Bulletin No. 277 Series { A, Economic Geology, 65
B, Descriptive Geology, 80 }

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

MINERAL RESOURCES OF KENAI PENINSULA, ALASKA

GOLD FIELDS OF THE TURNAGAIN ARM REGION

BY

FRED H. MOFFIT

COAL FIELDS OF THE KACHEMAK BAY REGION

BY

RALPH W. STONE

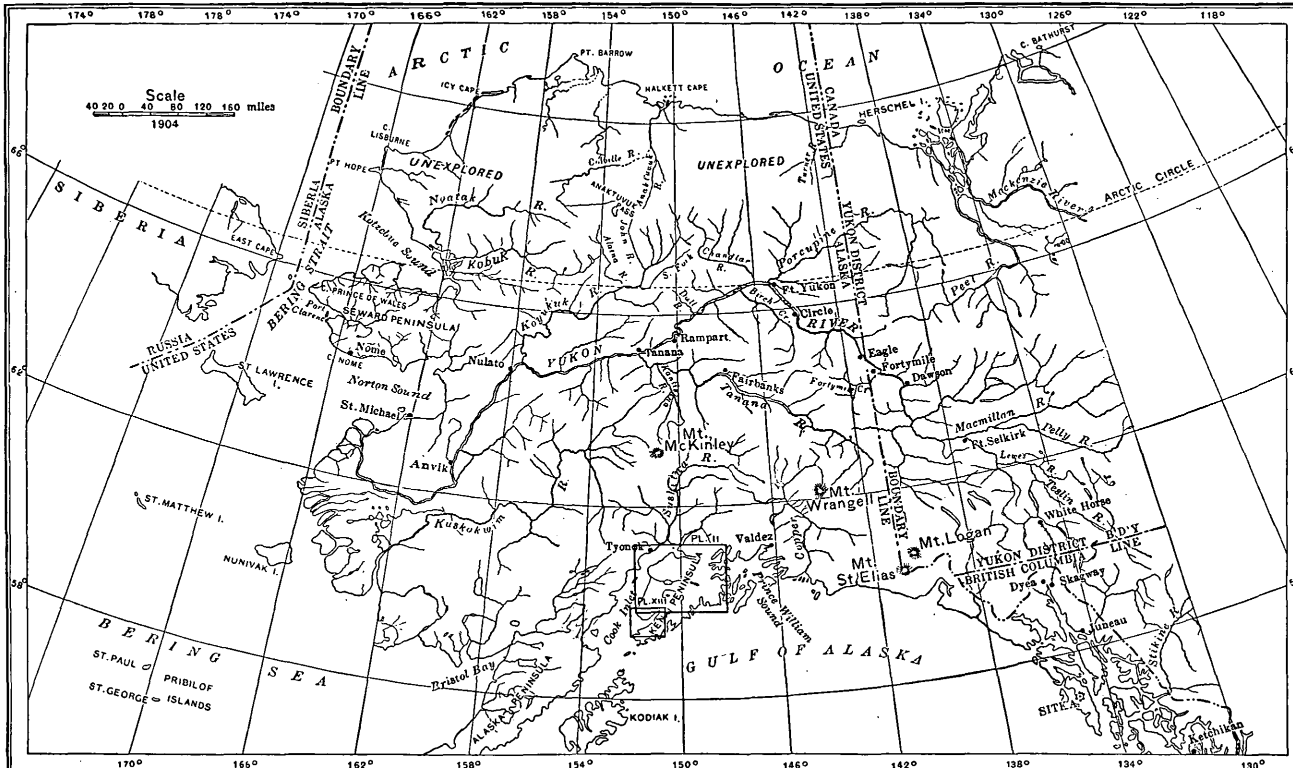
WASHINGTON

GOVERNMENT PRINTING OFFICE

1906

CONTENTS.

ILLUSTRATIONS.



OUTLINE MAP OF ALASKA, SHOWING AREAS COVERED BY LARGER SCALE MAPS (PLS. II AND XIII).

MINERAL RESOURCES OF KENAI PENINSULA.

GOLD FIELDS OF THE TURNAGAIN ARM REGION.[a]

By FRED H. MOFFIT.

INTRODUCTION.

LOCATION AND AREA.

Kenai Peninsula (see Pls. I, II, and fig. 1) lies in the most northern portion of the great upward bend of that part of the Pacific coast line inclosing the Gulf of Alaska. It is about equally distant from the western extremity of the Alaska Peninsula and from Portland Canal, or it may be said to be midway between the ends of the bow. More accurately stated, all but a few square miles of the most northern part of Kenai Peninsula lies between meridians 148° and 152° west longitude and parallels 59° and 61° north latitude, its most southern point being a little more than 700 miles north of the boundary between the United States and Canada. The peninsula has an area of approximately 9,000 square miles. It is bounded by Cook Inlet on the west and Prince William Sound on the east and is nearly cut off from the mainland on the north by Turnagain Arm and Portage Bay. These two bodies of water are arms of Cook Inlet and Prince William Sound, respectively, and are separated from each other by a strip of land 12 miles wide and 1,000 or 1,100 feet above sea level at its lowest point.

HISTORY.

EARLY EXPLORERS.

The region about Cook Inlet is historically one of the most interesting in all Alaska. First entered by Captain Cook in his search for the elusive northwest passage, it later became the scene of bitter strife between rival fur companies and of the earliest effort to develop the unknown mineral resources of the vast area known as Russian America. It is not, however, the purpose of this review to give a detailed account of the events that occurred after the discovery of the inlet by white men, except in so far as these relate to the investigation or development of the mineral resources of Kenai Peninsula. Suffice it to say that Cook Inlet, or the Gulf of Kenai, as it was called by the Russians, was visited in 1778 by Captain Cook, who spent some time in exploring its shores. The names Turnagain River (Arm), Point Possession, Anchor Point, Point Bede, Cape Elizabeth, and Barren Islands were all given by Captain Cook, after whose death the supposed river, by direction of Lord Sandwich, was named Cook River.

[a] An abstract of this paper has been published, under the title Gold Placers of Turnagain Arm, in Bull. U. S. Geol. Survey No. 259, 1905, pp. 90–99.

The inlet was again visited by English ships under command of Portlock and Dixon in 1786. These explorers remained for nearly a month, during which time they met with considerable success in trading for furs and, more important still from the standpoint of this report, made the first discovery of coal-bearing beds at Coal Bay, on the east side of Port Graham. Neglecting the Russian investigations carried on in the development of the Cook Inlet fur trade, we may next turn to the explorations made in 1794 by Capt. George Vancouver. His surveys were among the most valuable made on this part of the Alaskan shore and resulted in substantial corrections of Captain Cook's charts, especially with regard to latitude. Before he sailed from the inlet he had determined the fact, long known to the Russians, that its waters did not represent the mouth of a great river, as Cook had supposed, and the name Cook River was therefore changed to Cook Inlet.

MINING.

Early mining.—The first attempt to develop the mineral resources of Alaska was made in 1848 by P. P. Doroshin, a Russian mining engineer, who was sent from St. Petersburg by the Russian-American Company to examine Baranof Island and the Cook Inlet region. The locality which he chose for investigation on Kenai Peninsula was the Kenai River Valley, but although he found gold-bearing gravels he was not successful in finding gold in commercial quantities, the product of two seasons' labor, the summers of 1848 and 1850, amounting to only a few ounces of the precious metal. Doroshin himself says that work was confined to a tributary of the lower lake (Lake Skilak) and to two streams flowing into the river (Kenai River) connecting the upper and lower lakes, and that the quantity of gold obtained nowhere exceeded 0.0000004 of the gravels moved. Prospecting was greatly hindered by difficulties encountered in ascending the river, by the necessity of transporting all supplies on the backs of men, and in one case by forest fires. He further states that while the small results cooled the ardor of the chief manager of the Russian-American Company for gold seeking, he himself was convinced that gold was present and hoped that some other engineer might be more fortunate in finding it.[a]

One other effort to profit by the mineral resources of the region was an attempt, made about this same time, to establish a market in California for coal from Port Graham. Coal mining was undertaken by the Russian-American Company in association with merchants in San Francisco, but the venture did not prove successful. A further account of this undertaking will be found in Mr. Stone's accompanying paper on the coals of Kachemak Bay and vicinity, page 54.

Placer development.—The second period in that part of the economic history of the Kenai Peninsula relating to its mineral resources begins with the discovery of placer gold in the Turnagain Arm field. The exact year when prospecting began is perhaps not known, but it is said that gold was found near Hope about the year 1888 by a man named King, and that the first claim was soon afterwards located on Resurrection Creek, 2 miles above Hope, by Charles Miller. He did not work the ground himself, but leased it to others, and is reported to have "made a good living for ten years and never hit a lick." Gold was found near by, on Bear Creek, in 1894, by George Beady, F. R. Walcott, and —— Riley. This stream is said to have been worked by the Russians, but if this be true such operations must have taken place later than the time of Doroshin, for he expressly states that the streams prospected by him were tributary to what is now known as Kenai River.

Gold was found on Palmer Creek by George Palmer in 1894. These discoveries naturally led to prospecting on neighboring streams, and in the following year (1895)

---

[a] Petrof, Ivan, Population, resources, etc., of Alaska: Tenth Census of the United States, vol. 8, 1884, p. 78.

the first stakes were driven on Mills Creek by S. J. Mills, whose name it bears. Mr. Mills at the same time staked ground at the forks of Sixmile Creek (also named by him), which has been worked with profit to the present time, but the ground on Mills Creek was regarded with so little favor by Mills's partner, for whom it was staked, was so far from supplies, and so difficult to reach, that no attempt was made to work it, nor was the claim recorded. Some time during the following month (July, 1895) coarse gold was found on Mills Creek by Robert Michaelson and John Renner, old Yukon miners, who had been prospecting for quartz ledges in the mountains east of Canyon Creek without success and were returning to Hope. These two men, together with three others—Albert Brown, W. W. Price, and H. C. Pierce—staked ground on Mills Creek, July 29, and formed a company known as the Polly Mining Company. Their claims included all the stream between the mouth and Juneau Creek, and have since proved to be among the most valuable properties in the Turnagain field. In July, 1895, an assembly of miners from streams in the Sixmile drainage basin formed the Sunrise mining district and elected a local recorder. This recording precinct was distinct from the older Turnagain Arm district, which included the Resurrection Creek drainage system and, later, the creeks north of the arm. The two precincts were afterwards united, and recently, much against the desires and convenience of those most interested, the books of the recorder were removed to Seward, where they now are. Other discoveries of gold were made in the Sunrise district during the same year (1895), notably that on Lynx Creek by Fred Smith and W. P. Powers. North of the arm the first gold was found (in 1895) by F. J. Perry and Christopher Spillum, on California Creek.

The discoveries on Mills and Canyon creeks brought about during the following season (1896) the first considerable rush of prospectors to this field. Several thousand men, some state the number as high as 3,000, are said to have landed at Tyonok en route for Turnagain Arm and Sushitna River, while a considerable number crossed by way of Portage Glacier from Prince William Sound. This was the banner year on Canyon Creek, 327 men being engaged in mining its gravels during the summer. Crow Creek, tributary to Glacier Creek, was also staked about this time, but did not produce any gold till two years later. A second rush into the Turnagain Arm field took place in 1898. This was partly an overflow from the Yukon stampede and was not entirely due to the successes on Resurrection and Sixmile creeks.

A majority of the men who first entered the field (1894–95), as well as a few of those who took part in the stampedes of 1896 and 1898, were experienced miners. Many of them had spent years in southeastern Alaska or the Yukon country and nearly all had mined in the placer fields of the West. On the other hand, most of the later comers were inexperienced in any kind of mining and many were scarcely able to take care of themselves. Thousands of dollars worth of useless machinery and supplies are said to have been landed at Tyonok for transfer to the arm, only to be abandoned or given away. Several expeditions spent months in hauling cumbersome and unsuitable outfits through an unknown wilderness to localities which none of their members had ever visited and possibly never had heard of till they reached Alaska. Expensive hydraulic plants were established for the treatment of gravels that had never been prospected. It is doubtful if there is any other part of Alaska where time and money have been wasted in a more enthusiastically ignorant manner or concerning which stockholders in mining companies have been more utterly misled than some places on the Kenai Peninsula. The field did not justify the presence of any such numbers as came, and disappointment was the only result possible for most of them. Such conditions could produce only a feeling of distrust in the minds of those who had money to invest in mining enterprises, and hinder, in a serious way, the development of a field, many parts of which have since been worked with profit, and which without doubt still contains valuable gold deposits.

