 130 feet wide, though the present cut along the west side of the pay streak is only 80 feet wide. The length of the cut is about 115 feet. The gravel is 8 to 12 feet deep and consists mainly of angular to subangular fragments of the same general character as the bedrock in Granite Creek. A few boulders as large as 18 inches in diameter occur. The bedrock here is a fine-grained dark-gray sandstone striking N. 45° E. and dipping steeply northwest. About 2 feet of this material must be removed to obtain a good recovery of gold. The gold is rather fine grained but shotty and is also somewhat iron-stained. Three assays of this gold show a fineness of 853 parts of gold and 134 parts of silver in a thousand.

The work is done mainly by open-cut methods. Upstream from the cut an automatic dam has been built, but the scarcity of water during the season of 1933 retarded progress materially. A hose and nozzle connected with the dam also give a lower-powered hydraulic jet suitable for cleaning bedrock. A line of 24 sluice boxes is used; of these the lower 13 are merely flumes for getting rid of tailings, but the upper 11 pay boxes are all equipped with undercurrents. The present operator has worked on Granite Creek since 1920, sometimes with the aid of hired men and at other times alone.

On Malamute Gulch the mining is being done on the Virgin association. A long, steep cut up the gulch from its mouth shows where work has been done in earlier years. The overburden consists of about 35 feet of poorly assorted angular wash in a sandy matrix. Cobbles as much as 15 inches in diameter are of common occurrence, but large boulders are rare. This gravel is largely vesicular basalt, which comes from the spur directly above the gulch. The bedrock is a greatly decomposed monzonite and probably connects with the mass of similar material in the valley of Otter Creek. The gold lies mainly on or near bedrock. A little water is obtained from Malamute Gulch, and in the spring and during rainy periods in the summer this water is utilized to ground sluice off most of the overburden. The remaining few feet near bedrock is then washed against shear boards and shoveled into sluice boxes. A line of 20 boxes is used.

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SLATE CREEK

Slate Creek is a tributary from the south to Otter Creek, which it enters about 4 miles above Flat. It is about 4½ miles in length. Slate Creek has a western fork about 2 miles long, which enters the main creek about 1½ miles above its mouth, and it also has several headwater tributaries. The valley is wide and open, and the drainage basin is large for a stream of this length, so that a good supply of water for placer mining is ordinarily available. The usual run-off is probably about 400 miner's inches, but during the late summer of 1933 the water supply could not have been more than 15 percent of that amount. The gradient of the creek is only 0.9 percent at its mouth and about 1.5 percent at a point 2½ miles upstream.

Discovery claim is located at the lower end of Slate Creek. Adjoining Discovery claim is an unnamed claim staked crosswise of the creek, followed in turn by the S. S. S. association, another unnamed claim, the Star association, and then by claims 4, 5, 6, and 7 above Discovery, all staked crosswise of the creek. Above these, claims 8, 9, 10, 11, and 12 above Discovery are staked with their long dimensions parallel to the creek. The western fork of Slate Creek enters between the S. S. S. and Star associations.

Some granitic dikes and vein quartz crop out on claim 11 above Discovery, and a contact between slate and monzonite also occurs at the head of the western fork. The gold mineralization in the creek may have centered at these two places. The pay streak is considered to extend from claim 5 above to claim 11 above Discovery. The valley floor ranges in width from 600 feet on claim 4 above Discovery to 350 feet on claim 10 above Discovery and to 150 feet on claim 13 above Discovery. The pay streak is about 120 feet wide on claim 5 above Discovery and about 100 feet wide on claim 6 above Discovery and lies both on the creek bottom and in the rising slope of the east side. It is said to range in tenor from 20 to 45 cents to the square foot of bedrock. The depth of the overburden is from 13 to 30 feet, depending on whether it is measured in the valley bottom or on the rising east slope.

Mining has been done in a cut on the east side of Slate Creek, beginning near the line between claims 4 and 5 above Discovery and extending 1,600 feet upstream. The present work is on claim 6 above Discovery, where the pay streak has a width of about 100 feet. The overburden is 13 to 25 feet deep, of which the upper 3 to 15 feet consists of muck, overlying 10 feet of gravel. The bedrock is slate, but the gold is said to occur mainly in the lower 7 feet of gravel, with little or none on bedrock. The gold is said to be fine-grained, with very few nuggets.

The plant consists of a caterpillar drag-line excavator, driven by a Northwest-Wisconsin variable-speed 6-cylinder gasoline engine, which develops 90 to 130 horsepower on 5 to 8 gallons of gasoline an hour. The power plant also includes a 1½-kilowatt engine and generator for electric lighting. The scraper has a 55-foot boom and a bucket with a capacity of 1 cubic yard. In operation the muck is ground sluiced off, the upper part of the gravel is stacked along the side of the cut, and the lower 7 feet of gravel is elevated to a dump box at the upper end of the sluice line. The dump boxes and five sluice boxes are bolted together as a rigid unit, as on Flat and Happy Creeks. The two lower sluice boxes use undercurrents and matting, and considerable gold is thereby saved. Water for this work is obtained from a ditch along the east side of Slate Creek, about 1½ miles in length. About 3,400 feet of hydraulic pipe is used to convey water from the penstock to the dump box, where it is delivered under a head of 90 feet and is used in a giant to wash the gravel and also as bywater for sluicing. This plant employs eight persons.

MOORE CREEK

Moore Creek is one of the outlying creeks of the Iditarod district that was not visited by the writer in 1934, though examined in 1915. The Takotna River heads against Bonanza Creek and flows northeast for about 7 miles, then turns abruptly southeast. At the point where the abrupt turn occurs the Takotna River receives Moore Creek, a tributary from the north. Moore Creek has two branches, of which the eastern one is Willow Creek; the junction is about 30 miles N. 70° E. of Flat.

The Discovery claim on Moore Creek was staked in the fall of 1911, and the stream placers have been worked intermittently since that time. The stream claims are staked crosswise of the creek. Bench placers have also been worked along the east side of Moore Creek. Claim 5 above Discovery was the most productive creek claim at the time of the writer's visit in 1915, and to judge from recent returns it continues to be. Along the east bench of Moore Creek, opposite claims 1 below to 6 above Discovery, the Alaska association of eight claims was located, and still farther east on the bench were the B & C and OK associations.

The geologic conditions at Moore Creek are similar to those in the Iditarod district. The bedrock under the placers consists of sandstone and slaty shale, which in general strike northeast and dip steeply northwest. At the head of Willow Creek is a small body of quartz monzonite, which is considered the principal source rock of the gold, though the neighboring country rock is probably also mineralized. The creek placers on claim 5 above Discovery lie about

1,200 feet above sea level, and the pay streak is covered by an overburden 12 to 18 feet thick. This overburden consists largely of gravel, the pebbles of which range from a few inches to a foot or more in diameter and consist mainly of sandstone, shale, granitic rocks, and basic igneous rocks. On the bench the overburden is much thinner, consisting of 3 to 5 feet of gravel, overlain by 2 feet or more of vegetation and clay. The gold occurs in the base of the gravel and in the upper 1½ feet of bedrock. It is little worn and is associated with considerable vein quartz. Two assays furnished by the present operator on Moore Creek show that the average fineness is 767 parts of gold and 225 parts of silver in a thousand. Cinnabar is the principal mineral of the concentrates.

