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THE RUBY-KUSKOKWIM REGION ALASKA

BY

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AND

G. L. HARRINGTON

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PREFACE.

By Alfred H. Brooks.

The region described in this report lies in the west-central part of Alaska and includes three of the more productive Yukon placer districts—Iditarod, Ruby, and Innoko. These districts have produced about 20 per cent of the total mineral output of the Yukon Valley in Alaska. The Candle Creek placer district, which is the most productive placer camp in the Kuskokwim Valley, also lies in this region.

The information contained in this volume, although based primarily on surveys and investigations made by the authors in 1915, also includes many facts compiled from publications by previous workers. The several placer camps in the region have been described separately in various other reports (see pp. 2–4), but as most of these reports are out of stock or out of date, the present volume has been expanded into a summary report on the whole region. It includes, however, previously unpublished descriptions of the geology of a large part of the region.

The long delay in publication has been caused by the assignment of both authors to other urgent duties during the war, Mr. Harrington being in the Army as lieutenant of engineers; by the subsequent furloughing of both authors for private geologic work in South America; and by the resignation of Mr. Harrington.

THE RUBY-KUSKOKWIM REGION, ALASKA.

By J. B. Mertie, Jr., and G. L. Harrington.

INTRODUCTION.

LOCATION AND EXTENT.

The region here described is an irregular area lying between Yukon, Nowitna, Tuentna (Nixon Fork of the Kuskokwim), Kuskokwim, Iditarod, Innoko, and Yuko rivers. The eastern and west-

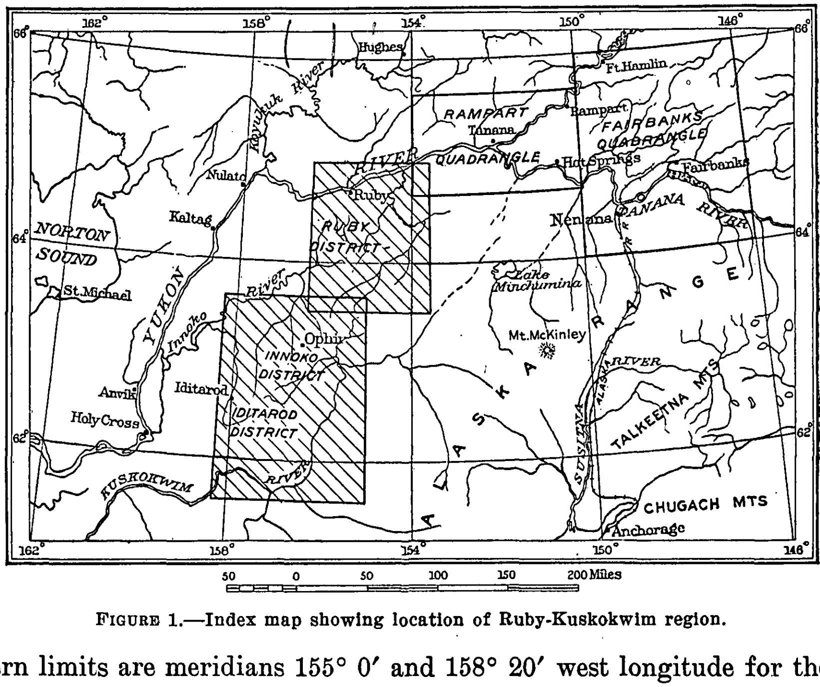

Figure 1.—Index map showing location of Ruby-Kuskokwim region.

ern limits are meridians 155° 0′ and 158° 20′ west longitude for the southern portion and 153° 37′ and 156° 23′ for the northern portion, and the northern and southern limits are parallels 64° 58′ and 61° 37′ north latitude. (See Fig. 1.)

This region is too large to be shown adequately on a single topographic or geologic map. It has therefore been mapped as two areas, to be known as the Ruby district and the Innoko-Iditarod region.

The Ruby district extends from Yukon River southward to parallel 63° 27′ north latitude and includes the Cripple Creek Mountains. The Innoko-Iditarod region begins at parallel 63° 39′ north latitude and extends southward to the Kuskokwim at Georgetown. The two areas thus overlap slightly. Plates I to IV (in pocket) are topographic and geologic maps of these two areas.

INVESTIGATIONS.

Parts of the region have been visited by a number of Survey geologists. Spurr,[1] in his traverse down the Yukon in 1896, passed the present site of Ruby and made some geologic observations on the crystalline limestones that outcrop along the south bank of the river, near the mouth of Melozi River. Similarly in 1898, in the course of his exploration of Kuskokwim River,[2] he skirted the southern edge of this district. His notes on the geology along Kuskokwim River down to Georgetown are still the only geologic data bearing upon that stretch of the river. The Geological Survey has also in its possession some unpublished notes on the Ruby Bluff made by Collier in 1902, incidental to his study of the coal resources of the Yukon.[3] In 1907 C. W. Gilmore, of the Smithsonian Institution,[4] ascended Nowitna and Yuko rivers for considerable distances from the Yukon and made some geologic notes. In 1908 a portion of the season was spent by Maddren[5] in an investigation of the region about the headwaters of Innoko River, and in 1910 he visited the Innoko-Iditarod region.[6] In 1910 C. G. Anderson carried a topographic reconnaissance from the present town of Ruby to the Innoko and Iditarod districts. H. G. Birkner, who was attached to the Anderson party, collected geologic data along the route, and these were used in the reports prepared by Maddren. In 1912 Eakin[7] spent eight weeks in a geologic reconnaissance of the Iditarod-Ruby region and an examination of the placer-mining operations in the Ruby, Innoko, and Iditarod districts. Again in 1913 Eakin visited the Ruby district and reported on the mining developments there.[8] The region between Georgetown, on the

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[1] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 173, 1898.

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

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

[4] Smithsonian Misc. Coll., vol. 51, No. 1807, 1908.

[5] Maddren, A. G., The Innoko gold-placer district, Alaska: U. S. Geol. Survey Bull. 410, 1910.

[6] Maddren, A. G., Gold-placer mining developments in the Innoko-Iditarod region: U. S. Geol. Survey Bull. 480, pp. 236–270, 1911; The Ruby placer district: U. S. Geol. Survey Bull. 520, pp. 287–296, 1912.

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

[8] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, 1914; Gold mining in the Ruby district: U. S. Geol. Survey Bull. 592, pp. 363–369, 1914.

Kuskokwim, and Iditarod was mapped topographically and geologically on a reconnaissance scale in 1914 by Sargent and Smith.[9]

During the summer of 1915 a strip of country extending from Ruby to Iditarod by way of McGrath, and adjoining on the east the area examined by the Anderson party in 1910, was surveyed topographically and geologically on a reconnaissance scale. In all, about 8,010 square miles was covered, of which, however, 2,090 square miles must be classed as resurveyed, having been covered by the work done in 1910. Two Geological Survey parties were engaged in this work. A northern party, in charge of C. E. Giffin, with G. L. Harrington attached as geologist, devoted its attention to the geology and mining operations in the vicinity of Ruby, Long, and Poorman. A topographic map was prepared, which supersedes the older map of this district and includes the area extending eastward to Nowitna River and connecting there with the area mapped by H. M. Eakin.[10] On the south connection was made with the work of the southern party. All the producing creeks were visited, and the geology and mineral resources were studied in such detail as the time available and the character of the country permitted.

The southern party, in charge of R. H. Sargent, with J. B. Mertie, jr., as geologist, began work at Poorman and carried the topographic and geologic survey through to Iditarod, passing through the mining districts at Candle Creek, a tributary of Tatalina River, and at Moore Creek, the South Fork of Takotna River. The mining properties on these two creeks, as well as most of those in the Iditarod district, were visited and examined by Mr. Mertie. A. H. Brooks also spent 10 days in the Iditarod district in an examination of the mining operations and geology in that vicinity. The results of his observations and study are incorporated in this report.

In the spring of 1917 G. L. Harrington spent a few days in Ruby and obtained information regarding the progress of mining at Long and Poorman. Later in the summer the Ruby district was again visited by Theodore Chapin,[11] who collected data regarding the actual and potential tin production of this area.

After outfitting at Ruby in 1917 Mr. Harrington with one camp helper descended the Yukon to Shageluk Slough in a poling boat and ascended Innoko, Dishna, and Tolstoi rivers to Tolstoi, to investigate the platinum-bearing gold placers in the vicinity of Mount Hurst.[12] Two weeks were spent in an examination and study of the

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[9] Smith, P. S., Mineral resources of the Lake Clark-Iditarod region: U. S. Geol. Survey Bull. 622, pp. 247–271, 1915; The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, 1917.

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

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

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

placers, and some additional details in a small area north of Mount Hurst were added to the topographic and geologic maps.

In the summer of 1920 G. C. Martin[13] visited the gold lodes at the head of Nixon Fork of the Kuskokwim and made some geologic observations in that vicinity. He also collected data on mining in the Innoko and Iditarod districts.

Data regarding mineral production and the progress of mining in other years have been collected by different members of Geological Survey parties incidental to work in other localities. A considerable amount of statistical information has been obtained from other sources.

The present report covers an area greater than that examined by the writers. It has seemed best to present as a unit all the geographic and geologic information at present available on the country lying between Yukon and Kuskokwim rivers and between meridians 153° 37′ and 158° 20′ west longitude. To this end the writers have drawn freely on the results of earlier workers.

ACKNOWLEDGMENTS.

Special acknowledgments are due to R. H. Sargent and C. E. Giffin, in charge respectively of the southern and northern field parties, for their ready assistance and cooperation in furthering the geologic work; also to the other members of the field parties, who showed at all times a gratifying willingness to help. In the office the writers have been aided materially by conferences with Messrs. Eakin, Maddren, and Smith in regard to areas mapped by them.

Without exception, the operators and prospectors in the region displayed an unfailing hospitality and evinced a desire to assist in the work so far as lay within their power. Information sought of them was given freely. To Mr. Vance McDonald, of Long, and Mr. David Strandberg, of Flat, the writers are particularly indebted for courtesies extended in this and other ways.

GEOGRAPHY.

GENERAL FEATURES.

The underlying conception of the Ruby-Kuskokwim topography should be that of a rolling country of low ridges, from which long, flat-topped spurs extend laterally into broad stream valleys. The monotony of this topography is broken at a number of localities by higher mountain groups, which, however, are not connected but stand out in isolated relief from the surrounding country. This region is

[13] Martin, G. C., Gold lodes in the upper Kuskokwim region: U. S. Geol. Survey Bull. 722, pp. 149–161, 1921.

in reality the southwestward continuation of the Yukon-Tanana belt at a lower level.

Yukon and Kuskokwim rivers, the trunk streams of central Alaska, drain this region, but the watershed between the two streams is near the southeastern border of the region, so that most of the surface water finds its way to the Yukon. Nowitna, Sulatna, and Yuko rivers, the Innoko and its various headwaters, and Iditarod River drain into the Yukon; Nixon Fork, Takotna River, and Tatalina River are the main tributaries of the Kuskokwim.

The region comprises two rather distinct physiographic provinces. The northern province lies between Poorman and Ruby, extending east and west to the limits of the area mapped. It is drained mainly by Sulatna and Nowitna rivers. The southern province begins at the hills south of Poorman and continues south and west to Ophir and Iditarod and south to the Kuskokwim. The northern province is distinguished from the southern by its generally lower elevation and relief, by the extreme width and flatness of its stream divides, by the tortuous courses of the streams, and by the abnormally wide spacing of the headwater tributaries.

In two areas within the region local glaciation has been pronounced enough to leave a record of its existence in the present topography. About 15 miles east of Ophir there is a high mountain group, the highest peak of which, Cloudy Mountain, has an altitude of about 4,500 feet. The area about the headwaters of one of the tributaries of Folger Creek that heads in this group shows a well-developed glacial topography. Several glacial cirques, one of which forms a hanging valley, drain into a U-shaped valley, in the lower part of which are undoubted glacial deposits. The other locality in which glaciation has played an important part is in the Beaver Mountains.

RELIEF.

The altitude of Yukon River at Ruby is approximately 250 feet. Yuko Mountain, about 2,300 feet above sea level, is the highest point in the Ruby district proper, and this mountain and the Twin Buttes, which have an altitude of about 1,800 feet, are the most conspicuous landmarks. Within the area mapped as the Ruby district (Pl. I), however, still higher mountains are present. Thus east of Sulukna River and extending southwestward into its headwaters is a range of high hills reaching well above 3,000 feet. Likewise, at the south end of the area, the Cripple Creek Mountains and a similar mountain group southeast of Nowitna River rise to altitudes respectively of 3,600 and 4,000 feet. These two groups belong physiographically with the southern province and are therefore shown also on Plate II.

In the Innoko-Iditarod region (Pl. II) the lowest part is the lower Iditarod Valley. The settlement of Dikeman has an altitude of about 200 feet and Iditarod about 300 feet. The highest point in the region is Cloudy Mountain, which rises about 4,500 feet above the sea. Numerous other conspicuous mountains are included in the region; the more prominent are the Cripple Creek Mountains, the high mountain group southeast of Nowitna River, another group of hills about 15 miles southeast of the Cripple Creek Mountains, Twin Mountain, Mount Hurst, the Beaver Mountains, including Crater Mountain, Takotna Mountain, Joaquin Mountain, and Camelback Mountain (also called Bonanza Mountain). South of McGrath Roundabout Mountain, though less than 2,000 feet in altitude, rises directly from the flats of the Kuskokwim and is thus a prominent landmark. Appel Mountain, northeast of McGrath, is another landmark of the same sort. Lookout Mountain and Twin Buttes are relatively high points on Cretaceous sandstone ridges on the trail between Iditarod and Georgetown. Barometer Mountain, one of the landmarks south of the Kuskokwim, rises to an altitude of over 2,600 feet.

DRAINAGE.

The larger streams of the region meander in broad, open valleys over much aggraded flood plains, which contain many swamps and oxbow lakes. In their upper reaches the streams characteristically flow in deep, narrow channels, between cut banks, with a general absence or marked scarcity of gravel bars. This is particularly true of Sulatna and Nowitna rivers, which drain the northern part of the region, but the same characteristic is shown by most of the minor streams. To the south, however, where mountain groups tend to steepen the headwater grades, this characteristic is not so marked. In practically the entire area the streams flow on gravel, sand, or silt rather than on bedrock. This is an almost invariable rule in the northern and western portions of the region but is less noticeable in the central, higher portion.

Throughout the lowlands the drainage is sluggish and the streams in general are aggrading. Only in the headward portions is cutting appreciable. Plate I shows traverses of Sulatna and Nowitna rivers, with their characteristic meanders.

There are many peculiar drainage features for which a satisfactory explanation will scarcely be arrived at until a more detailed history of the region has been worked out. Of this type are the large loop made by Big Creek and the still larger loop of the system made up of Long Creek, Sulatna River, and Nowitna River. The broad valley of the Nowitna becomes suddenly narrower below the mouth of Sulukna River. Then, joining the Big Mud, the Nowitna flows in a valley of a size proportionate to that stream and then its valley again opens out below the mouth of Little Mud River.

These features indicate that the early Quaternary or possibly late Tertiary drainage was materially different from the present system. Subsidence of the lower valley of Nowitna River has taken place, and the valley has been filled. The former channel of the Nowitna may have been dammed by the flows of lava so that the river was diverted or the diversion may have been caused by filling of the old valley during a period of subsidence in which points now 1,200 feet above sea level were covered, and on reelevation the new course followed was lower than the filled channel. A different drainage system than the present one is indicated also by the large loops of Big Creek and of the Long Creek-Sulatna River system.

Kuskokwim River presents an appearance somewhat analogous to the Nowitna. From a point above McGrath almost to the mouth of the Holitna the river flows southwestward in a wide alluvium-filled valley and then turns suddenly northwestward into a relatively canyon-like valley, cutting through the Georgetown hills to the mouth of Crooked Creek. The valley of the Kuskokwim above the gorge continues southwestward as a wide depression to Bristol Bay, and the lower end of this depression is occupied by Nushagak River and its tributaries. The impression gained by studying a relief map of Alaska is that the depression now occupied by the Tanana, Kuskokwim, and Nushagak was formerly a single great drainage system and that the gorge of the Kuskokwim is a feature of relatively recent date. The obvious readjustments in this old drainage basin were probably brought about by a combination of causes, among which crustal movements and alluviation, with consequent stream superposition, were predominant. The physiography and geology of the Nushagak Valley will have to be studied in more detail before a satisfactory explanation can be formulated.

Another striking drainage feature is the remarkable straightness of the line that marks the course of upper Iditarod River, Bonanza Creek, Fourth of July Creek, Takotna River, and Nixon Fork of the Kuskokwim and that is paralleled by a line marking the course of Tatalina River, middle Takotna River, and Waldron Fork, with a possible continuation to the south into George River. An almost equally remarkable parallelism is displayed by Susulatna and Nowitna rivers. As suggested in the discussion of the structure of the region, it is probable that these drainage alinements are determined by the structure of the rock formations.

In and near the Beaver Mountains there have been drainage changes due to glaciation.[14] Beaver Creek has lost a portion of its headward drainage, which now flows into Ganes Creek.

SPECIAL FEATURES.

In the Ruby district there are numerous isolated mounds found on the gentle slopes of the wide valleys, generally near the streams. On many of these mounds there is a good growth of deciduous trees that serves to give them greater prominence by the arboreal color contrast and at the same time emphasizes the difference in the soil conditions in the mounds and adjoining slopes, as the birch and aspen particularly favor the warmer, well-drained soils. One of the largest mounds is in the valley of Little Dome Creek; others are found on upper Poorman and Glacier creeks, and it seems probable that a mound on the west side of Tamarack Creek is of similar character. That showing the most characteristic features is in the valley of Main Creek about 5½ miles southwest of Dead Man Hill. (See Pl. V, *A*.) It is about 75 to 100 yards long and rises about 25 feet above the general surface. It is oval in outline, and there is a spoon-shaped depression 10 feet deep in the top. This depression has an outlet to the northeast, up the slope, from which a small stream of water was flowing in July, 1915, though there had been no rains for two days. The mound is composed of fine sand or silt, and both its outer and inner slopes are steep, so that it rises abruptly from the poorly drained, moss-covered slope on which it lies. This slope has a grade of about 0.5 per cent. There are several old prospect holes near by, and from their dumps it seemed reasonable to assume a depth to bedrock of at least 50 feet. At least half of this depth appeared to be occupied by fine material similar to that composing the mound, and the lower half is made up of gravel.

The mode of origin of these mounds is not clear, and in this area conclusive proof was not at hand to determine it. However, they may be accounted for in several ways, and from the variations in their form and relations to the adjacent topography it may well be that some are of one origin and others of another. Thus the mound in the valley of Main Creek is believed to have been formed by a spring bringing up from below the material that forms it. Similar mounds were observed by Leffingwell[15] on the Arctic slope. For some of the other mounds such an origin does not seem compatible with their outline and position, and it appears more likely that they

[14] Maddren, A. G., The Innoko gold-placer district, Alaska: U. S. Geol. Survey Bull. 410, pp. 13–14, 1910.

[15] Leffingwell, E. de K., The Canning River region, northern Alaska: U. S. Geol. Survey Prof. Paper 109, pp. 150–155, pl. 17, 1919.

are remnants of an older alluvial filling. This explanation may account for some of the slight prominences in the upper portion of Poorman Creek and some of those on Glacier Creek.

What is believed to be the incipient stage of still a third process of origin was noted on the south bank of Beaver Creek about a mile below the road house. A depression about 1½ feet deep and 2 feet wide surrounds a semicircular area having a radius of 25 yards, the creek forming the diameter of the semicircle. Between the depression and the creek the ground rises slightly above that on either side at a corresponding distance from the creek. The last stages are seen on Spruce Creek and on Poorman Creek near the mouth of Little Pup, in the slight elevations immediately adjacent to these streams. The entire masses forward of the depression have moved bodily toward the creek, so that they now appear as small hillocks at one edge of the stream, with a depression several feet wide and deep between them and the unconsolidated material from which they separated. They are, in fact, landslides in the soft incoherent silts on planes along which thawing has taken place and the gradient of these planes, although probably very gentle, has been sufficient for the detached masses to move forward by the action of gravity.

A feature of unusual interest in connection with the gold placers consists of the asymmetric valleys which are found in many parts of the region. Eakin[16] noted this feature on Spruce Creek in the Innoko district and described it as follows:

> The influence of structure upon topography is especially evident in the valley of Spruce Creek. * * * The stream follows a straight course on the line of strike of the bedrock. The bedrock dips westward, and in its down cutting the stream has migrated in that direction. The west valley wall is now a steep scarp, along the base of which the stream runs. The opposite side of the valley slopes gently upward away from the stream over a series of gravel-covered benches. The chief gold concentration in the valley antedates the latest rejuvenation of the stream. Consequently the placers are found in the bench gravels along the east side of the valley up the dip from the stream, and little gold is to be expected in the stream itself.
>
> An effect of structure similar to that seen in the form of Spruce Creek valley can be noted at places on the other streams of the Kuskokwim uplands. It should be borne in mind that in down cutting the stream shifts its position in the direction of the dip; that, as a result of such shifting, concentrations of gold are most likely to occur in the gravel benches of the broadly open side of the valley; and that where dips are vertical or nearly vertical the stream does not shift its bed, and any concentration will be found in its present gravels.

Whether or not the asymmetry of Poorman Creek is due to structure, or whether it is due to the difference in erosion resulting from the different amounts of solar heat received by the north and south sides of the valley, it is true that the principal bench claims on this

[16] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 14, 1914.

creek on which workable placers have been developed lie on the north side of the valley, the side on which the bedrock grade is gentler. Plate IX, *B*, shows the asymmetric valley of Fourth of July Creek, a tributary of Takotna River, where the steeper side is the north side.

To explain many of the topographic features, such as valley filling, but more especially to account for the long, flat, terrace-like even-topped ridges below altitudes of 1,200 feet, inundation to approximately that depth has been postulated. On several of the mountains, however, there are a number of high terrace-like topographic forms that lie well above this altitude. These terraces do not correspond in altitude on two mountains close together, they are unequally spaced on adjacent mountains, and they may slope in opposite directions. They show no wave-washed erosion débris, and they are practically confined to areas of coarse granular igneous rocks of acidic types or to areas of quartzite. In all these features they differ from the terraces that lie approximately at 1,200 feet and at various lower altitudes. The flat-topped ridge east and south of Ruby (Pl. VII, *A*) is of the water-cut type and lies at an altitude of about 900 feet.

These high terraces were produced by frost action and solifluction. The general process by which they were formed has been termed "altiplanation," and they are called "altiplanation terraces."[17] They are well shown on the quartz monzonite massif of Joaquin Mountain (Pl. I).

CLIMATE.

The Ruby-Kuskokwim region has a subarctic climate not unlike that of other parts of interior Alaska. No official record of the range in temperature throughout the different months of the year or of the annual precipitation is available. The variation in temperature, however, from summer to winter is great. At Takotna, on July 27, 1915, when the Survey party passed through, the thermometer registered 90° in the shade during the middle of the day; and it had been very warm before that date and continued to be warm for some time afterward. Such warm summer weather, however, is abnormal. In the middle of the winter temperatures as low as 60° below zero occur, so that the maximum annual range may be as great as 150°.

The summers are usually short and warm, and the winters are long and cold. The large rivers freeze over late in October and thaw early in May. The smaller streams freeze earlier in the fall and remain frozen somewhat later in the spring. There is, therefore, a period of about four months during which mining operations may

[17] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, pp. 78–82, 1916.

be carried on. The growing season is much shorter. Trees, grass, and other vegetation seldom begin to grow before the later part of May, and killing frosts may be expected about the last of August or early in September. On account of the great length of the summer days, however, vegetation grows very fast and in this way partly makes up for the shortness of the season.

The annual precipitation in this region has been estimated at less than 20 inches. From the reports of various men who have been in this region it is patent, however, that the rainfall is very variable in different years. Eakin[18] reported that only five days between July 17 and September 2, 1912, were without rain in some part of the region. Smith[19] likewise reported that

> In 1914 the streams were at a high stage, and Kuskokwim River was said to be more than 10 feet above its normal summer level. The observations made in 1914 by the Survey party, which record rainfall on 60 out of 99 days in the summer of that year, therefore leave an impression of heavier precipitation than is perhaps justified and do not necessarily indicate the average summer rainfall.

A report by Harrington[20] suggests that in the Tolstoi district a portion at least of the season of 1917 corresponded in rainfall with the season of 1914, for he states:

> Fair days in summer are usually very pleasant, but their number varies from year to year, as do the number of rainy days and the amount of rainfall. Usually, however, the later part of the summer has the greater precipitation. During July, 1917, the rains were unusually heavy and frequent, so that the Tolstoi reached and maintained a stage of water for about 10 days comparable with that of the normal spring high water. In one rain during this period there was a precipitation of more than 2 inches in a few hours. In the high hills near Mount Hurst the rainfall is apparently greater than in the low areas along the lower courses of Tolstoi and Dishna rivers, as these hills were frequently hidden in clouds when the sky was fairly clear over the valleys.

The condition of greater rainfall in areas of higher altitude is naturally to be expected, so that the wide valleys will in general have a somewhat lower precipitation than the mountains.

SETTLEMENTS AND POPULATION.

The principal settlements in this region are Ruby and Long in the northern part, Ophir in the central part, and Iditarod and Flat in the Iditarod district. In addition, there are or have been smaller settlements at Poorman, Cripple, Tolstoi, Takotna, McGrath, Discovery (Iditarod district), and Georgetown, and still smaller settlements on numerous producing creeks.

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[18] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 16, 1914.

[19] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, p. 35, 1917.

[20] Harrington, G. L., The gold and platinum placers of the Tolstoi district, Alaska: U. S. Geol. Survey Bull. 692, p. 340, 1919.

In all, the white population probably did not exceed 1,900 in 1915, of whom about 500 were at Ruby, about 100 at Ophir and on the creeks in the Innoko district, and about 700 in the Iditarod district, including Iditarod, Flat, Discovery, and the creeks near by. The remainder of the population was distributed in the smaller settlements and producing creeks and included a small number of men who were at work prospecting in the region. According to Eakin,[21] there are also several small Indian settlements along Innoko River. Dishkakat was one of these but had been abandoned by 1917. Another small Indian settlement lies at the base of Joaquin Mountain, on Takotna River, and a third is at Sleitmut, on Kuskokwim River.

In 1912 the population was estimated by Eakin at about 3,100, which is 1,200 more than the estimated number in 1916, showing that in the four years there was a decrease of nearly 40 per cent. The population in 1921 was still smaller. Elimination of the floating population that accompanies the opening of a new mining district and the concentration of producing ground into the hands of larger companies, accompanied by the inevitable introduction of modern mining machinery and labor-saving methods, are the causes of some of this decrease. In addition, economic conditions during the last few years have been very unfavorable to the progress of mining, and this has resulted in a marked thinning of the population.

GEOLOGY.

OUTLINE.

The region lying between Ruby and the Kuskokwim is made up of a number of rock formations of different ages, intruded at numerous localities by igneous rocks of different varieties and ages. Overlying all these are unconsolidated deposits of a number of types.

In the district from Ruby south to Poorman metamorphic rocks of Paleozoic age and possibly older, including schist, phyllite, slate, quartzite, chert, and limestone, form the major part of the country rock. Similar rocks occur farther east in the valleys of Sulukna and Nowitna rivers, where they have been mapped by Eakin.[22] The metamorphosed Paleozoic formations also appear in the vicinity of Tolstoi and Mount Hurst. From this complex it has been possible to separate out and map several formations of sedimentary and igneous character. These include crystalline limestone of unknown age; certain Devonian rocks, including limestone; a group composed of greenstone, greenstone tuff, and chert; and an igneous formation, composed of granite. The undifferentiated metamorphic rocks are grouped together as a separate formation.

[21] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 18, 1914.

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

South of Poorman and in the vicinity of Mount Hurst a chert-argillite formation of Paleozoic or Mesozoic age has been mapped. Interbedded with this chert is a series of rhyolitic flows, which are distinguished as a separate geologic unit.

From the Cripple Creek Mountains southward to Kuskokwim River there is a monotonous series of sandstone, shale, and conglomerate of Upper Cretaceous and in part of Eocene age. This formation has a wider areal distribution than any other in the region. Associated with it is a large variety of igneous rocks of Eocene or post-Eocene age, comprising a series of andesitic and basaltic lava flows and three mappable formations of intrusive rocks, including quartz monzonite, sodic intrusives, and basic intrusives.

The hard rocks, particularly in the valleys, are overlain by unconsolidated deposits of Pleistocene and Recent age. These deposits attain their maximum development in the Ruby district, where they form a mantle covering up nearly three-fourths of the hard-rock formations.

UNDIFFERENTIATED METAMORPHIC ROCKS.

AREAL DISTRIBUTION.

The rocks grouped under the heading undifferentiated metamorphic rocks appear in five separate localities. From Ruby to Poorman they form the major portion of the country rock but are largely concealed by a covering of Quaternary material. Another area lies to the east and southeast, in the valleys of Sulukna and Nowitna rivers. They are also present in the vicinity of Mount Hurst, and there are occurrences east and southeast of Dikeman which probably extend beneath the alluvium of Iditarod River and appear again in the area northwest of Iditarod. The southwest flank of the Kaiyuh Mountains [23] is made up of these rocks, and they crop out in several places along the Innoko below Dishkakat. Their extension [24] is found northeast of Ruby between Melozitna and Yukon rivers, and they are probably continuous even to the headwaters of the Dall, Chandalar, and Koyukuk.[25]

In the vicinity of Poorman the slate and associated arenaceous rocks may be in part of Mesozoic age, but as they contain no fossils and show practically no differences from the metamorphic rocks farther north, they have been grouped with these undifferentiated metamorphic rocks.

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[23] Maddren, A. G., The Innoko gold-placer district, Alaska: U. S. Geol. Survey Bull. 410, p. 45, 1910.

[24] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, p. 191, 1916.

[25] Maddren, A. G., The Koyukuk-Chandalar region, Alaska: U. S. Geol. Survey Bull. 532, pl. 5, 1913. Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: U. S. Geol. Survey Prof. Paper 10, pp. 31–32, 1902.

LITHOLOGY.

A widely diverse series of rocks is included in this group, embracing schist, phyllite, slate, quartzite, chert, and limestone. So far as it has proved practicable the areas of greenstone and of limestone, which really form an integral part of the complex, have been mapped separately, but the mantle of unconsolidated material and of vegetation obscures the nature of the underlying bedrock so effectively that there are doubtless many areas of greenstone and limestone that have not been discovered. The rocks of this series are dominantly recrystallized. They represent in large part ancient sediments which have been brought to their present condition through severe and long-continued metamorphism. They show locally a considerable amount of quartz and calcite veining.

Both in composition and in the secondary lithologic features superimposed by metamorphism the rocks resemble the Paleozoic and older schists of the Yukon-Tanana region. There are argillaceous rocks which show but little secondary structure; other rocks which have a distinct slaty cleavage; and still others, such as the crenulated phyllite and garnetiferous mica schist, which show a high degree of metamorphism. The rocks of a more sandy composition also show considerable variation, ranging from well-indurated quartzite to quartzite schist in which mica is very well developed. Some of the siliceous rocks that are so fine grained as normally to be considered chert in the field have suffered considerable alteration, which has developed cleavage and secondary minerals, so that they resemble talc schist. The limestone is discussed separately on pages 17–21.

IGNEOUS ROCKS.

Associated with the metamorphic complex are a number of types of igneous rocks, some intrusive and others probably extrusive. The intrusive rocks include rhyolitic and more basic dikes, granite, and rocks of intermediate types. Some of the greenstone may represent lava flows. The metamorphic equivalents of some of these rocks are also found. Practically all show some superficial alteration due to weathering.

LOCAL RELATIONS.

In the Ruby district the rocks appear most intensely altered in their eastern exposures. Garnetiferous quartz-mica schist crops out on the dome about 9 miles east of the Sevenmile road house on Boston Creek and also on the dome 3½ miles east of the Hub road house. Associated with the schist on Boston Creek is some black and white tourmaline-bearing schist, indicating that the metamorphism was not due wholly to dynamic agencies but that at least a part of the minerals are of pneumatolytic origin. To the west and south of these rocks, and presumably overlying them, are quartzose rocks which crop out in a number of disconnected areas and range from very fine medium and coarse grained quartzites to quartz-mica schist. These are not to be sharply differentiated on the one hand from the garnetiferous mica schist, nor on the other from the argillite and crenulated phyllite which occupy other parts of the area and with which they are in places so intimately associated that their separate mapping does not appear practicable. The quartzitic rocks make up the larger part of Boston Dome, Cecil Dome, and Scow Mountain and appear in several places along the Flint-Long Creek divide and on the trail near Ruby. Smoky quartz makes up a considerable portion of the grains in some of the quartzite beds, such as those that constitute the crest of Boston Dome and those on the left bank of Beaver Creek.

The phyllite and slate are exposed along the bluffs of the Yukon above and below Ruby, where they may best be studied. In places they show secondary cleavage, much crenulation, and a perfect network of minute quartz veins filling fractures; elsewhere there are larger quartz veins, whose shattered filling furnishes evidence of the stresses to which the rock has been subjected. At one place there are clearly defined step faults with a throw of a few inches, which indicate on a small scale a probable feature of the major structure also. From the scanty outcrops and the material comprising the stream gravel it appears that the slate and phyllite make up the larger portion of the area between Long and Poorman. With these is associated in some places coarser grained graywacke which contains feldspar and has a general resemblance to a dark quartzite. Such rocks were seen on Basin Creek. Of the area along the Innoko from 5 to 25 miles below Dishkakat, Maddren [26] states that the rocks are schists and correlates them with the rocks at Ruby and with the Birch Creek schist. He states also that similar rocks are reported to occur in the center of the Kaiyuh Mountains. Rocks of like nature are found also in the vicinity of Mount Hurst and along Iditarod River.

STRUCTURE.

Exposures showing the attitude of the rocks are unknown between Ruby and Poorman except along the river and a few of the creeks. Some indication of bedrock trends may be obtained from these exposures and by joining up isolated outcrops of the rocks that are of similar character. It is thus found that the principal structural

[26] Maddren, A. G., The Innoko gold-placer district, Alaska: U. S. Geol. Survey Bull. 410, p. 45, 1910.

direction is N. 30° E., with local variations of 20° to 30° east and west of this direction. Along the river the beds dip to the west at a moderate but varying angle. There is much evidence of folding and faulting along axes parallel to the main trend of the rocks. The shattered condition of some of the heavier beds and the deformation and brecciation are a part of this evidence. The faulting is apparent in a few places along the river bank near Ruby.

From the general attitude of the rocks and the distribution of younger rocks there is some justification for the belief that the structure as a whole is anticlinal, with the major axis pitching southwestward. The structure is of course too complex to be conceived as consisting of a simple anticline. The rocks exposed in the vicinity of Ruby lie on the northwest side of the axis. The structure is complex everywhere, but in the vicinity of the numerous intrusive masses additional complexities have probably developed. Near Deadman Hill there are outliers of younger rocks, embracing cherts, tuff, and volcanic agglomerate. The contact of these rocks with the underlying metamorphic rocks was not observed, but it is believed that they are infolded within the older formation, a green chlorite schist found a few miles to the southwest representing the volcanic agglomerate.

AGE AND CORRELATION.

The intensity of the metamorphism and the thoroughness of the recrystallization in these older rocks are comparable with those shown by the Paleozoic rocks of the Circle quadrangle, in the Yukon-Tanana region. Degree of metamorphism, however, is inadequate of itself as a basis for correlation, but it must be given considerable weight when studied in conjunction with lithologic similarities other than those induced by metamorphism.

Within the area mapped as an undifferentiated complex three areas of Devonian limestone have been recognized. To the east and southeast Eakin[27] found large areas of both Devonian and Ordovician limestone among the otherwise undifferentiated metamorphic rocks. Likewise, in the White Mountains northeast of Fairbanks Ordovician, Silurian, and Devonian limestones form an integral part of the metamorphic series. Along Yukon River between Eagle and the boundary Carboniferous limestones make up an important part of the sequence. and Carboniferous rocks, including some limestone, are also present in the Yukon-Tanana region. A comparison of the undifferentiated limestones of the Ruby-Poorman area with the limestones at several horizons in near-by regions suggests that systems other than the Devonian may be represented among these rocks; and their areal posi-

[27] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, pp. 23–27, 1918.

tion in the complex, the neighboring rocks, and their degree of metamorphism indicate that they may be in part of pre-Devonian age. The argillaceous and arenaceous rock types found in the area also are similar to the Paleozoic rocks of the Yukon-Tanana region.

