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CONTENTS.

PLACER GOLD MINING IN ALASKA IN 1902.

By ALFRED H. BROOKS.

GENERAL STATEMENT.

The great impetus given to prospecting for gold in Alaska, incident to the discovery of the rich Klondike fields, has resulted in the finding of a number of new and in the further development of several old placer districts. The gold output has shown a correspondent increase, rising from two and one-half millions in 1897 to about eight millions in 1902. While the development of quartz mining in the Pacific coast province of Alaska has steadily progressed during this time, more especially in the last two years, this development has not as yet affected the increase of output to any appreciable extent, for the production of the lode mines has remained practically the same. In southeastern Alaska plans have been formulated for extensive mining developments, and in many localities these plans are nearing completion; but as yet, outside of the older mines, such as the Treadwell, there are few which are actually producing. The increase of $5,500,000 during the last five years has, therefore, been chiefly from the placer mines. It is to be expected, however, that the quartz mines of southern Alaska, which are being opened up, will within the next two years add materially to the mineral production of the Territory.

Of the $6,000,000 or more[a] produced from the placer mines of Alaska in 1902, about $5,500,000 has come from the Seward Peninsula gold fields. The new diggings in the Copper River region have probably produced $225,000, and the Cook Inlet region and Porcupine district have probably produced $100,000, while the remainder is from the Yukon Basin, chiefly from the new diggings on Glenn Creek.

DISTRIBUTION AND SOURCE OF PLACER GOLD.

Placer gold has a wide distribution in Alaska. It has been found near the southern boundary of the Territory, and at various localities northward as far as the sixty-eighth parallel of latitude and westward as far as Bering Strait. Broadly speaking, the producing placer

[a] The exact production is not yet known, but is not less than five and one-half and possibly may be six and a half millions.

mines of Alaska which have thus far been opened up fall within a zone having a maximum width of probably 200 to 300 miles, stretching northwest from the southern Pacific coast, crossing the Arctic Circle, and bending westward to the shores of Bering Strait. It is not intended to imply that this zone in its entirety is a gold producer; such is far from being the case. This broad belt is simply drawn attention to as having, up to the present time, been the locus of the placers of commercial importance. The factors which have determined the formation of workable placers are frequently so local in their effect that the distribution of the placers is very irregular.

The field studies lead to the conclusion that the source of the gold lies, for the most part, in small quartz veins and stringers which are disseminated in metamorphic rocks. Gold also occurs in these rocks in the mineralized zone, where there is little if any gangue mineral present. Iron pyrite is the commonest mineral found in association with the gold in the parent rock. The few observations made indicate that the gold occurs both free and combined with pyrite. Quartz is a common gangue mineral, associated with some calcite. Galena is frequently associated with the gold-bearing quartz veins, and chalcopyrite and arsenopyrite have also been found. This list of minerals will undoubtedly be much extended when closer studies have been made.

The studies of the placer fields of Alaska lead to the conclusion that the gold in nearly every case has not traveled far, and can usually be traced to a local source. In the gulch and creek placers it can usually be traced to a source within basins which they drain. The exception is where a change of drainage may have introduced material derived from regions outside the creek basin. In nearly all parts of Alaska the placer gold owes its present position entirely to the erosion of the bed rock in which it was formerly disseminated, and to the sorting action of water and gravity, which has brought about its present concentrated form. This elementary principle is here emphasized because it is not uncommon to find, even among well-informed men, a tendency to entirely ignore the very simple facts, and to regard placers as the result of glacial action, or as having had a still more cataclysmic origin. As a matter of fact, all of the placers of Alaska, except a few near the southern coast, are outside of the limit of former glacial activity.

As has been stated, the gold of the placers has its source in small veins and stringers in the bed rock or was disseminated in mineralized zones. The facts now obtainable indicate that the outlook for future quartz mining in the placer fields of the interior of Alaska is not hopeful. While it is by no means impossible that larger gold-bearing veins carrying commercial values may be found, it seems probable that most of the placer gold has been freed from bed rock, where it was more or less widely disseminated, and subsequently concentrated

by the sorting action of water. It is not uncommon to hear Alaskan prospectors speak of the "mother lode," as if the gold had all been derived from one lode or zone of mineralization. Of this there is no evidence whatever. In considering the question of quartz veins in the placer fields, it should be remembered that the dense coating of moss makes bed-rock prospecting difficult and uncertain.

The auriferous deposits from which the placer gold is derived occur in metamorphic rocks of various kinds. They include schists of various types, phyllites, limestones, quartzites, and altered igneous rocks. Such metamorphic terranes find a wide development in Alaska, and probably occur in a number of different horizons. The study of the geology of Alaska has not progressed far enough to permit of correlations, or of definite statement in regard to the age of the metamorphic terranes or their structural relations. The mineralized metamorphic beds of southeastern Alaska are probably Mesozoic and older. Those of the Yukon are chiefly, if not entirely, pre-Carboniferous, and those of the Seward Peninsula are chiefly Paleozoic. Within the zone which has been designated as the one in which gold placers have been found, there are many large areas of these metamorphic rocks. These form belts which are not by any means continuous, as they are interrupted by areas of younger Mesozoic and Tertiary terranes. It has also been shown that they probably belong to widely different horizons. Broadly speaking, the mineral-bearing horizons of southeastern Alaska can be placed in one group, and those of the Yukon Basin and of the Nome region in another. It will remain for future studies to determine the relation between these two belts.

The age of intrusion of the mineral-bearing solutions is largely an unsolved problem. In the coastal belt of southeastern Alaska the mineralization took place probably in Mesozoic time, while in the Yukon region it was probably considerably earlier. The studies thus far made indicate that the mineralization accompanied disturbances of the strata, either by deformation or by igneous intrusions, or both, which were rather local in their effect. They seem to be closely affiliated to igneous rocks which are everywhere found in the regions of mineralization.

The studies of the alluvial gold deposits of Alaska have shown that *mode of formation and concentration* are the determining factors of the richness of the placer deposits. The writer has elsewhere[a] emphasized this fact in regard to Nome placers, and more recent observations convince him that it is also applicable to the gold deposits of the Yukon. In the simplest form of placers the gold is washed from the parent rock and concentrated in the beds of the streams, mingled with other detrital material Such placers have been exploited in many localities and have been found to be important gold producers.

[a] Reconnaissance of the Cape Nome and Norton Bay Regions, U. S. Geological Survey, 1901, pp. 144–151.

It is probable, however, that nearly all the very rich placers owe their origin to secondary concentration. This has been brought about by the erosion and dissection of an older placer and the reconcentration of the gold contained therein. This process of double sorting is probably the chief cause of the bonanzas which are not uncommon in the Alaskan placer mines, and will probably also account for those irregularities of distribution of the placer gold often within a single topographic basin, which are so puzzling to the miner.

A common form of the enrichment is the dissection of an auriferous gravel bench of the slopes of a stream valley by a tributary stream. This tributary stream carries the gold derived from the bench to the main stream, where it is mingled with the gold of the main stream, and causes an enrichment of the placers located at and below the junction of the two streams. In some instances the gravels of an older drainage system, lying often at considerable altitudes above the present stream floors, are dissected by the present waterways, and the gold contained in the older gravels is thus resorted and reconcentrated. Instances of this kind are not uncommon in the Nome region, and have been observed by the writer in the Rampart region of the Yukon.

Another form of concentration is that by wave action. In this mode of enrichment the waves concentrate the gold which has been deposited in the gravels of the coastal plains. It is in such a manner that the marvelously rich beach placers of Nome were formed.

It seems probable that the study of these questions of reconcentration will yet yield important commercial results, even in the better known mining districts of Alaska. A practical application of these principles would suggest that the prospector seek to trace old drainage channels and pay special attention to the junction of these with the present streams.

SEWARD PENINSULA.

During the last season the climatic conditions in the Seward Peninsula were not, by any means, favorable to a large gold output. While there were heavy rains in the fall, the months of July and August were very dry, and hence but little sluicing was done. It should be noted, however, that the experience of the last three years indicates that such meteorological conditions are to be expected every third year, if not every other year. The output, therefore, is probably not nearly as large as it would have been had water been available early in the season. Moreover, much of the development was in the nature of dead work in preparation for extensive operations during the present season. Ditches were dug, roads built, and pumping plants established, which will greatly accelerate the prosperity of the district and, undoubtedly, will materially increase its gold production. The problem of transportation is still a serious one. Under the best conditions the landing of heavy machinery and supplies on the Nome beach is a

difficult task, but during stormy weather it becomes well nigh impossible. After heavy machinery has been landed it is still a grave problem how to transport it from the coast to the mines. This involves the building of roads and, in some cases, the dredging of rivers.

The region immediately tributary to Nome is better prepared to meet these conditions than the more isolated camps. The narrow-gage railroad, which runs from the beach to the head of Anvil Creek, makes the transportation problem at that particular locality a simple one. Roads, moreover, have been built to adjacent creeks from the railway, so it is now possible to handle heavy machinery.

In Anvil Creek probably the most important development was in the auriferous gravels of the benches which are found on both sides of the valley. This gave a new impetus to mining, for the gravels in the creek bed itself were nearly all run through the sluices during the two previous years. The high-bench gravels, lying at altitudes of 500 to 800 feet above the sea, which were discovered in 1900, still continued to be developed. Some of these have great depth, and the extraction of the gold has been a difficult problem.

The so-called "tundra placers," or more properly coastal plain placers, still continue to be worked, but their development has not been commensurate to their probable importance. It seems more than likely that the gravels which make up this coastal plain, in many places, carry workable placers. These may be, in part, old sea beaches, or may be the channels of abandoned streams and rivers. The problem of handling large quantities of these gravels, which are a few feet above and below sea level, has not yet been solved. Most of the mining has been confined to shallow pits and trenches, and the operations have been hampered by lack of means to handle the surface water. The extraction of the gold has been largely accomplished by use of hand rockers. Winter mining has been carried on by means of petroleum and coal-burning steam thawers. With the aid of the thawer a pit is sunk to the pay streak, which is followed by drifting. The gold-bearing gravel is then hoisted to the surface and washed out during the open summer season. It is of interest to note that drills have been successfully employed in prospecting for the pay streak in the coastal plain gravels. The ground underneath the thick coating of vegetation is frozen throughout the year, but thaws to a depth of 2 or more feet where this coating is removed. If an economic method of mining these gravels in a large way and of extracting their gold contents could be devised, large profits would undoubtedly be made.