The largest production came from Moore Creek in 1912, when several plants were operating on this creek. Two plants, one in the creek and one on the B & C association, were operating in 1915. The later history of mining on Moore Creek is not known to the writer, except that one plant was operated in 1933, working a cut on claim 5 above Discovery, where 30,000 square feet of bedrock was cleaned. This plant employed five men.

It was also reported that work was in progress on one of the bench claims along the east side of Moore Creek, but lack of water rendered the progress of this work slow.

GEORGETOWN DISTRICT

Between Flat and Georgetown, gold placers are also being worked on Donlin and Julian Creeks (see pl. 6), but these localities were not visited by the writer, and the character of the placers and scope of the recent operations are not known. On Donlin Creek two men report having mined a small open cut by hydraulic methods, working along the southeast side of the creek, below the mouth of Snow Gulch. On Julian Creek another open-cut hydraulic plant was operated; here the work was on a larger scale than on Donlin Creek and the two operators employed three additional men.

LODES

No extensive lode-mining industry has yet been developed in the Ruby-Kuskokwim region, but the widespread occurrence of gold placers encourages the belief that gold lodes of economic value may be developed there. Mineralized bedrock has been observed at many localities where gold placers have been worked, and several attempts have been made to develop lodes of gold and other metals, with more or less success. In all probability the cycle of events here will be similar to that in other regions where the initial mining industry was placer mining—that is, as the placers become depleted attention will

be increasingly directed to discovering the bedrock sources of the metals found in the placers, with the result that a lode-mining industry, which already has begun, will develop progressively.

The principal metallic product so far found in the placers of this region is gold, and therefore gold lodes are likely to form the basis of the principal type of development. Other metallic ores, however, are found in the concentrates recovered with the gold; of these cinnabar, stibnite, cassiterite, and scheelite may later become of value. In general two main periods of mineralization are recognized in the Ruby-Kuskokwim region, though each of these periods may have included two or more distinct stages. Mineralization of the earlier period was restricted, so far as known, to the Ruby district and was characterized by gold and cassiterite, though this association does not necessarily imply exact contemporaneity in the formation of the two metals. It is believed that this mineralization occurred sometime in the Mesozoic era and that it was related to the intrusion of granitic rocks of the type now exposed at the head of Flint Creek. The later mineralization, which is known to have occurred in two or more stages, was characterized by gold and cinnabar, although stibnite also occurs at many places with the cinnabar. This mineralization occurred in Tertiary time, probably later than the Eocene epoch, and was related to the intrusion of monzonite and associated rocks. Mineralized ground of this later type is found at many places in the Ruby-Kuskokwim region south of Poorman, and no good reason is known why it may not also occur in the Ruby district; in fact, the cinnabar that occurs in small amounts in some of the placers of the Poorman area suggests that mineralization of both types may have occurred there. In the Long area, however, no traces of the second period of mineralization have yet been recognized.

The region also contains other metallic products—such, for example, as bismuth—which are so low in price that they could hardly be expected to become of economic value in a region so remote from centers of population. Nonmetallic products, such as sand, gravel, limestone, building stone, and the materials for making cement, also occur in this region, but they have essentially no value at this time, as no local need exists for them. Likewise, deposits of coal have been found, but the coal could have only a local market; so far this market has been adequately supplied by wood, but fuel oil and gasoline are being increasingly used for power.

Workable gold lodes were discovered in the Nixon Fork district in 1918 and have been worked continuously since that date. (See pl. 4.) Smaller gold lodes have been opened up in the Ophir, Iditarod, and Georgetown districts, but these have either not been developed to the stage of steady production or have not been productive enough to permit operation under present economic conditions. Silver-lead ores

have also been discovered, and at least two properties containing such ores have been brought to the stage of production, but for various reasons were unable to continue operations. Cinnabar lodes have been found at several localities, and a mine on one of these lodes near Georgetown, which was discovered in 1906, has been a small but steady producer of mercury from that time to the present. Cassiterite, the oxide of tin, is found only in the Ruby district, and its bedrock source has never been discovered. Scheelite, or calcium tungstate, has been found on Otter Creek and at other places, but its bedrock source also remains undiscovered.

One of the handicaps from which this region suffers, in regard to the development of both placers and lodes, is the lack of cheap transportation. Along the Yukon and Kuskokwim Rivers, the two arterial waterways of the region, transportation is probably as cheap as may reasonably be expected in a pioneer country, but in the area between the rivers the transportation of supplies and equipment is slow, difficult, and costly.

RUBY DISTRICT

Mineralized bedrock has doubtless been seen at many places in the Ruby district, but only at two localities has an effort been made to open lode mines. One prospect is on the north side of New York Creek, a headwater tributary of Beaver Creek, about three-eighths of a mile above the confluence of New York and Dome Creeks. This property has not been seen by the writer, but was visited after development work had ended by Brown,[18] who obtained additional data from Harry Boland, one of the owners. The following notes are abstracted from Brown's report.

The country rock at this property is mainly a micaceous quartz schist, with which are associated a minor amount of slaty and cherty rocks, all belonging to the group of undifferentiated metamorphic rocks. The cleavage of these rocks strikes about N. 30° E. and dips steeply southeast, and the ore bodies follow this same structural trend. The ore consists of argentiferous galena, more or less altered to cerusite, with which is associated a large amount of iron hydroxides, probably limonite, together with some siderite, rhodochrosite, and calcite and traces of quartz, pyrite, and ruby silver. The ore occurs in lenticular veins from a few inches to 3 feet thick, but at the main prospect shaft a mineralized zone from 4 to 15 feet thick was found. Numerous assays of the ore show silver ranging from 8 to 82 ounces to the ton. Several shafts, trenches, and prospect pits were opened in the hope of finding a body of workable ore, but the results of this

[18] Brown, J. S., Silver-lead prospects near Ruby, Alaska: U. S. Geol. Survey Bull. 783, pp. 145–150, 1926.

work appear to show that the veins are lenticular and the ore bodies too discontinuous laterally and vertically to make their exploitation profitable under present conditions.

Another silver-lead lode was discovered in the fall of 1918 at the northeast end of the Kaiyuh Mountains, west of the Ruby district. This property, which was known as the Perseverance lode, lies about 20 miles south of Louden. G. C. Martin, of the United States Geological Survey, visited this locality in 1921 and submitted a short report thereon, which was published in 1923.[19] According to Martin the country rock included quartzose, micaceous, and chloritic schists and also limestones, but the rocks at the site of the lode are schists, which strike northeast. The workings are said to have exposed an irregular body of ore as much as 2 or 3 feet thick, which, however, is fractured and includes masses of country rock that contain little or no ore. The ore apparently contained no valuable minerals except argentiferous galena. It was specifically tested for copper and molybdenum, but no traces were found. The Perseverance lode was operated during the fall and winter of 1920–21, and an adjoining property on the Valley claim was also worked in a small way. About 175 tons of ore is said to have been sledded to the Yukon and shipped. According to Brooks[20] 50 tons of very high grade silver-lead ore was also mined from the Perseverance lode in 1922, but no subsequent production is recorded.

