MINERAL RESOURCES OF THE LAKE CLARK-IDITAROD REGION.

By Philip S. Smith.

INTRODUCTION.

The area described in this report has for convenience been called the Lake Clark-Iditarod region. It is roughly quadrilateral and is bounded on the southeast by Lake Clark and on the northwest by the town of Iditarod—that is, it extends from latitude 60° to 62° 30′ N. and from longitude 154° to 158° W. Plate X (p. 270) shows the relation of this area to the southwestern part of Alaska.

Different parts of this region have been examined with very different degrees of thoroughness. Thus the region around Iditarod was examined by Maddren in 1910 and by Eakin in 1912, and the region contiguous to Lake Clark by Martin and Katz in 1908, and reports by these different geologists have been prepared and published.[1] To the east the early surveys of Spurr[2] and Brooks[3] have afforded the most authoritative statements as to the geology and geography of the country. To the west the main source of information has been the report of Spurr, although in 1914 Maddren visited the region and is preparing a report of his observations.

The area lying between the settlement of Iditarod on the northwest and Lake Clark on the southeast is divisible into three parts, the section near Iditarod being the best known and most exploited, the part near Lake Clark being the next best known, and the part between these two places being practically unmapped except for Spurr's survey of Kuskokwim River, which transects the unexplored portion from east to west.

All the available information derived from different sources has been considered in preparing this report, but many of the observations on the mineral resources were made by the writer while

[1] Maddren, A. G., Gold placer mining developments in the Innoko-Iditarod region: U. S. Geol. Survey Bull. 480, pp. 236–270, 1911. Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, 138 pp., 1912. Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, 45 pp., 1914.

[2] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 43–268, 1900.

[3] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, 234 pp., 1911.

attached to a Geological Survey party that traversed the region in 1914. This party, consisting of 7 men, was in charge of R. H. Sargent, topographer, and its supplies and equipment were transported by a pack train of 20 horses. The party left Iliamna Bay June 7 and reached Iditarod September 9. As a result of this trip about 5,000 square miles of previously unsurveyed country was mapped, the positions of certain previously known features were determined with more precision, data were obtained concerning the geologic and physiographic character and history of the region, and scattered notes were made about the flora, fauna, climate, and population. In the present report, however, only the facts bearing on the mineral resources of the region are given in detail; the other facts will be set forth more completely in another publication which is now in preparation.

To the members of the Survey who have served with the writer in the field and in the office hearty acknowledgments are due. Special thanks are given to R. H. Sargent, in charge of the field expedition, for his unfailing assistance in furthering the geologic investigations. Obligation is acknowledged to the field members of the expedition, E. C. Carlberg, C. A. Anderson, J. D. Nelson, Olaf Holt, and Earl Kelso. In the microscopic examination of the rock specimens collected by this expedition the writer was aided by J. B. Mertie.

The few white people living in the region all courteously assisted the expedition with the help and information they possessed. This was especially true of Commissioner Thomas W. Hanmore and Messrs. W. S. Foss and A. Ruel, at Iliamna village; of Messrs. Hans Sieversen and Frank Brown, at Newhalen and Sixmile Lake; of Messrs. Fred Bishop and E. W. Parks, near Sleitmut, on the Kuskokwim; of Capt. Jung and crew of the steamboat used in crossing the Kuskokwim; and of the residents of Iditarod and the miners and prospectors on Flat and Otter creeks.

The natives employed at Iliamna Lake, at Sixmile Lake, and on the Kuskokwim worked faithfully and efficiently to promote the objects of the expedition and deserve appreciative thanks. The services rendered by Sakaren, chief of the Nondalton natives, and of Wasca, one of the Kuskokwim natives living near the mouth of the Holitna, are acknowledged with especial gratitude.

GEOGRAPHY.

The northeastward-trending highland of the Pacific mountain system is one of the most prominent features of southwestern Alaska. In the Lake Clark-Iditarod region the main axis of the Alaska Range does not extend beyond the north end of Lake Clark, and the axis of the Chigmit Mountain lies to the east of both Lake Clark and Iliamna

Lake. The region here described therefore lies west of this great physiographic province and is part of the central plateau region. In few places is the mountain province separated from the plateau province by a sharply defined line, but the two usually merge into each other through a foothill belt. Although not a high mountain mass the plateau province is characterized by greatly deformed rocks ranging in age from Paleozoic to Tertiary.

Many of the large streams head in the highland area and flow thence across the general structural trend until, at a greater or less distance from the high mountains, they collect to form the major rivers whose courses are more or less parallel with the axes of the mountain system. Certain other streams originate in the plateau province and swell the master streams of the region, but most of these streams are shorter and of smaller volume.

By far the most important stream of the region is the Kuskokwim, which receives several tributaries from the east that rise in the high mountains as well as many other side streams that head within the plateau province. The three other major basins, from south to north, are the basin drained by Lake Clark, Iliamna Lake, and Kvichak River, the Mulchatna-Nushagak river basin, and the Iditarod River basin, the water of which is ultimately tributary to the Yukon. The first two of these discharge into Bristol Bay and the third into Norton Sound.

These four main basins form definite, easily delimited areas that serve well for purposes of description, but they are not geomorphologic units, for each individual basin shows several physiographic subprovinces, and several of the subprovinces extend uninterruptedly from one basin to another. Thus each of the basins is made up of highlands and lowlands, the boundaries of some of which are not coincident with the boundaries of the different drainage basins.

Taken as a whole, the Lake Clark-Iditarod region is an area of moderate relief with scattered, irregularly distributed, rather small highland areas separated from one another by lowlands, some of which are of large size. The relative proportion of highland to lowland is probably approximately 2 to 1. East of the Lake Clark-Iditarod region this ratio probably increases, but toward the west it decreases, so that in places it may even be reversed. Here and there the main streams lie near the surface of the broad, widely open lowlands, but in other places they are hemmed in by steep slopes that rise to the rolling uplands through which they flow.

Trees and bushes are common in the valley bottoms, but on the slopes they decrease in size and number until at 500 to 1,000 feet above the streams they are absent and only grasses and mosses grow or their places are taken by bare rocky ledges. The larger trees are dominantly spruce. Some of the trees are more than 18 inches in diameter, but their average diameter in the better-timbered areas is probably about 1 foot. Feed for stock is not plentiful in the poorly drained areas; in fact, it is so scanty that it must be searched for. In the higher parts of the region it is most abundant near the upper limit of the trees.

Game is rather scarce throughout the region, though hard-beaten trails indicate that in the past many of the larger animals were abundant. Probably not more than a hundred people live in the region outside of the few mining camps. The bare, undistinctive hills, the low brown flats with lakes and marshes, and the small number of people or animals make the region as a whole appear desolate and unprepossessing.

GEOLOGY.

Between the west coast of Cook Inlet and Lake Clark rocks of different ages and complex structure have been intruded by a batholithic mass of granitic rocks of Mesozoic age. Northwest of Lake Clark the hard rocks are composed dominantly of Mesozoic sediments, which are considerably deformed and have been intruded at different times by igneous rocks that differ in composition and age. Some Paleozoic rocks also are exposed here and there in the area. Although all these rocks are exposed at different places in the region, the widespread unconsolidated water-laid deposits which mantle the lowlands and, as it were, submerge the lower hill slopes constitute the dominant geologic formation. The accompanying geologic map (Pl. X) shows the main stratigraphic units, but owing to its small scale the details have been omitted. For instance, the representation of the unconsolidated deposits has been generalized so much that the map does not show that practically every part of the region south of the Kuskokwim that was visited is more or less covered with these deposits. Even the hills that rise to elevations of 3,000 feet or more above the sea have in many places pebbles and waterworn gravels on their summits.

The Paleozoic rocks that were recognized by the expedition of 1914 consist entirely of limestones. These rocks are exposed south of Kuskokwim River and form a series of bare white hills, which make prominent landmarks. Similar limestones are reported to occur on the Holitna and on the Kuskokwim near McGrath. Other Paleozoic rocks north and west of Iditarod, mostly slates, cherts, and greenstones, have been reported.

The Mesozoic rocks are dominantly shales and sandstones, but in places, especially near the base of the section represented in this area, there is a great thickness of conglomerate. Fossils of Cretaceous age have been found in some of these rocks, and others of Jurassic age have been found in adjacent areas, in rocks correlated with certain rocks of the Lake Clark-Iditarod region. All the rocks have been folded, faulted, and considerably eroded.

Igneous rocks, both intrusive and effusive, are associated with or cut the Mesozoic sediments. The intrusive rocks are mainly of granitic composition and probably represent more than one epoch of intrusion. Thus the granitic batholith east of Lake Clark is regarded as of pre-Cretaceous age, whereas acidic intrusives cut the Cretaceous rocks near Iditarod and at many places in the Kuskokwim basin. The intrusive rocks, so far as seen, occupy few large areas in the Lake Clark-Iditarod region. Instead they occur usually in rather small stocks, or even more commonly in dikes.

The largest area of effusive igneous rocks is in the vicinity of Lake Clark, where porphyritic rocks, in general of andesitic composition and probably of Lower Jurassic age, are exposed. In this same region other lavas of Tertiary or Recent age, which still retain a glassy aspect and surface flow structure, overlie the older rocks. Tuffs and agglomerates are associated with lavas of both these types. They range in color from dark brown or nearly black to cream-white. Some of them are interlaminated with the Mesozoic sediments, and probably parts of these sedimentary rocks are composed of volcanic tuff which has been but slightly worked over by water.

The unconsolidated deposits of nonresidual material are composed mainly of fluviatile, glacial, and glaciofluviatile sands, gravels, and silts. The glaciofluviatile material mantles the whole region so deeply that it obscures in large measure the records of the early part of Quaternary time. A definite limit between the glacial and glaciofluviatile deposits can not everywhere be drawn, as the two types show all phases of intergradation. Some distinct moraines are recognizable at a number of places, but most of the moraines have been obliterated by the outwash deposits from a later stage in the retreat of the now vanished glaciers. The glaciofluviatile deposits merge, on the other hand, into typical stream deposits. The modern streams in the main are reworking the older deposits and in relatively few places are eroding only the hard rock of their valleys. The deposits, therefore, contain a large amount of material foreign to the drainage of the stream in which they occur.

The geologic structure of the region trends, in general, northeast, but this broad structure is complicated by minor deformations, and the unconsolidated deposits, none of which have been affected by it, in large measure obscure this trend. The general structure between Lake Clark and the Paleozoic limestones of the Stony River basin appears to be that of a somewhat faulted and deformed synclinorium, the limestones appearing to be on the southern flank of the accompanying anticlinorium. Whether another syncline succeeds the limestones on the northwest has not been determined. The abruptness with which the topography breaks off from the limestone hills to the Kuskokwim flats suggests that a fault of considerable magnitude may occur here. Whether or not this is the correct explanation of the structure, the fact remains that the country north of the limestones is so deeply covered with recent deposits that no valuable structural observations have been made within a distance of about 50 miles northwest of the limestones. North of this point as far as Iditarod the rocks are in rather open folds, whose axes trend about northeast. Beyond Iditarod Paleozoic rocks are again exposed, as if on the southern flank of another structural system possibly similar to that near the Paleozoic limestones already described.

To the deformation by which the Pacific mountain system was produced, the structural features of the Lake Clark-Iditarod region seem to be mainly due. This deformation was apparently greatest in the Alaska range, the Chigmit Mountains, and the Aleutian range. In places remote from this main axis the amount of deformation is less, so that the major structure appears to become more regular toward the west and northwest. In no place in this region, however, is the structure of the pre-Tertiary rocks simple, and as a rule the dips are more than 30°.

GENERAL ECONOMIC CONDITIONS.

WAGES AND SUPPLIES.

Few mines and prospects are being developed in the Lake Clark-Iditarod region except in the immediate neighborhood of Iditarod, and information about many of the factors that determine the success or failure of mining ventures is rather meager. It has seemed desirable, however, to discuss the prevailing general conditions, for, although these would undoubtedly change if mining should increase, they afford the only sure basis from which deductions as to the future economic conditions may safely be made.

Wages during the summer for miners at the small mines near Iditarod are $5 a day and board, but at some of the larger mines they are $4 a day and board. In the more remote districts the usual wages are $7.50 and board, the board being assumed by the operators to cost about $2.50. Practically no natives are employed in the producing mines, and probably they are too few ever to have a marked effect on the cost of labor. Along Kuskokwim River, however, the usual wages paid to a native are $2 a day and board. This is also about the price demanded for native labor on Iliamna and Clark lakes. Nearer to the settlements of whites, in the interior, the natives usually receive somewhat more. Owing, however, to the fact that most of the natives' wages are paid in trade, the actual cost is considerably less than if they were paid in cash.

During the winter, when shallow placer mining is prevented by snow and ice, fewer men are employed and consequently the over-supply of labor tends to lower the wages paid. If more employment were obtainable during the winter, owing to an increase in deep placer mining or through the development of lode mines, this difference between winter and summer wages would probably decrease, but the summer wage would probably go down rather than the winter wage go up. This conclusion seems warranted by the fact that many more persons would find permanent employment during the seven or eight winter months that the shallow placer mines are now closed and would not be compelled to support themselves for an entire year on the proceeds of their labors during the four or five months of the open season. It is therefore believed that the general tendency of wages in the future will be to decrease.

In an area so remote as much of the Lake Clark-Iditarod region supplies of all kinds are expensive. This is inevitable because of the long transportation all goods must undergo, the dangers of loss or damage to which they are subjected in transit, the short time available for bringing them in, the need of an exceptionally large reserve supply, the financial uncertainty as to the stability of the boom towns and the merchants who flock to newly organized camps, the high cost of wages and the attendant high overhead and construction charges, the various social and educational disadvantages inherent on life in a remote region, which justify a larger income from investments, and the many other real though less tangible hardships to which all frontier life is subjected. With the natural changes that follow the permanent settlement and development of the region many of the drawbacks become less or disappear, so that the general tendency will be for the cost of supplies to decrease. Already the cost of supplies has been lowered several hundred per cent in less than four years. As an instance, in 1910 oats and hay sold in Iditarod for over 20 cents a pound, but in 1914 they sold for 6 cents a pound. Even at present, however, in remote parts of the district high prices prevail, and 25 cents is the smallest unit used.

Although prices are high when judged by the standards of the eastern United States, the supplies carried are usually of good quality and of great variety. The stores seem to carry a much better assortment of supplies than stores serving a settlement of similar size in the States. This is due in large measure to the exceptionally generous scale on which most Alaskans live. In the matter of food, for instance, even the poorest prospectors usually have canned milk, butter, and other things that elsewhere may be regarded as luxuries. Possibly this demand for a liberal ration is caused by the severe cold and the long-continued darkness to which the Alaskan people are subjected in the winter.

TRANSPORTATION.

One of the important items entering into all mining calculations is that of transportation. Not only does it materially affect the cost of supplies, but it may even determine the feasibility of an enterprise. To appreciate the importance of transportation it should be realized that practically the only ice-free winter route from the States to this part of Alaska leads to one of the small bays on the west side of Cook Inlet. From that place the route to the interior lies across the general trend of the country, so that several ranges must be traversed. A route of this sort presents many difficulties which add to the cost and time of transportation.

The more natural highways by way of Kuskokwim and Yukon rivers are blocked by ice from October to June. Furthermore, both of these streams lie north of the winter limit of sea ice, so that they can not be reached by boats from the States for seven months of the year. Therefore, although the rivers offer a water grade for hauling supplies and are much used for this purpose, they are of much less value than they would be if at least parts of them could be reached during the whole year by boats from the outside world.

During the winter, transportation is effected mainly by dog teams or, on well-beaten trails, by horse-drawn sleds. Road houses are maintained at intervals along the main lines of travel and afford food and shelter for both persons and animals. The main winter trail from Iditarod to the sea used for the transportation of mail runs in general eastward to Takotna, thence to McGrath, thence up the Kuskokwim across the divide at Rainy Pass, thence southeastward in the basins of Skwentna and Yentna rivers to the crossing of the Susitna at Susitna, and thence to Knik, a distance of about 500 miles. From Knik the usual trail is followed to Seward, where all the year around connection by steamboat with the States is maintained. Other much-traveled trails lead from Iditarod to the Yukon and the Tanana. Many of these trails are staked and flagged by the Alaska Road Commission, so that they are recognizable even in severe storms, which are by no means infrequent.

In summer the main lines of transportation to the region from the States are by a sea trip to St. Michael and thence up Yukon River, or by the so-called "inside passage" to Skagway, thence by rail to Whitehorse, and thence down the Yukon. The coastwise steamships that call at the ports on the southern coast of Alaska afford a third means of approaching the area. However, this route presents the difficulty, already pointed out, that from the western shores of Cook Inlet no easy route of transportation into the interior has been developed. Small ocean-going vessels can ascend the Kuskokwim in summer as far as Bethel, but no regular trips are made by this route.

The two main summer lines of transportation within the region are by Yukon and Kuskokwim rivers. A fleet of shallow-draft river steamers, operated by the White Pass & Yukon Route, follows a more or less definite schedule on Yukon River. Smaller boats belonging to the same company run up Innoko and Iditarod rivers to Dikeman. Above that point still smaller boats, operated by other companies or individuals, complete the water trip to Iditarod. Several individuals and independent companies also run river boats on irregular schedules to the Yukon and Innoko river ports.

On the Kuskokwim shallow-draft river steamers or launches run up the river from Bethel as far as Takotna. These boats seldom make more than three or four round trips a season, and the amount of freight they carry is small.

The recent decision of the Government to build a railroad to develop parts of Alaska called attention to the possible routes from the southern coast into the interior. Among others the route from Iliamna Bay to Iditarod and Yukon River was considered by the Alaska Railroad Commission,[1] but while its value for local uses was recognized it was dismissed by the commission, as it "is too far to the southwest to permit its use as a trunk line into the interior." This route had been privately surveyed in part and the papers on it had been filed in Washington in the General Land Office. The route presents no very difficult engineering problems and would afford easy grades into the interior, but much of it would lie in a country holding, so far as known, little promise of much economic value in the near future.

During the summer transportation within the region is carried on mainly by boats on the rivers and by horses or back-packing on cross-country trips. A few wagon roads have been built, but most of them are so wet and muddy that only very light loads can be drawn on them. In striking contrast to the other roads is the one from Flat City up Flat Creek. This compares favorably with many roads in the States, and although it was expensive to build it shows that good roads can be made even under the adverse conditions which are met in this part of Alaska.

A tram road for horse-drawn cars running on wooden rails connects Iditarod and Flat. This tram road is in operation only during the summer and carries freight the 8 miles between the two towns for 2 to 3 cents a pound. It undoubtedly could be kept open in winter, but at that time of year transportation across country is much less difficult than in summer and the people are not otherwise engaged, so that they can profitably do their own freighting.

[1] Railway routes in Alaska: 62d Cong., 3d sess., H. Doc. 1346, p. 8, 1913.

POWER.

At present the only place where power is in much demand is in the vicinity of Iditarod. At that place power for various uses is produced mainly by the use of wood or mineral oils as fuel. Timber was at one time fairly abundant in that region, but with continued cutting the supply is becoming less easily available. At one of the larger mines about 5,000 cords of wood is used each year for producing motive power and for thawing the frozen ground containing the placer gold. The manager estimates that the wood delivered at the boilers costs from $15 to $18 a cord. The supply of wood in the vicinity of this power plant has become so small that a new location nearer the river has been selected, and the wood will be used to generate electric power, which can be cheaply and effectively transmitted to the places where it is to be used for mining. The wood for this plant is cut in the more remote valleys and floated downstream to the site of the power plant, where it is cut into cordwood lengths. At the new plant the wood should not cost much more than $6 to $8 a cord.

Not only is wood used at the larger mines, but it is also the main source of the power used on the larger boats. The wood for the steamers does not cost so much as that used at the mines, for it does not have to be transported so far. Consequently most of the wood for the boats is sold at about $6 to $7 a cord. Most of the small boats and launches use gasoline or distillate for fuel. This fuel is also used on one of the dredges and at some of the smaller mining properties. The cost of distillate in small lots at Iditarod in 1914 was $5 a case of 10 gallons.

No water powers with volume larger than a few sluice heads have been developed in the region. Almost no coal is used.

The few facts regarding power given above have been taken entirely from data obtained in the immediate vicinity of Iditarod. In order to use this information for other parts of the region the facts require modification to fit the local conditions of the area to which they are to be applied. As a rule the determination of the amount of modification required will depend in large measure on personal judgment, but help in reaching a decision may be afforded by consulting the map (Pl. X) showing the distance and the available routes to the project under consideration. Increased transportation facilities may be expected to decrease the cost of oil fuels that are shipped in from a distance, but probably they will only slightly affect the cost of wood for fuel, because the depletion of the supply will more than counteract the improvement in the means of transportation.

MINERAL RESOURCES.

KINDS AND DISTRIBUTION.

The mineral resources of the Lake Clark-Iditarod region outside of the immediate vicinity of Iditarod have been so slightly explored that those at present known probably are only a part of the resources that full examination of the area would disclose. In the following pages a description of the developed deposits will be given, and attention will be drawn to those places in the undeveloped areas where geologic conditions indicate that similar deposits may be sought with some assurance of success.

The principal developed metalliferous deposits of the region are those in which gold is the mineral of value. This is due not only to the widespread distribution of gold, but also in large measure to the ease with which it is obtained in a nearly pure state and the consequently small charges for elaborate machinery, refining, or transportation of nonmetallic material. The gold deposits that have been most extensively developed are the placers, none of the gold lodes having yet reached more than the prospect stage. This is probably due to the ease of recovering the gold from placers, rather than to the absence of lodes. Gold placers have been mined in the vicinity of Iditarod, on Otter Flat, Chicken, and Happy creeks, and other tributaries of Iditarod River; on the Takotna and some of its side streams which are in the Kuskokwim basin; in the valley of Crooked Creek, a tributary of the Kuskokwim just west of the area described in this report; on the Holitna; on Bonanza Creek and the bars in the Mulchatna basin; and on Caribou Creek and Keejik River, in the Lake Clark drainage basin.

The only gold lodes that are being prospected are northwest of Lake Clark and at Candle Creek, on the Takotna. Neither of these was visited by the Survey expedition of 1914, and the only information regarding them was gained from prospectors and from the local papers. Some gold is associated with the base metals in the other lodes of the region.

Quicksilver has been reported at several places in the basin of the Kuskokwim. It occurs both in lodes in the form of cinnabar, the sulphide of mercury, and in gravel deposits in the form both of cinnabar and of native mercury. The occurrence in the gravels does not appear to be of much importance commercially. A description of the quicksilver deposits is given in a separate article by the writer and A. G. Maddren in another part of this volume (pp. 272–291).

Other metals, such as copper, antimony, silver, lead, molybdenum, and manganese, have been found in or near the region, and some of the deposits have been more or less developed. Copper has been reported at several places, and deposits have been prospected near Iliamna Lake and in the vicinity of Lake Clark. It occurs combined with sulphur in the form of the mineral chalcopyrite.

Antimony occurs most commonly as the sulphide, stibnite. It has been found associated with the mercury ores on the Kuskokwim and in the Iditarod basin in the vicinity of the igneous contacts. None of the stibnite deposits have been developed.

Silver-bearing lead ore, or argentiferous galena, has been found and opened to some extent in the hills south of Iliamna Lake. This place lies outside of the area described in this report, but is so close to it that similar deposits may be found within the area.

Molybdenite, the sulphide of molybdenum, has been found in small quantities in deposits west of the north end of Lake Clark. This ore carries some gold, and it is mainly on account of that metal that the deposit is being prospected.

Deposits containing manganese have been found in the same region as the silver-bearing galena. The mineral is the black manganese oxide. The same mineral has been reported also in the basin of the Kuskokwim.

Coal has been found at a few places adjacent to the town of Iditarod, in the central part of the Holitna basin, and in the Kuskokwim Valley south of Bethel, outside of the region here described. Rocks which elsewhere in Alaska are coal bearing have a rather wide distribution in the Lake Clark-Iditarod region, so that investigation of unexplored parts may considerably increase the number of known coal exposures. No deposits of oil nor of gas have been reported in this region, though they occur on the west coast of Cook Inlet, north of Iliamna Bay.[1]

The water resources of the area have been developed only on a small scale locally to meet domestic and mining needs. Fuller settlement and development of the region will undoubtedly necessitate examination of the now undeveloped water resources.

Each of the mineral resources above mentioned will be described in some detail in the following pages, and the known facts of geologic significance about each will be given. The information is far from complete, but may be of service to prospectors, investors, and others contemplating mining work in the region.

GOLD DEPOSITS.

IDITAROD REGION.

The gold deposits of the Iditarod region have been studied in some detail by Maddren and Eakin, and although some of the more accessible deposits were seen by the writer, the observations of the other

[1] Martin, G. C., and Katz, F. J., op. cit., pp. 126–128.

geologists have been so recently published that restatement of the details here seems inadvisable. Inasmuch, however, as the only active mines are situated in the vicinity of Iditarod, a summary of the general features may be of service in indicating the conditions under which the gold occurs and so furnish clues as to conditions under which it is likely to be found in the unprospected parts of the region.

According to Eakin:[1]

> Twenty-nine claims, located on eight different creeks, were worked in the Iditarod district in 1912. Thirty-six plants were engaged in the work. Of these 1 was a dredge, 22 were equipped with steam machinery, and 13 used manual methods. A total of about 975 men were employed. The value of the total gold production of the district, including Moore Creek (a tributary of the Takotna), for the year 1912 was probably a little in excess of $3,500,000.

In 1914 an additional dredge was running part of the season, about 15 plants, employing 500 men, were in operation, and the gold production reached about $2,060,000; otherwise the conditions were similar to those prevailing in 1912.

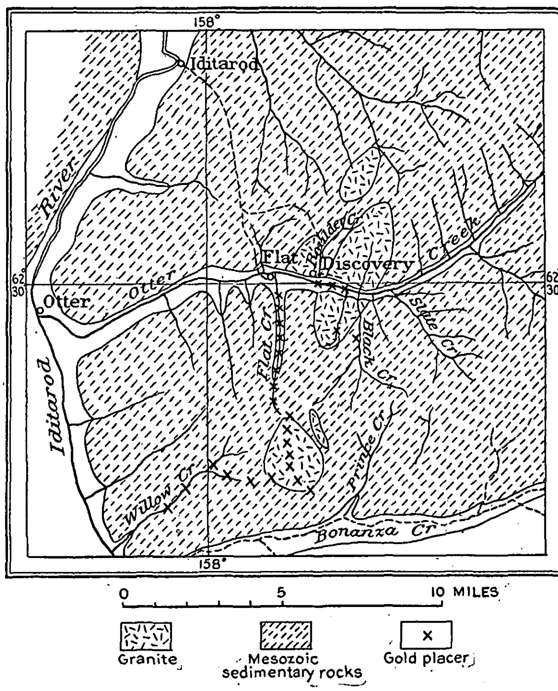

FIGURE 6.—Map showing distribution of placers and igneous rocks in the vicinity of Iditarod.

The gold comes entirely from placers, of which two distinct types are recognizable. In one the gold occurs in the stream gravels, forming typical creek placers; in the other it occurs associated with disintegrated but non water-sorted material, forming residual placers. Both types are areally associated closely with plutonic igneous rocks of granitic character. Figure 6, a copy of part of the geologic and economic map accompanying the report by Eakin,[2] shows the close relation between the distribution of the placers and that of the igneous rocks in the vicinity of Iditarod. No placers other than those shown on the figure are mapped by

[1] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pp. 35, 1914.
[2] Idem, pl. 3.

Eakin within 30 miles of Iditarod. This close relation is of the greatest importance in furnishing a clue to the places in near-by undeveloped areas where prospecting is justifiable.

Mining in the vicinity of Iditarod is carried on mainly by small plants. The general conditions do not differ materially from those encountered in placer mining in other parts of Alaska. Two dredges have been installed—one on Flat Creek and the other near Discovery claim, on Otter Creek—and are in successful operation. One of these is equipped with buckets having a capacity of 7 cubic feet. It is capable of handling over 4,000 cubic yards of gravel a day and has a working season of about 175 days. This dredge is operated by electricity, which is produced at a plant located near the mine. The ground mined is in general permanently frozen, so that it is artificially thawed before being dredged. Thawing is done by steam generated by the use of wood as fuel. The steam points are usually set only 8 feet apart, and more than 25 men are required for the thawing operations, which are therefore expensive. The depth that is dredged is seldom over 25 feet and the average is between 10 and 15 feet.

The success of this enterprise seems to be due to the high tenor of the gravel, owing to its derivation in large part from the near-by contact area, to adequate financial backing, and to efficient management. The efficiency of the management is shown not only in the actual handling of the dredging operations, but also in the thorough preliminary sampling of the ground, in the careful investigation of the incidental problems, such as the effectiveness and cost of thawing and in the close scrutiny of costs, so that wasteful or expensive practices are discovered and remedied.

The smaller plants, employing mainly hand labor, are confronted with many of the problems already noted. However, because the area of placer ground mined by them is less and the cost per unit is greater, the richer placers only are sought. The material usually mined, except in the residual placers,[a] is permanently frozen, so that the expense of thawing must be provided for. Most of the small mines have worked the shallower placers, and consequently are situated near the heads or on the slopes of the valleys. Under these conditions a considerable volume of water for sluicing or for mechanical purposes is obtainable only at high cost. The larger plants, employing powerful machinery, are able to work deeper placers and consequently are usually located in the valley bottoms, where the alluvium is deeper and the volume of the streams greater. However, the gradients of the valley floors are so low that a large supply of water at a considerable head is not obtainable except by ditches tapping the supply a long distance upstream from the mine. Some of the operators have tried to overcome this difficulty by pumping water from the larger tributary streams with gasoline engines, but this practice has usually been so costly that it has been abandoned.

KUSKOKWIM BASIN.

In the part of the Kuskokwim basin included within the Lake Clark-Iditarod region gold has been reported in the Takotna, George, Crooked, and Holitna basins, as well as at places on the main stream. In the Takotna basin the two places where gold has been found in commercial quantities are on Moore Creek, near the head of the main Takotna, and on Candle Creek, a small tributary of Tatalina River, which is the large southern affluent of Takotna River. The placers of Moore Creek have been mined for several years on a small scale. A stampede to this creek took place in 1910, but in 1912, according to Eakin,[1] only one claim was in operation. In 1914, so far as could be be learned, three mines were operated, employing about 13 men. Only pick-and-shovel methods were used in mining the shallow placers on this creek. A project was under way to bring in a gasoline-driven drill to test the deeper and more extensive deposits of Moore Creek, but no report has been obtained as to the success of the enterprise.

On Candle Creek auriferous placer ground was prospected during the winter of 1913–14 by means of a Keystone drill and by shafts, and good returns were reported. A mine equipped with steam bucket hoist was operating on this property in the summer of 1914. The depth of the deposit carrying the gold ranged from 10 feet near the head of the valley to 56 feet in the lower part. The gold near the head of the creek is reported by Maddren[2] to occur in residual granitic sands. The occurrence seems essentially identical with that of the residual deposits at the head of Flat Creek, in the Iditarod district, with stream placers extending downstream similar to those that occur on Flat Creek.

No mining has been in progress recently in the George River basin, but a rush of gold seekers invaded the headward part of this valley in 1910 and staked claims over much of the region. At that time Julian Creek was said to afford the best showing for placers, but in 1914 no one was permanently settled on the creek. This stream has not been visited by the Survey parties, but its geology is said to be similar to that of the placer areas already noted, in that the sedimentary rocks are cut by granitic intrusives.