EXPLORATION AND SCIENTIFIC INVESTIGATION.

Early exploration.—The presence of sea otter and salmon in the waters of Cook Inlet and the growth of a profitable fur trade with natives from the interior had led very quickly to acquaintance with a narrow strip of land bordering the inlet, but until the discovery of gold in commercial quantity little was known of the mountains back from its shores. After the purchase of Alaska by the United States, American companies continued the fur trade, establishing stations at various points. Their agents endeavored to gather all the data relating in any way to the commercial possibilities of the country, including, of course, the positions and descriptions of routes and trails. From time to time, also, exploring parties sent out by different departments of the United States Government visited the inlet and collected in various ways information on which much of our knowledge of the geography and natural resources of the region is based.

Among the more prominent of those contributing to a knowledge of the geology several names should be mentioned. Baron von Wrangell, for a time manager of the Russian-American Company's interests in Alaska, gave an account, among other things, of the volcanoes along the west shore of Cook Inlet and the coal beds of Port Graham.[a] Wosnesenski, who spent several years in Alaska at the expense of the Imperial Academy of Sciences of St. Petersburg, also visited the coal-bearing beds of Kachemak Bay.

Heer[b] described the fossil plants collected at Port Chatham by Furuhjelm. Grewingk[c] published a geologic map of the shore line of southern Alaska and a geologic section along the coast of Kenai Peninsula from Kachemak Bay to Kasilof River, based on data furnished by Wosnesenski and others.

Among later writers, Dr. William H. Dall[d] published the first comprehensive statements on the coals of Kachemak Bay and Port Graham as well as a description of the Kenai beds in which they occur. Dr. G. F. Becker[e] published a report on the gold deposits of Alaska, in which the then recently discovered gold placers on Turnagain Arm were mentioned. The work of Messrs. Dall and Becker in 1895 was one of the first investigations in Alaska undertaken by the United States Geological Survey. In 1898 Mr. Mendenhall,[f] also of the Survey, made a hasty trip across the peninsula from Resurrection Bay to Sunrise, and in the following year published the most reliable map of the region available since that time. This journey was part of the exploratory work of a party under the command of Capt. E. F. Glenn, who was sent by the War Department to discover, if possible, a practicable route from Cook Inlet to the Tanana.

Thus many of the major features of portions of the region were learned, while here and there less prominent facts were brought to light through the wanderings of prospectors and hunters.

Investigation in 1904.—These, then, were the conditions when in the early part of the year 1904 it was decided to send a reconnaissance party from the United States Geological Survey into the region between Cook Inlet and Prince William Sound, known as the Kenai Peninsula. The purpose of this party was twofold, first,

---

[a] Von Wrangell, Baron F. P., in Baer and Helmersen, Beiträge, vol. 1, 1839.
[b] Heer, Oswald, Flora fossilis Alaskana: Kongl. Svensk. Vet.-Akad. Handl., vol. 8, No. 8, Stockholm, 1869.
[c] Grewingk, C., Beitrag zur Kenntniss der orographischen und geognostischen Beschaffenheit der Nord-West-Küste Amerikas, mit den anliegenden Inseln: Verhandl. Russ.-k. mineral. Gesell. zu St. Petersburg, 1848, 1849; also separates, 1850.
[d] Dall, William H., Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 762–908. Also Correlation Papers—Neocene: Bull. U. S. Geol. Survey No. 84, 1892, pp. 232–268.
[e] Becker, G. F., Reconnaissance of the gold fields of southern Alaska, etc.: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp, 1–86.
[f] Mendenhall, Walter C., Reconnaissance from Resurrection Bay to Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, pp. 265–340.

to prepare a topographic map, and, second, to make a geologic reconnaissance of the region visited. The important area to be studied was the Turnagain Arm placer gold field, but in addition it was desired to map as much of the peninsula as circumstances would permit, and especially, if sufficient time remained after the completion of the more important work on the gold-producing creeks, to make a hasty journey through the central portion of the peninsula from Turnagain Arm to Kachemak Bay, in order to locate and map the several large lakes there which were known to the early Russian traders. The topographic work was placed in the hands of Mr. E. G. Hamilton, while the task of visiting the gold-producing creeks fell to the writer, who had charge of the expedition. In addition to the two members just named the party consisted of J. W. Bartlett, chief packer, J. G. De Forest, R. A. Hamilton, Court Benton, and Benno Alexander. Three of these men had had previous experience in Alaskan work, and all were valuable members of the party. To their willing aid at all times the success of the expedition is largely due. The writer wishes to take this opportunity to express his obligation also to the many men whose hospitality he has shared, or who have furnished him with aid or information during his season's work on Kenai Peninsula.

The necessary provision and camp equipment for the work of the party during the summer was secured in Seattle. Ten horses were taken and supplies for four months' work, since it seemed probable, from previous experience, that a longer working season would be possible on Kenai Peninsula than in the more northerly portions of Alaska. A part of these provisions was sent to Seward for immediate use during the first part of the work, while the remainder was shipped to Sunrise, on Turnagain Arm, where the party was expected to arrive about July 1. The expedition sailed from Seattle May 22 on the steamer *James Dollar*, in company with a second Geological Survey party in charge of G. C. Martin, with whom were associated T. W. Stanton and R. W. Stone. This party expected to make a geologic study of the coal and oil fields of the southern part of Kenai Peninsula and the eastern part of Alaska Peninsula. Mr. Stone's report on the coal fields of Kachemak Bay and Port Graham forms a part of this bulletin (see pp. 53–73).

A landing was made at Seward May 29 and camp was pitched on the beach. The plan of operation was to begin topographic mapping and geologic investigation at Resurrection Bay, thence to carry it northward across the eastern side of the peninsula to the gold fields of Turnagain Arm, and finally to close the season's labor by a trip along the foothills of the Kenai Mountains to Kachemak Bay. It was desired, if weather conditions permitted, to begin a system of triangulation which could be carried along with the topographic work, and thus establish the location of points to which later topographic work about Cook Inlet could be tied. The work of triangulation on Resurrection Bay proved impracticable, however, and had to be given up because of fogs and cloudy weather. Eight days were spent in mapping the region about Resurrection Bay, the work being done chiefly by boat and being interrupted by frequent rains.

Leaving Seward the party proceeded northward by way of Salmon Creek and Snow River to Kenai Lake, where, procuring a boat, several days were spent in mapping the shore lines and in making a second attempt to carry out the plan of triangulation. This latter effort, however, met with no better success than the first at Seward, and the plan was finally given up entirely. Leaving the lake the party followed Trail Creek to the mouth of Johnson Creek, and, ascending the latter stream, crossed over the divide to the head of Bench Creek. Bench Creek led to the east fork of Sixmile Creek, and camp was finally made about July 1, near the mouth of Canyon Creek, at "the forks." Provisions having been replenished from the supply at Sunrise, the party proceeded southward to Mills Creek, thence to Quartz Creek, and crossed the high divide between Summit and East creeks to the head of Resurrection Creek

Valley. After examining the placer deposits in this valley the party returned to Sunrise. It was then necessary to change the mode of traveling, for it was found impracticable to take horses around the head of Turnagain Arm. A boat was therefore procured, by which the streams east of Sunrise on both sides of the arm were reached. An examination of the placer gold deposits on Crow Creek completed the work in this region and the party returned to Sunrise, where the horses were again procured and the necessary preparations for the final part of the season's work were made. From Sunrise the route lay southward to Lake Kenai and down Kenai River to the lower end of Lake Skilak. It was intended to follow the foothills of the Kenai Mountains from Lake Skilak to Lake Tustumena, from which place it was thought that the east shore of Kachemak Bay and Homer could be reached with little difficulty. However, freezing weather and the increasing scarcity of feed for the horses forced the abandonment of this plan, and the party moved directly westward across the Kenai Flats to the town of Kenai. Two days later a steamer arrived for Seldovia, at which place the party landed September 29. The labors of the field season were completed by ten days' work along the southern shore of Kachemak Bay, and the party embarked from Seldovia October 18, arriving in Seattle November 5. During this trip of more than five months' duration an area of slightly more than 1,600 square miles was mapped topographically, all the producing gold placers of the peninsula were visited, and a geologic reconnaissance was carried over the whole area.

TOPOGRAPHY.

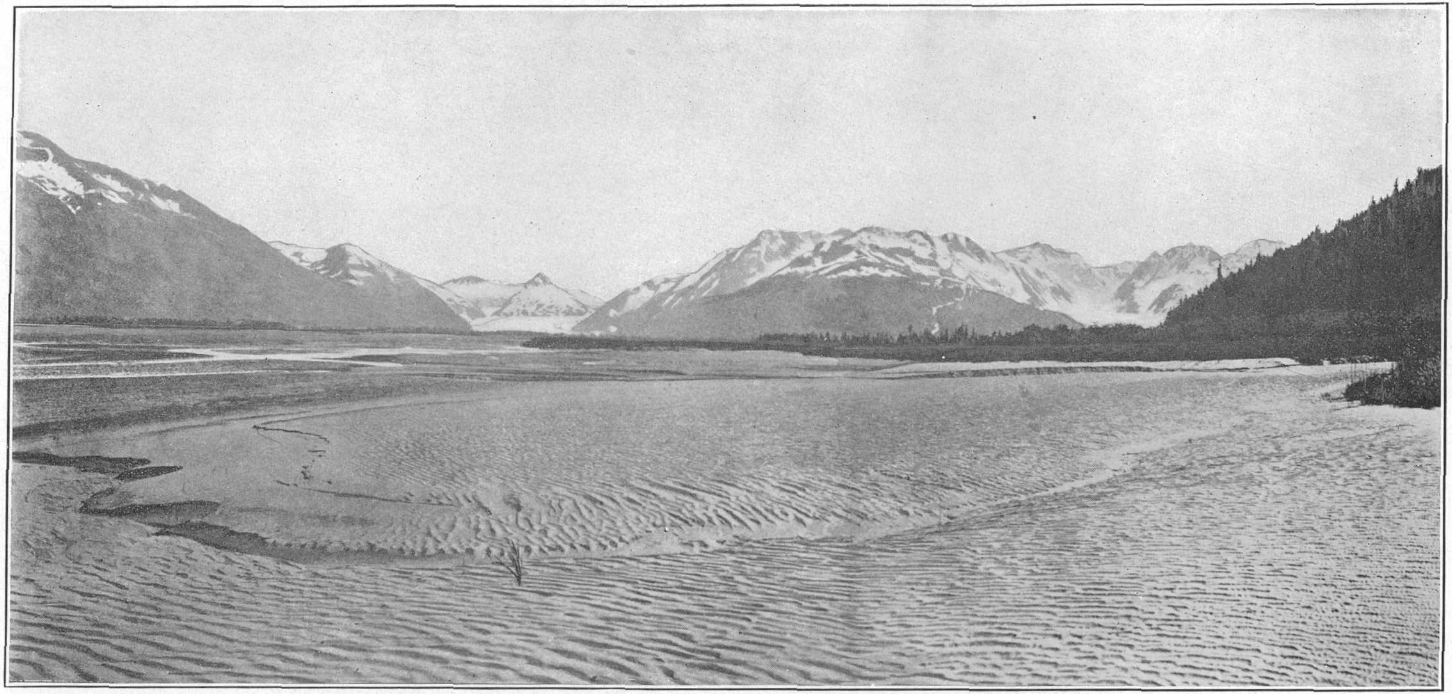
SHORE LINE.

Kenai Peninsula possesses a shore line more than a thousand miles long (Pl. I and fig. 1), an unusual length relative to its area and more remarkable because of its diversity. The outline of the whole southeastern coast from Portage Bay to Kachemak Bay is exceedingly irregular, deep indentations and projecting land masses, together with numerous islands, giving it a very broken appearance. Steep mountains, with rugged tops and with sides scarred by snowslides or landslides, rise abruptly from the water's edge and give to the landscape an aspect that is at once grand and forbidding.

Of the numerous bays which indent the coast of the Pacific and of Prince William Sound one only, Resurrection Bay, gives direct access to the interior of the peninsula. This bay, the Voskresenskaia, or Sunday, Bay of the Russians, is about 10 miles long and affords an excellent harbor, protected on all sides and open throughout the year, for which reason it was chosen as the southern terminal of the new railroad now under construction.

Portage Bay, in Prince William Sound, furnishes a means of communication between the upper parts of the sound and Cook Inlet. The portage over the glacier, though somewhat steep on the eastern side, is not difficult in favorable weather. It was made known to the Russians by the Indians, who traveled it long before the coming of white men, and was used by many of the earlier prospectors in entering the Turnagain Arm gold field.