Prospecting for lodes is in general a difficult and costly enterprise in the Ruby district, because the surface of bedrock at most places on the ridges is covered by residual debris and vegetal matter, and in the valleys it is deeply buried by alluvial deposits. In the Long area, for example, it is certain that the bedrock source of most of the placer gold is in the ridge between Long Creek and the headwaters of Flint, Trail, and Quartz Creeks; and the cassiterite, which occurs so universally in the placers of Long Creek and its tributaries, must also have come from the same general site of mineralization. These sources, however, have not been found, and it is of course obvious that in the absence of thorough testing and exploration there can be no assurance that such lodes of gold and tin, even if they can be located, will prove to be of sufficiently high grade to be workable. Systematic lode prospecting is consequently not only costly but highly speculative. It is therefore not surprising that little prospecting of this sort has been done, and it is not likely that such work on any considerable scale will be attempted by the present residents. As a frankly speculative project, however, financed by people who could

[19] Brooks, A. H., The Alaskan mining industry in 1921: U. S. Geol. Survey Bull. 739, pp. 38–39, 1923.

[20] Brooks, A. H., The Alaskan mining industry in 1922: U. S. Geol. Survey Bull. 755, p. 43, 1924.

afford to take the risks involved, a program of systematic prospecting for lodes in the bedrock of this area appears to be justified.

In the Poorman area the difficulties of prospecting bedrock are even greater, for the residual weathering is deeper and the alluvial cover above bedrock is thicker. The chief mineralized ground here occurs in an area about 3 miles square, bounded on the northwest and northeast by Poorman Creek. In this area, however, the evidence of pronounced residual concentration of the gold from low-grade lode material prior to the formation of the placers is so clear that it seems doubtful whether any gold lodes rich enough to be worked at a profit under present economic conditions exist or have existed at this site. Under such circumstances it seems to the writer that the Poorman area is less attractive for lode prospecting than the Long area.

CRIPPLE AND OPHIR DISTRICTS

South of the Ruby district the Mesozoic gold-cassiterite lodes are replaced by the Tertiary gold-cinnabar lodes, which at some localities are characterized also by such metallic products as stibnite, scheelite, and native bismuth, but these minerals are not so distinctive nor so universally found in the placer concentrates as cinnabar.

Little lode prospecting has been done in the Cripple and Ophir districts. One vein is known to have been located near the head of Wyoming Creek, in the Cripple Creek Mountains. This occurrence was reported orally by H. M. Eakin and recorded by Brooks.[21] According to the description the vein is about 30 inches thick. A specimen from the vein shows two bands, one of which consists of quartz intergrown with cinnabar and the other of bladed stibnite intergrown with interstitial vitreous quartz. The gold content of the sample was not determined.

Two lode prospects have been reported from the Ophir district, and others have undoubtedly been found. According to Eakin's unpublished notes a lode known as the Katz prospect was located on Eldorado Creek about 1¼ miles from its confluence with Ganes Creek. This prospect is said to have been a quartz vein 8 to 10 feet thick, striking N. 30° E. and dipping steeply southeast. This vein, which cut across the sandstone country rock, was traced for several thousand feet along its strike. The principal lode matter is granular vein quartz, but along the footwall, in a zone about 1 foot thick, a granular aggregate of quartz and stibnite occurs. A sample taken across the face of the vein at one locality, however, showed only a trace of gold and silver.

[21] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, p. 50, 1916.

Another property, known as the Independence mine, was brought to the stage of production and was operated for a year or two, about 1912. According to Maddren [22] this lode was near the head of Carter Creek, an eastern tributary of Ganes Creek. The ore body consisted of a quartz vein about 2 feet thick, which followed the hanging wall of one of the fine-grained dike rocks that are so prevalent in the Ophir district. Microscopic examination showed that gold occurred in the quartz, along iron-stained crevices, in vugs, and also within small masses of magnetite within the quartz vein. Many veinlets of iron carbonate were also observed, cutting the vein quartz, and similar material occurred in the adjacent dike and sedimentary rocks. This gold lode was developed and worked by means of several drifts and a shaft. During 1912 the ore was reduced with a crusher and stamp mill, and five men were employed, but in later years the property was abandoned.

NIXON FORK DISTRICT

Gold placers were first discovered on Hidden Creek, in the Nixon Fork district, by F. E. Matthew, in June 1917. In the course of further prospecting other placers were found in the streams northeast of Hidden Creek, including principally Ruby, Mystery, and Submarine Creeks, and it was observed that the gold continued into the extreme headwaters of these streams. This fact led to a search for the bedrock sources of the gold, and in 1918 the Crystal lode was discovered at the head of Ruby Creek by Pearson & Strand. An option was taken on the property by Thomas Eakin in 1919, and during the winter of 1919–20 several hundred tons of high-grade ore was mined and shipped to the Tacoma smelter. Meanwhile, prospectors had located other signs of mineralization along the contacts of the body of intrusive rock at the heads of these several creeks, and many other claims were staked. The more promising of these claims were taken over by the Treadwell Yukon Co., Ltd., early in 1920 and were actively prospected during that summer. In 1921 the company installed a 10-stamp mill and began a unified operation of these properties. The supply of ore, however, was found to be less than expected, and in 1923 the company discontinued operations, except on the Whalen lode, which it continued to work for another year. The various properties then reverted to their previous owners. Seven claims at the head of Ruby Creek, which included the site of the Crystal lode, together with the 10-stamp mill, were taken over by Pearson & Strand but subsequently passed into the hands of the Mespelt Bros. and their associates, who have operated these lodes

[22] Maddren, A. G., Gold placers of the Innoko-Iditarod region, Alaska: U. S. Geol. Survey Bull. 542, p. 298, 1913.

continuously since July 1926. The Whalen lode, at the head of Holmes Gulch, a tributary of Hidden Creek, reverted to E. M. Whalen. This mine, from which most of the output of the Treadwell Yukon Co. was recovered, was worked for a while by the owner but is now idle. The McGowan-Mespelt property, which includes the Southern Cross and Texas claims, lies northeast of the Crystal lode, close to the head of Mystery Creek.

The writer visited this district during the summer of 1933 and spent a day studying the placers and a day in an examination of the lodes to learn the present status of mining. The notes that follow are based on that study, supplemented extensively by earlier descriptions of Martin [23] and Brown.[24]

GEOLOGY AND MINERALIZATION

In the vicinity of the lodes the country rock consists of early Paleozoic limestone and Cretaceous sandstone and shale. Both the Paleozoic and Cretaceous rocks have been invaded by a mass of quartz monzonite and related rocks, along the borders of which mineralization has taken place. The intrusive mass occurs as a plug, which crops out in a roughly elliptical area with major and minor axes about 5 and 2 miles in length. The trend of the major axis is about N. 35° E. The intrusive rocks consist dominantly of quartz monzonite but include porphyritic variants of similar composition, which occur as marginal facies and as dikes. These monzonitic rocks are considered to be of Tertiary age, but they differ in certain respects (see p. 197) from those on Candle Creek, in the McGrath district, or at the head of Flat Creek, in the Iditarod district.

The principal gold lodes lie at or near the contact of this intrusive mass with the Paleozoic limestone, and most of those so far discovered occur in the limestone, though few of them are more than 100 feet from the contact. As these lodes occur on low ridges where outcrops are lacking, and as the underground work has been done mainly in bodies of ore, the contact relations between the intrusive and country rocks are not well known. Sufficient work has been done, however, to show that the western margin of the quartz monzonite, along which the lodes occur, is very irregular in outline and has numerous apophyses. It is also apparent that this irregular contact line has been further modified by cross faulting, some of which occurred prior to the deposition of the ores. In fact, it seems probable

[23] Martin, G. C., Gold lodes in the upper Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 722, pp. 149–161, 1922.