The upper and lower stratigraphic limits of the Ruby-Poorman complex, however, can not be given. The next younger formation consists of the chert-argillite formation south of Poorman, whose relation to the metamorphic rocks has not been determined. The only evidence as to the lower limit of the metamorphic series is lithologic and consists in the fact that the typical Birch Creek schist of the Yukon-Tanana region contains very little limestone. The regional metamorphism of that formation also is in general greater than that of the Ruby-Poorman rocks. It is believed, therefore, that the metamorphic rocks of the Ruby-Poorman area are mainly of Paleozoic age but contain possibly some infolded rocks that may be comparable in age with the Birch Creek schist.

UNDIFFERENTIATED LIMESTONES.

AREAL DISTRIBUTION.

Massive crystalline limestone appears at several localities in the Ruby-Poorman area, in close association with the undifferentiated metamorphic complex, of which it forms one of the separable units. The chief localities are along Yukon River, above and below Ruby, at Sulatna Bluff, and on the ridge between Timber and Poorman creeks. The extension of these rocks on the north side of the Yukon has been noted by Collier.[28] Also in the vicinity of Mount Hurst a belt of crystalline limestone makes up a portion of the low rounded knobs of the foothills.

CHARACTER AND LOCAL RELATIONS.

The common characteristic of this limestone is its complete recrystallization. As a result of this, the original bedding is usually indeterminable, though in some places apparent from the banding of the rock, which is believed to be due in part to original difference in the beds and in part to differential alteration across the bedding. The crystalline limestone ranges in color from light to dark gray, and some of it is bluish, but all appears white when seen from a distance.

In the exposures on Yukon River there appears to be a close association between the limestone and a garnetiferous mica schist. The garnets are about one-eighth of an inch in diameter and make up a considerable portion of the rock. In the outcrops about 4½ miles above Ruby there are two beds of limestone. The lower one crops out for 700 feet or more along the river at nearly right angles to the

[28] Collier, A. J., unpublished notes, 1902.

strike, with a dip of about 30° W. This is succeeded by about 500 feet of schist, which is partly covered by unconsolidated material, and this in turn is overlain by about 1,800 feet of limestone having about the same dip and strike as the lower bed. The rock overlying the limestone is concealed, but fragments of schist on the beach below the limestone outcrop offer a suggestion as to its nature. Between these outcrops and Ruby thinner bands of limestone appear, but their associations are not clear. In one place there are indications that the adjacent rocks have been brought into their present relations with the limestone by faulting. The limestone making up the bluff just below Ruby is isolated from other rocks by the Quaternary deposits at the mouths of Ruby Creek and the next creek below, but fragments of garnetiferous schist were found on the crest of the hill about a mile south of this bluff. The schist probably overlies the limestone.

In the exposure in the Sulatna bluff no bedding is apparent, and the rocks appear in massive, unbanded, shattered blocks. In places some of the fracture lines are so arranged as to suggest folding when viewed from a distance, but closer examination fails to confirm the suggestion. In the other exposures seen the structure is in accord with that of the adjacent metamorphic rocks.

Limestone is reported to occur on Birch Creek near the mouth of Straight Creek, but it was not seen by the writers. Limestone pebbles are associated with cobbles of greenstone schist in the gravel on Trail Creek about a mile above Elephant Creek. A small outcrop of limestone was seen near the head of Little Dome Creek on the south side of the creek. Apparently overlying it on the westward is much sheared actinolite schist. On account of the covering of unconsolidated material, the extent of these bodies of limestone has not been ascertained.

In the Tolstoi district the most conspicuous of the Paleozoic rocks is a limestone that forms the high conical hills on the northwest and west flanks of Mount Hurst and extends southwestward nearly to Tolstoi River.[29] It crosses Hurst Creek and appears at the base of the hills on the east side of this stream a short distance below the now abandoned Jap road house. A small outcrop lies between the forks of Mastodon and Mammoth creeks, and another appears on the south side of Myers Creek. Limestone pebbles are found in the gravel of Iron Creek, and this rock is said to crop out on the north side of the creek. Whether or not it extends north of Madison Creek is not known.

Schistose and siliceous phases of the limestone appear in the vicinity of Mount Hurst, and the siliceous rock is finely crystalline. Elsewhere the rock appears to show but slight effects of crystallization.

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

AGE AND CORRELATION.

The stratigraphic relations between the crystalline limestone and the surrounding rocks are obscured by the complexity of the structure and by the mantle of vegetation and Quaternary débris. Moreover, the exact age of the surrounding metamorphic rocks themselves is in doubt. Hence any statements as to the correlation of these rocks can be regarded only as suggestions.

The known facts are that in the Ruby-Poorman area two types of limestone occur. One of these, from which Devonian fossils have been collected, is in large part not recrystallized, though much brecciated and fractured. The crystallized limestone of the other type occurs along the Yukon and at Sulatna bluff in intimate association with mica schist, and it has obviously been more metamorphosed than the Devonian limestone in this area. This great metamorphism may be interpreted in two ways. It may be considered to be a local phase of intense alteration, and in that case the crystalline limestone may be equivalent in age to the Devonian limestone. On the other hand, the recrystallization of the limestone may be the result of a greater regional alteration, due to the greater age of this formation. Stratigraphic evidence on the age of the limestone in the Cosna-Nowitna region, however, obtained by Eakin[30] in 1915, has an important bearing on this question. He obtained Middle Devonian and Ordovician fossils from limestones in that region, where the rocks are little metamorphosed. The Ordovician limestone, too, overlies an older series of rocks which are comparable in many ways with those in the Ruby district here designated the undifferentiated metamorphic complex. It is probable, therefore, that limestone occurs at more than one Paleozoic horizon in this region. For this reason the crystalline limestone of the Ruby district above described is regarded as mainly pre-Devonian.

The limestone of Mount Hurst has been grouped on the map with the undifferentiated limestone. It was correlated tentatively with the late Carboniferous limestone of the lower Kuskokwim by Harrington[31] on the grounds of lithologic similarity and associations. This limestone is only locally crystalline and therein resembles the Devonian limestone of the Ruby-Poorman area. As no fossils have been found in it, its real age is not definitely known.

[30] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, pp. 19–27, 1918.

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

MIDDLE (?) DEVONIAN ROCKS.

AREAL DISTRIBUTION.

In the Ruby-Poorman metamorphic complex three small isolated areas of limestone are assigned to the Devonian. Devonian fossils were obtained in one of these areas. The two others are correlated with it on structural and lithologic grounds. By far the larger area mapped as Devonian is that lying along Kuskokwim River above and below McGrath.

LITHOLOGY.

The Devonian limestone in the northern area is badly sheared and partly recrystallized, some of it carrying crushed crinoid columns that have been replaced by white calcite and are conspicuous against the dark-gray color of the rest of the rock.

Spurr [32] describes the Devonian rocks along the Kuskokwim as follows:

> The Tachatna [now spelled Takotna] series consists of a series of gray, generally thin-bedded limestone, with limy, carbonaceous, and chloritic shales and some fine-grained arkoses. The rocks have been considerably folded and contain frequent quartz veins. They are cut by granitic dikes in rare cases.

He also says: [33]

> The first outcrop of rock seen after leaving the Tordrillo Mountains is 10 miles or more below the junction of the Kuskokwim with the East Fork and consists of much decomposed clayey limestone and slate, striking N. 55° E. and dipping 15° SE. These rocks contain quartz veins, which often carry pyrite in abundance.

STRUCTURE.

In the northern part of the region the structure is essentially that of the metamorphic complex of which the limestone forms a part. In the Kuskokwim area the structure is more plainly indicated as described by Spurr: [34]

> At intervals along the river the same rocks outcrop, showing continual but not close folding and having in general a northeasterly strike and a comparatively shallow dip to the southeast. Two miles below the high silt bluffs above described the river cuts the hills on its right bank, which are here composed of a heavy-bedded light-gray limestone, striking N. 45° W. and dipping 25° SW. This limestone contains many calcite veins and is highly fossiliferous, the fossils consisting mainly of corals which indicate a probable Middle Devonian age. * * * The same fossiliferous bed was found half a mile farther down the river and is probably at this point on the southwestern limb of a syncline, for between the two lies black limy shale intercalated with arkose which weathers

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[32] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 179, 1900.

[33] Idem, p. 123.

[34] Idem, pp. 123, 124.

dark red. The fossiliferous bed is probably 200 or 300 feet thick, being underlain by the same dark-red shale and sandstones which overlie. From this point down to the junction of the Tachatna [Takotna] the river frequently cuts in its right bank rocks of the same nature as those just described, consisting of limy shale or impure fissile limestone containing very small particles of sedimentary mica. The general strike of the rocks along here is northwesterly, while the dip is both northeasterly and southwesterly and varies greatly in angle, indicating considerable folding; in places it becomes vertical. * * * Farther down the river [in the vicinity of Vinasale] the strike is nearly constant, being a little north of west, and the dip is usually to the north at an angle of 45° or less; the river cuts directly across the strike. These rocks are rarely cut by porphyritic dike rocks of the granitic family.

AGE AND CORRELATION.

Spurr[35] obtained in 1898 a collection of fossils from the north bank of Kuskokwim River, about 13 miles in an air line above the mouth of Takotna River. Charles Schuchert reported on this collection as follows:

The material submitted consists of a blackish weather-worn limestone, containing corals. Of these there are the following:

- Favosites, much like F. billingsi of the Hamilton formation.
- Favosites, with smaller corallites. It may, however, be a variation of the one above mentioned.
- Alveolites, with very small corallites.
- Striatopora, sp. undetermined.
- Crepidophyllum?
- Stromatoporoids, two species, one having a globular and the other a ramose mode of growth.

There are no corals in this fauna pointing unmistakably to the Silurian (Upper), and since there is nothing present to disprove a Middle Devonian aspect, I assume that to be the age.

Eakin,[36] in 1912, obtained a small collection of fossils from the small limestone body 8 miles southwest of the Hub road house, at the head of Long Creek. Edwin Kirk reported as follows on these:

- Cladopora sp.
- Fragments of crinoid columns possibly referable to the genus Melocrinus.

These fossils indicate the Devonian age of the containing beds. Material quite similar to this both as regards lithologic character and fossil content has been obtained in the Nulato-Council region of Alaska.

Harrington, in 1915, visited the above-mentioned fossil locality but obtained only some indeterminate material.

It is evident that Devonian rocks are well represented in the Ruby district and that they continue eastward and southeastward into the Kuskokwim basin.

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[35] Spurr, J. E., op. cit., pp. 158–159.

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

MESOZOIC (?) ROCKS.

CHERT AND ARGILLITE.

AREAL DISTRIBUTION.

Beginning in the lower valley of Glacier Creek, a tributary of Sulatna River, a series of rocks composed dominantly of chert and argillite extends southward almost to the Cripple Creek Mountains. This geologic unit is bounded on the north and northwest by the complex of older metamorphic rocks, on the east by Tertiary and pre-Tertiary lava flows, and on the south by Upper Cretaceous and Eocene rocks. Its western limit is unknown.

In the vicinity of Mount Hurst, on the southeast flank of the metamorphic complex of that vicinity, two small belts are present, lying to the northwest and to the southeast of the metamorphic rocks.

Cherty rocks, which may be correlative with the chert-argillite series, are found also near Yuko Mountain, in the Ruby district, in association with greenstone. On account of the scarcity and indefiniteness of the rock exposures, it has been impossible to separate these cherts from the greenstone, which forms the major part of the country rock in that vicinity.

LITHOLOGY AND STRUCTURE.

There are very few good exposures of this series of rocks. The ridge that lies west of the South Fork of Sulatna River and extends southward into one of the headwater tributaries of Innoko River is the type locality; but even along this ridge the study of these rocks must be confined largely to talus. Only at four localities was it possible to measure the strike and dip of the beds.

The chert ranges in color from light to dark green, with white, blue-gray, and horn-colored varieties. Different-colored varieties may exist in the same specimen, giving to the rock a banded appearance. It is rather characteristic of these bands to finger out laterally into one another. The shaly members of the series are hard dark-gray argillites, composed of beds ranging from a fraction of an inch to 3 inches in thickness. Locally these rocks have a well-developed slaty cleavage.

At one locality on the ridge above mentioned the bedrock is a thin-bedded sandstone, with some layers of grit. Both sandstone and grit are well indurated. Also on the same ridge at a point about 4 miles from the forks of Glacier Creek similar grit and sandstone were observed. The grit, which is predominant, is a dark well-indurated rock made up of rounded pieces of black and green cherty and slaty fragments about a quarter of an inch in diameter. The fragmental character of the grit is most apparent on weathered surfaces. The bedding is not apparent. A fragmentary fossil imprint was collected from this rock, but it is possible that this sandy and gritty material is not an integral part of the chert-argillite series.

In the vicinity of Mount Hurst the structure is not well known. The trend of the chert is about north-northeast, and the two bands of these rocks lying on either side of the metamorphic series suggest anticlinal structure. It is very likely, however, that the structure is much more complex than the mapping indicates.

The members of the chert-argillite series have suffered considerable deformation, which has resulted in close folding and the development of secondary structure. Wherever it was possible to record the planes of bedding joint planes were noted. Slaty cleavage, where observed, appears to be parallel to the bedding planes, which may be distinguished by slight variations in color and texture across the structure. Much of the chert is brecciated and cemented together by secondary silica. It is probable, too, that incipient recrystallization is present in the more indurated rocks of this series, but recrystallization is not a regional characteristic of these rocks.

Four measurements of the attitude of these rocks along the ridge west of the South Fork of Sulatna River give an average strike of N. 52° E., which is assumed to be the regional strike. The dip, however, is inconstant both in degree and direction, showing that these rocks are much folded; and observations on the details of structure at one or two points induce the belief that close folding is the common condition.

IGNEOUS ROCKS.

Acidic lava flows and tuffs are intimately associated with the sedimentary members of the chert-argillite series. The available evidence as to stratigraphic relations is not entirely conclusive but seems to warrant the belief that these are interbedded lavas. Under the microscope they are found to be soda rhyolites.

Basic igneous rock is associated with the chert-argillite series at many localities, but nowhere is the relationship very clear. Andesite and basalt of greenstone habit, as well as pyroxene andesite and basalt of fresher appearance, are found within and bordering the area mapped as chert and argillite, but most of these rocks are believed to be lavas of later date. A body of gabbro bounds on the east the area of grit that lies on the ridge between Glacier Creek and the South Fork of Sulatna River. Two dikes of basaltic or basic andesitic nature cut the soda rhyolite that is interbedded with the chert-argillite series. It is probable that the basic rocks above mentioned are connected with the Tertiary volcanism.

AGE.

No fossils that can be identified have been found in any of the rocks of this series. The fossil imprint above referred to, which was found in the gritty beds on the ridge between Glacier Creek and the South Fork of Sulatna River, was submitted to T. W. Stanton, who reports as follows:

> From the form and sculpture of the imprint I judge that it was made by a fragment of a small immature ammonite. It is impossible to determine even the genus, but the sculpture suggests a Cretaceous or Jurassic type rather than anything else.

The field evidence, including the lack of general recrystallization in these rocks and their general lithologic dissimilarity to the rocks of the metamorphic complex, indicates that the cherts and argillite are younger than the metamorphic rocks to the north. The fossil determination above given affords no basis for any definite age assignment. The conglomerate beds, however, at or near the base of the Eocene rocks are composed largely of chert pebbles derived from this series. It is evident, therefore, that the chert-argillite series is pre-Eocene. In the absence of further data, these rocks are assigned provisionally to the Mesozoic, though they may prove eventually to be of Carboniferous age. Similar rocks found to the east by Eakin [37] were referred tentatively to the early Mesozoic.

UPPER CRETACEOUS AND EOCENE ROCKS.

AREAL DISTRIBUTION.

Rocks that are thought to be mainly of Upper Cretaceous age, though grading upward into the Eocene, form the country rock over much of the Ruby-Kuskokwim region. Beginning in the valleys of Susulatna and Nowitna rivers, these rocks extend southward and westward through Takotna and Ophir to Iditarod and southward to Kuskokwim River. On the northeast the belt extends into the flats of the upper Nowitna basin, beyond the limits of the area mapped, where these rocks are mantled by later unconsolidated deposits. South of the Kuskokwim the extension of this series has been studied and mapped by Smith.[38]

On the north side of Poorman Creek, about 1 mile below the mouth of Tenderfoot Creek, a coal bed has been uncovered. As coal is not known to exist in this region in rocks older than Upper Cretaceous,

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[37] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, p. 33, 1918.

[38] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, pp. 57-84, 1917.

this discovery is presumptive evidence that some Upper Cretaceous or younger beds have been folded or faulted into the older rocks that form the bedrock of Poorman Creek. It is possible that the slate in the vicinity of Poorman is all of Upper Cretaceous age, and that other slates in the area of undifferentiated metamorphic rocks west of Long Creek and on Quartz Creek, where coal is also reported, are also of Upper Cretaceous age.

LITHOLOGY.

All gradations between sandstone and shale are to be found in this series, including shaly sandstone and sandy shale and also some conglomerate. It is suspected that shale forms a larger proportion of these rocks than the outcrops on the ridges would indicate. The shale would naturally be more easily eroded than the sandstone, and it is probable that the valleys have a larger amount of shale bedrock than the ridges. Moreover, at certain localities intrusive rocks have invaded shaly beds of considerable extent, which form prominent outcrops on the ridges owing to the silicification and other contact metamorphism which they have suffered. It is rather significant that such bodies of shale are exposed only where metamorphism has rendered them competent to withstand erosion. In certain localities, according to Eakin,[39] the shaly beds are calcareous.

The conglomerate, like the sandstone, is derived from the older rocks in close proximity to it and generally consists of pebbles of chert and of rocks from the older metamorphic complex set in a gritty matrix of similar material. The conglomerate is more fully described on pages 27, 29, 30, and 34.

Some small coal seams are present in the Upper Cretaceous rocks. The thickness of the beds and the character and localities of the coal are set forth on pages 119–120.

The sandstone has been affected only to a moderate degree by the acidic igneous rocks which have invaded it. Such intrusive rocks have intensified the induration of the sandstone, and in some places partial recrystallization has resulted. The shale, on the other hand, has been recrystallized in certain localities, where it is associated with intrusive rocks, and changed to a hard, fine-grained, flinty rock composed of quartz and biotite. Plate V, *B*, shows a block of shale thus hardened and recrystallized by the intrusion of a granodioritic rock. This shale was observed along the ridge southeast of Fourth of July Creek. The basic intrusive rocks appear to have had no very appreciable effect on either the sandstone or the shale.

[39] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 23, 1914.

IGNEOUS ROCKS.

Both intrusive and extrusive rocks are known in this series. The intrusive bodies fall into three general groups—(1) quartz monzonite; (2) pyroxene diorite and gabbro, with their fine-grained equivalents; and (3) soda rhyolite and related intrusive rocks. The quartz monzonite and the basic intrusive rocks occur as laccoliths and dikes. The soda rhyolite, except at one locality, is known only in comparatively small intrusive bodies. In addition, there are some dikes of somewhat different character which are thought to be the products of differentiation of the larger bodies. Thus, dikes of oligoclase diorite and oligoclase dacite cut the sediments in proximity to the intrusive monzonite, and at one locality on the divide between Susulatna and Nowitna rivers there is a basic dike which is believed to be a differentiated product derived from the basic intrusive rocks.

The lava flows that are in certain localities associated with the Upper Cretaceous and Eocene rocks are, so far as known, all of basic character, consisting of pyroxene andesite and basalt. Interbedded with these flows are considerable amounts of tuffaceous material of like composition. These flows and tuffs appear to overlie the Upper Cretaceous sediments, though they may be in part interbedded with the Eocene beds. The eruption of the basic lavas took place, therefore, after the Upper Cretaceous epoch.

The igneous rocks are described in more detail on pages 55–74.

LOCAL DETAILS.

YUKON RIVER.

The Upper Cretaceous sequence of beds is well exposed along the north bank of Yukon River from Melozi to Louden. The base of the sequence appears at Melozi, where it is represented by conglomerate, sandstone, and sandy shale. These rocks are overlain (downstream) by fresh-water shale and sandstone that contain plants and fresh-water invertebrates, and the highest part of the section is composed of marine sandstone and shale containing marine invertebrates and a few fossil plants.

POORMAN CREEK.

On Poorman Creek about 1 mile below the mouth of Tenderfoot Creek a coal seam has been uncovered. To the west of the shaft prospect holes have been sunk which are reported to have passed through a brownish bedrock (probably clay or shale) and reached a soft, yellowish sandstone. The coal seam in the shaft was reported by the owner to have a general northeasterly trend and a steep dip to the northwest. If this observation is trustworthy, it places the coal below the sediments above described. These data suggest the infolding or faulting of some Upper Cretaceous beds at this locality, for the bedrock in Poorman Creek as a whole is considered part of the undifferentiated metamorphic complex. The mantle of unconsolidated deposits to the north and south of this locality precludes any knowledge of the areal extent of the coal-bearing rocks and renders their delineation impracticable.

NOWITNA AND SUSULATNA VALLEYS.

From the northeastern limit of these rocks in the Susulatna and Nowitna valleys, southwestward to the Cripple Creek Mountains, very few data are obtainable regarding their character and structure. The tops of most of the ridges are covered with vegetation, and only here and there is the bedrock visible. Observations on the structure were possible at only one or two localities. Where exposed the rock is a dark-gray sandstone, usually impure but in places strikingly quartzose, and such fragmentary data as are available indicate that the beds have a general northeasterly trend.

At one locality on the north side of Nowitna River, in the vicinity of the camp of July 2, the country rock is conglomeratic, being composed of conglomerate, grit, and sandstone. The conglomerate contains pebbles that reach 4 inches in diameter but average perhaps three-fourths of an inch. The pebbles are essentially chert, with a small proportion of vein quartz and black shale. The conglomerate itself is fractured and veined with quartz. There is no possibility of estimating the amount of conglomerate at this locality, but in the position of the conglomerate beds along the top of the hill there is a suggestion of a strike, which seems to be about N. 50° W.

A small amount of work with the pick indicated that the dip might be to the northeast. This conglomerate, when considered in conjunction with the older rocks at no great distance away, is interpreted as evidence that the thickness of the sediments at this point is not very great, but no inference is drawn regarding the original thickness of the Upper Cretaceous strata. This deduction is based on the assumption that the conglomerate represents a shore line that transgressed progressively northwestward in this vicinity. It is probable that this conglomerate represents the base of the Eocene. Very few intrusive rocks were observed in this area. One dike that cuts the sediments at a point in the vicinity of the camp of June 30 proved to be a hornblende vogesite.

Along the divide between the eastern headwaters of the North Fork of Innoko River and upper Susulatna River, northeast of the Cripple Creek Mountains, the contact between the Upper Cretaceous and Eocene succession and the chert-argillite series has been mapped by Eakin,[40] although the Eocene age of the upper part of this series of rocks was not recognized at that time. The beds in this locality are gritty and somewhat conglomeratic, but no coarse conglomerate was observed. The areal distribution of the Upper Cretaceous and Eocene rocks in this vicinity, which extend northeastward as a lobe into the chert formation and its associated rhyolitic flows, suggests strongly that they lie unconformably upon the chert, but the outcrops are too scarce and poor to permit the verification of this suggestion.

The Upper Cretaceous and Eocene sedimentary rocks of Susulatna Valley are bordered on the northeast by an extensive series of fine-grained basic rocks. Tuffaceous members in this series reveal the surficial character of the lavas. Although no absolute evidence of an unconformable relation between these lavas and the Upper Cretaceous and Eocene sediments has been discovered, the conclusion has been reached that, in this vicinity at least, such a relation exists.

The high mountain group at the head of Nixon Fork of Kuskokwim River (Tuentna River), known as the Nixon Fork Mountains, lies southeast of the Ruby district proper. These mountains were mapped topographically at distances of 10 miles and were not visited by the expedition of 1915. They are rugged, black-looking mountains and have the appearance of being a complex of sediments and intrusive rock. It is likely that the Upper Cretaceous sediments extend to these mountains and form a prominent part of the bedrock there.

East of the Cripple Creek Mountains, on the east side of Susulatna River, there is a group of high hills that form a prominent feature of the local topography. A metamorphosed shale forms the dominant bedrock in this vicinity and constitutes the highest peak in this group. On the northwest the country rock is sandstone from the Susulatna up to the base of the high hills. There it changes to a sequence of dark flinty rocks, which appear to be silicified and recrystallized shale. These rocks are commonly banded and show small folds and fractures. The thoroughly recrystallized varieties are composed essentially of fine quartz and biotite, and the banding is seen under the microscope to be due to the concentration of biotite in parallel layers, separated by layers of comparatively fine silica. Gradations from the completely recrystallized varieties to less metamorphosed shale were noted. Quartz veining is rather common.

No large body of igneous rock is known to be present in this vicinity nearer than the Cripple Creek Mountains, and the monzonitic rock there has not produced the contact metamorphism in this area, because quite unaltered sediments are known to exist

[40] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pl. 3, 1914.

between the two localities. It is believed that a large body of quartz monzonite underlies this metamorphosed shale at no great depth.

Several observations of strike and dip in this vicinity point to much discordance of structure, due doubtless to the underlying intrusive body. The rocks seem to have a general northeasterly trend, however, with an inconstant dip indicating much folding. In places a slaty cleavage has been developed, but this seems usually to be coincident with the bedding.

That this vicinity is a site of intrusion is proved by the character of the country rock to the east. Within a distance of 4 miles in that direction, a variety of intrusive bodies invade the sedimentary rocks. These are chiefly dikes but are not considered to be of mappable size. The principal varieties of igneous rock are quartz-oligoclase diorite and pyroxene andesite and basalt. The dioritic rock is believed to be an offshoot from the underlying monzonite magma. The country rock within this area of intrusion is dominantly argillaceous, being partly thin-bedded shale, partly slate, and partly pencil slate.

The sedimentary rocks close to the Cripple Creek Mountains were not seen by the writer. According to Eakin[41] the dominant sequence comprises "massively bedded sandstone with minor amounts of slate." The invasion of the sedimentary rocks by a mass of intrusive rocks, dominantly quartz monzonite, is the most significant geologic feature of the Cripple Creek Mountains.

HEADS OF SUSULATNA RIVER AND FOLGER CREEK.

Along the divide at the heads of Susulatna River and Folger Creek the sedimentary rocks are dominantly coarse reddish-brown sandstone, in places conglomeratic, with minor amounts of shale. The coarser sandstone and conglomerate are massively bedded in many places. The pebbles of the conglomerate are flint, vein quartz, black slaty rock, and schist. Pebbles as large as 5 inches in diameter were observed in the conglomerate.

At one locality on the divide, in the vicinity of the camp of July 15, it was possible to measure a partial section of the conglomerate beds, as follows:

Section near camp of July 15.

	Feet.
Conglomerate	5
Sandstone	12
Conglomerate	7
Sandstone	15
Conglomerate	15
Sandstone (base of section).	

[41] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 24, 1914.

The conglomerate at this point has a total thickness of 27 feet, and doubtless considerably more of it is present. The rocks of this section have a gentle westward dip, about 10° or less.

Fossil shells and plants were collected along the divide in this vicinity and are listed on page 39. The shells were found interbedded with the plants—in fact, some of the shells and plants were taken from the same slabs of rock. Where the fossils were found the country rock is a thin-bedded sandstone, with much cross-bedding, associated with considerable interlaminated conglomerate and conglomeratic sandstone. The fossil plants from this locality are determined to be of Eocene age, but the fossil shells associated with them are not diagnostic and may be either Upper Cretaceous or Eocene. It is very likely that the conglomerate, grit, and sandstone above described represent the base of an Eocene sequence of rocks.

The structure of the rocks at the heads of Susulatna River and Folger Creek is that of a basin. This structure appears to have been produced by igneous intrusion on four sides, by means of which the strata were tilted upward. These four centers of intrusion were the Cripple Creek Mountains, the two groups of hills east of Susulatna River, and the Twin Mountain area to the south. This induction leads to the belief that the surrounding igneous rocks are younger than these Eocene beds—a belief that is strengthened by the absence of igneous material in the conglomerate and associated sedimentary rocks. This fact can not be explained by the supposition that the surrounding igneous rocks were perhaps not yet uncovered to erosion, for some of these rocks are flows. The stratigraphy in this area therefore indicates that the Tertiary volcanism occurred in late Eocene or post-Eocene time.

INNOKO DISTRICT.

The writers did not see the sedimentary rocks in the mining district of the Innoko Valley. According to Eakin [42] argillaceous beds predominate there and are thinly and evenly bedded and rather slaty. This slaty character is not the general condition of the Cretaceous beds but is a sign of more intense alteration in this particular district than elsewhere.

Acidic dikes are of common occurrence in the Innoko mining district and consist chiefly of oligoclase dacite and soda rhyolite. Eakin [43] also reports that

> Quartz veins cut the rocks of the Innoko district generally and are especially common in the acidic dikes that intrude the sedimentary rocks. The veins that cut the dikes are usually not of massive form but occur as close stockworks. The mineralizing solutions that permeated the dikes and deposited the veins also changed the composition of the adjacent rock profoundly.

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[42] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 24, 1914.

[43] Idem, p. 28.

The alteration of the sedimentary rock, the presence of many acidic dike rocks, and the quartz veining, as well as the gold mineralization, point clearly to the presence of a body of intrusive rock, probably of monzonitic character, at no great distance below the surface. The dikes are probably differentiated offshoots from this larger magma, and the quartz veining should be interpreted as veining at or near the periphery of a granitic body, such as that at Twin Mountain, to the northeast.

TAKOTNA AND TATALINA VALLEYS.

In Takotna and Tatalina valleys the Upper Cretaceous rocks consist of thin-bedded sandstone, shale, and slate, grit or conglomerate forming no important part of the sequence. The attitude of the series at different localities is variable, apparently owing to the large number of intrusive bodies, yet there seems to be a general trend of about N. 55° E. The data regarding the regional dip are conflicting and inconclusive, and it is rather likely that there is no uniform dip. It is believed that the Upper Cretaceous rocks have been thrown up into a series of folds by means of which beds at the same stratigraphic horizons are exposed at widely separated localities. It is possible, however, that the sedimentary rocks of the Takotna Valley may represent a different horizon from that of the Upper Cretaceous rocks near Ophir Creek and those near Camelback Mountain.

As a whole the Cretaceous beds in this area are monotonously alike, consisting of dark shale and shaly sandstone. Locally the rocks are silicified, owing to the proximity of intrusive rocks. This silicification is best exemplified at Camelback Mountain, where shaly beds have been altered to red and green cherts, in places banded. It was from one of these areas of green silicified shale that the flattened fossil shell listed on page 40 was collected. The flattening of the shell and the complete silicification of the beds in which it was found indicate that the contact-metamorphic effect was marked. On the northwest side of Camelback Mountain the strata are much disturbed, and measurements of strike and dip can not be depended upon to furnish any evidence of the regional trend of these rocks. Likewise, on the southeast side of Fourth of July Creek, about 1½ miles above the mouth of Lincoln Creek, the shale country rock has been greatly fractured and intimately intruded by an indeterminate granular rock of granodioritic character. This feature is shown in Plate V, *B*. The shale is hardened by metamorphism and silicification and contains much secondary biotite of microscopic dimensions. Banded varieties similar to those previously described are also present.

At some localities, however, the rocks of this series appear to be more than ordinarily metamorphosed, without any evidence of the presence of igneous rocks near by. Thus, in the valley of Takotna River above the settlement of Takotna the sedimentary rocks appear to be unusually metamorphosed, consisting of a quartzitic type of sandstone and much slate. Likewise on the ridge separating Candle Creek from the Kuskokwim the bedrock is a quartzitic sandstone that shows considerable recrystallization, although in this locality the metamorphism may be due to the effect of igneous rocks beneath. The possibility remains, nevertheless, that some rocks older than Upper Cretaceous are present in the valleys of Takotna and Tatalina rivers.

Still farther east, along the Kuskokwim, beginning at a point 10 miles below Vinasale, Spurr[44] found a series of conglomerate and arkose to which he applied the name "Holiknuk series." He states that these rocks extend downstream as far as Kolmakof. These rocks may constitute the base of the Upper Cretaceous series. If so, the Upper Cretaceous sequence in the narrows of Kuskokwim River, downstream from Sleitmut, should be correlative with that along the Yukon downstream from Melozi.

None of the intrusive bodies in the Takotna and Tatalina valleys cover great areas, but a great variety of petrographic types exist. Quartz monzonite, quartz-oligoclase diorite, oligoclase dacite, soda rhyolite, pyroxene andesite, and basalt are all present. Basic lava flows have a considerable areal distribution at the head of Fourth of July Creek. These, like the other basic lavas, are thought to lie unconformably on the Upper Cretaceous rocks.

Camelback Mountain, which forms the divide between Moore Creek, a tributary of Takotna River, and Bonanza Creek, is another site of intrusion in the Upper Cretaceous rocks. Here, as at certain other localities previously described, the main intrusive body has not been uncovered by erosion. Small offshoots from the underlying stock appear at the surface, and these, together with the contact-metamorphic effects, form the basis for the assumption that a larger body of igneous rock lies at no great distance below.

TOLSTOI DISTRICT.

In the Tolstoi district Upper Cretaceous rocks are of considerable extent, appearing on both sides of Tolstoi River and on the north side of Mastodon and Madison creeks. Small patches of these rocks also appear along the lower part of the ridge west of Hurst Creek,

[44] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 159–161, 1900.

and they probably form the bedrock of Boob Creek and of the area between Boob Creek and Tolstoi River. Their distribution reflects clearly the effects of the intrusive rocks at Mount Hurst.

The lithology shows considerable variation. Wherever the base of these rocks was observed, as along the ridge between Hurst and Ledge creeks and also north of Mastodon Creek, it is a conglomerate composed of chert pebbles that rests on the irregular surface of the underlying chert. The sandstone shows a greater diversity of materials, including quartz, feldspar, fragments of carbonaceous rocks, and minerals of probably secondary origin, such as chlorite and calcite. If ferromagnesian minerals, such as hornblende, augite, or olivine, were originally present, they have now been so completely altered to secondary minerals as to be unrecognizable. The feldspars are also undeterminable on account of kaolinization. It is possible that some of these rocks are of Eocene age.

A considerable proportion of the Upper Cretaceous sediments are of the fine-grained argillaceous type and have been metamorphosed to form slate. Intrusion by the dioritic mass of Mount Hurst as well as by the diorite on the headwaters of Madison Creek has produced phyllitic phases of some of these rocks, so that they are not readily distinguishable from the older phyllite that is associated with the Paleozoic limestone. Both the slate and the phyllite are cut by numerous small quartz veins, which are probably the source of the gold. Some of the veined slate shows pyritization.

IDITAROD DISTRICT.

In approaching the Iditarod district from the northeast, it is apparent that the sedimentary rocks are fairly regular in their stratigraphic attitude, having a general northeasterly trend and a steep dip, usually to the northwest. The rocks that appear on the ridges are mainly massive or thin-bedded sandstone with a considerable amount of interbedded shale. Both the lithology and the fossil evidence indicate that Eocene beds are lacking in the area between Iditarod and Camelback Mountain.

Within the Iditarod mining district proper certain differences are noticeable. The shaly members are more indurated and in many places, especially near the intrusive bodies, have taken on a slaty cleavage, being in this respect analogous to the Upper Cretaceous shaly beds in the Innoko district. The contact metamorphism is expressed in the sandstone, near the acidic igneous rocks, by partial recrystallization, so that the rock is altered to quartzite. The head of Flat Creek, in the vicinity of the monzonite body there, shows very well the petrographic changes in the country rock above noted.

The structure of the Upper Cretaceous rocks in the vicinity of Flat shows local variations from the general attitude of the series. Without question these are due to the presence of igneous intrusive rocks. At the end of the spur east of Flat Creek a fine-grained sandstone crops out which strikes east and dips 80° S. At the head of Slate Creek, on a spur between the two main forks at an altitude of about 1,100 feet, the shale bedrock strikes N. 65° W. and dips 50° S. These and other measurements show the local irregularities of the Upper Cretaceous rocks in the vicinity of the intrusive rocks.

On Iditarod River at the mouth of Otter Creek Brooks[45] found bluff exposures of bluish sandstone and slate, with some interbedded conglomerate. The pebbles are largely chert and quartz, and the largest are reported to be about half an inch in diameter. Conglomerate with larger pebbles is reported to have been seen in excavating for the power house at this locality. Between the mouth of Otter Creek and Iditarod exposures of greenstone occur along the west side of the river, capped on top of the ridge by a volcanic conglomerate that consists of rounded to subangular pebbles of basic volcanic material, with a greenstone habit, as much as 6 inches in diameter, in a fine-grained tuffaceous matrix of like nature.[46] It is not known whether this volcanic conglomerate represents a local phase of the conglomeratic rock near the base of the Upper Cretaceous, or whether it is a tuffaceous member of the greenstone formation that crops out along Iditarod River above Iditarod. The presence of so much cherty rock farther west, in conjunction with the chert conglomerate at the mouth of Otter Creek, raises the question whether an Upper Cretaceous conglomerate could be so purely volcanic in this vicinity. Rightly or wrongly, this volcanic conglomerate, together with the underlying greenstone, has been excluded from the area mapped as Upper Cretaceous and Eocene in this report.