An account of the placers on Crooked Creek is given elsewhere in this volume (pp. 351–353).

Gold has been found at a number of places on the Holitna, but the only definite report concerning that region has been given to the Survey by Mr. W. R. Buckman, a prospector who spent the winter of

[1] Eakin, H. M., op. cit., p. 35. [2] Maddren, A. G., oral communication.

1902–3 in the basin of that stream. He states that small amounts of gold were found in many parts of the basin. On bars in the lower part of this stream accumulations of black sand with minute particles of gold were found, especially a short distance above the place where the Holitna is joined by the Hoholitna. On the headwater branches colors of gold were found in the lower parts of all the streams, but nearer the mountains the number of colors decreased and the indications of placers were less promising. The lower parts of these streams were difficult to prospect, as the gravel was unfrozen and consequently the ground was very wet. The gravels are composed of a variety of different rocks, including granite, sandstone, greenstone, quartz, conglomerate, and a little limestone. No placers that could be profitably mined were found. Considering the immense size of the area to be investigated and the difficulties of prospecting, the negative results obtained by this prospector in the short time spent on the search do not prove that further investigations of the region will not disclose workable deposits.

Two different outfits of two men each started up the Holitna late in August, 1914, intending to spend the winter prospecting in the upper part of the basin.

The occurrence of gold on the main Kuskokwim was noted by Spurr[1] in 1898, and he seems to have recognized its mode of occurrence so accurately that his description, which follows, is entirely adequate to-day:

As soon as the Kuskokwim leaves the vicinity of the Tordrillo Mountains, however, and flows through the Tachatna series and the succeeding Cretaceous rocks it seems to be entirely without any gold in its gravels. An exception to this was at the mouth of the Chagavenapuk, where the gravels contain many colors of fine gold, but these gravels consisted of the characteristic dike rocks of the Terra Cotta Mountains, where the stream heads, and undoubtedly the gold together with the gravels had been brought from this source. In the region below Kolmakof, where siliceous dike rocks again cut through the mountains, it is reported by traders that gold occurs in small quantities.

The gold on the Kuskokwim, therefore, is * * * derived from the mineralized rock and the quartz veins which result from the action of ore-bearing solutions accompanying or following the intrusion of Eocene dikes.

MULCHATNA BASIN.

Gold has been reported from several parts of the Mulchatna basin. Spurr[2] states:

As early as 1890 three prospectors, Harry Mellish, Percy Walker, and Al. King, are said to have ascended the Mulchatna 200 miles, and there to have found gold, which, however, was too fine and flaky to save. A few prospectors have been wintering on the Mulchatna the past season (1898), but the result of their explorations is not yet known. From one of them, Mr. Murkle, who came back after a month or two, the writer learned that fine colors had been found on the Mulchatna, but none on the Swan.

[1] Spurr, J. E., op. cit., p. 250.

[2] Idem, p. 261.

In 1909 Katz[1] visited the Iliamna region and obtained the following notes on the gold deposits in the Mulchatna basin:

On the Mulchatna, from the Koktalee up, and on the Koktalee also fine flour gold is found on all the river bars. Bedrock has not yet been prospected along these larger streams on account of ground water. Only summer work has been attempted so far, and as yet no permanent ground frost has been encountered. It is claimed that after May 15 no thawing is required. Above the forks of the Mulchatna, particularly on the middle fork, the gold so far found is coarser, and there is said to be pay. Some of the smaller tributaries carry coarse gold. On one of them two men opened a hole in 1909 and took out about $8 worth of coarse gold.

The prospecting so far has been confined to the present stream beds. The pay is said to be practically all on bedrock, which is reported by the prospectors to be chiefly slate. Limestone and "porphyry" bedrock also are reported. The gravels prospected are generally from 4 to 12 feet deep; one hole is 16 feet deep.

In 1914 the only prospecting for gold in the Mulchatna basin is reported to have been on Bonanza Creek. This is apparently a small stream, heading in an isolated group of hills, flowing in its middle course in a steeply incised gorge and in its lower part in a rather wide gravel-floored lowland of the middle and northern forks of the Mulchatna. A small camp, consisting of about six persons, has been established. This place was not visited, but from what are believed to be reliable reports it was learned that a hole 65 feet deep had been recently sunk to bedrock and gold discovered. Granitic intrusive rocks, cutting the sandstone and shale country rock, were found in the hills south of this creek, and probably their contacts were the source from which the mineralization was derived. No information as to the value of the placers found has been received, and the lack of actual investigation of the region makes conjectures as to the probable value almost worthless. Nevertheless, the impression gained from the study of adjacent regions was that while workable placers may occur their distribution must be irregular, or, as the miners say, "spotted," and they must be rather closely limited to those areas which derive placer material mainly from the contact zones that surround the igneous intrusives.

LAKE CLARK-ILIAMNA LAKE BASIN.

According to Katz:[2]

The effort to discover placers on the drainage tributary to Lake Clark from the north has not met with encouraging results. Prospects have been found on Caribou Creek, a northeasterly tributary to Chulitna River; on Kellet Creek and Ingersol, Lincoln, and Franklin gulches, which are headwaters of

[1] Katz, F. J., Notes on the Mulchatna region: U. S. Geol. Survey Bull. 485, pp. 131–133, 1912.

[2] Martin, G. C., and Katz, F. J., op. cit., p. 126.

Kijik River; and on Portage Creek, which enters Lake Clark about 35 miles above the outlet of the lake and which heads against the last-mentioned streams. These streams were not visited by the Survey party, and little information about them was obtained. Two men are reported to have done considerable work on Portage Creek, which netted a few hundred dollars' worth of coarse gold. It was further reported that they found the alluvium to be about 12 feet deep and composed chiefly of large glacial bowlders.

When the region was visited in 1914 no claims other than those at the head of Lake Clark were being prospected, and operations on these consisted of little more than the annual work required by law. A quartz vein had rather recently been discovered on the upper part of Kijik River, about 10 miles northwest of the extreme head of Lake Clark. The lead is reported to cut granitic rocks and is probably a pegmatite vein. The gold content is reported to be sufficiently high to make mining profitable, but the great expense necessary for the opening of a property at this place will probably preclude active development in the near future. Associated with the quartz and gold in this vein are small, irregularly distributed crystals of molybdenite, the sulphide of molybdenum. This mineral is in platy bluish silvery flakes, the largest aggregates of which are about half an inch in diameter. The occurrence of the molybdenite and the presumable pegmatitic character of this gold-bearing vein point to the conclusion that the vein was formed at moderate to high temperatures.

POSSIBLE FUTURE AREAS.

From the foregoing account of the places where gold-bearing deposits have been reported certain general conclusions may be drawn. The most important of these is that auriferous mineralization is closely associated with the intrusion of granitic igneous rock. This conclusion does not mean that gold deposits will be found wherever these igneous rocks occur, for many other factors determine the places where ore bodies are formed. It does mean, however, that the contact areas near the igneous intrusives are the most promising areas in which to prospect for mineralization and possible ore bodies. The positions of all known areas of igneous rocks of this sort have been indicated on the map accompanying this report (Pl. X). Much of the area, however, is still unsurveyed, and probably these rocks occur at other places. From the mode of occurrence at the known localities the occurrence of the igneous rocks that may be found in the unsurveyed areas is probably essentially similar—that is, these rocks have an irregular distribution and a rather small areal extent.

Judged from the facts now known, a great part of the mineralization is disseminated throughout the country rock near the contacts with the igneous rocks. Although in a region of disseminated mineralization the search for lodes may not be successful, the search for placers may be rewarded. The same general laws apply to prospecting for placers, however, as to the search for lodes, but certain other features must also be considered. The drainage must be so arranged that a considerable amount of the mineralized contact zone is traversed by the stream on which placer ground is sought, the concentration must have been effective, and the placer accumulation once formed must not have been subjected to any destructive erosional activity, such as glaciation, which has removed it.

In some parts of the region, notably in the basins of Kuskokwim and Mulchatna rivers and in the area draining into Lake Clark, the heavy outwash deposits from the former glaciers have mantled over the low parts of the region so deeply that whatever placer accumulations may have been formed before the glaciation are now in large measure concealed. Under these conditions prospecting is difficult, for it requires an understanding of the general geologic and physiographic history of the region in order to select the best places to examine in detail, and in addition requires an outfit suitable for prospecting the buried deposits. Upstream from the outwash deposits the streams are usually eroding bedrock or earlier stream deposits, and small placers are likely to be found. In many of these places, however, the streams are cutting down their courses and eroding the hard rock. This work has been in progress for so relatively short a time and the rocks attacked have weathered so slightly that the concentration of the valuable heavy mineral usually has not resulted in rich accumulations. Where the streams are cutting down in former stream deposits containing possible gold accumulations the renewed erosion may possibly effect additional concentration into very rich placers. In most places of this sort, however, the courses of the earlier and the present stream would not coincide in all parts and as the rich concentrations would be more or less limited to the places where they did coincide the distribution would be decidedly irregular. The prospector might, therefore, find rich spots here and there along the stream, whereas the surrounding area would not be rich enough to warrant mining.

Furthermore, the probable irregular distribution and rather small extent of the mineralized areas would not lead one to expect, from present indications, a widespread distribution of placers such as is common in areas like Seward Peninsula and the Fairbanks district, where colors of gold may be found on almost every stream or in every deposit of the unconsolidated rocks.

To summarize, the present conditions indicate that placers may occur in parts of the region traversed by the Survey party of 1914, but probably they are not widespread or regular in their distribution.

They may hold out promise of adequate returns to the observant and skilled prospector, but for others they will be difficult to find and costly to operate. So far as has been seen the chance of finding gold lodes that can be worked at a profit in the near future does not seem encouraging.

COPPER DEPOSITS.

Copper-bearing deposits have been developed only in the adjacent Iliamna-Lake Clark region. These have been described by Katz[1] as follows:

> The copper deposits of this region may be referred to two classes: (1) Chalcopyrite deposits in limestone—(*a*) associated with minerals of contact-metamorphic origin and (*b*) without evidence of contact-metamorphic origin; (2) chalcopyrite in quartz veins in greenstone and in granite.
>
> Only the deposits in the limestone have as yet developed any prospective value. These are known at four localities—2 miles west of the head of Iliamna Bay; 9⅔ miles west-northwest of the head of Cottonwood Bay; on Kasna Creek near Kontrashibuna Lake; and at Millet's, on Iliamna Lake 22 miles west of Iliamna village. At each of these localities the mineralization is in limestone near its contact with an igneous formation. At the last-mentioned place the contact is not exposed and there is no evidence as to its nature. At the other localities there are diorites or diabases intrusive into the limestone. The limestones are metamorphosed by coarse recrystallization of the calcite and the development of garnet, epidote, magnetite, hematite, and quartz, besides the sulphides pyrite and chalcopyrite. These developments in general are close to and parallel with the igneous contacts, but from place to place along these contacts they vary considerably in mineral association, in shape, and in size. They are irregular and nonpersistent. In all their features—their geologic position, mineralogy, and outline—they have the characteristics of contact-metamorphic deposits.

From what is now known of the general geology of the Lake Clark-Iditarod region few places seem to hold promise of containing deposits of copper-bearing minerals similar to those of the area just described. The general statements that have already been made concerning the probability of finding gold lodes apply also to the copper lodes. In addition, however, the lower value of copper and the greater cost of producing it in a refined state make a copper property probably much more expensive to develop than a deposit of free gold.

ANTIMONY DEPOSITS.

Stibnite, the sulphide of antimony, has been found at several places in the Lake Clark-Iditarod region, notably at Parks mercury prospect and in the divide near the head of Glen Gulch. The occurrence of the antimony ore at the mercury prospect is described somewhat fully elsewhere (pp. 278–280), so that further description here is unnecessary.

[1] Martin, G. C., and Katz, F. J., op. cit., pp. 116–117.

The occurrence of stibnite near the head of Glen Gulch has been examined by Maddren,[1] from whom the following facts were obtained. Stibnite occurs mainly in the larger quartz veins and near the contact of the granites and the sandstone and shale succession of rocks. One of these shattered contact zones at the head of Glen Gulch was prospected by means of open cuts, but the stibnite was found to be so irregularly distributed that the deposit could not be profitably worked under the existing conditions. This prospecting was not intended primarily to develop a lode valuable for its content of antimony, but rather one valuable for its content of gold.

Particles of stibnite are found in the concentrates from many of the placer claims and have doubtless been derived from the same source as the gold. The placers at the head of Flat Creek afford perhaps the best illustration of this condition.

The conclusion that the stibnite mineralization is closely associated with the intrusion of deep-seated igneous rocks of the granite family is indicated by the foregoing facts. The low price of antimony and the high cost of production make the probable commercial development of deposits of this metal in the near future in this region extremely doubtful. Inasmuch, however, as the antimony ore also carries some gold, possibly in some places the gold tenor may be great enough to warrant exploitation of the auriferous stibnite lodes.

SILVER-LEAD DEPOSITS.

No silver-lead deposits have been found in the Lake-Clark-Iditarod region, but in the Iliamna region, to the south, one deposit has been reported. This deposit was described by Katz and the following notes[2] are abstracted from his published report:

Silver prospects have been found in the limestone belt which extends southwestward from Iliamna village. The silver claims aggregate about 2 miles in length. However, but one group of eight claims has been developed sufficiently to make investigation possible. The only silver minerals disclosed are argentiferous galena (the sulphide of lead) and argentiferous sphalerite (the sulphide of zinc), which are also manganiferous and which occur in veins. In addition to these minerals manganiferous limonite and lead-bearing ocher, small amounts of smithsonite (zinc carbonate), and selenite (lime sulphate) are present in weathered parts of the veins. Pyrite is only locally and sparingly developed. Calcite and quartz, in veins that have been crushed, are found near the metalliferous veins but do not occur as gangue minerals in them. The limestone has been cut nearly at right angles to its strike by many small vertical dikes. Several larger dikes

[1] Maddren, A. G., oral communication.

[2] Martin, G. C., and Katz, F. J., op. cit., pp. 124–125.

and irregular masses were also observed, most of which are parallel to the strike of the limestone. The ore bodies appear to have been formed along fissures in the limestones. The fracture zones seem to be vertical. Along these the limestone is brecciated, and some pieces are slickensided. To judge from the material collected, the galena, sphalerite, and small amounts of pyrite filled the fractures. To some extent also the limestone is impregnated with these sulphides.

No production has been made from this property, but the owners report that samples have yielded from 80 to 196 ounces of silver and as much as $20 in gold to the ton, 35 to 50 per cent of lead, and 15 to 20 per cent of zinc. The black manganiferous gossan, they report, carries 2 to 6 ounces of silver to the ton.

MOLYBDENUM.

The only known occurrence of mineral containing molybdenum in the region is on Kijik River about 10 miles northwest of the extreme north end of Lake Clark. Little is known about the geologic conditions at this place. Apparently the molybdenum occurs as molybdenite in scattered flakes, in what is presumably a pegmatite vein closely associated with granitic intrusive rocks. So far as learned the molybdenite is not sufficient in amount to have commercial value on its own account, but the fact that the vein is said to carry some gold may make development of the property possible.

MANGANESE.

Manganese, as has already been noted (p. 267), occurs in the silver-bearing lead deposits south of Iliamna village. At that place it has not been utilized and apparently has no commercial value.

Dall[1] states that "black oxide of manganese has been received from the Kuskokwim." He gives no further notes concerning the locality from which the specimen was obtained nor concerning the mode of occurrence.

COAL RESOURCES.

In many parts of Alaska the Cretaceous rocks, which in general are similar to the bedrock of a large part of the country north of Kuskokwim River, are coal bearing. So far, however, no workable coal deposits have been found in the basin of the Kuskokwim within the area here called the Lake Clark-Iditarod region. At a few places on the hills east of Iditarod, however, coal crops out, and attempts to mine it have been made. Coal has also been reported on Big River and on the Holitna. Probably by more extensive exploitation other coal deposits will be found, but from what is now known of the coals

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[1] Dall, W. H., Alaska and its resources, p. 478, 1870.

of this geologic horizon, although they may be of economic value in a region of scanty fuel, they are not as a rule of sufficient value to allow their being transported far, and they can not be cheaply mined.

The coal deposit on which most development work has been done is situated on the tram road from Iditarod to Flat, about a quarter of a mile south of the crest of the divide between Otter Creek and Iditarod River. At the time of the writer's visit the property was lying idle and the excavations had filled with water. The following notes were obtained from Mr. W. W. Acheson, of Iditarod, who was familiar with the mine when it was in operation. The bed of coal which was exposed at the surface dips about 45° southwest. It is about 40 inches thick, and its walls are very smooth and in places slickensided. Near the surface considerable slate was mixed with the coal, but lower down the slate decreased in amount, so that at a depth of 50 feet it was almost entirely absent. This prospect had been developed by a 40-foot vertical shaft, from the bottom of which a 20-foot incline on the coal bed had been driven.

The coal on the dump appears to slack badly and when mined is intersected by numerous veins of ice. Many of the small pieces of coal on the dump have polished and slickensided surfaces. It has been used locally as fuel in the road house near by and also in a blacksmith's forge, but was not very satisfactory for the latter use.

The character and fuel value of the coal are not definitely known, for the information from the different sources was not in accord. A sample said to have been taken from this property, received from Charles Estmere, of Iditarod, according to Brooks[1] was analyzed by A. C. Fieldner, chemist of the Bureau of Mines, with the following results:

Analysis of coal from locality near Iditarod.

[Air-drying loss, 0.0]

	Air-dried.	As received.	Moisture free.	Moisture and ash free.
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	7.25	7.25	7.35	....
	100.00	100.00	100.00	100.00
Sulphur	1.10	1.10	1.12	1.21

Mr. Fieldner adds the following statement: "This analysis indicates that the coal is anthracite. The sample received was chiefly

[1] Brooks, A. H., The Alaskan mining industry in 1913: U. S. Geol. Survey Bull. 592, pp. 72–73, 1914.

slack, and the data at hand indicate that the coal bed is crushed. It is doubtful whether this coal could be utilized without briquetting."

A somewhat different statement as to the character of the coal was given by Mr. Acheson, who says that the material ignites rather easily and has the physical features of lignite. Perhaps these two discordant views can be reconciled by assuming the coal to be normally a lignite or subbituminous coal, similar to the other known Cretaceous coals, and that it has been metamorphosed locally into an anthracite through the deformation and shearing to which it has been subjected.

Coal has also been reported from several other places in this same neighborhood. An exposure of coal is said to have been found on the Iditarod side of the Iditarod-Flat divide, at a point about a mile northwest of the locality previously noted. No mining has been done at this place, and the character and extent of the coal have not been determined.

Northeast of the locality last mentioned are other coal croppings that have been slightly exploited. No work was in progress at that place, and the old pits were not visited. Some coal has been taken out, however, and it is said to have been used in Iditarod with satisfactory results, though probably at most not more than a few hundred pounds has been so used.

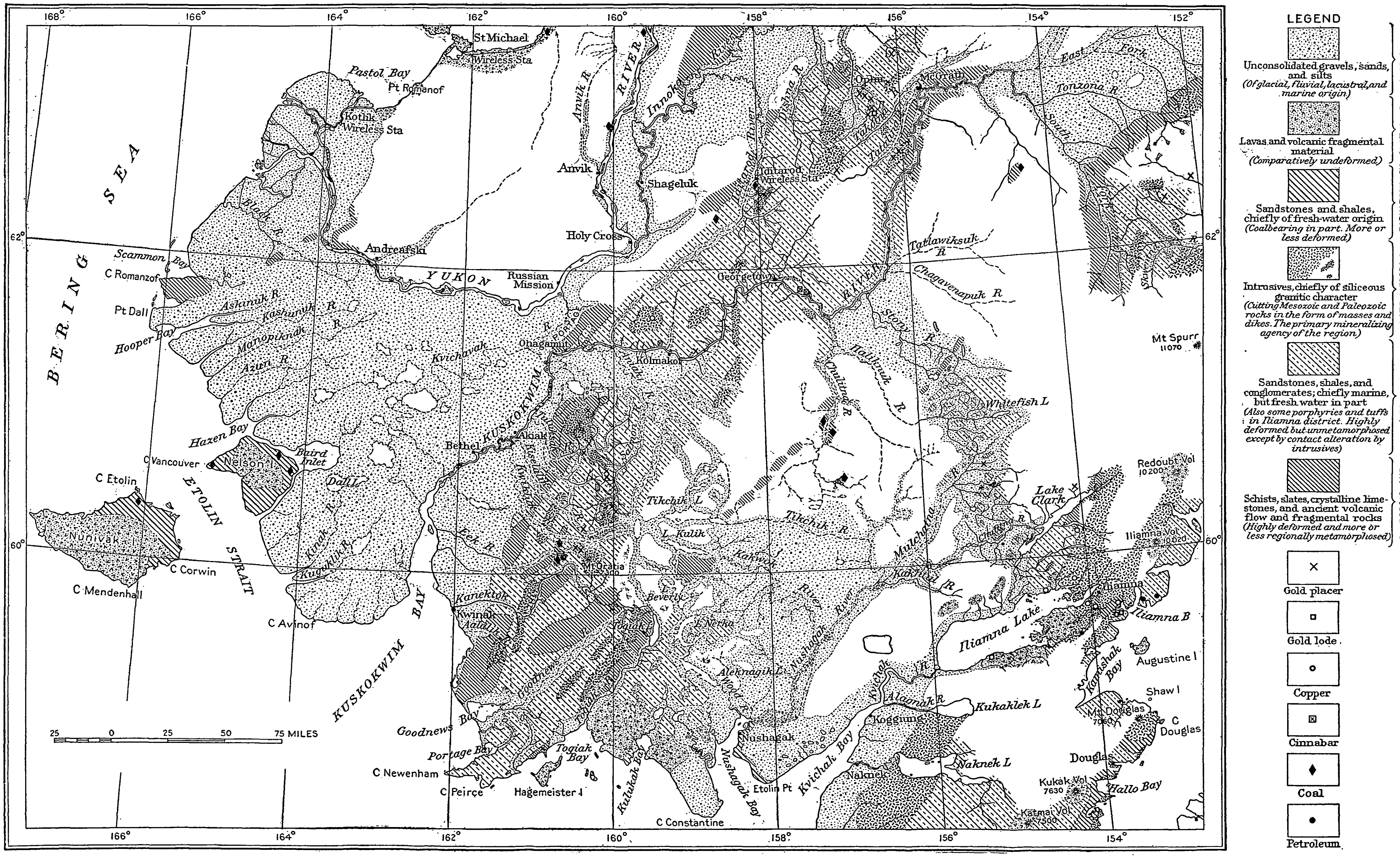
Coal-bearing rocks have been reported to crop out on the Holitna at two places. One of these is about midway between the mouth and the head of that river, and the other is some distance farther upstream. The deposits have not been carefully investigated, but the discoverer of them says:[1] "The coal indications on the Holiknuk [Holitna] are not extensive enough to permit the assertion that they will in time be of commercial importance."

Coal deposits have also been reported to occur on the western flanks of the Teocalli Mountains, on the eastern slopes of the basin of Big River, which is a tributary of the Kuskokwim lying outside of the area described in this report, but no details as to their extent or character have been published.

WATER RESOURCES.

As yet almost none of the available water powers of the Lake Clark-Iditarod region have been put to use. In large measure this neglect is due to the small demand for power, except in the mining camps, for the Iliamna-Lake Clark region contains probably some of the best water powers in Alaska. The future use of the now undeveloped water powers depends on their availability, which in turn

[1] Buckman, W. L., unpublished letter.



SKETCH MAP OF KUSKOKWIM REGION, SHOWING GEOLOGY AND MINERAL RESOURCES.

depends on the purposes for which they are to be employed and their cost relative to other sources of power. So many factors interact in relation to this matter and interact in so complex a manner that their evaluation can be effected only by analyzing a specific problem.

The general areas where mineral deposits may be sought with some assurance of success, as has already been pointed out, are those where intrusive masses cut the country rock and have brought in mineralizing solutions. Areas of this sort are scattered here and there throughout the Lake Clark-Iditarod region, but most of them are of small size and the harder igneous rocks form the higher parts of the upland. Consequently the mineralized areas in most places are drained by small headwater streams, which in their upper parts have exceedingly steep gradients and little volume. Under these conditions a water supply adequate for large-scale mining usually can not be found close at hand. In many places probably small mining plants can acquire sufficient water by building short ditch lines, but many of them will undoubtedly experience the same difficulty as has been felt by those situated in the mineralized area at the head of Flat Creek, where, when rain is not falling, the water supply is inadequate. Recourse to long ditch lines, such as have been built in Seward Peninsula to overcome the difficulties of a region topographically similar, may, of course, be feasible. Long ditch lines, however, are expensive, and their construction should not be advocated until their lines have been carefully surveyed, the volume of the supply they tap accurately determined, their installation critically investigated, and the mineral deposit to which they are planned to bring water proved to contain sufficient valuable minerals to defray their cost.

For agriculture the water supply would seem to be sufficient, even if a considerable part of the country should ultimately prove to be adapted to cultivation. In fact, one of the problems would probably be to drain the area rather than to bring additional water to it.

No hot or thermal springs have been reported to occur in the region, and the general geologic conditions indicate that they are not likely to be found except under special conditions.

QUICKSILVER DEPOSITS OF THE KUSKOKWIM REGION.

By PHILIP S. SMITH and A. G. MADDREN.

INTRODUCTION.

The central Kuskokwim region is the only portion of Alaska where up to the present time lode prospects of quicksilver that have attracted serious attention have been discovered. Minerals carrying this metal, however, have been noted in the gold-bearing gravels of several placer-mining districts of Alaska. For example, mercury minerals have been found in the concentrates of sluice boxes from placer claims in Seward Peninsula on Daniel, Iron, and Ophir creeks; in the Iditarod district on Happy, Black, and Glen gulches; and in the Yukon-Tanana region on Seventymile Creek. In none of these places, however, have commercial amounts of these minerals been discovered.

At two localities on the Kuskokwim considerable interest has been shown recently in lode prospects of quicksilver. One of these, the Parks prospect, is in the central part of the Kuskokwim basin, and the other is near Kolmakof, about 100 miles downstream from the Parks prospect. (See Pl. X.) The observations at the Parks prospect were made by Philip S. Smith, and those at the prospect near Kolmakof were made by A. G. Maddren.

The investigations of the quicksilver deposits were made in the course of general surveys of the Kuskokwim and adjacent regions in the summer of 1914. Descriptions of the results of these general surveys are printed elsewhere in this volume[1] or are in preparation, and should be consulted by those desiring information concerning the broader features of the geology and geography of the part of Alaska in which the quicksilver deposits occur.

HISTORICAL SKETCH.

Possibly the earliest published reference to the occurrence of quicksilver in Alaska was made by Dall,[2] who stated: "Mercury, in the form of cinnabar, exists in the Cretaceous strata of the Alex-

[1] Smith, P. S., Mineral resources of the Lake Clark-Iditarod region, pp. 247–271. Maddren, A. G., Gold placers of the lower Kuskokwim, with a note on copper in the Russian Mountains, pp. 292–360.

[2] Dall, W. H., Alaska and its resources, p. 477, 1870.

ander Archipelago. The locality is unknown, but fine specimens were in the possession of the Russians." So far as now known, however, cinnabar has never been found in any part of southeastern Alaska. The locality from which the quicksilver specimens came was therefore stated incorrectly to Dall by the Russians (presumably at Sitka), possibly because they did not wish to arouse in the newcomers interest in the remote part of the Territory. Apparently the Russians were disinclined to impart accurate information, for some of the United States officials who visited Sitka about the time of the transfer of the Territory to the United States reported that the Russians furnished very vague and indefinite data concerning the source of mineral specimens in their possession and the location of reported mineral deposits.

Petrof[1] appears to have first recorded the occurrence of quicksilver in Alaska in a region where its presence has been authenticated. He states that in the Kuskokwim region are—

well-defined veins of cinnabar, antimony, and silver-bearing quartz. * * * Cinnabar has also been discovered on the Kuskokwim, and assays made of the ore in San Francisco indicate a very valuable discovery there. * * * The mountains eastward of the Rédoute Kalmakovsky are high, heavily timbered around the base, and give ample evidence of the presence of mineral deposits, veins of quartz, cinnabar, and other ores being easily traced wherever the slopes and bluffs are exposed to view.

Ten years later, in the report of the Eleventh Census,[2] the following general statement, which contains little new information, was made concerning the occurrence of cinnabar in Kuskokwim Valley:

Veins of cinnabar crop out at various points along the river, but though they are known to contain a large percentage of mercury, their remoteness from shipping has thus far prevented their thorough examination or development.

Spurr,[3] who visited the region in 1898, reports as follows:

About 5 miles below Kolmakof, in a cliff on the right side of the river, a trader, Mr. Lind, found, several years ago, a vein of cinnabar, or ore of mercury, which has been mentioned in numerous reports of Alaskan governors and other publications. The vein occurs in a locality where the stratified shales of the Kolmakof [Upper Cretaceous] series are cut by frequent dikes of siliceous yellow-weathering rock. According to Mr. Lind, the vein is an impregnation of the arkose and other sedimentary beds with red cinnabar, the mineralized rock taking the form of a vertical zone a foot or two wide, often irregular and pinching out. Mr. Lind spent about $2,000 in mining some of the ore and getting it to the States, but on account of the small quantity and the low price of mercury, he lost on the venture.

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[1] Petrof, Ivan, Report on the population, industries, and resources of Alaska, pp. 13, 77, 90, 1884.

[2] Report on the mineral industries of the United States at the Eleventh Census, 1890, p. 106.

[3] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 261, 1900.

The references to cinnabar in the reports of Alaskan governors[1] noted above by Spurr are simply brief repetitions of the general information published in the census reports of 1880 and 1890, already quoted.

Spurr does not appear to have observed the outcrop or excavations from which the ore shipped by Mr. Lind was taken, although he notes the sedimentary rocks and describes a dike which is only about 200 feet downstream from the prospect. Apparently in 1898 artificial excavations along the bluffs were not large enough to attract attention to the spot where the cinnabar occurs, so that Spurr learned of the deposit only after arriving at Bethel, about a week later. At this place he seems to have met Mr. Lind and to have been informed by him of the facts quoted above. Spurr's failure to see the excavations is not surprising, however, for in 1914, even with the aid of persons familiar with the locality, Mr. Maddren found the indications of cinnabar obscure, in spite of the fact that further work is reported to have been done on this prospect within the last ten years.

DESCRIPTIONS OF PROSPECTS.

PARKS PROSPECT.

LOCATION AND DEVELOPMENTS.

The only place where any considerable amount of development work has been done on quicksilver lodes is at the Parks prospect, on the north bank of the Kuskokwim, about 15 miles above Georgetown by river, or about 330 miles above the mouth of the Kuskokwim. It is readily accessible, for the main workings are situated not more than 100 feet from the river and about 15 feet above it.

Quicksilver ore was discovered at this place about eight years ago (1906), and development work has been done on a small scale ever since. At no time, however, have more than two or three men been employed on the property, and this small force, with insufficient funds, has succeeded in opening the deposit only slightly. A small portable retort has been used in reducing the ore, and by means of it about 700 pounds of quicksilver has been produced. This has been sold to the placer miners in Seward Peninsula and in the vicinity of the prospect. By the crude process employed only about 4 pounds of ore can be treated at a time, so that the reduction of the ore has been slow and costly.