[24] Brown, J. S., The Nixon Fork country, Alaska: U. S. Geol. Survey Bull. 783, pp. 97–144, 1926.

that the ore-bearing solutions followed fault planes as well as contact planes in their upward migration.

The lodes consist of irregular-shaped masses of ore, which have no definite boundaries but fade out into less mineralized or unmineralized country rock. Some of these ore bodies are roughly lens-shaped or disk-shaped. Most of them, regardless of their shape, have vertical or horizontal dimensions of less than 100 feet. In addition to irregularity in shape there is a marked irregularity in the distribution of gold in them, for the ore commonly occurs in irregular-shaped shoots, of varying value, within a generally mineralized ore body. The methods employed for following and recognizing ore of workable grade differ at different properties, for at some places the prevalence of copper minerals is an index of high gold content, and at other places the reverse is true.

The ores consisted originally of gold-bearing copper and iron sulphides but have been extensively altered by processes of surficial oxidation, so that much of the gold has been released from the sulphides and now occurs as free gold recoverable by amalgamation. Most of the operating shafts so far sunk have shown this mixture of free gold and oxidized sulphides, but the ratio of oxidized to unoxidized ores differs in different ore bodies. Thus, the ore at the Whalen mine is described as being almost wholly oxidized, whereas in the Crystal lode, at the head of Ruby Creek, the ore consisted of unoxidized or little-oxidized chalcopyrite, pyrite, and bornite. The oxidized ores consist largely of the basic carbonates of copper and oxides of copper, intimately mixed with iron hydroxides. These oxidized ores have also doubtless been materially enriched by surficial processes, and as a result of such conditions it is to be expected that the ores will not only become leaner with depth but will also contain less free gold and will therefore become progressively less adapted to free milling. Inasmuch, however, as present mining operations have not extended below the zone of oxidation, and much surficial prospecting and mining remains to be done, this matter of decreasing tenor and increasing refractoriness with depth at present merits only placing on record for future consideration.

No detailed studies have been made regarding the origin and paragenesis of these ore minerals. Some thin sections of the main intrusive mass and of the ores and wall rock have been examined by the writer. From these it is apparent that the intrusive mass away from the contact, consists of a hypidiomorphic granular rock composed essentially of quartz, feldspar, and mafic and accessory minerals. The feldspar consists of orthoclase and plagioclase near andesine, and these two minerals occur in approximately equal proportions. The mafic minerals unlike those in some of the other

Tertiary monzonitic rocks of this region, show little evidence of crystallization as pyroxene but, instead, consist of either biotite or mixtures of biotite and hornblende. The accessory minerals are principally apatite, titanite, and iron ores. This rock is obviously a quartz monzonite, and this determination has recently been confirmed by a chemical analysis. No specimen of the quartz monzonite where it has been altered by ore-bearing solutions was available for examination, but one fine-grained dike below the 70-foot level in the High Grade shaft, against which the ore lay, was found to be so extensively silicified and sericitized that only the faintest outlines or ghosts of preexisting feldspars could be discerned.

Most of the oxidized ores, regardless of their composition, are green or greenish yellow, except those containing azurite, which are mottled green and blue. They are lusterless and earthy in appearance, and the fully oxidized ores look more like stained country rock than ore. Thin sections of some of the oxidized ores show a mixture mainly of calcite, iron hydroxides, and copper carbonates, with considerable sericite and quartz in some specimens and also more or less pseudo-isotropic chlorite. These minerals occur in part in a lamellar arrangement and in part in an irregular fashion suggestive of metasomatic replacement. This ore is evidently in large measure a limestone that has been replaced by ore minerals. Another type of ore, which occurs sparingly at the Mespelt property, is very fine grained and consists largely of epidote and subordinately of zeolites and other minerals. This rock contains many minute fractures, which are filled with iron hydroxides and copper carbonates. Another unusual type of ore that occurs in small amounts on the Southern Cross and Texas claims consists mainly of calcite, iron hydroxides, copper carbonates, garnet, epidote, and sericite.

The ore that has been mined at the several properties has probably ranged from $15 to several hundred dollars a ton, but the average value of the ore at the Mespelt property is probably between $25 and $35 a ton. (All these figures are based upon the old value of gold.) Besides gold the ore carries from 1 to 15 ounces of silver to the ton, and as only a small part of this is alloyed with the gold, most of it must occur in other forms. No free silver is believed to be present, as no native silver has been recognized and no silver nuggets are found in the placers derived from these lodes. It is therefore believed that silver or silver-bearing copper or lead minerals must be present in the unoxidized ores. The ore carries from 2 to 12 percent of copper, largely in the form of chalcopyrite and bornite in the primary ores, though a little chalcocite has also been noted. In the oxidized ores the copper occurs mainly as malachite, azurite, and black earthy oxides of copper. A small amount of native bismuth

also occurs in these ores, but numerous large bismuth nuggets are of common occurrence in the stream placers. One of these bismuth nuggets was analyzed in the laboratory of the United States Geological Survey for the metals golds, silver, and copper, but none of these were detected. Unlike the ores associated with the monzonitic rocks elsewhere in the Ruby-Kuskokwim region, these ores contain no cinnabar or stibnite, nor are these minerals found in the derived placer concentrates.

The wall rock is a fine-grained recrystallized limestone, locally much iron-stained but not in general greatly silicified or otherwise altered. In places, however, mining operations have exposed bands of highly altered wall rock containing typical contact-metamorphic minerals. Several samples of such rock from the High Grade shaft, on the Mespelt property, showed considerable variation in granularity, ranging from coarsely crystalline to aphanitic, but all of them consisted essentially of garnet, diopside, and epidote, with more or less calcite, zeolites, and apatite. A metamorphic aureole in the limestone near the quartz monzonite at the Whalen property is essentially a granular mixture of epidote (both pistacite and clinozoisite) and pyroxene, together with zeolites, titanite, apatite, sericite, calcite, chlorite, and a copper carbonate.

These characteristics of the intrusive rock, the ores, and the wall rock suggest that the Paleozoic limestone, or country rock, was extensively recrystallized at the time of the monzonitic intrusion and was locally silicified and silicated by contact metamorphism. It does not follow, however, that the ores are of contact-metamorphic origin. On the contrary, their general character suggests that they originated at a later stage in the intrusive sequence and were formed by the replacement of limestone by sulphide ores, which were derived from hypogene aqueous ore-bearing solutions. The presence of garnet, pyroxene, and apatite in some of these ores, however, suggests that these, at least, were high-temperature hydrothermal deposits, but the duration of the mineralizing process is not known, and most of the ores may have been formed at considerably lower temperatures.