The intrusive rocks in the Iditarod district are treated more fully in the description of the igneous rocks. Quartz monzonite and pyroxene diorite are the two principal varieties. Some extrusive rocks also are believed to be present, associated with the pyroxene diorite. This inference is based upon the presence of certain tuffaceous beds in the basic complex on the ridge east of Flat Creek.

The Upper Cretaceous sequence is known to be coal bearing in the Iditarod district. Along the tram road between Flat and Iditarod, at the summit of the intervening ridge, at least two thin coal seams have been prospected. These are described on page 119.

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[45] Brooks, A. H., unpublished notes on Iditarod district.

[46] Eakin, H. M., oral communication.

IDITAROD TO KUSKOKWIM RIVER.

The Upper Cretaceous section from Iditarod southeastward to Kuskokwim River has not been seen by the writers, and the following description is abstracted from the report by Smith [47] on this region. The rocks are sandstone and shale with some interbedded conglomerate members. Ripple marks and other shallow-water phenomena were noted. Indistinct plant remains are rather common, but the only determinable fossils found were shells. Volcanic rocks appear not to have any considerable areal distribution in this part of the Upper Cretaceous, although some lavas were recognized. Many small intrusive bodies are present, but neither they nor the extrusive rocks form any significant part of the stratigraphic sequence.

The structure of this part of the Cretaceous sequence is described by Smith as follows:

> Wherever seen the Mesozoic rocks north and west of the Holitna have been considerably deformed. They are so folded that they nearly everywhere dip at angles of more than 30°. In the vicinity of the mines near Iditarod steeper dips seem to be more common than elsewhere in the region, but at many other places vertical dips were observed. The direction of neither dip nor strike is persistent for long distances, although the strike is more uniform than the dip. Spurr notes that near the contact of these rocks with the underlying conglomerate the strike is about northwest. Farther down the Kuskokwim the strike swings around until it is nearly north, parallel to the general course of the Kuskokwim. Near the place where the expedition of 1914 crossed the Kuskokwim the strike is north and the dip is steep to the west, but a very short distance downstream from this place the dip changes abruptly, as if a thrust fault had dislocated the beds.
>
> At Parks quicksilver prospect, below Sleitmut, the strike of the sedimentary rocks is about northwest, and the dip is variable in amount but dominantly northeast. Between the Parks prospect and Georgetown the strike of the rocks is nearly east, and the dip alternates rather frequently from north to south. This general strike continues to and beyond Georgetown, but near Iditarod the strike swings around toward the north. The dip, however, changes from east to west within rather short distances.
>
> Owing to the absence of beds that mark easily recognized stratigraphic horizons in the sedimentary series, the structure of the region as a whole is not now determinable. Apparently, however, the strata lie in a broad synclinal basin and have been appressed into a number of subordinate folds, which are in places accompanied by faults.
>
> Both normal and thrust faulting has been recognized, but the amount of movement along any of the great fault planes has not been determined because of the absence of horizons that would permit the identification of the same bed on the two sides of a fault plane. Many of the faults observed probably mark rather small displacement, but some of them undoubtedly involve considerable movement.

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[47] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, pp. 77–84, 1917.

The numerous changes in the direction of dip, the absence of definitely recognizable horizons of reference, and the scantiness of good exposures prevented accurate determination of the thickness of these Mesozoic rocks. The region is characterized by rounded summits bearing abundant frost-riven fragments of rock. Some ledges in the lower part of the valley walls have been uncovered by the revival of the stream's down cutting, but the thick brush and the poor traveling made examination of many of these exposures so laborious that it could not be attempted on a reconnaissance trip like that made by the expedition of 1914. Several places, however, were examined where the Mesozoic section included thousands of feet of sediments without notable break.

Many of the rocks exhibit ripple marks and raindrop imprints. Cross-bedding, indicating that some of the sediments accumulated in shallow water or in water in which were rather strong and variable currents, was seen in several exposures.

Jointing is common in many members of this series. In some of the finer-grained rocks the joints are rather closely spaced, but in most of the coarser rocks the joints are rather far apart. The shales here and there show cleavage, but it is in only a few places slaty. None of the cleaved shales seen contained secondary cleavage minerals, such as mica or chlorite, and at no place did they show pronounced schistose structure. Near their contacts with the larger intrusive masses the shales and sandstones showed baking and similar contact-metamorphic features, but at few places had metamorphism extended far from the borders of the igneous masses or formed new minerals.

Slickensiding was noted on several fault planes, where beautifully polished, nearly mirror-like surfaces had been formed by movement, particularly at the Parks prospect. They were probably especially distinct there because that was the only place where excavations made it possible to see rocks unaffected by weathering. The amount of movement along the fault planes did not seem to have been great, for slips of only a few feet produced well-developed slickensides.

GENERAL STRATIGRAPHY AND STRUCTURE.

The local structural features of the Upper Cretaceous and Eocene rocks have already been given; it remains to correlate these features as far as possible and to designate their bearing on the stratigraphy of the sediments. It has been shown that the sedimentary rocks have a marked northeasterly trend and that this trend is interrupted locally by bodies of intrusive rock which have domed up the sedimentary rocks, changing their normal strike and dip.

The regional structure, however, is not well understood, partly on account of the dearth of good outcrops and partly because of the character of the work, which included only line traverses, without side trips. It seems certain, however, that there is no uniform attitude of the beds, for the dip observations vary both in direction and in degree. The presence of both northwest and southeast dips indicates that the beds are thrown up in folds; and the general stratigraphy suggests that the folds are relatively broad and open. In this respect the Upper Cretaceous and Eocene beds are in contrast with the rocks of the chert-argillite formation, which appear to be more closely folded.

At the south end of the Ruby district coarse sediments and conglomerate appear to lap up over the chert-argillite formation and interbedded rhyolitic flows and tuffs. The contact is not visible, but the structure indicates this relation. The incomplete section measured near the camp of July 15 showed over 50 feet of coarse sandstone and conglomerate, and the loose débris on the ridge near the contact with the chert-argillite formation indicates that coarse sediments are predominant in this vicinity. Also fossil land plants and marine shells were found together interbedded with the coarser-grained rocks near the bottom of the sequence. It is therefore inferred that these conglomerate beds and associated sediments represent a shore-line type of sedimentation. The definite determination of the plants in these rocks as Eocene leaves no alternative other than the conclusion that a considerable part of the sediments in the upper valleys of Susulatna River and Folger Creek are likewise of Eocene age.

To the southeast, within the limits covered by the expedition of 1915, the sediments are for the most part finer, consisting of sandstone, shale, and rocks of intermediate types. Some conglomerate beds were seen between Iditarod and Kuskokwim River, but it seems likely that these are intraformational in the Upper Cretaceous sequence, though somewhere near its base. It is altogether probable that most of the rocks southeast of the known Eocene beds belong to the Upper Cretaceous.

Nowhere in the sequence does the stratigraphic character of the beds point to a deep basin of deposition, and it is believed that the Upper Cretaceous sediments generally exposed in this region were laid down in fairly shallow water. Proof of this is to be seen in the frequent occurrence of ripple marks and cross-bedding and in the presence of carbonaceous material in the sediments. The material composing the coarse sandstone and conglomerate at the north and west sides of the basin came unquestionably from the older adjoining rocks. It is likely that the Upper Cretaceous and Eocene sediments as a whole were laid down in a shallow sea, which encroached on the land from the direction of Bering Sea and later retreated in the same direction.

The conglomeratic beds on the north and west and the finer sediments on the southeast, together with the fossil evidence, indicate that the beds representing the highest horizons are at the north end of the Innoko-Iditarod region. But the folding, as pointed out before, is general, and except that of the conglomerate beds above described, no marked stratigraphic horizon has been recognized that will aid in deciphering the amount of duplication of beds due to folding. In addition, the character of the work has precluded the observations necessary for deciphering details of the stratigraphy. The stratigraphic relations at the three fossil localities at the head of Susulatna River indicate that at least 1,000 feet of Eocene strata are present, but as the upper limits of the Eocene rocks are not known, a maximum thickness can not be assigned.

The relation of the Eocene rocks to the underlying Upper Cretaceous rocks has not been determined. It is not known whether the base of the Eocene rocks in the upper Susulatna Valley lies conformably or unconformably upon the Upper Cretaceous rocks. Therefore it may not be stated with assurance that this horizon represents the top of the Upper Cretaceous series. Likewise the base of the Upper Cretaceous rocks is in doubt, for it is only assumed, and not proved, that the conglomerate and arkose along the Kuskokwim below Vinasale, described by Spurr, constitute the base of the series. When to this uncertainty regarding the upper and lower limits of the Upper Cretaceous rocks is added the probable surface duplication due to folding and faulting it is evident that no trustworthy estimate of their total thickness may be given. Certainly, however, the thickness is to be measured in thousands of feet.

In addition to folding, the presence of faulting can not be overlooked. Certain topographic features appear to be the result of the forces that produced the regional structure, including possibly faulting. Takotna River up to the mouth of Fourth of July Creek, Fourth of July Creek to its headwaters, Moore Creek for a considerable distance, and the whole of Bonanza Creek line up in a remarkably straight direction, which bears about N. 55° E. Beyond the limits of the area mapped the valley of Nixon Fork of the Kuskokwim (Tuentna River) takes up this direction to the northeast, and to the southwest the valleys of Iditarod River and eventually the main Kuskokwim lie on this marked line. Parallel to it are other well-marked drainage directions, such as the valleys of Susulatna, Nowitna, and Tatalina rivers. It is believed that these prominent and parallel drainage lines have a structural significance. It should be noted that the major drainage line above referred to is the site of much intrusive action and mineralization. The mineralized areas at the head of Flat Creek, in the Iditarod district, and the Moore Creek mining district lie along this zone, and the Candle Creek area is only a short distance removed along a parallel structural line. Along this major line the structure is more complex than at some distance away; and this, together with the presence of so many intrusive bodies, is interpreted as evidence that marked stratigraphic readjustment has occurred along this zone. The exact significance of this feature has not yet been determined, but it is suggested that this line may mark a zone of weakness and faulting. It may be a reflection of the main uplift of the Alaska Range.

In the Candle Creek district the Upper Cretaceous beds lie in close proximity to the Middle Devonian series on Kuskokwim River, as mapped by Spurr. On the ridge that separates the Candle Creek drainage basin from that of the Kuskokwim the bedrock is largely a blocky quartzitic sandstone, which shows considerable recrystallization. This feature, however, has been interpreted as a contact-metamorphic effect, due to the monzonitic intrusion in Candle Creek. The contact there between the Cretaceous and Devonian rocks lies somewhere on the Kuskokwim slope, covered by vegetation. The absence of coarser sediments at this point is presumptive evidence that the base of the Upper Cretaceous rocks is not exposed. Hence it is inferred that a fault contact may form the boundary line in this vicinity.

FAUNA, FLORA, AND AGE.

Fossil shells have been collected in the Ruby-Kuskokwim region by H. M. Eakin in 1912, by P. S. Smith in 1914, and by the writer in 1915. These fossils as determined by T. W. Stanton, of the Geological Survey, are listed below:

[By Eakin in 1912.]

7822. No. 12 AE 2. Ridge north of Folger Creek, 2½ miles from margin of flats. *Unio* sp. Casts of a very small undescribed species. Specimens of a small *Unio*, possibly belonging to this species and in closely similar rock, were collected by Collier at Good Island on the Yukon above the mouth of the Koyukuk. The fossils give no direct information as to the age, as similar types occur in both Cretaceous and Tertiary, but from geographic relations the locality at Good Island ought to be near the base of the Upper Cretaceous.

7823. No. 12 AE 3. Ophir Creek, 1 mile above town. Float in creek bed. *Inoceramus* sp. Several fragmentary distorted specimens that may belong to *Inoceramus digitatus* Sowerby, an Upper Cretaceous species. Whether it is really this species or not, it is believed to be an Upper Cretaceous type.

[By Smith in 1914.]

9222. No. 14 AS 134. Station LXIII, George-Kuskokwim divide. *Inoceramus* sp. represented by fragmentary imprints. Probably Upper Cretaceous.

9223. No. 14 AS 135. Station LXIII, George-Kuskokwim divide. *Inoceramus* sp. fragments. Probably Upper Cretaceous.

9224. No. 14 AS 136. Same locality as 9223. *Inoceramus* sp. fragment. Probably Upper Cretaceous.

9225. No. 14 AS 136a. Same locality as 9223. *Inoceramus* sp. fragment. Probably Upper Cretaceous.

9226. No. 14 AS 166. Station LXXXVII. *Ostrea* sp., represented by small casts. *Inoceramus* sp., represented by fragments. Probably Upper Cretaceous.

9227. No. 14 AS 167. Near Station LXXXVIII near Georgetown-Iditarod trail. Fragments of two dicotyledonous leaves. Upper Cretaceous or Tertiary.

9228. No. 14 AS 170. One mile west of Station LXXVIII, Georgetown-Iditarod trail. *Ostrea* sp. *Inoceramus* sp. Both represented by fragments. Probably Upper Cretaceous.

[By Mertie in 1915.]

9364. No. 1. Head of Susulatna River 20.15 miles N. 47° E. of North Buttes east of Ophir. The most abundant form is a small pelecypod apparently belonging to the family Pleurophoridae. It is evidently undescribed and has not been satisfactorily identified generically. With these are a few imprints of a small slender gastropod. The horizon is probably not lower than Upper Cretaceous.

9365. No. 2. Divide between Folger Creek and Susulatna River, 19.15 miles N. 34.5° E. from north butte of Twin Mountain. This lot consists entirely of the same small pelecypod as the one in lot No. 1 and is doubtless from the same horizon.

9366. No. 3. Divide between Folger Creek, Susulatna River, and Nixon Fork of Kuskokwim, 15.5 miles N. 52° E. from north butte of Twin Mountain. *Turritella?* sp. This single specimen bears two fragmentary casts of a small gastropod possibly belonging to *Turritella.* It probably belongs to the same fauna as lot No. 1.

9367. No. 4. 1.1 miles from southwest peak of Camelback Mountain and 1.3 miles from northeast peak at head of Bonanza Creek. *Inoceramus* sp. related to *I. labiatus* Schlotheim. Probably Upper Cretaceous.

A collection of fossil plants was also made by the senior writer in 1915. These were examined and identified by Arthur Hollick as follows:

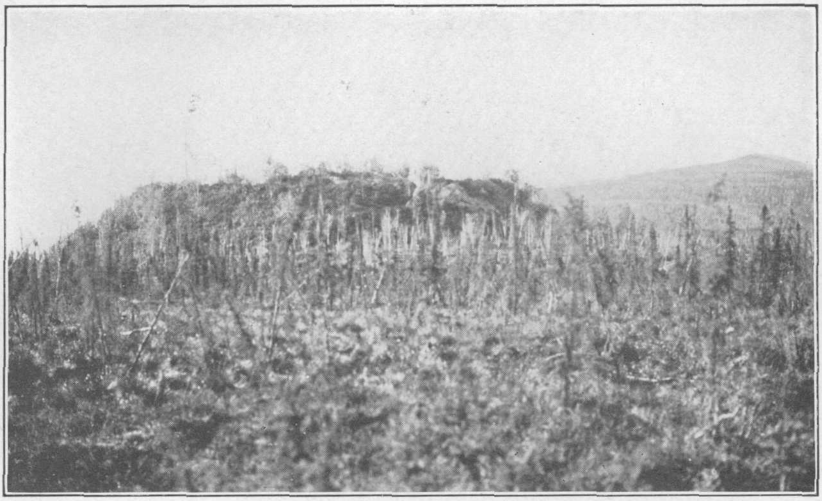
7007. No. 2. Divide between Folger Creek and Nowitna River, 19.15 miles N. 34½° E. of north butte of Twin Mountain. This lot consists of 17 pieces of gray shaly sandstone, containing well-defined plant remains, among which the following species are represented:

Aspidium meyeri Heer.
Ginkgo adiantoides (Unger) Heer, or G. borealis (Heer).
Populus arctica Heer.
Populus zaddachii Heer.
Corylus macquarrii (Forbes) Heer.
Paliurus (cf. P. columbi Heer).

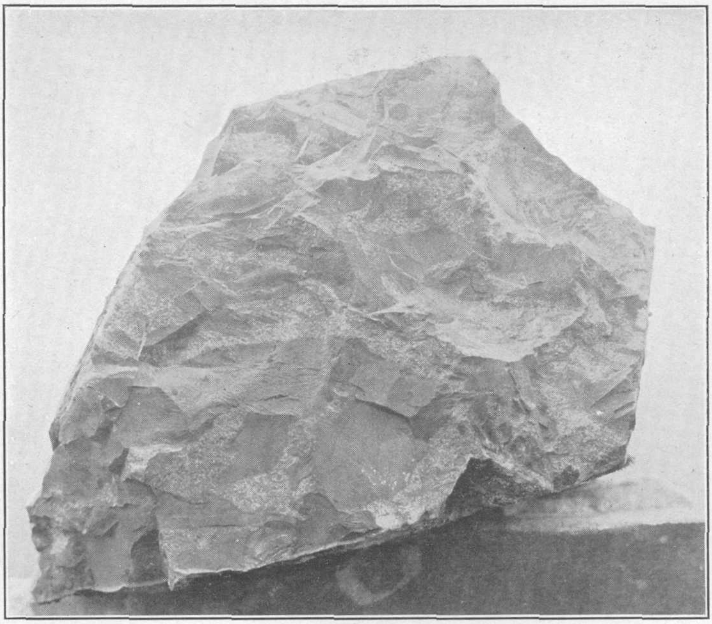
The geologic age of the formation, as indicated by the flora, is "Arctic Miocene" (Eocene).

It should be noted that this collection and the shells from locality 9365 came not only from the same horizon but from the same slab of rock.

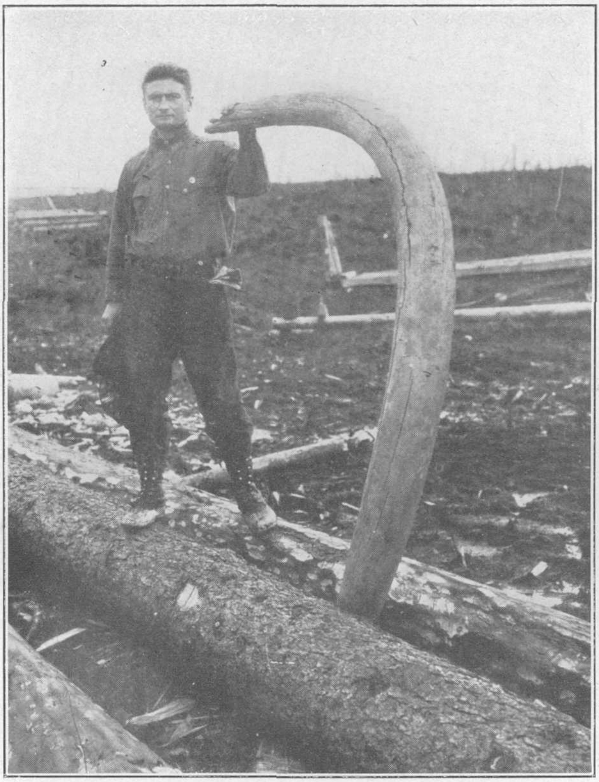
Insufficient fossil material of definitely determinable age has been obtained from this region to make a statement as to the exact age relations of beds that have been mapped as Upper Cretaceous and Eocene. The invertebrate material has been collected somewhat more widely than the plants, but owing to the fact that the Alaskan Upper Cretaceous fauna differs greatly from that of the western United States and is not so well known, it has not been possible to obtain definite determinations of all the fossil shells. In all probability both an Upper Cretaceous and an Eocene fauna are present, but the Eocene rocks, so far as known at present, are restricted to the area in and near the heads of Susulatna River and Folger Creek. The fossils definitely identified as belonging to the Upper Cretaceous



A. MOUND IN THE VALLEY OF MAIN CREEK.



B. SHALE, CONTACT-METAMORPHOSED BY INTRUSION OF FINE-GRAINED GRANODIORITIC ROCK.



A. TUSK TAKEN FROM UNDERGROUND WORKINGS ON BOOB CREEK.

B. GLACIAL TOPOGRAPHY AND HANGING VALLEY NEAR CLOUDY MOUNTAIN.

have been found in the central and southwestern parts of the Innoko-Iditarod region, and this has been interpreted as indicating that most of the sedimentary rocks south and east of the Innoko mining district are of Upper Cretaceous age.

LATE EOCENE OR POST-EOCENE ROCKS.

Although igneous rocks of late Eocene or post-Eocene age have a fairly wide distribution in the Ruby-Kuskokwim region, relatively few sedimentary rocks of like age are known. All available evidence, however, points to the period of volcanism at the end of the Eocene as a period of dominantly terrestrial conditions. Sedimentary deposits formed during this period should therefore be scarce, and such as are found may be expected to be of terrestrial origin.

A subangular cobble of conglomerate was picked up on the west slope of the hill that lies a few hundred yards southeast of Dead Man Hill. Although well cemented, the pebbles of the conglomerate were not deformed. The bedrock source of this cobble was not found. About 38 miles southeast of this locality and 2 miles southeast of the forks of Big Moose Creek a very small area of conglomerate was seen on the steep east side of a small basalt knob on the crest of the ridge. The well-rounded pebbles, the largest 5 inches in diameter, were largely of local derivation, including basalt, quartz, and a granitic rock, which was seen a few hundred feet to the west. The conglomerate is well cemented, and the matrix is made up of material similar to that of the pebbles. Age assumptions are based on the comparatively slight degree of induration of these rocks and on the fact that at the Big Moose Creek locality they include pebbles of the lava which are believed to be of Tertiary age. Their elevated position and degree of induration differentiate them from the recent stream gravel and from the older beach gravel. They are probably to be correlated with the late Tertiary terrestrial deposits on the north slope of the Alaska Range, which have been described by Capps.[48]

West of Cloudy Mountain, in the valley of Roberts Creek, tuff, tuffaceous sandstone, and shale are found apparently interbedded with basic lavas which are believed to be of late Eocene or post-Eocene age. These sediments also are therefore of like age.

QUATERNARY DEPOSITS.

AGENCIES AND PROCESSES.

The processes that have been acting during the Quaternary period in the Ruby-Kuskokwim region are of widely diverse nature, so that

[48] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 51-57.

it might well be expected that the resultant deposits would show the equally widely divergent phases exhibited in typical localities. To no single agency can be assigned the present form and distribution of the material mapped as Quaternary. Alpine glaciers left incontrovertible evidence of their presence in some of the higher mountain areas, and the accompanying débris was transported by streams to lower altitudes, there to be subjected to the normal processes of weathering, disintegration, and reworking by streams, or to be deposited in the great bodies of water which occupied much of the Nowitna basin and of which there is some evidence in the Innoko basin. At the same time the processes of disintegration peculiar to subarctic climates have been active in the higher areas. These have contributed no inconsiderable amount to the fragmental material, which has been further subjected to the normal processes of weathering and to comminution during its transportation by gravity and running water.

The superficial extent of these deposits far surpasses that of all the other formations, as it is only in the higher mountains on the sharper ridges, steep slopes, cuts along streams, or scattered dikes that the bedrock, not its broken-down detritus or some superficial covering, is exposed. In the mapping the Quaternary is made to include only silt and material that is of lacustrine, fluviatile, glacial, or fluvioglacial origin. The residual and talus material, being essentially the same as the underlying bedrock, is mapped with it. However, there is in many places no sharp line of demarcation between the residual material and other types of alluvial deposits, so that the lines drawn are of necessity approximations.

GLACIAL DEPOSITS.

The effects of glaciation have been noted in the central part of the region on the north side of the Beaver Mountains and of Cloudy Mountain, which rise above 4,000 feet. If glaciers ever existed in the lower areas or on the southward-facing slopes, evidence of their former presence has been masked by later erosion. Maddren[49] describes the glaciation in the vicinity of the Beaver Mountains in the following terms:

> The group of mountains between Dishna River and Ganes Creek was occupied by snow and ice fields of considerable local extent. The former glaciers eroded this mountain group strongly and laid down extensive moraines of unassorted angular rock blocks and boulders about the base of the group and out into the wide surrounding valleys on either side for considerable distances; while the larger volumes of water from the melting snow and ice carried con-

[49] Maddren, A. G., The Innoko gold placer district, Alaska: U. S. Geol. Survey Bull. 410, p. 58, 1910.

siderable quantities of cobbles, gravels, sands, and silts farther down the valleys and deposited them in an assorted arrangement.

Further describing the glaciation on Ganes Creek, he says:[50]

Ganes Creek, which is about 20 miles long, heads in a large, strongly glaciated basin that is surrounded by sharply irregular mountains 4,500 feet above sea level. It flows for about 3 miles in this mountain basin over and through a mass of large glacial boulders composed of the hard igneous rocks that make up the mountains. A large percentage of these boulders are varieties of porphyritic igneous rocks. Near the lower end of this cirque Ganes Creek is joined by a stream called Idaho Creek, of about the same size and character and flowing from a similar basin.

From the mountains Ganes Creek flows for about 5 miles in a northeasterly direction out across a wide basin that is now largely filled by morainal boulders. Topographically this basin appears to have been a part of the head of Beaver Creek valley before glacial time. About 1 mile southeast of this part of Ganes Creek is another large stream parallel to it, called Last Chance Creek. This stream is of about the same length and volume as upper Ganes Creek, heads in the same mountains in a similar basin farther south, and flows across the basin in the same manner. Ganes and Last Chance creeks are separated by a ridge which appears to have been a medial moraine during the period of maximum glaciation. This ridge, on its surface at least, is formed of morainal deposits, except near the middle of its length, where a large dome-shaped mass of cherty limestone bedrock outcrops. This dome is called Knob Hill. Last Chance and Ganes creeks join at the northeast side of the basin, at the head of the canyon that has already been described as occupying the middle course of Ganes Creek valley. Throughout the basin both of these creeks flow over deposits of morainal boulders which, like those in the cirques, consist mostly of igneous rocks derived from the glaciated mountains. From a point near the source of Ganes Creek to the head of Ganes Canyon, a distance of about 8 miles, the descent of the stream is about 500 feet.

With regard to the glacial débris he states:[51]

At the time of glaciation the upper part of the wide Beaver Valley was deeply filled with deposits of morainal material. Moreover, the glaciers themselves, when at their maximum extent, appear to have occupied the whole or at least a large part of this basin, completely covering the previous land surface. When the ice melted it left the upper Beaver basin clogged with a thick filling of morainal dumps. Although the detailed features of this glacial filling and damming of the upper Beaver Valley are not well known, it is very evident that the former drainage channels were so disarranged that a large volume of the water produced by the melting snow and ice could not find an outlet into the Innoko, toward the northwest, by way of the lower Beaver Valley. As a result it backed up and found an outlet across the lowest divide to the northeast, into what was then the head of Ganes Creek.

The most typical glacial deposits are found, however, on the north side of Cloudy Mountain at the head of Folger Creek. The streams head in cirques, with very steep walls. One of these cirques contains a lake in a rock-cut basin, and as there has been glacial scour in the main streams the outlet of the lake is in a hanging valley, as illustrated in Plate VI, *B*. Two cirques whose headward walls ap-

[50] Op. cit., pp. 67–68. [51] Idem, p. 14.

proach verticality appear to the left and in the left center of the picture. The upper portion of the valley is marked by the "pot and kettle" topography characteristic of the moraine left by a retreating glacier. It appears probable that valley glaciers extended considerably beyond the limits of the moraines which now show diagnostic features, and that their débris contributed in no small measure to the material which now makes up the silts and to other material which is being reworked and forming the present alluvial deposits. The difficulty of distinguishing material of glacial origin after it has been subjected to stream action, however, even where the processes may be observed, makes it practically impossible to state whether the older fluviatile deposits are or are not derived from glacial sources.

SILT AND HIGH GRAVEL.

This region contains deposits of rather widely varying character that are considerably older than the products of present alluviation. Perhaps the most widely distributed of these are the silt deposits, which occur at altitudes up to about 1,200 feet and which are more conspicuous and more widely distributed in the northern part of the area visited by the writers but form considerable portions of the unconsolidated deposits in the Innoko and Iditarod basins. Eakin[52] described the deposits of this nature found by him in the Yukon basin and discussed their origin in the following terms:

> The character of the silts indicates deposition in quiet water; the distribution and form of the gravel terraces point to origin by beach action. As there are other corroborative lines of evidence pointing to the extensive inundation of the low-lying parts of the region, probably during and following the period of maximum glaciation in interior Alaska, the silts are interpreted as the deposits made by the débris-laden glacial waters and the high-lying gravel terraces as largely the product of beach action on the shores of lakes that are now extinct. There are also more extensive high-level gravel deposits that are probably of fluvial origin, representing deltas built out into the margins of the ancient lakes by glacial and other streams.

In addition to the silt, beach gravel, and delta deposits, there are in a few places stream gravels that are undoubtedly earlier than those of the present streams.

At many localities in the Ruby district the silt appears well above the river, especially east of the divide separating the Yuko and Innoko drainage from that of Big Creek and Nowitna River. Only a comparatively small area west of this divide was traversed by the writers, and they had little opportunity to observe the silt deposits there, but along Yuko River Gilmore[53] noted sediments that appear

[52] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, p. 55, 1916.

[53] Gilmore, C. W., Smithsonian Misc. Coll., vol. 51, No. 1807, p. 10, pl. 3, 1908.

in bluffs "80 to 100 feet in height, composed mostly of fine light-colored unstratified silt. Some 60 feet down from the top is a layer of coarse gravel conformable with the silt, which may represent the Palisade conglomerate of Spurr."[54] Gilmore[55] also mentions further exposures of the silt in bluffs 200 to 250 feet high 8 miles below Louden, on the Yukon. It appears in low bluffs on Anvik and Stuyahok rivers and at numerous places along the Yukon between Anvik and Andreafski, and it makes up the bluff about 200 feet high a few miles below Russian Mission.

In the Kuskokwim Valley above McGrath there are great silt and gravel plains. These are mentioned by Spurr,[56] who describes bluffs 200 feet high made up of stratified gravel and sand and capped with a layer of silt which in turn has a cover of peat. Down the river a few miles, but still above the mouth of the Takotna, the section on the left bank of the river appears in the bluffs 100 to 150 feet high, which are made up of fine silt, yellow where oxidized but bluish gray where unweathered. Feeble cross-bedding occurs in these lower exposures. Spurr[57] also describes a bluff about 10 miles below McGrath, where silt is exposed in a thickness of 60 to 150 feet.

There is a divide between the Kuskokwim and the Nowitna at the head of the Nowitna, at an altitude of about 1,100 feet. Whether there was formerly a connection between these basins through this divide or through one said by Eakin[58] to lie at about 1,000 feet, through the Kantishna, Tanana, and Yukon valleys, is problematical on account of the unknown amount of reduction of the divides by erosional processes, including soil flow, acting under subarctic conditions. It appears, however, that such processes would be incompetent to lower the divide after the inundation of the Nowitna basin, and the occurrence of the silt along the Kuskokwim is a logical sequence of its presence in the adjoining basin above the altitude of the divide between the two rivers.

In the northern part of the region the silt is widely distributed. On the top of the high bank upstream from Ruby the soil is a fine light-colored silt containing but little organic matter. Holes dug to a depth of 8 or 10 feet show that pebbles are very few in number or absent. On Beaver Creek about a mile below the road house on the winter trail the stream has exposed the rock bluff on the left bank. This is capped with silt which, owing to its lack of coherence, is easily eroded when thawed. As a result the light-colored fine-grained silt covers the space between the bluff and the stream with an alluvial fan that is so constantly receiving additional material that

[54] Spurr, J. E., U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, pp. 199, 207, 1898.
[55] Op. cit., p. 12.
[56] Spurr, J. E., U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 122, 1899.
[57] Idem, p. 124.
[58] Eakin, H. M., oral communication.

growth of vegetation is prevented and the fan has much the appearance of the fine tailings from an ore-milling plant.

Throughout the northern part of the region there are many faintly outlined terraces at elevations somewhat above 1,000 feet. Although the nature of the material composing these terraces is almost everywhere obscured by the covering of vegetation, it is yet significant that rock outcrops were observed below this altitude only along stream cuts, and frost-heaved mounds more frequently showed angular fragments of the underlying bedrock above this altitude than below, owing to the terrace mantle of silt. Eakin,[59] discussing similar features elsewhere in the Yukon basin, states:

> The terraces of the Yukon form too complex a system to be fully understood without detailed examination. The general study made by the writer indicates that they are recognizable at a number of levels from 20 feet to 300 or 400 feet above the river. The lower terrace deposits consist mainly of the typical light-colored lacustrine silts. The higher ones, in places at least, are partly rock cut and include gravels in their composition.

It is believed that these terraces are due to the deposition of lake or estuarine sediments and not to the peculiar weathering agencies that tend to produce terrace-like effects in bedrock and that form considerable large angular detritus. The silt terraces are displayed especially well in the long, flat, even-topped spurs that strike off from the ridge between Long and Sulatna Bluff into the Sulatna basin and into that of Flint Creek. One of the most striking occurrences is that between the forks of Glacier Creek, where the silt lies out on the point of the ridge. This terrace shows up very prominently from a distance on account of the deciduous trees upon it, which appear in sharp contrast with the darker color of other vegetation.

In several places the silt in broad valleys is marked by peculiar features. The steep slope of bedrock breaks away to gentler slopes of talus, and these in turn give way to the very gently sloping silt terraces or plains, which may have a steeper slope at their front where they grade into the flood plain of the stream. On these silt plains are to be noted many lakes at altitudes usually about 800 to 900 feet, which occupy depressions, apparently wind blown, in the silt, as indicated by their varying forms and topographic position. Some of the lakes are crescentic in outline, but their position and the irregular form of near-by lakes eliminate the probability of their being oxbow lakes of stream origin. The largest seen was about 1,500 feet long by 200 to 300 feet broad. Most of them are much smaller, many being only a few feet across, and a great many are almost filled by vegetation. Among other places where such lakes were noted may be mentioned Big Moose Creek, a tributary of the South Fork of the

[59] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, p. 57, 1916.

Sulatna in the Ruby district. Farther south the Susulatna shows this feature, and it is exceedingly well-developed in the upper basin of the Nowitna, where the gently sloping plain eastward from the river is several miles in width and dotted with lakes.

Vegetation mantles most of the silt areas, and where exposed in small areas the silt may not be readily differentiated from residual soil. Owing to its incoherency it is not generally exposed along the smaller streams, as even its steep slopes quickly assume a covering of mosses. On the east bank of the South Fork of the Sulatna, however, the vegetation-covered banks rise abruptly for 50 to 200 feet, and through these banks even minute rills have cut narrow, sharply incised valleys, which do not show bedrock or gravel, so that they now enter the main stream at a normal gradient, a thing which would be manifestly improbable if they passed over indurated rocks. The conditions here closely approximate those observed on the Sulatna, where the river meanders are cutting more rapidly and the silt still stands in nearly vertical bluffs. A short distance below the mouth of Glacier Creek the silt is exposed in the south bank in a section 35 to 50 feet thick, of light-gray fine unconsolidated material, unstratified except for a few feet at the top, where a covering of peaty material occurs. From this point on down the river there are several exposures of the older silt in high-cut banks on one side or the other of the river; the last is in the bluffs which rise more than 100 feet directly from the river a few miles above " the loop " and which form the most prominent landmark on the east bank of the river when viewed from the crests of the hills between Sulatna Bluff and Cecil Dome.

These silt deposits have been correlated with those of the Palisades below Tanana. The presence of small fresh-water shells determines the age of the Palisades deposits to be Pleistocene, as do the numerous mammal bones described by Gilmore,[60] who also mentions [61] finding bones of Pleistocene mammals on Nowitna and Yukakaket (Yuko) rivers. Similar bones are found in the placers throughout the northern half of the region and at Tolstoi (Pl. VI, *A*), their presence in the muck and gravel often being indicated by small bright-blue specks of vivianite, a hydrous iron phosphate that in places coats the elephant tusks.