During the four years which have elapsed since the discovery of the Nome placers, the gold seeker has gradually worked his way inland, so that now there has been some prospecting done over nearly the entire Seward Peninsula.

During the last season gold mining was going on in the Nome region proper, in the Solomon and Eldorado River region, on the streams

tributary from the south to the Kruzgamepa in the Kuzitrin basin, and on streams tributary to the Niukluk. All of these belong to the Bering Sea drainage. A number of the streams which are tributary to Port Clarence were also found to carry commercial values. Some developments of placers on streams flowing northward to the Arctic Ocean have been made. None of the northerly flowing streams have, as yet, been found to be as rich as those of the older and better known districts of the South. Many have, however, produced gold in commercial quantities, and with further developments will probably become important producers.

What has been said of the Nome region proper applies in large measure to the other creeks in the region. In nearly every case where discoveries have been made the first developments are along the present stream channels. When these are worked out, which does not take long where the streams are small, the prospectors turn their attention to the benches and terraces, and these often yield good returns. In some cases placers have been practically abandoned which it seems to the writer may still carry gold in commercial quantities. Such may prove to be the case in districts like the Kugruk, where the miners have worked out the small creek beds and have neglected to thoroughly prospect the terraces and benches. Of special interest is the very large increase in the output of Ophir Creek, a northern tributary of the Niukluk. This stream was one of the first on which gold was discovered in the Seward Peninsula, and for several years was spasmodically worked, but it is only since the introduction of systematic methods of mining and extraction that Ophir Creek has become one of the largest producers of the region. It has been estimated that its production during the last year was upward of $1,000,000. These facts augur well for the future of the Seward Peninsula placer fields. It seems probable that there are other streams which may go through a history similar to that of Ophir Creek.

YUKON REGION.

Mining has been going on in the Upper Koyukuk Basin since the summer of 1899, and the basin has probably produced from $100,000 to $200,000 annually. This money has been chiefly taken out of half a dozen creeks which are tributary to the Upper Koyukuk about 600 miles from its mouth. About 500 miles of this distance can be made by river steamer. During the last season many miners returning from the Koyukuk seemed to be rather discouraged. There seems to be no question that there are workable placer fields in the district, but the high price of provisions and the short season have prevented many of these from being worked at a profit. With water transportation within a short distance of these placer mines there seems to be no reason why supplies should not be as cheap as on the Yukon. It is to be hoped that there will be a reduction in the cost of living, which

will enable developments to continue in this region, which lies north of the Arctic Circle.

Rampart is a small settlement on the Yukon about 1,000 miles from tide water. It has tributary to it a number of camps which have long produced some gold, and these are still producing, but not in great quantity. The important development of the season is that of Glenn Gulch, about 30 miles south of Rampart. Glenn Gulch is tributary to Baker Creek, which flows into the Tanana about 100 miles from the Yukon. The gulch itself has proved phenomenally rich, and a number of other streams in this region give promise of becoming producers. A description of this region by Mr. Collier will be found elsewhere in this volume.

The region lying between the Yukon and the Tanana is one in which many gold-producing creeks have been found. The earliest discoveries were all made on the Yukon side of the divide, but since 1898 much prospecting has been done on strems tributaries to the Tanana from the north. In only a few cases have these yielded anything of value, and, as far as known to the writer, the gold-producing creeks are all tributary to the lower 200 miles of the Tanana. Little information is available in regard to this region, but it is stated that considerable gold has been taken out of streams which flow into the Chena River, which joins the Tanana about 300 miles from the Yukon. The daily press has recently contained references to phenomenally rich placers found somewhere in this region. Pedro Creek, whose location is not given, is said to have been found to be very rich, but these rumors have not received confirmation.

The Birch Creek region embraces the headwaters of the stream of the same name, tributary to the Yukon near the Arctic Circle. It is one of the oldest placer districts of the Yukon, and still continues to produce some gold. With the cheapening of provisions on the Yukon the placer mining on some of the older creeks took a new lease of life, and such is the case on Birch Creek. Low-grade placers are now being developed in the Birch Creek Basin, which could not be economically developed under the old conditions. During the winter of 1901–2 much mining machinery was taken into the district. It is reported that the district contains extensive deposits of low-grade placers, which it is proposed to mine with refined methods.

Fortymile River enters the Yukon 20 miles above the international boundary. That its bars carry gold has been known for the last fifteen years, and streams tributary to it have been important gold producers for the last eight years. Many of these streams are still being worked, and a few new ones have been discovered. In many instances bench claims are being developed. While the gold production of the district has not been large, the placers are by no means exhausted, and it is possible that important discoveries will still be made.

During the last year placer mining has been done on a number of small creeks tributary to the Upper Yukon. On Boundary Creek, 12

miles above Eagle, two or three claims were worked last summer. In the immediate vicinity, on American Creek and Colorado Creek, tributary to Mission Creek, some mining was also done. Seventymile River was also the scene of mining operations, about 15 miles from the Yukon, and one hydraulic plant was run. On Fourth of July Creek, 50 miles below Eagle, 12 men were at work on claims last summer. Three claims on Coal Creek and several on Woodchopper Creek, 140 miles below, also received some development of their placers.

COPPER RIVER REGION.

Gold has been found in commercial quantities at two widely separated places in the Copper River Basin. The Chistochina gold field, which has produced nearly all the gold of the region, is in the drainage basin of a river of the same name which joins the Copper about 200 miles from the coast. This district contains several gold-producing creeks which can be reached by trail from Valdes. Gold placers have also been found at a number of widely scattered localities in the Copper River Basin. A description of this district by Mr. Mendenhall will be found elsewhere in this volume.

COOK INLET REGION.

The region lying adjacent to the head of Cook Inlet and about Turnagain Arm has long been a small gold producer. No very rich placers have been found, but the accessibility of the district made it possible to develop deposits which could not have been worked at a profit if located in the interior. Hydraulic mining has been going on in a small way for a number of years, and more elaborate plants are being installed. The open season of Cook Inlet comprises about five months, which gives the district two months' advantage, or more, over that of the interior, or of Nome. The developments of the last year have been rather in the way of introducing more refined methods of mining rather than of new discoveries.

PORCUPINE DISTRICT.

This is a small placer-gold district about 30 miles from Pyramid Harbor, an embayment of Lynn Canal, whence it is easily accessible by wagon road. It lies chiefly within the catchment basin of Porcupine Creek, a small stream which enters the Klehini about 20 miles above its junction with the Chilkat. The placers are so situated that they offer peculiarly difficult conditions for mining. They occur largely in small glacial benches and in the stream bed of Porcupine Creek, which has a very sharp rock-cut valley. To work these placers it has been necessary to divert the water of the stream by means of sluices, to give access to the gravels in the creek bed. This involved a large expenditure of time and money. During the last season these developments were still going on, and the district has not yet reached a large productive stage.

THE GLENN CREEK GOLD MINING DISTRICT, ALASKA.[a]

By ARTHUR J. COLLIER.

INTRODUCTION.

Glenn Creek is a small tributary of Baker Creek, a large stream which enters the Tanana from the north, about 80 miles from the Yukon. The mining camp there located is the site of the most important discovery of placer gold made in the interior of Alaska during the seasons of 1901 and 1902. This camp is about 28 miles in a direct line nearly due south of the town of Rampart, on the Yukon River. Rampart is the distributing point for Glenn Creek, as well as for several older mining camps, and has a population of about 300. It is approximately 1,000 miles from the mouth of the Yukon and 600 miles from Dawson, and can be reached by river steamer from Dawson in about three days, or from St. Michael in about a week.

The Glenn Creek trail from Rampart follows up Big Minook Creek for a distance of 25 miles to its head, then crosses a divide having an elevation of about 1,700 feet above the river and drops down to the Glenn Creek Camp, which has an elevation of about 800 feet above the Yukon. The distance from Rampart to Glenn Creek by this trail is about 30 miles, and along it the footing is so soft that two days are usually required in summer to make the trip comfortably, either by walking or by riding.

The camp is near Baker Creek, 18 miles from its junction with the Tanana River, at which place a small trading post has been established, which can be reached by steamer coming up the Tanana from the Yukon. Baker Creek is navigable for canoes up to within a few miles of the Glenn Creek Camp, but the trail from Glenn Creek to the Tanana is reported to be very swampy.

Since only five days could be spent by the writer in making the trip from Rampart to Glenn Creek and return, the information obtained is necessarily meager and the results are in many respects unsatisfactory.

[a] This paper is an abstract of a more extensive report, now in preparation.

The Glenn Creek mining camp lies on the northern edge of an extensive lowland basin known as the Baker Flats. These flats, opposite Glenn Creek, have a width from north to south of from 7 to 10 miles, but their greatest extension is in an east-west direction. This broad lowland is a depression which has been deeply filled by fluvial deposits. Near the mouth of Eureka Creek a prospect hole penetrated 65 feet of gravel without reaching bed rock. Along its southern margin there is a range of low, flat-topped hills, which separate it from the great lowland of the Lower Tanana, and through this range Baker Creek flows in a narrow gap. The creek forks just above this gap, and the eastern fork, which is the larger, is called the Hootlenana, while the western fork retains the name Baker Creek. Eureka Creek, which receives a large part of the drainage from the northern margin of the flats, enters Baker Creek near these forks. A broad bench was observed 100 to 200 feet above the valley level at the northern margin of Baker Flat. The gold placers thus far discovered are confined to a number of small creeks flowing into the Baker Flats from the north, and in the immediate vicinity of the Glenn Creek camp these streams are known to be gold-bearing only where they cut across the above-mentioned bench. Several miles to the east Pioneer Creek and other tributaries of the Hootlenana are gold bearing and it is probable that the gold-bearing belt extends about 20 miles along the north side of the Baker Flats, but it was not examined by the writer except in the immediate vicinity of Glenn Creek.

Active mining has been in progress on Minook Creek, near Rampart, since 1896, and the creek was probably prospected as early as 1882. From Minook Creek as a center prospectors have extended their search across the divides in all directions. In the summer of 1901 colors of gold were found on Eureka Creek and mining was attempted. Gold in paying quantities was discovered on Glenn Creek July 24, 1901, by a miner who had a contract for supplying wood at the mine on Eureka Creek. Colors of gold, but not in paying quantities, had already been discovered on Rhode Island and Omega creeks in this region.

GEOLOGY.

In the vicinity of Rampart on the Yukon the bed rock consists of a series of volcanic rocks interbedded with siliceous slates and limestones, called by Spurr the Rampart series.[a] From fossils collected last season near Circle this terrane is believed to be of Devonian age.