The presence of high-temperature minerals in the country rock and in some of the ores suggests that the quartz monzonite was intruded at a considerable depth below the surface; if so a great amount of erosion must have taken place since. However, at other localities in the Ruby-Kuskokwim region where monzonitic intrusives occur the structural, mineralogic, and geomorphic evidence all indicate that the Tertiary intrusives now visible at the surface were injected under a relatively thin cover of country rock and at some places broke through to the surface. The apparently considerable depth of intrusion of the monzonitic rocks in the Nixon Fork area

is a puzzling factor, because it seems impossible that so thick a cover of country rock could have been eroded since mid-Tertiary time. As the Tertiary age of these monzonitic rocks is well substantiated, it appears that this area affords an example of the occurrence of high-temperature minerals at relatively shallow depths. Such deposits have recently been discussed by Buddington,[25] who has proposed that they be called xenothermal deposits.

Eventually, however, and regardless of the thickness of the overlying cover, the surface of the land was lowered by erosion to a level at which these intrusives and the mineral deposits associated with them were brought into the zone of ground-water circulation. Then began the process of oxidation of the sulphide ores, which has continued to the present time, producing the carbonate ores that now exist. Limestone, however, is not a porous rock like sandstone, and underground water is not universally distributed throughout it; instead, the subsurface circulation tends to be restricted to fracture planes or solution channels. It is possible that some of the ore bodies were so effectually sealed in unfractured rock that they were not subjected to the action of underground waters and were only partly oxidized, whereas other ores, perhaps formed along old fault planes, lay directly in the channels of subsurface circulation and were completely oxidized. Such an interpretation would explain the present variable degree of oxidation of the ores.

One of the interesting but somewhat obscure problems connected with this mineralization is the variation in the fineness of gold at the several lode properties and the still greater variation of the lode gold as compared with the placer gold in the same area.

For the Mespelt property C. C. Mespelt kindly furnished 43 complete assay slips, showing not only the fineness but also the weight of bullion in each sample. With these data, which represent the entire production for this property in 1926–32, a weighted and therefore more precise mean value of the fineness of this gold was obtained. For the Whalen lode Livingston Wernecke furnished the weight of gold and silver in seven lots of bullion produced by the Treadwell-Yukon Co., Ltd., in 1922. These figures showed the ratio of gold to silver in the bullion but did not give the fineness; however, by assuming the same amount of dross as shown by Mr. Mespelt's data, 1.7 percent, the weights of gold and silver were recomputed into weights of bullion, and seven estimates of fineness were thus obtained. In examining these estimates the first two were observed to represent lower-grade gold, and these were assumed to have been taken from the Mespelt property; the other five, which represented about 73 percent of the production, were of distinctly

[25] Buddington, A. F., High-temperature mineral associations at shallow to moderate depths: Econ. Geology, vol. 30, no. 3, pp. 205–222, 1935.

higher grade and were assumed to represent gold taken from the Whalen lode. Both these values are weighted means. From the Southern Cross and Texas claims Winan & McGowan furnished a single assay, and from the placers of Ruby Creek Mr. Mespelt furnished a single assay. Of the placer gold from Hidden Creek 14 assays were contributed by F. E. Matthew (see also p. 194), but as the weight of each sample was not obtained only an unweighted mean could be computed. The data on the fineness of gold from the records furnished by all these operators are given below.

Fineness of lode gold from Nixon Fork district

Mespelt property

[Records of Mespelt Bros.]

	Gold	Silver
1926	0.776	0.202
	.775	.193
	.77925	.202
	.78075	.193
1927	.72950	.255
	.73175	.255
	.732	.249
	.732	.247
	.774	.185
	.73775	.225
	.734	.244
	.73975	.241
	.734	.245
	.73225	.246
1928	.73975	.244
	.73550	.249
	.745	.230
	.73225	.249
	.735	.246
1929	.770	.207
	.765	.206
	.757	.224
	.756	.221
1930	0.736	0.245
	.734	.246
	.749	.237
	.73950	.248
	.73350	.249
1931	.72450	.263
	.71525	.264
	.72075	.265
	.72050	.265
	.71975	.265
	.71925	.265
1932	.72750	.263
	.72275	.264
	.724	.265
	.72275	.256
	.72150	.266
	.74150	.253
	.73650	.258
	.74475	.205
	.778	.217
Weighted mean	.735	.247

Whalen lode

[Records of Treadwell Yukon Co., Ltd.]

	Gold	Silver
1922	0.8000	0.1750
	.8149	.1681
	.8110	.1720
	.8150	.1680
	.8111	.1719
Weighted mean	.812	.171

Mespelt property

[Records of Treadwell Yukon Co., Ltd.]

	Gold	Silver
1922	0.7457	0.2373
	.7346	.2484
Weighted mean	.740	.243

Southern Cross and Texas claims

1932	0.794	0.183

Fineness of placer gold from Nixon Fork district

Ruby Creek

	Gold	Silver
1929	0.808	0.107

Hidden Creek

	Gold	Silver
1925-32	0.928	0.59

These determinations of fineness have some significant implications. It will be observed that the gold from the Mespelt property is of lower grade than that from the Whalen lode or that from the Southern Cross and Texas claims. As the ores at the Mespelt property are not so thoroughly oxidized as those at the other two properties, the explanation is at once suggested that sulphuric acid derived from these sulphide ores has had a differential effect in dissolving silver from the ores during the process of oxidation. If this is true the highly oxidized ore of the Whalen lode should naturally have gold of higher grade than that at the Mespelt property. But the most remarkable difference is between the lode gold at the head of Ruby Creek and the placer gold of the adjacent Hidden Creek, the ratio of fineness being 735 to 928. Even if it is assumed that the Hidden Creek gold was derived from the more oxidized ores of the Whalen lode and from similar lodes at the head of Hidden Creek, the ratio of fineness is still 812 to 928. The reason for this great difference may be either that the gold at the apex of this lode system was originally of higher grade, or that the grade of the gold was increased by still more intensive oxidation in an environment of sulphurous solutions. With no definite evidence of an original difference in fineness and strong evidence of an increase of fineness due to oxidation, the second explanation seems more likely to be correct.

In the following descriptions of the three groups of properties the writer has been obliged to draw freely upon the published descriptions of Martin [26] and Brown,[27] as some of the lodes have now been worked out, and at others the shafts through which they were formerly reached are now abandoned or inaccessible.

MESPELT PROPERTY

The Mespelt property consists of 11 lode claims at the head of Ruby Creek. (See pl. 4.) The lodes on this property have been prospected and worked from five principal shafts of which records are available; these, named approximately in the order of their development, are the Crystal, Keen, Garnet, Recreation, and High Grade shafts. Three other shafts are known to have been sunk 50 to 100 yards south of the Recreation shaft, and numerous trenches and shallow pits have been dug for surface prospecting. The present site of operations is an inclined shaft about 100 yards up the hill slope from the Garnet shaft and about 200 yards above the High Grade shaft.

The Crystal shaft is near the head of Crystal Gulch, a headwater tributary of Ruby Creek. This shaft was begun in January 1919 and

[26] Martin, G. C., Gold lodes in the upper Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 722, pp. 149–161, 1922.

[27] Brown, J. S., The Nixon Fork country, Alaska: U. S. Geol. Survey Bull. 783, pp. 97–144, 1926.

was used as an operating shaft by Thomas Eakin during the winter of 1919–20 in producing several hundred tons of high-grade sulphide ore. The ore body here is of interest because it lies, according to Martin,[28] in the quartz monzonite not far from the limestone and because it is the only lode on this property where the ore was found in an essentially unoxidized condition. According to Martin's published description, the dimensions of the ore body were 10 by 20 by 65 feet. At one place at the bottom of the shaft a solid body of sulphide ore 6 feet in thickness was found. The ore is said to have consisted essentially of chalcopyrite, pyrite, and bornite in a gangue of calcite, siderite, and zeolites.