The ore occurs along the bank of the stream and has been followed in these natural exposures for a few hundred feet. The main development has been the driving of a crosscut adit about 200 feet long

[1] Swineford, A. P., Report of the governor of Alaska for the fiscal year 1886, p. 949; idem for the fiscal year 1888, p. 18. Knapp, L. E., idem for the fiscal year 1891, p. 31.

across the general strike of the shales and sandstones that form the country rock. The rocks stand well, so that almost no timber is used except in the fractured and disintegrated surface zone near the entrance of the adit. Several prospect holes and shafts, the deepest of which is said to be about 45 feet, have been sunk farther up the slope. Most of these old pits have been lying idle so long that they are now filled with water and are not accessible. Considering the length of time that the deposit has been known, only a small amount of development has been accomplished, and that has not been planned so as to disclose most effectively the characteristics of the deposit.

The slope of the adit affords a grade sufficient to carry off the water from the underground workings and to aid the tramming out of ore and waste. The back of ore above the adit level, however, is not great, and consequently if the property is developed power for pumping and hoisting must be provided. An attempt has been made to prepare for the installation of a modern furnace for reducing the ore, but lack of funds has allowed little to be done except the clearing of a site on the hillside near the crosscut adit. The installation of a furnace is hampered not only by lack of funds, but also by the lack of easily accessible material suitable for the construction. The sandstones and shales of the neighborhood are not strong enough for walls and supports, so that even the rougher construction materials must be transported several miles, and the special material, such as fire brick, must be brought all the way from the States. A fairly resistant igneous rock occurs a short distance downstream from the site selected for the furnace, but it is not abundant, and probably the nearest place where a strong, durable rock can be obtained is Barometer Mountain, about 5 miles south of the prospect.

GEOLOGIC OCCURRENCE.

The country rock in the vicinity of the prospect consists of sandstones and shales of Cretaceous age. The sandstones are rather fine grained and appear to contain no pebbly phases. Most of the grains are angular and consist of fragments of rather fresh dark iron silicates and quartz. Some of the sandstones contain a number or worn mica flakes which have evidently been derived from the now buried metamorphic or igneous rocks of older age. The shales are black and are so fine grained that the individual particles are not recognizable by the unaided eye. Near the mineralized areas these rocks are considerably shattered and in places much slickensided. The rupturing does not appear to be widespread, and a short distance from the claims the normal unshattered condition of the rocks prevails.

Igneous rocks of two distinctly different kinds have been recognized. One of these, a gray-green medium fine grained rock with prominent flakes of biotite over a quarter of an inch in diameter, is closely comparable with diabase, and the other, a light-gray, nearly white rock, belongs to the group of granitic rocks. The rock resembling diabase occurs as a poorly exposed, slightly inclined thin layer at some distance from the ore bodies. Its relations to the other rocks are not clearly shown, but apparently it is later than the shales and sandstones and occurs as a sill rather than as a flow interstratified with the sediments. When examined microscopically the rock is seen to be composed mainly of small laths of feldspar and large flakes of biotite. The feldspar is not excessively twinned, usually only twice, and is little decomposed, and the larger part of it has been determined to be labradorite. The biotite is in blades which are little decomposed and which show strong absorption in polarized light. Considerable chlorite is scattered irregularly through the thin section and apparently has been derived principally from the decomposition of ferromagnesian minerals. No undecomposed iron silicate minerals were recognized, but blades and fragments of altered minerals that, from their apparent original rectangular cleavage, are believed to have been augite are fairly common. The relations are not definitely proved, but this rock is believed to be older than the granitic rock.

The best exposures of the granitic rock are afforded in the crosscut adit. In this adit, beginning at the entrance and extending in a northeasterly direction toward the face, is a succession of sedimentary rocks having a low northeasterly dip, which increases toward the northeast. These sediments are cut, about 75 feet from the entrance of the adit, by a 3-foot dike of the light-colored igneous rock. Succeeding the dike is an area of much shattered and brecciated dark slates. The shattering is so thorough, though apparently on a small scale, that within short distances trends toward almost all points of the compass may be found. Although the strike of these rocks is not constant, the dip is in general so steep as to be practically vertical. Many stringers of quartz have been formed in the open spaces produced by this brecciation, and most of the ore minerals have been introduced into this zone. Beyond it the sediments are followed by more of the granitic igneous rock. This extends uninterruptedly for about 100 feet, to a point where more shattered shale was found. The contact between the shale and igneous rock was followed for about 30 feet, until the fact became apparent that the adit was curving backward so that it was only a few feet from the point where the deflection to the northwest had been made. The general conditions at this place are represented in figure 7, which shows the geology as exposed in this opening. The amount of exploration has not been sufficient to determine the shape or size of the igneous masses, but judged from surface indications they are not large, and they appear to be more or less cylindrical bodies rather than extensive plugs or batholiths.

When examined under the microscope the igneous rock is seen to be so much decomposed that few of the original minerals are preserved. The small amount of quartz in the decomposed rock indicates that little of this mineral was originally present. Carbonate occurs in the rock in considerable quantities as a secondary mineral. In some of this secondary carbonate small patches of cinnabar have been recognized. Sericite is a common secondary mineral. The rock is usually much stained with iron hydroxides.

At a prospect pit a few hundred feet from the main adit described above is an exposure of a light-colored igneous rock which probably belongs to the same period of intrusion as the igneous rock in the adit. It is, however, less weathered, and a microscopic examination of specimens from this place showed a porphyritic rock whose phenocrysts are quartz and completely altered feldspar. The feldspar had been altered to quartz, sericite, and a fine-grained indeterminate material. The groundmass is a fine-grained mixture of primary quartz and secondary products which doubtless had been derived from the decomposition of the original feldspars. In all probability the rock was an acidic porphyry, probably of rhyolitic or latitic composition. The porphyritic rock is much more quartzose than the decomposed rock found in the adit. The field occurrence, however, seems to point clearly to the close association of the two rocks, and therefore, although the rock from the adit appears to be much more basic, it probably is equivalent to the porphyritic rock from the prospect pit, and both are regarded as granitic or monzonitic porphyries.

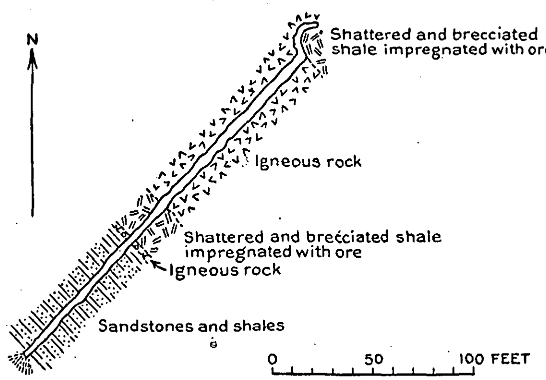

FIGURE 7.—Sketch map of the underground development at Parks quicksilver prospect.

The main occurrence of the ore is in the brecciated zone adjacent to the contacts of the igneous masses. Wherever this zone is found some mineralization has occurred. This shattered condition close to the igneous rocks is not limited to a single dike or stock but seems to be general wherever the sediments have been cut by intrusives. Where there are several dikes whose margins are mineralized exaggerated estimates of the possible future tonnage of the property are likely to be made if the true geologic structure and relations are not ascertained. This can be done only by careful prospecting by experienced men, but until development work of this sort has been done, the value of the property can not be determined.

Although the distribution and direction of the deposit have not been definitely determined, the dikes and igneous bodies seem to trend, in general, northwest, and this is probably the direction of their greatest horizontal extent. Some evidence in support of this view is afforded by the material in the creek several hundred feet west of the adit, about 50 feet from the Kuskokwim. This material is mainly ore, as if a highly mineralized lead were cut by the creek at this point. A notable feature of the unconsolidated material in this stream is the amount of native quicksilver it contains. The material in the bed of the creek, which is little more than a wet-weather stream, consists mainly of angular frost-riven fragments apparently derived from a near-by bedrock source. Pans of this slightly water-sorted material yielded so much quicksilver that perhaps half a spoonful was obtained from three moderate-sized pans. The origin of the native quicksilver was not determined definitely, but probably it was produced by the natural reduction of the cinnabar. This reduction may possibly have been assisted by the heat of former woods fires. The hillsides near the prospect have been recently burnt over, as is shown by blackened vegetation and standing fire-scarred trees, and other fires doubtless occurred in the past. The amount and distribution of the native quicksilver seem to preclude the possibility that it has been inadvertently spilled or has been lost in earlier operations. Native quicksilver, either as a primary constituent or as an alteration product, has been frequently reported to occur in cinnabar lodes, but it has seldom been reported to occur upon the present surface, as at the Parks prospect.

CHARACTER AND RELATION OF MINERALIZATION.

The mineralization is closely related to the shattered and brecciated contact zone between the igneous dikes and the sediments. The metallic minerals are almost exclusively cinnabar and stibnite. Iron pyrite in narrow stringers, most of them less than one-eighth of an inch wide, has been seen at a few places, but almost nowhere is it intermixed with other sulphides. In fact, it is so distinct that the impression gained in the field was that it had been introduced at an entirely different time than the ore minerals. Subsequent study in the laboratory, although affording no evidence in support of this view, has shown no facts that are opposed to it.

In few places is a distinct veinlike form recognizable in the deposit. On the river bank a little west of the main opening a veinlike mass about a foot wide showing a somewhat banded structure has been traced for a short distance. Normally, however, the mineralization follows the irregular partings between the shattered fragments of country rock, and consequently forms a network of anastomosing stringers and lenses.

The ore near the surface is weathered to a rusty brown iron-stained color. In the more oxidized portions of the deposit the cinnabar is practically unrecognizable by inspection of the fragments, owing to the coating of iron oxides. In less decomposed parts the characteristic red of the cinnabar becomes more evident, until in the unaltered parts the blood-red cinnabar is very striking.

The cinnabar occurs principally in small particles intimately mixed with the well-formed crystal blades of stibnite, the sulphide of antimony. These two minerals were deposited almost contemporaneously, for the stibnite incloses and is inclosed by the cinnabar. So closely do the two minerals occur together that the mineral livingstonite—the sulphide of antimony and mercury—was reported to be the metallic sulphide other than cinnabar occurring in this deposit. Tests by R. C. Wells, of the chemical laboratory of the Geological Survey, failed to find this mineral and instead proved that the supposed quicksilver content of the stibnite was really derived from the minute particles of cinnabar that were intimately intergrown with the stibnite.

Tests were also made by Mr. Wells to determine whether any of the compounds of selenium or tellurium and mercury were present. Neither selenium nor tellurium was found in analyses of bulk samples, and therefore the compounds of mercury and these elements must also be absent.

The stibnite occurs usually in distinct crystals, which in places are so closely intergrown that their boundaries are those impressed upon them by the other particles with which they are in contact and are not the normal crystallographic faces. In places, however, where room was available for the crystals to form—as, for instance, in the vicinity of the vugs—the stibnite is in its characteristic bladed form with shining cleavage planes. Some of the crystals of stibnite are an inch long and a quarter of an inch wide, but most of them are smaller and range in size down to hairlike radiating aggregates so minute that the crystal faces can not be recognized by the aid of a hand lens. In most of the specimens collected the stibnite occurs in considerably greater amounts than the cinnabar.

The character and amount of gangue that accompanies the ore differ notably in different parts of the exposures. In places the sulphides are practically the only minerals in the deposits. Usually, however, considerable quartz and carbonate accompany the ore minerals. The carbonate consists of siderite or ferruginous dolomite and usually occurs in crystalline masses. Clearly in one specimen and apparently in others the carbonate has been traversed by narrow quartz stringers, associated with which are the bulk of the metallic minerals. The quartz in these narrow stringers near the contact with the carbonate is almost opaline, but farther away it is more crystalline, and in places where vugs have been formed small, perfectly terminated quartz crystals project into the cavities. In some of the vugs perfectly formed crystals of cinnabar have grown on the crystalline quartz.

In thus calling attention to a paragenetic arrangement that has been observed in some of the specimens the impression should not be gained that the ore is characterized by a well-marked banded appearance. Instead all the minerals were deposited so nearly at the same time that even the carbonate, which appears in places to be one of the earliest minerals formed, contains inclusions of the cinnabar, which appears usually to be one of the later minerals.

PROSPECT NEAR KOLMAKOF.

LOCATION AND GENERAL TOPOGRAPHY.

A quicksilver deposit has been opened in the bluff on the north bank of Kuskokwim River, about 5 miles downstream (west) from the trading post of Kolmakof. This settlement is on the south bank of the main river about 160 miles above Bethel, a port for small seagoing vessels on the tidal portion of the lower river about 150 miles from Goodnews Bay, on Bering Sea.

The principal topographic features in the vicinity of Kolmakof are a broad alluvial lowland that forms the flood plain of a somewhat older wide valley, about 50 feet below which lie the present flood plain and channel of the Kuskokwim; a wide belt of moderately mountainous highland north of the river, with a generally rolling surface from 1,000 to 2,000 feet above sea level, diversified by the deeply eroded valleys of the larger tributary streams and many gulchlike valleys of lesser extent eroded by the smaller streams; and an isolated group of rather rugged mountains, locally known as the Russian Mountains, that rise prominently above the adjacent highlands to altitudes of 4,000 to 4,500 feet above sea level.

Near Kolmakof the Kuskokwim has an average width of about two-thirds of a mile, and its channel is practically unobstructed, only one or two alluvial islands overgrown with willows being present near its south bank. Downstream throughout its course from a point about 10 miles above Kolmakof the south bank of the Kuskokwim is composed of unconsolidated silts, sands, and gravels without any outcrops of hard bedrock. In this part the river flows alternately along sections of gently sloping bank bordered by sand and mud bars in shoal water and sections where the water is deeper and the current stronger, so that it cuts rapidly into the unconsolidated sediments and undermines them, forming steep slopes that rise from 10 to 25 feet above the water. At a few widely separated places the bluffs rise to heights of 40 or 50 feet above the river. Kolmakof immediately overlooks the river on one of the most prominent of these higher bluffs.

The north bank of the river is made up chiefly of rock bluffs from 100 to 400 feet high, interrupted at widely separated intervals by small isolated lowland areas of unconsolidated sediments. Narrow alluvial benches fringe the base of some of the rocky bluffs for short distances, but the river at flood stages flows at the foot of most of the bluffs, so that they are kept bare by the removal of the disintegrated talus, which makes a considerable part of the slopes above high-water mark. None of the bluffs along this section of the river are so abrupt as to hinder free passage on foot along their bases at ordinary stages of the river.

Kolmakof River, a considerable stream, enters the Kuskokwim from the northeast a mile below Kolmakof. About 20 miles farther down a somewhat larger stream, Owhat River, joins the Kuskokwim from the north. These two streams border the rugged Russian Mountains on the east and west, respectively. The tract between them is dissected into a number of broad rolling ridges and subordinate spurs by steeply incised valleys drained by creeks that flow southward into the Kuskokwim. The Kuskokwim has truncated the south ends of these ridges and formed a series of rock-cut bluffs. These bluffs, which start at a point about 4 miles below Kolmakof, are prominently developed for a distance of about 12 miles. In general, the profile of each major bluff section presents a gradual ascent from one tributary valley to a maximum height along the crest in the central part and an equally gradual descent to the succeeding valley.

GENERAL GEOLOGY.

In the vicinity of Kolmakof the hard-rock bluffs are made up principally of a widespread series of sedimentary rocks of considerable thickness which have been intruded by dikes and sills of both acidic and basic composition. Large masses of igneous rocks of granitic and porphyritic texture which seem to be of more deep-seated origin and which mark centers of laccolithic or batholithic intrusion occur in the higher isolated mountain groups, such as the Russian Mountains. Probably many of the small dikes and sills intruded into the sediments are offshoots of the larger masses of intrusive rocks of deep-seated origin. This relation, however, has not yet been definitely proved.

The sedimentary rocks are composed of alternating beds of sandstones and shales, most of which are from a few inches to about a foot thick. Some of these beds grade from sandy to shaly texture within short distances along their bedding, and at various horizons both sandy and shaly members show ripple markings or similar indications of deposition in shallow water. Some of the sandstones, however, have a thickness of 100 to 200 feet, and some of the shales are 200 to 400 feet thick. These heavier members appear to be developed at several different horizons in the series. The thin-bedded sandstones and shales aggregate at least 4,000 to 5,000 feet in thickness and form most of the exposures in the river bluffs. No marked lithologic differences were noted in the section except toward the top, where somewhat coarser textured arkosic sandstones of lighter color are developed in place of the finer-grained, more dense dark-gray quartzose sandstones that characterize the stratigraphically lower part of the series. Many of the shale members are slightly calcareous, but none are calcareous enough to be properly called limestone. All the shales are dark colored. Many of the nearly black shales are somewhat carbonaceous.

The quartzose sandstones are dominantly dark gray, fine to medium grained, and of dense texture. Some of these beds, however, contain coarse material and discontinuous layers of grit. No conglomerate was seen within the bulk of the sediments, although at or near the base of the series in adjacent areas heavy beds of this rock occur. Some of the sandstones, like certain of the shales, are slightly calcareous.

The arkosic sandstones are distinguishable from the quartzose sandstones chiefly by their lighter color, coarser grain, and heavier bedding. They also differ from the darker and denser sandstones in that they contain numerous scales of light-colored mica which may be easily recognized by the unaided eye. These arkosic sediments where unweathered are usually light gray; in weathered outcrops, however, they usually have pale-yellowish tints, and near the intrusive igneous contacts they are commonly light purplish or iron-rust brown.

At least 1,000 feet of these beds is exposed in the bluffs in which the cinnabar prospect near Kolmakof occurs. Fully as great thicknesses of sediments of the same general character are exposed in sections which may or may not be duplications, in part, at least, of the others. Therefore the total thickness of the sedimentary series is probably very great.

CHARACTER AND RELATION OF MINERALIZATION.

The details of the bluff in which the cinnabar mineralization occurs are shown in figure 8. At this place the bluff rises about 200 feet above the river. Few outcrops of bedrock are exposed along the upper portion of the bluff, except here and there where fresh slides have occurred. Most of the upper slope is covered by more or less unstable slide rock and loose soil, matted together by the roots of a close growth of brush and a considerable number of spruce and birch trees. Even where the rocks are exposed they are so deeply shattered and disturbed by surface creep that little can be determined about their structure and relations.

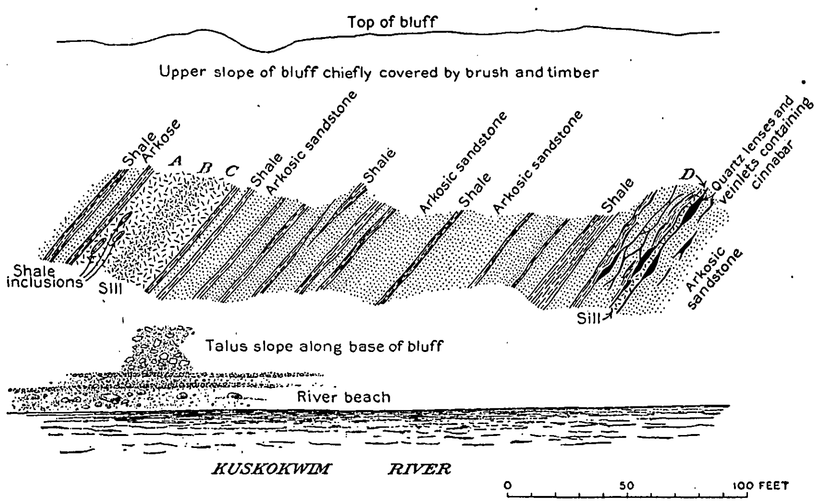

FIGURE 8.—Generalized section of bluff on Kuskokwim River about 5 miles below Kolmakof.

Usually the best exposures of undisturbed bedrock are found in a narrow strip 20 to 100 feet above the river, but even these are considerably obscured by disintegrated material and interrupted by gullies filled with slide rock. The country rocks at the prospect are interbedded arkose and shale. Several of the arkose beds are as much as 20 feet thick, but on the average they are considerably thinner. The shale beds range from thin layers to beds 2 or 3 feet thick. Rocks of this kind occupy a belt 3 or 4 miles wide along the river, but their northward extension is obscured by the covering of soil and vegetation. Sedimentary rocks of the same character are reported on the upper part of Kolmakof River, about 20 miles above its mouth, and probably they have a widespread distribution throughout the mountainous highland.

The beds of this belt of arkosic sediments strike N. 30°–80° E. Their dip changes along the different folds from southeast to northwest. At the quicksilver prospect (fig. 8) the rocks strike N. 60°–70° E. and dip 40°–50° NW.

For several miles upstream from the quicksilver prospect no intrusive rocks were seen cutting the sediments, but downstream from the prospect sills and dikes are numerous. Most of the intrusive masses are sills—that is, the molten igneous rock has been injected along the bedding planes of the sediments, rather than across the beds in the form of dikes. However, some of the intrusive sills follow one bedding plane for a distance and then cut across a few feet of beds to another bedding plane and follow it. Fragments of the country rock are included in both the sills and the dikes.

Two sills of igneous rock appear to have been the primary factors in the mineralization at the quicksilver prospect. The relations of these sills are shown in figure 8. The sills are about 200 feet apart. The larger sill, which is about 30 feet thick, is divisible into three parallel zones, marked *A*, *B*, and *C* in figure 8, and the smaller sill, which is 1 to 2 feet thick, is marked *D*. Apparently the larger sill is the one which Spurr[1] particularly noted and described as bostonite.

Four representative specimens collected from these different parts have been examined microscopically by J. B. Mertie, of the Geological Survey. The rock of zone *A* is an altered pyroxene andesite, composed of acidic plagioclase, much altered; a completely calcitized mineral, probably originally pyroxene; iron oxides, altered largely to limonitic material; apatite; calcite as secondary material, with cinnabar intimately associated; minute dark particles, also associated with the calcite and distributed throughout the rock; and pyrite, associated with a black opaque material. The general color of the rock from zone *A* is pale gray, with iron-rust tints along the fracture planes and darker purplish tints on the surfaces that have been most exposed to weathering. Cinnabar in the form of small red crystalline particles gives a faint pink tint to the calcite, with which it is intimately associated. The calcite occurs in minute gash veins, rarely more than one-twentieth of an inch thick or an inch long, distributed throughout the rock along irregular fractures and in small vuglike cavities. The cinnabar, which may be distinctly seen with a hand lens, is embedded in or intergrown with the calcite of the veinlets and incrusts the surfaces of the small cavities.

The rock in zone *B* is readily distinguishable from that in the other zones by its much darker gray color, fresher appearance, and greater hardness. These differences, however, may be due to differences in the amount of leaching that has occurred in the central and outer zones. The rock in zone *B* proves to be a pyroxene andesite, practically the same as that of zone *A*. It is composed of acidic

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 129, 216, 1900.

plagioclase, much altered; an altered mineral, apparently pyroxene; hornblende, more or less altered; biotite; olivine in small amount; iron oxides, largely altered to limonite; apatite; calcite, as secondary material, replacing rock minerals; and quartz, probably chiefly secondary. No cinnabar was recognized in zone *B*.

The rock of zone *C* is an altered hornblende andesite, that contains acidic plagioclase, much altered; possibly some altered pyroxene; hornblende in various stages of alteration; biotite; iron oxides, largely altered to limonitic material; apatite; calcite and zeolite, as secondary minerals; quartz, probably chiefly secondary; and pyrite, associated with a black opaque substance. Cinnabar appears to be absent. This rock is light gray, like that from zone *A*, and has along its joints and on exposed surfaces iron-rust stains, which impart to it a somewhat yellowish color.

The cinnabar mineralization appears to be confined to zone *A*, which contains the inclusions of shale country rock and occupies the hanging-wall side of the sill. Whether or not the carbon of the shale inclusions in zone *A* had a special influence upon the segregation of the cinnabar in this portion of the sill is not definitely known, though probably it did.

The smaller sill (*D*, fig. 8) appears to be the more important with regard to quicksilver mineralization and is near the place where most of the quicksilver ore has been obtained. This sill is an altered hornblende andesite, similar in composition to that of zone *C* in the larger sill. Its mineral constituents are acidic plagioclase, much altered; some completely altered minerals, probably for the most part originally hornblende, with some pyroxene; iron oxides, altered to limonitic material; apatite, unaltered; calcite, replacing rock minerals and in veinlets, associated with pyrite; quartz, probably chiefly secondary, in places associated with pyrite; and pyrite, intergrown with a black, opaque substance of unknown composition, which may be an alteration product of the pyrite or some other sulphide, possibly metacinnabarite, intergrown with the pyrite. This rock is light gray within, purplish iron-stained to a depth of an inch in the marginal portions of the irregularly fractured blocks, and bright rusty iron-stained along the less exposed joint planes.

No cinnabar was noted in the igneous rock of the smaller sill itself, but appreciable amounts occur in lenses and stringers of quartz near the sill and extend along joint and bedding planes of the adjacent sediments. The maximum width of the mineralization, including the sill, which is 1 to 2 feet wide, appears to be about 4 feet in the small part of the outcrop that is undisturbed by creep. The cinnabar-bearing quartz lenses are neither large nor numerous in the present exposure. Few of them are more than 6 inches thick or more than 2 feet long. The cinnabar is distributed irregularly and is roughly interbanded with quartz. The thickest band of fairly pure, more or less crystalline cinnabar observed was about a quarter of an inch wide. Practically all the cinnabar appears to be in the quartz lenses and stringers, although probably minor amounts also occur in the shattered sedimentary rocks between the two sills. Although the sediments on each side of the sills are probably impregnated with cinnabar in appreciable amounts, it is not likely that quicksilver ore of commercial grade occurs outside of the narrow area in immediate association with the smaller sill which is occupied by the quartz lenses. The amount of ore in this zone does not seem to be sufficient to be profitably exploited under the present conditions of the region. Intelligently directed development of this prospect, however, might possibly disclose larger ore bodies. No work was in progress at this prospect at the time of the writer's visit, and nothing was seen that showed that the deposit had ever been extensively developed. Only superficial excavations have been made from time to time at various points along the outcrop, and no attempts appear to have been made to trace the extent of the mineralization back from the crest of the bluff.

MISCELLANEOUS LOCALITIES.

Several claims have been staked in the vicinity of the Parks prospect, and explorations on a small scale have been made at these places. Willis & Fuller have been doing some work on the divide between Kuskokwim and George rivers, about 2½ miles northwest of the Parks property. Some quicksilver ore has been found, but the development has not been carried much farther than that required by law to hold the property. The geologic conditions in general are the same as at the Parks prospect and at the prospect near Kolmakof. Dikes of light-colored intrusive rock cut the sandstone and shale country rocks, and in the vicinity of the contacts mineralization has taken place.

Cinnabar has been found in the residual placer material in the areas of intrusive rock near Iditarod. Very little cinnabar has been observed with quartz in place, but angular fragments of vein matter that without doubt have been derived directly from joint fillings in the granitic rocks contain cinnabar. Fragments of this kind are commonly found in residual material in Happy and Black gulches. In the deposits, especially in Black Gulch, small subangular pebbles and grains of cinnabar, obviously derived from quartz veinlets, accumulate in appreciable amounts as concentrates in the sluice boxes. From 500 to 1,000 pounds of cinnabar pebbles are said to collect in an ordinary string of sluice boxes during 3 or 4 days of shoveling-in operations.

Though cinnabar occurs with quartz in some of the small veins that occupy joint cracks, it also occurs in subordinate association with stibnite. In these veins the cinnabar appears normally in the more quartzose portions of the stibnite bodies. Several small veins of this kind have been observed on the lower part of Glen Gulch. In these veins stibnite is the most abundant metallic mineral, and the cinnabar occurs as flakes and blebs associated with quartz. The stibnite-cinnabar mineralization seems to be confined to the stronger quartz stringers that are deposited here and there within the granitic rocks and to the stronger zones of small extent in the altered sediments at or near their contact with the intrusives. One of these zones of stibnite-cinnabar mineralization, several feet wide but not very long, occurs in slaty rocks along the contact at the head of Glen Gulch. Some open-cut work was done to prospect this area, but it was soon abandoned because the metallic minerals were found to occur in rather disconnected lenses and vugs with a large percentage of barren vein quartz, so that the deposit as a whole did not appear profitable under present conditions.

ORIGIN AND PROBABLE EXTENT.

In discussing the general views held as to the origin of the quicksilver deposits of the world, Lindgren[1] states:

> When it is noted that hot springs and volcanic surface flows are present in almost all regions of importance (except Almaden in Spain, Idria in Austria, and Nikitowka in Russia) and that cinnabar in considerable quantities is associated with undoubted spring deposits or is actually deposited in hot springs, the argument becomes very strong indeed that such hot springs have formed the majority of the deposits. For the few deposits that have no such clear connection with volcanic rocks for instance, those mentioned above the characteristic mineral association still holds good, and we are forced to the hypothesis that volcanism and hot-spring action are the causes of these also, though the products of the igneous activity may have failed to reach the surface and the hot springs may have subsided.

In other parts of the book cited, as well as in many of his other writings, Lindgren has clearly shown that he does not confine the term "hot springs" to those deriving their water from the surface but includes those that derive their water from hot ascending solutions, possibly of magmatic origin. If the term is used in this broad sense, the quicksilver deposits here described may appropriately be called hot-spring deposits. They are evidently closely associated with the igneous rocks and have derived their mineral content from the emanations of the intrusive masses in the form of solutions.

To judge from the geologic occurrence of the ores, the depth at which they were formed apparently was not great. This conclusion

[1] Lindgren, Waldemar, Mineral deposits, pp. 469–470, 1913.

is supported by the number of open spaces that are still preserved and the number of open spaces that were in existence when the mineralization took place but are now filled with ore and gangue. It is further supported by the shattered condition of the rock adjacent to the intrusions, for the shattering probably could have taken place only under slight load, such as is characteristic of the surficial part of the earth's crust.

The significance of the determination of the depth at which the mineralization took place is that it gives an indication as to the probable extent of the deposit, both vertically and horizontally. If the deposit was formed near the surface it probably, like the California deposits, decreases in tenor with increase in depth. In the California deposits practically no workable ore extends to a depth of more than 1,000 feet. Furthermore, the shattering of the country rock adjacent to the igneous intrusives formed an easily pervious zone, so that the mineralization would tend to be limited to this zone and not diffuse far into the unshattered rock. This shattered zone, so far as is now known, does not extend far from the intrusive rock; therefore mineralization is not to be expected far from the dikes. If the dikes are numerous the shattered rock may furnish sufficient space for the accumulation of considerable ore, but as a rule the zone surrounding a single dike does not exceed a few feet.

At Barometer Mountain, a few miles south of the Parks prospect, and at the Russian Mountains, north of the Kolmakof prospect, considerable masses of intrusive granitic rock are exposed. Possibly similar intrusive rocks also occur near the prospects but at so great a depth that only the apophyses from them are exposed at the surface. These apophyses may be represented by the dikes of intrusive rock near the ore bodies. If this interpretation is correct, probably in the deeper parts near the larger masses the country rock is not so much fractured and spaces for the deposition of the ore are not so numerous. Furthermore, at the higher temperature prevailing at greater depth the quicksilver minerals would not be so effectively deposited from the solutions that carried them as in the cooler rocks near the surface. Consequently a decrease in the amount of ore from the surface downward is to be expected.