The other larger bays on the Pacific side, Aialik, Nuka, and Port Dick, offer anchorage and protection from wind and waves, but, since they are cut off from the interior by high mountains, can hardly be of great future importance unless valuable mining properties are developed in their immediate vicinity. Port Chatham and Port Graham, or English Bay, on the Cook Inlet coast, were known and used by the Russians and at the present time often afford protection during stormy weather to the boats sailing these waters. Seldovia Bay, still farther north, is entered by large vessels and is the place where mail and freight destined for the upper settlements on Cook Inlet are transferred to the small steamer making that run.



HEAD OF TURNAGAIN ARM AT LOW TIDE.

The mud flats are covered at high tide. Portage Glacier is on the left and one of the small Glacier River glaciers is on the right.

The ragged coast line characteristic of the Pacific side continues around the southern end of the peninsula and northward into Kachemak Bay, where it gives place to a coast line of entirely different character.

Beginning with the north shore of Kachemak Bay and extending up the west side of Kenai Peninsula to Gull Rock, on Turnagain Arm, the coast is marked by a line of steep bluffs, without pronounced indentations, and only occasionally broken by stream channels. The bluffs reach their highest elevation in the vicinity of Homer and Kachemak Bay and gradually decrease in height toward the north. The unconsolidated gravels of the bluffs along some parts of the east side of Cook Inlet are gradually undermined by the waves, in consequence of which minor variations in the shore lines have taken place in very recent times. There is deep water at Homer Spit and along the southern side of Kachemak Bay, but the north side and upper end become a broad mud flat at low tide. Large vessels also find anchorage at Fire Island, in the upper end of Cook Inlet, while light-draft vessels may enter Turnagain Arm and the mouths of Kenai and Kasilof rivers at high tide. Besides these, however, there are no harbors on the Cook Inlet side of Kenai Peninsula for either large or small steamers. The mouths of Kenai and Kasilof rivers are marked by sand bars or mud flats that extend for long distances into the inlet, and familiarity with the channels is necessary in order to navigate the streams safely.

The shore of Turnagain Arm resembles that of the southern coast of the peninsula, in that the mountains on either side rise abruptly from the water. At low tide the arm becomes a wide mud flat crossed by stream channels whose positions are never fixed, but migrate yearly from one place to another (Pl. III). This flat has a gradual westward slope, and the high tides that are so dangerous near the entrance of the arm barely reach its eastern end. The whole of the Cook Inlet region is remarkable for its tides, whose swift currents often proved disastrous to the crazy craft of the early Russian traders, and have more than once caused the loss of life and property in recent years. A difference of 32 feet between high and low tide was measured at Homer wharf, near the mouth of Kachemak Bay, and the writer was told that a difference of 52 feet had been observed near the entrance to Knik Arm.

RELIEF.

The relief of Kenai Peninsula, like its shore line, presents two widely differing features. In fact, the form of its shore line results from differences in the relief of its land surface. Much the larger portion of the peninsula is a region of high mountains with rugged summits and deeply cut valleys (fig. 1). This mountainous region occupies the eastern part of the peninsula and makes up approximately three-fourths of the total area. Like the peninsula itself, the mountainous area is widest (60 to 70 miles) in the north, its width gradually decreasing toward the southwest, until near Seldovia it is reduced to not more than 20 miles. The remaining fourth includes the broad plateau extending along the whole western side from Kachemak Bay to Turnagain Arm. This plateau is about 25 miles wide and slopes gently northward from the high table-land back of Homer to the Chickaloon Flats, south of the arm, or from an elevation of about 1,800 feet on the south to an elevation of about 50 feet on the north. The surface is slightly undulating, is dotted with numerous small ponds or swamps, and is crossed by winding streams. Stunted growths of timber, chiefly spruce and poplar, are interspersed with marshy areas, and a thick carpet of moss covers much the greater part of the region.

The Kenai Mountains reach an elevation of as much as 6,000 or possibly 7,000 feet in the north, but are not so high in the south. The axis of the chain lies well toward the eastern side of the peninsula and thereby gives rise to peculiarities of drainage which will be referred to later. Numerous glaciers originate in the higher portions of the range and several approach within short distances of the coast, where the débris brought down by the ice forms broad flats, crossed here and there by the ever-shifting watercourses. It has been said that the mountains are peculiarly rugged, but an exception is found in the smoother rounded hilltops north of Kenai River and east of the upper part of Resurrection Creek. As will be seen later, the appearance

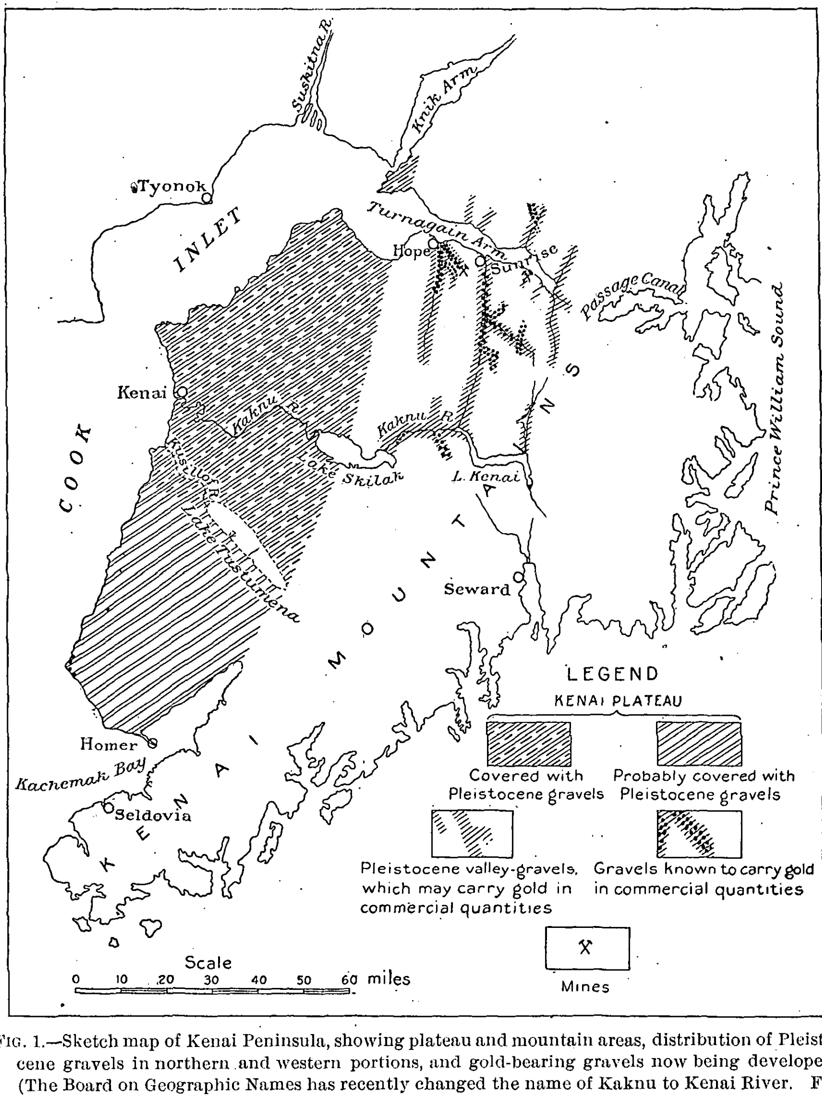


FIG. 1.—Sketch map of Kenai Peninsula, showing plateau and mountain areas, distribution of Pleistocene gravels in northern and western portions, and gold-bearing gravels now being developed. (The Board on Geographic Names has recently changed the name of Kaknu to Kenai River. For "Kusillof R." read Kasilof R.)

of these mountains has been modified by glaciation more profound in its effects than any that took place to the south.

DRAINAGE.

Owing to the fact that the axis of the Kenai Mountains is close to the eastern or southeastern side of the peninsula, the drainage is principally toward the west and north, while the streams flowing into the Pacific and Prince William Sound are short (Pl. II). The two largest streams of the peninsula, considering the volume of water which they carry, are Kenai and Kasilof rivers, which flow into Cook Inlet within a short distance of each other. Both rivers drain large lakes and both receive no small part of their waters from melting glacial ice, as is evident from their white appearance, due to rock flour carried in suspension. The Kenai River system is much the longer of the two. The upper part, known as Snow River, is a glacier-fed stream rising in the mountains bordering the west side of Prince William Sound. It is about 10 miles long and flows into the upper end of Lake Kenai, which has a length of 22.5 miles and is merely a widening of the stream due to the deposition of gravels in the valley at its lower end. The portion of Kenai River between the upper and lower lakes, Kenai and Skilak, is 16 miles long. For a distance of several miles below Kenai Lake the grade is gentle and the water quiet, but as the stream approaches the lower lake the swiftness of its current increases, and at one point the channel contracts to a narrow rock-walled canyon. From Lake Skilak to Cook Inlet the stream meanders widely, forming a series of bends and oxbows, whose total length of 53 miles is more than 50 per cent greater than the distance directly from the lake to the mouth of the river. From the mouth of the middle river (the portion between the lakes) to the head of the lower river the distance is 14.5 miles, and the length of the lower river is 53 miles, thus making the total length of the stream, including Snow and Kenai rivers and the lakes, 116 miles.

The grade of the lower river is not great; the highest tides reach a point 15 miles above the town of Kenai, and there is no swift water below Moose River. The rapids, about 2 miles above Moose River, are somewhat dangerous for boats in time of low water, because of numerous bowlders in the channel.

Kasilof River, draining Lake Tustumena, the largest body of fresh water on the peninsula, is much shorter than lower Kenai River and is not so crooked, but, like it, possesses a low grade, so that small boats are taken with little difficulty from the cannery at the mouth to the lake. These two rivers have long been used as highways by the natives, who ascend them in bidarkas, and who at one time inhabited a number of villages along their banks and on the shores of the lakes drained by them. Lakes Skilak and Tustumena lie on the borderland between the Kenai Mountains and the flat country west of them. Lake Skilak has a total length of 16 miles and a maximum width of 4 miles and is about 386 feet above sea level. The eastern half of the lake is surrounded by high mountains which give place on the west to the low, rolling hills of the Kenai Plateau.

Lake Kenai, as has been stated, has a length of 22.5 miles, a maximum width of only 1.5 miles, and an elevation of 435 feet. Its peculiar form will be best understood by referring to the map (Pl. II). The mountains rise abruptly from the water and are strewn with débris from the upper slopes, so that traveling along the shores is difficult. Lakes Kenai and Skilak are commonly known to the miners of Turnagain Arm as Upper and Lower Kenai lakes.

Lake Tustumena was not visited by our party, but is reported to be 35 miles long and about 9 miles wide. One or two large glaciers and a number of short streams drain into it.

Besides the two rivers previously described, two smaller streams, Chickaloon and Indian rivers, cross the upper part of the Kenai Plateau. These two streams flow toward the north and empty their waters into Chickaloon Bay, the western end of Turnagain Arm. In addition to those named, a number of minor streams drain the numerous small lakes and ponds of the plateau and find their way into Cook Inlet or Kachemak Bay.

The streams of the Pacific and Prince William Sound slopes are short, none of them, with the exception of Resurrection River, being over 10 or at the most 15 miles long. They occupy steep, narrow valleys and often descend from the mountain sides to the sea in a series of waterfalls. The waters of many of these are derived in part from glaciers or melting snows and consequently vary greatly in quantity at different seasons of the year. Resurrection River is between 20 and 25 miles long. It rises in the mountains southwest of the northward bend in Lake

Kenai and flows through a wide gravel-floored valley to the head of Resurrection Bay. Its waters are derived partly from melting glacier ice.

The principal streams flowing into the eastern half of Turnagain Arm are Resurrection Creek, Sixmile Creek, and Glacier Creek. These all have a general northerly direction and carry considerable water; but as they lie within the placer gold field, whose drainage will be described in greater detail in the section on economic geology, they are merely mentioned here.

GENERAL GEOLOGY.

Lack of variety is a noticeable feature of the rocks found throughout a large part of Kenai Peninsula and is especially apparent in hasty reconnaissance work, where there is little opportunity to study details.

SEDIMENTARY ROCKS.

DISTRIBUTION.