Deposits of well-rounded and assorted gravel occur at widely separated localities and were probably formed along beaches or in deltas. These deposits lie well above any present streams that would appear competent to produce boulders of this size and form. As examples may be cited the boulder gravel of Skookum Bar, near the Boston-Big Creek divide, and the nearly spherical boulders that ap-

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[60] Op. cit., pp. 17–22. [61] Idem, p. 23.

pear along the trail near the 2-mile post out of Ruby. The terraces on the hill slopes across the Yukon north of Ruby also contain gravel which is thought by some miners, on account of the abundance of white quartz in it, to be related to the White Channel gravel of the Klondike. A few well-rounded boulders were seen 5 miles above Ruby on the steep slope a short distance back from the river and about 200 feet above it. Rounded gravel was found at the bottom of a hole said to be 60 feet deep on the crest of the divide between Long and Basin creeks southwest of Long. Large rounded boulders occur at an altitude of 1,200 feet in considerable amount on the east side of the nearly flat ridge 6 miles a little west of south of Yuko Mountain and resemble beach gravel in their distribution. Rounded gravel is reported also from the Long-Flint creek divide near Long, but was not seen. Maddren,[62] describing additional deposits of similar material on the lower course of the Innoko and on the upper course of the Kluklaklatna, says:

> Their distinctive features are their moderately elevated positions without any particular relation to the present or any past river channels that can be recognized and the uniform character of the material. These deposits may be remnants of cleanly washed bars of former swift streams or of old beaches of late Tertiary or Pleistocene age. There appears to be fairly good evidence that considerable areas of the Yukon Valley and of the other large river valleys of Alaska were occupied by large lakes during late Tertiary or Pleistocene time, and it is surprising that more definite evidences of their shore lines, in the form of beach deposits, are not easily observed.
>
> It is not difficult to conceive that the present or past rivers of this region have deposited bars made up entirely of quartz cobbles, gravels, and sands; and it is equally possible to understand how the wind-driven waters of lakes, by long-continued washing and the constant grinding of shore material upon itself, should wear away and remove all the softer portions and leave only the harder quartz in the concentrated condition in which these deposits are now found. The writer is inclined to favor the theory of beach-wash rather than river-wash origin for these deposits.
>
> It is interesting to note that colors of gold are reported to be found in this washed-quartz formation in the deposit called Skookum Bar, in the Ruby Creek district, and also at the locality where the formation occurs on Kluklaklatna River.

In the Tolstoi district unconsolidated material that is mainly of Quaternary age covers much of the lowland area, extends nearly to the heads of many of the smaller streams, and occupies the interstream ridges. This material is in part alluvial, but probably is also in part of marine or lacustrine origin, and the flat-topped hills at altitudes of 800 to 1,000 feet may be wave-cut terraces upon which these sediments were deposited. Most of these sedimentary deposits are thin and have been removed in large measure or have been left in only small areas. In the lowlands the former stream courses were

[62] Maddren, A. G., The Innoko gold-placer district, Alaska: U. S. Geol. Survey Bull. 410, pp. 59–60, 1910.

filled with gravel, sand, and silt, but upon the reestablishment of drainage systems after the period of inundation a large amount of the unconsolidated material was removed. Between Tolstoi and Boob Creek prospect holes that have been sunk to a depth of 125 feet pass through about 60 feet of muck and ice which overlies an equal thickness of silt, sand, and gravel.

The gold and platinum content of the gravel has been concentrated either by the action of waves on beaches or by the currents of streams, or there may have been a reconcentration by streams from older deposits formed along beaches or streams.

OLDER STREAM GRAVEL.

Besides the old beach gravel there are to be found in numerous places deposits of gravel that were formed considerably earlier than those in the present stream valleys. On the lower part of Flat Creek, south of Poorman, the present stream appears to cross at a considerable angle the course of an older stream, or possibly an old channel of Timber Creek, which is indicated by several feet of well-oxidized gravel lying below the little-oxidized present stream gravel, which in turn lies below several feet of muck. In numerous streams bench gravel is developed. It appears on the west side of Flint Creek near the mouth of Root Gulch, as shown by numerous prospect holes. This gravel also is much weathered. Maddren,[63] describing the drainage conditions of the Innoko, states that there was an interval following glaciation in which down cutting was more rapid and that

> During this period the erosion has been so rapid that on the larger streams considerable areas of the preglacial valley-floor filling of gravels have been left perched on the present valley sides as bench deposits. In places these bench gravels occupy positions 100 feet or more above the present streams, but on the gold-producing creeks the benches are on an average about 60 feet above the water level. About the mouths of Little, Spruce, and Ophir creeks, where they merge with the much wider valley of the main Innoko, there are also some elevated bench deposits. These are not creek benches but benches of the Innoko Valley.

If the hypothesis of a regional Pleistocene inundation is accepted, it is possible that these benches and the accompanying gravel are due to wave cutting along the sides of the drowned valleys.

MODERN STREAM DEPOSITS.

Most of the streams in all but their headward courses flow between banks of rather fine material of flood-plain origin, and the bottoms of many of the streams are paved with gravel or coarse sand. The

[63] Maddren, A. G., The Innoko gold-placer district, Alaska: U. S. Geol. Survey Bull. 410, pp. 65, 68, 1910.

height of the banks varies in general with the size of the streams, although to this rule there are numerous exceptions, as some of the smaller streams have high banks. It was necessary to bridge many of the small streams on account of lack of good approaches to a crossing, the depth of the streams or the lack of solid bottom. It was generally noted that good crossings were more easily found on the larger than on the smaller streams. Even the large tributaries of the lower Sulatna, however, flow in deep channels between steep mud banks to their mouths, and the points where their sluggish waters enter the main stream are but little marked except by their greater clarity, so that large tributaries may be mistaken for much smaller ones or may even be wholly overlooked.

At the mouth of Tamarack Creek the banks of the Sulatna are about 8 feet high and are made up largely of fine sand with gravel layers inlaid near the bottom. The bars consist of coarse sand and gravel with pebbles as much as 2 inches in diameter. Downstream the banks gradually increase in height to considerably over 30 feet a few miles above its mouth and then gradually become lower. The material in the banks and on the bars becomes finer and finer, and bars are fewer. Owing to the presence of organic matter the material in the banks is uniformly darker than that contained in the older silt bluffs, which are cut in a few places.

Along the Nowitna the banks are made up of silt and fine sand and at normal stages are from 10 to 15 feet high. The bars consist almost wholly of sand with but few pebbles of any size; on many there are fragments, probably ice rafted, of fossil bones of various Pleistocene mammals. The alluvial banks of the Yukon are from 8 to 15 feet high, and in places there is a narrow sandy beach at the foot of the bank. On the north bank there is a considerable amount of gravel brought down by the short streams from the high hills near the river. Melozi River, entering from the north, has built a large delta at its mouth and has forced the Yukon over so that it is cutting into the bank on the opposite side. On the south side there is very little gravel, and the banks and beaches consist of silt and fine sand. Some of the small streams have built small deltas, as illustrated in Plate VII, *A*; some of the buildings in Ruby along the water front stand on the delta of Ruby Creek. The creeks enter the river through deep cuts across these deltas. During high water the river sediments often dam up the mouths of these streams, and for a time after the water goes down each tributary has a small pond at its mouth until it can cut through the bar deposited by the river.

In the river itself there are numerous islands and bars which have been built up of the fine material brought in by tributaries and whose position and form is constantly changing. The cut banks of silt on both sides of the river are eroded at each period of high water, and many of the islands, as well as places along the banks, are being undercut constantly. Some of the cutting is done by the current, but the greatest amount is due to wave cutting during high winds, which create a heavy surf along the banks. Where this is taking place, the banks are fringed with trees that have toppled over into the water. Practically identical conditions exist on all the large rivers in the area. The type of sedimentation is indicated in the accompanying view of shallow-water ripple marks in a bar in the Yukon (Pl. VII, *B*).

The upper Innoko basin was not visited by either of the writers. The deposits have been described by Maddren,[64] who traversed the river in 1908.

> From the North Fork to the mouth of the Innoko recent alluvial deposits are the most widespread formation in the valley. They form the principal part of the low banks of the river and of the swampy flat lands that stretch away from these banks for miles. From the North Fork downstream to a point about 30 miles below Dishkakat the present bars of the Innoko consist largely of fine gravel and sand, but on the lower river they are all of fine silts and mud. This change in the texture of the alluvium is also noticeable in the banks of the river as it is descended.
>
> The banks of the Innoko average about 10 feet in height from North Fork to Dishkakat, but from that place to Shageluk Slough the height gradually decreases. In places on the lower river the banks are only 3 or 4 feet above the water. Along the 50 miles of its course above Shageluk Slough there are some natural levees about 6 feet high that have been formed through the deposition of silt along the sides of the main river channel by the flood waters that spread far out on either side during the spring freshets.
>
> The recent sediments are for the most part of a darker color than the older unconsolidated sediments, with which they are associated to some extent. This darker color appears to be due to the larger proportion of vegetable matter that is mixed with them.

The gradient of most of the streams of the region is low except at their heads, and this headward steepening is stated by Eakin [65] to be less than would normally be expected. As a result they are no longer actively intrenching their courses, and differences in the stage of the water may produce an alternation of aggradation and degradation. At normal stages many of the smaller streams carry very little débris, though they are much discolored by organic matter.

Meanders are normal for all the streams in this region, including the Kuskokwim and parts of the Yukon. The size of the meanders is a function of the size of the streams. The limit of meanders is normally equal to the width of the flood plain, but for some of the

[64] Maddren, A. G., op. cit., p. 60.

[65] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 13, 1914.

larger streams like the Innoko and Iditarod the flood area probably exceeds the meander width by several miles. A considerable part of the erosion that is taking place appears to consist in the migration of meanders downstream, the material from the bank on the concave side being carried down until it is redeposited in the slack water on the bar on the convex side. The material held in suspension seems to be derived largely from this source, for most of the tributaries bring in water which is clearer than that of the main stream. By this migration of meanders the lower portion of the banks shows gravel layers and the upper portion is covered with finer material of flood-plain origin.

Below the mouth of the South Fork of the Sulatna the water for some miles is clearer than above it, probably owing to the flocculation of the material in solution and suspension by the mixing of the water of the two streams. As a result, the gravel in the bank is red from the precipitated iron and has the appearance of a conglomerate. It is cemented by the iron sufficiently to make it coherent, yet not so firmly that it can not be readily broken apart with the hands.

The alluvial gravel, sand, and silt are widespread throughout the area. They are not sharply separated in either character or topographic position from residual material or from older water-borne sediments. They are largely derived from these older sediments and merge with them. Detailed descriptions of the younger sediments of many of the creeks will be found under "Mineral resources" (pp. 88–115).

A considerable portion of the alluvial gravel of some of the larger streams is probably much older than the modern stream deposits, yet no line of distinction can at present be drawn. Such gravel of doubtful age fills the bottoms of some of the larger stream courses. On Birch Creek, a tributary of Flint Creek, there is from 40 to 50 feet of gravel overlain by an equal thickness of silt. Eakin [66] mentions a shaft on White Channel Creek which penetrated 45 feet of silt and 140 feet of gravel without reaching bedrock. It seems extremely likely that at least a portion, if not all, of this gravel antedates the silt which covers so great an area in the northern half of the region.

Eakin [67] states further that

> In general the depth of the alluvium corresponds rudely with the width of the valley. In the lower reaches of the Sulatna and its tributary streams depths of over 100 feet are commonly to be expected, and depths of 200 feet and more should not be surprising at the border of the more extensive flats.

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[66] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 26, 1914.

[67] Op. cit., p. 26.

Of this thickness it would appear that only the superficial portion should be considered as of recent origin.

RESIDUAL AND ELUVIAL DEPOSITS.

Residual deposits are those formed by the disintegration of the underlying bedrock. They are of course acted on by gravity, and the débris tends to migrate down the hill slopes, forming eluvial deposits. Eakin [68] describes their occurrence as follows:

> Residual clays are widespread in the whole region and cover much greater areas than either the silts or the gravels. They mantle the lower hills and ridges and have crept down into the valleys. The gravels of the valley bottoms are covered as a rule by a considerable thickness of clay, much of which has come from the adjacent hillsides. * * *
>
> Only those [residual mantle deposits] covering the slopes and hilltops at the heads of Flat, Chicken, and Happy creeks in the Iditarod district are known to have economic value. At this locality a gold-bearing deposit ranging in depth from a few feet to 20 feet has been developed by the weathering of the monzonite batholith and the associated rocks. The igneous rock weathers first along the joint planes, and as weathering continues it forms large spheroidal masses, which are separated from each other by distintegrated rock. This weathering has been accompanied by more or less creeping of the loosened materials on the slopes, and the action of water has removed some of the finer particles.
>
> The long-continued action of these processes has produced residual boulders of various sizes that illustrate all stages in the transformation of the angular blocks of bedrock to spheroidal forms. Mixed with the monzonite boulders are weathered fragments of other types of rocks that have crept down from the hilltop above. The interstices are filled with granular sands and angular fragments of quartz stringers. The local removal of the sands has caused a concentration of the boulders at the surface in some places.

ORGANIC DEPOSITS.

Except on the higher hills and steeper slopes the surface of the country is almost completely mantled by a thick covering of vegetation, composed mostly of moss and lichens, in places bound together by tree roots. In the poorly drained depressions and lakes along streams and on the silt plains water-loving grasses and other plants of an aquatic habit are found. The greatest accumulations seem to be on the flattest and most poorly drained surfaces. The climatic conditions are such that the product of each year's growth is only partly decomposed, so that there gradually accumulates a considerable thickness of unconsolidated vegetal material. This material is generally called peat. The crest of the ridge southeast of Ruby has been cleared and burned over several times to remove this covering. Even after burning there are numerous little patches left where it persists. In these patches the top has been burned off, but from 2 to 3 feet of

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[68] Op. cit., pp. 26, 27.

peat still remains. Along the trail between Tamarack Landing and Poorman there are numerous places where old wagon ruts are nearly hub deep in the peat, a solid foundation having been reached only after the wheels struck the underlying frozen silt. The winter trail from the head of Long Creek to Sulatna road house is impassable in summer for this reason, as the peat is then so much deeper, especially in the vegetation-filled lakes and sloughs which the trail crosses. Along practically every cut bank the peat forms the top layer, often giving an idea of a greater thickness than it really possesses, because, on account of its coherence, it tends to creep over the bank as the silt falls away beneath it.

In that portion of the Innoko region not visited by the writers Maddren [69] found similar peat deposits and ascribes the darker color of the recent sediments as compared with older unconsolidated sediments to the larger proportion of organic matter in them. He says:

> The vegetable matter in the silts is apparently derived in large part from the peat deposits, which lie mostly on top of the recent alluvium but which are also at many places interbedded with the silts. It appears that the peat derived from the heavy growth of sphagnum mosses over all the swampy land may be considered the most characteristic and widespread of recent deposits. Peat beds several feet in thickness, interbedded with silts, are exposed repeatedly along the low-cut banks of the Innoko.

Under present conditions there seems to be little likelihood of any immediate use being made of these deposits, as there appears to be sufficient timber to furnish the amount required for fuel for some time except in the vicinity of Iditarod. Here, if anywhere, the utilization of peat as a fuel might be attempted if bodies of sufficient thickness could be found. It is not generally considered a resource, however, but rather a detriment by those who wish to utilize the ground for agriculture, or by that much larger class who find that the peat makes soft, laborious footing as they travel across the country in their efforts to find and develop its hidden mineral resources.

GROUND ICE.

Along stream valleys and in the lowlands throughout practically the entire area there is a considerable amount of ice which occurs in layers or lenses in the frozen silt. The thickness of these ice lenses ranges from a few inches to several feet. They probably originate in several ways, among which may be mentioned the sealing over with moss and vegetation of small shallow lakes, and the freezing of water along lines of parting in the silt, with a later thickening of these thin ice seams by the freezing of water that has percolated down to them. Another explanation may serve for other oc-

[69] Maddren, A. G., op. cit., pp. 60–61.

currences of a slightly different type. Thus in the Tolstoi district it was noted that there is a covering of silt and sheet ice over practically all the gentler lower slopes, and when a small or intermittent stream has cut through the surface mat of vegetation it rapidly erodes the silt and ice to the gravel or to bedrock. By sloughing of the steep sides vegetation may reach the bottom of the cut, 20 feet or more in depth. By continuous sloughing, or by repeated freezing and thawing in fall and winter, the crevice is completely filled with ice and muck, and the next year the stream may follow a different course.

The sheet ice in the vicinity of mining operations on Boob Creek is of considerable extent. The cut made through the silt and ice by the breaking of a ditch had not yet melted so much as to cause the slumping of the upper layers of peat and moss and the covering of the underlying banded ice. A photograph of the ice at this locality is reproduced in Plate VIII, *C*.

IGNEOUS ROCKS.

SUBDIVISIONS.

Seven formations of igneous rock are shown on the geologic maps (Pls. III and IV). The major subdivision of these is based on age. Thus one Paleozoic igneous formation is mapped. It is designated greenstone, greenstone tuff, and chert and is a complex composed largely of basic igneous rocks in an advanced stage of alteration. With it are mapped certain cherty rocks whose origin is uncertain but which are so intimately associated with the greenstone and tuff that it is not practicable to make a separation between the two. This complex then constitutes the earliest igneous group. Wherever practicable the greenstone has been separated out and the chert is grouped with the undifferentiated metamorphic rocks.

Two types of Mesozoic (?) igneous rock are differentiated. One of these is a potash granite, which is correlated doubtfully with the Mesozoic. The other is a series of acidic lava flows composed of soda rhyolite and oligoclase dacite, which are in part interbedded with the chert-argillite formation.

The Tertiary igneous rocks consist of five mappable formations. One consists of basic flows composed of pyroxene andesite and basalt. The others are made up of intrusive rocks and include quartz monzonite, basic intrusive rocks comprising pyroxene diorite, gabbro, pyroxenite, pyroxene andesite, diabase, and basalt, and acidic dike rocks that comprise oligoclase-quartz diorite, soda granite, oligoclase dacite, and soda rhyolite. A fifth formation of Tertiary age, consisting of a mixture of the quartz monzonite and the basic intrusive rocks, is designated "undifferentiated intrusive and extrusive rocks."

GREENSTONE, GREENSTONE TUFF, AND CHERT.

AREAL DISTRIBUTION.

At Yuko Mountain and extending for about 10 miles northeast and southwest of it there is a rather involved series of rocks of widely divergent character. They consist mainly of greenstone, greenstone tuff, and chert. On account of the poor exposure of bedrock and the intimate association of the different members of this complex it has been necessary to map them as a unit. At Twin Buttes, about 20 miles to the south, there is another occurrence of such rocks. It is likely that much of the country rock between Twin Buttes and the Kaiyuh Mountains is also of this nature, and that these rocks connect southwestward with the greenstone series that occurs along Innoko River below the mouth of the North Fork. Near Mount Hurst is an additional area of greenstone, in part separated in mapping from the metamorphic complex of this district.

Elsewhere in the Ruby district the greenstone has been separated from this complex and mapped as a separate unit. The chief occurrences of the separably mappable greenstone are in the valley of Long Creek, in the upper Sulatna Valley, at the west end of Cecil Dome, about 6 miles south of Ruby, and on a hill about 2 miles southeast of Ruby.

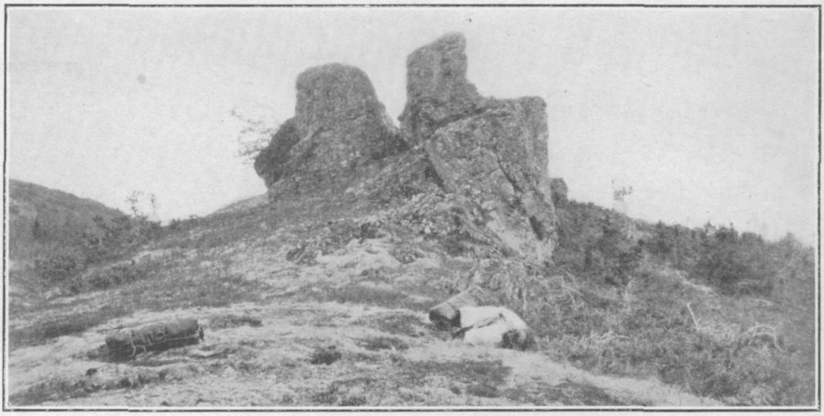
PETROGRAPHIC CHARACTER.

Igneous rocks of a number of types are here grouped together under the general term greenstone. These rocks embrace both coarse and fine grained varieties and without doubt include both intrusive and extrusive rocks. In the hand specimens, however, there is much similarity in the appearance of the different varieties. All are much altered and have a greenish-gray to dark-green or reddish-brown color, due to the secondary minerals developed in the process of alteration. The tuffaceous facies, being fragmental in places, exhibit mottled tones. All the greenstones show the effect of dynamic and chemical alterations. Many are crushed, fractured, and partly recrystallized; and in some the recrystallization is complete.

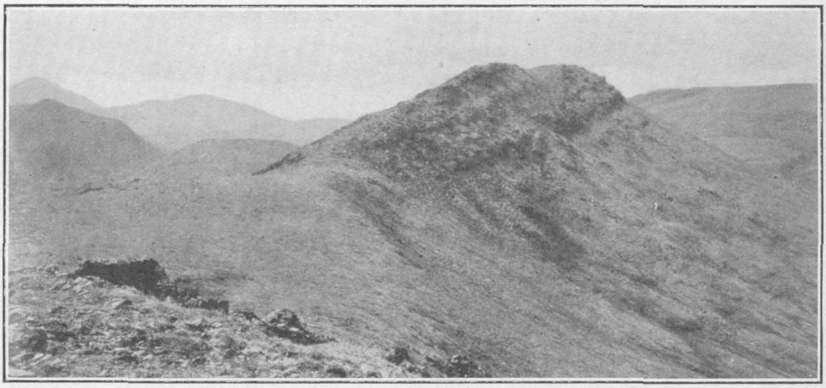
Under the microscope it is apparent that the greenstone includes the altered phases of several kinds of igneous rocks, among which gabbro, diabase, basalt, quartz diorite, and andesite have been identified. The gabbro, diabase, and basalt are the most plentiful and represent probably the main greenstone type. The quartz diorite and andesite have been recognized in only a few localities and are not mappable as separate units. They are included with the basic greenstone because of their greenstone habit, which is developed to a degree commensurate with that of the other varieties of greenstone. Nothing definite is known of the relations existing between the

A. RUBY AND THE SMALL DELTA OF RUBY CREEK.

B. SHALLOW-WATER RIPPLE MARKS IN SAND ON A SAND BAR IN YUKON RIVER.



A. LAVA FLOWS 2½ MILES NORTH OF CAMP OF JUNE 29.



B. LAVA SHEETS AT HEAD OF ROBERTS CREEK.

C. SHEET ICE IN A CUT NEAR THE CAMP OF THE TOLSTOI MINING CO. ON BOOB CREEK.

dioritic and andesitic greenstones and the more basic varieties, but it is not unlikely that the more acidic greenstone may have been intruded into the more basic rocks.

In the valley of Long Creek the basic greenstone consists of gabbro, diabase, and basalt. A typical occurrence of the gabbro is at Midnight Creek, where the rock contains two varieties of pyroxene—augite and a much altered orthorhombic variety. The plagioclase is entirely decomposed to secondary material. Magnetite is also present.

Along Long Creek both above and below Long altered diabase and basalt, as well as altered gabbro, are found. The diabase and basalt are partly recrystallized, but there remains enough of the original texture to identify the rocks. The diabase consists essentially of badly shattered augite and cloudy plagioclase, with some original oxides of iron. Much secondary quartz, epidote, sericite, and chloritic material is developed. The basalt likewise is partly recrystallized and consists of augite, brown glass, chloritic material, actinolite, and epidote. Another specimen taken in this vicinity is entirely recrystallized, being composed mainly of actinolite, zoisite, and chlorite with accessory titanite, quartz, and secondary acidic plagioclase.

Along the west side of Long Creek a short distance below Long altered quartz diorite occurs in intimate association with altered gabbro. Dioritic rock of the same general character is present also in the gravel of Long Creek. The quartz diorite is much crushed and shattered, and some of the specimens taken from the gravel are gneissoid in appearance. Some of the specimens are partly recrystallized. Usually the feldspar is altered beyond recognition, but in one specimen it was determined to be a plagioclase between oligoclase and andesine. Such mafic minerals as were originally present are entirely altered, largely to chloritic material, which occurs in stringers and irregular patches. Sericite, kaolin, secondary quartz, and iron oxides (in part secondary) make up the rest of the rock.

Between Glacier and Tamarack creeks, also in the Ruby district, an area of andesite with a greenstone habit is mapped. This is a dark-green porphyritic rock, composed of phenocrysts of plagioclase and hornblende in a groundmass that is largely undeterminable. The plagioclase is entirely sericitized and can not be determined. The hornblende is chloritized. Small plagioclase laths occur in the groundmass, which appears to be an altered glassy material. Primary apatite and magnetite are preserved, but the quartz that is present appears to be secondary.

At and near Yuko Mountain occur gabbro, diabase, and basalt, which in their petrographic character and degree of alteration are like those found on Long Creek. Tuffaceous beds are also present.

As before stated, these rocks are intimately associated with cherty beds. At Twin Butte the basic greenstone includes flows of diabase and basalt, but according to Eakin [70] these rocks are interbedded with argillite.

At the north end of Yuko Mountain more acidic rocks are found, but they can not be mapped separately. One of these is a quartz diorite of greenstone habit, similar to that which occurs on Long Creek. The plagioclase is oligoclase, graphically intergrown with quartz. Chlorite, epidote, and sericite are the principal secondary minerals. This rock is mineralized by pyrrhotite. Another acidic rock collected at this locality from talus has been determined to be a quartz monzonite. This rock does not possess a greenstone habit and is believed to represent some of the later intrusives.

The cherty rocks in the neighborhood of Yuko Mountain range from white or light gray to red, but some appear greenish. Their origin is a matter of doubt. In thin section small grains of quartz and laths of feldspar are determinable, but the groundmass is so fine grained as to appear glassy. Banding is visible in the rock, but the microscope fails to reveal whether it is due to sedimentation, to flow structure, or to shearing. The thinness of some of these bands appears to preclude the possibility of their being due to successive flows, and their general appearance, both in the hand specimen and in thin section, suggests that they may in part represent beds of altered volcanic ash. Some of the beds are less flintlike and may be due to the admixture of argillaceous with siliceous material.

The best exposures of greenstone tuff occur a short distance east of Deadman Hill, along the trail from Ruby to Long. The tuffaceous fragments are subangular to angular and range from a fraction of an inch to 6 inches in size. Together with the igneous fragments is much argillite and cherty material. The cement is a dense greenish material, made up largely of chloritic minerals and secondary quartz. Associated with the tuff are bodies of basic greenstone, similar to those occurring elsewhere in the Ruby district, and cherty beds.

STRUCTURE.

It has not been possible to obtain any data bearing on the structure of the surficial members of the greenstone complex. The attitude of lava flows is usually apparent only where much bedrock is exposed, and even there the attitude of the beds may be shown in a general way. Conditions favorable to such observations are lacking in the Ruby district, but there are a few outcrops of the cherty beds that yield some information regarding the structure.

[70] Eakin, H. M., oral communication.

North and northeast of Yuko Mountain the greenstone complex appears to lie in about the same attitude as the underlying metamorphic complex, with a strike about N. 25° E. and a gentle westerly dip. Southwest of Yuko Mountain the strikes vary largely, ranging from north and northwest to west, with westerly and southerly dips. Doubtless the change in strike is due in part to the numerous intrusives, such as those which make up a considerable portion of Yuko Mountain, but it is probably in part due also to conformity with a larger feature, already mentioned, the southwestward-pitching anticline of the metamorphic complex. The area has been subjected to severe stresses, which have been relieved by folding of the less resistant beds and by folding and shattering of the harder cherts. Two small areas of chert and greenstone tuff in the vicinity of Deadman Hill are believed to represent masses of these rocks infolded in the older metamorphic series.

AGE.

It is believed that some of the surface lavas of this complex are interbedded with the cherty members, and it is rather likely that the gabbroic and dioritic rocks are intrusive into this complex, but no information is available as to the priority of these two types of intrusive rock.

It is rather likely that the greenstone complex of the Ruby district represents more than one period of volcanic activity, and that rocks of different ages are grouped together. In the Fairbanks quadrangle greenstone has been recognized at three horizons—in the Ordovician, in the Devonian, and in the Carboniferous.

In the upper Matanuska Valley and in the Cook Inlet region greenstone is definitely known in the Lower Jurassic. As no fossils have been found among the fragmental rocks associated with the greenstones of the Ruby district, the age of these rocks can not be stated with assurance. It is the opinion of the writers, however, that the greenstones and associated rocks from Yuko Mountain southwestward should be correlated with the Rampart group, which is now believed to be of Mississippian age.

GRANITE.

AREAL DISTRIBUTION.

Three bodies of potash granite of mappable size are known in the Ruby district. One of these lies at the head of Flint Creek, another lies along the ridge east of Birch Creek, a tributary of Flint Creek, and the third is on the east side of Sulatna River, above the "loop." Several small dikes that crop out along Yukon River about 1½ miles below Ruby proved on examination to be soda-granite and are included and described with the Tertiary soda rhyolite and soda granite.

PETROGRAPHIC CHARACTER.

The granite is a gray or yellowish-gray holocrystalline, coarsely granular rock, locally porphyritic, with phenocrysts of orthoclase and quartz. It is composed essentially of quartz, orthoclase (sometimes microcline), and mica (both biotite and muscovite), with a subordinate amount of oligoclase or oligoclase-albite. Iron oxides are almost entirely lacking, but apatite is present in some specimens. At the Birch Creek locality a light creamy-gray fine-grained porphyritic dike about 1½ feet wide was observed by the junior writer cutting the coarser-grained granite, but in composition the invading and invaded rock were practically the same. All these rocks are fresh and unaltered.

AGE.

There is no stratigraphic evidence bearing on the exact age of the granite. It seems to invade the metamorphic complex in much the same manner as the intrusive greenstone. On the other hand, it is not known anywhere in the Innoko-Iditarod region among the Cretaceous sediments. From this it is inferred that the granite is of pre-Cretaceous age, but it can not be positively assumed to be younger than any formation other than the metamorphic complex. The freshness of the rocks and their striking similarity to some of the granites in the Yukon-Tanana region are interpreted as presumptive evidence of their Mesozoic age.

SODA RHYOLITE AND OLIGOCLASE DACITE (FLOWS AND TUFFS).

AREAL DISTRIBUTION.

Sodic rocks of surficial character are known only at two general localities—in the headwaters of the South Fork of Sulatna River, extending south into the valley of Susulatna River, and in the vicinity of Mount Hurst. Certain light-colored rhyolitic rocks that have been noted in the metamorphic area to the north may also be representatives of this group. The rhyolitic rocks near Mount Hurst, however, are interpreted by Harrington [71] as flows of Tertiary age, but it is possible that they may be pre-Tertiary.

PETROGRAPHIC CHARACTER.

The extrusive soda rhyolite and oligoclase dacite range from cream-colored and buff rocks to yellowish or reddish-brown varieties. They are very fine grained and aphanitic. Most of the

[71] Harrington, G. L., Gold and platinum placers of the Tolstoi district: U. S. Geol. Survey Bull. 692, pp. 346–347, 1919.

specimens examined are porphyritic; the phenocrysts are mainly plagioclase with locally some biotite. At the head of the South Fork of Sulatna River these rocks appear to be most altered. In this vicinity tuffaceous members occur, and it is probable that the high degree of alteration is due to the presence of the tuff, which, on account of its porosity, afforded avenues for the circulation of underground water. From these altered varieties little may be learned of the original character of the rock. The phenocrysts of plagioclase and the entire groundmass are usually altered to a microaphanitic material resembling chalcedonic quartz, showing only aggregate polarization. With this material are associated a considerable amount of sericite and some hydroxides of iron. This silicification is probably due to the transfer to the rhyolitic rocks of silica by underground water from the chert-argillite series, which lies in close proximity. The tuffaceous rocks exhibit the maximum silicification.

In the Susulatna Valley, where the rhyolitic lavas are least altered, they are holocrystalline rocks, many of them porphyritic, with phenocrysts of andesine or labradorite and smaller ones of biotite. The andesine is commonly sericitized in part. The groundmass is fine grained and granular and consists essentially of intimate intergrowths, in some places graphic, of quartz and oligoclase-albite. There are also concentrated areas of black iron oxides which certainly represent original biotite. Some scattered grains of iron hydroxides, derived from iron oxides, are present as an accessory constituent.

The mean composition of the plagioclase feldspars present in those specimens which have phenocrysts of basic plagioclase is about that of oligoclase, and the rocks are designated oligoclase dacite. Many of the nonporphyritic types have only the albitic plagioclase of the groundmass and therefore are better described as soda rhyolite.

RELATIONS AND AGE.

On the divide between the South Fork of Sulatna River, Susulatna River, and Innoko River, these rhyolitic lavas are exposed, the divide trending across the strike of the beds. It is at this locality that the extrusive character of these rocks is best shown. The presence of tuffaceous varieties with the main igneous rock is taken as proof of the surficial character of the lava. Also, as indicated on the accompanying geologic map, the lava is closely associated with bands of chert. Nowhere in this area was it possible to observe or measure directly the attitude of the lava beds, but the general trend of the associated cherty rock is about the same as that of the main chert-argillite formation to the north—that is, N. 60° E. It is believed, therefore, that these zones of chert are a part of the series, interbedded with the acidic lava flows. The chert-argillite formation on the headwaters of the South Fork of Sulatna River is much brecciated, and it is significant that the rhyolitic rocks near their contact with the chert-argillite formation are similarly brecciated.

The inference is drawn from these data that the acidic lavas here described are of the same age as the chert-argillite formation, which may be either Paleozoic or Mesozoic. The alteration which these lavas have suffered and their consequent dull stony or lithoidal appearance may be taken as corroborative evidence that they represent an older period of extrusion than that of the Tertiary volcanism. The areal position of the rhyolitic lavas, at the southern extremity of the chert-argillite series, adjoining the Upper Cretaceous and Eocene rocks, and the maximum silicification at the northern extremity of the lavas indicate that the volcanic activity which produced them may have taken place at or near the end of the period represented by the chert-argillite series.

PYROXENE ANDESITE AND BASALT (FLOWS AND TUFFS).

AREAL DISTRIBUTION.

There are three areas within the Ruby-Kuskokwim region where extensive lava flows of basic character are recognized. Effusive rocks have also been observed in close association with the intrusive basic rock at a number of localities. The largest of the three areas of undoubted lava flows lies in the valleys of Sulatna, Lost, Nowitna, and Susulatna rivers. Another area lies east of Ophir, between Twin Mountain and Cloudy Mountain, largely in the valley of Roberts Creek, and the third occupies the divide between Ditna River and the headwaters of Fourth of July and Moore creeks. A fourth small area of andesite, probably in large part flows, lies about 12 miles north of Mount Hurst. The determination of intrusive or extrusive character for some of the smaller bodies of fine-grained basic lava is uncertain, for the necessary data were not always available.

PETROGRAPHIC CHARACTER.

The pyroxene andesite and basalt are usually dense, fine-grained rocks, dark gray to black when fresh but weathering to a reddish-brown color. Vesicular varieties, some of them amygdaloidal, have been found at a few localities. Near the camp of June 27 the lava was very vesicular, the gas cavities attaining a maximum size of 3 inches. These cavities have been filled with quartz and chalcedony, the former composing the center of the fillings and the latter making up the outside. These round siliceous amygdaloids give to the rock much the appearance of a conglomerate when observed only superficially. The general type is nonporphyritic, but porphyritic facies exist. None of these rocks has suffered any considerable dynamic metamorphism. All gradations exist between holocrystalline varieties and others in which glass predominates over the crystalline components. All the rocks, however, are fine grained. Flow structure is present in many specimens. In the porphyritic rocks plagioclase is the common phenocryst, but in a few specimens phenocrysts of pyroxene are also present.

The plagioclase phenocrysts in both the pyroxene andesite and the basalt are labradorite. The difference between the two rock types is most apparent in the composition of the groundmass and in the arrangement of the minerals therein. In the holocrystalline varieties of the pyroxene andesite two kinds of plagioclase, labradorite and oligoclase, are present in about equal amounts. The labradorite occurs as tiny laths, embedded in a matrix of anhedral oligoclase. In some specimens the plagioclase that forms the matrix is as acidic as oligoclase-albite. Thus there is developed a somewhat trachytic fabric, wherein soda-rich plagioclase occupies the place of orthoclase, as usually seen in trachyte.

The average composition of these two feldspars would be that of andesine, and it is for this reason that these rocks are called andesites. In one specimen a little orthoclase was also observed as anhedral interstitial grains. In other respects the pyroxene andesite does not differ from the basalt, for augite and iron oxides form the other constituents in both rocks. Apatite is a common accessory mineral. The pyroxene is in much of the rock partly altered to serpentinous or chloritic material and calcite. In some specimens this alteration is complete, but the feldspars are generally not decomposed to any considerable degree.