So far as observed, the ores show no considerable downward enrichment through the action of descending surface waters. Small particles of a mineral that may be metacinnabarite, the black sulphide of quicksilver, which is generally believed to be formed as a secondary sulphide, have been seen at the Parks prospect, but their number is not great. As noted by Lindgren,[1] "the suiphide of mercury is practically insoluble in water, and ordinarily the processes

[1] Lindgren, Waldemar, op. cit., p. 801.

of oxidation in the outcrop of the ore deposits are of little importance." Consequently a decided decrease in the tenor of the ore in depth through absence of downward enrichment is probably not to be expected.

POSSIBLE FUTURE AREAS.

The mineralization by which quicksilver was introduced clearly seems to have accompanied the intrusion of the igneous rocks. The neighborhood of these intrusives is therefore the place to prospect for lodes of this metal. All the known intrusions of these rocks have been indicated on Plate X. Much of the region, however, is still unexplored, and consequently other bodies of these rocks probably exist in the places that have not been studied.

The quicksilver minerals near Iditarod were found close to the contact of the large igneous masses, but at the other prospects they occur near the contact of smaller bodies, some of them only a few feet wide. The search for the exposed large igneous masses is relatively simple, for most of the intrusive rocks are more resistant than the surrounding sediments and therefore are somewhat more prominent topographically than the other rocks. The smaller dikes and sills usually do not form noticeable topographic features and are more irregular in their distribution. Most of the small dikes are more or less closely associated with the larger igneous masses and are abundant a short distance from these bodies. In many places, however, the larger masses, from which the dikes are offshoots, are not exposed at the surface, and their presence can be inferred only from the abundance of the small dikes. Search for places of this sort is exceedingly difficult, and they can be found only by close scrutiny of the float and bedrock exposures. When the dikes are found, prospecting to determine whether or not quicksilver mineralization is associated with them will usually be slow, laborious work.

The intrusive rocks by which the quicksilver mineralization was introduced cut the Cretaceous rocks but are believed to be older than the late Tertiary and recent effusive igneous rocks and sediments. Consequently prospecting for deposits of this sort does not seem warranted in areas occupied by rocks of more recent age than the younger part of the Tertiary.

Although the search for quicksilver deposits might disclose others than those now known, the character and occurrence of those that have been found and the difficulties of reduction and marketing seem to indicate that not many productive deposits will be opened in the region. A search for gold placers in the vicinity of the igneous rocks would probably be far more profitable than the same amount of search for quicksilver deposits.

ECONOMIC CONDITIONS AFFECTING THE PRODUCTION OF QUICKSILVER.

Quicksilver ores are relatively rare in nature. Consequently a brief statement as to the general uses of this metal, the amount produced, and the value has been thought desirable. This statement is given because only by considering these different factors can the economic conditions which affect the production of quicksilver be realized and properly evaluated in determining the probable future of any particular deposit.

McCaskey[1] describes the uses of quicksilver as follows:

> Quicksilver is used mainly in the manufacture of fulminate for explosive caps, of drugs, of electric appliances and scientific apparatus, and in the recovery of precious metals, especially gold, by amalgamation. A new use in Scotland is the floating of lights of lighthouses upon a body of quicksilver. A use in England, in the United States, and possibly elsewhere, is the coating of ships' bottoms with a paint containing quicksilver, to prevent organic growth. Mercuric oxide (red oxide of mercury) is the active poison in antifouling paint successfully used on ships' bottoms. The metal appears to be but little employed in silvering mirrors, as nitrate of silver is now chiefly used for the purpose. Increasing use of quicksilver is probably to be expected in the manufacture of electrical appliances and of fulminates, and possibly of paints for protective coatings on metals. The demand for quicksilver for amalgamating gold and silver has greatly decreased, as is well known, with the decreased supply of free milling ores and the increased application of cyanidation to gold and silver ores. Industrial chemistry and inventive genius are to be looked to for increasing the demand.

The production of quicksilver for the world in 1913, according to figures compiled by McCaskey,[2] stated in metric tons of 2,204.6 pounds, was as follows: Spain, 1,490 tons; Italy, 988 tons; Austria-Hungary, 855 tons; United States, 688 tons; Mexico and other countries (estimated), 150 tons; total for the year, 4,171 metric tons. The exports of quicksilver from the United States in 1914, according to records of the Department of Commerce, were 33,900 pounds, or a little more than 15.3 metric tons; the imports of quicksilver in 1914, according to the same authority, were 685,604 pounds, or a little less than 311 metric tons. Imports are subject to a duty of 10 per cent ad valorem. In the United States 33 mines and prospects produced quicksilver in 1914. Of these, 23 were in California and the other 10 in Arizona, Nevada, and Texas. Formerly a small amount of quicksilver was produced also in Oregon, Utah, and Washington, but in recent years none of the quicksilver mines in these States have been in operation.

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[1] McCaskey, H. D., Quicksilver in 1913: U. S. Geol. Survey Mineral Resources, 1913, pt. 1, pp. 198–199, 1914.

[2] Idem, p. 210.

According to statistics furnished by the Department of Commerce the imports of quicksilver into Alaska during 1914, all from the States, were as follows:

Imports of quicksilver into Alaska in 1914.

Place of shipment.	Amount (pounds).	Value.
Seattle	13,176	$8,477
San Francisco	1,275	607
	14,451	9,084

The following table gives the amount of ore treated and the recovery, by States, for 1913:[1]

Quicksilver ore treated and average recoveries by States, in 1913.

State.	Ore treated (short tons).	Metal recovered per ton (pounds).	Percentage of ore recovered as metal.
California	119,159	9.8	0.49
Nevada	8,755	14.1	.71
Arizona and Texas	8,464	26.7	1.34
Total and average for United States	136,278	11.1	.555

McCaskey,[2] in a preliminary statement, gives the following notes on the market and prices of quicksilver in 1914:

The domestic quicksilver market was unfavorable and the prices very low during the first seven months of 1914, but upon the outbreak of the European war the prices jumped and producers in a position to profit were encouraged to make their maximum output. The average San Francisco domestic price was $40.23 a flask of 75 pounds for the year 1913, against $42.05 in 1912 and $46.01 in 1911. * * * It is estimated that * * * the average price for the year [1914] will therefore be about $49—the highest since 1890. The total productive capacity of the quicksilver mines of this country as at present known is by no means unlimited, and although high prices may bring spurts of activity and new ore bodies may at any time be discovered, the present outlook is not for excessive production. These facts and the present improbability of excessive importation indicate high prices throughout the war, at least.

[1] McCaskey, H. D., Quicksilver in 1913: U. S. Geol. Survey Mineral Resources, 1913, pt. 1, p. 201, 1914.

[2] McCaskey, H. D., Quicksilver production in 1914: U. S. Geol. Survey Press Bull. 201, January, 1915.

GOLD PLACERS OF THE LOWER KUSKOKWIM, WITH A NOTE ON COPPER IN THE RUSSIAN MOUNTAINS.

By A. G. Maddren.

SCOPE OF REPORT.

During the summer of 1914 the writer investigated the mineral resources and general geology of that portion of the Kuskokwim region which extends southwestward from the well-known Iditarod gold placer district to the basins of Aniak and Tuluksak rivers, large tributaries of Kuskokwim River from the south. Placer gold has been known to occur in these basins since 1908 and has been mined in a small way from that year to the present.

This report treats primarily of placer-gold deposits on upper branches of Tuluksak and Aniak rivers, which flow from opposite slopes of a mountain ridge that separates these two drainage basins. Together these basins may be conveniently designated the Tuluksak-Aniak gold placer district. The combined drainage areas lie chiefly between latitude 60° 30′ and 61° 30′ N. and longitude 159° and 161° W. The direct distance between the Tuluksak-Aniak and Iditarod districts is about 150 miles. (See Pl. X, p. 270.) Within the intervening area several minor localities of mineral deposits are known. Those in which active interest was being shown during 1914 were visited. Other reported prospects at widely separated places throughout this general field could not be visited because of lack of time, facilities, and definite information as to their exact position. However, such notes as were gathered about them are here presented.

Information was also gathered from available sources concerning mining developments and prospects southwest of the field personally examined, including the section of the Kuskokwim Mountains that extends from the Tuluksak-Aniak district to Bering Sea, a direct distance of about 180 miles. (See Pl. X.) It was intended at the beginning of the season to visit all the active mining localities of the lower Kuskokwim region, but on entering the field it was found necessary to curtail this plan because of the isolation of the several camps, the lack of summer trails and overland transportation facilities, and the general scarcity of supplies both at the trading posts along Kuskokwim River and at the mining camps. No pack animals were available for carrying a camp and supplies over the mountains south of Kuskokwim River. It was not possible to cover the whole region in the time available by boating up the swift tributaries of the Kuskokwim to the mountains and then man-packing with light equipment to the several mining camps. Very rainy weather during most of the season was also a great hindrance to field observations. As a result personal field examinations were, by force of circumstances, limited to the upstream half of the lower Kuskokwim region as a whole and were confined chiefly to the neighborhood of the main river except in the Tuluksak-Aniak district. This district was covered by back-packing a few necessities overland a distance of 75 miles on the outgoing trip and the same distance on the return and by depending almost entirely on the generous hospitality of the miners and prospectors on the several creeks for shelter and food from their scanty stores.

ACKNOWLEDGMENTS.

The writer wishes to record grateful appreciation to Messrs. Huber, Schmidt, and Heckman, on Ophir Creek; Mr. R. S. Eskridge, on Bear Creek; Mr. W. Y. Fisher, on Marvel Creek; Mr. and Mrs. Johnstone, on Cripple Creek; and Mr. Parks, on Loco Creek. Mr. Gordon Bettles, of Kolmakof, not only gave his personal guidance during a three days' trip to the Russian Mountains to examine lode prospects but entertained the party at one of his cabins during that time.

For information regarding mining and prospecting in that part of the region which was not visited the writer is under obligations to Messrs. Johnson, Lindstrom, Fowler, Joaquin, Felder, Moran, King, Heron, Hitzner, and others. Mr. Charles Estmere has kindly furnished a drainage map of Kiselalik and Kuethluk rivers based on traverses made by him through those valleys during the spring of 1914.

The writer was accompanied throughout the trip by Burt Kennedy as geologic field assistant, and from the middle of July to the later part of September by Robert Plummer as field utility man.

ITINERARY.

The field here discussed was reached by the Seattle-Skagway coastal steamship route, the railroad across White Pass to Whitehorse, and the Yukon River steamboats to Iditarod.

Field work began in the middle of July with an overland journey from the Iditarod district, in which the party followed a pack trail 65 miles long that crosses the Kuskokwim Mountains and has its southern terminus at Georgetown, a settlement on Kuskokwim River about 400 miles above its mouth, or 250 miles above Bethel, the supply port for Kuskokwim Valley. On the way to Georgetown the placer gold locality on the middle course of Crooked Creek, a few miles west of the trail, was visited. From Georgetown Kuskokwim River was descended by a poling boat for about 90 miles to the native village of Ohagamut (Oknagamute). The gold placer locality on New York Creek, a few miles above Hoffmans (Napaimut), was visited; the prospect of cinnabar about 5 miles below Kolmakof was examined; and a side trip was made to a copper lode locality in the Russian Mountains about 12 miles northwest from Kolmakof.

From Ohagamut the outlying northern foothills of the mountains that lie between Tuluksak and Aniak rivers, about 15 miles distant, were reached by ascending a tortuous chain of creeks and ponds to Whitefish Lake, a considerable body of water, 6 miles wide and about 10 miles long, that lies along the southern border of the expansive lowlands which characterize the lower part of the Kuskokwim Valley.

From Whitefish Lake an overland back-packing trip was made southward about 75 miles through the mountains of the Tuluksak-Aniak district. Ophir Creek, a stream about 15 miles long, that discharges into Whitefish Lake, and along which prospects of placer gold occur, was ascended to its source in Rockpile Pass, at the base of Mount Hamilton; and Bear Creek, which heads against Ophir Creek and forms one of the chief headwaters of Tuluksak River, was descended for about 15 miles to the scene of placer gold mining along its middle course. Thence the divide which separates the drainage basins of Tuluksak and Aniak rivers was crossed by way of East Fork of Bear Creek, and the valley of Dominion Creek was descended to its junction with Robin Creek, along which prospects of placer gold are reported to have been discovered. Robin Creek was ascended to its source on the north flanks of Marvel Dome, which was skirted on the west by crossing the headwaters of Eagle Creek as far as Marvel Creek, a stream about 6 miles long that drains the southern slopes of Marvel Dome and empties into Eagle Creek about 2 miles above its mouth. Marvel Creek is about 30 miles south of the diggings on Bear Creek and is the most productive gold-bearing stream that has been discovered in the Aniak basin up to the present time. Field observations were continued southward about 15 miles from Marvel Creek to Cripple Creek and two of its headwater branches, Dome and Loco creeks, the gravels of which contain some placer gold.

The return was made overland to Whitefish Lake by the same general route followed on the southward trip, and thence to the main river by the boat route. Kuskokwim River was descended to the settlement of Bethel, where the party arrived late in September. Seattle was reached early in November by an ocean voyage through Bering Sea and across the Pacific on a small trading schooner, which makes the trip between that port and Kuskokwim River about twice each summer.

GENERAL GEOGRAPHY.

The major topographic features of this region are a broad belt of mountainous highlands, named the Kuskokwim Mountains, which extend inland northeastward from Cape Newenham, on Bering Sea, for fully 500 miles, and a trunk valley system, drained by Kuskokwim River, that extends into the interior approximately the same distance as the mountain belt.

KUSKOKWIM VALLEY.

The Kuskokwim Valley may be divided into three natural geographic provinces—a lowland province, which lies along the northwestern flanks of the Kuskokwim Mountains and extends about 200 miles inland from the mouth of the river on Bering Sea; a central province, along the middle length of the river, which is deeply entrenched for a distance of about 150 miles from east to west across the entire width of the Kuskokwim Mountain belt, diagonally transverse to the trend of the mountains; and an extensive interior basin province, which lies along the southeastern flanks of the inland section of the Kuskokwim Mountains and is occupied by the large headwater branches and upper course of the main river.

Inasmuch as the headwater or interior basin province of the Kuskokwim Valley, together with the eastern portion of the central province downstream as far as Georgetown, are described by P. S. Smith in another part of this bulletin (p. 249), further mention of these areas will not be made here. The same statement applies to that part of the Kuskokwim Mountains which extends northeastward from the section across them between Georgetown and the Iditarod mining district. A reference to the Kuskokwim-Iditarod section is contained in Smith's report (p. 252), and a large part of this range northeastward from this section has been described in previous Survey publications by Eakin[1] and the writer.[2] Therefore the descriptions of the Kuskokwim Valley here presented will be confined to the western section of the central province from Georgetown downstream and to the lowland province.

An extensive tract of lowlands borders the lower course of Kuskokwim River for a distance of about 300 miles above its mouth. About

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

[2] Maddren, A. G., The Innoko gold-placer district, Alaska: U. S. Geol. Survey Bull. 410, 1910; Gold-placer mining developments in the Innoko-Iditarod region: U. S. Geol. Survey Bull. 480, pp. 236–270, 1911.

100 miles of these lowlands farthest from the sea are of the true valley type in that they occupy a broad area within the Kuskokwim Mountain belt that is bounded by sloping highlands on each side. The remaining 200 miles of lowlands, through which the river flows to the sea, may be more properly considered as being of the coastal-plain type in that they are bounded by highlands only along their southeastern borders within the limits of the Kuskokwim drainage basin, and in that the main river in this stretch is more or less affected by the tides of Bering Sea. On the north the Kuskokwim lowlands merge imperceptibly into similar lowlands that extend along the lower course of Yukon River. These two coalescent lowland tracts expand westward between the lower courses of Kuskokwim and Yukon rivers, a great triangular coastal plain whose area is fully 30,000 square miles. Kuskokwim River flows southwestward through the southern portion of this great lowland in general parallelism with the trend of the Kuskokwim Mountains, on the southeast, at distances of 15 to 30 miles from their foothills. All the large tributaries to the main river throughout this section flow from these mountains.

The tides of Bering Sea extend up Kuskokwim River for fully 100 miles above its mouth, through which distance extensive mud flats and bars obstruct its channel. For another 100 miles upstream from this estuarine portion the current of the river is alternately slackened and accelerated by tidal flow and ebb.

Among the rivers of Alaska the Kuskokwim ranks second to the Yukon in length, volume, and navigability. Light-draft ocean vessels may ascend its tidal portion for a distance of about 150 miles above Goodnews Bay, on Bering Sea, or to the settlement of Bethel, and river steamboats may follow its channel for fully 500 miles above Bethel.

KUSKOKWIM MOUNTAINS.

SUBDIVISIONS.

Geographically the Kuskokwim Mountains may be divided into two principal tracts, northeastern and southwestern, of about equal length and breadth, separated by the middle course of Kuskokwim River. The northeastern or inland tract lies north and northwest of the middle and upper parts of Kuskokwim River, between that stream and tributaries to the Yukon which drain the northwestern flanks of the mountains. The southwestern mountain tract lies south and southeast of the middle and lower parts of Kuskokwim River, between the Kuskokwim and the headwaters of Nushagak and Togiak rivers, which flow southward into Bristol Bay. (See Pl. X, p. 270.)

RELIEF.

In general the Kuskokwim Mountains may be described as a belt of strongly rolling ridges and spurs, 80 to 100 miles in width, in which the summits range from 1,000 to 3,000 feet above sea level, and the most persistent trend is northeast. There are, however, considerable variations from this general trend in parts of the belt.

The most pronounced features of relief in this mountain belt are isolated groups of rugged peaks and higher domelike mountain masses scattered here and there throughout the belt and rising to altitudes of 4,000 to 7,000 feet, so that they stand prominently above the highland elevations that occupy the greater part of the belt. The highest peaks in the belt are situated along the middle of its southwestern division between the sources of Kuethluk and Kanektok rivers. One of the most prominent of these peaks stands at an altitude of about 7,300 feet, and several others in this vicinity, including one named Mount Oratia, are about 6,000 feet in altitude. Throughout the remainder of the Kuskokwim Mountains, however, there are few summits more than 5,000 feet in altitude, and in the inland tract, north of the main river, there are no peaks over that height.

The relief immediately along Kuskokwim River, produced by its direct erosion, is most pronounced in the upper half of the central valley province. In this part a well-developed gorge is entrenched to a depth of more than 1,000 feet across the highland belt for about 50 miles, extending 20 miles above and 30 miles below Georgetown. The river is here confined on both sides by steep mountain slopes, spurs from which are truncated to form rocky bluffs along the banks at frequent intervals. This is the only part of the trunk valley that is so restricted as to present marked relief immediately along both banks. Downstream from this section, throughout the remainder of the mountain belt, broad valley lowlands border the south bank of the river. In sharp contrast to these lowlands, however, the north bank of this part of the river is formed mostly of more or less continuous stretches of rocky bluffs which are truncated from the highland ridges and stand from 200 to 600 feet above the river.

The valleys of the larger tributaries to the Kuskokwim within its gorge section, such as George River and Crooked Creek, have entrenched forms which correspond to that of the trunk valley; but in the lower half of the mountain province the large tributaries occupy rather broad basins which conform with the wider trunk valley in this part. The basins of Aniak River, on the south, and of Kolmakof and Owhat rivers, on the north, are some of the largest of these wider valleys.

DRAINAGE.

Kuskokwim River and its tributaries drain by far the largest part of the Kuskokwim Mountains. In general the main drainage lines show strongest development along the structural trends of this mountain belt—that is, the largest and longest tributaries, as well as the greater part of the trunk river, occupy valleys which extend mainly in a southwest direction, with the trend of the mountains. The most marked exception to this trend of the drainage is shown by the course of the main river in its middle section, which cuts somewhat diagonally across the mountain belt from east to west. Above and below this transverse section the river follows the southeastern and northwestern flanks of the mountain belt, respectively.

GLACIATION.

There is evidence that many of the higher groups of peaks of the Kuskokwim Mountains which stand from 2,000 to 3,000 feet above the main part of the highland belt were the centers of well-developed mountain glaciation during a former period when the drainage conditions of this region were somewhat different from those of the present, or at least that the glaciation considerably modified the character of the former drainage system, from which the present drainage system is inherited.

On the slopes of the high peaks between the headwaters of Kuethluk and Kanektok rivers there are mountain glaciers of considerable size, which appear to be the remnants of much larger and longer mountain valley glaciers. There is ample evidence that formerly such glaciers were numerous and extensive along the central part of the southwestern division of the Kuskokwim Mountains, where they appear to have been developed on almost all the mountain masses above 4,500 feet in altitude. This evidence consists of steep cirque basins at the heads of some of the mountain valleys and bowlder moraines heaped along the valley floors below the cirques, in some places for only a mile or so and in others for many miles. There are also widespread deposits of glacial outwash gravels along these valleys, beyond the moraines, some of which extend for many miles. Some of the details of these glacial features and their economic significance will be discussed in connection with the placer gold deposits which they have affected.

MINERAL RESOURCES.

HISTORICAL OUTLINE.

Cinnabar appears to have been the first mineral authentically reported to occur in the Kuskokwim Valley. For a number of years it was the only mineral definitely mentioned in the few reports published on this region. An account of the discovery and development of these deposits is presented as a separate paper in this bulletin (pp. 272–291).

During the pioneer period of placer mining in the interior of Alaska, before the rush of gold seekers to the Yukon Valley in 1897, apparently only a few transitory attempts were made to prospect in the Kuskokwim Valley. Prospectors are known to have passed through this valley as early as 1889, when Frank Densmore led a party from the Tanana Valley to the Kuskokwim and descended that river to the Yukon portage. About the same time another pioneer prospector, Al King, made the same trip. Afterward Joe Goldsmith crossed from the Yukon by way of the Russian mission portage and ascended the Kuskokwim for several hundred miles. James Cleghorn and Harry Mellish also crossed this portage and wintered at Kolmakof. None of these men, however, appear to have made discoveries of mineral deposits of sufficient value to induce them to remain in or return to the Kuskokwim Valley.

This region appears to have been neglected as a field for prospecting during the early years of the gold excitement that centered in the Klondike and spread along various tributaries of the Yukon. It was not until the Nome boom, in Seward Peninsula, reached its height during 1900 that further attention was directed toward the Kuskokwim region. One of the results of the rush of people to that district was the movement of a small number of men from Nome to the region about the mouth of the Kuskokwim during the summer of 1900, and they prospected in that vicinity for several years. Placer gold was discovered at several localities in the vicinity of Goodnews Bay, and productive mining, on a small scale, was undertaken on Butte Creek, in the basin of Aalalik River near the settlement of Quinhagat, and has been carried on for the last ten years or more.

During the winter of 1900–1901 a typical dog-sled stampede to the Kuskokwim Valley was made by a considerable number of men from Nome. The movement was based on vague rumors of the discovery of placer gold on a stream designated "Yellow River," but the location of this stream in the Kuskokwim Valley does not appear to have been even approximately fixed. Some parties searched for it as far up the Kuskokwim as its headwater branches in the Alaska Range, near Mount McKinley. Ultimately a number of the stampeders arrived on the stream now named Ophir Creek, in the Tuluksak-Aniak district, and decided it to be their goal. Prospects of placer gold are reported to have been found on this stream by these men, and old hewn stakes are now standing in this valley to testify that claims were located there some years ago. Old-timers who participated in this excitement, which is known as the "Yellow River" or "Pete McDonald" stampede, state that the name "Yellow River" was applied to the sluggish outlet of Whitefish Lake, into which Ophir Creek discharges; and that it was so named because the water of the outlet stream is discolored by the combination of iron oxide and decayed vegetable matter so characteristic of swamp water. Others claim that "Yellow River" should be identified with Aniak River because of the silt which is stated to discolor one or more of its headwater branches.

About the time of the "Yellow River" stampede copper-bearing lode prospects were located in the Russian Mountains northwest of the trading post of Kolmakof, but these lode claims and the placer claims on Ophir Creek also were soon relinquished by failure to perform assessment work upon them, and no further interest was shown in them until 1913–14, when they were relocated.

The basin of Holitna River, a large south-side tributary of the Kuskokwim, received considerable attention from prospectors during 1902–3. W. R. Buckman, one of these men, made the first comprehensive sketch map of this extensive drainage area. Outcrops of coal-bearing rocks were noted at several localities. Although colors of gold are reported to occur in many of the gravel bars of this basin, productive deposits have not been found up to the present time.

The discovery of placer gold on the headwaters of Innoko River in 1906 caused a considerable movement of prospectors from Nome up Kuskokwim River the following year. It is estimated that several hundred persons left Nome for the Innoko diggings by way of the Kuskokwim River during 1907. Most of them arrived at their destination after various delays and risks due to unsatisfactory transportation, especially across Bering Sea and into the mouth of the river. A few of these persons, however, did not go all the way to Innoko district but stopped at various points along Kuskokwim River and turned their attention to prospecting some of its tributaries.

One of these parties, of whom William Fisher was a member, ascended Tuluksak River. After finding colors of gold in the gravel bars at several points along that part of the main stream that flows from the mountains, the Fisher party finally discovered gold in commercial quantities on Bear Creek, either in 1907 or 1908. Besides staking two discovery claims on the main creek, the party also located discovery claims at the mouths of two of its tributaries, Bonanza and Spruce creeks. Open-cut mining has been conducted along this stream since that time.

The discovery of the rich Iditarod placer gold deposits during the winter of 1908–9 led to the finding of gold prospects during the summer of 1909 in the basins of George River and Crooked Creek, tributaries to the Kuskokwim running southward from the Iditarod district. The rush of people to the Iditarod in 1910 led to an overflow into the central part of the Kuskokwim Valley during that year and the widespread location of placer claims throughout the basins of George River and Crooked Creek and along the upper valley of Iditarod River. One of the results of this excitement was the establishment of a considerable settlement, named Georgetown, on Kuskokwim River at the mouth of George River in the autumn of 1910. The failure of the prospects on George River and Crooked Creek to develop into large producers of gold caused the practical abandonment of this settlement by the spring of 1911.

At this time the revival of rumors as to the richness of the gold prospects in the Goodnews Bay district and reports of more recent discoveries there caused many of the disappointed men congregated at Georgetown to go to the mouth of the Kuskokwim as soon as the river was free of ice. On finding these reports greatly exaggerated most of the men who took part in the movement returned up Kuskokwim River during the spring and summer. Some of them, however, undertook to prospect several tributaries to the lower Kuskokwim before returning. One of these parties, consisting of Harry Buhro, Kid Fisher, and Fred Labelle, concluded to examine the basin of Aniak River. They appear to have based their decision on the report that a lone and somewhat mysterious prospector, named "Old man" Keeler, had made discoveries of gold in the gravel bars of this river during the summer of 1910, and that a small party of prospectors, who were trailing Keeler, had built a cabin at the mouth of a stream, now named Dominion Creek, in the autumn of 1910 and had spent part of the previous winter there. Buhro, Fisher, and Labelle verified the occurrence of bar prospects and then undertook a somewhat systematic search for the streams from which the gold in the bars might be derived. In August, 1911, Buhro discovered coarse gold on a stream, now named Marvel Creek, in the basin of Salmon River, the westernmost headwater branch of Aniak River. More or less unsuccessful mining has been done on Marvel Creek since 1912.

Other parties who descended the Kuskokwim from Georgetown in 1911 ascended Eek, Kuethluk, and Kiselalik rivers, large streams emptying into the lower Kuskokwim and draining the northwestern flanks of the Kuskokwim Mountains southwest of Aniak and Tuluksak rivers. Prospects of placer gold were discovered on the upper course of Eek River in two creeks, one named Rainy and the other Kopon or Gobown. Although prospecting has been continued on these creeks and others in their vicinity for the last three years, no productive mining has been done up to the present time. In 1913, however, shallow placer deposits were discovered in a short gulch stream on upper Kuethluk River, named Canyon Creek, from which about $14,000 worth of gold was produced during the summer of 1914.

ECONOMIC CONDITIONS.

The foregoing chronologic account of prospecting in the Kuskokwim Valley, while by no means complete as to details, shows that there has been a more or less constant though shifting movement of prospectors throughout this region during the last 15 years. Although the whole valley may be considered to have been covered in a general way, much of the prospecting has been only of a preliminary character.

Such productive localities as have been found point to the conclusion that other deposits of commercial importance may be expected to occur wherever intrusive bodies of granitic rocks cut the country rocks, and that there is still a large field for prospecting in this region, especially for the systematic prospecting that will search out the areas of granitic intrusive rocks and examine them thoroughly in the manner that is suggested on page 306.

Systematic prospecting has been greatly handicapped by the scarcity of permanent supply posts at convenient points along the main river. Most of the prospectors have been obliged to consume much of their time each year in transporting their outfits long distances in order to reach the parts of the region they desired to examine. None of the small productive camps have resulted in the establishment of settlements at the scenes of mining that would furnish facilities of supply near at hand and enable prospectors to devote the greater part of their time to the thorough examination of surrounding areas. From time to time the promise of discoveries in one locality or another has stimulated the establishment of supply posts at a number of points along Kuskokwim River, but the unsettled condition of population and mining development has prevented these posts from becoming fixed with a degree that could be depended upon from year to year.

SETTLEMENTS AND TRANSPORTATION.

The native settlement of Bethel, on the tidal portion of Kuskokwim River, about 100 miles above its entrance into Bering Sea, is the most important supply station for this region, and probably it will always be of commercial importance because of its natural location as a port of entry for ocean-borne traffic to the extensive region drained by Kuskokwim River. Bethel was established in 1886 as the local headquarters of a Moravian missionary society, and since that time has served more or less as a trading center for the native population and a place of supply for prospectors within reach of it. Shallow-draft seagoing power vessels can reach Bethel during the season of open navigation, from June to October, and for the last five or six years a somewhat irregular trade has been carried on between Bethel and Seattle, Wash. Kuskokwim River is navigable for stern-wheel steamboats for fully 500 miles above Bethel. Consequently this place is a logical point for the discharge of ocean traffic and its transshipment up the river. Without doubt the greater part of all supplies for the Kuskokwim region will be brought to it by this water route, no matter where future developments in the valley may take place.

Several river steamboats have been operated on Kuskokwim River each summer since about 1907, when the miners came from Nome to the Innoko district by way of this river. The trade of these boats increased until 1911, when several additional boats were placed upon the river, but since then it has fallen off and in 1914 only one large river boat was required to carry all the freight offered. At its maximum the freight carried on the river each summer amounted to about 2,500 tons, but in 1914 it had dwindled to about 500 tons.

The excitement that resulted in the building of the mushroom settlement of Georgetown in 1910–11 greatly stimulated commercial activity along Kuskokwim River for a year or so. Besides the establishment of several stores at Georgetown, a well-stocked station was placed at the site of the old Russian trading post of Kolmakof, about 65 miles below Georgetown or 150 miles above Bethel. The Kolmakof station was established with the primary object of serving the prospective diggings in the Aniak and Tuluksak basins, to which supplies could be hauled across the Kuskokwim Valley lowlands by way of a winter sled trail. However, both the Kolmakof and Georgetown stations were discontinued in the spring of 1914, and the goods they contained were transferred up the river to a station on Tacotna River, which is still maintained. These changes were due to a marked falling off in business activity because of the fact that mining developments in the Tuluksak-Aniak district have not progressed as rapidly as was expected.

GENERAL DISTRIBUTION.

PLACER GOLD.