About 8 miles south of Rampart a series of siliceous slates, quartzites, and schists was found, which continues with more or less variation across the divide to Glenn Creek. The relation of the Rampart series to this slate and schist series could not be determined with cer-

[a] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 155-169.

tainty, but the evidence indicates that the Rampart series is younger. If this be true, the schist series of the upper part of Minook Creek and of Glenn Creek may be correlated with either the Fortymile or the Birch Creek series of Spurr. No evidence of faulting or intrusions of granite in this series, as indicated by Spurr,[a] was seen along Minook Creek by the writer. The rocks contain small quartz veins and stringers in many places, and the débris from them includes pebbles of igneous material other than granite, suggesting the presence of intrusions of various kinds.

A few specimens of the sedimentary rocks have been examined microscopically. These vary in degree of alteration, in some cases being garnetiferous mica-schists, in others quartzites consisting of interlocking quartz grains. All the specimens examined contained more or less muscovite. Microscopically these rocks resemble the Birch Creek series as described by Spurr.[b] A similar series of schists occurring at many places along the Tanana River[c] has been described by Brooks under the name Tanana schists. They outcrop for some distance along the Tanana below the mouth of Baker Creek, making it probable that the schist series forms a continuous area from Minook Creek, 8 miles above Rampart, to the Tanana below Baker Creek. These schists have been correlated by Brooks[d] with the Birch Creek-Fortymile series of Spurr.

DESCRIPTION OF PLACERS.

Glenn Creek is a small stream, in summer carrying less than a sluice-head of water, which rises in a bench on the north side of Baker Flats and flows southward to the flats. The creek occupies a broad, shallow depression less than 50 feet deep, which makes a hardly noticeable break in the topography.

About one-half mile west of Glenn Creek, Gold Run, a still smaller stream, also flows southward to Baker Flats, and about one-half mile farther west Rhode Island Creek, a larger stream, has cut a deep trench nearly to the local base-level of Baker Flats. About a mile east of Glenn Creek, Eureka, a large creek, enters Baker Flats, also from the north, occupying a deep, well-marked trench. Each of the creeks named above carries placer gold in paying quantities for a distance of about a mile, and the bench between Glenn Creek and Gold Run also has been found in places to be covered with gold-bearing gravel rich enough for exploitation.

The productive placers of Glenn Creek are confined to four or five claims within a mile of the head of the creek. In this distance the creek bed has a fall of about 5 feet in 100.

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[a] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, Pl. XXXVIII.

[b] Ibid., p. 144.

[c] See Reconnaissance in the Tanana and White River basins, Alaska, 1898: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, map 24.

[d] Ibid., pp. 468 and 469.

On Discovery Claim, at the edge of Baker Flats and at the lower end of the productive part of the creek, a prospect hole 40 feet deep failed to reach bed rock. In all the claims above Discovery bed rock can be reached at a depth of from 5 to 20 feet. The bed rock is a schist, usually called slate by the miners. It ranges in color from dark blue to gray, and is often graphitic. It represents a rather argillaceous sediment which has been subjected to only a moderate degree of metamorphism, sufficient to produce many metamorphic minerals, but not to entirely destroy the original structure. This bed rock is often cut by stringers of quartz, which are reported to strike nearly east and west. These stringers are white and at the outcrop are decomposed along with the remainder of the bed rock, which is often so disintegrated that it can be shoveled out like fine gravel.

The width of the pay streak varies from 20 to 60 feet. In one place a pay streak 7 feet thick is reported. On the lower claims the pay streak is near the surface, so that summer work "by stripping and shoveling" is possible. In the upper claims the pay streak is found below several feet of muck and barren gravel, and is mined with steam thawers in winter and washed in the spring. Early in August, when the creek was examined, only one claim, known as Claim No. 2, was working. The others were shut down because the dumps had already been sluiced. On Claim No. 2 miners were shoveling into the sluice boxes directly from the pay streak. It was impossible to see the bed rock in place, or to see a full section of the gravel from the surface down in the deeper workings. The pay gravel consists of angular fragments of schist and a small amount of vein quartz, with occasional rounded bowlders of a basic, igneous rock. The gold is not evenly distributed in the pay streak. Sometimes the best pay is found on the surface of a layer of decomposed bed rock. "Stringers" of gold on this bed rock were found carrying $10 to $35 to the pan. These "stringers" are lines of gold parallel with the bed rock, which look when uncovered as if the rock had been sprinkled with gold. On some of the claims values are reported to have been found to a depth of 2½ feet in a hard, blocky bed rock. On some of the lower claims above the bed rock there is a waxy clay, called by the miners "gumbo," which is probably decomposed rock in situ. This clay ordinarily does not carry gold, but on one of the upper claims a gumbo ball is reported to have carried $1 in fine colors.

In the summer of 1901, after the discovery, a small amount of gold was taken out before the end of the season. During the winter of 1901–2 a large part of the pay streak was taken out by drifting, and the dumps were washed in the following spring. It was estimated by a representative of the Eagle Mining Company, which owns several of the claims, that the creek had produced approximately $150,000 prior to the 1st of August, 1902.

Gold Run occupies a very slight depression parallel with Glenn

Creek and about one-half mile to the westward. It is a tributary of Rhode Island Creek, into which it empties a short distance above the Baker Flats. Claim No. 1 of Gold Run joins with Claim No. 3, Rhode Island. The bed rock consists of schists similar to those on Glenn Creek. It is described by the prospectors as a "blocky schist."

The pay gravel consists of angular fragments of this bed rock, which show very little if any rounding, such as would be expected in channel-washed gravel. The prospecting shows a pay streak from 12 to 40 feet wide. At the lower end of Claim No. 1 the pay streak, which varies greatly in thickness, is divided by a reef. Beyond the limits of the pay streak the gravels continue to show prospects of gold. The pay streak in one instance is reported to be 3 feet thick and to underlie 11 feet of muck and barren gravel.

Very little gold has as yet been taken from this creek, though the prospecting shows a distribution of gold somewhat similar to that on Glenn Creek. Preparations were being made for mining on five claims on this creek during the winter of 1902–3. During the winter of 1901–2 the pay streak from an area 15 by 20 feet was mined out. This dump has yielded $1,000, but has not all been washed.

It was proposed to work the creek during the winter of 1902–3 with steam thawers according to the following plan: Shafts were to be sunk to bed rock, a depth of 10 to 15 feet. From the foot of each shaft the pay streak would be drifted on for a distance of about 40 feet, with a cover of 10 or 11 feet. It was regarded as impracticable to drift farther than this on account of the difficulty of carrying steam pipes and moving the pay dirt to the foot of the shaft and keeping the gangway open. Steam thawers, if properly managed, are more economical in mining frozen ground than the old method of "burning" with wood, for the reason that the steam points can be driven directly into the ground where thawing is needed, and the pay dirt can be mined immediately as it is thawed, whereas by the old method work is interrupted while the fire is burning and, at best, a night's burning will not thaw more than 1 foot of gravel.

Gold Run does not carry sufficient water for sluicing after the snows have melted in summer, and mining operations will necessarily be suspended during the summer months.

Rhode Island Creek is larger than either Glenn or Gold Run and flows in a well-marked valley cut about 100 feet below the level of the bench on which the streams described are located.

The bed rock consists of schists similar to those at Glenn Creek, except that it probably contains more graphitic schist than at Glenn Creek. The strike of the bed rock is reported to be northwest and southeast. Stringers of quartz have not been found in it.

The gravel consists of more or less angular fragments of schist similar to that at Glenn Creek, except that graphitic schists are more common, as well as pebbles and bowlders of igneous rocks. Two types

of igneous rocks were recognized, one of which is a green, compact rock, probably an altered intrusive from the schist series, while the other is an unaltered rock of very basic type. The creek has not been thoroughly prospected on account of inundation of the prospect holes. In the middle of the creek, bed rock has not been reached, but good prospects have been found on the rims. At Claim No. 5, about one-fourth of a mile above the mouth of Gold Run, a shaft was being sunk on the left limit of the pay streak, with a view to draining the bed rock with a steam pump. This shaft penetrated, to a depth of 12 feet, broken bed rock similar to that on Glenn Creek. The pay streak here is believed to be from 50 to 60 feet wide. The average yield from a number of pans taken from the pay streak was reported to be 11 cents. About one-half mile above this place mining was in progress on a claim on which the bed rock has been partially drained. The claim had not been fully crosscut, but it was believed to have a pay streak 60 feet wide. Where it has been prospected the pay streak is 2 feet thick and underlies 6 feet of muck and barren gravel. Twenty-five and 50 cent pans have been obtained from this pay streak. The owners of this mine were attempting to work it in summer, stripping off the muck and barren gravel and shoveling the pay dirt into sluice boxes.

On the bench between Glenn Creek and Gold Run have been found shallow gravels carrying placer gold in paying quantities. It is reported that generally on this bench the bed rock is covered by a layer of clay, probably derived from the decomposition of the bed rock. This clay carries a little gold, the coarsest being near the surface. The gold does not extend far up the hill to the northward, but can be traced down the hill for several thousand feet. Two claims have been located on which gold is found in paying quantities. At the upper end of the upper claim the excavation shows 6 inches of reddish-clay soil overlying 1 foot of gravel consisting of clay mixed with small pieces of gray schist similar to the bed rock, but containing occasionally large, well-rounded pieces of a basic igneous rock. This gravel is the pay streak and rests on bed rock. At the lower end of this excavation, about 200 feet from the point described, 4 feet of nearly barren gravel wash overlie the pay streak, which consists of 1 foot of gravel made up of broken fragments of schist bed rock. The pay streak has a width of 65 feet. Beyond the pay, however, on the south side, a prospect hole was sunk through 4½ feet of broken schist débris, showing little, if any, gravel wash. Colors of gold were found near the bottom of this hole. On this claim the attitude of the gravel indicates a current from the north.

The lower claim has been prospected at a point one-fourth mile southeast of the upper claim. Here prospect holes show the gravel to be from 6 to 8 feet thick. The position of the pebbles indicates deposition by a current flowing nearly east. The gravel contains a

few large, round bowlders of igneous rock. It is claimed that this gravel from the surface down will pay for washing, and that the pay goes into the bed rock to a depth of 1 foot. The pay streak is more than 100 feet wide.

The gold on these claims is comparatively coarse, nuggets as large as one dollar being common, though the average pieces are smaller than one cent. On the lower claim the pieces of gold are probably finer than on the upper. The pay streak at the former place is reported to average 6 cents to the pan. The gold nuggets have a rough surface, showing that they have not traveled far.