In order to present a clearer idea of the rocks and their general relationships, a brief résumé of the known facts concerning them will first be given, after which the various lithologic units will be described at greater length. These units are partly of sedimentary and partly of igneous origin, the former being here divided into five groups, whose chief characteristics are described below:

1. The central and northern Kenai Mountains are made up principally of interbedded gray, black, or bluish-black slates and gray arkoses, possessing, as a whole, a remarkably uniform appearance and composition. Interstratified with the slates and arkoses are occasional conglomerate and quartzite beds, but these do not form any considerable part of the mountain mass and are irregular in their occurrence. Locally the series is cut by granitic dikes. This succession of sedimentary beds includes the oldest known rocks of the peninsula, and, although its age is not definitely known, is referred to the upper Paleozoic. It was named the Sunrise "series" by Mendenhall.[a]

2. South of Kachemak Bay the Kenai Mountains near the coast are made up chiefly of contorted red and green cherts and green diabase, cut by light-colored porphyritic dikes (Pl. IV, *B*). The relation of these rocks to the Sunrise "series" is not known, but Stanton refers them tentatively to the Triassic.

3. At various localities along the coast from Kachemak Bay to Port Graham are bedded fragmental rocks ranging from fine-grained tuffs to agglomerates, tilted and slightly folded but much less altered than the cherts on which they are believed to have been deposited unconformably. They are fossiliferous and on the evidence of the organic remains found in them are considered to be of lower Jurassic age.

4. The upper member of the list of bedded sedimentary rocks is a succession of sandstones and shales, with interbedded coal seams, which overlies the lower Jurassic unconformably and forms the whole northern coast line of Kachemak Bay and the eastern coast line of Cook Inlet as far north as Cape Kasilof. Isolated masses of these rocks also occur at various points on the south shore of the bay. These beds, while slightly folded and sometimes faulted, are not always thoroughly consolidated. They were described by Dall and furnish the type exposures of his so-called Kenai beds, which he referred to the Miocene, but which are now considered to be of late Eocene age.

5. Finally, the Kenai Plateau is overlain unconformably by thick deposits of silts, sands, and gravels, which extend also into the valleys of the Kenai Mountains. At the mouth of Kenai River the gravel bluffs are between 75 and 100 feet above tide, but farther east the gravels in some of the valleys reach an elevation of nearly 2,000

[a] Mendenhall, W. C., Reconnaissance from Resurrection Bay to Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 305.

feet. These gravels are largely of glacial origin, and were laid down before the retreating ice front.

The geologic column of Kenai Peninsula therefore includes the supposedly Paleozoic Sunrise "series," red and green cherts of probable Triassic age, lower Jurassic sediments of the Seldovia region, and the Eocene Kenai beds which form the tilted plateau at the foot of the Kenai Mountains. To these must be added the surficial deposits of Pleistocene and Recent time. This succession is represented in the following table:

Geologic column of Kenai Peninsula.

Age.	Period.	Epoch.	Remarks.
Cenozoic	Quaternary	Pleistocene	Silt, gravel, and sand of the Kenai Plateau and high gravels found in the valleys of Kenai Mountains.
			Unconformity.
	Tertiary	Eocene or Oligocene.	Kenai formation.
			Unconformity.
Mesozoic	Jurassic		Lower Jurassic beds of Seldovia Bay.
			Unconformity.
	Pre-Jurassic (Triassic?).		Chert beds of Kachemak Bay, etc.
Paleozoic(?)			Sunrise "series."

SUNRISE "SERIES."

Occurrence.—The slates and arkoses of the Sunrise "series" form the mass of the Kenai Mountains in the middle and northern part of the peninsula. Toward the south they give place partly or wholly to other rocks, some sedimentary, some igneous, which will be described later in the portion of this paper dealing with the Kachemak Bay and Port Graham regions (pp. 19-25).

Character.—The slates are usually fine grained and often possess a cleavage so well developed that in some localities it is possible to break them into thin plates like roofing slate. Locally they are schistose. The arkoses are composed chiefly of angular fragments of quartz and feldspar, derived from the disintegration of the rocks of an ancient land mass. Under the microscope the particles are seen to be remarkably fresh, indicating that the weathering of the original rocks was rapid, and that from a geologic point of view the period during which they accumulated was short. They differ greatly in the size of their particles; some beds are of uniform grain, while others show coarse material in a finer groundmass and approach the conglomerates in structure. Flat pieces of slaty rock, or even bowlders, appear in some beds, but these do not resemble the rounded pebbles of the typical conglomerates and do not form so large a proportion of the bed. The whole rock series is closely folded, and the arkoses as well as the slates show cleavage, which, however, is much less well developed in the former than in the latter. Jointing is more noticeable in the arkoses than in the slates, and divides them into irregular angular blocks that are readily displaced by frost and ice. These blocks are conspicuous in the talus slopes below arkose ledges. Large blocks in the stream channels are more generally arkose than slate. This is probably due in part to the better developed jointing of the arkoses, and in part to planes of weakness in the slates resulting from their more perfect cleavage, which allows them to be broken up more easily.

The general strike of the sedimentary beds in the vicinity of Resurrection Bay is about N. 10° E., but in going northward toward Turnagain Arm it was found that, aside from local variations, the strike gradually becomes more easterly and suddenly reaches a maximum easterly deviation on the north shore of the eastern end of the arm, where a strike of N. 60°–70° E. prevails. The strike of the cleavage, however, which near Resurrection Bay is in general the same as that of the bedding, remains nearly constant, so that from Glacier Creek eastward there is often a large angle between the strikes of cleavage and bedding. While folding is often close the beds are not generally overturned. Faults are numerous and have probably had an important influence in determining the topography of the region, especially the form of Kenai Lake and some of the other valleys, but the amount of displacement is difficult to determine owing to the uniformity of the Sunrise "series" and the lack of reference beds from which to make measurements.

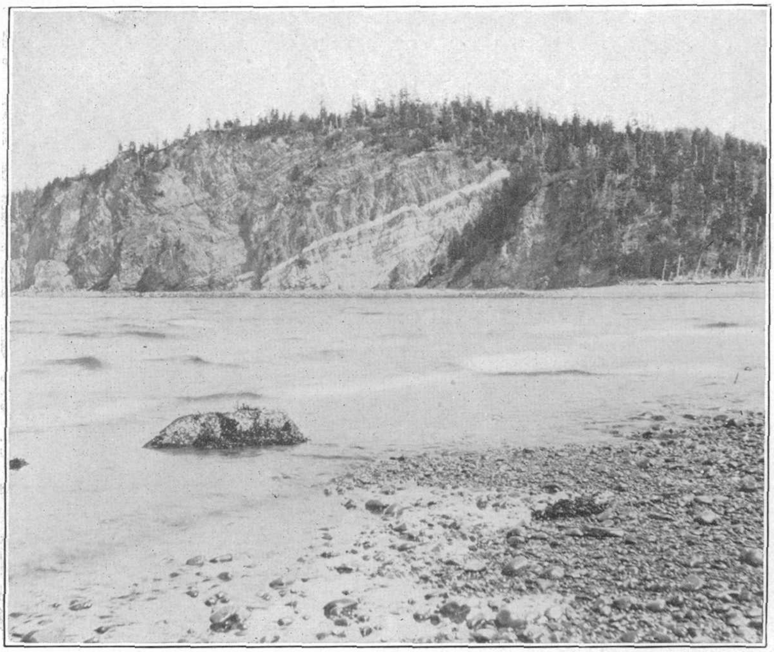
The composition of the occasional conglomerate beds throws some light on the source of part of the material making up the arkoses, for both may have been formed, to a certain extent, by the weathering of the same rocks. The pebbles of the conglomerates vary somewhat in different localities, but they are always well rounded and consist chiefly of argillaceous rock and granite, with less frequent quartzite or quartz. A conglomerate bed 6 to 8 feet in thickness on Resurrection Creek is made up of rolled granite pebbles with a few rounded quartzite fragments in a gray argillaceous groundmass. Quartzite beds are usually of no great thickness and were observed most frequently east of Resurrection Bay, west of Resurrection Creek, and along the north shores of Turnagain Arm. Several massive quartzite beds, from 4 to 6 feet thick, are conspicuous in the vicinity of the glacier east of Seward, about 2 miles from the bay. The beds here, which lie in immense folds, slightly overturned to the east, furnish the best instance of overturning met during the season. The arkoses sometimes approach the quartzites in appearance owing to a large increase in the amount of quartz present. Conglomerates and quartzites, while they attract attention locally, form a relatively unimportant part of the Sunrise "series," whose principal members are the slates and arkoses just described.

Age.—No fossils have been found in the Sunrise "series" on Kenai Peninsula and as yet there is no evidence on which a definite statement of its age can be based. Mendenhall made a provisional correlation of the Sunrise "series" with the Valdez formation of Prince William Sound, described by Schrader[a] as consisting of highly metamorphosed "bluish-gray and dark quartzites, arkoses, and quartz-schists, interbedded with generally thin beds of dark-blue or black slate, shale, mica-schist * * * and stretched conglomerates." The correlation was based on lithologic similarity. According to Mendenhall the rocks of the "Matanuska series," occurring in the valley of Matanuska River, probably overlap the Sunrise "series" from the northwest. Part of the Matanuska rocks are of lower Cretaceous age, and he therefore concludes that the Sunrise "series" is pre-Cretaceous and assigns it provisionally to the upper Paleozoic.

Schrader and Spencer[b] later suggested a possible identity of the "Orca series" (also found on Prince William Sound) and the Sunrise "series." They further state that the "Orca series" may be equivalent to the "Yakutat series," but the fossils of the latter were also found at Kadiak Island and are regarded by Ulrich[c] as indicative of the lower Jurassic. The lower Jurassic beds of Seldovia, while they may not be equivalent to those of Kadiak Island, are, as will be shown later, distinctly younger than the Sunrise sediments. It is apparent, therefore, that if the "Yakutat series" is really of Jurassic age and the Orca-Yakutat correlation holds, the Orca-Sunrise correlation can not hold.

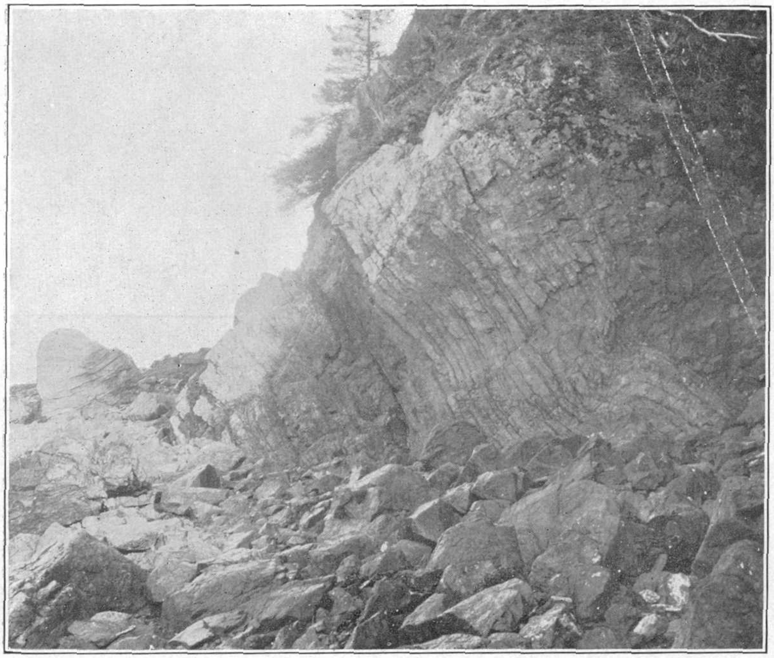
One other statement is here presented as having some bearing on the age of the Sunrise "series." The relation of the previously mentioned red and green cherts to

[a] Schrader, F. C., Reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, p. 408.
[b] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska: Special publication U. S. Geol. Survey, 1901, p, 36.
[c] Ulrich, E. O., Alaska, geology and paleontology: Harriman Alaska Expedition, vol. 4, p. 126.



A. JURASSIC CHERTY LIMESTONE, ETC., AT PORT GRAHAM.

Two miles southeast of the coal outcrops.



B. CONTORTED CHERTS AT SELDOVIA BAY.

Cherts in the middle of the picture, diabase on the right.

the Sunrise sediments is not definitely known. No fossils were found in them, but Stanton regards them as probably Triassic. Reasons for this determination will be given in the proper place. The cherts are sharply folded and much faulted, but are not so much altered as the slates and arkoses, a fact which may be due to differences in the lithologic character of the beds or differences in the intensity of the forces producing alteration, or both. If, however, it can be regarded as indicating an age less than that of the Sunrise sediments, we have further evidence that Mendenhall's provisional assignment of them to the Paleozoic is correct. We may say, therefore, that no paleontologic evidence has yet been discovered on Kenai Peninsula fixing the upper age limit of the Sunrise formation more definitely than that it is pre-Jurassic.