Gold is the chief mineral resource now known within the lower Kuskokwim region. Prospects of placer gold are widely distributed in the gravels of a number of streams throughout the mountain belt, but gold has been mined in commercial quantities at only a few localities. The most productive of these are on Bear Creek, in the Tuluksak basin; Marvel Creek, in the Aniak basin; Canyon Creek, on upper Kuethluk River; and Butte Creek, in the basin of Aalalik River. All these localities are in the southwestern division of the Kuskokwim Mountains, and at all of them mining is now being carried on. There are also a number of other creeks within and between the basins of these streams on which prospects of gold have been found. These will be noted in the descriptions of the productive areas.

In that part of the mountain belt that lies north of the middle Kuskokwim, between this river and the Iditarod district, placer gold is being mined in small amount on Crooked Creek, a tributary that empties into the Kuskokwim about 18 miles below Georgetown. Good prospects are being developed also in a small basin, drained by New York Creek, near the bank of the Kuskokwim a few miles above Hoffmans (Napaimut). Prospects of gold are reported to occur on Mission Creek, which flows into the Kuskokwim about 20 miles below Kolmakof from the southwestern part of the Russian Mountains, but no active interest was being shown in this creek during 1914.

During the winter of 1910–11 about 100 men were engaged in prospecting along the upper Iditarod Valley, and since then a few persons have visited this area from time to time. It is reported that prospects of fine gold may be obtained from the bars along the upper course of this river 30 to 70 miles southwest of the Iditarod mining district. The gold in the river bars appears to be traceable to creeks tributary to the river on the right side. These creeks, named in ascending order, are Dome, Moose, Little, Tiny, Slate, Rainy, and Williams. Little Creek is the only one on which valuable prospects were found and is reported to have yielded pans showing 1 to 2 cents worth of fine gold from some of the gravels. The tributaries on the left side of this part of Iditarod Valley appear to be barren of gold. No productive mining has been done within this area up to the present time.

LODE PROSPECTS.

An ore deposit, of the fissure-vein type, composed chiefly of chalcopyrite and arsenopyrite and containing copper, gold, and silver, occurs in the Russian Mountains about 12 miles northwest of Kolmakof. This is the only lode prospect in the lower Kuskokwim region on which serious development work is known to have been done. In 1914 it was prospected by means of a shaft to the depth of about 40 feet.

Float specimens of the copper minerals malachite and azurite are reported from the valley of Kuethluk River, and the presence of galena (sulphide of lead) in the same valley is indicated by a few pebbles of this mineral in the bar gravels of this river.

The occurrence of realgar (sulphide of arsenic) has been noted by prospectors in the headwater area of Eek River.

A prospect of cinnabar occurs on the right bank of Kuskokwim River about 5 miles below the trading post of Kolmakof. It is described elsewhere in this bulletin (pp. 280–286).

COAL PROSPECTS.

Coal crops out in the foothills along the northwest flanks of the Kuskokwim Mountains on Eek and Kuethluk rivers, but little is known either of the areal extent of the coal-bearing formation or of the number and thickness of the beds, for no development work has been done on them.

GENERAL CHARACTER OF MINERALIZATION.

In a broad geologic sense, the widely scattered occurrences of gold and other metals mentioned above appear to be connecting links in a chain of mineral deposits of closely related origin, which seem to have a general though somewhat sporadic development throughout the Kuskokwim Mountain belt. However, they do not warrant the statement that the Kuskokwim Mountains, throughout their extent, are characterized by a mineral belt, in the usual sense of that term.

The agent that introduced or governed the metallic mineralization, especially of gold, appears to be the igneous rocks, chiefly of siliceous granitic types, which are intruded into the country rocks in the form of large and small dikes and extensive massive bodies. Both forms of intrusion are known to occur at intervals from the Tuluksak-Aniak district to the Iditarod district and thence northeastward to the Innoko district. The gold of the productive placer deposits in these districts is, without exception, found in close association with the intrusive rocks and the altered contact zones about their borders. It is reported that the same association with granitic intrusions is characteristic of the placer gold deposits of the Kuethluk, Eek, and Aalalik basins, southwest of the Tuluksak-Aniak district, and the Candle Creek area, south of the Innoko district. Thus an intimate relation appears to be established between the placer gold deposits of the Kuskokwim Mountain belt and the intrusive siliceous granitic rocks that are irregularly but persistently distributed at intervals throughout these mountains. So far as now known there is no exception to the broad application of the above statement, although there appear to be local variations in the mode of original occurrence of the gold, both within the masses of the intrusive rocks and in the contact zones of mineralization about them. For example, in the Iditarod district the gold appears to be deposited chiefly within the body of a massive intrusive granitic rock, but in the Innoko district no massive intrusive rocks occur in the immediate area of gold mineralization and the gold appears to have been introduced by mineralized siliceous dikes that cut the sedimentary country rocks. In the Tuluksak-Aniak district large bodies of the granitic intrusive rocks occur, and the gold of the productive placers on Bear Creek appears to be traceable to these rocks. The alluvial history of the gold-bearing gravels in Bear Creek is so obscured by the presence of glacial outwash gravel deposits of great thickness and extent that it is difficult to trace the placer gold to its primary bedrock source, but there appears to be no doubt that the intrusive rocks of this district have effected the gold mineralization, as in the other districts cited.

SUGGESTIONS TO PROSPECTORS.

The best procedure for prospecting in the Kuskokwim Mountain belt is to search out the areas that contain granitic intrusive rocks, either in the form of large bodies or of dikes, and to confine operations to them or to their vicinity. Special attention should be given to the granitic rocks themselves where they show evidences of veinlets and where they are deeply decayed, as in the Iditarod district. Where the intrusive bodies have been eroded or are in the form of dikes cutting the country rocks, particular attention should be given to the stream deposits that are derived directly from such areas and the zones of contact alteration that generally occur in the country rocks about the borders of the granitic intrusions.

An attempt should be made to recognize the differences between the areas of granitic rocks which have been subjected to mountain glaciation and those which have not, for the unglaciated areas are more favorable for rich placer concentrations. Erosion by glacial ice has been severe enough in some of the higher mountains of the Tuluksak-Aniak district to scatter broadcast any placer gold which may have been accumulated from mineralized intrusive rocks before glaciation occurred. The placer gold deposits of the Iditarod district, on the other hand, illustrate the conditions that may be expected in an area which has not been subjected to glacial erosion, but in which all the evidence points toward slow residual decay of the mineralized granitic rocks and moderate stream concentration throughout a long period of time undisturbed by glacial activity.

TULUKSAK-ANIAK DISTRICT.

LOCATION AND EXTENT.

The Tuluksak-Aniak district comprises the drainage basins of Tuluksak and Aniak rivers, two large tributaries of the Kuskokwim that empty into it from the south at points about 70 miles apart.

The area of the Tuluksak basin is about 1,500 square miles and that of the Aniak basin about 3,000 square miles. The Tuluksak basin lies on the northwestern flanks of the Kuskokwim Mountains, but its headwater branches do not reach far into the interior of the mountain belt. On the other hand, the Aniak basin, which lies east of the Tuluksak basin, is entirely within the mountain belt. Several large headwater branches of the Aniak rise far in the interior of the mountain highland, opposite those of Nushagak and Togiak rivers, which drain a considerable part of the southeastern flanks of the Kuskokwim Mountains. (See Pl. X, p. 270.) The combined area of these two basins lies chiefly between latitude 60° 30′ and 61° 30′ N. and longitude 159° and 161° W. (See Pl. XI, p. 350.)

TULUKSAK RIVER.

The mouth of Tuluksak River is about 60 miles above Bethel, and it is stated that a slight tidal effect is noticeable in the main river up to this point. The lower half of Tuluksak River meanders across the Kuskokwim lowlands by a course fully 60 miles long, though in this part the lowlands are only about 20 miles wide. Within the mountains the Tuluksak has two principal headwater branches, the southern of which is named Fog River and the northern of which is formed by three large streams, named in upstream order Granite, California, and Bear creeks. Each of these creeks occupies a valley of considerable area and is fed by many large tributaries. Bear Creek will be further described under the discussion of its gold placers, the only deposits of economic importance so far developed within the Tuluksak basin.

LOWLANDS BETWEEN TULUKSAK AND ANIAK RIVERS.

The lowlands crossed by the lower course of Tuluksak River extend northeastward up the Kuskokwim to Aniak River, a distance of about 50 miles. Throughout this distance they present the same general aspect, but in their up-river half they are a few miles narrower and occupy a more or less well-defined valley, bounded by rolling highlands on each side. This somewhat confined tract of lowlands within the mountain belt is more clearly a valley than the expansive delta-shaped coastal plain that extends westward from the vicinity of Tuluksak River to Bering Sea along that part of Kuskokwim River which is affected by the tides. The change from the coastal-plain type to the valley type of lowlands is imperceptible, but may be considered to occur between Tuluksak and Aniak rivers, approximately where the Kuskokwim emerges from the mountain belt.

Within the limits of the mountains almost the whole lowland area lies south of the main river. In other words, the Kuskokwim flows along the northern margin of the lowlands, against the flanks of the highlands that form the north slope of the broad lowland valley. The lowland tract contains a practically continuous chain of shallow flood-plain lakes and ponds, with intervening swamps, extending along its southern border against the foothills of the mountains between Tuluksak and Aniak rivers. Nearly all the drainage from the mountains between these two rivers empties into this chain of lakes and ponds, from which it flows indirectly into the Kuskokwim across the wide tract of lowlands by way of a number of very tortuous and for the most part sluggish creeks and sloughs. Thus this lowland tract is poorly drained and is subject to widespread inundations at times of flood. The only streams that maintain well-established courses from the mountains on the south across the full width of the lowlands to the Kuskokwim are Tuluksak and Aniak rivers. Even these large streams maintain their channels with difficulty, as is shown by their wide meandering.

The largest of the shallow bodies of water on this lowland tract is Whitefish Lake. Although 6 miles wide and about 10 miles long this lake has a maximum depth of only about 30 feet and in the greater part of its area is less than 10 feet deep. Whitefish Lake receives a stream about 15 miles long, named Ophir Creek, on which occur prospects of gold that will be described in the discussion of placer deposits.

ANIAK RIVER.

Lower Aniak River flows across the Kuskokwim lowlands in a meandering channel approximately 45 miles long, at a place where the lowlands are about 15 miles broad. South of the lowland tract, within the mountain highland belt, the broad basin of the Aniak is drained by three principal branches, the westernmost of which is named Salmon River and the others Middle Fork and East Fork, respectively. Little is known about the two latter branches beyond the fact that their sources lie well within the mountains, opposite the headwaters of Nushagak River, to the south. Although prospects of gold are reported to occur within the areas drained by the Middle and East forks of the Aniak, so far the only productive deposits of placer gold that have been developed within this basin occur in the valley of Salmon River.

MOUNTAINS BETWEEN TULUKSAK AND ANIAK BASINS.

The wide basin of Aniak River separates a portion of the Kuskokwim highland on the west from the main part of the mountain belt, so that a considerable mountain area occupies a somewhat isolated position between the upper courses of Tuluksak and Aniak rivers. The extent of this mountainous area is about 30 miles from east to west and 60 miles from north to south. It is surrounded by broad lowlands on all sides except the south, where it merges with the main mountain belt that extends southwestward.

The higher ridges of this area, which form the divide between the Tuluksak and Aniak drainage basins, have average altitudes of about 3,000 feet above sea level. The spurs that descend from these ridges to the lowlands form a wide belt of rolling foothills on the west, north, and east flanks of the mountains. About the center of the area several summits stand prominently above the general elevation of the main ridges. The highest of these summits, Marvel Dome, has an altitude of about 4,800 feet. Mount Plummer, whose altitude is about 4,600 feet, stands about 4 miles northwest of Marvel Dome, between the sources of East Fork of Bear Creek on the north and Eagle Creek on the south. A third summit, Mount Hamilton, about 4,300 feet in altitude, stands in the northern part of the area at the sources of Bear and Ophir creeks. Because of its somewhat outlying position, Mount Hamilton overlooks a broad expanse of the Kuskokwim Valley lowlands and may be seen for many miles from points both up and down the main river, so that, although not the highest, it is one of the most prominent summits in the district and serves as a general landmark. Locally Mount Hamilton is known as Bear Creek Dome.

BEAR CREEK AND ITS GOLD PLACERS.

TOPOGRAPHIC FEATURES.

Bear Creek is one of the largest headwater tributaries of the northern branch of Tuluksak River. (See Pl. XI, p. 350.) Its sources occupy a large semicircular basin which lies immediately south of Mount Hamilton and opens toward the east. From this basin the creek flows southeastward for about 5 miles and thence southwestward for about 10 miles through two high mountain ridges, which form the dominant topographic features of this part of the district. In the middle part of this southwesterly course Bear Creek flows for about 4 miles across a pronounced central basin that is inclosed by the two ridges. This inclosed basin is about 15 miles in length, its greater dimension extending in a northwesterly direction, somewhat transverse to the trend of the main valley. The greater part of this central basin area lies southeast of Bear Creek and forms a wide lateral expansion to the valley of the main stream that is drained by two of its longest tributaries—East Fork, about 9 miles long, and Myrtle Creek, about 7 miles long. The part of this basin on the opposite side of Bear Creek is drained by Bonanza Creek, whose length is about 6 miles, and by Spruce and Happy creeks, each about 3 miles in length.

Where Bear Creek crosses the two mountain ridges above and below the expansive central basin along its middle course its valley is considerably constricted. The tributaries in these sections are relatively short and more gulchlike in character than those which drain the central basin.

UNCONSOLIDATED DEPOSITS.

The Bear Creek valley is occupied by widespread deposits of gravel and silt in the form of gently sloping and more or less continuous benches that extend along the entire length of the main stream and throughout the lower area of the expansive central basin drained by East Fork and Myrtle and Bonanza creeks. The main channel of Bear Creek and the lower courses of all its tributaries are more or less intrenched into these deposits to depths ranging in different parts of the valley from 10 to 100 feet or more. In general the amount of the intrenchment is progressively greater downstream, yet this condition is not markedly apparent at first glance because large quantities of the alluvial deposits formerly present along the immediate courses of the streams have been removed as the intrenchment proceeded, especially along the middle course of Bear Creek, where it flows through the central basin and where the alluvial deposits appear to have been deepest. Within this central basin the removal of unconsolidated material along Bear Creek has proceeded to a stage wherein this stream has reduced its flood plain almost to bedrock and for some time has been cutting laterally into the alluvial benches, thus forming a narrow strip of flood plain, from a quarter to half a mile in width, along its channel. The gravels of this flood plain range in depth from 3 to 8 feet and rest on a bedrock floor of fairly uniform grade.

Considerable amounts of coarse gravels and cobbles, with some bowlders, have been secondarily concentrated in this flood plain from the thick bench deposits as a result of their intrenchment, especially along the present channel of Bear Creek. Somewhat away from the present course of the main stream, in those parts of the flood plain that have not been reduced so nearly to the bedrock floor, the unconsolidated deposits appear to be composed more of finer gravel, together with sand and silt that do not appear to have been reconcentrated by the action of the present stream. At least, the larger part of the unconsolidated material somewhat removed from the present channel of Bear Creek is not so coarse as that along the channel. These finer sediments may be, at least in part, deposits that were laid down along the valley floor before the widespread bench gravels were deposited throughout the valley. In other words, a considerable amount of the finer gravels and silts on the bedrock floor of the flood plain may represent the products of an older cycle of stream erosion in this valley that have not yet been affected by the secondary concentrating activities of the stream which are now intrenching and removing the thick bench deposits.

The greater part of the placer gold of this valley, so far as its distribution has been disclosed by prospecting and mining up to the present time, occurs in the gravels of the flood plain which have not been recently washed by the present stream and in the crevices of the shattered and decomposed bedrock upon which the gravels rest.

GOLD PLACER DEPOSITS.

DISTRIBUTION.

The most productive gold placer deposits so far found in the Bear Creek valley occur in the central basin and immediately above it. Most of the claims that have been prospected and worked are located as 20-acre tracts of the conventional dimensions—that is, approximately 1,320 feet in length and 660 feet in width. The longer dimensions of most of the claims extend along the course of the valley, but a few claims cross the trend of the valley in order to inclose more of the shallow gravel deposits.

The initial claim, designated Upper Discovery on Bear, is located just above the mouth of Myrtle Creek. Bonanza Creek empties into Bear Creek near the upper end of Upper Discovery claim. Downstream from this claim more or less prospecting and open-cut mining has been done on claims designated consecutively Nos. 1 to 6 below Upper Discovery. Upstream from it four claims, designated Nos. 1 to 4, above Upper Discovery have been mined to a considerable extent by open-cut methods. Several so-called bench claims located along the right margins of claims Nos. 1 to 6 below Upper Discovery include part of the shallow ground not covered by other locations.

A claim at the mouth of Bonanza Creek, designated Discovery claim for this stream, which immediately adjoins the claims along Bear Creek, has been worked in a profitable manner and may well be considered in connection with the shallow ground along the main creek, with which it is closely associated. Bonanza Creek is staked upstream from its mouth for several miles, but no productive mining appears to have been done within its valley above Discovery claim.

The only other ground on a tributary to Bear Creek in this part of its valley on which mining has been done is on Spruce Creek, a small stream discharging into Bear Creek on claim No. 4 below Upper Discovery, about 1½ miles below Bonanza Creek, on the same side of the valley. The alluvial deposits of Spruce Creek from its mouth to its source are covered by eight claims, each of 20 acres, of which the one at the mouth is designated Discovery claim and the others Nos. 1 to 7 above Discovery. The only mining which has been done on Spruce Creek is represented by an open-cut working on claim No. 1.

Practically all the alluvial ground immediately along Bear Creek has been staked for placer mining and prospecting has been done as far upstream as claim No. 25 above Upper Discovery. A chain of 20-acre claims extends downstream from Upper Discovery for about 3 miles, or to the mouth of East Fork. Below East Fork, where the valley broadens as it leaves the higher mountains and passes through a belt of foothills, a more or less connected series of 160-acre association-group claims has been located. Altogether 10 or more of these association groups, each about 1 mile in length, are so arranged as to occupy about 8 miles of the valley bottom and the benches along the sides. Very little prospecting of a conclusive character has been done on these large tracts, but it is reported that prospects of gold may be obtained from some of their gravels, especially on rims of bedrock that are exposed here and there by the down-cutting of the main stream. The gravels on these bedrock rims may belong to the widespread bench-gravel deposits which fill the valley, but there is a strong possibility that they may be remnants of older stream gravels which have been buried by the bench gravels and recently exposed by the intrenching activity of Bear Creek. This may account for the opinion held by some of the prospectors that the bulk of the bench gravels on lower Bear Creek are poor in gold content. The only productive ground in this valley below the mouth of East Fork that has been worked to any extent is on a small tributary named Tiny Gulch, situated about 8 miles below Upper Discovery claim, on the left side of the main stream.

Except on the Tiny Gulch claims and on claim No. 1 above Discovery on Spruce Creek practically all the productive mining so far done in the Bear Creek valley has been confined to a tract about 3 miles in length, covered by the claims from No. 6 below to No. 4 above Upper Discovery, inclusive. The several so-called bench claims which adjoin claims Nos. 1 to 6 below Upper Discovery along the valley bottom may be included with the creek claims, as they are merely extensions of them. Discovery claim on Bonanza Creek may also be considered to belong essentially to the flood plain of Bear Creek, as it bears a close relation to the contiguous claims along Bear Creek at the confluence of these two streams. The features of this more or less productive tract may well be described without reference to the claim boundaries, because the gold-bearing gravel deposits which it contains have had the same history in all essential particulars.

CHARACTER OF BEDROCK.

The bedrock along the productive section of Bear Creek, defined above, is almost entirely obscured from view by the shallow gravels of the flood plain and the deep bench gravels which border the flood plain on both sides. Bedrock is exposed along the main creek at only a few points, where the stream flows strongly against the escarpments of the benches and has cut away their bases so as to form bluffs. In the lower part of several of these bluffs, especially in one on Upper Discovery claim, bedrock is laid bare in a slightly truncated outcrop beneath the thick bench gravels. To judge from this outcrop and the rather unsatisfactory exposures of bedrock floor that were observed in the few newly dug open cuts available for inspection during 1914, it appears that the dominant bedrock of Bear Creek within the productive area is a massive siliceous granitic intrusive rock. This rock is fine grained in texture and contains considerable biotite mica. It is somewhat decomposed and much fractured. Most of the igneous bedrock is broken into small angular fragments that may be readily loosened with a pick and lifted with a shovel, but some of it is in the form of larger blocks, a foot or more in dimension. These blocks and fragments are closely keyed together, and the innumerable crevices between them furnish spaces for the rapid circulation of water and the lodgment of particles of gold.

The massive granitic bedrock is in turn intruded by dark-colored dikes of diabasic rock which are softer and less fractured than the granitic rocks they cut, or rather the severe crushing to which they have been subjected is shown by mashing, distortion, and slickensided surfaces instead of by distinct, sharp-cut fracturing. Little can be determined in regard to the number and distribution of these dikes, owing to the widespread deposits of unconsolidated material on the bedrock. Small outcrops of the dikes, however, are encountered at frequent intervals in the open cuts on nearly all the claims that have been prospected or mined. Some of the exposures indicate a thickness of 10 to 20 feet for the larger dikes, but others show only a few inches of intruded material. The miners recognize these intrusives by their darker color and softer or tougher texture. Although the granitic bedrock is considerably decomposed, the dark dike rock is more so, and the surface portion of some of it has the consistency of hard clay. Bedrock of this kind appears to have been favorable for the retention of the placer gold in places where it has not been subjected to the strong scour of recent stream action; but in many places where such scouring has occurred it is quite barren of gold. It is much easier to dig and clean than the hard, fractured granitic bedrock, in whose crevices the gold lodges more beneath the surface.

In order to make a good recovery of placer gold from the shattered granitic bedrock the top layer of blocks must be pried apart, but as these blocks readily disintegrate into still smaller fragments the cleaning of the rock is tedious.

In taking up the shattered granitic bedrock considerable care must be exercised to exclude flowing water from the cuts as much as possible, for if water is allowed to flow through the crevices the sediment that fills them and holds the particles of gold is washed from the blocks, with the result that the gold immediately sinks into deeper crevices, from which its recovery by manual labor is almost impossible. In the most successful operations about 1 foot of the shattered bedrock is taken up, but in much of the mining that has been done no attempt was made to recover the gold in the bedrock and only the gravels were shoveled into the sluice boxes.

CHARACTER OF THE GRAVELS.

The gravel deposits along the present flood plain of Bear Creek from claim No. 6 below to claim No. 4 above Upper Discovery are from 3 to 8 feet in depth. In the distance of about 3 miles covered by these claims Bear Creek falls about 50 feet to the mile. The surface of the valley bottom back from the main channel of the stream also conforms in general to this average grade, though here and there it shows minor differences of level of a few feet. The average width of the flood plain is about a quarter of a mile. Although the slightly higher portions of the flood plain have the appearance of low benches and parts of them are located as so-called bench claims, prospecting has disclosed the fact that the gravels of which they are composed are in few places more than 6 feet in depth.

For the most part the surface of the narrow flood plain is bordered on each side by the abrupt but not particularly steep escarpments of the much deeper bench deposits into which the present flood plain of Bear Creek is intrenched. As is to be expected, however, there are here and there a few narrow tracts of intermediate benches, which lie between the higher benches and the lower surface of the shallow flood-plain deposits and evidently mark progressive stages in the development of the intrenched channel as it stands to-day.

The shallow deposits along Bear Creek are composed, for the most part, of well-washed gravels mixed with a small percentage of sand and clay. About a foot of silty soil has accumulated over the more stable portions of the flood plain, and in some parts sand and clay make up the bulk of the alluvial deposit, extending within about 1 foot of the bedrock floor, upon which is a layer of gravels.

The gravels are composed of the several kinds of rock that occur in the valley basin, the sandstone and hard shale or slate country rock, the volcanic agglomerate and tuff associated with these sediments, and the siliceous and basic igneous rocks intruded into them. Most of the gravel is of the siliceous granitic rock, probably because its hardness makes it more resistant to wear. The gravel ranges in size from small pebbles to cobbles 6 to 10 inches in diameter. A few bowlders as large as 3 feet are present.

In general the deposits are rather loosely compacted—that is, the spaces between the gravels and cobbles are not tightly filled or sealed with sand or clay. As a consequence water circulates rather freely through the flood-plain deposits. The supply of water in Bear Creek is so abundant that all the unconsolidated deposits along the flood plain are more or less charged with it. Wherever open cuts are dug to bedrock a free seepage of water almost invariably appears in the excavations, and the low grade of the bedrock floor makes it difficult to construct satisfactory drains to carry the seepage water away from the working cuts. In addition to this the greatly shattered bedrock to a depth of several feet is also charged with a large volume of seepage water that circulates more or less freely. In many places this water appears to be flowing readily through open crevices and often it is under sufficient pressure to cause it to bubble perceptibly, like a small spring, from some of the crevices. Other crevices, however, are more or less sealed by fine sediment, and many of these clogged spaces contain fine particles of gold.

Evidently because of this extraordinary volume of free seepage water the gold-bearing deposits are entirely unfrozen throughout the year, a condition which is unusual for the interior of Alaska, where it is the rule for alluvial ground to be at least partly frozen. The occurrence of the placer gold chiefly in the gravels immediately on bedrock and in the crevices of the shattered bedrock would naturally be expected when consideration is given to the amount of water that flows through the deposits. Yet there is nothing unusual in this distribution of gold, as it is generally so distributed even in frozen placer deposits except where there has been more than one period of gold concentration in a cycle of drainage development.

In the valley of Bear Creek there appears to have been but one primary period of gold concentration—that is, only one period during which the conditions of direct stream erosion and concentration of the products of disintegration of mineralized bedrock were favorable for the formation of placer gold deposits along the present bedrock floor of Bear Creek. The evidence at hand favors the view that the placer gold now found along Bear Creek was concentrated there before the present bench deposits were laid down throughout the valley.

Three distinct periods of drainage development are recorded by the unconsolidated deposits in Bear Creek valley to-day. The record of the oldest may be read in the bedrock form of the valley. It marks a time when the streams were eroding and concentrating the disintegrated bedrock and the gold of mineralized areas of the bedrock. The second period was that during which the valley basin was deeply filled by the alluvial deposits that now form the extensive high benches along the sides of the valley. During this period the streams were so heavily loaded with gravels and silts that concentration did not occur on bedrock, and such concentrations as were already there, as a product of the earlier drainage system, were deeply buried by the continued additions to the sediments, until they were built up to their maximum thickness. The third or youngest period of drainage development is the one which may be observed in the valley to-day. Its principal activity is the intrenchment of the present drainage courses into the thick alluvial deposits laid down during the second period. Although considerable quantities of these thick deposits are being removed in consequence of this intrenchment and coarse gravels from the removed alluvium are being concentrated along the trunk stream and its larger tributaries, this process does not involve a concentration on bedrock such as was effected by the drainage of the oldest period—that is, it does not involve the concentration of newly disintegrated bedrock along the immediate lines of intrenchment except in the few minor areas already cited, where small outcrops of bedrock have been exposed beneath the bench gravels at widely separated intervals along the immediate channel of Bear Creek. In brief, the present drainage development is not of the kind that might be expected to effect a concentration of gold from bedrock, because the bedrock is not being eroded and as a matter of fact has been protected from erosion since the first period of drainage development described above. The drainage of the present period has hardly incised its trunk course near enough to bedrock to have any influence on it whatever. For these reasons the second and third periods of drainage development in Bear Creek valley are considered to have played a very minor part in the concentration of the placer gold now found along the bedrock floor of the valley. In other words, the gold concentration is considered to have occurred almost entirely if not altogether during the first period of drainage development.

The chief facts supporting this argument for only one period of gold concentration in Bear Creek valley may be summarized as follows: Placer gold is produced primarily at stages of drainage development when the streams are concentrating disintegrated rock from mineralized areas. The Bear Creek valley has just passed through a period of drainage development during which its bedrock was not being eroded, but on the contrary was being covered deeply with unconsolidated sediments. Although the present streams have recently begun to erode again, the down-cutting has barely reached the stage where the streams are working near the bedrock floor of the valley and has not yet brought about a condition in which they could make any primary concentration of gold from bedrock. Neither do any of the present large tributaries to Bear Creek appear to be now contributing an appreciable amount of placer gold to the main creek, along which the richest deposits occur. If such a process of enrichment were now in progress, one or more of the larger tributaries to the productive section of Bear Creek should contain gold in proportion to the deposits along the main stream, but this does not appear to be the case.

The only alternative supposition to account for the gold now found along Bear Creek is that which assumes that the gold is derived, by secondary concentration, from the thick bench deposits during the progress of their intrenchment. This supposition does not appear to be satisfactory, because if such were the derivation of the gold it would be natural to expect a proportional distribution of gold along at least some of the intrenched tributaries to the productive section of Bear Creek, which might have acted as an agency of enrichment to the deposits along the main stream, but evidence that the gold had a widespread distribution throughout the bulk of the bench deposits is lacking. At least the outwash character of the bench deposits appears to preclude the possibility that placer gold has been concentrated in particular tracts within them and not in others. The coarser constituents of the bench alluvium show uniform concentration by the down-cutting of both the main stream and its tributaries; consequently it should be expected that placer gold derived from the same source should also be concentrated more or less uniformly along the intrenched stream channels if it were present in the bench deposits with the gravels. As the placer gold along Bear Creek and its tributaries seems not to be uniformly distributed, the only conclusion that appears to satisfy the facts as now known is that the gold has no essential connection with the thick bench gravels or their intrenchment, but is closely related to the period of stream erosion and concentration that preceded the deposition of the thick alluvium of the benches. In other words, the placer gold appears to belong to the oldest period of drainage activity of which there is a record in the Bear Creek valley. This conclusion is more significant when the glacial outwash character of the bench deposits is considered, as will be described below.

The gold now found along Bear Creek occurs on both sides of the present channel, as if the stream in its meandering had cut through what may previously have been a more or less continuous pay streak belonging to an older concentration and thus, by removing the gold-bearing gravels here and there, had produced the somewhat barren spaces that the miners term "blanks." As has been stated, the greater part of the placer gold of this valley occurs in tracts of gravels and shattered and decomposed bedrock that have been least disturbed by the present down-cutting of the stream to, or nearly to, the bedrock floor. Furthermore, the gravels with which the gold is most closely associated appear to be finer and more oxidized than the general run of coarser gravels that have been reconcentrated from the bench deposits.

From the preceding discussion it may be easily understood that the concentration of placer gold along Bear Creek has not had a simple history, but one of many complexities. As one of the chief episodes of this history is that which introduced the thick bench deposits, a description of these deposits is given below.

BENCH DEPOSITS.

The escarpments of the dissected benches which border the present flood plain of Bear Creek are for the most part abrupt, but not particularly steep except where they are now being eroded by the creek as it meanders from one side of its flood plain to the other. Beneath the thick bench gravels in a few of these steep, freshly cut bluff banks are exposed slightly truncated outcrops of bedrock, which indicate something of the gently rolling configuration of the floor upon which the bench deposits rest.