In the more glassy varieties of pyroxene andesite laths of labradorite are set in a glassy matrix whose index of refraction is less than that of Canada balsam. This glassy material probably represents in large part uncrystallized acid plagioclase. Chloritic material is also developed, being derived from pyroxene or its glassy equivalent. Iron oxides are present as euhedral crystals, accompanied here and there by apatite.

The basalt differs from the pyroxene andesite only in the absence of oligoclase, the plagioclase being entirely labradorite. There are holocrystalline and partly glassy varieties, some of them showing flow structure, and the porphyritic habit is about as common as in the andesite. The augite grains are set in the interstices between the labradorite laths, giving the typical intersertal fabric.

Sufficient work has not been done in this region to determine the volcanic sequence—that is, whether the andesite was extruded prior to, after, or intermittently with the basalt. If the number of specimens collected may be taken as an index to the relative amount of these two types of lava, it would appear that the pyroxene andesite is more common than the basalt, but this can not be positively affirmed at present.

LOCAL RELATIONS.

Sulatna, Lost, Nowitna, and Susulatna valleys.—In the valleys of Sulatna, Lost, Nowitna, and Susulatna rivers the basic lavas have their widest distribution, having an areal extent of about 800 square miles. In this area there is no question as to the surficial character of the basic rock, for tuffaceous varieties and vesicular lava may be seen at many localities. Further, the position of the basaltic rocks is such as to suggest strongly that they were poured out upon the surface.

At the head of the South Fork of Sulatna River, where the exposures are best, the basic lava caps numerous hills, which at the base prove to consist of a rhyolitic rock that is thought to be interbedded with the chert-argillite series. Likewise in the saddles between these lava-capped hills fragments of the rhyolite are present, indicating that the lavas were extruded over an older lava rock. No contacts were observed, but from the observations above noted it appears that in this particular area the basic lavas have approximately a horizontal position. Rough measurements with the aneroid barometer from the highest rhyolitic slide on some of these lava-capped hills to the tops give a minimum thickness of about 200 feet for the basic lava, on the assumption that the flows have a horizontal attitude. Erosion, however, may have removed much of the lava.

Only at one point in this entire area was it possible to discern the attitude of the lava flows and to measure their strike and dip. This was about 2½ miles north of the camp of June 29. Plate VIII, *A*, shows the position of the lava at this point. The flows strike N. 45° W. and dip 25° NE. This tilted position of the lava does not accord with its horizontal attitude a short distance to the north, but the presence of basic lava east of this locality, extending down into the present valley of Susulatna River, indicates that the lava may have flowed down into some preexisting valley. The discordance in attitude may, however, be due to folding of the lava beds.

Valley of Roberts Creek.—In the valley of Roberts Creek, east of Ophir, the basic lavas are exposed, and at several localities the bedding of the flows may be seen. Plate VIII, *B*, shows the pronounced bedding of the lavas at the head of Roberts Creek, about 2½ miles northeast of the camp of July 21. The surficial character of the lava is further shown by the presence of interbedded tuff and tuffaceous sandstone and shale. The clastic members appear to be of terrestrial origin and are believed to be contemporaneous with the period of

Tertiary volcanic activity. Four measurements of the strike of the lava and interbedded tuff in this area yield an average strike of about N. 17° E. The dips are fairly constant, being about 30° and invariably to the southeast, toward the Cloudy Mountain massif. The attitude of the sedimentary beds to the north and south of this area is in striking contrast to this, for they appear to dip away from the intrusive masses of the region. From this observed relation it is inferred that the basic lavas probably rest unconformably on the eroded surface of the Upper Cretaceous rocks.

Headwaters of Dishna River and Fourth of July and Moore creeks.—The route of the 1915 Survey party lay to the east of the area of lava flows at the headwaters of Dishna River and Fourth of July and Moore creeks. The southwest end of this area was visited, however, and the inference as to the surficial character of the lava was confirmed. Considerable tuffaceous rock is associated with the lava, and this is much altered to hydroxides and oxides of iron, which give a reddish-brown look to the hills at the head of Fourth of July Creek. One structure observation taken on what appeared to be the bedding of the lava gave a strike of N. 55° E. and a dip of 50° N. Being the only observation obtainable on the attitude of the lavas in this vicinity, this has less weight than the observations made in the valley of Roberts Creek. Yet it should be pointed out that this dip observation shows the lava flows to be pitching in toward the Beaver Mountains, which, as elsewhere shown, are a complex of Tertiary intrusive rocks. This relation is similar to that shown in the valley of Roberts Creek, where the lavas dip in toward the intrusive rocks of the Cloudy Mountain massif.

North and northwest of Mount Hurst [72] flows of andesite and rhyolite cover the low flat-topped hills that merge northward with the lowlands of Dishna and Innoko rivers. These rocks have been mapped by Harrington as Tertiary, but no absolute evidence of their age is available. It is quite possible that they may belong in the Mesozoic.

Other areas.—At a number of other localities in the Ruby-Kuskokwim region fine-grained pyroxene andesite and basalt are present, but in places it is difficult to decide whether the igneous rock is extrusive or intrusive. On the south side of Fourth of July Creek about 2½ miles southwest of the camp of August 14, a hill composed of tuffaceous material and basaltic rock was seen. The tuffaceous beds strike N. 75° W. and dip 45° S. There was no question as to the surficial character of this rock.

At other localities, however, as on the ridge between Flat and Slate creeks, in the Iditarod mining district, tuffaceous beds and fine-

[72] Harrington, G. L., The gold and platinum placers of the Tolstoi district: U. S. Geol. Survey Bull. 692, pp. 346–347, 1919.

grained basic igneous rock are intimately associated with porphyritic pyroxene andesite and basalt which are thought to be intrusive. Also, on the northeast side of the basic intrusive mass at the headwaters of Susulatna River and one of the tributaries of Nixon Fork of the Kuskokwim some bedded lavas were observed high up on the mountain side, but the boundary between intrusive and extrusive rocks could not be determined nor the proportions of each ascertained. Where basic intrusives and extrusives have occurred thus in intimate association, the mapping shows what is thought to be the dominant type.

Basic lavas and tuffs are also reported to exist along Innoko River above the junction with the North Fork. These, however, may be a part of the greenstone complex, which is a prominent part of the country rock at Yuko Mountain and at Twin Buttes, in the Ruby district.

AGE AND THICKNESS.

The age of the basic lavas, though not absolutely established, may be inferred with a considerable degree of certainty. In the valleys of Sulatna, Lost, Nowitna, and Susulatna rivers these lavas apparently overlie the rhyolitic lavas and tuffs of Paleozoic or Mesozoic age. In Susulatna Valley they are also associated with rocks of probable Eocene age in such a manner as to suggest that they are either interbedded with these rocks or overlie them as lava caps. Moreover, the conglomerate beds of known Eocene age contain no pebbles of the basic lavas nor of the basic and acidic intrusive rocks, though all three of these types of igneous rocks occur near by. Also, in the valley of Roberts Creek, west of Cloudy Mountain, the attitude of the lavas suggests that they may overlie unconformably the sedimentary beds to the north, which are of Upper Cretaceous and Eocene age. It is therefore believed that these basic lavas were poured out subsequent to the deposition of the basal Eocene conglomerate and are therefore either late Eocene or post-Eocene in age.

The thickness of the basic lavas is difficult to estimate, owing in part to dearth of outcrops but more particularly to inadequacy of data. It is believed that their minimum thickness is 500 feet, but it is likely that they are considerably thicker.

PYROXENE DIORITE, GABBRO, PYROXENITE, PYROXENE ANDESITE, DIABASE, AND BASALT.

AREAL DISTRIBUTION.

Basic rocks are widespread throughout the Ruby-Kuskokwim region, both as large and small intrusive bodies. At many of the smaller occurrences where the rock is fine grained, the evidence of the intrusive character of the rock consists largely in the absence of bedded lava, flow lines, and tuffaceous material and is therefore negative in nature. It is not unlikely that some of the areas thus mapped as intrusive may be so only in part.

The chief bodies of basic intrusives are the large mass at the headwaters of Susulatna River and one of the tributaries of Nixon Fork of the Kuskokwim, the still larger mass at and around Cloudy Mountain, a small occurrence of basic rock associated with the quartz monzonite at Twin Mountain, one forming a large part of the mountain south of Takotna, one at the head of Candle Creek, two at and near Mount Hurst, one at Camelback Mountain, one at the head of Bonanza Creek, and much of the basic rock around Flat and Discovery in the Iditarod mining district. The Cripple Creek Mountains[73] and Beaver Mountains[74] are known to have central areas of monzonitic rock surrounded by large peripheral areas of basic intrusive rock and perhaps some surface lava. These two areas are therefore shown as a separate pattern among the igneous rocks, under the designation undifferentiated Tertiary intrusive and extrusive rocks. There are also many smaller bodies of basic intrusives, comprising dikes, sills, and small laccoliths. The more prominent of these smaller bodies lying along the route of the Survey party of 1915 are shown on the geologic map.

PETROGRAPHIC CHARACTER.

The basic intrusives are dense light-gray to dark-gray or black rocks with a varying degree of granularity. All are holocrystalline, and most of them are porphyritic. They include pyroxene diorite, gabbro, pyroxenite, pyroxene andesite, diabase, and basalt.

The pyroxene diorite is a light to dark gray rock and when seen among the stream gravels appears several shades lighter than the rock in place, giving the impression that it is a granitic rock. It is usually porphyritic, and has phenocrysts of plagioclase, of the variety labradorite, which very commonly are zonally grown and show rims of more acidic plagioclase. Augite and locally biotite are also present among the phenocrysts. The groundmass consists of lath-shaped crystals of labradorite, with grains of augite and magnetite, set in a matrix of acidic plagioclase, which has an average composition about that of oligoclase-albite, though ranging to slightly more basic or more acidic varieties. The average composition of the two kinds of plagioclase in these rocks is about that of andesine, and for this reason these rocks are referred to the family of diorites rather than to the gabbros. Many specimens of this class contain a considerable amount of quartz, usually intergrown, in plasce graphically, with the oligoclase of the groundmass. Here and

[73] Eakin, H. M., oral communication. [74] Maddren, A. G., oral communication.

there the pyroxene has rims, which show slightly smaller extinction angles than the centers of the crystals. Apatite, in small euhedral grains, is a constant accessory mineral. Nonporphyritic varieties of the pyroxene diorite are exceptional but are very similar to the groundmass of the porphyritic varieties.

The gabbro seen is a rock of more basic type than the pyroxene diorite. It is dark in color, in places almost black, and in the specimens examined was not noticeably porphyritic. It is quite impossible to distinguish this rock in the field from the dark-colored varieties of the pyroxene diorite. The gabbro consists essentially of plagioclase, pyroxene, and oxides of iron, in a granular fabric. A number of the gabbroic rocks contain olivine. Apatite is always accessory. The plagioclase of the gabbro, in contradistinction to that of the pyroxene diorite, is always the single variety labradorite. The pyroxene is usually augite, but hypersthene has also been observed.

Only one specimen of pyroxenite was examined. This specimen was collected by A. G. Maddren at Mount Hurst in 1908. It is a dark, coarsely granular nonporphyritic rock, consisting almost entirely of augite, with a subordinate amount of diallage.

The pyroxene andesite is the fine-grained equivalent of the pyroxene diorite. It is practically the same as the pyroxene andesite occurring among the Tertiary lava flows (see p. 26), except that it is almost universally porphyritic. The phenocrysts usually consist of labradorite and augite. It has the characteristic dual form of plagioclase, labradorite and oligoclase-albite, giving an average of andesine. Quartz is accessory in some of the specimens.

The basalt also is identical with the basalt described among the Tertiary lavas, except that, like the intrusive pyroxene andesite, it is more porphyritic.

Diabase is not of common occurrence among these intrusive rocks. It is of the same composition as the gabbro but is somewhat finer grained and has the characteristic ophitic fabric, in which a number of labradorite laths, in similar orientation, are intergrown in a single individual of augite. Olivine is locally present.

At one locality in the Susulatna Valley (p. 27) a dike rock that is thought to be a product of differentiation of the basic lava cuts the Cretaceous sediments. This is a hornblende-soda vogesite. From 75 to 80 per cent of the rock is composed of hornblende, which is related to basaltic hornblende, being pleochroic in shades of green and brown. The interstices between the hornblende prisms are filled with oligoclase-albite in large part but also with a little orthoclase. Magnetite and apatite are the accessory minerals. The rock, as a whole, is little altered. In individual specimens considerable chlorite and serpentinous material is developed, with a little sericite and hydroxides of iron. Evidence of dynamic metamorphism is absent.

The pyroxene diorite and its fine-grained equivalents are evidently distinct from the gabbro and its fine-grained relatives, but the association of the two is so intimate and the difficulty of distinguishing between them in the field is so great that it is not possible, from the data obtained in reconnaissance work, to map them separately. The constant occurrence of augite in all these rocks, however, indicates their close relationship. It is likely that the pyroxene diorite and andesite were intruded after the gabbro and basalt, but the difference in the time of intrusion of the two types is not regarded as great. The two types probably represent nearly related stages of intrusion within the same general period of volcanism.

A notable feature of these rocks as a whole is the large amount of fine-grained igneous material present. This, in conjunction with their intimate association with basic surface lava, is the basis for the belief that the basic intrusives solidified under no great depth of cover and in many places penetrated to the surface.

AGE.

The basic intrusives invade rocks that are known to be either of Upper Cretaceous or Eocene age. In the valley of Roberts Creek no sharp line separates the basic intrusive from the basic extrusive rocks, and it appears that these two types are closely related genetically. No definite evidence is available, however, as to whether the intrusive basic rocks are younger or older than the basic lavas or contemporaneous with them. The association of the two types of rock, however, is so close that the conclusion has been reached that the basic intrusive rocks, like the basic extrusive rocks, are of late Eocene or post-Eocene age.

The basic intrusive rocks, however, are older than the monzonitic rocks which cut them at numerous localities—for example, at the summit of Cloudy Mountain, at Twin Mountain, at the mountain south of Takotna, at Candle Creek, at Camelback Mountain, and at the head of Flat Creek, in the Iditarod district. The constant association of the two types of intrusive rock and certain family resemblance, such as the general presence of pyroxene in both acidic and basic intrusives, is evidence that they have a close genetic relationship and that no great time interval elapsed between their periods of intrusion.

QUARTZ MONZONITE.

AREAL DISTRIBUTION.

Quartz monzonite is present at many localities in this region, usually but not universally in association with more basic intrusive rocks. At Cloudy Mountain, Twin Butte, the mountain south of Takotna, Candle Creek, Camelback Mountain, on Flat and Otter creeks in the Iditarod district, and at Barometer Mountain and vicinity the two types of intrusives occur together. At Tolstoi the monzonite is associated with diorite. At Joaquin Mountain, on the south side of Takotna River below the forks, only a small amount of basaltic rock is in the vicinity of the monzonitic rock; and at the monzonitic area about 9 miles south and 2 miles east from Joaquin Mountain no basic igneous rock was observed around or associated with the more acidic intrusive rock. Eakin[75] reports the general distribution of granite dikes in the Innoko district, but mentions no basic rocks in that vicinity. The "granite dikes" referred to are probably quartz monzonite. With the exception of Cloudy Mountain and the Innoko district all the localities above mentioned represent areas of quartz monzonite of considerable extent. At Cloudy Mountain only dikes were observed, cutting the basic rock.

PETROGRAPHIC CHARACTER.

The quartz monzonite is usually a light-gray rock, weathering still lighter, but in a few places the percentage of mafic minerals is large and the rock is very dark. Some quartz monzonite on Otter Creek at the mouth of Cottonwood Creek, which is very rich in biotite, exemplifies this darker phase. All of this intrusive rock is holocrystalline, and most of it is granular and nonporphyritic. The porphyritic types are for the most part the dikes, as in the Cloudy Mountain occurrence. The mass of monzonite about 9 miles south and 2 miles east from Joaquin Mountain is the only body of monzonitic rock of any considerable size that is prevailingly porphyritic. In the porphyritic rock the plagioclase and to a lesser extent the mafic minerals—mica, augite, or hornblende, as the case may be—form the phenocrysts.

The quartz monzonite is composed of orthoclase, plagioclase, quartz, augite, biotite, and hornblende, with small amounts of magnetite, apatite, and zircon. The plagioclase varies in the different occurrences from acidic oligoclase to acidic labradorite and is present in amounts about equal to that of the orthoclase. The orthoclase and plagioclase are in places graphically intergrown, as in the saddle that forms the divide between the heads of Slate Creek and Flat Creek, in the Iditarod district. Augite-mica diorite and augite-mica-hornblende-quartz diorite are the types found at most of the known localities. The augite-biotite type is present at Twin Mountain, at Cloudy Mountain, at Bonanza Mountain, and at the head of Flat Creek, in the Iditarod district. The augite-biotite-hornblende type is developed at the mountain south of Takotna and at Joaquin Mountain. Biotite-hornblende-quartz monzonite was found at Twin Moun-

[75] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 25, 1914.

tain, Tolstoi, and Candle Creek. At Cloudy Mountain some mottled blue and brown tourmaline occurs in the monzonite. The dark-looking monzonitic rock at the mouth of Cottonwood Creek, on Otter Creek, previously referred to, was found on microscopic examination to be an olivine-bearing augite-biotite-quartz monzonite.

Economically the quartz monzonite is the most important of the igneous rocks described in this report. It is the source, directly or indirectly, of all the gold and other metallic minerals, except platinum, in the country extending from the Cripple Creek Mountains to Iditarod and south and east to Kuskokwim River.

AGE.

The quartz monzonite invades Upper Cretaceous and possibly Eocene rocks, as well as the basic intrusive rocks. It is therefore of late Eocene or post-Eocene age.

OLIGOCLASE-QUARTZ DIORITE, SODA GRANITE, OLIGOCLASE DACITE, AND SODA RHYOLITE.

AREAL DISTRIBUTION.

At many localities in the Ruby-Kuskokwim region sodic rocks occur as dikes and small intrusive bodies. The surveys in 1915 showed that these rocks are present along Yukon River below Ruby, in the beds of Spruce and Poorman creeks, northeast of the contact-metamorphosed shale that forms the high mountain group east of the Cripple Creek Mountains, in the valley of Roberts Creek, at the mountain about 9 miles south of Joaquin Mountain, at a number of localities in the valleys of Moore and Fourth of July creeks, and at Camelback Mountain. Work in 1917 showed their presence in the vicinity of Tolstoi. Undoubtedly detailed geologic work will disclose areas other than those now known.

GEOLOGIC OCCURRENCE.

On the Yukon about 1½ miles below Ruby there are some small intrusive lenses and dikes which have been identified as soda granite and soda granite porphyry. These intrude only the metamorphic complex, no younger rocks being present in the vicinity. For this reason the age of these intrusives is not definitely known. It is likely that they are correlative with the known Tertiary rocks of this type farther south, but they may represent an intrusive phase of the pre-Tertiary soda rhyolite lava. Likewise in the valley of Poorman Creek about a mile below Poorman mining operations have uncovered soda rhyolite bedrock, which there is intermingled with slate that may be a part of the older metamorphic complex or may be Cretaceous. The age of this soda rhyolite, like that of the similar rock along the Yukon, is not known definitely, but the fact that it is associated with a coal seam which is thought to be of Upper Cretaceous age, as described on pages 26–27, is presumptive evidence that it is a Tertiary intrusive. The shape and dimensions of this mass of soda rhyolite will remain unknown until further mining operations have exposed more of it.

Northeast of the contact-metamorphosed shale that forms the high mountain group east of the Cripple Creek Mountains numerous dikes and small intrusive bodies cut the Cretaceous rocks. These intrusives consist both of pyroxene andesite and of the sodic rocks under discussion. This general area, including the mountain group of metamorphosed shale, seems to have been a site of intrusive action. The sodic rocks in this area are oligoclase dacite and oligoclase-quartz diorite porphyry.

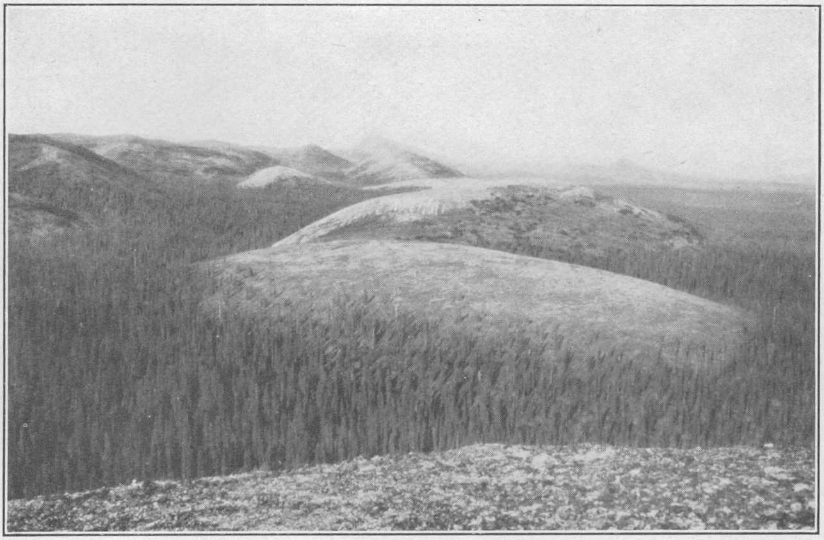
At one locality on the west side of Roberts Creek opposite the camp of July 23 the whole side of the hill is covered by slide rock that has been identified as an oligoclase dacite. The top of the hill at this place is composed of basic tuffs, and it is inferred that the dacite is a dike or other intrusive body cutting the tuffs.

About 9 miles south of Joaquin Mountain is a dome-shaped mountain made up of soda rhyolite. The surrounding country rock is Cretaceous, and it is therefore inferred that this is a large intrusive body.

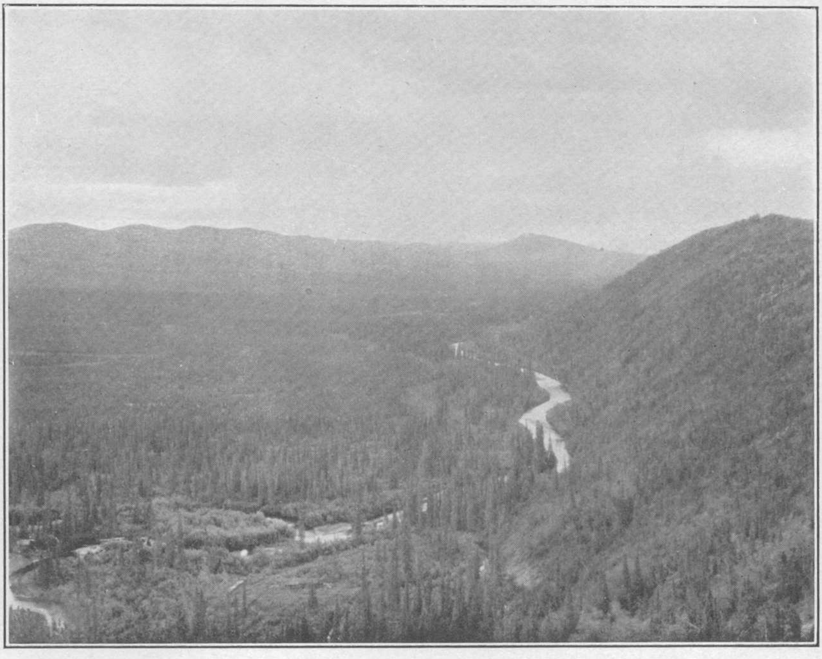
In the valley of Moore Creek, near the camp of August 11, are two small bodies of oligoclase dacite, as shown on the map. These are intrusive in the Cretaceous rocks. Most of the sodic rocks found in the valleys of Moore and Fourth of July creeks, however, are mica-soda rhyolite. The largest mass of these rocks forms an elongated body occupying the ends of the spurs along the northwest side of Fourth of July Creek. Plate IX, *A*, a view taken from the southwest end of this mass, looking to the northeast, its direction of elongation, shows the physiographic form. The dacite appears to intrude the Tertiary basic lava flows, as well as the rocks of the Upper Cretaceous series. The other bodies of soda rhyolite in the valley of Moore Creek also invade the Upper Cretaceous rocks.

On the west flank of Camelback Mountain, at the head of Bonanza Creek, a large dike of soda granite intrudes the Cretaceous rocks, occurring only a few feet from the locality where fossil collection No. 9367 was made. The Cretaceous rocks have been much silicified by the soda granite, and the fossil-bearing beds themselves are altered from shale to cherty material.

Soda rhyolite of the same general character as those above described is present as dikes in the Innoko mining district and has



A. SODA RHYOLITE SPURS ON NORTHWEST SIDE OF FOURTH OF JULY CREEK.



B. ASYMMETRIC VALLEY OF FOURTH OF JULY CREEK, A TRIBUTARY OF TAKOTNA RIVER, LOOKING DOWNSTREAM.

been connected genetically with a part of the mineralization in that area by Eakin,[76] who says of these dikes and their attendant mineralization:

> A single gold lode has been developed in a small way in the Innoko district at the Independence mine, near the head of Carter Creek, an eastern tributary of Ganes Creek. The lode consists of a quartz vein, averaging about 2 feet in thickness, that occurs along the hanging wall of an altered rhyolite dike intrusive in the Cretaceous sedimentary rocks.

It is possible that some of the occurrences of sodic rock above described and referred to as intrusives, especially those in the valley of Moore and Fourth of July creeks, may be in part extrusive. The sodic rocks in the vicinity of Mount Hurst have been considered by Harrington [77] to be flows, but they may be of pre-Tertiary age. All the other occurrences, however, chiefly because of their physiographic form and lack of tuffaceous material, have been interpreted as intrusive bodies.

PETROGRAPHIC CHARACTER.

Oligoclase-quartz diorite and oligoclase dacite.—As might be expected from their habitat, these rocks are prevailingly fine grained and porphyritic, but otherwise they do not differ materially in texture from the finer-grained varieties of the quartz monzonite. Only one of the specimens examined (that obtained in the valley of Roberts Creek near the camp of July 23) contained any glass, all the rest being holocrystalline. The phenocrysts are usually plagioclase and quartz, locally also biotite and augite. These are essentially quartz-oligoclase rocks and differ materially from the monzonite in the total absence of orthoclase. They differ from the Tertiary soda rhyolite and soda granite in that the plagioclase is more basic, and because of the larger amount of mafic minerals present, including pyroxene, which has not been observed in the soda rocks. The quartz and oligoclase are in places graphically intergrown. Biotite, and to a less degree pyroxene, are the essential mafic minerals. Magnetite and apatite are accessory.

These rocks contain a considerable amount of chloritic and serpentinous material, derived from the alteration of mafic minerals, and for this reason the character of the dark minerals is less evident than in most of the Tertiary intrusives. In some specimens the plagioclase is partly sericitized. This amount of alteration is due probably to the habitat of these rocks—that is, in dikes, which

[76] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 38, 1914.

[77] Harrington, G. L., Gold and platinum placers of the Tolstoi district: U. S. Geol. Survey Bull. 692, pp. 346–347, 1919.

are commonly zones of weakness and channels for the circulation of underground water.

Soda granite and soda rhyolite.—The soda granite along the banks of the Yukon, below Ruby, is a light-gray to light greenish-gray holocrystalline rock, in part porphyritic. The phenocrysts are sodic plagioclase of the same composition as that of the groundmass. The essential minerals of the rocks are oligoclase-albite and quartz, usually in granular habit but in places graphically intergrown, and a small amount of biotite. Apatite and iron oxides are also present as accessory minerals.

The soda granite at Camelback Mountain is a fine-grained light-gray holocrystalline rock, with an hypidiomorphic-granular fabric. It is composed of quartz, plagioclase, and biotite. Albite is the main plagioclase, but andesine is present in subordinate amounts.

The soda rhyolite that lies altogether in the drainage basin of Takotna River and its tributaries, with the exception of the mountain 9 miles south of Joaquin Mountain, is when fresh almost white in color, much of it showing tablets of biotite and hornblende standing out in strong contrast to the light-colored matrix. All the soda rhyolite is porphyritic, the phenocrysts being sodic plagioclase, usually quartz, and the black minerals above mentioned. The groundmass is aphanitic but when resolved under the microscope proved to be a panidiomorphic-granular or sugary aggregate of quartz, albite or oligoclase-albite, and biotite. The quartz and plagioclase are in places graphically intergrown. Much of the biotite is decomposed to chloritic material and sericite, but the other minerals are fresh and unaltered. Apatite and iron oxides are accessory.

AGE.

It is inferred from the geologic occurrence that all these acidic dikes of sodic nature are products of the Tertiary volcanism of this region. They appear to invade the basic intrusive rocks, but their relation to the monzonitic intrusives of this general period of volcanism is not definitely known. It is possible that they are similar to or identical with the aplitic type of intrusive, observed by Brooks,[78] which cuts the monzonitic rock at the head of Glen Gulch, in the Iditarod mining district. In any event, they are believed to be related to the same general period of volcanism that produced the quartz monzonite and the basic intrusives and extrusives and are therefore assigned to late Eocene or post-Eocene time.

REGIONAL STRUCTURE.

From the arrangement and distribution of the various rock units as shown on the accompanying geologic maps (Pls. III and IV) and

[78] Brooks, A. H., unpublished notes on the Iditarod district, 1915.

from structural data obtained in the field, it is possible to present certain structural generalizations. Thus, in the northern part of the region between Ruby and the South Fork of Sulatna River, it appears likely that the major structure is in a broad way that of an anticline trending about N. 30° E. and plunging southwestward. The structure in this area is, of course, very complex, and it is not meant to imply that anything resembling simple anticlinal structure is present. In general, however, the structure and distribution of the metamorphic rocks suggest this relation, for the more intensely altered rocks are found in the upper valley of Long Creek, in what appears to be the center of the fold, and the greenstone, limestone, and less altered sedimentary rocks occur to the northwest and southeast of this zone. Locally the structure has been modified by the intrusion of numerous bodies of igneous rocks, including granite and basic intrusives of greenstone habit.

Faulting of the thrust type has also occurred. The evidence in hand suggests that the thrusts have been from the west and northwest, rather than from the southeast, as in the Fairbanks quadrangle. The limestone near Ruby is overlain by older garnetiferous schist, the whole sequence of rocks dipping westward. It is probable that this is due to thrust faulting. Another possibility to be considered is that the entire group of rocks northwest of Poorman may be a block thrust over the younger rocks to the southeast.

Little information is available concerning the structure of the cherty rocks lying between Poorman and the South Fork of Sulatna River and extending southwestward almost to the Cripple Creek Mountains. They are known, however, to be closely folded, but evidently their structure is less complex than that of the undifferentiated matamorphic rocks. Their distribution is not understood. They may be a part of the general anticlinal fold above mentioned; they may represent a block of rocks younger than the metamorphic rocks, faulted downward; or they may be in their normal position, with the metamorphic rocks thrust over them from the northwest.

In the vicinity of Mount Hurst the metamorphic rocks and the chert series occur together, associated with a variety of other rocks. The repetition of the chert northwest and southeast of Mount Hurst suggests that here also an anticline may exist, but the distribution of the limestone and also of the other rocks of this area and their peculiar boundary lines suggest that faulting has also been an important structural factor. The intrusion of igneous rocks must also have had considerable influence in molding the structure of the rocks around Mount Hurst.

The structure of the Upper Cretaceous and Eocene rocks is much simpler than that of the older rocks, although its details are by no means thoroughly understood. It is believed that the Upper Cretaceous beds are thrown up into a series of open folds, whose major elongation is about northeast or possibly N. 55° E. This structural trend is at variance with that of the metamorphic rocks farther north. It is likely that the trend of the metamorphic rocks is a composite one, which was formed in several stages. The stresses that determined the present structure of the Upper Cretaceous rocks were probably the result of only one of several such dynamic adjustments that have affected the older rocks.

The andesitic and basaltic lavas of the Nowitna basin, though at some localities strongly tilted, appear to be little deformed. They doubtless flowed out upon an uneven land surface, and a certain small part of their lack of horizontality may be due to original slope. There is no doubt, however, that notable dynamic movements have taken place subsequent to their solidification.

The structure of the Upper Cretaceous and Eocene sedimentary rocks and the Tertiary lava flows has been modified locally by the intrusion of later igneous rocks. The invasion by large intrusive masses, such as those forming the Cripple Creek Mountains, the Beaver Mountains, and the Cloudy Mountain-Twin Mountain massif, could not have failed to modify the general structure. The doming influence, which would be expected, is evident in the Eocene rocks south of the Cripple Creek Mountains and is probably prevalent elsewhere. An anomaly, however, is seen in the apparent dip of the lava sheets on Roberts Creek, toward the intrusive mass of Cloudy Mountain. This abnormal dip may be due to later intrusion on the west side, in the vicinity of Twin Mountain.

A striking feature of the topography is the remarkable conformity of the stream courses with the regional trend of the rocks. In the northern part of the region the courses of Yuko and Sulatna rivers and some of the smaller streams reflect the structural trend of the metamorphic rocks—that is, about N. 30° E. North of the Yukon the Melozitna shows the same course. To the south, however, in the Upper Cretaceous and Eocene sequence, the stream courses veer around to a direction nearly due northeast. The Susulatna and Nowitna as far down as Big Mud River follow this course, and the upper Nowitna flows parallel with the Susulatna. The most striking example of all is the continuity of a structural line marked by the valleys of Nixon Fork of the Kuskokwim, lower Takotna River, Fourth of July Creek, upper Moore Creek, Bonanza Creek, and upper Iditarod River. This structural line, with a direction of N. 50° E., extends 140 miles diagonally across the Innoko-Iditarod region and continues both to the northeast and southwest. Other streams in this area follow the same general trend.

These marked topographic trends are with little question closely related to the regional structure, but insufficient details of the stratigraphy are known to deduce their structural significance. It is probable that they represent fault zones along which adjustment of stresses took place during the regional elevation at the end of Eocene time. They may therefore be considered contemporaneous with the later stages of the uplift of the Alaska Range.

GEOLOGIC HISTORY.

The geologic history of the Ruby-Kuskokwim region is long and intricate. It dates back possibly to pre-Cambrian time, but unfortunately much of the early geologic history is obscure, and the geologic record of many of the recent events is lacking. There is, however, a partial record which is of considerable interest.

The record of the earliest geologic events, from pre-Cambrian time to the beginning of the Mesozoic, is concerned with the region around Ruby, Long, and Poorman. The earliest known rocks, those of the undifferentiated metamorphic complex, show only in a very general way what took place at the time of their formation. They are now so thoroughly recrystallized that the history of sedimentation, diastrophism, and volcanism alike is in large part obliterated. Additional obscurity is added to the record by the almost universal covering of Quaternary sediments, soil, and vegetation. The character of the recrystallized rocks, however, shows that at the time of their formation the geologic processes of the present day were active. Thus the quartzite, slate, phyllite, and limestone and in part the schist and chert indicate that sedimentation was the dominant process in pre-Paleozoic and early Paleozoic time. The crystalline limestone correlated tentatively with the Ordovician affords an additional link in the early geologic record. Much remains to be learned, however, of the origin of limestone, so that the mere presence of such rock does not warrant any inference as to the climate at the time of deposition, nor as to the conditions attendant on its deposition. Volcanism, too, was a factor in the early geologic history of the region, for some of the recrystallized rocks appear to have had an igneous origin. Diastrophism, however, which has taken place at many different periods, both early and late in geologic time, has destroyed the stratigraphic relations between the igneous and the sedimentary rocks as well as between the various members of the sedimentary rocks of the metamorphic complex.

Considerable sedimentation is known to have taken place in Devonian time. In the Ruby district the sediments then laid down are represented by an infolded area of rocks on the divide between the heads of Beaver and Long creeks. Other Devonian rocks are probably present in this area, but only fossil evidence is adequate to differentiate them. To the east, in the Cosna-Nowitna region, according to Eakin,[79] and along Kuskokwim River, Devonian rocks are likewise exposed, less metamorphosed than in the Ruby district but evidently belonging to the same series. From these facts it is inferred that the body of water in which these Devonian rocks were laid down extended over a considerable area. The fact that these rocks have suffered different degrees of metamorphism shows that in one or more of the later periods the regional diastrophism was more intense at certain localities, as in the Ruby district, than at others, as in the Cosna-Nowitna region. The fossils so far found in the Devonian rocks at Ruby and on the Kuskokwim are mainly corals, indicating that tropical or subtropical conditions prevailed during the time of deposition of these rocks.