CHERTS.

Occurrence.—The contorted cherts that occur at numerous localities along the shores of Kachemak Bay and Cook Inlet (Pl. IV, *B*) from Aurora to Port Graham have been described by several writers, but more especially by B. K. Emerson and Charles Palache in the account of the Harriman Alaska Expedition. The results published by them will be freely used to amplify the observations made by various members of the Geological Survey during the season of 1904.

Since these cherts were involved in at least a part of the main movements that affected the Kenai Mountains, and since their exact relation to the Jurassic sediments is not known, they are here discussed in connection with the Sunrise "series," although it is thought that future investigation will probably separate them. Typical exposures, such as those found near Seldovia village, on Yukon Island, or at Halibut Cove, present a succession of very regular thin chert beds, rarely over 2 or 3 inches thick, separated by clay or shale partings. In at least two localities, especially near the east side of the entrance to Seldovia Bay, calcareous siliceous rocks occur which are thought to belong in the same "series."

Character.—The origin of the cherts was recognized by Professor Palache, who described them as radiolarian cherts. They are red or green in color, and the beds are strikingly folded (Pl. IV, *B*). Faults are not infrequent. The movements which affected the cherts resulted in the production of a vast number of small fissures, which have since been filled with quartz and calcite and are now shown on the rock surface, or in a thin rock section, by a fine network of sharply defined quartz and calcite veins.

These cherts are associated with masses of green diabase, which probably were intruded after the formation of the chert beds, although it is possible that the masses of igneous rock were poured out at different times while the cherts were forming and that the present irregular occurrence of the cherts resulted from faulting. No contact alterations were noticed in the cherts by members of the survey parties, nor were any distinctly extrusive characteristics seen in the diabases, which, however, have been greatly disturbed and considerably altered. Both the cherts and the basic igneous rocks are cut by light-colored porphyry dikes. These igneous rocks will be discussed later.

Age.—In the account of the Harriman Alaska Expedition [a] the extraordinary similarity in structure and lithologic character of the Halibut Cove cherts and associated igneous rocks (except the porphyry dikes) to rocks of the same kind occurring in the Franciscan formation of the California Coast Range is pointed out. The California cherts were described by Lawson [b] and were doubtfully assigned to the Jurassic or to the very lowest Cretaceous. Professor Emerson [c] makes the statement that "correlation over such wide distances, based only on lithologic similarity, has of

[a] Alaska, geology and paleontology: Harriman Alaska Expedition, vol. 4, p. 26.
[b] Lawson, A. C., Geology of the San Francisco peninsula: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 420.
[c] Emerson, B. K., Alaska, geology and paleontology: Harriman Alaska Expedition, vol. 4, p. 27.

course little value, but taken in conjunction with other evidence for the existence of Mesozoic rocks in the Cook Inlet region, the facts may here be given a certain amount of significance."

Evidence collected by Stanton in 1904, while not decisive, points to a greater age for the cherts than that suggested by Professor Emerson. The cherts of Kachemak Bay and Seldovia resemble other banded and contorted cherts in Kamishak Bay on the west side of Cook Inlet. The latter cherts yielded upper Triassic fossils, and though the same objection to correlation by lithologic characters over a considerable distance might be raised, yet in this case it appears that such objection would have far less force. Further, although no contact was seen, the fossiliferous tuffs and sandstones near Seldovia probably overlie the cherts. Stanton's evidence indicates that these tuffs and sandstones belong to the lower Jurassic. Evidence for the relative ages of the cherts and Jurassic sediments is found in the fact that the chert series has been more severely folded, more cut by intrusives, and subjected to greater metamorphism than the tuffs and sandstones of the adjacent area. Since outcrops of one of these classes of rocks lie close to outcrops of the other it can hardly be objected here that degree of alteration is not a proper criterion by which to judge the relative ages of the two rock masses, and it is therefore concluded that the cherts are older than the sandstones and tuffs and that their age is probably Triassic.

LOWER JURASSIC BEDS.

Occurrence.—So far as is now known the rocks grouped together under the heading lower Jurassic beds are best developed along the shore of Cook Inlet from the west side of Seldovia Bay to a point halfway between Seldovia and Dangerous Cape, and along the north shore of Port Graham (Pl. XIII). Whether or not they extend west of Port Graham is not known, since that part of the coast was not visited by the Survey parties.

Character.—The beds are of fragmental deposits thought to be of volcanic origin. They vary from fine tuffs to agglomerates containing large blocks of weathered igneous rock; some cherty calcareous beds are also present. These deposits are cut by basaltic and rhyolitic dikes and are fossiliferous. The tuffs are greenish black or reddish gray in color and vary greatly in the coarseness of the fragments forming them, resembling sometimes a close-grained sandstone, sometimes a fine conglomerate. Sharp angular fragments of feldspar, both orthoclase and acid plagioclase, form a conspicuous portion of the dark varieties and are contained in a matrix consisting largely of chlorite material. No quartz was observed. The coarse tuffs also contain angular feldspar fragments, but the other constituents are more difficult to determine, since the rocks have been highly altered. Calcite and chloritic material is abundant.

These tuffs contain organic remains on which the determination of their age is based. Some of them at first glance were regarded as sandstones or possibly arkoses, but the character of the material composing them and their association with agglomerates which, although modified by the action of water, are clearly of igneous origin, indicate that they are not wholly the product of a rapidly weathered igneous land mass, but consist of the finer water-laid fragments thrown out during volcanic eruptions. A half mile or more west of the entrance to Seldovia Bay the finer-grained fossiliferous beds are overlain by other beds containing in a finer matrix large fragments of red, white, and green igneous rock, generally angular. The same sort of beds occur again a short distance to the west, interstratified with fossiliferous tuffs, and make up a considerable part of the formation. The whole time of deposition of this series of beds seems to have been one of volcanic activity. As stated in discussing the age of the cherts, the relation between the lower Jurassic beds and the cherts is probably one of unconformity. The relation to the overlying Kenai sediments is also one of unconformity, for the horizontal Kenai beds are found in small basins of tilted and folded Seldovia tuffs at several localities on the Cook Inlet coast below Seldovia Bay. The tuffs lie in open folds (Pl. IV, *A*), whose dips occasionally are as great as 60°, and have undergone little mechanical alteration, although the chemical changes are pronounced at times. The observed strikes appear to bear little relation to one another, or rather the relation was not made out.

Age.—Evidence for the age of the lower Jurassic beds is derived from the fossils contained in them. These fossils were collected by Doctor Stanton and other members of the party under Doctor Martin's charge and the determinations were made by Doctor Stanton. They show that the beds probably belong to the lower Jurassic and that they are not exactly equivalent to the Jurassic sediments found on the west side of Cook Inlet, which are younger. A list of preliminary determinations of the fossils is here given, with the localities from which the fossils were obtained:

Field No 904.—West side of Seldovia Bay, opposite village, one-fourth mile southeast of locality No. 905.

Trigonia sp. *a*. This abundant form belongs to the section Glabræ.
Cardinia sp. *a*.

Field No. 905.—Entrance of harbor, west point, Seldovia.

Pentacrinus.
Trigonia sp. *a*.
Trigonia sp. *b*.
Myophoria? sp.
Cardinia? sp. *b*.
Pecten sp. *a*.
Pinna cf. P. expansa Hyatt.
Fragments of an ammonite of undetermined genus.

Field No. 906.—Three-fourths of a mile west of locality No. 905.

Cardinia sp.
Trigonia? sp. *a?*
Pleurotomaria (?)
Ammonite. Fragmentary imprint.

Field No 907 A.—Shore of Cook Inlet, 2 miles west of Seldovia Bay.

Cardinia sp. *a*.
Pecten sp. *b*.
Gryphæa sp.
Perna ??
Pseudomelania? sp.

Field No. 907 B.—Same locality as 907 A, but 200 feet higher.

Trigonia sp. *a?*
Trigonia ?
Pinna cf. P. expansa Hyatt.
Pecten sp. *b*.
Pecten sp. *c*.
Astrocœnia?
Arietites? sp. One fragmentary specimen, which certainly belongs either to this or to a closely related genus of ammonites.

Field No. 908.—Shore of Cook Inlet, 3 miles west of Seldovia Bay.

Pecten sp. *b*.
Pecten sp. *d*.

Field No. 909.—Port Graham 1½ miles southeast of coal mine.

Trigonia? Fragmentary imprints.
Pecten sp. *a*.
Ostrea or Gryphæa.

Doctor Stanton says of these fossils collected on and west of Seldovia Bay:

The evidence can not be considered final on account of the imperfect state of preservation, the small number of species, and the lack of definitely characteristic forms, but so far as I can judge from the present collections and from the field relations of the beds containing them it seems most probable that all of these small lots belong to one general fauna and that the age of the beds is lower Jurassic. The fossils are certainly Mesozoic and there are no species in common with the middle and upper Jurassic faunas, which are so well developed in formations of great thickness on the west side of Cook Inlet and on the Alaska Peninsula, while there are several types that are apparently older than any that are found in those faunas. On the other hand, the only reason for suggesting Triassic age is the presence of shells doubtfully referred to *Myophoria* from superficial characters, and their evidence is overbalanced by the Jurassic affinities of the other species.

KENAI FORMATION.

The main features of the sediments comprised in the Kenai formation, as well as the distribution of the sediments themselves, have already been given in outline. (See p. 16.) This formation, consisting of partly consolidated sandstones and shales, is of economic importance because of the lignitic coal seams interstratified with its various members. As previously pointed out, it rests unconformably on the Seldovia lower Jurassic rocks.

Fossils from the Kenai beds of Port Graham and Ninilchik were described by Heer as early as 1869. The former locality was afterwards visited by Dall,[a] who collected fossils there, as well as from other localities on the north side of Kachemak Bay. The Kenai beds probably underlie the whole of the Kenai Plateau, but their northward dip carries them below sea level a few miles south of Kasilof River, and they do not appear again. These coal measures were thought by Heer to be of Miocene age, but Doctor Dall referred them to the Oligocene and gave a list of plant and animal remains collected at Port Graham, among which are both Coniferæ and broad-leaved trees, the total number of species amounting to 44. He says: "The deposit appears to have formed at the bottom of a lake."

Dr. F. H. Knowlton in the same report[b] gives a list of plant remains from the Kenai formation collected by Doctor Dall in 1895, as well as those previously known from the same region, and states that they are believed to be of Eocene or Oligocene age.

Later, in speaking of the typical Eocene strata of Chicagof Cove, Doctor Dall[c] says:

The only representative of the Eocene epoch known in Alaska previous to the Harriman Expedition was the Kenai series [formation], which had been referred by Heer to the Miocene and by others to the Eocene, but which has of recent years been recognized as Oligocene by the present writer and others.

In the same publication[d] Doctor Knowlton, after describing a collection of fossil plants from Kukak Bay, makes this statement concerning their age:

It is hardly necessary at this time to go into a history of the plant-bearing horizons of Alaska. * * * It is sufficient to state that the named species above enumerated are typical of the so-called arctic Miocene, which is now regarded as of the age of the upper Eocene. The species described in this paper as new are in various ways allied to forms characterizing this horizon, and I do not hesitate to refer this collection to the upper Eocene.

The Kenai beds were studied by Mr. Stone in his investigation of the lignites of Kachemak Bay and Port Graham, and their detailed description will be found in his report, which forms part of this bulletin (pp. 57–59).

---

[a] Dall, W. H., Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 787 and 842.
[b] Op. cit., p. 876.
[c] Alaska, geology and paleontology: Harriman Alaska Expedition, vol. 4, p. 101.
[d] Ibid., p. 162.

IGNEOUS ROCKS.

CLASSIFICATION.

The igneous rocks on the Kenai Peninsula are practically confined to the southwestern portion of the Kenai Mountains, which in the vicinity of Seldovia are largely made up of them. The most abundant of these are diabases associated with the cherts, both of which are cut by porphyry dikes. Gabbro is reported from the same region but was not observed by members of the Survey parties in 1904. The diabases have been greatly sheared and otherwise altered, so that their true nature is sometimes in doubt. Besides the diabase and other massive eruptives of the Kenai Mountains there are igneous rocks in the Seldovia region associated with the sediments of the lower Jurassic tuffs. Whether or not there are any extruded or intruded igneous rocks interbedded with the Seldovia sediments has not been determined, but the beds are cut by dikes of igneous rock, some of which are rhyolitic and some basaltic in character. In the northeastern part of the Kenai Mountains the Sunrise formation is cut by dikes of light-colored granite.

DIABASE.