The evidence that the unconsolidated deposits of gravels and silts in the central basin of the Bear Creek valley were formerly much thicker than they are now is furnished chiefly by the margins of these alluvial deposits against the bedrock slopes that border this central basin. These margins are distinctly indicated where the gently sloping surfaces of the alluvial benches abut against the steeper bedrock slopes along the flanks of the mountain ridges and spurs, especially between the larger tributaries, where they have been protected from removal by recent erosion. For example, on the broad bedrock spur between Bonanza and Spruce creeks the upper margin of the alluvial bench stands fully 400 feet above the present flood plain of Bear Creek at the mouth of Myrtle Creek, and on the slopes of the main valley on each side of Happy Creek, opposite the mouth of East Fork, remnants of alluvial benches stand fully 500 feet above the main creek. South of Bear Creek the area between East Fork and Myrtle Creek, which discharge into Bear Creek at points about 3 miles apart, is entirely occupied by an alluvial bench. The surface of this broad bench slopes gradually up toward a mountain spur that stands about 3 miles south from Bear Creek. On the flanks of this spur the margin of the alluvial deposits stands at an elevation of over 500 feet above Bear Creek, which is somewhat higher than the margin of the bench deposits on the north side of the valley, between Bonanza and Spruce creeks. The upper limits of the alluvial bench deposits in the more constricted sections of the Bear Creek valley stand at the same general level as those within the central basin.

The general accordance of level of the margins of these widespread alluvial deposits along the main valley of Bear Creek and throughout its central basin appears to point to the conclusion that this valley was formerly filled with alluvium nearly, if not quite, to the height indicated by the margins of the present benches. At least the alluvial filling was much deeper than at present, for the upper limits of such deposits are clearly of the type that was controlled by one stage of stream aggradation. This view necessitates the conclusion that the surface upon which the alluvial deposits were spread, when they reached their maximum development, must have extended across the whole area of the central basin and up and down the main valley of Bear Creek at the elevation indicated by the present marginal limits of the alluvial deposits. In other words, the evidence of the present benches indicates that practically the whole area of the Bear Creek valley, with the exception of its headwater basin, was filled with unconsolidated gravels and silts, which at the mouth of Myrtle Creek reached a maximum depth of at least 400 feet and at the mouth of East Fork a depth of about 500 feet.

The surface on which the streams were depositing this material was, without doubt, a progressively rising or aggrading one until the maximum thickness of the alluvial deposits was built up. Since then the process has been reversed, and there has been a progressive lowering of the surface during which a considerable bulk of the alluvial deposits has been removed, or ground-sluiced, from the central basin; and the main stream and its principal tributaries have intrenched their channels.

It is obvious that the drainage conditions under which Bear Creek valley was filled with gravel and silts, especially in its extensive inclosed central basin, must have been entirely different from the present conditions, under which that material is being gradually removed. A sufficient cause to account for these conditions, however, is found close at hand, in the part of the central basin that is drained by the upper 6 miles of East Fork, where there are distinct and strong evidences of mountain valley glaciation.

GLACIATION ALONG EAST FORK.

The sources of East Fork occupy a distinct glacial cirque whose steep walls have been eroded in the north flank of Mount Plummer. This summit has an altitude of about 4,600 feet, and the bottom of the cirque is about 2,000 feet below the summit. The point of discharge of East Fork into Bear Creek, about 9 miles from its source, is fully 2,000 feet lower than the bottom of the cirque. Thus the part of the central basin drained by East Fork has a steep gradient, which is ample to permit the discharge of a large quantity of alluvial material into the Bear Creek valley when conditions are favorable for the erosion of such material from the mountains.

The upper 6 miles of the East Fork Valley is now occupied by extensive glacial moraines, which give proof that the mountains bordering this part of the central basin have been subjected to profound erosion. These morainal deposits are composed chiefly of large bowlders, which for the most part have a typically disorderly arrangement, with many potholes and other characteristic glacial features. Some of the potholes hold lakelets and ponds. A group of such lakelets occurs about 6 miles from the source of East Fork, or 3 miles from Bear Creek, at an elevation of about 400 feet above the main stream, approximately at the margin of the broad bench which extends between East Fork and Myrtle Creek. These lakelets appear to mark the site of a well-developed terminal moraine that was deposited by the glacier which formerly occupied East Fork.

Without going into details it may be stated that a glacier at least 6 miles long formerly occupied the upper valley of East Fork and is believed to be a cause sufficient to account for the amount and character of the alluvial bench deposits that now occur throughout the valley of Bear Creek. At its maximum development the East Fork glacier may have reached quite to the mouth of East Fork and thus dammed the whole valley of Bear Creek above that point. On the other hand, such damming of the Bear Creek valley as is necessary to account for the alluvial benches throughout its extent may have been caused by outwash gravels, which were discharged in such large quantities from the glacier's terminus, near the group of lakelets mentioned above, as to effectually clog the valley above East Fork. In either case it is apparent that the Bear Creek valley was filled with outwash gravels and silts, chiefly of glacial derivation, up to the marginal limits of the present widespread benches; and it is also apparent that much of this material has been removed since the melting of the East Fork glacier.

EFFECTS OF GLACIATION ON PLACERS.

The processes of glacial erosion and deposition are very unfavorable to the formation of placer deposits—indeed, they are generally considered to be destructive of such concentrations. Placer deposits of value are not to be expected in areas that show evidences of having been directly eroded by glacial ice unless there has been in such areas a period of stream erosion upon mineralized bedrock since the ice disappeared. Any placer concentrations that might have existed in such areas before the glaciation will have been almost invariably scoured away and scattered broadcast in the sediments outwashed from the glaciers by their melting waters. Gravels and silts deposited by heavily loaded glacial streams, beyond the areas eroded by ice, are not to be expected to concentrate placer gold; for usually such deposits are built up so rapidly by dumping of material in unassorted arrangement as to preclude the processes of stream concentration. On the other hand, however, outwash sediments of this character may be expected to bury previous placer concentrations and thus protect them during the period of active glaciation and long enough afterward for the stream drainage that may succeed the glacial drainage to remove the overburden of glacial outwash deposits.

Although the upper basin of East Fork is occupied by considerable masses of intrusive granitic rock, there is no evidence at hand to prove that the glaciated part of this basin contains rocks mineralized with gold. The evidence that placer gold was deposited in appreciable amounts with the glacial outwash sediments that now form the widespread benches throughout the Bear Creek valley is also negative, as has been considered on pages 314–318.

There is, however, one locality in the Bear Creek valley, on Spruce Creek, where some placer gold appears to have been concentrated in the glacial outwash sediments either during the period of their deposition or during the succeeding period of intrenchment and removal. Nevertheless the chief concentration of gold in Spruce Creek appears to have taken place on its bedrock floor during the period of erosion and concentration that preceded the period of glacial activity. Although the manner of occurrence of some of the gold on Spruce Creek appears to indicate concentrating activity at intervals throughout all three periods of erosion and deposition now recorded by the unconsolidated deposits in the Bear Creek valley, this locality seems to be characterized by special features not found in the valley as a whole. These features are pointed out below.

SPRUCE CREEK.

Spruce Creek is a small tributary, about 3 miles long, that discharges into Bear Creek from the northwest about 1½ miles below Bonanza Creek. Its valley consists of upper and lower sections of quite different character. Its upper mile drains a bedrock basin eroded from a steep mountain spur whose crest stands about 2,000 feet above the mouth of the creek. The stream descends fully 1,500 feet in this distance of 1 mile. In the lower 2 miles the valley is eroded in the bench deposits that are distributed throughout the central basin of Bear Creek. In this lower section the stream has a descent of about 400 feet and does not flow on bedrock at any point.

The erosion of the lower 2 miles of Spruce Creek has removed a large amount of the thick bench deposits, but on the left a well-preserved area of these sediments, 1½ miles broad, extends to Bonanza Creek as a gently sloping bench. There is also a narrow bench of these sediments along the right side of lower Spruce Creek. The upper limits of these bench deposits, on both sides of Spruce Creek and up its valley, stand at approximately 400 feet above the present flood plain of Bear Creek at the mouth of Spruce Creek. From the uniform level of the upper limits of the bench deposits in and about the Spruce Creek valley, and in fact around the entire border of the central basin of the Bear Creek valley, it appears that these sediments attained a thickness of about 400 feet at the present mouth of Spruce Creek at the time of their maximum accumulation. Whether this deep filling really occurred or not, there is ample evidence to show that in the lower 2 miles Spruce Creek has eroded a large quantity of unconsolidated sediments from its valley during the last or intrenchment period of drainage development of Bear Creek and its tributaries. Spruce Creek, being one of the minor tributaries to Bear Creek, is not to be expected to show as thorough intrenchment of the bench sediments within its valley as the trunk stream and its larger tributaries. The result is that a considerable thickness of unconsolidated sediments still remains along the bottom of the lower section of the Spruce Creek valley. For instance, at a point about 1,500 feet above the mouth of the creek the sediments that occupy the valley are at least 20 feet in depth. This depth of sediments is disclosed in an open cut about 280 feet long and 15 to 20 feet wide situated on the lower part of claim No. 1 above Discovery on Spruce Creek. This development work was commenced in 1913 and continued during the summer of 1914 with the labor of about six men. The trench is designed as a bedrock drain. Its upper end, which is 280 feet from the place where it was begun, is 15 feet below the surface. A pipe driven into the sediments at this point indicates the bedrock floor of the valley to be about 5 feet deeper than the trench, or 20 feet below the surface.

An average section of this cut shows from 2 to 4 feet of vegetable muck as a surface layer. Below this muck is from 2 to 3 feet of coarse gravel that contains occasional bowlders as much as 1 foot in diameter. These bowlders are of granitic and agglomerate rocks, and the gravels are made up of the same kinds of rock, together with pebbles of hard sandstone and shale. Beneath these gravels is a layer of bluish clay, from 1 to 1½ feet thick, of the kind that is characteristic of glacial sediments. The deposit below the blue clay is a brown sandy clay with pebbles. It is believed that sediments of this character extend to bedrock.

Several thousand dollars' worth of gold has been mined from the sediments of this cut by washing them through a line of small sluice boxes as the work of excavation progressed. Those who have done this work believe the brown pebbly clay in the bottom part of the cut to be a sort of false bedrock, or, rather, they have found that much of the placer gold occurs above the lowermost sediments and that the best concentration appears to occur on or in the layer of blue clay. Nevertheless gold to the amount of 1 cent to the pan is reported to occur in the brown pebbly clay so far as it has been prospected, and it is thought that good concentrations of gold should occur on the bedrock beneath this clay. Some gold occurs in practically all the sediments, from the layer of muck on the surface to the bottom of the cut.

The washing of the gold from both the blue and the brown clay is difficult because of their tendency to form lumps or balls in the sluice boxes unless thoroughly disintegrated with water; and as the water supply of Spruce Creek is not ample, even for so small an operation, considerable delay was experienced both from the clay and from the accumulation of tailing gravels at the lower end of the sluice, where it was often necessary to employ as many as three men spreading tailings in order to keep the boxes free.

The placer gold mined from this trench is fairly coarse and rough. Small nuggets, worth from 75 cents to $1, are not uncommon. Many of these have quartz attached to them, and the general character of the gold indicates that it has not traveled far from its bedrock source.

The men who made the open cut on claim No. 1 also located the upstream claims Nos. 2 to 6 above Discovery, but have done no development work on them; consequently nothing is known regarding the depth or character of the unconsolidated deposits of these claims except what may be inferred from the cut on claim No. 1. It is probable that the sediments do not exceed 30 feet in depth on any of these claims and that on the upper claims they become more shallow. Claim "No. 7 above" is also staked. These seven claims, together with Discovery claim, at the mouth of the creek, are each about 20 acres in area and of the usual length of a quarter of a mile; thus they cover the 2-mile section of the Spruce Creek valley that is eroded in the unconsolidated bench deposits. The upper mile of the creek does not appear to have been staked for placer mining, although it is reported that prospects of gold may be obtained from the rather meager accumulations of washed gravels which occur along this section.

The upper mile of Spruce Creek appears to have had a simple history; throughout its existence it has been eroding the disintegrated bedrock from the steep mountain slopes of its basin, concentrating this material along its bed, and delivering the stream-washed sediments to the more gently graded lower section of the valley. On the other hand, the history of sedimentation, erosion, and concentration along the lower 2 miles of the valley is somewhat complex in that the products of erosion from the steep headwater basin have not been delivered under uniform conditions of stream activity. Before the bench deposits filled the lower 2 miles of the valley the eroded material from its upper basin was, without doubt, deposited and more or less concentrated along the bedrock floor of the lower section in a normal manner. But upon the invasion of large quantities of bench-forming sediments into the lower section of Spruce Creek valley, apparently in greater part from sources outside of that valley, the stream-washed material delivered from the upper bedrock basin of Spruce Creek appears to have become incorporated with the thick bench sediments, as they were built up, in an unassorted manner and forming a minor part of the deposits as a whole. After the bench sediments ceased to be deposited within the lower valley the stream entered upon the period of intrenchment that has recently characterized all the drainage of the central basin of Bear Creek. During this period large amounts of the unconsolidated bench deposits have been removed and the valley has assumed the form it now presents.

Under the conditions of sedimentation and erosion here outlined it is evident that different kinds of water action have had an important influence on the manner of occurrence of the placer gold contained in the deposits along the lower 2 miles of Spruce Creek. In the absence of evidence to the contrary it may be assumed that all the placer gold in the Spruce Creek valley originated from bedrock within the rather small area of its present drainage basin and not from an outside source. The delivery of the placer gold appears to have been going on before, during, and after the building up of the bench sediments. Secondary concentration of the gold from the bench sediments that have been removed from the valley, together with additions from the upper bedrock basin since the period of intrenchment began, probably accounts for all the gold that occurs above the horizon of the blue clay in the unconsolidated sediments of the lower 2 miles of the valley.

The origin of the gold in the brown pebbly clay beneath the layer of blue clay is not so clear. The more oxidized condition of these brown sediments may mean that they were laid down before the thick bench gravels were introduced into the valley. As has been stated, the conditions of gold concentration on the bedrock floor of the valley beneath the brown sediments are not known at present.

It is possible that some of the placer gold on the bedrock floor of Bear Creek in the vicinity of the mouth of Spruce Creek is derived from the Spruce Creek valley. This inference seems to be especially applicable to what appears to be older and finer gravels that lie beneath the coarser unoxidized flood-plain gravels along Bear Creek and that do not appear to have been disturbed by the recent erosion of that stream. These gravels may be closely related to the older sediments along the bed of Spruce Creek. Such a delivery of gravels and placer gold to the Bear Creek valley from a minor tributary like Spruce Creek could very well have occurred before the deposition of the bench sediments, but there does not appear to have been a favorable condition for such delivery since the invasion of this tributary valley by the thick bench deposits. As the benches were built up to progressively higher levels within the Spruce Creek valley the ability of the small stream to wash gravels containing placer gold to positions much beyond the upstream limits of the progressively rising flood plain was diminished, because the grade of the stream was materially lessened downstream from those limits. Therefore the sediments from the upper bedrock basin of Spruce Creek, together with any placer gold they may have contained, were doubtless incorporated with the bench sediments at successively higher positions up the valley during the accumulation of the bench-forming sediments, instead of being carried down the valley to positions they may have formerly reached along its lower course or beyond in the valley of Bear Creek.

During the period of removal and intrenchment that has succeeded the period of bench accumulation Spruce Creek has not been able to clear its valley of the bench deposits that filled its lower 2 miles and return to its bedrock floor along that section. Consequently any placer gold that may have been concentrated along its bedrock floor during the period that preceded the deposition of the bench sediments should still be there in a practically undisturbed condition. However, Spruce Creek has removed a large amount of the bench sediments and has effected considerable secondary concentration of those sediments during that process. The unoxidized gravels, with small bowlders and cobbles, that lie above the layer of blue clay probably represent the products of this secondary concentration. The placer gold that occurs above the blue clay is evidently also the result of this secondary concentration. It therefore seems probable that practically all the placer gold deposited along the lower 2 miles of Spruce Creek since the deposition of the bench sediments began has been more or less concentrated by secondary stream action within the area of the valley itself and has not enriched the placers of Bear Creek in any material degree.

Spruce Creek appears to be about the only tributary to the central basin of the Bear Creek valley that could have been a source of some of the placer gold now found in Bear Creek—at least it is the only tributary so far discovered that contains gold in commercial amounts. The lack of placer gold in commercial amounts on the other tributaries is probably attributable to the character of the bedrock in which their basins are eroded—that is, it indicates that the bedrock of these tributaries is not mineralized with gold in appreciable amounts. In fact, the bedrock affording the most favorable conditions for gold-bearing mineralization, from which placer gold might be derived, appears to have a distribution that conforms somewhat closely with the area in which the placer gold deposits now occur. This distribution of placer gold within an area of bedrock that appears favorable for gold-bearing mineralization is one of the chief facts in support of the opinion, already expressed, that most of the placer gold now found along the main course of Bear Creek was concentrated in this part of the valley before the invasion of the glacial outwash sediments from East Fork. Conditions favorable for the concentration of placer gold from bedrock along the central course of Bear Creek have been practically lacking since the bench-forming sediments were introduced, because nearly all of the bedrock has been buried. Moreover, as the bench sediments were built up the gradients of the lower courses of all the streams tributary to the central basin of Bear Creek were so lessened that most of them were probably unable to deliver much of the sediment derived from their upper bedrock basins very far beyond the progressively rising upper limits of the flood-plain levels within the lower parts of their valleys. The result of such a condition of stream drainage would be that any placer gold that might be derived from the upper bedrock basins of the tributary streams during the period of bench accumulation would not have a favorable opportunity of being delivered beyond the limits of the valleys of such tributaries to positions along the present central course of Bear Creek. For this reason it does not seem probable that any large percentage of the placer gold now present along the central course of Bear Creek was deposited there by secondary concentration during the period of removal and intrenchment of the bench gravels. The fact that concentrations of placer gold of commercial importance have not been discovered along the larger tributaries to the gold-producing section of Bear Creek seems to indicate that the bedrock of those basins is not mineralized with gold in appreciable amounts. On the other hand, the fact that the character of the bedrock along the central course of Bear Creek, within the general area now occupied by the commercially valuable placers, appears to be entirely favorable for gold-bearing mineralization strengthens the view that the placer gold is essentially of local derivation.

CHARACTER OF BEDROCK.

The country rocks of the upper basin of Spruce Creek are composed of thick strata of agglomerate and fine-grained tuffaceous rocks interbedded with some sandstones and shales, all of which are well hardened and considerably fractured.

A large body of intrusive granitic rock cuts the country rocks near the head of Spruce Creek and forms the crest of the mountains to the south. Contact mineralization from this body of intrusive rock seems to be indicated in the country rocks of the Spruce Creek basin by small quartz stringers in the joint cracks. Some of this quartz is reported to contain gold, and the fact that placer gold attached to vein quartz is found in the creek is corroborative of this report.

On Discovery claim at the mouth of Spruce Creek a fine-grained granite rock that contains considerable biotite mica forms the bedrock in several prospect holes. It is probable that rock of this kind is the chief bedrock of this claim, and also of the claim upstream from it, where decomposed fragments of similar rock are reported to have been brought up by the pipe that was driven into bedrock in the open cut previously described. Rock of the same kind was observed on Discovery claim at the mouth of Bonanza Creek and forms a large part of the bedrock of the productive placer claims along Bear Creek between Spruce and Bonanza creeks and for about 1 mile above Bonanza Creek. The conclusion appears to be warranted that intrusive granitic rocks have a rather extensive and apparently continuous areal distribution beneath the unconsolidated bench deposits in that part of the Bear Creek valley where productive placers are now known to occur. It is not known whether the igneous rocks that lie beneath the bench deposits along the central part of the Bear Creek valley connect with the granitic intrusive body that crops out along the crest of the mountains south of the source of Spruce Creek, but it is thought that these intrusive bodies are closely related if not actually connected.

It may be that the mineralization from which the placers of Bear Creek are derived is intimately associated with the intrusive bedrock upon which much of the placer gold is now concentrated. The fact that the siliceous intrusive rocks along Bear Creek are in turn intruded by basic dikes may be of significance in this connection, for such relations are in many places associated with gold mineralization. Although vein quartz is not uncommon in the joint cracks of both the intrusive and the country rocks of this area, it is not developed in marked amount. The only indication of metallic mineralization with the quartz in the joint cracks that was observed in the placer-bearing area is on Discovery claim at the mouth of Bonanza Creek, where a thin quartz stringer showed discoloration by green malachite stains.

DEVELOPMENT AND PRODUCTION.

GENERAL CONDITIONS.

Since 1909 from 10 to 25 men have been engaged in mining and prospecting on Bear Creek. The actual mining has been done during the summer, but the unfrozen condition of the gravels has enabled some opening-up work and prospecting to be carried on during the winter. Most of the men, however, have been obliged to devote a considerable part of each winter to sledding their supplies for the year to Bear Creek from the trading posts of Bethel and Kolmakof, on Kuskokwim River. The distance by winter trail from Bear Creek to Bethel is about 115 miles and to Kolmakof about 55 miles. The trading post at Kolmakof was maintained only during 1912 and 1913, so most of the supplies used on Bear Creek have been obtained at Bethel. During the last several years freight has been hauled from Bethel to Bear Creek on sleds drawn by reindeer that belong to the natives. The charge for this haul is 5 cents a pound. The same charge has been made for hauling freight from Kolmakof with dog teams.

So far the production of gold from Bear Creek has not been sufficient to encourage the establishment of a supply station at or near the diggings. Such an enterprise should not be difficult to maintain if enough business should be offered. Shallow-draft steamboats can readily ascend Tuluksak River to a point about 30 miles above its mouth, near its junction with Fog River, and poling boats can be used for freighting supplies up the remainder of the river into the lower course of Bear Creek, within a few miles of the diggings. This water route has been used from time to time for transporting supplies with poling boats from Bethel to Bear Creek.

CHARACTER OF DEVELOPMENT.

All the placer mining on Bear Creek up to the present time has been done by simple open-cut, pick-and-shovel methods with small sluice boxes. The low grade of the stream has prevented the adoption of hydraulic methods except for small amounts of crude ground-sluicing to remove superficial accumulations of turf and soil. In 1911 a steam-power scraping and hoisting equipment was brought to Upper Discovery claim, but it has not been placed in operation.

Most of the excavations that have been made on Bear Creek are distributed along the 3 miles of the stream included in the claims from No. 6 below to No. 4 above Upper Discovery. Nearly all the ground so far demonstrated to be productive lies within this area along the main stream, with the exception of Spruce Creek, Tiny Gulch, and Discovery claim, at the mouth of Bonanza Creek. This latter claim is in reality merely a lateral extension of the contiguous claims that lie along the main creek. Such work as has been done above and below this 3-mile tract is now practically abandoned, and the same statement applies to much of the work that has been done within this tract.

All the open cuts have been laid out in the form of bedrock drains or trenches, and many of them have not been developed beyond this form. In some places, however, where the gravel has given more promise of immediate returns, the trenches have been expanded laterally into excavations of considerable dimensions. The most extensive of these pits have been made on Upper Discovery claim, on claims No. 4 below, and Nos. 1, 2, 3, and 4 above Upper Discovery, and on Discovery claim at the mouth of Bonanza Creek.

PRODUCTION.

The value of gold that has been produced from the placers of Bear Creek during the six years of mining from 1909 to 1914, inclusive, is estimated by those in a position to judge to be about $35,000. Full data for the yearly production are not available.

It is reported that the value of the gold produced in 1909 was about $3,500. Most of this gold was mined from a small area on Tiny Gulch. The ground staked on Tiny Gulch comprises only two 20-acre claims, on which the gravels are from 2 to 3 feet in depth. Since 1909 the production from this ground has not been more than a few hundred dollars' worth each year. The value of the output in 1914 is reported to be about $650, and the total value of the gold produced from the two claims on Tiny Gulch during the period 1909–1914 probably does not exceed $5,000.

About $6,000 worth of gold was the average yearly production for Bear Creek from 1910 to 1913. Most of this gold was mined from the open cuts along the main stream, where the gravels vary from 4 to 8 feet in depth. An average of 40 to 50 cents' worth of gold to the square foot of bedrock is the best yield reported to have been obtained from the larger cuts, and much of the mining in these cuts has not yielded more than 20 cents to the square foot of bedrock. In most of these cuts, however, no particular effort seems to have been made to take up much of the shattered bedrock, in the crevices of which considerable gold is lodged, or to control the abundant flowage of seepage water in the cuts while the bedrock was being cleaned. In several operations where more care has been exercised in taking up the bedrock average yields of 30 cents to the square foot of bedrock have been obtained; and in one operation in which particular attention was given to saving the gold in the bedrock an average yield of nearly 50 cents to the square foot is reported.

During the greater part of the summer of 1914 from 12 to 15 men were engaged in mining on Bear Creek, and the total production was about $7,000 worth of gold. The largest number of men engaged on a single operation was six, on claim No. 1 above Discovery, on Spruce Creek. Several of these men were working for wages and received $10 a day without board. Most of the other men were working independently on their own claims or under layman agreements. Two operations were conducted by men working alone; another by two men working as partners on a lay; and a third by two men who owned the claim and hired another man to help.

PROPOSED DEVELOPMENTS.

In 1914 an improved type of portable prospecting drill, operated by gasoline power, was taken to Bear Creek with the object of testing the deposits for dredging. The men who contemplate dredging operations have purchased or bonded nearly all the placer ground along Bear Creek from claim No. 6 below to claim No. 3 above Upper Discovery. During 1914 the drill was used to test this ground, especially that part of the tract included in claims Nos. 1 to 6 below Upper Discovery. The results of open-cut mining that has been done on Upper Discovery claim and the two claims above it are considered to furnish fairly satisfactory data as to the gold content of the gravels on the upper part of the tract which it is planned to dredge. It is reported that a small dredge may be installed on Bear Creek within the next few years. The character of the gravels and bedrock seems to offer no difficulties to dredge mining. It appears that 10 feet is the maximum depth to which a dredge will have to dig in order to handle the gold-bearing deposits on Bear Creek effectually.

Steam power, with wood for fuel, has been considered somewhat favorably for operating a dredge on Bear Creek, but the supply of spruce timber readily available in the valley is not abundant. Most of the timber in this valley is situated downstream from the tract to be dredged, with the exception of a meager amount on the two lowermost claims of the tract, which is not adequate for the operation of a dredge for any great length of time. Consequently the hauling of wood from the lower part of the valley will be a considerable item of expense in operating a dredge with steam power. There is a possibility, however, of obtaining cheaper and more satisfactory power for dredging by installing a small hydroelectric plant on the East Fork of Bear Creek 3 or 4 miles above its mouth. The volume and grade of this stream appear to be ample for such a purpose.

CALIFORNIA AND GRANITE CREEKS.

California and Granite creeks are two streams of about the same length and volume as Bear Creek and, together with that stream, comprise the chief headwater tributaries of the northerly branch of Tuluksak River. (See Pl. XI, p. 350.) They are west of Bear Creek and empty into Tuluksak River from the north about 8 miles apart. California Creek, which lies about midway between Bear and Granite creeks, is by some considered to be the head of Tuluksak River and is so designated, the name California Creek being used in a more restricted sense for one of the tributary streams within this valley.

The valleys of California and Granite creeks are bounded by low mountains and foothills that lie in a broad belt west of the higher mountains that surround the valley of Bear Creek. The headwater basins of these two valleys are separated from the valley of Ophir Creek, to the north, by mountains from 2,000 to 3,000 feet in altitude. These mountains are made up chiefly of massive intrusive granitic rocks. It is reported that the greater part of the valley of Granite Creek is eroded from massive granitic rocks, hence the name of the stream. Rocks of this character are also reported to have a widespread distribution within the valley of California Creek.

Colors of gold are reported to have been found in both Granite and California creeks before gold was discovered on Bear Creek. In fact, it is stated by old-timers that the prospects found on these two creeks encouraged them to extend their search across the divide into the valley of Bear Creek. These men did not consider granite bedrock a good "formation" to prospect for gold. This opinion was probably held generally among Alaskan prospectors until the Iditarod placers were discovered.

The prospects of gold in the valleys of California and Granite creeks appear to be intimately associated with residual and stream-washed products of decay from the granitic rocks. Apparently there are in these valleys no complications of concentration caused by glaciation, such as exist in the Bear Creek valley. Under these conditions the residual granite sands and the stream-washed material derived from them should be worthy of further prospecting.

BOGUS CREEK.

Bogus Creek is a stream of minor size that flows by a tortuous course across the Kuskokwim lowlands about midway between lower Tuluksak River and Whitefish Lake. Its upper course drains part of the outlying foothills situated between Granite Creek and the Kuskokwim lowlands.

It is reported that colors of placer gold may be obtained from the stream gravels of this valley. About 10 years ago a prospecting shaft was sunk here to a depth of 50 feet, and the sediments were found to be frozen to this depth. Since then no further prospecting has been done in the valley. The prospectors who sunk the shaft on Bogus Creek also sunk a shaft to a depth of about 50 feet in frozen ground in the valley of Tuluksak River at a point about 5 miles below the mouth of Granite Creek. It is reported that fine colors of gold were found in both these shafts.

OPHIR CREEK.

LOCATION AND GENERAL FEATURES.

Ophir Creek is a stream of considerable volume, about 15 miles in length, whose source is in Rockpile Pass on the west flank of Mount Hamilton, north of Bear Creek, on the other side of the divide. (See Pl. XI, p. 350.) It flows in a direction somewhat west of north into Whitefish Lake, which is the largest of a chain of lakes and ponds in the Kuskokwim lowlands along the northern border of the foothills between Tuluksak and Aniak rivers. This large lake and Ophir Creek are about midway between the lower courses of the two rivers just named.

Rockpile Pass has an elevation of about 2,000 feet and Whitefish Lake of about 250 feet above sea level, consequently Ophir Creek descends about 1,750 feet in its length of about 15 miles. A thousand feet of this descent is in the upper 3 miles of the creek, where the valley is dominated by Mount Hamilton and its subsidiary spurs. For several miles below this steep upper section the creek falls about 200 feet to the mile and its valley is bordered on both sides by rolling mountain ridges about 1,500 feet in altitude. Thence to its mouth the grade of the stream gradually becomes less, the valley broadens, and the ridges on the sides gradually descend to gently sloping foothills that merge with the Kuskokwim lowlands.

Ophir Creek has no tributaries of consequence from the east and only three of any considerable length from the west. The uppermost of these is about 3 miles long and empties into the main creek about 4 miles from Rockpile Pass. This branch is of note chiefly from the fact that a hot spring is situated within its basin, about 1½ miles above its mouth, in consequence of which it is named Hot Spring Creek. This spring is of scalding temperature at its point of issue, but the water it discharges is cooled within a few hundred yards by mixture with surface water. It flows from a massive granitic intrusive rock that occupies a large area in the upper part of the basin of this tributary. Its waters do not appear to be mineralized; at least no sinter material is deposited about the spring.

The other two west-side tributaries to Ophir Creek are each about 4 miles in length and flow into it about 3 and 5 miles, respectively, below Hot Spring Creek. All three of these tributaries rise on a domelike mountain mass whose summit is about 2,800 feet above sea level. This is the highest mountain flanking the valley of Ophir Creek except those about its source.

The valley of Ophir Creek is in sharp contrast to that of Bear Creek in that it contains no glacial features. Glacial activity appears to have had no part in its development, which as a whole is that of normal stream erosion and deposition in a mountainous country of moderate relief.

CHARACTER OF BEDROCK.

The country rocks of the Ophir Creek valley consist chiefly of stratified volcanic fragmental material of basic composition interbedded with minor amounts of shale and sandstone. Much of the volcanic material is in the form of fine-grained and thinly bedded tuffs, but it includes members of considerable thickness made up of medium-textured agglomerate. All the country rocks are much hardened, and in some of the tuffs and shales slaty cleavage has been developed along the planes of bedding.