At the upper claim some sluicing has been done with water collected in a system of ditches on the surface of the bench. These ditches provide a limited amount of water when the snow is going off in the spring and after heavy rains in the fall. A ditch about 2 miles long has recently been dug to bring water from Rhode Island Creek, but except in a rainy season the water from this source will probably be insufficient for sluicing.

Mining has been in progress on Eureka Creek, 1 or 2 miles east of Glenn Creek, for the last two years. These mines have not been great producers of gold, and the writer was unable to visit them. They are reported to be confined to a section of the creek bed 1 mile long, and situated nearly opposite the mines on Glenn Creek.

Good prospects of gold are reported from Omega Creek and McKinley Creek in this region, and within a few miles of Glenn Creek. Their exact location is not known and they were not examined by the writer.

During the last season gold prospects were found on Pioneer Creek and several other northern tributaries of the Hootlenana. These lie east of Glenn Creek and probably within 10 miles of it.

One prospect hole was sunk to a depth of 65 feet in the gravels of Baker Flats. While no pay streak has been located, colors of gold are reported. It will require further prospecting to show whether these gravels are workable as gold placers.

On Minook Creek and on its several tributaries, known as Hunter, Little Minook, Ruby, and Slate creeks, placer mines were in operation last summer.

SUMMARY.

In the vicinity of Glenn Creek the known gold placers are confined to the creeks and benches within an area about 1 mile wide and 2 to 3 miles long, lying parallel to the north side of the Baker Flats. This area coincides roughly with the limits of a broad bench cut on bed rock, 100 to 200 feet above the level of the lowland. Two of the creeks carrying placer gold rise within this bench, while two larger ones are gold bearing only where they cross it.

The bench generally is covered by a soil derived from the bed rock

in situ, but in some places bodies of shallow gravel occur. These gravels consist principally of angular material derived from the immediate bed rock, but they contain some bowlders and pebbles which have undoubtedly been transported. The gravels of the creeks and gulches incised in the bench are essentially similar to those found on the bench.

From the evidence in hand, it seems at least possible that the lowland of the Baker Flats is the bed of an extinct lake and that the broad bench at Glenn Creek is in part a beach and in part a local peneplain produced at the base-level of this lake while it existed. The mixture of local and transported material is readily explained in this way, either by water action alone or by floating ice.

The pieces of gold found here are apparently not greatly waterworn, and have probably not been carried far from their original position in the bed rock. The bed rock of the gold-bearing area consists of schist, belonging to a series which has an extensive distribution in this region. On Glenn Creek, however, a system of quartz stringers striking parallel with the longer dimension of the gold-bearing area has been noted, making it seem probable that there is a zone of mineralization in the bed rock underlying the gold-bearing area.

The information at present available regarding the geology and physiography of this region is too meager to warrant any definite conclusions as to the origin of the placers, but the following explanation, which is believed to agree with the facts as far as known, is advanced tentatively:

The gold at Glenn Creek has been derived from a zone of mineralization in the bed rock north of Baker Flats. This zone extends eastward for 10 or 12 miles, to the northern tributaries of the Hootlenana, on which placers have recently been found, but is less than a mile in width. As the bed rock was eroded, the gold from this mineralized zone was concentrated by both wave and stream action along the margin of the old Baker Lake. By the draining of this lake the old beach was left as a high bench, and the gold from it has been partly reconcentrated in the beds of recent streams, to make the creek placers, while a part of the original beach deposit remains in the form of bench placers.

THE CHISTOCHINA GOLD FIELD, ALASKA.[a]

By WALTER C. MENDENHALL.

GENERAL DESCRIPTION.

The Chistochina gold field is a small placer area in the northwestern part of the Copper River Basin, Alaska, near the intersection of the one hundred and forty-fifth meridian west longitude and the sixty-third parallel north latitude. The district is among the foothills just south of the Alaskan Range, which rises to heights of 8,000 or 9,000 feet in the vicinity, and serves as a gathering ground for ice fields and glaciers, from which torrential rivers flow north to the Tanana and south to the Copper. All of the diggings at present are on two streams, both tributary to Chistochina River, which flows into the Copper. The larger, but not the more important of these, the Chesna, is about 12 miles long and empties into the Chistochina 11 miles below its source, in the Chistochina Glacier; the smaller, Slate Creek, which, with its tributary, Miller Gulch, yields nine-tenths of the gold of the district, is only 4 or 5 miles long and joins the Chistochina just as the latter emerges from the glacier.

The field is usually entered over the military trail from Valdes, the nearest seaport, 225 miles to the south, but is accessible from Eagle City on the Yukon, about 250 miles north. The lack of navigable streams along these routes means that supplies must be transported practically the entire distance by pack train or sled, and that therefore the district is one of the most remote and difficult of access in Alaska.

GEOLOGY.

Our present knowledge of the geology of the region may be briefly summarized as follows:

That part of the Alaskan Range lying immediately north of the gold area is made up principally of micaceous schists whose thickness and age are unknown.

Immediately south of the schists and separated from them by a fault, whose throw probably exceeds 10,000 feet, is a belt of Permian

[a] This paper is an abstract from a more complete discussion which is shortly to appear in a paper entitled: The Mineral Resources of the Mount Wrangell District, Alaska.

beds consisting in the upper part of shales and limestones, but including, at lower horizons, tuffaceous sediments and flows, which have an aggregate thickness of 6,000 or 7,000 feet. Many basic igneous masses occur as dikes or intrusive sheets in these sediments. They are especially abundant near the fault. The shales are slightly metamorphosed in the vicinity of Slate Creek and Miller Gulch, where some cleavage has developed and a few quartz stringers are found cutting them. Eocene lignite-bearing beds occur here and there in small patches infolded with the Permian.

South of the Permian belt occurs a complex terrane of older rocks, consisting of conglomerates, quartzites, tufaceous beds and probably flows, which appear to be faulted against the Permian. This terrane is intruded and altered by dikes and greater masses of granite and quartz-porphyry. One effect of the intrusion and alteration is a general impregnation by pyrite, whose oxidation products color the rocks rust-red and render them especially conspicuous.

In addition to these easily separable consolidated rock masses, unconsolidated clays and gravels, either primarily or secondarily of glacial origin, occur in the valleys generally. Near the sources of the streams these deposits are confined to flood plains or narrow bordering terraces, but downstream the area covered by them widens, until it merges with the broad drift-filled valley of the upper Copper Basin, from whose borders isolated bed-rock areas rise as islands.

Besides these Pleistocene deposits in the lowlands, a thin sheet of cobbles, called by the prospectors the "round wash," is conspicuous on the hilltops about the head of Slate Creek, Miller Gulch, and some of the tributaries of the upper Chesna.

GOLD OCCURRENCES.

Practically all of the gold mined at present is taken from Miller Gulch, Slate Creek, and the Chesna River, whose combined yield for 1902 is estimated at $225,000. Of this amount, Miller Gulch probably furnished $175,000, Slate Creek $30,000, and Chesna River $20,000.

Miller Gulch, whose yield is thus seen to be much greater than that of any other stream in the district, is a steep ravine, less than a mile long, tributary to Slate Creek. Its bed, decreasing in width from 200 or 300 feet near its mouth to but 4 or 5 feet near its source, is sheeted over with gravel to a depth of from 4 to 8 feet. This gravel is composed principally of fragments of the somewhat metamorphosed Permian shales in which the ravine is cut, but has an admixture of diabase and "bird's-eye porphyry" from the intrusives in the shale, and of cobbles from the "round wash" which occurs over the tops of the adjacent hills. The gold is rather uniformly distributed across the gulch, but vertically exhibits the usual concentration near bed rock. The richness and shallowness of the gravels, and the steep gradient of the stream, giving abundant fall, have made it easy to win the

gold by simple sluicing methods, and have caused the early development of Miller Gulch to a maximum of production, while the poorer or deeper diggings in the other creeks, where in some instances expensive plants are required, have been neglected.

The waters of Miller Gulch, discharging into Slate Creek, carry with them some of the gold from the gulch. As a consequence, for a short distance below the junction, Slate Creek is rich; indeed, nearly all of the gold which it has yielded has been obtained here. Above Miller Gulch, on Slate Creek, bed rock is not always within easy reach, in part because of burial beneath alluvial fans from tributary creeks, in part because of irregularities attributable to glacial action; and where bed rock is accessible, the yield is not more than $10 or $15 a day to the man—about the wage of the district.

The gravels of Slate Creek contain representatives of all the rock types found in Miller Gulch, and in addition a certain proportion of material derived from the older quartzites, pyroclastics, and granitic intrusives occuring on the south side of its lower valley.

On Chesna River the diggings are confined to two localities about 8 miles apart, one near the source, the other near the mouth of the stream. The greater part of the work on the upper Chesna has been confined to a small tributary called Ruby Gulch. In the upper part of this gulch the conditions of accessibility of bed rock and of geologic relations resemble those of Miller Gulch, but the gravels are not so rich, and the workable ground is not so extensive. The operators, however, have been able to make satisfactory profits in their work. Along the lower course of Ruby Gulch the operations have been rather in the nature of development. Bed rock is not reached, the gravel being removed by ground sluicing to a clay stratum on whose surface the gold is found. The yield here is reported to about pay expenses.

The valley of the middle Chesna is clogged by glacial deposits, and for a number of miles the cursory attempts to find bed rock have not been successful, but along the lower Chesna, beginning at a point about 1½ miles above the mouth and extending thence upstream nearly the same distance, bed rock is within easy reach for short distances on either side of the river. There is a shallow canyon a few hundred feet long near the lower end of this stretch, and present operations are confined to small areas above and below this canyon on the discovery claim of the district.

The Chesna has been tapped a few thousand feet above the canyon and the water conducted by a ditch along the south bank of the river to a point just below the canyon, where a hydraulic plant has been installed with a head of 125 feet.

Although over considerable areas the gravel is but 4 to 8 feet deep, it was found impracticable to handle it effectively by ordinary sluicing methods, because of the presence of large bowlders and much water, but those who have installed the hydraulic plant anticipate

that by its use and the construction of drainage ditches the gold can be easily and profitably secured. As pans are reported to run from 1.7 to 5.5 cents each below the canyon, with a maximum yield of $1 on bed rock, their anticipations seem to be justified.

ORIGIN OF THE GOLD.