The late Paleozoic history of the Ruby district is obscure, because no sedimentary rocks later than Devonian and earlier than Mesozoic have been recognized. The district contains a variety of igneous rocks of this age, however, both extrusive and intrusive. The greenstone tuffs described on page 56 show that terrestrial conditions were prevalent during at least part of this general period, but beyond this little may be said. The intrusive rocks grouped collectively under the term greenstone consist of gabbro, diabase, basalt, quartz diorite, and andesite, and probably include still other varieties. These different intrusives point to a prolonged period of volcanism in this region during late Paleozoic time. This volcanism was probably accompanied or followed by a widespread regional uplift and the reestablishment of terrestrial conditions over a large area.

The absence of any of the earliest Mesozoic rocks in this region, as contrasted with the complete sequence exhibited in the Cook Inlet country and in the Copper River valley, suggests strongly that such rocks never existed here. There must somewhere have been a large land mass to supply the material for the earliest Mesozoic sediments to the southeast, and it is probable that the Ruby-Kuskokwim region was a part of that land mass. Erosion could indeed have completely obliterated the Triassic rocks, if they were ever present, but in that case their removal must have been completed before the deposition of the chert-argillite series, because those rocks, if of Jurassic or Lower Cretaceous age, must have overlain and protected them, at least in part.

The development of the chert-argillite series in the Ruby district and around Mount Hurst suggests, however, that the ocean may have transgressed inland to the Ruby-Kuskokwim region in the later part of Mesozoic time. This conclusion, however, is justified only if the

[79] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull 667, pp. 25–27, 1918.

ammonite found at one locality belongs with these rocks. The extent of the marine invasion and the climatic and other conditions that attended it are unknown.

Rhyolitic lava flows appear to be interbedded with the upper part of the chert-argillite series, and it has therefore been assumed that the retreat of the sea and the introduction of terrestrial conditions brought about another period of elevation, which was accompanied by the outpouring of rhyolitic lava at certain localities.

The potash granite that intrudes the metamorphic rocks in the Ruby district is considered, on account of its unaltered condition, to represent a period of post-Paleozoic igneous activity. It is also believed that the intrusion of this granite occurred in pre-Tertiary time, because no similar intrusives are known to invade the Upper Cretaceous rocks. It is probable, therefore, that the potash granite was injected into the older rocks during some period in the early Mesozoic, but its age can not be exactly determined.

As the exact age of the chert-argillite series is not definitely known, the history of the region between the extravasation of the rhyolitic flows and the beginning of Upper Cretaceous time is unknown. Terrestrial conditions may have been continuous, or further sedimentation may have taken place, with the subsequent removal of the sediments thus formed prior to Upper Cretaceous time.

At the beginning of the Upper Cretaceous epoch there was a widespread subsidence of the land in this region, accompanied by a general invasion of the sea. This Upper Cretaceous sea must have covered all of the Ruby-Kuskokwim region and probably much of the surrounding country. In this region the distribution of the rocks indicates that the sea transgressed inland from the southwest against the metamorphic rocks. It is possible, however, that the metamorphic complex of rocks around Ruby may have been a highland area, against which the sea transgressed on all sides; if so, the general direction of the transgression may have been somewhat different.

The general character of the Cretaceous sediments indicates nearshore conditions universally in this region. This shows either that the Upper Cretaceous sea never attained any great depth here, or that the overlying sediments, formed in deeper water, have been removed by subsequent erosion. The numerous intrusions of Tertiary igneous rocks have so disturbed the original bedding of the sediments, however, that it is probable that some of the deep-water shales, such as those found by Smith[80] south of the Kuskokwim, would have been folded in and preserved, if such sediments had ever been deposited in this region.

[80] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, pp. 64-66, 1917.

The physical conditions accompanying the termination of the Upper Cretaceous epoch are not clear, for, as previously pointed out, the upper limit of the Upper Cretaceous beds is not recognized with assurance. If no unconformity exists between the Upper Cretaceous and Eocene beds, the transition between the two epochs may have been continuous and gradual, accompanied perhaps by a regional elevation which eventually led to the establishment of dominantly terrestrial conditions. If, however, a stratigraphic break can be shown to exist between the Upper Cretaceous and Eocene beds, the Eocene conglomeratic beds must be interpreted as the result of a renewal of marine or estuarine sedimentation following a period of regional uplift and erosion at the end of the Upper Cretaceous. The former of these two hypotheses is believed the more probable.

The beginning of Eocene time is represented by the conglomeratic sediments at the heads of Susulatna River and Folger Creek. The upper limit of these sediments has not been recognized, although a thickness of perhaps 1,000 feet is present. At some time after this Eocene sedimentation a period of great igneous intrusion and extrusion began. It is likely that the Eocene was dominantly an epoch of elevation, during which a progressive change took place in this region from marine to terrestrial conditions. The volcanism is believed to have been concomitant with the culmination of this regional elevation. In other words, the igneous activity is interpreted as a result and not as a cause of the regional elevation. The Tertiary volcanism is therefore believed to have taken place in late Eocene or post-Eocene time.

Whether terrestrial conditions were prevalent throughout this region during the greater part of Tertiary time and continued on into the Quaternary, or whether there was marine sedimentation during this period, is unknown. The two small deposits of conglomeratic material assigned to the Tertiary give little information as to their mode of formation or their original extent. If extensive deposits of either marine or terrestrial origin were formed, they were removed during the later part of the Tertiary. Mountain-building movements, accompanied by faulting, took place at some time after the extrusion of the lava flows, resulting in the remarkable parallel arrangement of some of the larger streams, but a period of stable equilibrium toward the end of Tertiary time had resulted in a generally mature topography.

It appears likely that at the beginning of Quaternary time drainage lines had been developed for the most part along present stream courses, although it is not certain that all the present drainage features were then established. Thus, the Yukon at Ruby now flows in a channel which is not in accord with the width of its valley above and below, or indeed with its size, and its waters formerly found outlet to the Pacific by a different course. The base level of erosion was relatively much lower or the land surface stood at a much greater relative altitude than at present. This is made evident by the great depth of the silt and gravel in some of the creeks tributary to the Sulatna, as well as in some of those in the Innoko drainage basin.

There have been several changes of level during Quaternary time. The earliest of these was the general depression of the land surface of the Yukon Valley. Points that now stand as much as 1,200 feet above sea level in the northern part of the region were inundated. The amount of depression in the vicinity of Iditarod is not so clearly evident as farther north, but apparently was but little less. As the land surface at the beginning of the depression was at least 200 feet higher than at present, the total amount of depression was not less than 1,400 feet in some portions of the area. Inundation proceeded by stages, and terraces were carved in bedrock at each successive stage. One of the pronounced pauses was at what is now about 600 feet above sea level and resulted in a fairly defined terrace, upon which beach placers were formed where conditions were favorable. It appears likely that some of the placer ground of Long Creek is of beach origin, as well as some of the bench placers of Poorman and possibly of other creeks, the so-called "spotted" and disconnected character of the pay streak being readily accounted for if beach concentration is postulated. It is noteworthy that a similar pause in inundation at about the same altitude, marked by a corresponding terrace, has been proved in the Tolovana district,[81] which lies within the same basin.

The products of residual decomposition furnished a large proportion of the material that was reworked and deposited as gravel, sand, and fine silt within this basin, but it is also probable that a considerable amount of these sediments is the result of glacial activity not only in the high mountain areas of the Ruby-Kuskokwim region but also in other regions adjacent to the Tanana drainage basin. Glaciers on the north slope of the Alaska Range were formerly of considerable extent[82] and furnished enormous amounts of fine rock débris, which was deposited when it reached the interior sea occupying the Tanana basin.

The period of inundation and that of glaciation are tentatively held to have been synchronous, at least in part, for both occurred during the Pleistocene, both of necessity extended over a considerable time, a long interval elapsed between the maximum and present stages of glaciation, as well as between the maximum inundation

[81] Mertie, J. B., jr., The gold placers of the Tolovana district: U. S. Geol. Survey Bull. 662, pp. 252–256, 1918.

[82] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 59–65. 1919.

and the reelevation of the land surface to its present level, and for both an equally long interval has elapsed since the present stage was reached.

From the distribution of the silt remnants that are found along the east side of the region the basin must have been nearly filled with sediments. Upon reelevation of the land surface the unburied headward portions of the streams gave direction to their rejuvenated lower reaches, which, as elevation proceeded, for the most part quickly intrenched themselves in the incoherent material that filled the old valleys, finding this easier than seeking new channels in the bedrock of the old interstream areas. One prominent exception is to be mentioned. With the recession of these inland waters a new outlet to the ocean had to be found, as those channels that had formerly served this purpose were now so deeply filled with lacustrine sediments that other places on the rim of the drainage basin were lower. As a result the Yukon—probably a composite stream wholly different from any pre-inundation river—flowed over the rim of the basin at Ruby and thence flowed into what was probably a tributary of the Koyukuk. The diversion of the Kuskokwim through the low mountains at Georgetown may have been due to similar causes, but if so definite proof is lacking. Another example of a filled-in channel appears to be afforded by the course of Nowitna River from the mouth of the Sulukna to the mouth of Lost River, as the former course was through the low divide that separates Lost and Nowitna rivers, whereas the present course follows that of former tributaries of Nowitna and Big Mud rivers, as well as the former course of the Big Mud to the mouth of Lost River. A canyon-like valley from Mastodon Creek to Big Mud River and a somewhat wider valley, comparable in size to that of the Big Mud, to Lost River make such an interpretation appear logical.

The principal feature of late Quaternary history is the readjustment of streams to grades established upon the reelevation of the land surface, with the accompanying removal of silt and other unconsolidated material. Involved with the stream adjustment has been the accumulation of placer gold through the normal processes of concentration by erosion in a gold-bearing terrain, as well as through the reworking of stream and beach placers of early Quaternary and possibly of Tertiary age.

MINERAL RESOURCES.

GENERAL FEATURES.

Placer gold is the only mineral deposit in the Ruby-Kuskokwim region that has been exploited on a commercial scale. There are several general areas where placer mining is now being carried on. These areas are considered and discussed separately below.

Where so much placer gold is found it is reasonable to expect the development of gold-lode mining sometime in the future. As yet, however, little lode mining has been done in this region. Eakin [83] reports the development of a gold lode in a small way in the Innoko district. At the head of Flat Creek, in the Iditarod district, there are numerous small quartz stringers that look promising as potential gold lodes. On the hills north of Moore Creek vein quartz carrying gold was picked up by the senior writer. It is probable, however, that the placer-gold areas in this region will be more or less depleted before lode mining begins, for in much of the region rock exposures are not plentiful, and prospecting for gold lodes means much development work.

The gold lodes in the vicinity of Nixon Fork have been described by Martin.[84]

Development work was carried on during 1920 on the prospect known as McDonald's mine, in the Russian Mission Mountains.

In the summer of 1915 considerable stibnite (the sulphide of antimony) was shipped from the Fairbanks district, showing the possibility of the exploitation of antimony deposits in Alaska in case of exceptional demand for that metal. Stibnite ore has been uncovered at several localities in the Innoko and Iditarod districts. Such deposits may be exploited at some later date.

Cinnabar (the sulphide of mercury) is found in the concentrates on a number of creeks in the region. The economic importance of cinnabar as a mineral product for export from this region is questionable, but probably in time it will be used as a local source of mercury for use on the copper plates that are utilized in catching the fine gold. The cinnabar in the concentrates at Candle Creek has been treated in retorts and used for this purpose. The abundance of cinnabar in the concentrates at certain localities lends encouragement to the belief that future prospecting may uncover cinnabar lodes of economic importance.

Cassiterite (the oxide of tin) occurs on several creeks in the Ruby and Tolstoi districts, in the concentrates from the gold-bearing gravel. The amount is too small, however, for this region to be considered as a possible important source of tin.

Scheelite (the tungstate of calcium) occurs in the concentrates taken from Otter Creek, in the Iditarod district. It is therefore present in the basin of that creek, and probably the bedrock source will sometime be discovered. The possible value of such a discovery depends on the character and extent of the deposit. Scheelite

[83] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pp. 28–29, 1912.

[84] Martin, G. C., Gold lodes in the upper Kuskokwim region: U. S. Geol. Survey Bull. 722, pp. 149–161, 1921.

deposits in the Fairbanks district were mined for their content of tungsten during the war.

Coal has been found in several places in the Ruby and Innoko-Iditarod districts. In the Ruby district it has been found on Poorman Creek and has been reported from Quartz Creek. There is also some evidence of coal on one of the tributaries of Basin Creek, and Maddren[85] states that coal is reported from Homestake Creek, a tributary of the upper Nowitna.

In the Iditarod district two seams are known to exist at the crest of the ridge between Flat and Iditarod. These seams have not been prospected to a depth sufficient to learn the true character of the coal; but if there is any place in the Ruby-Kuskokwim region where native coal would prove valuable it is in this locality, where wood is so scarce and costly.

ECONOMIC CONDITIONS.

SUPPLIES.

Ruby is the distributing point of supplies for Long, Poorman, and the creeks in the neighborhood. Goods were formerly landed at Ruby by way of St. Michael, although some supplies were brought down the river by the first boats from Whitehorse. Nenana, where the Government railroad reaches the Tanana, has now become the important supply point for Ruby. A wagon road permits easy haulage from Ruby to Long. Poorman may be reached by the ridge trail during summer or by small power boats up the Sulatna. Winter haulage from Long and Ruby is used when possible.

Candle Creek receives its supplies from McGrath in winter at a lower rate than in summer, when supplies are brought down the Kuskokwim from McGrath, landed at a point about 4 miles from the creek, and brought over the hill by a pack train. The freight rate from Seattle to McGrath is probably not greatly different from that to Ruby.

Ophir, the central point for the Innoko district, obtains supplies both by way of the Yukon and by the Kuskokwim route. With the establishment of reliable service to Bethel from Seattle and from Bethel up the Kuskokwim the latter route in time will probably come to be the more used, because of the relative cheapness of supplies at Takotna, as compared with the cost of boating up Innoko River from Holy Cross.

Iditarod is the supply point for Discovery and Flat and the surrounding creeks. Supplies are taken to Moore Creek on the main Seward trail in winter from Iditarod. During the summer supplies are sent by way of Discovery on pack animals. Most of the supplies for this creek are hauled in winter.

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

TRANSPORTATION AND COMMUNICATION.

River steamboats formerly plied on Yukon River from Whitehorse to St. Michael, but with the completion of the Alaska Railroad the service of the American Yukon Navigation Co. from Tanana to St. Michael was discontinued. Service by boats of this company has also been discontinued on Innoko and Koyukuk rivers. The Alaska Railroad, however, now operates two river steamboats which ply on a weekly schedule between Nenana and Holy Cross, and supplies are transported up the rivers tributary to the Yukon and downstream from Holy Cross by independent small river boats and launches. On the Kuskokwim one river boat made two round trips from Bethel to McGrath during the summer of 1919 and an additional trip up river in the fall. This is more or less typical of the Kuskokwim service. From McGrath freight is carried by gasoline launches up Takotna River to Takotna. The Innoko is navigated by small river steamboats or gasoline power boats up to the mouth of the North Fork, whence supplies are brought up to Ophir by horse scows and poling boats. Small launches go on up the Iditarod as far as the mouth of Otter Creek.

A wagon road and a winter trail connect Ruby with Long and Poorman. Small launches, however, navigate Sulatna River up to the mouth of Tamarack Creek, at which the wagon road crosses. Most of the supplies intended for summer delivery at Poorman are therefore brought up to this point by boat and freighted the rest of the way.

In the Innoko district there is a wagon road between Ophir and Ganes Creek, and summer and winter trails connect Ophir with the other creeks near by and with Takotna. A wagon road from Takotna to Ophir was being built in the summer of 1920. A tramroad equipped with wooden rails and with an automobile rebuilt on a truck serves as a passenger railway between Iditarod and Flat. In addition, wagon roads connect Iditarod with Flat and Discovery. The wagon road to Flat continues on up to the head of Flat Creek, serving the mining properties on the creek and at the summit. The Government winter trail between Iditarod and Seward passes through Moore Creek and through Takotna and McGrath. Moore Creek also has communication with Discovery over a summer trail.

TIMBER AND FORAGE.

Timber grows in the valleys and on the upland slopes over much of this region. Nowhere is the growth very thick, nor are the trees very large, but the supply is sufficient for the local demand. Along the valley floors or where the ground thaws in summer trees as much as 24 inches in diameter may be seen, which are available for lumber and mining purposes. The smaller trees serve a useful purpose as fuel. On the poorly drained flat ridges and gentle slopes the growth is usually poor.

Spruce is the most common variety and occurs from the valley bottoms clear to the upper limit of timber. With it are associated birch, tamarack, and cottonwood. Along the creek banks and near timber line, especially along small drains, alder and willow brush grows very thickly.

The upper limit of timber is a variable line in the country between Ruby and Iditarod, owing to the fact that this area is a transition zone between the wooded portion of the interior and the treeless tundra of southwestern Alaska. In the vicinity of Ruby and Long timber seldom grows above an altitude of 1,800 feet, and the country around Iditarod and Flat has little timber above the 1,500-foot line. Untimbered spurs extending well down into the valleys are common everywhere, yet in some especially favored gulches timber reaches to an altitude above 2,000 feet. In general, timber becomes scarcer toward the southwest, as indicated by the figures given above. (See Fig. 2.)

Forage for stock is plentiful along the valley floors of some of the larger streams, such as the Sulatna, the Nowitna, and the Takotna, but on the upland slopes grass is scarce. Where the country has been burned over and the moss destroyed, however, good grass may usually be found.

GAME AND FISH.

Game is by no means plentiful, especially near the settlements. In the mountain areas, back from the mining camps, caribou may be seen occasionally, but nothing comparable to the immense herds of the Yukon-Tanana region is known in this region. Bears are present but can not be said to be numerous. Occasionally a porcupine is encountered. Moose are seldom seen.

Small game, such as rabbits, ptarmigan, and grouse, appear to vary in abundance from year to year. During the summer of 1915 very little small game was in the country, but earlier travelers record an abundance of small game, and since that date these animals appear to have increased in number.

Salmon, whitefish, pike, and other large fish are taken in Yukon and Kuskokwim rivers. In the uplands between these rivers grayling are caught in many streams, and in the mountain areas trout inhabit the creeks.

Some furs are obtained in the region, but trapping for furs appears to be a much less important industry here than in other sections of Alaska.

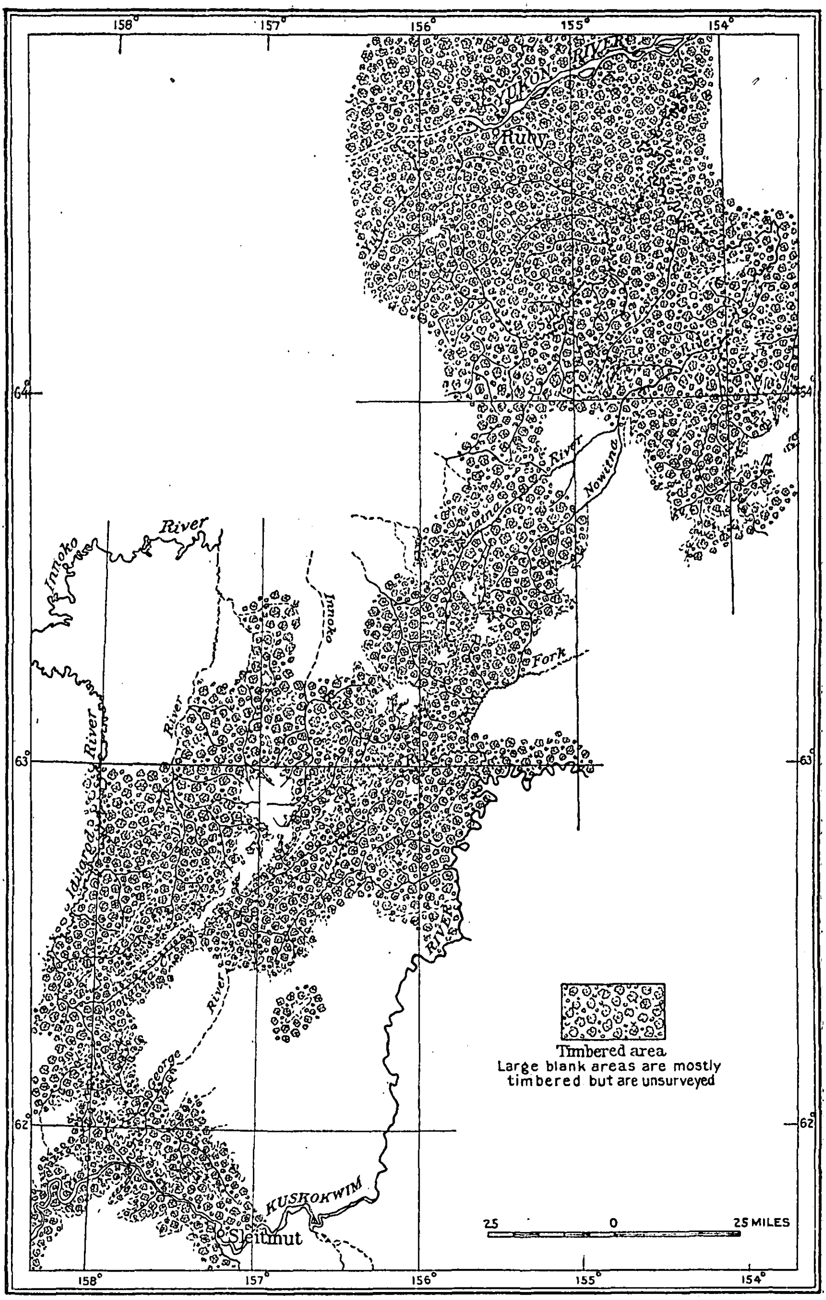


FIGURE 2.—Map showing distribution of timber in the Ruby-Kuskokwim region.

OTHER MINING FACTORS.

The general wage paid for labor in this region is $5 or $6 a day and board, but men performing work that requires experience or special knowledge, such as winchmen and engineers, have received $9 or more.

Until 1915 wood was the only fuel used except for dredges and some of the other large power plants. At Long and Poorman wood is fairly plentiful. In the Iditarod district the supply is smaller and the cost higher. Much of the neighboring country has been deforested to supply the demand. In 1917 it was necessary to bring wood from the head of the Dishna. Another possible source of supply is the Iditarod River valley above Otter Creek. It is possible that some small coal seams between Flat and Iditarod may be developed and prove useful as fuel; this appears doubtful, however, for even with the scarcity of fuel no development had been attempted as late as 1920.

The obtaining of a supply of water for use in mining is a serious problem at some localities, especially where the producing ground lies in the upper basin of a creek. This problem is particularly acute at the properties that surround the granitic mass at the head of Flat Creek. There many ditches have been dug along the upper slopes to catch the surface water, and this supply is augmented by the construction of snow fences, which cause the snow to pile up in huge drifts in the winter and to last late in the summer. At Candle Creek, where the workings are also close to the head of the creek, a bedrock basin has been excavated to collect the surface and underground water. Along creeks where many operators are at work, as at Long, the water supply is sometimes insufficient, especially during a dry spell. Where the pay streak is several miles down the creek, however, and too many are not tapping the supply, the water is usually sufficient, because the heavy carpet of moss over the country acts as a sponge, preventing the rapid run-off of surface water after hard rains.

GOLD PLACERS.

RUBY DISTRICT.

HISTORY OF MINING.

The history of mining in the Ruby district to 1913 has been given by Eakin.[86] The present population of the district is probably below the figure he sets. He states:

> The first discovery of gold in the Ruby district was probably that made on Ruby Creek near the site of the present town in 1907. The value of the pro-

[86] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pp. 43, 44, 45, 1914.

duction from this locality is uncertain, estimates ranging from a few hundred to two thousand dollars. The deposit first discovered proved to be of no great value, and it was not until 1910, when the discoveries on Long Creek and its tributaries were made, that a widespread interest was aroused in the region and led to the development of the present mining district and the settlement of the town of Ruby. The discovery was made by Fernander and Johnson near the mouth of Bear Pup, a tributary of Long Creek, late in July, 1910. A large influx of people occurred during the following summer, and valuable deposits were located on several other creeks in the neighborhood. A substantial town was built in a single summer on the banks of the Yukon at the mouth of Ruby Creek and was called Ruby. Since then the population of the district has remained over a thousand. The business of the town has assumed good proportions, stores and hotels have been built, sawmills installed, a telephone line put into service between the town and the creeks, and telegraphic connection has been made with the Government line on the opposite side of the river.

Active mining began during the winter of 1910–11, but the work was handicapped by the lack of suitable machinery. A great deal of machinery was delivered at Ruby during the summer of 1911 and was hauled to the creeks and installed during the following winter. The summer of 1912 therefore witnessed the first operations under fairly favorable circumstances.

In the Ruby district mining was in progress in 1912 on six creeks, all located in a small area about 25 miles south of Ruby. Four of these creeks belong to the Long Creek system, namely, Long Creek, Upper Long Creek, Bear Pup, and Midnight Creek. The other two creeks are Glen Gulch, a tributary of Flint Creek heading against Bear Pup, and Trail Creek, which is the next creek east of Flint. * * *

In 1913 the mining industry on the whole showed considerable advance over the condition of the preceding year. The six streams that produced in 1912 were worked again in 1913, most of them on a largely increased scale of operation. The changes were brought about mainly by the installation of heavy steam machinery in place of the light hoists and hand windlasses used before. New placers, some of them very promising, were discovered on eight new creeks. Prospecting was being done on still other creeks, and the results obtained in places suggest the likelihood of a further increase in the number of producing creeks.

Of these new placers Poorman and Tamarack creeks have since proved to have valuable gold deposits.

The principal feature in 1914 was the development of workable placers on Swift, Birch, Tamarack, Poorman, and Flat (tributary of Timber) creeks, upon which some prospecting had been done in 1913 or earlier. Work on the wagon road had been carried about 7 miles from Ruby, beyond which wagons followed numerous trails to Long, and occasionally a wagon was able to follow the ridge to Sulatna Bluff, where Sulatna River was crossed on the poor wagon trail to Poorman. A poor wagon trail also existed between Flat and Poorman. During the winters of 1913–14 and 1914–15 churn drills were used to advantage in prospecting, both in the search for new deposits and in the development of those already known.

By 1915 a number of creeks were practically worked out; Bear Pup was one of these, and Glen Gulch another. The chief new producing creek was Spruce, but the workable area was also extended on Tamarack, Poorman, and Flat creeks.

The material for the dredge of the Yukon Gold Co. was assembled at Ruby during the summer and taken to Greenstone Creek during the winter of 1915–16 and erected that winter and the following spring. This dredge was in operation during 1916. Work on the road progressed as far as the Hub road house during the summer of 1916. The principal feature of the year in the vicinity of the Sulatna was the continued active mining on Spruce Creek, and the finding of gold on right-limit bench claims of the second or third tier from the creek at Poorman.

On Midnight Creek a small production of cassiterite was made—the first from this district.

In 1918 there was a sharp decline in the production from the Ruby district, the decline having been postponed through the operation of the dredge in 1916 and 1917. The dredge was idle in 1918. A still further decadence in mining is to be noted for the following years. The dredge machinery was dismantled and removed during the winter of 1920–21.

GENERAL CHARACTER OF PLACERS.

The placers of the Ruby district are in general of uniform character. Most of them are deeply covered, irregularly distributed discontinuous bodies lying in the bottoms of the broad silt-buried valleys, and though numerous producing placers are on so-called bench claims, they are generally little if any higher than the bedrock bottoms of the filled valleys in which they lie. Colors of gold may be found in the bottom of almost any valley throughout the slate and schist area, but the gold is not concentrated sufficiently to make its recovery commercially practicable, and it is only where there has been considerable primary concentration or a local reconcentration that the deposits are being worked. On none of the creeks throughout the district is there an extensive continuous pay streak. An increase in richness may be noted at the mouths of some small lateral draws, even of those whose basins are very small, and this result might be obtained by concentration of the placer gold from the breaking down of gold-bearing quartz ledges within the drainage basins of these small tributaries or by reconcentration of placer gold from high benches, which of themselves may not contain sufficient gold to be workable economically.

RUBY CREEK.

The gold deposits on Ruby Creek are of greater interest historically than economically, as it was on this creek that the first mining was done in the Ruby district. The creek is less than 2 miles in length, and the placer ground lies near its mouth on a small bench on the east bank. The gravel and overlying muck average a little more than 12 feet in thickness. At the bottom is a layer of finer wash filling the interstitial spaces in a blocky limestone bedrock, overlain by and interbedded with other thin layers of gravel. Above this is the muck, which contains larger, well-rounded boulders of intermediate igneous rocks, together with cobbles of vein quartz. The fine gold is associated with the sediments in and on bedrock. The total production from Ruby Creek is probably little over $5,000. During the summers of 1915 and succeeding years work was done intermittently on the creek, but the smallness of the catchment basin makes it possible to work only while the seepage from rains affords water for sluicing.

LONG CREEK AND TRIBUTARIES.

Regarding the deposits in the Long Creek basin Eakin[87] says:

> The valleys of Long Creek and its tributaries contain remnants of older alluvial deposits that stand considerably above the present flood plains of the streams. The bedrock floors of the valley are practically level in cross section, so that the depth to bedrock often increases away from the streams toward the valley wall. There is also a general increase in depth to bedrock downstream.

Above Long all the mining has been done on the left side of the stream at distances of 100 to 600 feet from it. Just above the mouth of Bear Pup the ground is only 20 to 30 feet deep, but farther up it ranges from 30 to 50 feet, of which the bottom 6 to 8 feet is gravel. In some places the pay streak is on bedrock; in others it is above a false clayey bedrock, which may be 2 or 3 feet above the true bedrock. The muck contains numerous fragments of unworn, brecciated vein quartz. Over half the gold on claim "No. 3 above" was in nuggets, and although many of these show some rounding, a very considerable number have a spongy appearance, and their edges are but slightly rounded, indicating that the gold has traveled only a short distance from its bedrock source.

Gold has been mined on lower Long Creek from Long to a point below Snow Gulch, and most of the workings are farther from the stream than those above Bear Pup. It is about 75 feet to bedrock on the Mascot bench at Long, but this depth is due to the distance from the creek up the hill slope along the flatter slope of the asymmetric valley. The workings are at about the creek level. Farther downstream the gravels are covered by less overburden. At the lower end of the Novikaket Association's ground, a mile below Fifth of July Creek, the depth to bedrock ranges from 20 to 40

[87] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pp. 40–41, 1914.

feet, depending on the distance from the main stream. A little below Snow Gulch Long Creek flows over a bedrock riffle, and from this point downstream the bedrock slope is greater than the present stream gradient. Eakin[88] estimates that the depth to bedrock increases at least 10 feet to the mile below the last workings on Long Creek.

The section varies somewhat in the different localities. The uppermost 15 to 30 feet consists of muck; below this is 5 to 30 feet of mixed gravel and muck, commonly termed "slide," in places represented by a layer of rather fine gravel called "chicken feed"; and below this is the auriferous gravel, or "sediment," which may be 8 feet thick. The nature of the pay streak varies greatly. In some places it lies within the top 1 or 2 feet of bedrock or in gravel on the bedrock; in others it is above a false bedrock or clay seam which lies 2 or 3 feet above true bedrock and below which there is usually no gold.

The gold is almost everywhere associated so closely with a gravel containing rather large pebbles embedded in a clayey matrix that it is necessary to break up the material before it passes through the sluice boxes, for it would not only pass out without releasing its gold but would perhaps pick up gold from the boxes as it rolled through them. To avoid this result the gravel is washed into the dump box by a jet of water from a nozzle, the pressure for which is obtained by pumping; thus the clay lumps are disintegrated before reaching the sluice boxes.

In general the gravel is frozen, and little timbering is necessary. On the Mascot bench, however, thawed ground was found, and it was necessary to advance the drifts by forepoling, thus increasing the cost of mining very appreciably. Under average conditions ground that carried from 85 cents to $1.25 to the square foot of bedrock could be profitably worked in 1915 by underground methods. There is much ground which just affords wages, but one place is said to have averaged more than $15 a square foot of bedrock surface over a considerable area, and most of the operations have been conducted on ground averaging $1.50 to $3 to the square foot of bedrock.

As early as 1915 it was found that the first passage of the gravel through the sluice boxes did not recover all the gold, so that the tailings on the Mascot bench were reworked, cable-drawn scrapers being used. Some $25 nuggets were obtained, and it seems noteworthy that nuggets so large should have gone through the sluice boxes. An explanation may be afforded by the possibility that they had been transported in clay-cemented lumps of gravel. Another explanation may be sought in the fact that the water used for the

[88] Op. cit., p. 41.

first sluicing was impounded, pumped back into the sluice boxes, and used over and over again. The fineness of the suspended silt and the small area of the settling pond prevented anything near complete clarification; consequently the water for sluicing was exceptionally dirty. The amount of silt present increased the viscosity and specific gravity of the liquid and decreased the relative weight of the gold, so that it was more easily carried or rolled. The following principles, discussed by Gilbert,[89] may serve to explain why the coarse particles of gold should be more easily transported in a silt-laden stream:

> The law found for stream traction is that the load of the initially transported grade is increased by the moderate addition of other débris, provided the added débris is relatively fine. * * * In stream traction the pathway for larger particles is smoothed by the presence of smaller particles, and rolling is promoted.

The gravels of Bear Pup were so shallow as to permit mining by open-cut methods. The section consists of 6 to 8 feet of gravel, overlain by about 15 feet of muck. The muck was sluiced or scraped off, and the gravel was hoisted in order to get height for the line of sluice boxes. The stream has been practically worked out in the channel for over 1½ miles above its mouth.

Some of the stream gravel was fairly rich, and several nuggets worth $50 or more were found. This gold shows some wear but is far from being completely rounded. The largest nugget discovered in the Ruby district, so far as known to the writers, valued at $1,900, was found on the Mascot bench at the mouth of Bear Pup. A $200 nugget is reported from the bench claim below, and the gold apparently gets finer down Long Creek, that from the claim below the Novikaket group being very fine. It is said to assay from $17 to $17.65 an ounce. No consistent difference is to be noted in the value of the gold from the upper and lower workings.

At 3 miles below Long, in a small depression between Snow Gulch and Fifth of July Creek, about a third of a mile from Long Creek, a working shaft 75 feet deep passes through 40 feet of muck and 35 feet of mixed gravel and slide rock. Most of the gold lies close to the white clay bedrock, but some of it is scattered through 4 feet of the clay. It is very irregularly distributed. The gold is fine, and the nuggets are few and small, the largest being worth about $5.

Short Creek valley is less deeply filled with alluvium than the valleys farther up the main stream. The covering of muck amounts to but 6 or 8 feet and lies above 4 to 6 feet of well-worn gravel and sand containing numerous iron-stained boulders of quartz and cobbles of greenstone. These deposits were worked by open-cut methods

[89] Gilbert, G. K., The transportation of débris by running water: U. S. Geol. Survey Prof. Paper 86, p. 213, 1914.

about half a mile above the winter trail and are said to contain a little gold for half a mile farther up the creek. The gold content is low but generally runs in a somewhat irregular and poorly defined channel. The so-called pay streak usually lies within a foot of bedrock. The frequent lack of water in Flat Creek, from which water for sluicing was obtained, proved a serious hindrance to mining on this creek. Besides the gold, some cassiterite was obtained in the concentrates from the boxes. It was rather finer grained than that found on other creeks in the district. No attempt has been made to save it.

The gravel on Midnight Creek was worked by underground methods. The only property worked in 1915 lies about a mile above the winter trail to Sulatna River. Operations were carried on at a relatively shallow depth, the muck being only about 14 feet thick, and the 4 feet of gravel immediately beneath was being mined. Apparently the mining was done on a false bedrock or clay-cemented band, as true bedrock was not seen, nor was angular blocky gravel found on the dump, which contained many large boulders of quartz and greenstone. The depth to bedrock increases considerably downstream, as a hole sunk near the winter trail is said to have been 80 feet deep. If the depth at the locality where mining was being done is 20 feet a continuation of this grade would give a depth of over 125 feet to bedrock at the mouth of the creek. The gold found has all been very fine, with a few 25-cent nuggets. Associated with the gold is a considerable amount of cassiterite, which it might prove advantageous to save, although the annual production from gold placer operations would amount to only a few hundred pounds.

Greenstone Creek is like Midnight Creek in many respects, and its valley includes extensive deposits of auriferous gravel, though their tenor is said to be low. They also contain a small amount of cassiterite. The placer ground is said to be over 100 feet wide in the bottom of the valley, which is considerably wider, and to extend for over 2 miles along the valley. After considerable preparation, this creek was mined by a dredge with favorable results.