Although the principal output of the Treadwell Yukon Co. came from the Whalen lode, the company also did considerable work on the Pearson & Strand claims, now held by the Mespelt Bros. The principal site of the Treadwell Yukon Co.'s operations on the Mespelt property was at the Garnet shaft, which was sunk near the west end of the wagon road, at the head of Crystal Gulch. The Garnet shaft was examined by both Martin [29] and Brown [30] but is no longer accessible. According to their description the shaft was sunk to a depth of 270 feet, and a winze was sunk 40 feet deeper. The lower workings at this shaft were in the quartz monzonite and produced little ore. The best ore was found in limestone in the upper workings. Drifts were driven from the shaft, and a considerable quantity of ore was removed. The ore body appears to have been from 4 to 6 feet in width, but the high-grade ore was unevenly distributed in it. Much of the ore was thoroughly oxidized and consisted of chloritic material, iron ores, and quartz, with many thin films and small masses of malachite and azurite. As at the Recreation shaft, however, unoxidized cores of pyrite and chalcopyrite occurred in the ore, making a complete recovery of the gold by crushing and amalgamation impossible.

After the Treadwell Yukon Co. had ceased operations at this property and before the Mespelt Bros. had taken it over, Pearson & Strand, the original owners, sunk three shafts about 50 to 100 yards south of the Recreation shaft, and also did some drifting. Here a body of high-grade oxidized ore was found at or close to the surface. This ore consisted of auriferous copper carbonates and oxides, together with some secondary chalcocite. The gold was in the free state, and some of the ore is said to have had a value of hundreds of dollars to the ton, though the average value was probably between $50 and $100 a ton.

[28] Martin, G. C., op. cit., pp. 159–160.
[29] Idem, p. 160.
[30] Brown, J. S., op. cit., pp. 131–132.

The Keen shaft also was in the quartz monzonite, about 1,000 feet east of the western border of the quartz monzonite and along the wagon road. Little is known of the ore body at this shaft, but it is reported to have been a vein about 4 feet wide. The ore was evidently a sulphide ore, consisting of iron-stained quartz that contained pyrite and probably also arsenopyrite.

The Recreation shaft is north of the Garnet shaft and about 600 feet west of the margin of the quartz monzonite. This shaft was sunk to a depth of 100 feet. At the 50-foot level ore was followed in a drift for only 35 feet, although it was traced at the surface for 200 feet. The ore body in this drift had a thickness of 6 feet. Both the shaft and the drift were entirely in limestone, and the ore was mainly of the oxidized type. Microscopic examination of the ore showed that it consisted of iron oxides and hydroxides, quartz, chlorite (in part spherulitic), malachite, some azurite, and a little apatite. Some of the ore, however, showed unoxidized cores of chalcopyrite and bornite.

Much of the earlier work done by the Mespelt Bros. was in the High Grade shaft, which is about 100 yards down the hill slope from the Garnet shaft. Although mining was not in progress at this shaft at the time of the writer's visit, it was possible to descend and examine the old workings. The High Grade shaft is 150 feet deep and has 70-foot and 150-foot levels that go northeast and southwest from the shaft. There are two ore bodies striking about N. 25° E., one of which has an average dip of 65° SE. and the other an average of 40° NW. These ore bodies meet and coalesce at or near the surface but diverge downward. The southeastward-dipping ore body, however, cuts off the other one, suggesting a difference in their age. Both these ore bodies are irregular in strike and more so in dip. They are also variable in thickness, which in the southeastward-dipping ore body ranges from 2 to 11 feet, and in the northwestward-dipping ore body from 2 to 9 feet. Both these ore bodies are developed in the limestone, and, as elsewhere, the footwall and hanging wall are indefinite. A short distance below the 70-foot level these ore bodies end abruptly against an altered dike rock, and their continuation was not found in the 150-foot level below. The ores are partly oxidized, as at the Garnet and Recreation shafts, but are not so completely oxidized as on the Whalen property. About 3,000 tons of ore has been mined from the southeastward-dipping ore body, mostly from its lower part, and about 2,000 tons from the northwestward-dipping ore body, mostly from its upper part.

About 100 yards up the slope of the hill from the Garnet shaft the Mespelt Bros. are now sinking a new inclined working shaft, with 40- and 100-foot levels. The dip of the shaft is about 35°. At this place

there is a small apophysis or dike from the main body of quartz monzonite, and the ore lies along or near the contact between this igneous rock and the limestone. The ore body is ill defined but in general strikes N. 35°–65° E. and dips at all angles from zero to 90°, with an average dip about that of the inclined shaft—that is, about 35° NW. The ore body has no well-defined footwall or hanging wall, but the monzonitic apophysis or dike lies along or near the footwall side of the ore body. The ore has been found mainly in pockets and as short stretches of vein material. The higher-grade ore has the characteristic green copper stain, but some lower-grade ore, which has a value of $10 a ton or less, is merely iron-stained. This leaner ore was of little value up to 1933, as the operators could not handle at a profit ore that had a value of less than $12 to $15 a ton. With the present increased valuation of gold, however, this ore should be of workable grade.

The reduction plant at the Mespelt property consists of a 10-stamp mill and accessory equipment. The ore is dumped along the road above a little tunnel, whence it is loaded into small mine cars and trammed about 100 feet to the top of the mill building. It first goes to a grizzly and into a jaw crusher, where it is reduced to a 1½-inch size. It then goes to the stamps, and afterward over the first set of amalgamation plates. Leaving the plates, the ore then goes to a classifier, whence the fines are run off, and the coarser material is conveyed to a ball mill, in which a certain grade of country rock, quarried on the property, is used for balls. The pulp then goes to a second set of tables and finally to the waste. This waste is being ponded below the mill and is gradually accumulating in volume. It will probably be worked later by leaching or cyanidation, as the material contains the unoxidized sulphide ores, and some of it is said to have a value as high as $22 a ton (based on the old value of gold). The power plant consists of two 70-horsepower boilers and a 125-horsepower steam engine. A steam press is also used for pressing the excess mercury out of the amalgam, and the gold is retorted on the ground. The capacity of the mill, when adequate water is available, is 50 tons of ore in a 24-hour day, but little milling was done during the summer of 1933 on account of scarcity of water. Custom milling is also done for other properties in the vicinity. As the present working shaft is some distance from the mill, a separate Fairbanks-Morse gasoline engine is used for hoisting. This engine is geared up to accomplish the work required of it. Seven persons were engaged in working this mine.

McGOWAN-MESPELT PROPERTY

Several hundred feet northeast of the Mespelt property are two lode claims, the Southern Cross and Texas, which are owned jointly

by William D. McGowan and the Mespelt brothers. The lodes on this property are being worked by McGowan and Winan. The older work on these claims, principally on the Southern Cross claim, was done in the Garnet trench and the Twin shafts. Two later shafts, connected by underground workings, now constitute the site of operations on this property.