The gold from the various streams on which operations are conducted is rather uniform in form, color, and assay value. It generally occurs in flattened scales or grains, and is but rarely rough and irregular. It is clean looking and bright yellow in color, and its assay values are reported to vary from $18 or $18.50 per ounce on Miller Gulch and the upper Chesna to $18.72 on the lower Chesna.

One-ounce nuggets are not unusual on Miller Gulch, and one piece is reported which weighed 4 ounces. On Ruby Gulch the largest nugget found is valued at $12.75, but nuggets are very rare on the lower Chesna, the gold being in the form of thin, flat scales. These variations in coarseness and in assay value are of the kind which would be expected if the source of the gold were in the region near the head of Miller and Ruby gulches, where the gold is coarser and the values are lower.

Some of the operators of the district, admitting that the gold comes from the vicinity of upper Slate Creek and Chesna River, maintain, with much show of reason, that it is derived there from the "round wash," which is particularly heavy about the head of Miller Gulch and Slate Creek. It is also present on the divide between Ruby Gulch and the next stream east, so that the advocates of this theory are able to prove that each stream at present worked to a profit drains an area in which the "round wash" is found. They likewise regard the smooth surface of the gold as evidence that it is waterworn and has therefore been brought from some extraneous source, as is so evidently true of the "round wash."

Some facts, however, are distinctly opposed to this hypothesis, and others admit of as ready explanation on another basis.

A small stream, on which a group of claims known as the "Big Four" has been staked, heads opposite Miller Gulch and flows down to the Chistochina Glacier. The heaviest deposit of the "round wash" known in the region occurs on the slopes drained by this brook, which seems therefore to be more favorably situated than Miller Gulch, relative to this deposit as a source of the gold; but the Big Four claims yield fine gold in moderate amount and are not to be compared in richness to Miller Gulch. Furthermore, Ruby Gulch and the creek next east of it seem to be equally favorably situated in relation to the deposit of the "wash" which occupies the divide between them, yet one has yielded operators a handsome return and the other is not profitable.

It is even more significant that the sources of the gold-bearing creeks are all within an area whose extent coincides with a region of local metamorphism in the Permian shales, and that no other metamorphosed areas of these beds and no other gold districts within them are known. Where they have been metamorphosed an incipient cleavage is developed and the shales carry a few narrow quartz stringers. It is believed that the flat, smooth character of much of the gold is sufficiently accounted for by its origin in these shales and by its purity and consequent softness, which lead to rapid smoothing and polishing with but little transportation.

It is therefore concluded that the gold originates in these Permian beds, and that in its genesis it is related to the local metamorphism which they have suffered. It is evidently post-Permian in age, and since Eocene beds deposited unconformably upon the Permian are but little folded and wholly unmetamorphosed, it is probably also pre-Eocene.

STREAM TIN IN ALASKA.

By ALFRED H. BROOKS.

While studying the gold placers at York, on the Seward Peninsula, Alaska, the writer's attention was called to the occurrence of stream tin (cassiterite) in the placers. The stream tin was found at two localities in the region. The first is on Buhner Creek, a westerly tributary of the Anikovik River. The mouth of Buhner Creek is about 3 miles from Bering Sea. The occurrence is best located by stating that it lies about 10 miles east of Cape Prince of Wales, and very near the northwestern extremity of the continent. On Buhner Creek 2 to 3 feet of gravel overlies the bed rock, which consists of arenaceous schists, often graphitic, together with some graphitic slates. The bed rock is much jointed, the schists being broken up into pencil-shaped fragments. They strike nearly at right angles to the course of the stream and offer natural riffles for the concentration of heavier material. A hasty reconnaissance of the drainage basin of this stream, which includes not more than a square mile of area, showed the same series of rocks throughout its extent. At a few localities some deeply weathered, dark-green intrusives were found, probably of a diabasic character. The slates and schists are everywhere penetrated by small veins, consisting usually of quartz with some calcite, and frequently carrying pyrite and sometimes gold. These veins are very irregular, often widening out to form blebs, and again contracting so as not to be easily traceable.

The stream tin is concentrated on the bed rock with other heavy minerals, and was found by the miners in the sluice boxes. A sample of the concentrate in one of the sluice boxes was examined by Mr. Arthur J. Collier, and yielded the following minerals: Cassiterite, magnetite, ilmenite, limonite, pyrite, fluorite, garnets, and gold. The determination of percentage by weight was as follows: 90 per cent tin-stone; 5 per cent magnetite; other minerals, 5 per cent. The cassiterite occurs in grains and pebbles, from those microscopic in size to those half an inch in diameter; they have subrounded and rounded forms. In some cases there is a suggestion of pyramidal and prismatic crystal forms. The cassiterite varies in color from a light brown to a lustrous black.

A second locality of this mineral was found on the Anikovik River about half a mile below the mouth of Buhner Creek. Here the cassiterite was also found with the concentrates from the mining operations. One pebble of stream tin obtained from this locality was about 2 inches in diameter.

It will be necessary to make a more detailed examination of this region to determine where this mineral occurs in the bed rock. The facts obtained by the writer point toward the conclusion that its source was in the quartz and calcite veins in which the gold was found. No cassiterite was, however, found in this vein material.

No evidence was found that this cassiterite is in any way connected with granitic intrusions, which is its usual association in other regions. As far as known there are no intrusives of such rocks within the drainage basins of streams where the tin was found. The nearest known granitic rock is the biotite-granite stock which forms the promontory of Cape Prince of Wales and which is at least 10 miles distant.

This discovery of stream tin has, at present, scientific rather than commercial interest. No developments have been made which would warrant the conclusion that valuable tin deposits exist in the York district. It is worth while, however, for the prospectors who visit this region to familiarize themselves with the physical properties of the mineral, so as to be able to recognize it if found. By this means deposits carrying values may be discovered, and the cassiterite will probably be traced to its source in the bed rock.

COPPER DEPOSITS OF THE MOUNT WRANGELL REGION, ALASKA.

By WALTER C. MENDENHALL and FRANK C. SCHRADER.

GEOGRAPHY AND EXPLORATIONS.

Near the southeast corner of the mainland mass of Alaska, very near the intersection of parallel 62° north latitude and meridian 144° west longitude, stands Mount Wrangell, 14,000 feet high, an active volcano, and in many respects the most impressive, although not the highest, peak of the group to which its name is given. This group, a complex pile of volcanic material, with half a dozen or more great summits over 12,000 feet in height, occupies the angle between two diverging branches of the St. Elias Range.

The drainage of a part of its northern and of all its western and southern slopes is carried to the Pacific by the Copper River, while White River and the two main branches of the Tanana, called the Nabesna and the Chisana, rise on the north slope east of the Copper and flow by way of the Yukon into Bering Sea.

In the drainage basins of the upper portions of these streams, on both sides of the range, it has been known for many years that native copper exists. Yukon and White River Indians used it in the interior in the earlier days for knives and bullets, and Copper River natives exhibited similar specimens at the coastal trading stations long ago. Lieutenant Allen in 1885 secured specimens of bornite from Chief Nicolai at Taral, but most of the knowledge possessed by white men concerning these occurrences has been secured since 1898, when they first entered the region in force. Since then prospectors have explored rather thoroughly the southern field, which includes the basins of the Chitina and the Kotsina, large eastern branches of Copper River. As a result of this exploration, they have located many claims in this region and have done a little development work. At the same time somewhat less thorough prospecting has been carried on in the more distant and less accessible region north of the Wrangell Mountains, but thus far the search for promising copper deposits has been less successful there.

In 1891 Dr. C. Willard Hayes,[a] while en route with Lieut. Frederick Schwatka from Fort Selkirk to the coast at the mouth of Copper River, visited the Kletsan Creek deposits on the upper White River. In

[a] An expedition through the Yukon district: Nat. Geog. Mag., Vol. IV., pp. 117-162.

1899 the same locality was visited and described in some detail by Mr. Alfred H. Brooks,[a] of the Geological Survey, while en route from Pyramid Harbor to Eagle City with Mr. W. J. Peters. In addition to the Kletsan Creek occurrences Mr. Brooks gives notes on the extension of the copper belt toward the west.

In 1900 Messrs. Schrader and Spencer[b] visited the southern field and issued a comprehensive report on its geology and mineral resources, particular attention being given to the copper occurrences.

In 1902, while Mr. W. C. Mendenhall extended the earlier work of Messrs. Schrader and Spencer in the western portion of the southern field, Mr. F. C. Schrader visited the region about the head of the Copper, the Nabesna, and the Chisana rivers. The results of all these studies, with such information as can be gleaned from other sources concerning the localities which the geologists have not visited, will shortly be issued as a paper on the mineral resources of the Mount Wrangell district, and for a full account of what is at present known on the subject this report should be consulted. Only that portion of it which bears upon the copper occurrences is summarized here.

SOUTHERN DISTRICT.

This, the best known and probably the richest of the two copper belts of the region, occupies a strip nearly 100 miles long and of varying width along the southern base of the Wrangell Mountains. Throughout this zone, in the drainage basins of the Chitina, the Kotsina, and the Cheshnina there are scattered deposits of copper ores, some of them very promising.

GEOLOGY.[c]

The lowest stratigraphically, and therefore the oldest, of the economically important formations of this belt, is a great series of successive basalt flows, now somewhat altered, which has been called the Nicolai greenstone. A thickness of not less than 4,000 feet of this basalt is exposed near the western part of the area in which it is known, and its maximum may be very much greater, as the base of the formation is nowhere exposed. The thin sheets in which this fluid lava issued now lend themselves to the determination of structure in the formation almost as well as does bedding in sedimentary rocks.

After the close of the period of great volcanic activity of which the Nicolai greenstone is the record an era of sedimentation set in, apparently without any intervening erosion. The first of the sediments deposited was a massive white limestone, which is particularly prominent along the Chitistone River and has therefore been called the

[a] A reconnaissance from Pyramid Harbor to Eagle City, Alaska: Twenty-First Ann. Rept. U. S. Geol. Survey, Pt. II, 1900, p. 377 et seq.

[b] Geology and mineral resources of a portion of the Copper River district, Alaska. Special publication of the U. S. Geol. Survey, 1901.

[c] This account of the geology is summarized from the report of Schrader and Spencer.

Chitistone limestone. A series of interbedded thin limestones and shales which carry Triassic fossils were next laid down, and these had accumulated to a thickness of several thousand feet before the era of sedimentation was brought to a close. Within the Chitina Basin the massive Chitistone limestone does not carry fossils, but it has been correlated with similar beds beyond the Scolai Range to the north, from which Permian shells have been taken. If we accept this evidence as determining the Permian age of the Chitistone, it becomes highly probable that the greenstone beneath it, with no erosional interval intervening, falls in the Carboniferous, and perhaps in the Upper Carboniferous. A more definite conclusion than this can not be reached with the evidence at present available.