Diabases are observed wherever the cherts occur, having been found at numerous localities from Port Graham to Aurora. They extend into the mountains east of Seldovia, and with the cherts are the only rocks seen there. They were examined by Palache and described in the account of the Harriman Expedition by Emerson, who states that with the cherts of Halibut Cove "are associated intrusive masses of diabase, much crushed and altered, showing in places a distinct spheroidal structure, the surface of the spheroids being largely covered with minute spherulites."[a] Judged by the thin rock section the samples collected at Halibut Cove are not from the most typical diabase exposures. Specimens obtained at a number of localities from Seldovia to Yukon Island have been examined and show a coarse green diabase with long lath-shaped plagioclase feldspars and crystals of pale-green pyroxene and brown hornblende. The pyroxene and some serpentinous material, apparently an altered glass, make up the larger part of the filling between the feldspars. Long needle-like apatites are numerous, while biotite is less so. Ilmenite, largely altered to leucoxene, is found in all sections. Secondary calcite is often present. Dark patches of fine-grained rock are sometimes seen in the field exposures, which proved to consist of small scattered olivine crystals, somewhat altered, in a felty groundmass of fine lath-shaped feldspars. An opaque ore, probably magnetite, is disseminated through the rock, and its decomposition products, giving the section a reddish cast, show the advanced alteration.

Diabase predominates very greatly over the associated cherts, which were much disturbed either by its intrusion or by subsequent faulting. In the course of a day's tramp extending several miles into the mountains southeast of Seldovia no other rocks were seen. The exposures show that the whole mass has been subjected to extensive movements and that while the cherts responded to distorting forces by a folding of the beds the diabases yielded by fracture and movement of the blocks thus formed, so that some outcrops look like an altered giant conglomerate or a pile of rounded bowlders whose slickensided surfaces often have a mirror-like polish. If the Triassic age of the cherts is established and the diabases are extrusive rather than intrusive the time of eruptive activity is fixed; if, however, the diabases are intrusive there are no data at hand by which their age can be determined, but they took part in at least the later movement affecting the Kenai Mountains, before the deposition of the Seldovia Jurassic beds, and are therefore older than that movement.

[a] Alaska, geology and paleontology: Harriman Alaska Expedition, vol. 4, p. 26.

GABBRO.

The only data regarding rocks of this character are those collected by Becker,[a] whose note on them is here given:

A gabbro occurs at the southerly bounding wall of the Grewingk Glacier, on Kachemak Bay. The structure is granular, and the ferromagnesian silicates are olivine and augite. The former predominates, but is largely converted into serpentine. The feldspars in this rock are so clouded with decomposition products as not to be capable of identification. Doubtless fresher specimens might have been collected in the neighborhood. These were taken at the glacier wall on account of the relations of the glacier to the disintegration of the mass.

DIKES.

Reference has been made in a number of places to the different dike rocks on the peninsula. Dikes of one kind or another are known to cut all the different rock formations except the Kenai. Those recognized so far belong to the more acidic igneous rocks and include granite, dacite, porphyry, and rhyolite. As regards their distribution it may be said that they are much more numerous in the southern than in the northern part of the peninsula and that if they are present at all in the central part it is in only a few places. Those of the Seldovia region will be considered first.

Dacite-porphyry dikes.—Reference is again made to the report of the Harriman Alaska Expedition for a description of these dikes. Speaking of the cherts and diabases of Halibut Cove, Professor Emerson[b] says:

The series is cut by a group of conspicuous light-colored porphyry dikes, standing nearly vertical, parallel, and 20, 10, 50, and 60 feet in width, respectively. Under the microscope these dikes proved to be much altered dacite-porphyries, showing phenocrysts of embayed quartz, acid plagioclase, much altered to calcite and kaolin, and occasional orthoclase in a granular to granophyric groundmass of quartz and feldspar. Chlorite is sparingly present throughout the rock, but the bisilicate from which it was derived could not be determined. The dikes are quite coarsely porphyritic near their centers, but toward the contact with the cherts become almost aphanitic. The cherts are whitened for a few inches from the contact, but not otherwise altered.

Diabase dikes.—A small diabase dike, about 3 feet thick, was found cutting Jurassic tuffs at a point 2 miles west of the entrance to Seldovia Bay. It is fine grained, grayish green in color, and is made up of lath-shaped plagioclase feldspars, the interspaces being filled chiefly with green chloritic material. Small, nearly colorless crystals of pyroxene are also present, as is considerable magnetite. Occasional small spherulitic feldspar aggregates are seen scattered on the surface of a hand specimen.

Rhyolite dikes.—Only one small dike of rhyolitic rock was observed, about 2 inches thick, and this also occurred in the Seldovia formation. The hand specimen shows a dark, cryptocrystalline, almost glassy groundmass, thickly strewn with small angular fragments of quartz and feldspar. Under the microscope both quartz and feldspar are seen occasionally to have their crystal forms well developed. Orthoclase and acid plagioclase are present but somewhat altered.

GRANITE.

No igneous rocks were found in place between Resurrection Bay and Turnagain Arm. On the north side of Turnagain Arm, however, the Sunrise series is cut by dikes of light-colored granite, whose fragments appear frequently in the stream gravels. Bowlders of granite are occasionally found in the gravel deposits of the Sixmile drainage basin. Two or three large bowlders of a more basic igneous rock, diabasic in character, were also seen. In the Resurrection Creek drainage basin a greater number of granite bowlders were observed during the season's work than in the region lying farther east; nevertheless they are still far less important, both in variety and quantity, than in the gravels west of the Kenai Mountains, as observed

[a] Becker, G. F., Reconnaissance of the gold fields of southern Alaska, etc.: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, p. 47.
[b] Alaska, geology and paleontology: Harriman Alaska Expedition, vol. 4, 1904, p. 26.

about Skilak Lake, Kenai River, and the beaches of Cook Inlet at Kenai. The occurrence of granite in these localities will be taken up again in the description of the gravel deposits.

According to Mendenhall, whose most careful study of them was made in the vicinity of Portage Bay, the members of the Sunrise formation are intruded by igneous dikes, chiefly aplitic in character, but more basic in at least a few places. The writer's failure to find such dikes in the mountains southwest of Portage Bay and the fact that dikes of that nature are present in the Crow Creek neighborhood suggest that they may be of local occurrence. It is evident, however, that occasional dikes in the region visited might escape observation in a reconnaissance survey. The bowlders along Crow Creek, while very light in color, are generally of granite rather than aplite and are practically unaltered, showing that they were intruded after the folding of the Sunrise "series" was nearly if not quite as far advanced as at present. The light-colored granite dikes are very conspicuous where they occur, cutting large exposures of the darker slates and arkoses, and may often be recognized at a considerable distance.

The present knowledge of these igneous rocks is not sufficient to determine what relation, if any, they bear to the origin of the gold deposits, nor is their age known further than that they were intruded after the sediments of the Sunrise formation had been folded and more or less altered.

SURFICIAL DEPOSITS.

CLASSIFICATION.

The surficial deposits of the Kenai Peninsula may be divided into two general classes—deposits laid down in water, such as streams, lakes, or the sea, and deposits laid down by glaciers and more or less modified by the action of water. Some of the deposits of the two classes may be so closely related to one another or so similar in appearance that it is difficult to draw any sharp line between them, if it is possible to make any distinction at all. Immense deposits of gravel, sand, and clay occupying the valley floors of all the larger streams and also extending into the valleys of the side streams form one of the conspicuous topographic features of the region south of Turnagain Arm. Far more extensive, though generally less noticeable except along the streams and the shores of Cook Inlet, is the Kenai gravel sheet—the gravels and sands covering the highlands and flats west of the Kenai Mountains. These last-named deposits differ somewhat in composition and appearance from the valley gravels, but were probably laid down during the same period and to a certain extent under the same conditions. Near the mountains and in the valleys both have been more or less modified by glacier and stream action. For convenience in description and to distinguish them from the deposits of the present streams the deep gravels above the streams will be referred to as high or bench gravels.

WATER-LAID DEPOSITS.

High gravels.—Within the mountain area high terraces or benches are most prominent in the valleys of Sixmile and Resurrection creeks, around the lower end of Kenai Lake, and in Kenai River Valley between the two lakes. High gravels are also present but less noticeable along the streams emptying into Turnagain Arm. Between Canyon and Quartz creeks and on Resurrection Creek they reach elevations of 1,500 to 1,600 feet above sea level. The surface of the gravels is not horizontal, but slopes gently toward the middle of the valley from either side and downstream as well. On the benches of some streams, notably Canyon, Juneau, and Seattle, numerous small, marshy areas surrounded by spruce timber or alders mark the filled-in basins of former ponds. Though such open spaces are always wet, they are usually followed by trails, since the difficulties of forcing a way through the thickets are thus avoided.

The gravels were laid down in an old valley at a time when, as will be shown later, the land stood at a lower level with reference to the sea than at present. Their thickness, therefore, is not uniform, but depends on the surface form of the underlying rock floor. Streams have cut channels through them and in many places now flow in canyons whose walls are high banks of gravel. The gravel banks at the mouth of Cooper Creek measure about 200 feet from the bed of the stream to their top. Their base is not exposed, and even if it were this measurement might not represent their original thickness, for gravel benches around the lower end of Kenai Lake reach an elevation of 500 feet above the water level. Kenai Lake itself is due, in part at least, to damming of the old valley by these gravels, and it therefore follows that the base of the deposits is considerably below the surface, possibly below the bottom of the lake. At Sixmile Point, on Resurrection Creek, the top of the gravels is between 300 and 400 feet above the stream or about 1,000 to 1,100 feet above sea level. Similar deposits are cut by Sixmile Creek and other streams. Near Mills Creek the high gravels have been cut into a series of sharply-defined terraces from 10 to 30 feet high, extending from Canyon Creek to the western valley side. Gravels occur on the mountain sides west of Quartz Creek on Turnagain Arm nearly 2,000 feet above tide. There are also benches in some valleys, such as that of East Creek in the Resurrection Creek basin, where the gravels reach an elevation of 3,000 feet, but these were probably deposited along the margins of glaciers that have since disappeared.

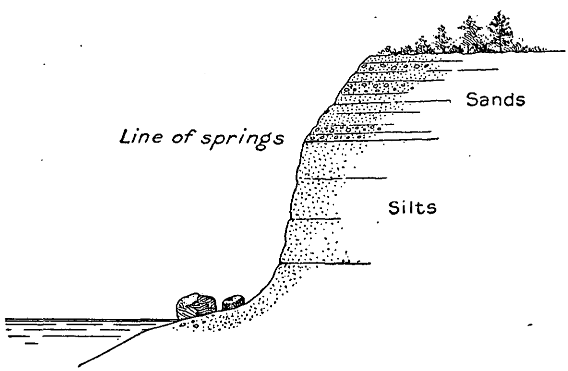


FIG. 2.—Diagrammatic sketch, showing relations of sands and silts at Kenai.

These deposits consist of washed gravels, sands, and clays. The gravels may be sandy, clayey, or ferruginous, and are made up in large part of fragments identical with the rocks of the neighboring hills. There is, however, a small percentage of granite and of some basic igneous rock which was not found in place and which may have come from a source outside the valleys where it occurs. One evidence of this is the fact that the amount of this material increases toward the west, from the head of East Fork to the inlet. All the rock fragments are more or less waterworn, and the smaller pieces are well rounded. Locally, also, they are strongly cemented with clay or iron oxide.

The sands contain a much greater proportion of flat scales of slate and arkose than of quartz, and sometimes show cross-bedding. At various places on different creeks sands of this nature, overlain by tough clays, carry a large amount of water. They are not firmly packed, and cave in continually when the attempt is made to sink a shaft in them. Since they carry no gold and it is difficult to handle the water, prospectors rarely try to penetrate them. Undoubtedly many of these sand beds are in fact stream deposits.

Most of the clays are bluish or gray in color. They usually contain some gravel and are really very fine sand or rock flour—a product of grinding by glacier ice, which gives the milky look to the waters of numerous streams on Kenai Peninsula and to Kenai Lake.