The Garnet trench was dug along the contact between the limestone and the quartz monzonite. The ore in this trench was notable because it consisted largely of garnet, with which were intergrown films and small masses of malachite and azurite. In thin section the accessory minerals augite, sericitized plagioclase feldspar, apatite, epidote, and chloritic minerals were also identified. This association of minerals relates the deposit to an early stage of the mineralization, when high temperatures were prevalent.

The Twin shafts were located near the center of the Southern Cross claim. From the description given by Martin, the ore was of the highly oxidized type and occurred along the contact of a fine-grained porphyritic dike, which projected into the limestone. The ore was said to be very soft and too much decomposed for petrographic study. A sample of the ore from the 50-foot shaft was assayed by the Treadwell Yukon Co., Ltd., and was found to have a value of $90 a ton. Ore taken along the contact with the porphyritic dike in a short drift at the bottom of the 20-foot shaft was found to assay $20 a ton.

The main shaft at the site of the present mining is about 320 feet northwest of the contact between the limestone and the quartz monzonite. The working shaft is driven on an incline of 26° and is 110 feet deep but 250 feet down the incline. Drifts go off at the 30-, 75-, and 100-foot levels, and a 25-foot winze has been sunk from the 100-foot level. The ore body in general strikes N. 70° E. and dips south at varying angles from 60° to 0°. In places, particularly in the lower workings, there is a hanging wall of intrusive rock, but higher in the mine some limestone intervenes between the ore body and the intrusive rock. Neither the hanging wall nor the footwall, however, is well defined, for the ore body fades out into the limestone country rock. In the upper workings the ore body has a thickness of 2 to 5 feet. One section of the ore shows 2 to 3 feet of coarsely crystalline calcite along the footwall, followed upward by about 6 inches of cupriferous ore, in turn followed by 2 feet of less cupriferous (and therefore brownish rather than greenish) ore, which extends to the hanging wall. At this place the less cupriferous ore is of higher grade than that which carries so much malachite and azurite. In the lower workings there is slickensiding and evidence of faulting, and the ore body pinches to a thickness of a few inches. Most of the ore has been taken from a zone between the 30- and 75-foot levels, and the best ore has come from the zone between 45 and 70 feet below the surface. This ore is obviously

of the well-oxidized type, in which a large part of the gold is free. The fineness of this gold, based on an assay made in 1932, is 793¾ parts of gold and 183 parts of silver in a thousand. The ore is milled at the Mespelt mill.

WHALEN LODE

The Whalen lode lies at the head of Holmes Gulch. This property is the site of a large part of the former output of the Treadwell Yukon Co., Ltd., but no work is now in progress, and the underground workings are inaccessible. The mine was examined both by Martin [31] and by Brown.[32] As the description by Brown is the more recent and is the only fairly complete information published regarding this property, it is quoted below:

> The Whalen mine is on a low knob at the head of Holmes Gulch, in an altered portion of the Paleozoic limestone or "blue lime." The limestone forms an irregular narrow tongue or possibly even an isolated "island", although the ridge to the west was not examined to determine this relation. The topography suggests that slate may intervene along the saddle between this limestone and the main front farther west.
>
> The altered limestone is less than 200 feet from exposures of fully crystalline quartz monzonite, and it seems likely that the porphyry border usually present around the monzonite has been cut out at the surface by faulting. In a prospect shaft 300 feet about N. 20° E. from the main shaft the contact is very clearly a fault between limestone and monzonite. The fault trends almost toward the shaft. Contrary to expectation, monzonite forms the hanging wall, as the fault dips about 80° SE. The drag also suggests that monzonite had dropped against limestone, possibly as the result of some later reversed movement along a previously normal fault by which limestone must have been dropped against monzonite, cutting out the porphyry border. * * *
>
> The shaft is inclined about 80° away from the monzonite contact. Down to the 100-foot level it penetrates altered limestone. A drift trending N. 15° E. also penetrates limestone for about 50 feet, where there is a fault contact with much altered porphyry, in which the drift extends 25 feet. This fault trends nearly east, and dips steeply. The opposite drift to the southwest is in limestone for 50 feet, as far as it was accessible. So also is a short crosscut to the south. Jointing, slickensiding, gouge, and brecciation show evidence of movement with intense shearing.
>
> Much of the altered limestone is a white or gray rock, recrystallized but not otherwise greatly modified. Mixed through this rock in irregular streaks or bands are masses of darker rock that is much more severely altered. This darker rock consists of typical contact-metamorphic silicates, such as zoisite, pyroxenes, garnet, and similar minerals, together with a great deal of fine-grained quartz, which replaces the original limestone. These masses in many places are closely associated with irregular knots and blebs of much modified intrusive matter, doubtless originally monzonitic.
>
> The ore occurred in irregular masses and ore shoots not confined to any definite vein or structure. It has been almost wholly oxidized to the bottom of the workings, but enough of primary ore remains to indicate that it con-

[31] Martin, G. C., Gold lodes in the upper Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 722, p. 160, 1922.

[32] Brown, J. S., The Nixon Fork country, Alaska: U. S. Geol. Survey Bull. 783, pp. 128–130, 1926.

sisted mainly of pyritic sulphides, especially pyrite and chalcopyrite, with free gold, the gold being the chief portion of value. The sulphides have altered to limonite, malachite, and black earthy oxides of copper, and the ratio of copper to iron is rather high. The circulating ground water which assisted in this oxidation has modified considerably the original distribution of the copper and carried it into shear zones where no ore was originally present. For this reason the gold does not follow strictly the distribution of the copper minerals, although in general the richest gold-bearing material corresponds to the material that has the higher content of copper. The amount of copper is small, probably not more than 1 or 2 percent for any considerable tonnage of ore.

The metals were irregularly distributed, but considerable good ore running $70 and more to the ton was extracted. Martin stated that in 1920 a crosscut on the 40-foot level showed 32 feet of ore, reported to average $68 a ton in gold. The clean-up ore being milled in 1924 was estimated by the operators to run about $56 a ton.

In addition to gold, the ore carried from 1 to 3 ounces of silver to the ton. The richest ore was restricted definitely to the upper part of the workings, above the 100-foot level, and was mined out above this level until the surface caved into a large "glory hole." One or two pockets of ore, smaller and not so rich, were found between the 100- and 200-foot levels but nothing of great value.

IDITAROD DISTRICT

No lode mining was in progress in the Iditarod district in 1933, but veins and other deposits carrying gold and ores of mercury, antimony, and arsenic have been noted by prospectors and placer miners at numerous localities, and some attempts have been made to mine such deposits. In the description of the placers of Otter Creek reference was made to a 3-foot vein of quartz and stibnite that occurs in bedrock on the Discovery bench and also to vein material of quartz and cinnabar found in the placers at the same locality. Similar veins occur farther up in Glen Gulch, and an attempt was made in 1922 to mine a deposit of this type at the head of Glen Gulch. A stamp mill was installed and considerable ore was mined, but the quantity of free gold was found insufficient to make the work profitable. It is reported that a stamp mill and mining machinery were shipped to Flat in the fall of 1934, by the Golden Horn Mining Co., which intended to reopen this property and begin mining in 1935. Although the character of this particular deposit is not known to the writer, most of the veins of this type are gold-bearing ores of quartz and stibnite, in which considerable cinnabar also occurs at some places. The ores are deposited in small veins or in systems of veinlets, either in the quartz monzonite close to its border or in the adjoining country rock. These veins and veinlets are essentially mineral fillings in cracks and fractures of the country rock, and one of their characteristics is their irregularity and discontinuity.