Following the outpouring of the Nicolai lavas and the deposition of the succeeding calcareous terranes a period of stresses was inaugurated. during which these rocks were everywhere thrown into a succession of open folds. Accompanying or following this folding the rocks were brought within reach of subaerial erosional agencies, and the folds were truncated; but the land was not, it is believed, reduced to a plain. On the contrary, a distinct relief remained, and when the next period of deposition began the sediments were laid down in local basins and unconformably upon the truncated edges of the folds in the older rocks. These deposits were gravels and muds, which have since consolidated into the conglomerates and shales of the Kennicott formation. They were deposited during Jura-Cretaceous time.

After the deposition of these gravel beds the region was again elevated and folded slightly, and a period of erosion began which reduced the land to a generally plane surface. This plain was elevated, dissected, and partly buried under the extravasated igneous material whose accumulations have produced the peaks of the Wrangell Mountains.

This, in brief, is the history, as at present understood, of the events which have resulted in the accumulation, burial, folding, erosion, and later partial reburial of the rocks which are economically important in the region. Of these the chief is the Nicolai greenstone. As is often true of greenstones in other parts of the world, this rock seems to have contained originally minute quantities of copper disseminated throughout its mass. During the operation of the processes to which the formation has since been subjected some of this disseminated copper has been concentrated at various points within the mass of the greenstone or the overlying limestone, and some of these accumulations are of sufficient magnitude to constitute workable copper deposits.

A plane which has seemed to be a favorite locus for these accumulations is the contact between the greenstone and the overlying limestone. Nearly all of the prominent ore bodies are on or near this plane, sometimes in the greenstone just below it, sometimes,

but more rarely, in the limestone just above it, and occasionally in fissures which cross it.

The ore bodies have assumed various forms, and for convenience of discussion these forms have been divided into two general classes, vein deposits and bunch deposits.

The vein deposits are so defined as to include all tabular ore masses, whether in true fissures or along joint or fault planes or shear zones. The ores may be found only in shoots within the planes which have controlled their form, but are characteristically of indefinite extent in one or two directions.

The "bunch" deposits, on the other hand, are irregularly bounded masses of ore, from a few inches to a few feet in diameter, which usually are not obviously related to fractures or fissures or joint planes, but in form are much like basic segregations in igneous rocks—i. e., they generally have indefinite limits, grading from masses of practically pure ore at the center through leaner and leaner phases, into the entirely unmineralized inclosing country rock. These "bunches" are so numerous in certain parts of the field within the upper part of the greenstone that prospectors who have opened a number of them, 400 or 500 feet below the base of the limestone, have been led to conclude that a ledge of ore parallels the contact at this horizon.

MINES AND CLAIMS.

In order to give an idea of the different types of deposits and the conditions of development, some of the best-known occurrences will now be described.

Nicolai mine.—The Nicolai mine is located near the eastern part of the Chitina copper district, on Nicolai Creek, a few miles west of the Nizina River. The vein, a fissure with definite walls, is in the greenstone not more than 50 feet below the base of the limestone. It trends about N. 50° E. and dips 75° SE., and a displacement of not more than 50 feet has taken place along it. The main fissure, which may be traced for several thousand feet, although it shows no ore except near the place of discovery, is paralleled at distances of 90 and 140 feet by two other fissures, which also contain copper minerals. In the vicinity of a shaft which has been sunk in the process of development, the vein has a width of from 8 to 12 feet and is about equally divided by a horse of greenstone 3 or 4 feet across. The ore on either side of this horse is practically pure bornite with only a small amount of quartz associated in an irregular way. Locally there is a band of chalcopyrite lying next the hanging wall.

In 1900, when the shaft had been sunk to a depth of 30 feet, ore from 2 to 4 feet in thickness was exposed throughout this depth.

Bonanza claim.—This claim is located upon a high ridge between Kennicott Glacier and McCarthy Creek, and is about 8 miles west of the Nicolai mine. This vein also is a fissure, which cuts across the contact between the greenstone and the limestone, although for some

distance below the contact the vein is barren. It is irregular in width, varying between 2 and 7 feet, and has a strike of about N. 40° E. There is no quartz or other vein material associated with the ore, although there is sometimes a considerable amount of crushed limestone between the walls. The ore is practically pure chalcocite, or copper glance, which is exposed in solid masses 2 to 4 feet across and 15 feet or more in length. Besides the ore within the fissure there are bedded ore bodies running off into the limestone along the planes of stratification. The ore is regarded as a replacement of the limestone. A selected sample gave over 70 per cent copper and 14 ounces of silver per ton, with a trace of gold.

Louise claim, Elliott Creek.—Elliott Creek is a tributary of the Kotsina River and is near the western end of the copper area. The Louise claim is on a small branch of Elliot Creek called Rainbow Creek. Here, in a shallow open cut, a slickensided face of greenstone, forming a well-defined and, so far as exposed, regular foot wall, is revealed. This face strikes N. 10° E. and dips 70° NW. The cut does not expose an equally definite hanging wall, but adjacent to the foot wall is a crushed zone, which has an extreme width of 15 or 16 feet. Within this zone the greenstone is generally irregularly fractured, but at the present surface there exists, in the center of this crushed mass, a "horse" of solid greenstone 7 or 8 feet wide. It is probable that the slickensided foot wall is a fault plane, but since no displacement was observed in the limestone above, its throw can not be great. The mineralization within this belt consists of an impregnation of chalcopyrite and bornite, the latter mineral being superficially more abundant. The impregnation follows the fractures and partakes of their irregularity, the exposed surfaces of the greenstone fragments generally showing more or less ore.

Goodyear claim, Elliott Creek.—Across Rainbow Creek from the Louise claim and a few feet below it, an open cut in greenstone reveals a well-defined fissure vein 4 to 5 feet wide, striking N. 12° E. and dipping 45° SW. The vein can be traced 50 or 75 feet up the slope toward the limestone contact before it is buried under the talus.

The gangue minerals are quartz and calcite, entirely distinct from the perfectly definite walls of greenstone, and this gangue carries heavy bodies of bornite and a smaller quantity of chalcopyrite. While the heavy ore bodies are confined to the vein, the shattered hanging wall and the more massive foot wall are impregnated with copper sulphides for some distance above and below.

In the upper part of the open cut a slight horizontal fault has displaced the vein laterally, so that the hanging wall above the displacement is continuous with the foot wall below it.

Eleanor, Davy, and associated claims, Kotsina River.—Two thousand five hundred feet above the level of the Upper Kotsina River, near the crest of a sharp ridge separating two tributaries, Peacock

Creek and Roaring Gulch, a number of claims have been staked in that belt in the greenstone, a few hundred feet below the limestone, which seems everywhere to carry "bunches" of copper ore. No development work has been done here, but the exposures on the faces of the greenstone cliffs show small ore bodies from a few inches to 2 or 3 feet in diameter and irregular in outline. They usually have cores of nearly pure bornite or chalcocite, but marginally these copper minerals become mingled with the surrounding greenstone as though the replacement had been less complete on the borders of the mass.

In one or two instances narrow fissures from one-half inch to 1½ inches wide were noted which extend downward from ore pockets and are themselves filled with copper sulphides, but in the majority of cases no such connection between pocket and veinlet is to be seen.

The most of the copper in the district is in the form of the sulphides, bornite, chalcocite, and chalcopyrite, but native copper also is known. A bowlder of the latter weighing several tons has been found in the gravels of Nugget Gulch, a tributary of the Kuskulana River, near the western end of the area; and on the upper Kotsina River several claims in which native copper occurs associated with other ores have been staked in the greenstone 4,000 or 5,000 feet below the contact with the limestone. Two of these, the Keystone and the Copper King claims, are described here.

Keystone claim.—Two short forks, both glacial streams, unite to form Kotsina River. The southern one of these drains two glaciers, and in a little narrow post-Glacial gorge just below the foot of the northernmost of these glaciers is the Keystone claim. Here in the wall of the canyon, in the greenstone, are some compact quartz stringers and lenses, varying in width from a mere line to 5 or 6 inches. They strike east and west and are approximately vertical.

Epidote is associated with the quartz, sometimes in equal amount, as a gangue mineral in the veins. Native copper occurs in the epidote and in the quartz, but is more abundant in later irregular crevices traversing both minerals of the gangue. A small amount of chalcocite is present also, and in one prominent example it fills a narrow fissure which intersects masses of both epidote and quartz and is evidently later than either.

Copper King claim.—This prospect is situated on the north side of the Kotsina Valley about one-fourth mile west of the Keystone claim and 700 or 800 feet above the river level. It consists of an altered belt of greenstone, in part amygdaloidal, extending several feet east from a well-defined north-south vertical crevice, along which there has probably been some movement. The greenstone within this altered zone has been rendered quartzose, the quartz occurring as stringers and as a filling of the amygdules. The septa between the latter are sometimes changed to granular epidote and chlorite.

Native copper occurs here and there in the mass in grains and

flakes, sometimes intimately associated with chalcocite. The latter mineral occurs with the native copper and in minute crevices which seem to be later than the general alteration and silicification.

NORTHERN DISTRICT.

North of the volcanic pile of the Wrangell Mountains, in the valleys of the Copper, of the two forks of the Tanana River, called the Nabesna and the Chisana, and of the White River, native copper has been reported from time to time, and the reports have been substantiated by prospectors and others who have brought out nuggets of the metal.

GEOLOGY.

The geologic conditions under which the copper occurs in the northern district are different from those which prevail in the Chitina Basin. Although the Nicolai greenstone, which is the great copper reservoir for the southern field, is probably present, it does not play the important part that it does south of the mountains.

A great calcareous series, which is believed to be equivalent to the Chitistone limestone, is clearly recognized over a large area. It has been affected by complex structures in the northern as in the southern district, and after its deformation and erosion Mesozoic beds have been deposited unconformably upon its edges, and the still later lavas of Mount Wrangell have buried many of its outcrops. In these respects its history is similar to that of the equivalent beds to the south. The essential difference, however, is in its relation to the basic igneous rocks. Instead of being clearly deposited conformably upon the surfaces of earlier flows, it has been extensively cut by later intrusives, and the contacts with these diabases, which are altered in many cases to greenstones, seem to be the loci for the accumulation of native copper and other copper ores. One occurrence, of no economic importance, is known in an altered mass of diorite.