Last Chance, Basin, and Ptarmigan creeks are tributaries of Long Creek from the west. They have been prospected, but Basin Creek is the only one upon which mining has been done. Two of its tributaries, Willow and Swift creeks, received attention in 1915. Some prospecting was done on the headward tributaries of Willow Creek in an effort to locate shallow ground for open-cut work, but the results were unfavorable. A few holes were also sunk about a mile from the mouth of the stream. The upper holes are 35 feet deep, and a quarter of a mile farther down bedrock was not reached at 70 feet. Mining was done on a false bedrock of clayey gravel. The gold is fine, bright, and but slightly rounded. Little or no sulphide is associated with it, but there is much magnetite.

The upper part of Swift Creek has been worked by open cuts. On a claim on the lower part of the creek there is 6 to 8 feet of gravel overlain by 10 to 12 feet of muck. The muck is removed by sluicing, and the gravel is hoisted by a windlass. A considerable amount of the gold is in nuggets; one valued at $50 was the largest seen. One layer of the gravel is very black and carbonaceous. The source of this material is doubtful, but it may be decomposed débris from a buried coal seam farther upstream, as coal fragments are said to have been found near by.

UPPER SULATNA RIVER AND TRIBUTARIES.

Long Creek joins Sulatna River about 3 miles below the mouth of Greenstone Creek. The next tributary on the east is Monument Creek, on which prospecting has been done for several years and some mining operations were conducted in 1913. Since then there has been further prospecting, and a small production was made from this creek. Ophir Creek has been prospected, but there were never any extensive mining operations on it. Late in the summer of 1915 a small prospecting outfit was working on Star Creek, but did not discover workable deposits.

On the south side of the Sulatna there are several creeks that have received attention. Gold Run, Banner, and Spangle creeks were early staked, and good prospects are said to have been found on Gold Run and Banner creeks, but no mining was undertaken. Spangle Creek was prospected, and then the titles to the claims were allowed to lapse. It was restaked in 1915, and one party of three men did some prospecting in August, but without results. Fourth of July Creek was being held in 1915, but little or no work has been done to ascertain the value of the ground. Later reports indicate that a small production was made from this creek.

Spruce Creek was among the creeks early staked and then left idle after a nominal amount of prospecting. A part of it was still held in the winter of 1914–15, but the lower part was open to location. Active prospecting on this ground showed workable deposits and led to the restaking of the creek below the mouth of Schist Creek. During the summer of 1915 six outfits, comprising about 15 men, were prospecting or mining on the creek for a part of the summer and obtained considerable gold. Since 1915 a very considerable production has been made from the creek. The stream flows in a rather broad valley with a gentle gradient, apparently about the same as that of the buried bedrock channel, which lies at depths of 55 to 70 feet. Mining operations have been conducted for about 2 miles along the valley, and the depths are found to vary between these figures throughout this distance. The ground is generally frozen to bedrock, but thawed ground and water were encountered at one place, and the hole was abandoned for summer work. The gravel is from 2 to 5 feet thick and is made up of several varieties of igneous rocks and dark siliceous slate, usually with considerable clayey material. The gold is found in the gravel close to bedrock. Most of it is well rounded and rather fine, though several \$2 to \$3 nuggets have been found. Some of these nuggets contain vein quartz. The workable gravel ranges from that yielding 75 cents a square foot of bedrock to spots from which \$12 pans are reported.

Tamarack Creek was staked in 1912 and was actively prospected in 1913, and considerable mining has been carried on since. A number of holes were sunk about 1½ miles from the Sulatna, but in 1915 the first plant was located about half a mile farther upstream, and work was being done for about 1½ miles along the creek above this. The holes average 60 feet in depth throughout that part of the creek which was worked. The bottom layer consists of 1 to 5 feet of "soft" bedrock above the true bedrock. Above this is 3 to 8 feet of gravel, and the rest is muck. The gold lies in the upper foot of soft bedrock and in the lower 3 feet of gravel, on what appears to be the rim of an old channel. The gold is rounded and shotty, not flaky, and runs mostly in pieces worth 10 cents to \$2. One \$50 nugget has been found. Assay returns show that the gold ranges in value from \$16.50 to \$17 an ounce. Mining costs in 1915 were reported to range from 40 cents to \$1 to the square foot of bedrock, and the gravel worked yielded 75 cents to \$2.50 to the square foot of bedrock.

TRAIL CREEK.

Workable ground extends for over 2 miles along Trail Creek, and colors are said to have been obtained down the valley for 17 miles. During the winter of 1914–15 four plants were working on the creek, and three of these continued operations during the following summer. Operations were carried on for a number of years. There is a small difference in the thickness of the valley filling within the area where mining is being done. The upper workings show a thickness of 30 to 35 feet of frozen muck and gravel, of which the gravel forms 2 to 5 feet. At the lower workings the thickness increases to about 40 feet, with about the same amount of gravel. It is said that 7 miles downstream the depth to bedrock is 70 feet. The upper course of the creek presents conditions similar to those on Long Creek, the depth to bedrock increasing away from the creek, owing to the difference in bedrock and surface profiles.

The gold lies close to bedrock, in the little-rounded coarse gravel. It is irregularly distributed, but the gravel is reported to be richer at the mouths of small tributary gulches. The average value is said to be between $1 and $2 to the square foot of bedrock surface. On the upper part of the creek about 10 per cent of the gold is in nuggets worth over $5; the largest nugget reported had a value of about $300. Some of the gold is spongy in appearance and shows little rounding, but some is well rounded. Assay returns give the value of gold in this vicinity at about $16.85 an ounce. The gold and silver content of the gold as mined is in the ratio of 5.5 to 1.

FLINT CREEK AND TRIBUTARIES.

During the winter of 1914–15 considerable prospecting was done with a churn drill near Root Gulch, on upper Flint Creek, but without result, and no mining was done in 1915. In former years there has been considerable prospecting of the creeks between Root and Glen gulches, but no extensive mining. Most of the dumps from the prospect holes show angular granitic débris, associated with the gravel of metamorphic rock, both near the creek and on some of the ill-defined terraces that are considerably above it.

Two miners on Glen Gulch took out small winter dumps in 1915 about 1½ miles above the mouth of the creek, and two other outfits did some winter prospecting, but nothing was attempted during the summer, nor have there been any extensive operations since 1915. At the locality where the work was done, on the south side of the creek, the depth to bedrock is 25 to 30 feet, of which from 1 to 7 feet consists of gravel. Farther upstream the ground is shallower, and some open-cut mining was done. Considerable good ground was found about a mile up from Flint Creek but has been mined out. Prospecting at the mouth of Glen Gluch in the deeper gravels has thus far proved fruitless. The ground is frozen, and thawing is necessary. Here the gold is usually found in the first foot of gravel or in the shattered bedrock. The gold is somewhat rough, and some of it is coarse, nuggets worth as much as $150 being reported.

When mining operations were begun on Glen Gulch ground was staked on Lucky Gulch, and there was some prospecting, but the results obtained were not promising and no mining has been done.

In 1914 Birch Creek was staked and considerable prospecting was done on it. During the winter of 1914–15 three mines were being worked and some other claims were being prospected. Since 1915 extensive operations have been carried on. Bedrock on this creek is deeper than on any of the others worked, as it lies 70 to 90 feet or more below the surface. On the south side of Crooked Creek to its mouth (but below that on the south side of Birch Creek) there is an ill-defined silt terrace several feet above the creek level. As the bedrock slope is less than that of the surface of the terrace, holes sunk on the terrace are considerably deeper than those put down in the present stream valley. Normally they show 40 to 50 feet of silt and sand, and the rest of the depth to bedrock is made up of gravel with clayey layers. Some of the silt layers are reported to contain leaf impressions. Near the mouth of the creek there are layers of iron-cemented gravel near the bottom of the section. The iron is probably derived from the oxidation of the pyrite in the sand or from the leaching of the pyritiferous slate, which, with numerous large boulders of vein quartz, makes up the gravel on lower Birch Creek. On the upper part of this stream igneous rocks constitute a larger proportion of the gravel.

Gold is found for 2 miles or more along the lower course of Birch Creek and between Straight and Crooked creeks. It occurs on or near bedrock, which is granite on the upper workings and black pyritiferous slate farther downstream. The gold from the granite is fairly coarse, much of it is badly tarnished, and the concentrates contain cassiterite and a little pyrite. The concentrates from the lower workings are composed mainly of pyrite, and the tailings dumps emit a distinct odor of sulphur dioxide, produced by its oxidation.

Mining and prospecting are rendered difficult by thawed ground and live water, which may be encountered below 80 feet. The amount of water and the depth make it almost impossible to prospect without a rather large plant that has sufficient boiler capacity to do the necessary pumping.

POORMAN CREEK AND VICINITY.

Poorman Creek lies in the Innoko River basin, being separated from the Sulatna drainage basin by a broad ridge whose altitude is between 1,050 and 1,100 feet. Duncan and Tenderfoot creeks, tributaries of Poorman Creek, rise in this ridge opposite the heads of Tamarack and Spruce creeks, which flow into the Sulatna.

Poorman Creek was staked early in 1913, and in the same year some prospecting was done and a small amount of gold produced. Since 1913 mining has been actively carried on. Mining in 1915 was confined to a stretch of about 3 miles along the north bank of the creek, except for one outfit working on Little Pup, a tributary from the south. In general the work was done on bench claims. The old channel in places lies on the second-tier bench on the north side of the creek. Since 1915 still higher bench claims have become producers.

The north bank is the gentler, and, as in the vicinity of Long Creek, the bedrock floor of the old valley is wider than the present stream, and depths to bedrock increase with distance from the creek. There seems also to be a slight increase in depth downstream. The thickness of the valley filling ranges from 45 to 80 feet, as determined by mining operations; the deepest shaft was on one of the bench claims.

The section consists of coarse gravel, 2 to 12 feet; fine, sharp, clean gravel or "chicken feed," 6 inches to 12 feet; and muck and ice lenses to the surface. The material is frozen down to bedrock. The coarse gravel consists largely of boulders of vein quartz and rusty quartz breccia or conglomerate, with varying amounts of igneous rocks, quartzite, slate, and chert. In the concentrates pyrite is the most common mineral, but it decreases in amount downstream. Rounded and polished pebbles of cassiterite showing concentric structure are common, as is also barite, and there is a small amount of magnetite.

Most of the gold lies close to the bedrock surface, but it may extend up into 2 or 3 feet of gravel. Its assays average about $17.30 an ounce. Nuggets worth $25 have been found, but as a rule the gold is rather fine. It is mostly somewhat rough, and fragments of vein quartz are attached to many of the larger pieces. Though usually bright, the gold from at least one prospect was dull and nearly black. The minimum cost of mining was about 60 cents to the square foot of bedrock in 1915, but some ground running a little less has been worked. The richest ground is said to carry about $5 in gold to the square foot.

Flat Creek was staked during the winter of 1913–14 and yielded considerable gold in the following summer. The production was materially increased in 1915, and there has been a considerable production since that date. The creek is a small tributary of Timber Creek, which heads against Little Pup. The gradient is gentle, but there is an abrupt headward steepening. The uppermost workings lie less than a quarter of a mile from the head, and others extend down the creek for about 1½ miles. Near the head the depth to bedrock is 50 feet, 2 feet of which is gravel. Farther downstream the depth increases to 55 feet, including 5 feet of coarse material. In the workings of the two outfits farthest downstream the depth increases to 65 feet, including over 20 feet of gravel. Of this 20 feet the lower 15 feet is somewhat rusty and oxidized, differing from the upper layer of unoxidized gravel characteristic of the rest of the creek, and probably represents an old channel of Timber Creek. This gravel carries some gold on bedrock. On the upper part of the stream most of the gold is found in or near bedrock in the subangular gravel, but some of it occurs above a clay seam constituting a false bedrock a short distance above the base of the gravel. Associated with the gold are pyrite, rounded grains of cassiterite, magnetite, and a small amount of arsenopyrite. It is peculiar in its fineness and extreme roughness and in the amount of quartz attached to even the smallest particles. Such nuggets as have been found are small. It is stated that assays show that the gold has a value of about $15.75 an ounce. Mining costs in 1915 were approximately 75 cents a square foot, and the bedrock ground carried from 50 cents to $4 a square foot.

OTHER CREEKS.

There are numerous other creeks in the district that contain some auriferous gravel, and many of the tributaries of the Sulatna have been prospected in the endeavor to locate workable deposits. Easy Money and Tip creeks were prospected in 1912. At their junction it was 80 feet to bedrock. On White Channel, a tributary of Trail Creek, holes were sunk more than 150 feet without reaching bedrock but disclosed the presence of an unknown depth of white quartz gravel. Some prospecting was done here during the winter of 1914–15. Quartz Creek has also received some attention, and holes sunk on the main stream and on Rabbit Creek early in 1915 represent the last work done. Fine colors were obtained, but no workable placer ground was located.

More or less prospecting has been done along Big Creek, a tributary of the Yukon, ever since the first discoveries were made in the district. No mines have yet been developed. Beaver and Main creeks and other streams between Ruby and Long have been prospected without finding workable deposits.

Late in the summer of 1915 there was a stampede from Ruby to stake ground a few miles upstream and across the Yukon on one of the lower terraces. The auriferous gravel lies below 20 feet or more of clean white quartz boulders, which are covered with several feet of fine sediment or muck. It was found that the gravel did not contain gold in quantities sufficient to warrant mining.

At various times prospectors have sunk holes on the creeks between Tamarack Creek and Nowitna River, but the so-called "hard formation" has never yielded even a fair prospect, and their endeavors were shifted to creeks lying within the metamorphic area, or to the slate farther south, which gave greater promise.

CRIPPLE CREEK MOUNTAINS.

The gold-bearing creeks in the Cripple Creek Mountains have not been visited by members of the Geological Survey since 1912. It was reported to the senior writer, in Iditarod, that this locality is still in the prospecting stage, although some mining is being carried on both by drifting and open-cut methods. The status of operations there in 1912, when the creeks were visited by Eakin,[90] was as follows:

The work that has been done in the vicinity of the Cripple Creek Mountains on Cripple Creek, Fox Gulch, Colorado, and Butte creeks has been all prospecting. Workable deposits of placer gold apparently exist on some of these streams, but the existence of large placers has not yet been demonstrated. The gravels on the streams range in depth from 10 to 20 feet. Values vary and probably range in places up to $2 a square foot of bedrock surface. The future of placer-mine development in this locality will depend upon the extent of such deposits, which will be known only when much additional work has been done.

A small amount of work has been done in succeeding years.

INNOKO DISTRICT.

HISTORY OF MINING.

The following extracts from Maddren's report[91] summarize the history of exploration and mining in the Innoko district to 1908:

Prospectors are known to have passed through the Kuskokwim Valley as early as 1889. In that year Frank Densmore, one of the American pioneers of the interior of Alaska, passed from the Tanana to the Kuskokwim with a party of prospectors and descended the Kuskokwim to the Yukon portage. About the same time another pioneer prospector, Al King, made the same trip. Afterward Joe Goldsmith crossed the portage from the Yukon below Russian Mission and ascended the Kuskokwim several hundred miles. James Cleghorn and Harry Mellish also crossed this portage and wintered at Kolmakof, and since that time others have occasionally visited that country from year to year, especially since 1898. It is reported that prospectors visited the Innoko in 1898, during the earlier days of the gold excitement in Alaska. But none of these men appear to have been sufficiently encouraged by what they found to remain. However, since the discovery of placer gold in paying quantities on some of the headwaters of Innoko River, in 1906, this field has received more attention from prospectors than any other district in the Yukon basin. * * *

The actual discovery of placer gold in commercial quantities in this region was made during the summer of 1906 by a party of prospectors consisting of Thomas Gane, F. C. H. Spencer, Mike Roke, and John Maki. These men came into the headwater country of the Innoko Valley from the Kuskokwim and found a few colors of gold on the bars of the main Innoko a short distance below the mouth of its principal headwater tributary, now named Ganes Creek. Later in the season of 1906 they ascended Ganes Creek with the hope of finding the source from which these colors of gold were derived, and during August or September they located Discovery claim, on Ganes Creek, about 10

[90] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 38, 1914.

[91] Maddren, A. G., The Innoko gold-placer district, Alaska: U. S. Geol. Survey Bull. 410, pp. 21–23, 1910.

miles above its mouth. At this time, their provisions having become exhausted, the party returned to the Kuskokwim for a new outfit of supplies, but these they failed to find there, so they again crossed to the headwaters of the Innoko and descended that river to the settlements on the lower Yukon. They returned to Ganes Creek during the winter of 1906–7, hauling supplies with them on sleds. In the meantime news of the discovery had spread to prospectors who were scattered in various parts of the upper Kuskokwim Valley, so that during February and March, 1907, stampeders from the Kuskokwim arrived on Ganes Creek. The news also reached Nulato, on the Yukon, and others rushed to the Innoko from that place and the settlements near by. By early spring encouraging reports of the discovery had reached Nome and Fairbanks, so that as soon as summer navigation of the rivers was possible a great many people were ready to go to the new placer district. It is estimated that during 1907 about 800 or 900 people went to the Innoko from Fairbanks, and several hundred from Nome.

Up to the time of the 1907 summer arrivals attention had been devoted to locating claims on Ganes Creek. Over 50 claims were located on this stream below Discovery claim and over 80 claims above it. These claims covered all the ground on Ganes Creek from its mouth to its source. Besides the creek claims along the present valley floor, all of the promising bench ground within the valley was located, though more as a last resort by those who had arrived too late to get creek claims than from any particular knowledge as to where the values were to be found. As a matter of fact, most of the locating on Ganes Creek was done before the winter snows had left the ground.

Many of those who flocked into the Innoko district in the summer of 1907, finding Ganes Creek completely located, became discouraged and left the country. Others, however, remained and devoted their energies toward prospecting other streams. As a result of this search prospects were found on Little, Spruce, and Ophir creeks, which drain into the Innoko to the northwest of Ganes Creek. These streams were entirely covered by locations during the summer of 1907, although gold in paying quantities had not been demonstrated to exist on them at that time. In fact, with the exception of a small production of gold on one or two of the bench claims on Ganes Creek, little was done during the summer of 1907 but to locate a great many claims on nearly every watercourse within the mountainous part of the upper Innoko Valley. As a result, most of those who had come to the region during the summer had by early fall so exhausted their means that they could not remain during the winter, and so left for Fairbanks and Nome.

It is estimated that about 150 men spent the winter of 1907–8 in the district. The greater part of the time of these men was taken up with the task of providing themselves with food from rather distant points on Yukon and Kuskokwim rivers, for entirely inadequate amounts of supplies had been brought to the region during the previous summer. However, some winter prospecting was carried on, notwithstanding the discouraging conditions. Most of the prospect holes were sunk on Ganes Creek, but a few were put down to bedrock on Little and Ophir creeks. In the latter part of January, 1908, rich auriferous gravels were discovered at several separate localities on Ophir Creek within the same week. As a result of these finds, all but three or four men stampeded from Ganes Creek to Ophir Creek in February, 1908. On the basis of the meager facts at hand, very optimistic surmises were hastily made concerning the width, length, and richness of the pay streak that was presumed to extend along the whole course of Ophir Creek. Without further investigation, enthusiastic reports were at once dispatched to Fairbanks and Nome and had the effect of restoring a keen interest in the district. As a result, half a dozen small stern-wheel river steamboats went from Fairbanks to the Innoko on the opening of river navigation, early in June. These boats carried about 500 persons and several hundred tons of miscellaneous cargo and landed them at the upper limit of navigation for such boats, on the banks of the Innoko at points from 75 to 100 miles below Ophir Creek.

In 1910 Maddren revisited the district but chronicles [92] only that "Since 1908 a little prospecting and a great deal of locating have been done along both the northwest and southeast flanks of the Kuskokwim Mountains where they separate the headwaters of the Dishna and Iditarod, tributaries of the Innoko, from those of Takotna, Black, and George rivers, tributaries of the Kuskokwim."

The principal development between his two visits to this locality was the discovery and the beginning of mining of the gold deposits on Spruce and Yankee creeks in 1909, after the discoveries and the beginning of mining the preceding year on Little and Ophir creeks.

Since 1910 no important developments have taken place, and mining has been done on the creeks above named. In 1916 operations were confined chiefly to Ophir, Ganes, and Yankee creeks. Holdings have been consolidated on Yankee Creek, and in 1920 a dredge was in transit to this creek.

Although in the Ophir district, the Tolstoi placers may well be considered separately. Maddren's report for 1910 contains the following statement: [93]

Some prospecting has been carried on at intervals since 1907 on eastern tributaries of Tolstoi Creek, a large branch of Dishna River, and it is said that fine colors of gold are so widely distributed within the deposits of the valleys of Madison and Mastodon creeks that prospects may be obtained at a number of places. So far, however, no concentrations of gold of sufficient worth to pay to mine have been found on any of the tributaries of Tolstoi Creek.

From Harrington's report [94] the following paragraphs are taken:

Incident to the stampede to the Innoko, in the vicinity of Ophir, many claims were staked on streams in the Dishna drainage. A few men prospected their claims faithfully, although the high cost of supplies and the difficulty of getting them at any price necessarily made prospecting difficult. Many claims were held by other men, however, and upon them only sufficient work was done to maintain titles or not even the amount of work required by law. Title to most of these claims had been permitted to lapse by 1915, and when a rush during the spring and summer of 1916 followed the discovery of gold during the previous winter most of the ground along the creeks lay open for restaking. Prospecting was carried on quite extensively during the summer of 1916, but Boob Creek alone made any production and that small. Preparations for mining on a larger scale were made, however, and during the winter and spring of 1916–17 a considerable production was made by the

[92] Maddren, A. G., Gold placer mining developments in the Innoko-Iditarod region: U. S. Geol. Survey Bull. 480, p. 237, 1911.

[93] Idem, p. 237.

[94] Harrington, G. L., The gold and platinum placers of the Tolstoi district: U. S. Geol. Survey Bull. 692, p. 349, 1919.

plant which operated on claim No. 2 below Discovery and the adjoining fraction above this claim. During the winter of 1916–17 there was a stampede from Ruby, Ophir, and Iditarod, which brought the population of the district up to about 450, most of whom staked claims. This stampede was followed during the winter by active prospecting on a large number of the creeks tributary to Tolstoi River, but for the most part this work failed to develop workable placer ground. As a result the population dwindled, until in July, 1917, there were only about 50 left in the district. About $50,000 in gold was taken out in 1917, the result of the operations of about 25 men on five plants, most of the production being on Boob Creek. Boob Creek is the only creek in the district that produced platinum. The platinum was not separated from the gold but was sold with it to the bank in Iditarod. The platinum in the gold was said to amount to about 1 per cent, so that about 30 ounces of platinum was produced in 1917. The only plant which made any considerable production up to July, 1917, was located on Boob Creek. Extensive mining operations have been confined to that creek, where one plant was in operation, and several outfits were engaged in prospecting during the spring and summer.

A number of other creeks were prospected thoroughly during the spring and summer of 1917, but except on Boob Creek, where practically the entire production was made on two claims, no noteworthy production was made. However, it is said that in 1919 about $8,000 was produced from Madison Creek and its tributaries.

GOLD PLACERS.

For the sake of completeness, the detailed description of the placers of this district as written by Eakin [95] is included in this report.

Prior to the summer of 1912 the only workable placer-gold deposits known to exist in the Innoko district were those on Ophir, Spruce, Little, Ganes, and Yankee creeks. These streams are practically parallel and are tributary to Innoko River from the southwest—except Little Creek, which is tributary to Ganes near its mouth—in the order given, progressing upstream. The placers on all are within a few miles of the Innoko. Gold prospects are said to occur on several other streams in the same neighborhood. * * *

All placers of the Innoko district are of medium or shallow depth. The bedrock throughout the placer areas consists of members of the Cretaceous sedimentary series and of igneous intrusives. The latter are mainly acidic dikes and sills. * * *

Ophir Creek.—The mines of Ophir Creek have been among the chief producers of the Innoko district, but the available placer ground is now nearly exhausted.

Auriferous gravels formerly extended almost continuously along Ophir Creek valley for about 2 miles. They ranged up to 70 feet in width. The alluvium is 30 feet deep at the lower end of the valley. Its depth gradually becomes less upstream, and in the upper mines it is less than 20 feet.

Bench gravels have been exploited at a single point at claim No. 6 above Discovery. The bedrock floor of the bench is 7 feet above the flood-plain level and is overlain by a 10-foot thickness of gravels.

[95] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pp. 35–38, 1914.

The alluvium of Ophir Creek is largely composed of slightly worn materials of the local bedrock. Well-worn gravels are rare. Silt and muck are also included in the upper part of the deposits. Practically all the alluvium is permanently frozen.

Spruce Creek.—The developed placers on Spruce Creek are on a low bench on the east side of the valley about 3 miles above the mouth of the stream. Two claims have proved rich enough to support mining by economical open-cut methods. A ditch delivers water from a point farther upstream, at the upper margin of the bench deposits. The overburden is ground-sluiced off, and the gold-bearing material is then shoveled by hand into lines of sluice boxes.

The gold occurs in the shattered surface of bedrock and in an overlying stratum of gravels 2 to 6 feet thick. The gravels are overlain by 10 to 15 feet of very wet frozen muck or silt. The width across valley of the deposit available for mining differs from place to place but is at some places more than 100 feet. The gold tenor of different parts of the deposit depends largely upon the roughness of the bedrock surface beneath and is extremely variable from place to place. Little is known of the gold tenor of the gravels farther downstream, where the bench continues for the length of several claims.

Little Creek.—Auriferous deposits occur for about 2 miles along the valley of Little Creek. They have proved to be rich enough to support mining through much of this extent. They are in part the gravels of the present flood plain and in part bench deposits. The flood-plain deposits are relatively narrow and those of the benches relatively broad.

The lower creek claims and the bench claims contain shallow placers worked by open-cut methods. The stream gravels are 18 to 30 feet deep farther upstream, where underground methods of mining are employed.

The alluvium in the lower creek placers is made up almost entirely of gravels. It includes a few large boulders, but they offer no special hindrance to mining by the methods in use. There is usually a slight overburden of muck. The greater depth of the creek placers farther upstream is due chiefly to the greater thickness of muck above the gravels.

The benches are best developed along the middle reaches of the stream's course, and where widest they extend 500 feet from the creek. About 300 feet of this width is said to carry values sufficient for profitable mining. The gold occurs throughout a considerable thickness of gravel that is overlain by a thin deposit of muck. In mining a method is employed that is similar to that used on Spruce Creek—that is, the overburden is removed and the gravels are concentrated as much as possible by ground-sluicing, after which the gold-bearing materials are shoveled by hand into lines of sluice boxes.

Ganes Creek.—Ganes Creek has a pronounced development of gravel-covered benches along the right side of the valley and below the canyon a rather broad gravel-covered flood plain. Gold occurs in the gravels of both types of deposits, but thus far only the bench gravels have proved available for mining. It seems likely that the flood-plain gravels may contain fairly high values in places, but the work of prospecting them is difficult because they are thawed.

The original concentration of gold in the Ganes Creek valley occurred in preglacial time, when the stream was much shorter and had less volume. Apparently a continuous pay streak was formed at that time extending for miles along the stream. When the stream cut down to its present level, part of the old pay streak was carried down and reconcentrated in the present stream gravel and should be found in the reaches between the gold-bearing benches. Parts of the original concentration remain in the bench gravels. Where lateral streams cross the course of the old pay streak they have concentrated its values from the width of the tops of their recently cut valleys to the narrow gravel deposits in their bottoms. This form of reconcentration has probably produced some of the richest spots of the Ganes Creek valley.

The Ganes Creek placers have been worked almost entirely by open-cut methods. Water for sluicing is taken from the small tributaries of Ganes Creek, and in many places work has progressed slowly on account of the small supply. The bench gravels have now been nearly worked out, and the future of Ganes Creek as a producer will depend largely upon the gold tenor of the flood-plain gravels. If systematic prospecting should prove their worth, these gravels would be admirably adapted for dredging.

Yankee Creek.—The Yankee Creek placers are between 6 and 7 miles above the mouth of the stream and are all included apparently in two association groups of claims, each comprising 160 acres. Yankee Creek has an exceptionally broad, flat valley, and the auriferous deposits have a correspondingly wide cross-valley extent. The alluvium consists of a stratum of gravel 5 to 7 feet thick, which is overlain by a thin bed of muck. The ground is mostly thawed in summer and is worked exclusively by open-cut methods.

Boob Creek and vicinity.—The following descriptions of the placers in the vicinity of Boob Creek by Harrington [96] constitute the latest available data on the district.

[On Boob Creek] the deposits are worked by underground methods, for the auriferous gravels, 2 to 4 feet thick, lie beneath 25 to 35 feet of muck and ice. The surface gradient of the stream is low, not over 50 feet to the mile.

Besides gold and platinum other minerals which may have economic importance are cinnabar and cassiterite, which are found in small amounts. Cinnabar occurs in small pebbles up to half an inch in diameter of a characteristic red color. Cassiterite in the form known as wood tin occurs in the typical botryoidal form, showing radiate structures when cracked open. The pebbles are somewhat darker than those seen in the Ruby district, being nearly black. The crushed mineral gives a very light brown powder.

A small sample of the platinum from Boob Creek was presented to the Survey by Mr. J. S. Pitcher, of Tolstoi. It was analyzed by R. C. Wells in the chemical laboratory of the Survey and found to have the following composition:

Analysis of specimen of platinum from Boob Creek, Tolstoi district.

Platinum	83.4
Iridium	.4
Palladium	.3
Copper	None.
Rhodium	.3
Iron	9.8
Osmiridium, silica, and undetermined	.6
Nickel	None.
	94.8

Pyrite, magnetite, garnet, feldspar, and quartz also occur in the concentrates. The quartz is found in small brilliant transparent crystals as well as in the milky-white form from veins. A considerable number of grains of nearly opaque brownish-black grains of obsidian or volcanic glass were also noted.

Some of the tributaries of Tolstoi River, which head against Mount Hurst or its spurs, were prospected during the spring and summer. Up to July none

[96] Harrington, G. L., op. cit., pp. 350, 351.

had made any production. Considerable prospecting had also been done on tributaries of Mastodon Creek other than Boob, but without result.

On Madison Creek and several of the streams flowing into it, including Esperanto, Joffre, and Eldorado creeks and their tributaries, considerable prospecting has been done. On Iron Creek, which empties into Eldorado, there were at one time seven or eight outfits, but in July only one of these was working about 2 miles from the head of the creek. Mining was being done in an open cut by three men who were shoveling into the boxes. The gravels were largely composed of phyllitic rocks and granite but included some pebbles of limestone. Sections show from 2 to 4 feet of gravel overlain by about 4 feet of muck. A considerable amount of stripping had been done, and it was planned to work during the summer. No platinum was found on this creek. A considerable amount of prospecting had been done on a number of claims near the head of Madison Creek, but work during July was confined to two claims. On claim No. 5 above Discovery * * * 4 feet of muck overlies about 8 feet of gravel, and the gold is found in the lower 4 feet. The gold from this claim is flaky, fine, and worn. No platinum was seen in pannings, which in addition to the gold contained magnetite, ilmenite, augite, hornblende, garnet, and zircon, none of which have economic value under these conditions of occurrence. The creek valley is about 150 to 200 feet wide on this claim. The ground in the center is said to be thawed, although it is frozen on either side. Operations were largely carried on with the purpose of ascertaining the extent and richness of the stream gravels. A small production was made from this and adjoining claims under the same ownership.

One man was working on claim No. 7 above Discovery. A number of prospect holes had been sunk, and the dirt from these holes and some short crosscuts had been rocked out. The gold, although somewhat worn, is considerably coarser than that found on claims lying farther down the creek and is described as "shotty" rather than flaky. An association of minerals similar to that on the lower claims is found in the concentrates.

CANDLE CREEK.

On the upper part of Candle Creek, a tributary of Tatalina River about 12 miles long, active mining was begun on a four-claim association by the owners in 1914 and continued by laymen the following year.

Open-cut methods were being used at the time this creek was visited, in 1915, but a hydraulicking outfit was nearing completion. On account of the scarcity of water in the headwaters of the creek a bedrock basin has been excavated above the workings to catch surface and ground water, and a head of 100 feet will be developed. This creek had proved to be sufficiently rich for the installation of a dredge, which was operated for a short time in 1918 and practically a full season in 1919, although it was found that the large boulders occurring in the creek caused considerable trouble.

A pear-shaped body of quartz monzonite, with the small end pointed downstream, forms the bedrock in the upper part of Candle Creek. It extends downstream about 3 miles, ending about three or four claims above Discovery claim. The divide at the head of Candle Creek is made up of a hard, dense basalt, but the spurs on both sides of the valley are composed largely of sandstone and shale, presumably of Cretaceous age. The stream gravel is from 9 to 15 feet thick in the upper part of the creek, where it is being worked, and thickens gradually downstream. Boulders 4 feet in diameter occur in the gravel, and smaller ones are numerous. Basalt and monzonite are the chief materials of the gravel.

The gold is irregularly distributed through the gravel in grains averaging about 1 cent. Very little flour gold is reported. The heavy sand recovered with the gold is reported to be largely cinnabar, with some magnetite.

There can be no doubt that the gold at this locality is connected genetically with the quartz monzonite. Quartz veins cut the monzonite bedrock, and it is entirely probable that these veins, with perhaps mineralized zones in or adjacent to the monzonite, constitute the source of the gold. Furthermore, it appears that the richest ground is on the upper part of the creek, where the bedrock is quartz monzonite. Below the monzonite prospect the tenor of the gravel is lower.

A dredge was set up on Candle Creek in 1917 and began operations in 1918 but did not have a very successful season that year, owing to mechanical difficulties. Beginning with 1919, however, this dredge became a steady producer, operating in 1919, 1920, and 1921.

MOORE CREEK.

The workings on Moore Creek, the south fork of Takotna River, are on the upper part of the creek, about 10 miles below its source. The gold-bearing gravel at this locality was discovered and staked about 1910, and mining has been carried on since in a small way.

The bedrock here consists of sandstone and shale, standing vertical or dipping steeply to the north and striking in general to the northeast. On the creek claim the gravel is about 10 feet thick and is composed of cobbles ranging from 6 inches to 3 feet in size, mainly sandstone, shale, granite material, and basic igneous rock. On the bench claims the gravel is only 3 feet thick and is covered by 2 feet of clay and vegetation.

On the bench diggings mining is carried on by pick and shovel. Hydraulicking is used only for stripping off the overburden. The water is brought in a ditch from Willow Creek, a tributary of Moore Creek. On the creek claim hydraulicking is utilized in moving the gravel. The water coming from the bench diggings is impounded and delivered to the nozzle under a head of about 20 feet.

The gold is little worn and contains much quartz. Cinnabar is the chief heavy sand found in the concentrates, but this is much more plentiful on the creek claim than on the bench claims. Zircon and a little magnetite are also present.

Here, as on Candle Creek, the gold is connected genetically with the mineralizing effect of quartz monzonite. A body of monzonite occurs in the hills to the north, at the head of Willow Creek, and it is not unlikely that similar bodies may be present farther up Moore Creek, for a considerable amount of quartz monzonite has been noted at Camelback Mountain (known locally as Bonanza Mountain), at the head of Moore Creek.

IDITAROD DISTRICT.

HISTORY OF MINING.

Maddren's description of the placers of the Iditarod district[97] summarizes the history of exploration and mining through 1910, as follows:

> In the later part of the summer of 1908 two prospectors, W. A. Dikeman and John Beaton, who had been to the Innoko district earlier in that year but were not encouraged by the outlook there, descended the Innoko in a small steamboat. Upon reaching the large southwestern branch of the Innoko, now named the Iditarod, these two men decided to explore that stream and prospect on its headwaters. They ascended the Iditarod as far as the low stage of water of that season would permit their boat to go and there prepared for winter by building a log house which has since been called "Discoverers' Cabin." This house is situated on the main river about 8 or 9 miles below the present town of Iditarod, or some 25 miles below the mouth of Otter Creek. During the early winter they sledded a prospecting outfit southward from their winter quarters across several low ranges of hills to Otter Creek and decided to look for gold in the valley of that stream at a point about 12 miles above its mouth. Their choice of a location to prospect, decided upon at haphazard, as it was in midwinter, proved most fortunate, for they were rewarded by finding gold at a depth of only about 12 feet in the first holes they dug to bedrock, the discovery being made on Christmas Day, 1908. The discoverers then located a moderate number of claims for about a mile along Otter Creek for themselves and a few friends.
>
> Owing to the distance of Otter Creek from settlements or routes of travel and to the fact that the discoverers were practically alone, information about the newly found prospects of gold did not spread rapidly. It was not until the summer of 1909 that other prospectors gathered there from the Innoko and Yukon districts. The result of their arrival was the locating of claims that covered practically all the valley lands of Otter Creek, its tributaries, and the adjacent streams. Almost no mining was done during the summer of 1909 because of the lack of equipment and supplies. During the latter part of this summer most of the several hundred people on the Iditarod were chiefly concerned with getting enough supplies at hand to enable them to remain through the coming winter. Considerable amounts of supplies that were shipped to the new district did not arrive because Iditarod River was at a low stage during the open season of 1909 and navigation was closed by ice earlier than usual that autumn.