The deposits constituting the Kenai gravel sheet are continuous with the high-valley gravels and differ from them in that a large part of the material is finer and that there is a much larger percentage of fragments not derived from the Kenai Mountains. They cover the whole area between Cook Inlet and the foothills, but, except where they form terraces or are cut by streams, are generally obscured by overlying moss or brush. High banks of gravel confine Kenai River (below Lake Skilak) but decrease in altitude toward the west. At Kenai the bluff on which the town was built is between 75 and 100 feet high. A bluish-black silt containing some gravel forms the lower two-thirds of the bluff and is overlain by sands and gravels. This upper third is often firmly cemented with iron oxide and resembles a weathered ferruginous sandstone. The contact of silts and sands is distinctly shown by the outline of the bluff, for the silts stand at a higher angle than the sands (fig. 2), by the difference in color, and by a line of springs whose waters have streaked the silts with iron stains. It is evident that the ground water seeps down through sands and gravels to the less porous silts and then follows the contact until it finally emerges in springs. Granite forms a large proportion of the beach gravel, and also furnishes most of the numerous bowlders strewn along the shore. These angular bowlders or blocks reach diameters as great as 8 to 10 feet and are evidently not all derived from the same source, since they represent a variety of granites. Similar granites are found in the valley of the Sushitna, but are not known in the Kenai Mountains. It is therefore probable that their source must be sought somewhere to the north rather than on the peninsula.

The depth of these gravels was undetermined, for at no point visited by the writer had streams cut through to the underlying rock. Such measurements could probably be made at Cape Kasilof, where the northward dipping Kenai beds rise above sea level, or at other points still farther south, although there is reason to believe that the thickness decreases in that direction.

This gravel sheet has been referred to the Pleistocene and is undoubtedly connected with the northward retreat of the ice sheet presently to be described.

Stream deposits.—By stream deposits are here understood the sands, gravels, or clays laid down by a stream in its channel. Such deposits occur on all the streams of Kenai Peninsula and differ from the high gravels principally in that they are less continuous in horizontal extent; that their bedding is more imperfect; that in general the fragments are less worn, and that they are due in part to the weathering of the country rock which has taken place since the high gravels were laid down. Their most conspicuous portion is the surface wash, consisting of angular fragments varying in size from coarse sand to bowlders 2 feet or more in diameter. Such wash is without lines of bedding and usually has a thickness of 2 to 10 feet, but occasionally reaches a thickness of 15 or 20 feet. This deposit rests at times directly on the bed rock, but may overlie other gravels. Here and there small basins contain well-stratified deposits of fine gravel, sand, or clay. These include some of the "quicksands" mentioned in describing the high gravels. When a stream is cutting through bench gravels and has not yet reached bed rock, well-stratified newer stream gravels are not readily distinguished from the older deposits on which they rest.

GLACIER DEPOSITS.

Surficial deposits due to valley glaciers are so closely associated with those laid down by streams that there is sometimes difficulty in determining which factor was more important in a given case or to which class a certain deposit should be referred. Undoubtedly both ice and water have worked together in many places and the deposits are to be regarded as due to the joint action of both. One of the characteristics of débris left by melting glacier ice is that, where unmodified by water currents, the fragments lie in confused heaps, just as they were thrown down, and that there is little or no separation of fine from coarse material. The best example of purely glacial deposits seen by the writer is in the middle valley of Crow Creek. An old terminal moraine stretches across the valley at this place, and its character has been well brought out by the cut made through it to reach the gold-bearing gravels of the basin above. This moraine is made up of angular blocks of rock, all of which are probably derived from the immediate region. Above and below are basins of stratified gravels and sands deposited by water. The débris of the moraine was apparently thrown down during a period in which the ice front was stationary, allowing the rock load to accumulate in front of the glacier, or possibly the moraine may be due to a pushing forward by the advancing ice of the loose material on its bed. After the ice retreat this moraine persisted as a dam, behind which the stream was ponded, and thus fine gravel and sand could there come to rest. Considering the former wide distribution of valley glaciers it is remarkable that more moraines like that of Crow Creek were not observed. This apparent absence may be accounted for on the supposition that the glacier deposits have been modified by stream action or concealed by the high gravels.

Another class of deposits due to glaciers but modified by water includes the sand and gravel plains extending outward from the ice front. Along the streams the plains are at some places miles in length, as in the valley of Resurrection River. The floors of Glacier, Twentymile, and Portage creeks and of Glacier River furnish good examples in the Turnagain Arm region, as do also the flats at the head of Skilak and Tustumena lakes farther south. The Kenai gravel sheet and the high gravels of the Kenai Mountains have been described as water-laid deposits, but their material was largely the product of glacial erosion and was laid down in front of the retreating ice, the silts found in many localities around the inlet representing the finer offshore deposits.

GEOLOGIC HISTORY.

DEVELOPMENT OF TOPOGRAPHY.

GENERAL STATEMENT.

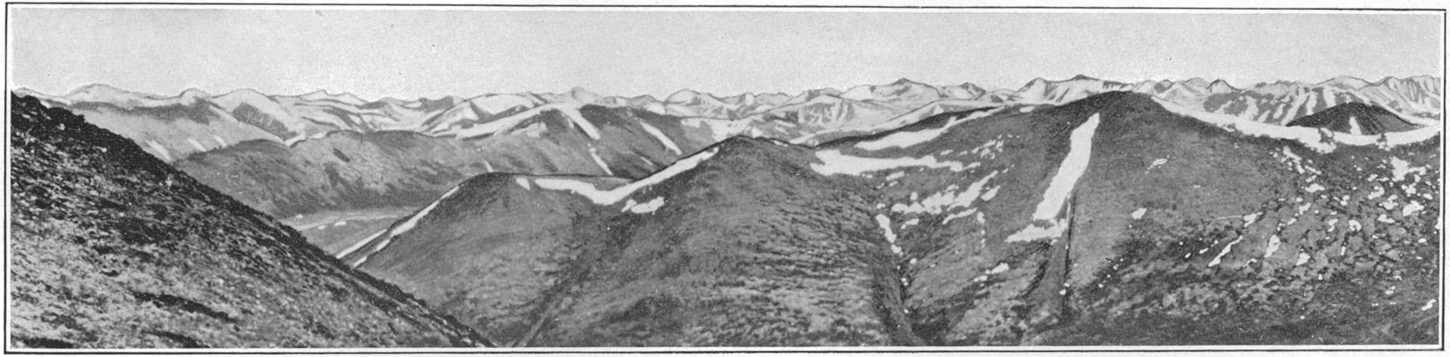
A study of the general surface features of Alaska has led to the recognition of four well-marked geographic provinces,[a] which, named from south to north, are as follows: The Pacific Mountain system, including numerous near-by parallel mountain ranges adjacent to the Pacific along the whole southern coast of Alaska; the Central Plateau region, a broad central zone the axis of which is followed by Yukon River and which includes the drainage of the greater part of Alaska and Yukon Territory; the Rocky Mountain system, including several mountain ranges and forming the westward continuation of the Rocky Mountains of the United States and Canada; and, finally, the Arctic Slope region, including the greater part of Alaska north of the latitude of Cape Lisburne, or, more accurately, all the region north of the Rocky Mountains.

Kenai Peninsula lies in the first of these provinces (the Pacific Mountain system), and the mountain range constituting the axis of its mass is one of the numerous ranges to which reference was made. Although much remains to be learned concerning the development of topography in this province, for as yet only the most prominent features are known and these in an imperfect way, it is possible to give some account of the events which occurred.

FORMATION OF PENEPLAIN.

After the deposition of Mesozoic sediments, but probably not till post-Kenai time, came an uplift which subjected the region to some further alteration, as is shown by the folding of the younger sediments, and began or possibly merely continued a long

[a] Brooks, Alfred H., The geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906.



A

B

PANORAMIC VIEW FROM HEAD OF RESURRECTION CREEK.

Looking east and south Photographs are taken from an elevation of 5,000 feet and show the accordance of summits in the Kenai Mountains. The average elevation is between 4,000 and 5,000 feet above sea level.

period of erosion, which resulted in the reduction of the then existing land mass almost to a plain at sea level. This plain is indicated by the nearly uniform level of the tops of Kenai Mountains. Standing on one of the hills about the upper end of Resurrection Creek, at an elevation not far from 5,000 feet, and looking eastward over the mountains of the interior peninsula, one sees their ragged peaks scattered before him in apparent confusion, but all rising to nearly the same altitude. Here and there a peak projects slightly above the general level or sinks below it, but at a distance the resultant effect on the eye is a horizontal line. (See Pl. V.) This plain is the southern continuation of that observed by Schrader and Spencer in the Chugach Mountains north of Prince William Sound and called the Chugach Plateau. As stated by Spencer:[a]

> The Chugach Plateau is considered to have originated in the uplift of a base-leveled land surface, and from the fact that this feature of erosion has been found to bevel the edges of folded and upturned lower Cretaceous strata, its age is considered to be late Mesozoic or Tertiary.

UPLIFT AND EROSION.

After the long period of erosion came another uplift, which renewed the cutting power of the streams and gave them opportunity to deeply trench the old plain. Indeed, this period continued so long that the trunk streams were not only able to cut their channels to sea level, but were permitted to widen them extensively, while the inter-areas were carved into a complicated system of sharp ridges and steep, narrow gulches. How much the plain was lowered during this process is not known, but no flat-topped mountains were seen, and the sharpness of nearly all ridges would indicate that they are now somewhat below the level of the land surface which conditioned their altitude. This interval of valley making possibly took place at a time when the land stood at a higher elevation than now, for the valley floors of many streams lie well below the present sea level. It should be stated, however, that this condition might be the result of some other agency, as glacial erosion, which has been mentioned in explanation of the deep fiords of Prince William Sound.[b]

BEGINNING OF GLACIATION.

The period of subaerial erosion was interrupted by a change of climatic conditions and the beginning of a period of extensive glaciation in which the valleys were still further modified and reduced practically to their present forms. This alteration consists mainly in a deepening and straightening of the existing valleys, most of which occurred during the advance and maximum development of the ice fields. The resulting débris was spread before the ice front, and on the retreat of the glaciers to the higher altitudes covered the valley floors as well. The influence of glaciation on the topography will be more fully considered in later paragraphs.

DEFORMATION.

Finally another uplift brought the Pleistocene gravels above sea level. Mendenhall[c] holds this uplift to have been differential, and cites as proof the southerly tilt of the old Matanuska River Valley and the northerly tilt of the Kenai Plateau. In the Matanuska Valley the tilting is shown by the position of the gravels, but more clearly by the high gradient and recent cutting of the river, which now flows in a narrow channel cut in an old broad valley. The floor of the old valley emerges from beneath the gravels of the lower river about 20 miles above the head of Knik Arm, but at

---

[a] Spencer, Arthur C., Pacific Mountain system in British Columbia and Alaska: Bull. Geol. Soc. Am., vol. 14, 1903, p. 120.

[b] Schrader, F. C., and Spencer, A. C., The Geology and Mineral Resources of a Portion of the Copper River District, Alaska, 1901, p. 81.

[c] Mendenhall, Walter C., A reconnaissance from Resurrection Bay to Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, 1898-99, pt. 7, p. 333.

Glacier Point, 50 miles farther up, stands from 400 to 500 feet above the river, giving the old valley floor a slope of nearly 10 feet to the mile.

The evidence for the production of this tilting during post-Glacial time is based on the correlation of gravels at the head of Matanuska River with gravels near its mouth. Mendenhall suggests that Turnagain Arm represents an axis of minimum uplift toward which both the Kenai Plateau and the old Matanuska Valley were made to slope. It is seen that the accuracy of the determination of the suggested time of tilting depends on whether or not the Cook Inlet and the Copper River Plateau gravels at the head of Matanuska River were laid down at the same time and elevation, since if deposited at about their present elevation the present river channel may have been largely cut before the ice mantle appeared. A simultaneous tilting of the areas north and south of Turnagain Arm appears reasonable, but if occurring in post-Glacial time would offer a most serious objection to the suggestion of block faulting as explaining the relation between the Chugach and Kenai plateaus, for it is inconceivable that erosion so great as that involved in that suggestion could take place in so brief a period. The uplift which began after the ice retreat and lifted the Pleistocene gravels to the position now occupied is so recent that many of the streams have not yet cut through the gravel deposits in more than a very small part of their length and are still actively engaged in that work.

RELATIONS OF KENAI AND CHUGACH PLATEAUS.

At least three explanations may be suggested for the relation of the Kenai Plateau to the higher Chugach Plateau, which is indicated by the accordant mountain tops of eastern Kenai Peninsula:

1. That the Kenai was laid down during a period in which the then partly dissected Chugach Plateau was submerged and that all traces of the deposit have since been removed from within the mountain area, the portion outside the mountain area having been folded and having its surface planed down to the present level.
2. That the Kenai sediments were deposited on the Chugach base-leveled surface before its dissection, during a period in which the area was totally or partially submerged, the difference in elevation of the present Kenai Plateau and the Chugach Plateau (from 3,000 to 4,000 feet) resulting from displacement along a fault which marks the western boundary of the Kenai Mountains.
3. That during the deposition of the Kenai sediments the partly dissected Chugach Plateau represented by the Kenai Mountains stood above sea level, erosion of that land mass furnishing some part of the Kenai beds.