OCCURRENCES OF COPPER ORE.

The evidence at present available, although incomplete, is better than that upon which earlier judgments were based. It does not indicate that these northern occurrences have *much* commercial value. A brief description of some of them follows:

Monte Cristo Creek and California Gulch are respectively western and eastern tributaries of the Nabesna River, which they join within 3 or 4 miles of the foot of the glacier. A mass of altered diorite occurs in this region, and along the lines of fracture in this diorite there occur sporadically films and blotches of malachite, which is probably derived from a little chalcopyrite contained in the altered rock.

In the mountains just east of California Gulch fragments of low-grade copper ore, consisting essentially of pyrrhotite and copper

pyrite, are found in the gulches. These are of such size as to indicate that the ore bodies from which they came must be at least 6 inches wide. The ore is of so low grade, however, assaying but six-tenths of 1 per cent, that the deposit is without value. This ore is supposed to be related to an intrusive contact between the greenstone and the limestone about the heads of the gullies in which the ore is found.

On Camp Creek, an eastern tributary of the Nabesna, about 15 miles below the glacier and about 3 miles above the mouth of Cooper Creek, Mr. Alfred B. Iles reports a vein of chalcocite from 6 inches to 2 feet in thickness. Both the limestone and the greenstone are present in this region, and it is probable that the ore occurs in association with them.

Natives living on the Chisana (Upper Tanana) in 1902 had in their possession a number of small copper nuggets, and one mass which weighs 35 to 40 pounds. These, they say, came from a small creek which flows into the Chisana from the west at a point about 5 or 6 miles above the foot of the glacier. Occasionally the nuggets have adhering to them fragments of amygdaloidal greenstone and of calcite gangue. It is likely that they occur in the usual way, in association with the contact of the diabase and the Permian limestone.

Prospectors, among whom may be mentioned Mr. D. K. Van Cleef, report the finding of numerous copper nuggets along the north base of the Nutzotin Mountains between the Upper White and the Chisana. Mr. Van Cleef reports also the probable existence of a sulphide vein in a canyon of the middle White.

Kletsan Creek, which drains the north base of Mount Natazhat, is a southern tributary of Upper White River. Native copper in placer form has been known in this region since Dr. Hayes[a] visited it in 1891, and it was probably a source of supply for the Indians long before that. Mr. Alfred H. Brooks[b] in 1899 reported one nugget 8 or 10 pounds in weight, and numerous other smaller pieces from this locality. In a search for the origin of the nuggets, Mr. Brooks found stringers of the native metal occurring in calcite veins in dioritic greenstones near the intrusive contact of the greenstone with Permian limestone. No other minerals except a superficial staining by malachite were observed. The character of the bed-rock geology and the finding of native copper in stream gravels led Mr. Brooks to infer that conditions similar to those at Kletsan Creek are likely to be found in the region between the Upper White and the Chisana.

From these meager descriptions it will be realized that the search for valuable deposits in the field north of the Wrangell and Skolai Mountains has not thus far revealed any large ore masses, but as the search has been by no means exhaustive it is entirely possible that deposits of practical importance may be found in the future.

[a] An expedition through the Yukon district: Nat. Geog. Mag., Vol. IV, pp. 117-162.

[b] A reconnaissance from Pyramid Harbor to Eagle City, Alaska: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, 1900, p. 377 et. seq.

COAL RESOURCES OF THE YUKON BASIN, ALASKA.[a]

By ARTHUR J. COLLIER.

INTRODUCTION.

The coal beds of the Alaskan part of the Yukon Basin occur in soft sandstones and shales, with intercalated beds of conglomerate. These beds are in part in the Nulato series of the Upper Cretaceous and in part in the Kenai series of the Eocene. The two series are apparently conformable and have strikingly similar lithologic characters. They can be separated only after close stratigraphic and paleontologic study, and hence it is not now possible to state definitely what part of the coals are Cretaceous and what part are Eocene.

For the purpose of discussing its coal resources the Yukon Basin of Alaska may be divided into three provinces. The Upper Yukon includes that part of the valley lying between the international boundary and the great lowland known as the Yukon Flats. The Middle Yukon includes that part of the valley lying between the Yukon Flats and the mouth of the Tanana, and the Lower Yukon the portion of the valley from the mouth of the Tanana to the sea. In the Upper and Middle Yukon provinces the coal-bearing rocks occur in small basins surrounded by older rocks. The sandstones of these basins, as far as determined, belong to the Kenai series, and are correlated with the coal-bearing beds of southern Alaska. With a single exception these coals are either high-grade lignites or lignitic bituminous coals.[b]

The coal-bearing beds of the Lower Yukon are exposed continuously for 200 miles along the river, and they probably extend westward to include the area which has been reported near Norton Sound. This terrane is made up of sandstones, shales, and conglomerates, which probably form an uninterrupted sedimentary series, ranging in age from the Middle Cretaceous to the Upper Eocene, and hence including both the Nulato and the Kenai series. Both these series carry coals of economic importance in this province, practically all of which are of a bituminous character.

In the following pages the localities will be described according to

[a] Abstract of paper in preparation.

[b] A coal whose content of water is above 10 per cent and whose fuel ratio is less than 1 is regarded as a lignite. The fuel ratio is the quotient of the fixed carbon divided by the volatile combustible matter. Coals whose classification by this rule is in doubt have been called lignitic bituminous coals.

their geographic position, beginning at the international boundary and going down the river.

UPPER YUKON PROVINCE.

Mission Creek and Seventymile River.—A small basin of coal-bearing rocks, 7 or 8 miles in width, lies near Mission Creek, 12 miles below the international boundary. The beds are of Kenai age and the coals are probably lignites. Twenty-five miles below, on Seventymile River, is another small basin of Kenai rocks from which coal has been reported, but nothing of economic importance has as yet been developed at either of these localities.

Washington Creek.—On Washington Creek, which enters the Yukon from the south, about 82 miles below the international boundary, there is a large area of coal-bearing rocks which is probably a part of a long basin or series of basins lying south of the Yukon and including the coal-bearing formations on Seventymile River, Bonanza Creek, and Coal Creek. No fossils were obtained in the Washington Creek coal basin, but an Upper Eocene age is inferred from the lithologic character of the sandstone, the mode of occurrence of the coal beds, and the character of the coal. In all these respects this coal basin resembles that at Cliff Creek, in Canadian territory, from which Eocene fossils were obtained. The coal here occurs in a formation consisting of alternating beds of lignite, clay, and carbonaceous shale, resembling that at Cliff Creek. In this formation seams of clear coal above 5 feet in thickness occur. The coal is a high-grade lignite, having an average fuel ratio of about 1 and a water content of from 10 to 15 per cent. The ash in samples analyzed varies from 2 to 4 per cent, and the sulphur is less than three-tenths of 1 per cent. Wherever they have been opened the coal beds of the Washington Creek Basin show no evidence of faulting, and the coal is not crushed, but can be obtained in large pieces which "check" but do not break up readily on exposure to the air. Coal beds have been opened in this basin at localities several miles apart, showing that they have considerable extent. Where these beds have been prospected the dips vary from 35° to 45°.

The relief of the basin is low, and probably the greater part of the coal lies below drainage level, so that pumping will be necessary if the mines are worked.

This coal has not been mined on a commercial scale. The development in evidence consists of a tunnel 65 feet long and a slope 106 feet long. Other workings were of a temporary nature and have caved in. A good winter trail has been opened from the coal beds to the Yukon River, and last winter 5 tons of coal were sledded to the Yukon for a steam test on a river steamer. This is reported to have given entire satisfaction. A railroad 10 to 12 miles in length will be required to bring this coal to the Yukon.

Bonanza and Coal creeks.—A similar basin is reported on Bonanza

Creek, a tributary of Charley River, about 10 miles northwest of the Washington Creek Basin.

Coal Creek, about 11 miles below Charley River, has coal of a similar character. These deposits are about 6 miles from the Yukon, and they have not yet been successfully exploited.

Nation River mine.—The localities thus far described all lie on the south side of the Yukon and seem to belong to a series of Kenai basins which extends from the Klondike River, in Canadian terrritory, northwest to Coal Creek, in American territory, a distance of about 160 miles.

On the north side of the Yukon, 52 miles below the international boundary, coal outcrops, and has been mined to some extent on Tahkandit or Nation River, 1½ miles from the Yukon. The coal-bearing formation extends down the Yukon for several miles and is generally more intensely folded than the sandstones above described. From the evidence in hand it may be regarded either as Permian or a later formation, presumably Kenai, infolded with Permian rocks.

The coal is distinctly bituminous, having a fuel ratio of 1.39 and a water content of 1.39 per cent. The ash percentage is 3.04, while the percentage of sulphur is very high as compared with other Yukon coal, being 2.98 per cent. This coal shows no vestige of woody structure and in the laboratory makes a good coke. The coal has been intensely crushed and affected, probably by a shearing movement of the inclosing sandstone, so that the bed is not well defined, but the coal was found in lenses and kidneys often as large as 8 feet thick and 13 feet long.

In 1897 the Alaska Commercial Company attempted to open a coal mine at this place. About 2,000 tons[a] of coal were mined and sledded to a landing on the Yukon River. Owing to the irregularity of the bed and the consequent uncertainty of the supply and expense of mining it was abandoned several years ago.

MIDDLE YUKON PROVINCE.

Between the Upper Yukon and Middle Yukon provinces, along the river, there is a break of about 300 miles in which there are no coal beds known.

Dall River.—On Dall River, which enters the Yukon from the north side, at the lower end of the Yukon Flats and about 450 miles below the international boundary, a coal bed occurs, 70 miles from the Yukon, in shales which are supposed to belong to the Kenai series. This coal bed contains irregular streaks of clay, but the lower 4 or 5 feet of the seam are believed to be of good quality. No practical tests and no analyses of the coal have been made.[b]

[a] For estimates of the amounts of coal produced the writer is indebted to Mr. W. E. Williams, a mining engineer who has had charge of coal mines on the Yukon since 1897.

[b] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound: Professional Paper U. S. Geol. Survey No. 10, 1902.

Salt Creek.—Coal is also reported by prospectors to occur on Salt Creek, which enters the Yukon from the north, 25 miles below Dall River.