[97] Maddren, A. G., Gold placer mining developments in the Innoko-Iditarod region: U. S. Geol. Survey Bull. 480, pp. 237–238, 1911.

In spite of these handicaps some systematic prospecting of the claims on Otter Creek was undertaken during the winter of 1909–10, and some gold was mined from small underground drifts. The reports about this work were either sent out in such optimistic form or became so magnified in transmission that a great deal of interest was aroused about the new district, with the result that when navigation opened on the Yukon in May, 1910, a couple of thousand people and a considerable amount of supplies and machinery were bound for the Iditarod. Until the middle of July the traffic to the new camp taxed the capacity of the available steamboat transportation on the Yukon and for a time the movement threatened to reach the proportions of a so-called stampede.

In 1910 Otter and Flat creeks were the principal producers, though gold had been found on Happy Gulch and Willow Creek. By 1912 the producing creeks included also Chicken Creek, Black Creek, and Glen Gulch. The first dredge in the district was installed by the Yukon Gold Co., on the Marietta group, Flat Creek, in 1912. In 1914 a small gasoline-operated dredge was installed on Otter Creek. Large power scrapers were also employed on a number of claims during 1914 and succeeding years.

In 1915 mining was done on Flat, Chicken, Happy, and Willow creeks and on the divide at the head of Flat Creek. In the vicinity of Discovery mining was in progress on Otter, Black, and Slate creeks and on Glen Gulch. In all, 24 mines were worked. Two dredges were active, but most of the plants used mechanical scrapers and hydraulicking operations. Open-cut work, involving shoveling and sluicing, as well as a little drift mining, was also done.

There was a falling off to 15 in the number of mines operated the following year. These included 3 dredges, 1 drag line excavator, 4 scrapers, and 7 open-cut mines, operated chiefly by hydraulic methods. In 1917 there was a decrease in production, due largely to the troubles in operation of the largest dredge.

In 1918 there was a sharp drop in production, due mainly to the closing down of some of the smaller but important plants.

The most interesting feature of the development of mining methods since 1918 has been the use of cold-water thawing. In 1919 this method is reported to have been used with considerable success by some plants. In 1920 a lesser degree of success appears to have been attained.

GENERAL FEATURES.

The Iditarod district is a well-established mining community and has maintained a very considerable production of placer gold since mining operations began in 1909. Two towns, Iditarod, on Iditarod River, and Flat, on Otter Creek, at the mouth of Flat Creek, have post offices and, together with Discovery, farther up Otter Creek, handle the business of the district. Flat and Discovery are the supply points for the adjoining mining operations.

All the mining is of the placer type, no gold or other lodes having yet been developed into producing mines. Placer ground is being worked on Otter, Flat, Black, Slate, and Willow creeks and Glen Gulch and on the slopes of the granitic dome at the heads of Flat, Chicken, and Happy creeks.

CHARACTER OF DEPOSITS.

Eakin,[98] in discussing the placer deposits of this district, has divided them into two types—the alluvial deposits of gravel in the present stream valleys, and the residual deposits, or those in the development of which water has played only a minor part. Some of the stream deposits, such as those in Glen Gulch and on Otter Creek, at Discovery, partake of the nature of residual deposits in that they lie in an area of monzonitic bedrock, which is the source of the gold. The residual deposits proper, however, are those in the formation of which stream action has had no place; and some of the deposits on the slopes of the granitic mass at the heads of Flat, Chicken, and Happy creeks exemplify this type particularly well.

STREAM PLACERS.

Otter Creek.—Mining is being done both on creek and bench claims on Otter Creek, in the vicinity of Discovery. There are six creek claims, running from claim No. 2 above Discovery claim to claim "No. 3 below." These are joined upstream and downstream by association claims. A tier of bench claims on the north bank and two tiers of bench claims on the south bank lie alongside the creek claims. About six single and association claims were being worked during the season of 1915.

The bedrock at Discovery is a body of monzonite, which extends upstream to the mouth of Slate Creek and ends downstream about three claim lengths below Discovery claim. The valley wall north of Discovery is a basaltic rock, so that the monzonite on that side of the creek is confined to the present valley floor. To the south the monzonite reaches well up into the head of Glen Gulch, where it attains its maximum width. Above and below the monzonite on Otter Creek the bedrock consists of sandstone and shale, supposedly of Cretaceous age, with a general strike of about N. 70° E. and a steep dip to the northwest. The gravel is composed of granitic and basaltic material, together with considerable sandstone and shaly material. The maximum depth to bedrock is about 15 feet in the creek bottom but becomes gradually less on the bench claims.

[98] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 31, 1914.

Mining on the bench claims near Discovery is being done by means of mechanical scrapers. These remove all the loose gravel and convey it to cars, which are hauled up an inclined track and dumped into the dump box, at the head of a chain of sluice boxes. The upper part of the bedrock, which also carries some gold, is picked by hand and wheeled in barrows to the cars.

A dredge of the bucket-elevator flume type, using distillate for fuel, is at work mining the gravel of the creek. The gravel is frozen and is prepared for the dredge by thawing.

According to Brooks,[99] there are two kinds of gold on Otter Creek, a coarse and a finer variety. These two are of different appearance. The coarse gold is darker than the fine and much waterworn. The fine gold is angular and bright. The concentrates contain cinnabar, arsenopyrite, and scheelite.

The monzonite that lies in the bed of the stream is undoubtedly the source, directly or indirectly, of the gold on Otter Creek. The fine, bright, unworn gold comes directly from quartz veinlets and mineralized zones within the monzonite. Brooks is inclined to believe that the coarser and darker gold has its source in antimony or cinnabar lodes that closely adjoin the monzonite.

Glen Gulch.—The gravel of Glen Gulch is shallow, and manual methods were employed in mining it. The bedrock is monzonite, as on Otter Creek, and the gold occurs at the base of the gravel and in the disintegrated bedrock.

Black Creek.—The following note, written by Eakin,[1] is an adequate description of conditions on Black Creek:

> The placers of Black Creek are not well defined as to extent. It seems likely that continuous placer deposits do not extend for any great distance in the valley. However, workable deposits have been discovered locally at several places. The bedrock in general consists of members of the sedimentary series and of local bodies of intrusive monzonite. As on the other creeks, the depth of the Black Creek placers is not great, the usual range being 12 to 16 feet.

Slate Creek.—Small placer-mining operations were carried on at the lower end of Slate Creek in 1915. It is reported that the bedrock is much the same as on Black Creek and that the gravel is unfrozen.

Flat Creek.—On Flat Creek a dredge, two plants operating on bench claims, and a bucket hoist operating in the upper part of the creek were at work in 1915. The company working the dredge owned all the creek claims in the lower 3 or 4 miles of Flat Creek, down to Otter Creek, and its operations were the most extensive.

The bedrock at the extreme head of Flat Creek is monzonite. Below, down to Otter Creek, sandstone and shale, rather more in-

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[99] Brooks, A. H., unpublished notes on Iditarod district, 1915.

[1] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 32, 1914.

durated than other Cretaceous rocks near by, form the rock floor of the valley. Locally beds of quartzite and slate were recognized. Dikes of igneous rock cut the sedimentary rocks. Along the wagon road, about halfway up Flat Creek, the rocks strike N. 60° E. and dip 50° NW. This general northeasterly direction is believed to be the regional strike in this vicinity. The creek gravel at the point where the dredge is at work is about 10 feet deep and carries little or no overburden.

The bedrock configuration of Flat Creek, according to Brooks,[2] differs markedly from that of Otter Creek. On Otter Creek the bench and creek deposits merge gradually with one another, there being no sharp break or bedrock rim between the two. On the east side of Flat Creek, in its upper part, there is a bedrock reef which sharply separates the bench deposits from the creek deposits. Moreover, the gravel deposits are of different thickness and character at several localities. The bench deposits, however, merge with the creek deposits farther downstream.

The creek mining is of two kinds. The bench claims are worked by mechanical scrapers, much as at Discovery, on Otter Creek. The dredge operates in the creek gravel, which is frozen and has to be thawed ahead of the dredge.

The gold is of two grades.[2] That taken from the bench gravel is coarser and of higher grade than that taken from the creek gravel (known as the " formation gold "). There is, however, more or less intermingling of these two types, especially farther downstream, where the bench and creek deposits coalesce.

The gold of Flat Creek is undoubtedly derived from the monzonitic mass at the head of the creek. Unlike the gold around Discovery, on Otter Creek, it can not be considered to have any of the characteristics of a residual gold deposit, for nearly all of the Flat Creek valley has a sedimentary bedrock. The Flat Creek gold, therefore, is a typical creek-placer deposit.

Willow Creek.—Willow Creek was visited in 1915 by A. H. Brooks, who states that two plants were operating there. One of these employed a drag-line excavator, and the other was operating underground, raising the gravel with a bucket hoist.

Bench and creek claims are staked here, as on Otter Creek. Like that of Otter Creek, the valley is unsymmetrical, the valley wall on the west being abrupt. The bedrock is slate, and the gravel is made up largely of sedimentary rock, with lesser amounts of granitic and basaltic material. There is about 10 feet of muck overlying from 3 to 4 feet of gravel on the bench ground, but the muck thins rapidly

[2] Brooks, A. H., unpublished notes on Iditarod district, 1915.

toward the creek. The gold lies in the lower 1 or 2 feet of gravel and in the decomposed bedrock.

The source of the gold is not established. The deposit is apparently not a continuation of the Happy Creek pay streak, for Happy Creek does not carry gold to its mouth. Moreover, the gold is coarser and of somewhat higher grade. Brooks is inclined to believe that outlying lodes from the main monzonite mass have been the source of the gold.

RESIDUAL AND ELUVIAL PLACERS.

Residual and eluvial placers have been described by Eakin. Ten claims and associations may be described as belonging to these types. Five of these are at the head of Flat Creek, two at the head of Chicken Creek, and three at the head of Happy Creek.

The monzonitic bedrock, which is the source of these placer deposits, is much sheared and mineralized. The mineralization appears to have been accomplished in two or more ways. Numerous quartz veinlets, from an eighth of an inch to 2 inches in width, cut the monzonite. These carry free gold and are therefore a known source of some of the gold. Many of them have a general east or north of east direction. There are also numerous iron-stained joint planes which are probably also sources of gold. Most of them strike in accordance with the quartz veinlets, but some have a northwesterly strike. Brooks[2] has observed that on several claims there is a little evidence of quartz veining or of extensive sheeting. The monzonite is iron stained and massive, and the inference is that the rock may have been completely saturated with the mineralizing solutions.

The monzonite is deeply weathered, commonly to a depth of 5 to 10 feet and in some places deeper still. It weathers out into great rounded boulders, which very much resemble waterworn material. Some of these have moved down the slope and are found overlying finer gravel, and in such places gravel may appear to underlie bedrock.

Mining on this granitic dome is attended with difficulties. Most of the work is done by open cuts and hydraulicking. The great difficulty, especially in the hydraulicking operations, is the scarcity of water. Ditches have been dug at numerous places along the upper slopes of the dome to catch the surface and ground water. These ditches lead the water to reservoirs, where it is impounded to give the necessary head for hydraulicking or to give a steady flow for open-cut work. Obviously, the length of time during which gravel may be washed is limited by the amount of water available. The work begins when the reservoir is full and ends when the water is ex-

[2] Brooks, A. H., unpublished notes on Iditarod district, 1915.

hausted, having thus an intermittent character during the day. The owner of the claims at the head of Flat Creek has built snow fences during the winter, to cause the snow to collect in huge drifts, thus augmenting the summer water supply. This method will probably be followed by other operators.

The gold is bright and angular and contains much quartz. Much of the gold is very fine, and one of the operators reported that 10 per cent of his total output was recovered by amalgamating on copper plates, a process that is commonly followed. The richest part of the placer is usually near the bedrock.

GOLD LODES.

Little gold-lode mining has been done in this region. Quartz and quartz-calcite veins are very common in the Ruby district, but it remains to be demonstrated how many of these are capable of supporting lode mining. Several good-sized quartz veins near Ruby have been prospected, and although small quantities of gold are reported, none of the veins has yet proved to be of commercial importance. The fact, however, that good-sized nuggets with intergrown quartz are often found favors the belief that richer veins are present and will ultimately be located and mined.

Eakin[3] reports that in the Innoko district quartz veins are common, especially in the vicinity of acidic dikes. One such vein was being worked in 1912. Of this he says:

> The Independence mine is near the head of Carter Creek, an eastern tributary of Ganes Creek. The ore body is a quartz vein, averaging about 2 feet in thickness, that occurs along the hanging wall of a rhyolite dike intrusive in the sedimentary series. The microscope shows that the gold lies in iron-stained crevices and vugs in the quartz and is also embedded in grains of magnetite within the quartz vein. Veinlets of iron carbonate cut the quartz, and iron carbonate is abundantly present in the altered sedimentary rock on the one hand and in the altered dike on the other. The dike is much altered in places, so that the original character of the rock is obscure.
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> The altered sedimentary and igneous rocks both contain more or less gold. The workings show that the vein is continuous to a depth of more than 90 feet, and there are no evident geologic reasons that it may not extend to a much greater depth.

Little work has been done on this lode since Eakin's visit.

In the Iditarod district quartz veins are not common in the sedimentary rocks, except close to the intrusive rocks. The monzonite, however, contains many quartz veins. In the monzonite at the head of Flat Creek much of the quartz is bluish and carries free gold in grains that are visible to the naked eye. The presence of arsenopyrite and cinnabar in the concentrates here indicates that these min-

[3] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 28, 1914.

erals probably occur in the quartz veins. Over 500 pounds of the rich gold-quartz material has been gouged out from veins in the monzonite at the head of Flat Creek and shipped to the Selby smelter, in Tacoma, Wash.

In the vicinity of Nixon Fork of the Kuskokwim John Strand discovered a gold lode while prospecting for placers during the winter of 1918–19. A number of other claims were soon staked, and some production of ore was reported in 1919. The lode was visited by Martin [4] in 1920, and his report contains a description of the lodes.

Efforts have been made for a number of years to develop a lode mine in the Russian Mission Mountains. Some work was done at this property during 1920.

ANTIMONY AND QUICKSILVER LODES.

Vein deposits of stibnite and of stibnite and cinnabar are known to exist in the vicinity of the monzonite intrusive bodies. None of these have been worked, but it is quite possible that some of them or other lodes as yet uncovered may become producers in the future.

At the head of Wyoming Creek, in the Cripple Creek Mountains, Eakin[5] found a 30-inch vein of stibnite and quartz. A specimen from this locality shows that quartz and cinnabar form the walls and stibnite the center of the vein. The vein is said to occur in the contact zone between the monzonite and the sedimentary rocks.

In the Innoko district Eakin [5] saw a 12-inch vein of stibnite and quartz at the Kaatz prospect, 1½ miles above the mouth of Copper Gulch, a tributary of Ganes Creek. This vein strikes N. 30° E., dips 75° SE., and is traceable, in association with a rhyolitic dike, for 6,000 feet. Stibnite is disseminated through the vein but is concentrated along the footwall. An examination of a thin section of this ore shows conclusively that the quartz was injected into the vein and was followed later by the stibnite.

At the border of the quartz monzonite area at the heads of Flat, Chicken, and Happy creeks lodes carrying stibnite and cinnabar are present. A sample from one of these lodes, collected by Eakin at the head of Chicken Creek, shows a vein 2 inches thick. It is mentioned, not because of its potential significance as a lode deposit, but because it shows very well the same feature that was noted in the ore from Wyoming Creek—that is, quartz and cinnabar along the edge of the vein and stibnite in the center.

At the head of Glen Gulch, in the Iditarod district, a stibnite claim on what is known as the Mohawk lode has been staked. This

[4] Martin, G. C., Gold lodes in the upper Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 722, pp. 149–161, 1921.

[5] Eakin, H. M., oral communication.

is a mineralized shear zone about 2 feet wide, at the contact of the monzonite with the country rock. The strike of this zone so far as could be determined is N. 45° E. and the dip 45° S. according to Brooks. This zone, like most of the others mentioned, carries gold. Some narrow stibnite-bearing veins have also been found on the lower part of both Glen Gulch and Black Creek.[6]

The Parks prospect, on the north bank of Kuskokwim River, about 15 miles above Georgetown, has been described in considerable detail by Smith and Maddren.[7] The ore is cinnabar and stibnite, and the lode is in a shattered or brecciated zone at the contact between the country rock and intrusive igneous rock. The intimate association of granitic and diabasic material, the characteristic feature of the igneous rocks in this region, is also to be seen here. According to the authors cited, the cinnabar and stibnite are intimately intergrown, and the deposition of the two minerals was almost contemporaneous. The gangue is quartz and ferruginous carbonates. In 1919 a battery of retorts was taken up the Kuskokwim and installed at the Parks prospect, and in August of that year a considerable number of men were working on the property. No work was reported for 1920.

Maddren[8] has described the deposits of quicksilver that lie west of the Parks prospect.

In 1920 extensive preparations, including the procuring of a 60-ton smelting outfit and the landing of a portion of this equipment at the mouth of Crooked Creek, below Georgetown, are reported to have been made, looking to the development of a quicksilver deposit on the upper Iditarod River, about 15 miles from the mouth of Crooked Creek.

STREAM TIN.

Stream tin in the Ruby-Kuskokwim region is not considered by the writers to be plentiful enough to warrant a discussion of its possible economic significance. Many queries, however, have been made by miners regarding the nature of certain heavy brown pebbles recovered by them in the concentrates. The following notes are intended as an answer to such queries.

Tin in the form of the oxide, cassiterite, is obtained in the concentrates on Short, Midnight, Greenstone, Monument, and Trail creeks, in the vicinity of Long, and represents a phase of mineralization which was doubtless associated with the intrusion of the

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[6] Brooks, A. H., The antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, pp. 47–49, 1916.

[7] Smith, P. S., and Maddren, A. G., Quicksilver deposits of the Kuskokwim region: U. S. Geol. Survey Bull. 622, pp. 274–280, 1915.

[8] Idem, pp. 272–291.

coarse-grained granite that occupies the crest of the ridge at the head of Flint Creek. A similar granite intrusion and its attendant mineralization account for the presence of tin on upper Birch Creek. On Ruby Creek there is no known exposure of granite, but the concentrates likewise contain cassiterite. The cassiterite occurring at these places is in the crystalline form, translucent to opaque, and from yellow-brown to black. It much resembles rutile or wolframite in appearance.

On Poorman and Flat creeks, in the vicinity of Poorman, as well as on Spruce and Tamarack creeks, and on Boob Creek, in the Innoko district, the cassiterite is in the form known as wood tin, showing no crystal form but having surfaces which are mammillary or reniform and internally showing concentric structure in which bands range from yellow to dark brown. The source of this tin is unknown, but probably it is of vein origin. This form much resembles limonite and is not readily distinguished from that mineral, although it is much harder, and the crushed mineral is lighter in color than limonite.

A simple test for both forms of cassiterite consists in placing fragments of the mineral in a glass or enameled dish with some granulated zinc and pouring over them sulphuric or hydrochloric acid. After heating a few minutes cassiterite shows a coating of tin, which becomes more evident after rubbing on a piece of cloth to brighten it.

Chapin visited the Ruby district in 1917 to investigate the possibilities of tin production in that district. His summary of the mining operations for this mineral, which includes the results of his studies in 1917, is appended:[9]

The following statement is based on a hasty reconnaissance of the Ruby district in 1917 to determine the possibility of the production of tin. Although stream tin occurs at a number of places in the gold placers, there has been only a slight output. Cassiterite has been noted in the concentrates from Long, Spruce, Short, Tamarack, Midnight, Trail, Monument, Birch, Ruby, Poorman, Flat, and Greenstone creeks. The cassiterite is plentiful at few places, and at no place has enough been found to pay for mining it, except as an accessory to the gold. The gravels on Midnight Creek have been prospected for tin, and 14 sacks of concentrates were shipped to Singapore. This shipment consisted of 1,037 pounds of ore which assayed 52.2 per cent, or 537 pounds, of metallic tin. The net return of $156.22 from ore recovered from 6,000 square feet of bedrock gives a yield of about 2½ cents a square foot. Evidently the amount of tin recovered from even the richest tin placers now known is so small that even the shallow gravels can not be worked profitably for the tin alone. At best it adds but little to the profit derived from the gold. It is also evident that the tin ore is so disseminated that it will be very difficult to recover any large quantity, although a few tons may be saved each year by the placer gold miners.

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

COAL.

Coal-bearing rocks of Cretaceous age occur at numerous places in the lower Yukon basin, and some small mines have been opened in them, but the demand for coal has been slight, and consequently the development has not been extensive. In the Ruby-Iditarod region coal has been reported from several places. A prospect hole 9 or 10 miles from the head of Quartz Creek, in the Ruby district, is said to have reached coal at a depth of 100 feet. On Swift Creek, a tributary of Basin Creek, a layer of the gravel shows a high percentage of carbonaceous material, resembling the detritus from a coal seam, and coal fragments are said to have been found near by.

Coal has been found in a prospect hole sunk to a depth of 50 feet on lower Poorman Creek. Water filled the hole at the time of the writers' visit, and the extent of the coal was not observed. A crosscut driven from the foot of the shaft is said to show coal having a dip of 70°. This indicates a seam of considerably greater thickness than is found elsewhere in the adjacent regions. There is said to be 15 feet of yellow gummy gouge between the coal and the overlying gravel, and this gouge also forms partings in the coal. Only a small quantity of the coal has been mined—at most a few tons. It is subbituminous, igniting with difficulty but burning readily after ignition. Some of it has been used as blacksmith coal but has not proved wholly satisfactory for this purpose. On exposure to the air it slacks badly, although it is probable that the material seen was obtained near the surface of the seam and in consequence would tend to disintegrate more readily than coal taken at greater depths, beyond the influence of atmospheric agencies. Owing to the depth and the distance from any considerable market, the present utilization of this coal seems extremely doubtful.

Maddren obtained information in 1910 from a prospector to the effect that coal had been found on Homestake Creek, in the Nowitna basin, at a depth of 46 feet, and that it also occurred at the head of the Nowitna.

The open-cut mining on Moore Creek has exposed the bedrock along the creek, and at one place there is a very carbonaceous layer in the shale. Little is known of this occurrence, but it is probably only a thin carbonaceous seam.

In the Iditarod district coal croppings have been reported from a number of localities. Smith[10] has described these in detail and has given an analysis of some coal taken from a prospect on the tramroad between Iditarod and Flat.

During the winter of 1914–15 another coal prospect was opened in the same vicinity, near the junction of the wagon roads from

[10] Smith, P. S., Mineral resources of the Lake Clark-Iditarod region: U. S. Geol. Survey Bull. 622, pp. 268–270, 1915.

Flat and Discovery. Additional work was to be done on this property during the winter of 1915–16. The owners stated that the strike of the beds is N. 38° E. and the dip of the coal seam about 80° SE. A shaft 30 feet deep has been sunk, the lower 25 feet of which is in frozen ground. The section of coal, as given by the owners, is as follows: Shale (hanging wall); coaly shale, 10 inches; clean coal, 14 inches; shale (footwall). A sample was taken from the dump, and analyzed by A. C. Fieldner, of the Bureau of Mines, with the following result:

Analysis of coal from Iditarod district.

	Air dried.	As received.	Moisture free.	Moisture and ash free.
Proximate analysis:				
Moisture	1.33	1.52		
Volatile matter	7.70	7.69	7.81	8.24
Fixed carbon	85.77	85.60	86.92	91.76
Ash	5.20	5.19	5.27	
	100.00	100.00	100.00	100.00
Ultimate analysis:				
Hydrogen	3.37	3.38	3.26	3.44
Carbon	86.03	85.87	87.19	92 04
Nitrogen	1.56	1.56	1.58	1.67
Oxygen	3.05	3.21	1.90	2.01
Sulphur	.79	.79	.80	.84
Ash	5.20	5.19	5.27	
	100.00	100.00	100.00	100.00
Calorific value:				
Determined—				
Calories	7,958	7,943	8,063	8,513
British thermal units	14,324	14,297	14,517	15,323
Calculated from ultimate analysis—				
Calories		7,983		
British thermal units		14,369		

It is likely that there are a large number of coal beds in the Cretaceous rocks in this general neighborhood, and other beds will therefore probably be discovered in the course of time. The fact, however, that only thin beds have so far been uncovered indicates that these are the rule rather than the exception. Nevertheless, in the Iditarod district, where wood is becoming scarce, such beds may prove to be of considerable importance as a source of fuel for local consumption. They certainly merit further prospecting.

MINERALIZATION.

It is not possible from the data obtainable on a reconnaissance trip to say the final word regarding either the general or the economic geology of a region. Hence the conclusions arrived at regarding mineralization may later be controverted in part by more complete data. At present, however, the data at hand point to mineralization during two periods in the Ruby-Kuskokwim region. This conclusion is based on evidence regarding the genesis of the placers, on the character and distribution of the quartz veins, and on the character of the concentrates taken with the gold.

In the Ruby district, exclusive of the Cripple Creek Mountains, quartz veins are very common throughout the sedimentary and igneous rocks, and Eakin [11] regards these veins as the source of the gold in this district. Many such veins, however, are apparently barren, and it is rather likely that there may be several series of quartz veins, of which certain ones, related perhaps to a definite period or periods of mineralization, are the sources of the gold. It is also possible that a certain part of the mineralization was more diffuse, the gold being disseminated in the country rock independent of the quartz veins. So little of the bedrock, however, is exposed in the Ruby district that scant opportunity is afforded for verifying any hypothesis. The original source of the gold likewise is in doubt. Without question, it is derived from igneous rocks, but much of the placer ground lies at considerable distances from any known bodies of intrusive rocks of the type usually considered to be a source of gold. It is therefore evident that the mineralization was connected indirectly rather than directly with igneous rocks, and that the gold came to its ultimate position in the bedrock through the agency of mineralizing solutions which may have migrated considerable distances from the source rock before they deposited the precious metals. Such a result indicates that the mineralization must have taken place at a relatively high temperature and under considerable pressure and therefore presumably at considerable depth.

The age of this mineralization is not evident from the geologic record, but it is inferred to have taken place during some period or periods in the Mesozoic era. Within the Ruby district and farther east in the Cosna-Nowitna region, granite has been mapped which is believed to be of Mesozoic age. This granite has been assigned to the Mesozoic because of its petrographic character and its restriction to areas of pre-Tertiary rocks. The mineralization of the Ruby district was probably connected genetically with this Mesozoic (?) granite. On the other hand, some of the rocks mapped as greenstone in the Ruby district were originally dioritic and might also have been a source of gold. The greenstones, as a group, are believed to be of Paleozoic age. The possibility therefore exists that a part of the mineralization in the Ruby district may have taken place during Paleozoic time, though this is believed to be less likely than the previous hypothesis.

[11] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 43. 1914.

In the other placer-gold areas to the south, including the Cripple Creek Mountains, the Innoko district, Candle Creek, Moore Creek, and the Iditarod district, different conditions prevail. The mineralization was everywhere connected directly with acidic intrusive rocks, chiefly quartz monzonite, and these intrusives, as previously shown, are known to be of Tertiary age. At some localities—for instance, at the head of Flat Creek, in the Iditarod district—the gold placers are residual, being weathered directly out of the quartz monzonite bedrock. The gold occurs in small seams and stringers, some with and some without vein quartz. At other localities the placer is some distance downstream from the intrusive rock, but it is always clearly related to such rock. In general, quartz veins are uncommon, except within intrusive bodies and near their perpheries, a condition which is in sharp contrast to that prevailing in the Ruby district. A further difference exists in regard to the character of the quartz veins. The common accessory sulphides observed in the quartz veins in the vicinity of Ruby, Long, and Poorman are pyrite and arsenopyrite. In the southern areas cinnabar and stibnite, as well as pyrite and arsenopyrite, are found in the quartz veins and lodes.

The concentrates recovered with the gold from the placers of the northern and southern areas also show differences. The rock-forming iron minerals, magnetite and ilmenite, are found universally. Pyrite and arsenopyrite likewise are not localized. Around Ruby, Long, and Poorman, however, cassiterite is very common in the concentrates, and on Poorman Creek barite also occurs. The occurrence of barite is not considered to have any significance, for it is widespread in Alaska; but cassiterite has not been found genetically associated with Tertiary intrusive rocks in the Ruby-Kuskokwim region. Cassiterite is present in the placers of Boob Creek, near Mount Hurst, but the evidence there points to a composite Mesozoic and Tertiary mineralization. On the other hand, cinnabar is found universally in the southern area, with stibnite and scheelite in some places. The only known occurrence of any of these minerals in the northern area is at Spruce Creek, northeast of Poorman, near the south end of the northern area, where cinnabar occurs in the concentrates. If, as is supposed, the southern area represents a later period of mineralization, it is possible and likely that this period should be represented in the north, especially near the boundary between the two areas. Hence the occurrence of cinnabar on Spruce Creek is not anomalous. On the other hand, the restriction of cassiterite to the northern area is quite essential to the truth of the hypothesis to be proposed. It does not necessarily follow, however, that cinnabar and stibnite are restricted universally in Alaska to areas of the Tertiary type of mineralization, nor that cassiterite is restricted to areas of the Mesozoic type. So far as known at present, this restriction is general, but exceptions may later be found. The marked restriction of these minerals to areas of the different types of mineralization in the Ruby-Kuskokwim region, however, is highly suggestive evidence of the distinctness of the two types there, irrespective of the application of the hypothesis to Alaska as a whole.

From the foregoing considerations the writers are led to believe that there were two distinct periods of mineralization in the Ruby-Kuskokwim region. The mineralization in the vicinity of Ruby, Long, Poorman, and in part on Boob Creek, near Tolstoi, took place first, but its age can not be stated with certainty. It may have been either Paleozoic or Mesozoic, but the fact that Mesozoic intrusions elsewhere in Alaska have produced marked mineralization, whereas there is no definite record of Paleozoic mineralization, affords presumptive evidence in favor of considering the mineralization in the northern area to be of Mesozoic age. The mineralization in the southern area, including the Innoko and Iditarod districts, as well as Candle Creek, Moore Creek, and the territory extending southward along the Kuskokwim, was connected genetically with the quartz monzonite and associated intrusive rocks and is therefore known to be of Tertiary age. If this hypothesis is true, the mineralization in the Ruby district took place in the old land mass that existed prior to the deposition of the Upper Cretaceous and Tertiary sediments that form the regional bedrock south of Poorman. The older mineralization was therefore earlier than the Upper Cretaceous; the younger mineralization was Tertiary and probably post-Eocene.

Further subdivision of the two periods of mineralization may later be effected, when additional data are obtained. This subdivision will be harder to work out for the older type of mineralization, because time has obscured the evidence. In the areas of Tertiary mineralization, however, certain evidence is available that might be utilized. Gold is found in the quartz veins and also in seams and stringers without quartz, though closely associated with the quartz monzonite in both occurrences. It is also found within the stibnite ores, which may or may not be connected with quartz veins. Microscopic work has shown that the stibnite and some of the gold is later than the quartz veins.

Attention has already been called to the two different kinds of gold found in the Iditarod district. All these facts are certainly suggestive of the possibility that the gold mineralization may have taken place in two or more distinct stages, within the same general period, but the evidence is not yet complete enough to warrant the proposal of a definite hypothesis.

POSSIBLE AREAS FOR PROSPECTING.

The areas in which the two types of mineralization above referred to have occurred coincide in their distribution in a general way with the two physiographic provinces of the region, and both the mineralization and physiography are factors that must be taken into account in giving advice to the prospector.

In the Ruby district, exclusive of the Cripple Creek Mountains, placer gold is not known to be directly dependent for its position on bodies of intrusive rock, though such bodies were probably influential in the formation of the quartz veins. Were it possible to know the character of the country rock in this district, the best advice would probably be to prospect in creeks in whose upper basins the country rock is cut by numerous quartz veins. It happens, however, that in the major part of the Ruby district the bedrock is effectually covered by a mantle of unconsolidated deposits. The prospector and geologist are therefore alike in the dark as to what creeks are likely to become producers. The ultimate solution of the problem lies in prospecting.

In the Cripple Creek Mountains and in the Innoko-Iditarod region the conditions are different. Here, too, the valleys are filled with alluvium, but the ridges are higher, and bedrock exposures may usually be found on the interstream divides. Such exposures afford a general idea of the character of bedrock in the valley bottoms. It is now commonly recognized that the gold placers in this part of the region are closely associated with granitic rocks. Streams that head in areas of granitic rocks or that have a granitic bedrock are therefore the most favorable places to prospect. It does not follow, however, that gold will be found universally around such rocks, but it may be stated negatively that in this region gold is never found very far from granitic bodies.

There is one point which may be of value to the prospector in searching for granitic rocks. Such rocks may be present in the valley bottom, covered by alluvium, and the interstream divides may give no indication of this fact—that is, the granitic body may be small and confined to the valley bottom. This condition occurs on Candle Creek and Otter Creek. It has been observed, however, that most of the granitic intrusives in this region are surrounded, adjoined by, or in some way associated wlth basic intrusive rocks, such as gabbro, diabase, and basalt, and it is rarely that both the basic and acidic intrusives fail to crop out on the divides. Therefore, where basic intrusive rocks are found the prospector should look carefully down the valley slopes and in the valley wash for granitic detritus. On Otter Creek and Candle Creek the presence of large masses of basic rock on the adjoining divides would have caused the initiated to search for granitic rock in the neighborhood.

PRODUCTION OF GOLD AND SILVER.

The production of gold and silver in the Ruby, Innoko, and Iditarod mining districts for 1922 and previous years is stated below. From these tables it is apparent that the total value of the gold recovered from the Ruby-Kuskokwim region to date is $27,456,000 and of the silver $124,960, with a total value for both metals of $27,580,960.

Placer gold and silver produced in the Ruby district, 1907-1922.

Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.
1907-8	48.38	$1,000	7	$4
1909				
1910				
1911				
1912	8,465.63	175,000	1,157	712
1913	37,974.37	785,000	5,188	3,134
1914	48,375.00	1,000,000	6,609	3,655
1915	33,862.50	700,000	4,626	2,345
1916	41,118.75	850,000	5,618	3,697
1917	42,811.88	885,000	6,073	5,046
1918	19,350.00	400,000	3,000	3,000
1919	7,981.88	165,000	1,255	1,406
1920	8,223.75	170,000	1,113	1,213
1921	8,223.75	170,000	1,158	1,158
1922	5,950.13	123,000	819	819
	262,386.02	5,424,000	36,643	26,189

Placer gold and silver produced in the Innoko and Tolstoi districts, 1907–1922.

Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.
1907	628.87	$13,000	67	$44
1908	3,483.00	72,000	370	196
1909	16,447.50	340,000	1,746	908
1910	15,721.87	325,000	1,669	901
1911	12,093.75	250,000	1,284	681
1912	12,093.75	250,000	1,284	681
1913	13,545.00	280,000	1,438	869
1914	9,675.00	200,000	1,027	568
1915	9,191.25	190,000	976	495
1916	10,642.50	220,000	1,130	744
1917	8,465.63	175,000	1,113	917
1918	5,805.00	120,000	608	608
1919	6,772.50	140,000	717	803
1920	4,982.62	103,000	529	577
1921	5,321.25	110,000	569	569
1922	10,836.00	224,000	1,264	1,264
	145,705.49	3,012,000	15,791	10,825

Placer gold and silver produced in the Iditarod district, 1910–1922.

Year.	Gold.		Silver.	
	Fine ounces.	Value.	Fine ounces.	Value.
1910	24,187.50	$500,000	4,254	$2,297
1911	120,937.50	2,500,000	21,270	11,273
1912	169,312.50	3,500,000	29,778	18,313
1913	89,977.50	1,860,000	9,551	5,769
1914	99,652.50	2,060,000	10,578	5,849
1915	99,168.75	2,050,000	10,526	5,337
1916	94,331.25	1,950,000	10,013	6,589
1917	72,562.50	1,500,000	11,050	9,105
1918	59,985.00	1,240,000	9,000	9,000
1919	35,071.88	725,000	5,300	5,937
1920	24,429.37	505,000	3,628	3,954
1921	16,931.25	350,000	2,482	2,482
1922	13,545.00	280,000	2,041	2,041
	920,092.50	19,020,000	129,471	87,946

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