An extensive mass of granitic intrusive rock occupies the slopes and ridges of the west side of the Ophir Creek valley in its upper half. The basin of Hot Spring Creek is eroded mainly in this granitic rock, which also forms the domelike mountain mass drained by this stream and the two other larger tributaries of Ophir Creek. The hot spring previously mentioned is near the eastern border of the intrusive mass, where it is in contact with agglomerate country rock. This massive granitic intrusive extends southward from the basin of Hot Spring Creek across the divide into the valley of Bear Creek and thence farther south into the basin of Aniak River, as is described on page 338.

Besides the massive body of granitic rock there are dikes of the same kind cutting the country rocks about the head of the valley, especially in the flanks and subsidiary spurs of Mount Hamilton. Several dikes of andesitic rock cut the stratified volcanic country rocks on the east side of the valley of Ophir Creek about the middle of its length.

UNCONSOLIDATED DEPOSITS.

The change in the grade of Ophir Creek is directly reflected in the character of the stream-washed deposits along the valley bottom. In the upper 5 miles of the valley the greater proportion of the unconsolidated deposits are coarse gravels and cobbles. A number of bowlders of moderate dimensions are also present, especially toward the head of the creek. Downstream from this section of coarser wash the stream gravels become progressively finer, and along the lower half of the valley silts make up a large part of the stream deposits, although fine gravels occur in the present bed of the stream all the way to its mouth. The flood-plain deposits along the lower half of Ophir Creek have the form of wide, low-lying, swampy tracts. The surface of this lowland stands only a few feet above the normal stage of stream flow, and during floods it is extensively inundated. The banks of the main stream throughout the central section of the valley are only a foot or two high, and consequently this part of the flood plain is also subject to overflow. In brief, Ophir Creek is essentially an aggrading stream, flowing upon and building up its flood plain from its mouth to its source. Apparently the stream has had this character throughout its recent history, at least. Possibly this is the reason why the gold in its gravels is not well concentrated but rather widely distributed.

There are no well-developed bench deposits, in the real sense of the term, along the valley of Ophir Creek—that is, there are no deposits that have been laid down by the main stream at a higher level and then intrenched by it. The only sediments that bear the relation of benches to the present flood plain are gently sloping alluvial-fan deposits that have been discharged into the main valley from short gulches along some parts of the central section of the valley. Where these lateral gulches are close together the sloping-fan deposits from them coalesce with one another and give the appearance of benches, especially where the meanders of Ophir Creek are now cutting into them. These so-called bench deposits are frozen for the most part, but nearly all the unconsolidated sediments along the flood plain are unfrozen.

GOLD PLACER PROSPECTS.

It is reported that gold was discovered on Ophir Creek by some of the men who participated in the "Yellow River stampede" during the winter of 1901–2. The prospects were merely fine colors obtained from shallow holes made with wood fires. Although claims were staked at that time no serious prospecting was undertaken, as none of the parties had outfits adequate to enable them to remain in the district.

Ophir Creek does not appear to have attracted further attention from prospectors until 1913. In that year a dozen or more prospectors located claims along the course of the stream for a distance of about 10 miles. These claims extend from a point about 4 miles above the mouth of the creek to a point near its source. In upstream order the principal claims are designated Lower Discovery, Nos. 1 to

12 above Lower Discovery, Nos. 6 to 1 below Upper Discovery, Upper Discovery claim, and Nos. 1 to 8 above Upper Discovery. Most of the claims are 20 acres in area, but some of them are association-group claims of 40 acres.

Most of the men who located claims on Ophir Creek in 1913 came prepared to remain throughout the winter. As a result half a dozen cabins were built and considerable serious prospecting was done. This work was fairly well distributed along the creek, and consequently a good idea of the nature of the alluvial deposits has been gained. Sufficient prospecting has not yet been done, however, to warrant a definite statement as to the value of the gold content in the gravels, though it seems to have been demonstrated that fine gold is somewhat generally distributed along the creek.

The presence of free seepage water in the unfrozen gravels along the flood plain prevented the successful sinking of holes to bedrock on the larger part of the creek claims, but a number of holes were sunk to bedrock in the frozen deposits on both sides of the creek, and two open trenches, or bedrock drains, were dug at places where the gravels were shallow enough for this kind of prospecting.

On Lower Discovery claim a hole 23 feet in depth was sunk to bedrock. It is reported that about 7 feet of sediment at the bottom of this hole prospected about half a cent to the pan.

Another hole about 38 feet in depth was sunk through gravel which is said to have prospected colors through the entire thickness of the deposit with the exception of about 2 feet at the top. This hole is the deepest on the creek.

On claim No. 6 above Lower Discovery a trench intended for a bedrock drain but not carried to bedrock was dug in the flood-plain gravels to a depth of about 3 feet. Colors of gold are said to have been obtained from the gravels of this excavation.

Prospects of 1 cent to the pan are reported to have been obtained from seven or eight holes that were sunk to a depth of 5 or 6 feet on claim No. 7 above Upper Discovery. None of these holes reached bedrock, however, for seepage water was encountered at the depth indicated.

On claim No. 5 below Upper Discovery a hole 14 feet deep was sunk in frozen ground on the right side of the creek. Bedrock was not reached at this depth, but colors of gold are reported to have been obtained.

On Upper Discovery claim a trench 150 feet in length was dug as a bedrock drain and was 7 feet below the surface at its upper end. Colors of gold were panned from this trench, and a drill hole, 5 feet in depth, was driven at its upper end to bedrock, which is thus shown to be about 12 feet beneath the surface of the flood plain at this point.

Prospects of several cents to the pan are reported to have been obtained from this drilled hole.

Two holes were sunk in frozen ground on claims Nos. 3 and 4 above Upper Discovery and encountered bedrock at a depth of 15 feet. A drill hole was made in thawed ground which encountered bedrock at about the same depth. No report as to the prospects that may have been found in these holes was obtained. The same statement applies to claim No. 6 above Upper Discovery, where a hole was sunk in frozen ground to a depth of 22 feet without reaching bedrock.

No prospects of gold have been obtained from Hot Spring Creek, but it is reported that shallow pits on the two other west-side tributaries to Ophir Creek have yielded prospects.

From the work that has been done on Ophir Creek it appears that, owing to the large amount of wet unfrozen ground along the creek, prospecting with a drill should be the most satisfactory method of determining whether the deposits of this valley are of commercial value or not. Drilling was attempted during the winter of 1913–14. The most essential parts of a drill outfit were sledded to Ophir Creek from Bear Creek, where the machine had been operated with steam power the previous year. Several joints of 4-inch casing 5 feet in length, two heavy bits, and a bailer were assembled with the intention of drilling holes by hand. This outfit proved somewhat heavy for effective hand drilling, and most of the time of those interested was consumed in devising a portable drill tower provided with mechanical arrangements for increasing the power of the drill. Inadequate facilities prevented the successful accomplishment of this undertaking and consequently very little actual drilling was done.

From what has been learned of the depth and character of the unconsolidated deposits along Ophir Creek dredge mining would appear to be the method most applicable to the exploitation of the gravels providing they prove to contain sufficient gold.

Ophir Creek is somewhat favored as regards the transportation of heavy mining equipment and supplies, for the water route from Kuskokwim River to Whitefish Lake is available if the proper kind of boat is used. It would be less difficult to place a small dredge on Ophir Creek than on the other placer creeks now known in the district, because tedious and expensive overland hauling would not be necessary.

DOMINION AND ROBIN CREEKS.

LOCATION AND GENERAL CONDITIONS.

Dominion Creek, a stream about 10 miles in length, flows southeastward into Salmon River from the high mountains that stand between its sources and those of Myrtle Creek and East Fork of Bear Creek. (See Pl. XI, p. 350.) The chief headwater basin of Dominion Creek lies on the eastern flanks of Mount Plummer, on whose northern flanks East Fork has its source. This headwater basin has been glaciated, like that of East Fork, although not to so great an extent. There is no question, however, that a considerable body of ice occupied the upper portion of this branch of Dominion Creek during the time when the East Fork glacier was in existence. The ice mass on the Dominion Creek side of Mount Plummer appears to have extended down the valley a mile or more at the time of its maximum development. Its limits are marked by morainal heaps of rock débris. The remainder of the valley bottom is occupied by outwash deposits of gravel and silt which extend to its confluence with the valley of Salmon River, whose bottom is also occupied by extensive alluvial deposits. The outwash deposits along the lower 4 or 5 miles of Dominion Creek are being intrenched by the present stream.

About 3 miles above the mouth of Dominion Creek, its chief tributary, named Robin Creek, enters from the west. Robin Creek is about 5 miles in length. Its upper part, 1 mile long, has a northerly direction and its lower part an easterly direction. The headwaters of Robin Creek occupy a steep basin on the northern flanks of the highest mountain in the district, Marvel Dome, whose altitude is about 4,800 feet. This basin is clearly a glacial cirque and is similar in all respects to the glaciated basin at the head of East Fork of Bear Creek, on the northern slopes of Mount Plummer. The northern slopes of both Mount Plummer and Marvel Dome appear to have been the most favorable situations for the development of glacial conditions in this district, but, although glaciation has also occurred to some extent on their eastern slopes, no glaciers were formed on the southern slopes. The significance of the differences in the character of erosion and stream deposition that have resulted from the presence or absence of glaciers will be pointed out later.

The floor of the glaciated headwater basin of Robin Creek is occupied by considerable morainal débris. Other evidences of the former occupation of this basin by a considerable body of glacial ice are also present. From this evidence it appears that the ice extended down the valley at least 2 miles and possibly farther. The remainder of the valley bottom is deeply mantled with heavy glacial outwash material, much of which is in the form of bowlders. These outwash deposits merge with those of the Dominion Creek valley. The lower 2 miles of Robin Creek is intrenched into them, in accordance with the intrenchment along the lower course of Dominion Creek.

CHARACTER OF BEDROCK.

The basins of Dominion and Robin creeks are almost entirely occupied by a series of interbedded sandstones and shales. The only other rocks known to occur within the area drained by Dominion Creek and its tributaries are granitic intrusives that cut the sedimentary series. These intrusive rocks appear to be distributed in a more or less continuous belt along the high crest of the divide that borders the drainage basin of Dominion Creek on the west, extending from Mount Plummer on the north to Marvel Dome on the south. Although the greater part of this divide is composed of sedimentary rocks, the harder granitic rocks define the serrated crest because of their greater resistance to erosion.

The sedimentary rocks cut by the granitic intrusives along this divide are considerably hardened along the zones of contact, the sandstones being altered to quartzites and the shales to slates. These altered sediments are much fractured and more or less veined with quartz stringers. Although no metallic mineralization was observed in the quartz veins, it may be presumed that some of them contain gold, at least on the southern slopes of Marvel Dome, where productive placers appear to have been derived from their disintegration and erosion.

GOLD PLACER PROSPECTS.

The lower 5 miles or more of Dominion Creek and the part of Robin Creek from its confluence with Dominion Creek to its moraine-filled headwater basin have been staked for placer mining, but very little systematic prospecting has been done in these valleys. It is reported that colors of gold may be obtained from the gravel deposits near the mouth of Dominion Creek.

In the vicinity of claim No. 3, below Discovery, on Robin Creek, which is about a mile above its mouth, several cabins have been built and some prospecting has been done, but no mining has yet been undertaken. The prospects of gold that have been found along this creek indicate that it is widely scattered. This does not appear strange in view of the character of the coarse bowlder-bearing glacial outwash deposits along Robin Creek, and especially of their unassorted condition and their deposition by torrential waters. Bowlders from 1 foot to 5 feet in diameter are very numerous in the unconsolidated deposits of this valley, particularly along the narrow flood plain of the present stream, where more or less secondary concentration has taken place during the recent intrenchment. Because of these conditions the unconsolidated deposits are difficult of exploitation and do not appear favorable for placer mining. At least they are unfavorable to mining if ordinary manual methods are employed, even if they should be demonstrated to contain considerable gold.

Prospectors were led to investigate Robin Creek in particular because of the fact that its headwater basin is eroded from the belt of intruded and altered sediments that passes through Marvel Dome. It was reasoned that if such bedrock relations produced placers of value in the valley of Marvel Creek, on the southern flanks of Marvel Dome, the same relations at the source of Robin Creek, on the northern flanks of this mountain mass, should have produced the same results. It is possible that this reasoning is correct, but the prospectors failed to recognize the fact that the valley of Robin Creek has been affected by glaciation, while that of Marvel Creek has not been glaciated to any appreciable degree. It is obvious that the presence or absence of glaciers which effects the character of erosion and stream concentration on the opposite slopes of a mountain mass, such as Marvel Dome, has also a direct effect on the concentration of placer gold from mineralized areas within the mountain mass.

EUREKA CREEK.

Eureka Creek, which drains the eastern flanks of Marvel Dome, is about 6 miles in length, flows eastward, and empties into Dominion Creek, about a mile from Salmon River. It appears to have many of the characteristics of Robin Creek. Its source is in a steep basin on the eastern slopes of Marvel Dome, separated from the headwaters of Robin Creek by a typical glacial arête. This basin is eroded from the area of altered sedimentary rocks and granitic intrusives already described as forming the central mass of Marvel Dome. The unconsolidated deposits within the basin appear to be of glacial character and the lower valley is occupied by outwash sediments of the same character as those along the valleys of Dominion and Robin creeks.

Small prospects of placer gold are reported to occur in the gravels along parts of the valley of Eureka Creek, where a number of claims have been located, but no mining has been done on them. The remarks made regarding the possibilities of mining on Robin Creek seem to be applicable to Eureka Creek.

MARVEL CREEK.

LOCATION AND GENERAL FEATURES.

Marvel Creek is a stream of moderate volume which flows southward from Marvel Dome about 6 miles into Eagle Creek, which is tributary to Salmon River from the west. (See Pl. XI, p. 350.) The mouth of Marvel Creek is about 2 miles above the mouth of

Eagle Creek. On the east the valley of Marvel Creek is separated from that of Salmon River by a broad mountainous ridge whose rounded summits stand about 3,000 feet above sea level. On the west it is separated from the upper valley of Eagle Creek by a similar ridge. Both these ridges may be considered as southward spurs of Marvel Dome.

The comparatively narrow valley floor of Marvel Creek lies from 1,000 to 2,000 feet below the summits of the ridges, and the valley slopes rise with moderate steepness to the summits, which lie about a mile distant from the creek on both sides. Thus Marvel Creek has no tributaries more than a mile in length.

CHARACTER OF BEDROCK.

The country rock of the Marvel Creek basin appears to be a series of interbedded sandstones and shales similar to the sediments that occur in the basin of Dominion Creek, to the north. The only other rocks observed are the granitic intrusive bodies that cut these sediments in Marvel Dome. In the headwater basin of Marvel Creek there appear to be two masses of granitic rock cutting the sedimentary formations. These extend in a northwesterly direction through the higher mass of Marvel Dome and lie along both sides of the chief headwater branch of Marvel Creek. Along the course of the creek, between these bodies of granitic intrusives, there extends a mass of the sedimentary country rock, which has been considerably hardened and now has the form of blocky fine-grained quartzites and hackly slates. The bodies of intrusive rock appear to terminate in the rugged southeastern spurs of Marvel Dome. No traces of intrusives were observed south of these high spurs in the sedimentary rocks that extend from them and form the rounded ridges bordering the valley of Marvel Creek for 5 miles from its headwater basin. Although the sandstones and shales of these ridges are for the most part well hardened they show no evidences of mineralization from intrusive rocks. Between and near the granitic intrusive bodies, however, considerable contact alteration has occurred. The sedimentary rocks between the two granitic bodies show the greatest alteration, being hardened to dark-gray quartzites and black slates. Several rusty-reddish zones of weathering or oxidation extend through this belt of altered sediments, especially along and near the contacts with the intrusives. No other evidences of mineralization are discernible except a few quartz veinlets.

The sandstones and shales along the outside contacts of the granitic masses are also hardened to quartzites and slates, or the intermediate varieties of such altered sediments termed argillites and phyllites.

The strongest effects of contact-zone hardening die out a short distance away from the granitic intrusives. The hardened sediments of these outer contact zones are considerably fractured into blocks, and the fracture spaces are sealed with vein quartz in the form of irregular stringers. Most of these quartz stringers range in thickness from that of a knife blade to several inches, but a few of them are 8 to 10 inches thick. The largest quartz stringers are distributed along the east flank of the easternmost granitic body, where they show most prominently in freshly broken talus blocks of a more massive member of the sandstones that is coarser grained and less hardened than most of the other sediments near the granites. The quartz is of the glassy porcelain-white variety commonly termed "bull quartz" by prospectors. None of the vein quartz shows appreciable traces of metallic mineralization of any kind beyond red, iron-stained films here and there along fractures, due to surface weathering. All the quartz is surprisingly devoid of traces of sulphide mineralization. However, in the absence of any other evidence, the mineralization associated with the granitic intrusives within the headwater basin of Marvel Creek appears to be the only possible source of the placer gold now found along the creek.

GOLD PLACER DEPOSITS.

FORM OF THE CLAIMS.

Marvel Creek is staked for placer mining from its mouth to its headwater basin. The claims are in the form of six association groups, named, in upstream order, the Pioneer, Camp Robber, Yellow Jacket, Hornet, Wild Horse, and Ready Money. Each of these association groups except the Ready Money comprises an area of about 120 acres, or the equivalent of six ordinary 20-acre placer claims. The dimensions of these group claims are approximately 5,200 feet in length and 1,000 feet in width. The Ready Money group contains only the equivalent of three 20-acre claims and is half the length of the other groups. As the valley bottom of Marvel Creek is comparatively narrow, practically all the gravel deposits along the course of the stream are included in a tract 1,000 feet in width. This consideration led the locators to adopt the dimensions stated. Gold was discovered on this creek in August, 1911, and the claims described were staked at that time.

CHARACTER OF THE GRAVELS.

The steep headwater basin of Marvel Creek, on the southern slopes of Marvel Dome, does not appear to have been glaciated. Thus it is in contrast to the upper basin of Robin Creek, on the northern slopes of the mountain. This contrast is shown not only in the headwater portions of these two streams but in the alluvial deposits along the lower sections of their valleys as well. As a whole the gravels in the Marvel Creek valley are much better assorted than those in the valley of Robin Creek—that is, they show the results of more thorough concentration by normal stream action.

Most of the gravel deposits along Marvel Creek are comparatively shallow. They are distributed along the present flood plain of the stream for a width of 200 to 800 feet and are from 5 to 25 feet in depth. There are also some small, disconnected higher gravel deposits along the borders of the present flood plain that range in depth from 10 to 30 or more feet. These have the position and form of poorly defined sloping bench deposits along the base of the bedrock slopes of the valley. Their surfaces are, for the most part, not very distinct from the lower slopes of the valley, and in some places they merge imperceptibly with the higher portions of the flood plain.

About 4½ miles from the mouth of Marvel Creek, at the point where its two chief headwater branches flow from the steep slopes of Marvel Dome and join, at the upper end of the Ready Money claim, the alluvial deposits are deeper than on the claims below the Ready Money. On this claim a shaft 60 feet deep failed to reach bedrock. The material excavated from this shaft contains a considerable proportion of bowlders of moderate size and many large cobbles. The greater thickness of the unconsolidated deposits at this point and their coarseness are due to the fact that the steep headwater branches of the creek are able to deliver large quantities of heavy wash into the head of the main valley from the slopes of Marvel Dome.

Downstream from the Ready Money claim the alluvial deposits become progressively shallower and finer, yet heavy cobble wash and a number of bowlders occur along the valley for several miles. A peculiarity of the bowlders along the middle section of the creek is that the greater number of them appear to rest on or near the top of the finer gravels, instead of on bedrock beneath the finer wash. Their position with relation to the finer wash seems to be due, at least in part, to their having been carried along the flood plain during periods of torrential stream flow, as if rolled along the top of finer gravel deposits that had been previously distributed along the bed of the valley during more moderate periods of stream flow.

On the Pioneer claim, where the Marvel Creek valley expands laterally into that of Eagle Creek, the sloping bench deposits are much more extensive than up the valley on the other claims, where such deposits occur only here and there as narrow strips along the sides of the flood plain. On the upper part of the Pioneer claim Marvel Creek meanders against a section of the bench gravels on the left and has truncated its channel a few feet into a point of the bedrock floor upon which the higher gravels rest. It is on this exposure of bedrock, or "rim rock," as it is termed by the prospectors, that gold was discovered on Marvel Creek. Although this discovery is reported to have consisted of $1.08 worth of fairly coarse gold in six pans of gravel, further prospecting at this locality has failed to show the presence of gold in paying quantities. None of the bench gravels farther up the creek have been demonstrated to contain enough gold to pay for working. All the productive gold-bearing gravels appear to be included in the creek gravels of the present flood plain.

The gravels of the Marvel Creek valley are composed chiefly of the sedimentary country rocks. Pebbles and cobbles of the hardened phases, quartzite and slate, predominate. The gravels include also, however, a considerable quantity of cobbles and bowlders of the granitic intrusive rocks that occur on Marvel Dome, at the head of the creek. In general, the gravels are coarse and not well rounded. They include many flattish and somewhat angular forms that have the appearance of talus blocks, whose edges and corners have been only slightly rounded. These shapes are particularly characteristic of the cobbles and bowlders.

Considerable silt is present in some of the gravels, and along some parts of the valley layers of tough yellow clay occur on or near bedrock. Some of the miners contend that the best concentrations of gold occur on these patches of clay and that very little gold occurs in the fine gravels or shattered bedrock beneath the clay layers. Other miners assert that much of the gold is contained in the shattered bedrock. As the bedrock alternates from hard blocky sandstones or quartzites to shattered shales or slates according to the manner in which the sedimentary country rocks are interbedded, it is natural that the conditions for the concentration of gold on or in bedrock should vary from place to place. Some of the layers of clay appear as if they might be the products of the residual decay of the shale bedrock with which they are intimately associated. Practically all the unconsolidated creek gravels are unfrozen and are therefore difficult to prospect by means of shafts.

The fall of Marvel Creek in the distance of about 5 miles covered by placer claims is about 600 feet. About 400 feet of this descent has a grade of about 3 per cent, and the remaining 200 feet, along the lower half of the creek, has a grade of about 1½ per cent. The volume of water in the creek appears to be ample for ordinary mining operations.

DEVELOPMENTS AND PRODUCTION.

The locators of the placer claims on Marvel Creek have not undertaken to mine the ground themselves but have adopted the leasing system of development. During 1912 practically all the ground staked along the creek was leased to several persons under the usual agreement that a percentage of all production should be paid to the owners as mining progressed. These leases were not apportioned according to the boundaries of the claims as staked but covered parts of claims or two adjoining claims, according to the desires of the lessees.

The principal operation undertaken in 1912 was on a tract of ground that lay chiefly on the upper part of the Camp Robber claim, but also included the lower part of the Yellow Jacket claim. Here an open cut of about 20,000 square feet was excavated by pick and shovel. The gravels were washed through a line of ordinary small sluice boxes. Shoveling in was commenced about the middle of July and continued to the end of September. Over 500 ounces of gold, or approximately $10,500 worth, was mined from this cut. Thus the ground averaged about 50 cents to the square foot in gold recovered.

The bedrock in this cut is a brown coarse-grained blocky sandstone that appears to form a slight bedrock barrier across the floor of the valley. Considerable gold is reported to be contained in the crevices of this rock. It is stated that much of this gold in the bedrock was not recovered by the operation described, because the blocks could not be easily cleaned or washed through the small sluice boxes employed. No mining has been done in this cut since 1912.

Open-cut pick-and-shovel mining was commenced in 1912 on two adjoining leases farther up Marvel Creek, one of which covered 1,200 feet of the central part of the Hornet claim, and the other the upper 2,100 feet of the Hornet and lower 600 feet of the Wild Horse claim. About $3,500 worth of gold is reported to have been mined from the lease of 1,200 feet on the Hornet claim in 1912. Work on this ground was continued during 1913 and about $1,250 worth of gold was produced. In 1914 an attempt was made to expand operations on this lease by installing a flume 24 inches wide and 1,600 feet long with the purpose of ground-sluicing the gravels and hydraulicking them through the flume in large quantities. For this purpose a ditch was dug along the left slope of the valley that delivered ample water to a penstock about 100 feet above the working pit. Canvas hose was used to deliver the hydraulic water to small nozzles. Poor judgment appears to have been exercised in setting the flume in order to give it sufficient grade to carry the gravels and to bring its upper end to a position on bedrock where it could be effectively used for mining of this kind. As installed in 1914 this flume had several sharp curves along its course, where the gravels clogged in the boxes, and its upper end was set about 4 feet above the bedrock floor of the valley, with the result that the gravels, after being ground-sluiced into the cut, had to be shoveled into the flume for washing.

Much of the gravel washed was conveyed from the cut to the boxes in wheelbarrows. A large amount of freely flowing seepage water was present in the cut and hindered the efficient cleaning of the shattered bedrock. The bedrock in this cut is shattered sandstone and shale, and the overburden consists of these country rocks with some of granite. Bowlders of these rocks weighing as much as 100 pounds, together with many cobbles of the same kind, are abundant in the deposit. The gravels containing gold in paying quantities appear to have what is termed a spotted distribution in the deposits as a whole. The operation of 1914 was unsuccessful. A clean-up on August 14 of about 700 square feet of bedrock, representing the labor of four men for 15 days, yielded only $136 worth of gold. Work that was carried on until the later part of September was not expected to yield more than 10 cents to the square foot of bedrock surface. Probably not more than $1,500 worth of gold was produced from this lease of 1,200 feet of ground on the Hornet claim during 1914. The approximate production of gold from this tract may be summarized as follows: 1912, $3,500; 1913, $1,250; 1914, $1,500; total, $6,250. Those interested in this property plan to reset the flume on bedrock in a proper manner and continue mining operations during 1915 by ground-sluicing and hydraulicking with canvas hose.

No mining was done during 1914 on the tract included in the lease that covers the upper 2,100 feet of the Hornet claim and the lower 600 feet of the Wild Horse claim. In 1912 preliminary work on this ground yielded about 6½ ounces of gold, worth about $120. This work was continued in 1913, when about six men were employed for the season. The mining was carried on by shoveling into a line of ordinary small sluice boxes. An area of about 11,000 square feet of bedrock was worked in this manner. The yield is reported to have been about $2,500 worth of gold and to have barely paid the expenses of operation.

A company was organized in 1912 under the name Marvel Creek Mining Co., and reorganized in 1913 under the name Marvel Creek Mining & Development Co., to mine the gravels along the lower half of Marvel Creek. The company leased for five years the tract covered by the Pioneer, Camp Robber, and Yellow Jacket claims and the lower 850 feet of the Hornet claim. The plan of operation adopted was similar to that attempted on the central section of the Hornet claim—that is, it involved ground-sluicing and hydraulicking through a large flume. In 1913 a ditch nearly 1 mile long was dug along the right slope of the valley to furnish hydraulic water, and a large number of flume boxes, 30 inches wide, were built and partly set in place. In the spring of 1914, the flume was completed, and early in June active mining was begun with a crew of 13 men.

Mining was continued until July 21, but did not progress favorably because the flume did not have sufficient grade to carry the gravel and was not set on bedrock. It was necessary to shovel all the gravel up into the flume and to keep several men working along the boxes to prevent the gravels from clogging in the flume. It is reported that panning tests showed the gravels to contain values from 50 cents to $1 to the square foot of bedrock. The cost of the operation, as undertaken, is stated to have been about 50 cents to the square foot. The gold recovered from a clean-up for the seven weeks of operation amounted to 104 ounces, worth about $1,775. Owing to this poor showing operations were discontinued. The men employed received only one-third of the wages due them for their labor. Two men continued to shovel gravel into this flume during the remainder of the season. The total production for the operation is estimated to be about $2,000.

The difficulty with the two large flumes installed on Marvel Creek in 1914 was due primarily to the fact that the flumes were not properly set on bedrock with sufficient grade. It seems doubtful whether the grade of the bedrock floor along the lower half of this creek is sufficient to allow setting such a flume so that it would carry the gravels satisfactorily. It appears that some means is necessary for stacking the tailings delivered at the lower end of the flume. However, a simple conveyer operated by a Pelton wheel or similar water-power device should prove efficient for the purpose of elevating and stacking the gravels to a height of 15 or 20 feet. Farther up the creek, on and above the Hornet claim, a 3 per cent grade may be obtained for setting a bedrock flume, and it is probable that the disposal of tailings would not be so difficult, yet mechanical means for such disposal in the form of a tailings giant or stacker may prove necessary.

The value of the total production of gold from Marvel Creek for the three years in which mining has been done may be summarized as follows: 1912, $14,120; 1913, $3,750; 1914, $3,500; total, $21,370.

FISHER CREEK.

Fisher Creek is a stream about 9 miles in length, of good volume, that discharges into Salmon River from the southwest about 5 miles above the mouth of Eagle Creek. Its chief headwaters drain the eastern slopes of Fisher Dome, a mountain mass about 4,000 feet in altitude. From this mountain the upper half of Fisher Creek flows southeastward; it then makes a right-angle turn to the left, so that the lower half of its course flows northeastward into the Salmon.

The basin of this stream is eroded from the same series of interbedded sandstone and shale country rocks that occupy the valley of

Marvel Creek to the north. In the high mountainous ridge that borders the upper half of the Fisher Creek valley on the northeast a few outcrops of granitic dike rocks cut the sedimentary series. Intrusive rocks of the same kind are reported to occur in more massive form in Fisher Dome, at the source of the creek. Prospectors consider that the conditions of intrusion and mineralization in Fisher Dome are similar to those in Marvel Dome.

The men who discovered gold on Marvel Creek state that they obtained fair prospects of fine gold in the gravel bars at the mouth of Fisher Creek before they found coarse gold on Marvel Creek. After staking Marvel Creek they also located placer claims along the course of Fisher Creek, but no prospecting of consequence was done on the latter stream until the winter of 1913–14. At that time a cabin was built at the bend of the creek, about 4 miles above its mouth, and about half a dozen holes were sunk to bedrock in the vicinity of the cabin. These holes, which ranged in depth from 15 to 30 feet, penetrated frozen deposits of silt and gravel. No prospects of gold were found of sufficient worth to encourage further developments. Apparently the upper part of the creek near Fisher Dome, where the intrusive rocks and associated evidences of mineralization are reported to be more abundantly developed, has not been prospected up to the present time.

CRIPPLE CREEK AND TRIBUTARIES.

Soon after Marvel Creek was discovered extensive locations of placer claims were made on the headwaters of Salmon River, especially on Bell and Cripple creeks, two large streams that enter the river on the right from the southeast. Bell Creek is situated immediately east of Cripple Creek, and its mouth is about a mile below the confluence of that stream with Salmon River. Although the gravels within the valley of Bell Creek have been prospected in a preliminary manner, no developments have been undertaken.

GENERAL FEATURES OF CRIPPLE CREEK.

Cripple Creek is a stream of large volume, about 14 miles in length, that discharges into Salmon River about 4 miles above Fisher Creek, or 8 miles above Eagle Creek. This stream, with its three chief west-side tributaries, named in upstream order Porcupine, Dome, and Loco creeks, drains an extensive headwater basin of Salmon River, bounded on the south by mountains whose summits stand from 4,000 to nearly 5,000 feet above sea level. These mountains appear to have been occupied by extensive glaciers during a former period. The rather gentle slopes of the upper half of the

Cripple Creek basin are mantled by heavy morainal deposits, composed chiefly of large bowlders. The irregular features of deposition characteristic of such deposits are well developed on the broad, gently sloping ridge that separates Dome and Loco creeks, and also on the slopes of the upper valley southeast from Loco Creek. Potholes, containing small ponds of water, occur along the margin of the moraine.