Drew mine.—The Drew mine is the only point at which coal has actually been mined in this province. It is on the right bank of the Yukon opposite the mouth of Hess Creek, 25 miles above Rampart and about 500 miles below the international boundary. Its position is an important one, since there are no valuable coal deposits known along the Yukon, either above or below it, within 200 miles. The coal-bearing formation exposed here is confined to a great bend of the Yukon River, and its known extent does not exceed 4 square miles, though it may be continued beneath the silts of the Yukon and Hess Creek. The coal-bearing formation here consists of a great thickness—probably over 5,000 feet—of soft sandstones, shales, and conglomerates of Kenai age, standing nearly vertical and striking at right angles with the course of the river.

From croppings seen along the river bank, it is believed that there are seven seams of coal contained in about 1,000 feet of soft sandstone and shale of the upper part of the series, but only one has been exploited. Within the mine this bed was found to consist of two seams of clean coal in about 19 feet of coaly shale. These seams measured 13 and 25 inches and were separated by 4 feet of bony coal and black shale. The analyses show that the coal from the two seams is lignitic and quite similar in quality, having fuel ratios between 0.93 and 1.08, and a water content above 9.5 per cent. Both samples show over 13 per cent ash. A sample taken from the croppings of one of the other veins which has been partially opened up had a fuel ratio of 0.72 and a water content of 14.44 per cent, but the percentage of ash is only 4.64.

The development in this mine includes a shaft 75 feet deep, from the foot of which a crosscut tunnel about 30 feet long reaches the coal bed. The shaft is cribbed and housed and equipped with steam hoisting gear. A bunker of about 80 tons capacity is conveniently located on the river bank, from which the coal can be loaded on steamers. About 1,200 tons of coal have been mined here, the greater part of which was used for steaming purposes on river boats, but did not give entire satisfaction. This dissatisfaction was due in part, no doubt, to the inexperience of the firemen and the unsuitable grates used. The coal was carelessly mined so that, as supplied at the bunkers, it contained more or less unnecessary dirt, but in spite of this it sold readily for $15 per ton while the mine was in operation. For the past two years the mine has been shut down under an attachment suit instituted by the Northern Commercial Company.

Minook Creek.—A series of sandstones, probably of Kenai age, outcrops along the Yukon in the vicinity of Minook Creek, and also

extends up the valley of that stream. Attempts at coal mining have been made on Minook Creek, near the mouth of Hunter Creek, but the workings have been abandoned and have since caved in, so that the thickness of the bed could not be determined. A sample taken from the dump of the old prospect shows the coal to be a glossy lignite, which tends to break up into small cubical grains on drying. The analysis shows a fuel ratio of 0.87 and a water content of 11.21 per cent. Probably in freshly mined coal the water content would be much higher.

Below Rampart.—A similar coal outcrops 2 miles below Rampart on the left bank of the Yukon. A sample from the dump of an old prospect showed upon analysis a fuel ratio of 0.86 and a water content of 16.43 per cent. Between Rampart and the mouth of the Tanana two large areas of Kenai sandstone occur which have been reported to carry beds of coal, but so far as is known to the writer they have no commercial importance.

Cantwell River.—On the Cantwell River, which is a southern tributary of the Tanana River, about 100 miles from its junction with the Yukon, Brooks reports a great thickness of lignite-bearing sandstones believed to be Eocene. At one locality about 50 to 60 feet of lignite is contained in fifteen different seams. The analyses of this fuel shows that it has a fuel ratio of 0.66 and a water content of 13.03 per cent.

LOWER YUKON PROVINCE

Palisades.—At the Palisades, a series of silt cliffs about 55 miles below Tanana, a number of beds of lignite are exposed in the face of the cliff. This lignite is of Pleistocene or late Tertiary age and occurs in beds often several feet in thickness. It is of inferior quality, being but little changed from wood or peat, and has no economic value.

Nohatatiltin.—The Nohatatiltin coal bed is situated on the right bank of the Yukon 55 miles above Nulato and about 760 miles below the international boundary. It is in sandstones containing fossils of Eocene age, which probably overlie conformably Upper Cretaceous rocks of the Nulato formation. Two beds of coal were examined and two others are reported to have been opened by prospectors. Owing to the disturbed condition of the sandstone it is not certain that these may not all be parts of one faulted bed. The largest bed seen has a thickness of 1 foot and is not of commercial importance. The coal is a low-grade bituminous, having a fuel ratio 1.17 and a water content 6.88 per cent.

Pickart mine.—This mine is 10 miles above Nulato, on the right bank of the Yukon, and 425 miles from its mouth. The coal bed is contained in a typical exposure of the Nulato sandstone, from which Upper Cretaceous fossils have been obtained. One coal bed 30 inches thick and having a dip of 35° has been exploited. The coal is bitu-

minous, having a fuel ratio of 2.38 and a water content of 1.03 per cent. In the laboratory it makes a compact coke.

Mining was begun at this place in 1898 by the Pickart Brothers. About two years ago the mine passed into the hands of the Alaska Commercial Company, and in the summer of 1902 it was abandoned on account of some "rolls" in the floor of the bed which cut off the coal. The development consists of a drift tunnel about 600 feet long, above which all the available coal has been mined. No bunkers were used. The coal was piled on the river beach at the mouth of the mine and loaded on steamers by means of wheelbarrows.

Nulato coal bed.—About 1 mile above Nulato, a prospect hole shows 2½ feet of bony coal, with several bands of clay, in the Nulato sandstone. This seam contains 6 inches of clean coal, which is used to a limited extent for blacksmithing at Nulato.

Bush mine.—This mine is located on the right bank of the Yukon, 4 miles below Nulato. The inclosing rock is Nulato sandstone. The development is not far enough advanced to show the nature of the coal bed. In the tunnel, which extends about 40 feet, large bodies of crushed coal 4 or 5 feet in thickness are exposed. The coal is regarded as bituminous, having a fuel ratio of 1.76 and a water content of 11.17 per cent. The high percentage of water is probably due to decomposition of the coal in the croppings. No coal has been produced, but the owners have contracted to deliver 400 tons before next summer.

Blatchford[a] *mine.*—This mine is located 9 miles below Nulato. The coal bed occurs in sandstone, probably of Upper Cretaceous age, which has been correlated with the Nulato sandstone. One workable coal bed has been opened at this place. This bed has been crushed and sheared by the movements of the inclosing strata, making it very irregular. Large masses, 8 feet in diameter, have been found and mined out, showing that before it was disturbed the coal bed probably had considerable thickness. The coal has a tendency to break up into fine pieces, though it is a bituminous coal, having a fuel ratio of 3.30, the highest of any coal on the Yukon, and a water content of 1.36 per cent. The ash is only 2.22 per cent, making it by proximate analysis the best coal seen by the writer on the Yukon River. This mine has no visible development or permanent equipment. The workings lie below the level of the river, and the entrance is covered with water during the summer months, so that it can be worked only in winter after the freezing up of the river, when the ice filling the upper workings must be mined out before the coal can be reached. The mine has probably produced about 300 tons of coal.

Williams mine.—This mine is located on the right bank of the

[a] This name is also written Blatsford. The correct spelling is in doubt.

Yukon, about 90 miles below Nulato. The coal is in sandstones, from which fossils of Eocene age have been collected.

One bed 39 inches in thickness, in two nearly equal benches, separated by a clay parting about 1 inch thick, has been opened. The bed, which has a dip of 45°, is very regular and shows no variation, either in strike or thickness, in a distance of 400 feet. The coal is bituminous, having a fuel ratio between 1.20 and 1.50 and water content between 6 and 7 per cent. The ash in the lower bench is 3.53 per cent and in the upper bench 8.63 per cent. The coal does not coke. This mine produced some coal as early as 1900, and early in 1902 it passed into the hands of the present owners. The equipment consists of a drift 400 feet long, starting from the river bank above high water. The greater part of the coal above this drift has been mined. The coal cars bring the fuel to the mouth of the mine, where it is piled on the river beach and loaded on steamers by means of wheelbarrows. One thousand seven hundred tons of coal, which sold at the mine for from $10 to $15 per ton, have been produced.

Coal mine No. 1.—This mine is on the right bank of the Yukon, 25 miles below the Williams mine. The coal is contained in sandstones, which may be either Upper Cretaceous or Eocene in age. One coal bed, having a thickness of from 2½ to 3 feet, has been mined. A sample of the coal taken from the cropping shows on analysis that the coal is bituminous, with a fuel ratio of 1.61 and a water content 4.82 per cent. The Alaska Commercial Company attempted in the winter of 1898 to open a mine here, and 900 tons of coal were taken out, but the mine was abandoned the same year on account of the difficulty encountered in keeping out the water.

Hall Rapids.—Near Hall Rapids, about 30 miles above Anvik, a small bed of coal has been found in a formation consisting of white and yellowish tuffs of undetermined age. This coal has a lignitic appearance, but on analysis shows a fuel ratio of 1.35 and a water content of 8.23 per cent. The coal bed is probably of no value on account of its limited extent. Similar coals or lignites are of frequent occurrence in these tuffs.

On the Upper Koyukuk River.—A coal bed containing 9 feet of comparatively pure coal occurs near Tramway Bar.[a] This coal is either Upper Cretaceous or Eocene, but the exact age is undetermined. The analysis shows that it is a bituminous coal, having a fuel ratio of 1.40 and a percentage of moisture of 4.47 per cent.

Anvik River.—On the Anvik River, about 50 miles up, coal is reported by Mr. J. W. Chapman, missionary at Anvik. The point is about 10 miles back from the Yukon and probably is in a general way opposite the Williams mines. The coal is exposed in the river bank and is used by the natives in making black paint.

[a] Schrader, F. C., Reconnaissance on Chandlar and Koyukuk rivers: Twenty-first Ann. Rept. U. S. Geol. Survey, Part II, p. 485.

SUMMARY.

The coal-bearing formations are distributed along the Yukon conveniently for steaming purposes from the international boundary nearly to the mouth of the river. The coal beds are practically undeveloped, though limited amounts of coal have been mined at eight different points scattered along 1,000 miles of the river. Probably about 9,000 tons have been produced in American territory, which have sold at from $10 to $20 per ton. The seams from which coal has been produced vary in thickness from 13 inches to 5 feet, and in some instances they have been crushed and broken by movements of the inclosing strata, so that the beds are very irregular. The coal varies in quality from lignite to semibituminous. It has been used chiefly for steaming purposes on river boats and has come into competition with wood cut along the river. During the summer of 1903 crude oil from California will be burned on some of the steamers on the Yukon. Should its use on the Yukon prove practicable, the development of the coal beds will no doubt be retarded by it.

The Yukon will probably never supply coal for exportation, but the coal beds at present known seem to be capable, with proper development, of furnishing all that will be required for local use.