Another lode prospect is located on the north side of Otter Creek, about 100 yards below the mouth of Malamute Gulch. The workings are caved, but the strike of the vein appears to be about S. 25° W., which is in the direction of the lode at the head of Glen Gulch. No

data are available regarding the size of the vein, but the ore consists of arsenopyrite in quartz and calcite, and some of it is said to have carried considerable gold.

Many small veins of quartz, stibnite, and cinnabar have been found in this district, but none of them have so far been of sufficiently high grade or sufficiently continuous to be profitably mined. On the Upgrade claim, however, at the head of Flat Creek, many small stringers of gold quartz were exposed under the placers, and some of these were so decomposed from residual operation that they could be gouged out and sluiced. These little veinlets had a general east-west trend and besides free gold carried arsenopyrite and cinnabar.

Another lode property that may be included in the Iditarod district is a cinnabar mine, which was worked some years ago. This mine was on Montana Creek, a tributary of the upper Iditarod River, and was said to be 23 miles by trail from the Crooked Creek landing on the Kuskokwim River. The lode was discovered in 1919 and was opened in 1920 by the Fidelity-Kuskokwim Quicksilver Co., later the Thrift Mining Co. In 1924 the original 4-tube retort was discarded and a new 12-tube retort with a capacity of 5 tons of ore a day was installed. In 1925 this company was the largest producer of quicksilver in this region, but in later years its work was discontinued. According to various descriptions the lode occurred at a contact between sandstone and intrusive rock and consisted of a vein 3 feet 8 inches wide, though smaller veins occurred in the same vicinity.

Another cinnabar lode in the same general vicinity is the De-Coursay lode. This is said to be on or near the divide between the Iditarod River and Crooked Creek. It has been prospected recently, but no attempt has yet been made to work the deposit.

GEORGETOWN DISTRICT

The Georgetown district lies south of the divide between the Iditarod and Kuskokwim Rivers. Reference has already been made to the gold placers of Donlin and Julian Creeks, in this district, but the area is much better known as the site of lode deposits of cinnabar.

The principal cinnabar lode is at the Parks mine, on the north bank of the Kuskokwim River about 15 miles above Georgetown. (See pl. 6.) This property has not been visited by the writer but has been described by Smith and Maddren.[33] According to the published description, the country rock consists of sandstone and shale of Cretaceous age, intruded by dikes and small masses of granitic rocks and their fine-grained equivalents. The ores occur in brecciated

[33] Smith, P. S., and Maddren, A. G., Quicksilver deposits of the Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 622, pp. 272–291, 1915.

zones at or near the contacts between the country rock and the intrusives. Cinnabar and stibnite are the principal ore minerals; some narrow stringers of pyrite also occur, but not in close association with the other sulphides. Some quartz and ferruginous carbonates are usually mixed with the ore, but at places the sulphides are free of gangue minerals. This deposit of cinnabar was discovered in 1906 and has been worked intermittently to the present time.

COAL DEPOSITS

Deposits of coal occur in the Cretaceous rocks at many places in the Ruby-Kuskokwim region, and some attempts have been made to open small mines, but the demand for coal has been slight, and development work has not been justified.

In the Ruby district a prospect hole 9 or 10 miles from the head of Quartz Creek is said to have reached coal at a depth of 100 feet. On Swift Creek a layer of the gravel earlier worked showed a high percentage of carbonaceous material resembling detritus from a coal seam, and fragments of coal were found nearby. On Poorman Creek coal was found in a prospect hole at a depth of 50 feet below the surface. A crosscut from the foot of this shaft is said to have exposed a bed of coal with a dip of 70°. A small quantity of this coal was mined and used locally, mostly as blacksmith coal, but it did not prove entirely satisfactory for this purpose. It is a subbituminous coal, which ignites with difficulty but burns readily after ignition. Coal is also reported at several places in the basin of the Nowitna River.

In the Iditarod district coal outcrops have been reported from several localities. One deposit of coal was found along the old tramroad between Flat and Iditarod, about a quarter of a mile south of the crest of the ridge. According to Brooks,[34] this coal bed was reported to have a thickness of 15 to 30 inches, with a shale roof and a slate floor. The strike was said to be N. 60° E., and the dip 50° SE. A later description by Smith [35] states that the coal bed is 40 inches thick, with smooth slickensided walls, and a dip of 45° SW. Near the surface some slate was mixed with the coal, but at a depth of 50 feet the coal was almost free of slate. This deposit was developed about 20 years ago by a 40-foot vertical shaft, from the bottom of which an inclined shaft was driven along the seam. At another locality a short distance away another shaft was sunk to a depth of 30 feet. Here the coal was found to strike N. 38° E. and

[34] Brooks, A. H., The Alaskan mining industry in 1913: U. S. Geol. Survey Bull. 592, p. 72, 1914.

[35] Smith, P. S., Mineral resources of the Lake Clark-Iditarod region, Alaska: U. S. Geol. Survey Bull. 622, pp. 269–270, 1915.

dip 80° SE.[36] The section, as stated by the owners, was as follows: Shale (hanging wall); coaly shale, 10 inches; clean coal, 14 inches; shale (footwall).

A proximate analysis of the coal from the first shaft was made in 1913, and proximate and ultimate analyses of the coal from the second shaft were made in 1915. These analyses are as follows:

Analyses of coal from locality near Iditarod

Sample 1

[Analysis by A. C. Fieldner, U. S. Bureau of Mines, 1913]

	Air dried	As received	Moisture free	Moisture and ash free
Proximate analysis:				
Moisture	1.40	1.42	----------	----------
Volatile matter	6.60	6.60	6.70	7.23
Fixed carbon	84.75	84.73	85.95	92.77
Ash	72.5	7.25	7.35	----------
	100.00	100.00	100.00	100.00
Sulphur	1.10	1.10	1.12	1.21

Sample 2

[Analysis by A. C. Fieldner, U. S. Bureau of Mines, 1915]

	Air dried	As received	Moisture free	Moisture and ash free
Proximate analysis:				
Moisture	1.33	1.52	----------	----------
Volatile matter	7.70	7.69	7.81	8.24
Fixed carbon	85.77	85.60	86.92	91.76
Ash	5.20	5.19	5.27	----------
	100.00	100.00	100.00	100.00
Ultimate analysis:				
Hydrogen	3.37	3.38	3.26	3.44
Carbon	86.03	85.87	87.19	92.04
Nitrogen	1.56	1.56	1.58	1.67
Oxygen	3.05	3.21	1.90	2.01
Sulphur	.79	.79	.80	.84
Ash	5.20	5.19	5.27	----------
	100.00	100.00	100.00	100.00
Calorific value:				
Determined:				
Calories	7,958	7,943	8,063	8,513
British thermal units	14,324	14,297	14,517	15,323
Calculated:				
Calories	----------	7,983	----------	----------
British thermal units	----------	14,369	----------	----------

The analyses of the two samples agree remarkably well. They indicate that the coal at this locality is close to anthracite in composition, but that it has the physical features of a subbituminous lignitic variety. Its character is best explained as the result of accentuated local metamorphism.

[36] Mertie, J. B., Jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, p. 120, 1924.

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