Dome and Loco creeks have intrenched their channels into the mantle of moraine, and in some places along their courses have exposed the bedrock floor upon which the morainal deposits rest. From the amount of intrenchment by these streams it may be roughly estimated that the morainal deposits vary in thickness from 25 to 100 feet or more.

The lower half of the Cripple Creek valley, especially along its west side, is occupied by thick deposits of glacial outwash gravels, which also extend down the valley of Salmon River for fully 20 miles to and beyond Dominion Creek, from which similar gravels were discharged into the valley of the main river, as described on pages 337–339. Since these gravels were deposited Cripple Creek and Salmon River have intrenched their channels through them to the bedrock floor upon which they rest, and at many places the streams have cut into the bedrock to depths of 10 to 30 feet. These bedrock exposures, however, do not appear to represent an actual downcutting below the old bedrock grades so much as the lateral truncation of noses of bedrock slopes or spurs that lie buried beneath the gravels, against which the present streams have been deflected during their intrenchment.

CHARACTER OF BEDROCK.

The country rock of practically all that part of Cripple Creek basin that is not hidden by morainal deposits consists of the hard quartzite and slate phases of the sandstone and shale series that occupies the whole area of the Salmon River valley so far as it was examined. The high mountains at the head of Cripple Creek were not visited, but from the predominance of large bowlders of granitic intrusive rock in the morainal deposits throughout the upper half of the Cripple Creek basin it is surmised that massive bodies of granitic intrusives make up a considerable part of the mountains that adjoin this basin on the south. Prospectors report that a large dikelike body of granitic rock is exposed beneath the morainal deposits on the upper course of Dome Creek, and that the domelike mountain at the source of this creek is made up chiefly of intrusive granitic rock.

On the high mountain ridge east of Cripple Creek, between it and Bell Creek, a wide dikelike body of siliceous intrusive rock cuts the sedimentary country rocks. It is quite possible that many other dikes of a similar kind are intruded into the sedimentary rocks of this basin.

GOLD PLACER PROSPECTS.

Prospects of placer gold occur along the lower 7 or 8 miles of Cripple Creek, within the area occupied by the thick deposits of outwash gravels, and also along the lower half of Dome Creek, which is intrenched into these deposits. The gold has two modes of occurrence—in the shallow, recently washed gravels along the narrow intrenched flood plains of the present streams, and in the thick outwash gravel deposits that now have the position of benches above the drainage levels. It is evident that the gold in the benches is older than the gold in the recent stream wash, and it is probable that all the gold along the beds of the present streams is derived from the the thick bench deposits by the process of secondary concentration that has accompanied the intrenchment of those deposits down to the bedrock floor of the valley.

The source of the gold in the bench gravels, however, is not so evident. Two assumptions may be made regarding it. One is that the gold now found on the older bedrock floor of the valley, at the base of the bench gravels, was concentrated there before the thick deposits of outwash gravels buried the old valley floor. The other is that the gold was introduced into the bench deposits while they were being laid down. If the latter assumption is correct the gold should be distributed more or less generally through the thick gravel deposits, because they are not well assorted. The small amount of prospecting that has been done in the bench deposits of this valley, chiefly by means of several short tunnels, appears to indicate that the placer gold in the bench deposits is concentrated on or very near the bedrock floor, and that the higher portions of the gravels contain little if any gold. While not conclusive, this scanty evidence might be interpreted to favor the first assumption.

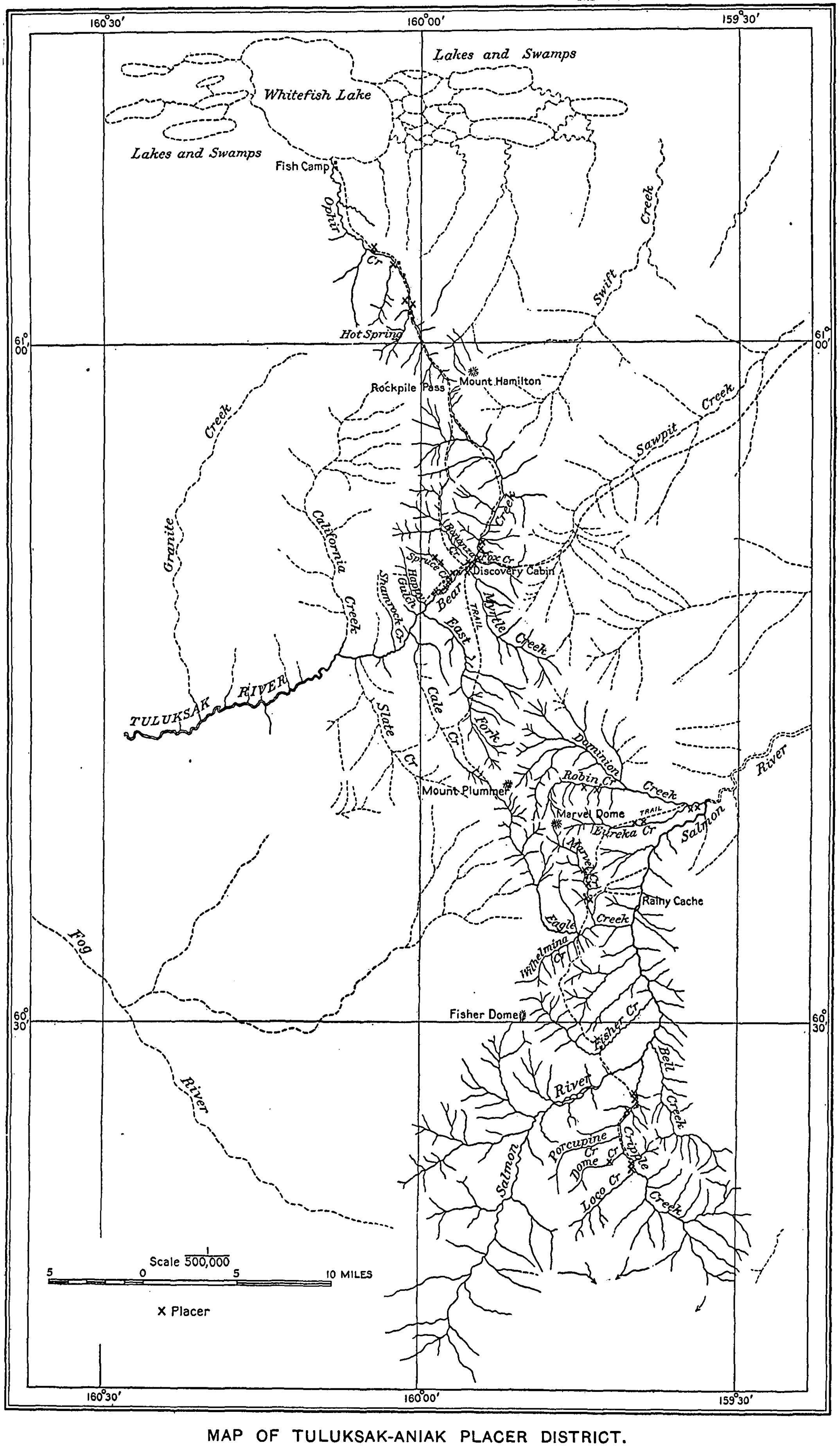
No commercially productive mining has been done on Cripple Creek or its tributaries. The prospecting of the bench gravels by means of tunnels, already mentioned, was done at a point about 2½ miles above the mouth of Cripple Creek, on its left side, where the stream has cut into the bedrock floor to a depth of 10 or 15 feet. It is reported that one tunnel was dug into the gravels for a distance of about 60 feet and that some of the gravels on bedrock showed 2 cents' worth of gold to the pan. The bench gravels at this place are at least 100 feet thick, and it is the opinion of mining men who have examined them that they are too deep to be mined by dredges even if they should be demonstrated to contain commercial quantities of gold.

About 200 yards below the mouth of Loco Creek, on the left bank of the main stream, a narrow strip of bench has been prospected by ground-sluicing and open-cut work. This bench lies along the margin of the morainal deposits that extend between Dome and Loco creeks and appears to consist chiefly of stream-washed morainal material. It contains a number of large morainal bowlders. The water for ground sluicing was conveyed by ditches from small pot-hole ponds on the margin of the moraine a short distance back of the narrow bench and about 50 feet above it. Most of this work was done in 1913. In 1914 one man continued the operation on a small scale. It is not known how much gold was mined, but from the fact that the men who initiated the work abandoned the property it is understood to have been unprofitable.

In the flood plain of Cripple Creek about a mile below the mouth of Loco Creek a bedrock drain was being dug by one man during 1914. A few dollars' worth of fine flaky gold was obtained from this trench, but the presence of gold in commercial quantities had not been demonstrated.

Shallow bar gravels along the present bed of Cripple Creek from 2 to 3 miles above its mouth were washed with a rocker, by one man, during the summer of 1913. This method of mining was much favored during that season by very low water in the streams. Gravel bars that were entirely inaccessible during ordinary stages of stream flow were then within reach. It is reported that some bars, or rather small areas within them, yielded as much as $1 worth of fine gold in an hour of rocking. This, however, was far above the average yield. In 1914 several men attempted to mine one of the most promising of these bars on a larger scale by shoveling into a line of sluice boxes, but the results of this work were practically negligible. The extreme lightness of the gold made it very difficult to save, and a higher stage of the stream prevented digging in as favorable parts of the bar as were available in the summer of 1913.

The gold in the shallow gravel bars along the narrow intrenched flood plain of Cripple Creek is probably derived chiefly from the bench gravels by secondary concentration. In eroding into and removing the large quantity of outwash gravels that formerly filled the valley to a considerable depth the main stream appears to have reached and reestablished itself upon the original bedrock floor of the valley, with minor modifications here and there where it has cut laterally into the bedrock floor, as is shown by the low bluff outcrops of bedrock beneath the bench gravels along some sections of the creek. Cripple Creek is a stream of large volume and its grade is sufficient to give it considerable power to transport the gravels along its bedrock floor. It is also subject to violent and sometimes torrential floods each season, and often several



MAP OF TULUKSAK-ANIAK PLACER DISTRICT.

floods occur in one season. Consequently the gravel bars along its channel are not stable but shift more or less from year to year or even from one period of high water to another in the same year. Without doubt a uniform concentration of gold in the present bar gravels is impossible, owing to these fluctuations in the eroding and transporting activities of the stream. Under these conditions the formation of a pay streak of placer gold of any marked continuity in the bar gravels is not to be expected.

PLACERS ON MIDDLE KUSKOKWIM RIVER.

Placer gold has been mined from two tributaries of Kuskokwim River—Crooked Creek and New York Creek—in the middle section of the main valley, where the river has cut across the broad mountain belt of the region from east to west, as described on pages 295, 297.

CROOKED CREEK.

Crooked Creek is a large stream that empties into Kuskokwim River from the north about 18 miles below Georgetown. This settlement, which is now practically abandoned, is half a mile below the mouth of George River, another large north-side tributary to the Kuskokwim, whose basin lies immediately east of that of Crooked Creek. The sources of both Crooked Creek and George River are divided on the north from the headwaters of Bonanza Creek, a large tributary to Iditarod River.

The valley of Crooked Creek extends from north to south for a direct distance of about 35 miles. The area of the valley within which prospects of placer gold occur occupies about 7 miles of its middle length and is about 25 miles south of the rich placers on Otter and Flat creeks, in the Iditarod district.

The country rocks from which the valley of Crooked Creek is eroded comprise the thick sedimentary series of interbedded sandstones and shales that characterize the whole Kuskokwim Mountain belt. In the vicinity of the placer gold locality these sedimentary rocks are cut by considerable bodies of siliceous intrusive rock. It is probable that mineralization from the intrusive rock is the source of the placer gold.

Placer gold was discovered on Crooked Creek in 1909 by prospectors who entered the Kuskokwim Valley from the Iditarod district. The rush of people to the Iditarod in 1910 caused a large overflow of men into the valleys of both Crooked Creek and George River during the later part of that year, especially after gold in paying quantities was found in August on Snow Gulch, a short tributary to Crooked Creek from the east. The excitement that followed this discovery resulted in widespread staking of ground for placer mining throughout the valleys of Crooked Creek and George River and culminated late in the fall in the establishment of the settlement of Georgetown.

The productive mining on Crooked Creek is practically confined to the lower courses of Quartz, Snow, and Ruby creeks, three gulch tributaries that flow into the main stream from the east. The placer gold occurs in bench gravels that lie along the east side of Crooked Creek and have been intrenched to depths of 15 to 30 feet by the lower courses of the gulch streams, and in the present gravels of these streams, derived by secondary concentration from the bench gravels as a result of the intrenchment.

Quartz Gulch, which empties into Crooked Creek about 12 miles from its source, has proved to be the largest producer of placer gold in the valley up to the present time. In 1910 gold to the value of $1,400 was mined from claim No. 1, at the mouth of this gulch; and in 1912 this claim produced gold to the value of $29,000, of which $23,000 was mined from the stream gravels during the summer and $6,000 from short drifts into the bench gravels during the winter. The open-cut summer mining was done in gravels 6 to 7 feet deep, and the winter drift mining in bench gravels 20 to 25 feet deep. The productive area on Quartz Gulch is rather small, being practically confined to the lower part of claim No. 1, at the mouth of the stream. During 1913 and 1914 two men have mined on this claim and their production of gold has been about $3,000 each year.

On Snow Gulch, which is about half a mile below Quartz Gulch, the first mining in the Crooked Creek valley was done in 1910, at a point about 1,000 feet above its mouth. Here gold to the value of about $2,000 has been produced. In the bench gravels to the right of this locality about $600 worth of gold was mined in 1911 and about $2,300 worth in 1912. Snow Gulch is the only one of the three productive tributaries on which placer gold is reported to be distributed along any considerable distance of the stream. For five claims above its mouth, or a distance of about 1¼ miles, the stream gravels yield appreciable prospects of gold. This distance corresponds approximately to the width of the bench gravels in this part of the Crooked Creek valley, across which the tributaries from the east have intrenched their lower courses on leaving their upper rock-cut gulch sections. It may also be noted that the eastern contact of the igneous intrusive rock which occurs in the gold-bearing area crosses Snow Gulch from the steep mountain spur that separates Snow and Quartz gulches, about 1¼ miles above the mouth of Snow Gulch. This contact with the sedimentary country rocks may mark a zone of gold mineralization from which the placer gold along the stream below this point may be derived.

Ruby Gulch, which is about half a mile below Snow Gulch, is similar to it in all essential features. In 1911 placer gold to the value of about $3,000 was mined from this stream at a point near its mouth.

It is reported that prospects of gold occur along the valley of Crooked Creek from the mouth of Quartz Gulch downstream for a distance of about 7 miles, to the mouth of Crevice Creek, a tributary from the east. Prospect holes sunk in the bench gravels that lie to the left of the main creek throughout this distance have shown values of 10 cents to the pan, and one hole near the mouth of Crevice Creek is reported to have yielded a prospect worth $2.

The production of placer gold from the valley of Crooked Creek may be summarized as follows:

Production of placer gold in Crooked Creek valley.

Year.	Quartz Gulch.	Snow Gulch.	Ruby Gulch.
1910	$1,400	$2,000	
1911		2,900	$3,000
1912	29,000		
1913	3,000±		
1914	3,000±		
	36,400±	4,900	3,000

Total, $44,300±.

NEW YORK CREEK.

New York Creek is a small stream that discharges into Kuskokwim River from the north about 3 miles above the small native trading settlement of Hoffmans or Napaimut, which is about 9 miles above Kolmakof. Placer gold was discovered on Murray Gulch, a short right-side tributary to New York Creek, in 1910. More or less prospecting has been done each year since the discovery along the lower three-fourths of a mile of Murray Gulch and in the valley of the main stream near the mouth of this gulch. Although good prospects of coarse gold have been found both in the deep gravels along the bed of Murray Gulch and in strips of bench gravels along the slopes of its valley, no systematic mining operations have yet been undertaken.

A rocky bluff about 500 feet high, on the north bank of Kuskokwim River just below the mouth of New York Creek, affords a good exposure of the sedimentary country rocks of this area, together with some siliceous dikes that are intruded into them. The sedimentary rocks consist of heavy beds of sandstone, from 4 to 6 feet thick, interbedded with dark shales, standing at high angles. The sandstones are much cross fractured or jointed, and the shales are much compressed and crushed. The dikes are intruded diagonally across the strike of the sediments as irregular bodies that range from 1 foot to 3 feet or more in thickness.

The vein minerals that fill the joint seams in the sandstones and the sheared spaces in the shales consist of an intergrown mixture of calcite and quartz. Lenticular stringers of these minerals, from 1 inch to 3 inches thick, are deposited along the borders of the dikes that cut the sediments. Some highly carbonaceous, almost graphitic gouge has resulted from the crushed shales along the borders of the dikes. Fragments of the shale country rock are included in the dike rock. Zones of reddish iron-stained country rock are common in the vicinity of the dikes.

Both the sedimentary and dike rocks shown in this bluff extend northwestward from the river across the basin of New York Creek. Outcrops of the dike rocks that correspond in trend with those in the river bluff, and are probably extensions of the same bodies, cross the upper part of Murray Gulch 1 mile above its mouth and about three-quarters of a mile back from the outcrops in the bluff. The bedrock source of the placer gold in Murray Gulch is probably closely related to these intrusive rocks, or to zones of contact mineralization along their borders in the sedimentary rocks. All the placer gold that has been found in Murray Gulch appears to be distributed downstream from the dikes that cross the headwater basin of the gulch.

Three 20-acre placer claims cover practically all the alluvial deposits along Murray Gulch that have yielded prospects of gold. The claim at the mouth of the stream is designated Discovery and the claims upstream from it Nos. 1 and 2 above Discovery.

The unconsolidated sediments along the present course of the stream consist chiefly of silt overlying several feet of gravels that rest on bedrock. There is also considerable decayed vegetable matter, or muck, on top of the silt. These deposits are about 35 feet deep at the lower end of Discovery claim and in the valley of the main creek near by. Up the gulch the depth becomes gradually less, being about 15 feet on claim No. 1 above Discovery. The greater part of the sediments along the present stream are frozen, although some of the gravels beneath the silts carry free seepage water.

Most of the prospecting on Murray Gulch has been done by sinking shafts to bedrock. A small prospecting boiler has been used to thaw the frozen ground with steam. In the spring of 1911 the first shaft was sunk at a point about a quarter of a mile above the mouth of the stream, where the deposits are about 15 feet deep. It is reported that two buckets of gravel from the bottom of this hole contained coarse gold to the value of $30; the largest nugget had a value of $3.65, and the smallest piece a value of 30 cents. However, the gold content of the gravels opened by this shaft was not uniform, and the showing first obtained appears to be the best that has been found on the creek up to the present time. Other work done in the vicinity of this shaft in 1912 resulted in the production of $300 worth of gold from small drifts whose bedrock area was about 400 square feet, the average yield being about 75 cents to the square foot. Altogether, placer gold to the value of about $1,000 has been produced from the prospect shafts and drifts along Murray Gulch.

In 1914 one man prospected bench gravels that lie along the left slope of Murray Gulch by digging trenches at right angles to the direction of the valley. Stream-washed gravels were uncovered at two levels—a lower one about 15 feet above and 50 feet back from the present flood plain of the creek, and a higher one about 70 feet above and 260 feet back from the creek. These gravels do not show on the surface, but are disclosed by removing from 2 to 4 feet of muck and disintegrated bedrock that form the surface cover of the slope. The gravels of the lower level are reported to contain gold in fair paying quantities. The higher gravels show 75 cents in gold to the square foot of bedrock surface. Coarse gold to the value of $80 was picked up by hand from these gravels as the prospect trench was being dug across them. This gold is rough and does not show appreciable wear by stream washing. In this regard it is in contrast to the placer gold in the bed of the present creek. It is planned to bring water to these bench gravels by a ditch about 4,000 feet in length and to mine them by ground-sluicing.

PLACERS SOUTHWEST OF THE TULUKSAK-ANIAK DISTRICT.

The part of the Kuskokwim region described under this heading was not visited by the writer, but the descriptions presented are based on information furnished by reliable persons who are familiar with the area.

Southwest of the valleys of the Tuluksak and Aniak the northwestern slopes of Kuskokwim Mountains are drained by several rivers of considerable length and volume that discharge into the lower tidal section of Kuskokwim River. These rivers, named in order from northeast to southwest, are the Kiselalik, Kuethluk, Eek, and Kanektok. Their sources are in the highest part of the Kuskokwim Mountain belt, where the prominent summits and groups of peaks have altitudes from 5,000 to 7,000 feet above sea level. There are glaciers on some of the higher slopes of these mountains to-day, and prospectors who have explored this region report that there is strong evidence of former widespread glaciation throughout the mountains. This evidence is chiefly in the form of deposits of morainal bowlders and outwash gravels. The outwash gravels occupy all the larger valleys within the mountains and expansive areas along the borders of the Kuskokwim lowlands where the rivers leave the mountains.

Fine colors of gold may be obtained from the present bar gravels of almost all the larger streams that have intrenched the outwash gravels, but placer gold in commercial quantities appears to be confined to the shallow gravels in the smaller gulch tributaries to the larger streams that have not been affected by glaciation. The best-known example of a rich placer deposit of this character is on Canyon Creek.

CANYON CREEK.

Canyon Creek, a small tributary to a branch of Kuethluk River, is about 110 miles northeast of Bethel by winter sled trail. The mountains in the vicinity are about 5,000 feet in altitude and the mouth of Canyon Creek is estimated to be about 2,000 feet above sea level. It is far removed from timber, and lumber for sluice boxes was hauled to it from a point in the lower valley, 40 miles distant. The supplies for the camp are hauled with reindeer from Bethel for 5 cents a pound.

The narrow gulch drained by Canyon Creek is about 2 miles in length. Seven 20-acre placer claims include practically all the gold-bearing gravels in the gulch. In width the gravel deposits vary from 50 to 300 feet. On claim No. 2 below Discovery, near the mouth of the creek, and on the lower end of claim No. 1 below Discovery, the deposits are more than 14 feet deep, as has been shown by prospecting shafts to this depth, which could not be completed to bedrock on account of flooding by seepage water. The overburden gravels penetrated by these shafts did not contain much gold, but it is reported a drill will be used to prospect the bedrock on this part of the creek. On and above Discovery claim the gravels are shallow, ranging in depth from 1 foot to 4 feet.

Gold was discovered on Canyon Creek in 1913 and mining operations were commenced in 1914. The value of the total yield of gold for this year is reported to be about $14,000. This production was made by eight to eleven men, who mined for the whole or a part of the season. The work was done on the upper end of claim No. 1 below Discovery, the lower end of Discovery claim, the lower end of claim "No. 2 above," and the lower end of claim "No. 3 above." It is reported that the values of gold in the gravels are not uniformly distributed, but that the ground mined in 1914 averaged about 45 cents to the square foot.

The stream has a good grade and an ample flow of water for the shoveling operations that are necessary in mining.

A quartz porphyry dike that cuts the country rocks at the head of Canyon Creek is supposed to be the source of the bedrock mineralization from which the placer gold is derived. The placer gold is chiefly in the form of small and flat, but plump and heavy, nuggets, of the type called "pumpkin-seed gold" by the miners.

RAINY AND KAPON CREEKS.

Rainy and Kapon creeks are two headwater tributaries of Eek River that are about 6 and 8 miles long, respectively. They lie about 5 miles apart and are situated approximately 12 miles southwest of Canyon Creek.

The country rocks along these streams are reported to be slates and conglomerates, cut by granitic intrusives.

Placer gold was discovered on Rainy Creek about 1911, and prospecting has been carried on for the last three years. Claim No. 2 above Discovery, on Kapon Creek, has been opened to some extent. Two men worked there during the summer of 1914, ground-sluicing through a small flume. The grade of the stream is reported to be from 5 to 7 per cent, but the gravels are rather coarse and their tenor of gold is rather low. The gold is dingy colored and in the form of flat hammered flakes. The concentrates associated with the gold are black magnetic sand, small pebbles of cinnabar, and grains of arsenical iron pyrite.

GOODNEWS DISTRICT.

The Goodnews mining district comprises a moderately mountainous area that extends along the eastern shore of Kuskokwim Bay from the vicinity of Goodnews Bay on the south to the lowlands of Kanektok River on the north. A Moravian mission settlement named Quinhagak, at the mouth of Kanektok River, is the post office and supply post for the district.

The chief part of the mountainous area of this district is drained by Aalalik River, a small stream which discharges into Kuskokwim Bay about 7 miles below Quinhagak.

The mountains of this district are reported to be composed of schists, slates, crystalline limestones, and granitic intrusive rocks. Some of the schists and metamorphosed limestones are garnetiferous.

Prospectors from Nome entered the region about Goodnews Bay during the summer of 1900, and since that year discoveries of placer gold have been reported in various parts of the district from time to time. Prospects of gold appear to be generally distributed on most of the tributaries of Aalalik River, within the mountains, 10 to 20 miles back from the coast, and also on some of the short streams that drain the seaward slopes of the mountains into Goodnews Bay, south of the headwaters of Aalalik River, and into Kuskokwim Bay, to the west. Productive mining has been done upon two streams in the district up to the present time. These are Butte and Kowkow creeks.

Butte Creek is a small tributary to Faro Creek, a large branch of Aalalik River, about 30 miles southeast from the settlement of Quinhagak. Open-cut pick-and-shovel mining has been done on Butte Creek for about ten years, and it is reported that gold of a value between $50,000 and $60,000 has been produced from three or four claims during this period. In 1914 a scraping plant with a gasoline engine for power was installed on claim No. 1 below Discovery for the purpose of mining the deposits more effectively. The gravels on Butte Creek are about 5 feet in depth. Most of the mining has been done on Discovery claim and claims Nos. 1 and 2 below Discovery. These claims, of about 20 acres each, include nearly all the placer deposits on this creek.

Kowkow Creek is about 5 miles south from Butte Creek. The gravels on this stream are about 6 feet in depth. One man mined on Discovery claim for about half the season of 1914.

The production of gold from Butte and Kowkow creeks in 1914 was about $4,000.

Some hand-drill prospecting was done on Faro and Trail creeks in the summer of 1914 with the object of testing the more extensive gravel deposits on the larger streams of the Aalalik basin for dredging. It is reported that the gravels were found to range from 6 to 12 feet in depth, and that the prospects of gold obtained from a dozen or more holes were far less than those which are obtained on Butte and Kowkow creeks, where the average tenor of the gravels is about 30 cents to the square foot.

BEACH GOLD ON TOGIAK BAY.

It is reported that one man was rocking placer gold from beach sands on Togiak Bay during the summer of 1914. The country rocks near by are said to be schists. No details were learned of this new placer gold locality.

COPPER IN THE RUSSIAN MOUNTAINS.

LOCATION AND TOPOGRAPHIC FEATURES.

The Russian Mountains comprise an isolated group of rugged summits that stand prominently above a rolling tract of the Kuskokwim Mountain belt that lies north of the main river, downstream from Kolmakof. (See Pl. X, p. 270.) The central peaks of this group range in altitude from 4,000 to 4,500 feet above sea level and are 10 to 15 miles northwest from Kolmakof. The rugged area dominated by these peaks has an extent of about 10 miles, both from east to west and from north to south. The group as a whole is flanked by rolling ridges and sloping spurs of the surrounding highland that stand from 1,000 to 2,000 feet above sea level.

The broad valleys of Kolmakof and Owhat rivers, two considerable tributaries to Kuskokwim River from the north, mark off the Russian Mountains and their highland flanks from the Kuskokwim Mountain belt as a whole. Kolmakof River empties into the main river about 1 mile below and opposite the settlement of Kolmakof and receives all the drainage from the eastern slopes of Russian Mountains. Owhat River enters the Kuskokwim about 20 miles downstream from Kolmakof and receives the drainage from the western slopes of the mountain group. The headwaters of Owhat River encircle the Russian Mountains on the north and drain its slopes on that side. The southern slopes of the mountain group are drained by small creeks that flow directly into Kuskokwim River between Kolmakof and Owhat rivers.

GENERAL GEOLOGY.

The areal geology of the Russian Mountains appears to be directly expressed by the topographic features of the group. The rugged mountain masses of the high central area are composed of intrusive granitic rocks that are chiefly of deep-seated porphyritic character. The highlands that surround the central igneous mass are made up of the sedimentary series of sandstones and shales that form the greater part of the Kuskokwim Mountain belt. The Russian Mountains appear to be made up of a batholithic igneous mass intruded into the sediments.

MINERALIZATION.

A deposit of gold-bearing antimony is reported to occur at or near the contact of the central igneous mass with the surrounding sedimentary rocks on the upper part of Mission Creek, in the southwestern part of the Russian Mountains. Prospects of placer gold are reported to be present in the gravels of Mission Creek below this locality, and the placer gold is presumed to be derived from the zone of stibnite mineralization. It is not improbable that there may be other occurrences of mineralization of the contact type about the borders of the intrusive igneous rocks.

COPPER LODE.

A lode deposit of metallic sulphides occurs in the central part of the Russian Mountains, several miles within the outer limits of the massive intrusive rocks, in the upper basin of Cobalt Creek, a stream that flows for 8 miles northward into upper Owhat River.

Four claims, collectively known as the February group, are staked along a vein deposit of the fissure type that may be traced by its surface croppings for a distance of about 4,000 feet. The general strike of the vein is N. 20° W. and its dip is 85° SW. The width of the vein has been determined at only one point, near the north end of its outcrop, where a shaft has been sunk upon it to a depth of about 40 feet. In this shaft the fissure walls are well defined. At the surface these walls are about 5 feet apart, but at a depth of 25 feet they are about 30 inches apart, and this width between the walls continues to the depth of 40 feet without appreciable change.

The gangue of the vein is quartz. The metallic sulphides with the quartz are a mixture of chalcopyrite, arsenopyrite, and pyrite. The ore carries copper, gold, and silver, but the writer did no sampling. At the time of visit the greater part of the shaft was filled with water, so the minerals could not be examined in place. It is reported that the arsenopyrite appears to be more abundant near the surface and the chalcopyrite at the bottom of the shaft.

The wall rocks are considerably leached near the surface, but that of the footwall appears to be more porphyritic than that of the hanging wall. Along both walls are thin seams of a fine-grained talcose gouge, considerably stained with malachite. Malachite stains together with dark iron-rust stains occur on much of the quartz that marks the surface outcrop of the vein.

This prospect was first brought to the attention of white men about 15 years ago by Indians, who discovered it while hunting. It was staked at that time but abandoned soon afterward. The present claims were staked in 1913, and a log cabin was built near by early in the winter of that year. A shaft was sunk to the depth of about 25 feet early in 1914 and was continued to a depth of 40 feet or more during the winter of 1914–15.

The best route for hauling supplies to the property is by way of a winter sled trail from Kolmakof, 18 miles long. This trail follows the valley of Suter Creek, a tributary to Kolmakof River, and swings around the northeast end of the Russian Mountains into lower Cobalt Creek. The nearest timber is on the upper part of Suter Creek, about 5 miles from the prospect. The divide between Suter and Cobalt creeks is estimated to be not more than 1,000 feet above Kuskokwim River at Kolmakof. It would not be difficult to construct a wagon or tram road to the property by this route.