Taking up the first hypothesis it may be said that evidence collected by various geologic workers in Alaska and the neighboring Canadian possessions seems to show more and more clearly that all or nearly all of the region was base-leveled during Tertiary time, and that the present topography has originated since that base-leveling took place. Kenai beds are found to have undergone such leveling in regions whose planation is provisionally correlated with this general base-leveling, the evidence indicating that the planation does not represent a stage of erosion after the original plane had been extensively dissected, but that the general base-leveling took place later than Kenai time. If, therefore, the time when this erosion took place is established as post-Kenai the first hypothesis fails.

With reference to the second hypothesis it must be said that no direct evidence was found to indicate the occurrence of faulting along the western face of the Kenai Mountains. Such faulting not only would be of considerable maximum displacement, amounting to not less than 4,000 or 5,000 feet, but would extend in the direction of its strike for possibly 200 miles. This hypothesis involves also the removal by erosion from the mountain area of a volume of rock which, although probably in no way comparable to that carried away during the long period of base-leveling, is yet greater than the quantity necessary to fill the present valleys and restore the land surface approximately to a plane, for it includes what was removed from the base-leveled surface and possibly from the overlying Kenai deposits as well.

It is not necessary, however, to suppose that the Kenai beds ever extended over that portion of the Chugach Plateau that is preserved in the Kenai Mountains, which may have formed a very low land surface during Kenai time. This hypothesis, according to which the Kenai Plateau is a fault block depressed with reference to the Kenai Mountain area, also offers one explanation for the northward slope of the plateau surface, since such a block might be displaced unequally at the north and south extremities and thus produce the tilting which, so far as now known, took place only on the west side of the peninsula and did not affect to any great degree the Kenai Mountains. It is possible that future study may show the mountain area to have been tilted also, but at present it appears probable, from the very meager evidence at hand, that if the Chugach Plateau in Kenai Peninsula dips at all it is toward the south rather than the north. Such an explanation of the tilting of the Kenai Plateau may meet with difficulties when the Matanuska Valley tilting is studied, yet it should be borne in mind that the two movements may have different causes, and if so must be accounted for in different ways.

The third hypothesis which at first thought appears the simplest, also meets with objections. This hypothesis represents the Kenai beds as deposited during a period in which the Kenai Mountains were above sea level and possibly stood at about their present elevation. Kenai sediments were deposited offshore and their gravels, sands, etc., were supplied largely by weathering of the neighboring land mass. Either the Kenai was never laid down within the mountain-area valleys, or if deposited has since been removed. The continuance of a land surface possessing such high relief as that seen in the Kenai Mountains from early Tertiary time to the present is possible, but the great objection to this hypothesis is the one already raised—that a preponderence of evidence now favors a later age than Kenai for the Chugach Plateau, that is, the Chugach Plateau was not produced till after the sandstones, shales, and lignites of the Kenai formation were laid down and folded.

Of the three hypotheses presented the second has something in its favor, but as yet only a few of the facts bearing on it are known. If the present topography originated as has been outlined, by dissection of a former land mass which was first base-leveled and then elevated several thousand feet above sea level, the first and third hypotheses are impossible unless either the period of planation took place before Kenai time or the planation of the folded Kenai beds took place after the Chugach Plateau was formed, both of which conditions appear to be contrary to fact. A presentation of various explanations for the accordance of summits in alpine mountain systems has recently been made by Mr. Daly [a] in which it is urged that a number of causes work together in such regions to produce that result. While the truth of the peneplain hypothesis when applied to certain topographic regions is not questioned, the explanations (isostatic adjustment, differential weathering, glaciation, etc.) offered for the forms of alpine mountains are opposed to the peneplain hypothesis in that they do not require the occurrence of a period of planation before the mountain uplift begins. There can be no doubt that most, if not all, the causes suggested are operative in some degree, but it is not possible now to say what part each took in the topographic development of the region under discussion.

GLACIATION.

While glaciation and its influence in determining topographic features might more properly be considered an incident in the general development of land forms, its importance on Kenai Peninsula is sufficient to make its separate treatment desirable.

[a] Daly, Reginald A., Summit levels among alpine mountains: Jour. Geol., vol. 13, No. 2, 1905, p. 105.

Several localities where permanent ice masses occur have already been mentioned, and others will be seen by referring to the map. Among the more important are Portage Glacier and the near-by glaciers on Twentymile Creek and Glacier River; also the glaciers on Lake Skilak, Lake Tustumena, and Kachemak Bay, as well as the smaller ones on Snow River, Resurrection River, and the east side of Resurrection Bay. Grewingk Glacier, on the south shore of Kachemak Bay, was visited by Dall, and later, at the time of the Harriman Alaska Expedition, was revisited by Dall and G. K. Gilbert. Mr. Gilbert's description is found in the account of that expedition. Only one or two of the glaciers mentioned were visited by the Survey party in 1904. At present most, if not all, of them appear to be in a state of retreat.

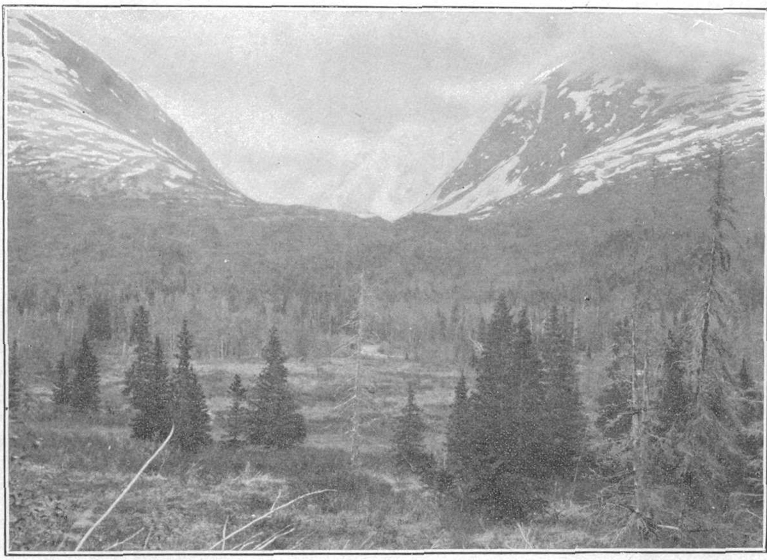
The present glaciers represent only a small remnant of the great system of ice rivers which once moved west, south, and east toward the sea from the valleys of the Kenai Mountains. Almost any valley one might choose gives evidence of former ice occupation. (Pl. VI, *A*.) Hanging valleys, from which streams plunge over steep cliffs to the main valley below, are seen in many places. (Pl. VI, *B*.) Along both shores of Turnagain Arm outcrops striated and rounded by moving ice are found where Portage Glacier, reenforced by ice streams from Twentymile Creek, Glacier River, and other valleys opening on the arm, flowed westward to unite with the much greater streams from Sushitna and Matanuska valleys. The valley of the Kenai-Snow system was the bed of an ice river, of whose greatly diminished mass there now remains only the glaciers of Snow River and Lake Skilak. North of Lake Skilak, at the lower end of the middle river, hilltops 1,200 to 1,400 feet above sea level are domed and beautifully polished, giving evidence of the minimum thickness and the erosive power of the ice. Here the striations, which, aside from local variations, have in most places about the same directions as the trends of the valleys, run across the ridge in a direction N. 10° W.

The extent of the ice mantle of which the Kenai glaciers formed a part is not fully known. It is probable, however, that the mountain areas inclosing the lower Sushitna Valley (these include the Alaska Range and the Chugach and Talkeet mountains) were centers of accumulation from which ice streams filling the valley converged toward Cook Inlet. In 1902 Brooks and Prindle found evidence of glaciation (perched bowlders and striæ) on isolated hills in Sushitna Valley 2,500 feet above sea level. Similar evidence was found along the front of the Alaska Range, while in Mantanuska Valley Mendenhall determined from the occurrence of scored and polished rock surfaces that the ice had a thickness of 3,000 to 3,500 feet. Ice streams from the valleys united in a broad sheet at the foot of the mountains in some such way as ice streams now unite at places along the Pacific Coast farther southeast. How much of Cook Inlet was occupied is uncertain, but the granite blocks on the beach at Kenai indicate that it extended at least as far southward as that locality. We may, therefore, think of the former ice mantle on western Kenai Peninsula as made up of numerous streams descending from the elevated mountainous country to the east and flowing westward to unite with one another and the broad ice stream moving southward through Sushitna Valley and Cook Inlet. Such ice sheets, lying just outside the mountains, have been called piedmont glaciers, in distinction from the alpine glaciers of the mountain valleys.

All these evidences of the former ice mantle are also proofs of climatic conditions different from those prevailing on Kenai Peninsula nowadays. More snow fell in the cooler than was melted in the warmer seasons, and the accumulating ice gradually flowed away from the principal centers, scouring out the valleys and bearing with it the débris which had been plucked from its bed or had fallen on its surface, and which now forms a large part of the high benches and broad sheets of gravels, sands, and silts already described.

A. VIEW DOWN EAST CREEK TOWARD RESURRECTION CREEK.

Good example of a glaciated valley.



B. HANGING VALLEY NEAR THE HEAD OF JOHNSON CREEK.

Photograph taken late in June.

SUMMARY.

The events just described as important factors in producing the land form, as seen on Kenai Peninsula, may be summarized as follows: During a time now thought to be later than that in which the coal measures of the Kenai (upper Eocene) were laid down the land mass then existing was reduced by erosion almost to a plain. This plain probably stood at an elevation very little above sea level, but later was raised to a considerable height, and thus allowed the processes of erosion, which had almost ceased, to be vigorously renewed. Erosion continued so long that the streams were not only enabled to thoroughly dissect the old plain, but were also permitted to cut their channels deeply and broaden their valleys. This period of erosion was necessarily a long one, and in it the major features of the present topography were established. One interruption occurred, however, when the advancing ice mantle moved down the valleys and out over the lowlands, but even then the manner and intensity of erosion only were changed. Valleys were straightened and broadened and the resulting rock waste was spread out before the ice front. Finally, the retreat of the ice was followed by land elevation and a renewal of stream activity, which left the land forms as they now are.

ECONOMIC GEOLOGY.

GOLD.

PLACER DEPOSITS.

GENERAL STATEMENT.

It has been shown that the Russian-American Company's efforts to develop both the gold and coal resources of Kenai Peninsula met with failure. As Doroshin himself states in his account of the two seasons' prospecting carried on for the company, his labor had no other effect than to chill the ardor of the directors for gold mining, so that it was not until long after American occupation that his belief in the existence of profitable gold deposits was justified, and even now none of the streams on which his work was carried on have produced gold in commercial quantities.

During the first few years of mining excitement following the discovery of gold on Resurrection Creek in 1895, more or less prospecting was done on nearly all the creeks of the Kenai River drainage. Other creeks on the west side of the peninsula were also prospected, but development work has been confined chiefly to the region of Turnagain Arm. Gold is widely distributed and is found in nearly all the surface deposits, the high bench gravels, stream gravels, glacial débris, and some of the sediments west of Kenai Mountains. Except at one place, however, it is only in the stream channels, where concentration has occurred, that the deposits have sufficient value to permit their exploitation with profit under the methods used. Gold is here derived, with little doubt, from the high gravels and glacial débris as well as from the rock waste of recent erosion. Since the real beginning of mining in 1895 the Turnagain Arm field has probably yielded over a million dollars, but it has been found impossible with the data at hand to give a more satisfactory estimate of the total production.

As has just been stated, the gold-bearing gravels which have made the Cook Inlet region important as a producer of the precious metal are found chiefly in the valleys of the streams emptying into the eastern half of Turnagain Arm. There are, however, less productive gravels at a number of localities, notably in Kenai River Valley, in one or two streams flowing into the eastern end of Lake Tustumena, and at Anchor Point.

A brief outline of the placer gold field is here presented to bring out some facts not directly evident from the map (Pl. II), while the more detailed description of individual streams will follow. For convenience the four principal drainage basins where gold-bearing gravels are exploited will be referred to by the names of the trunk streams—Resurrection, Sixmile, and Glacier creeks and Kenai River. The first three are the important streams in what may be called the Turnagain Arm field, all of whose producing creeks are included in a rectangular area, 25 miles from north to south, and 20 miles wide, with its center situated about 5 miles southeast of Sunrise.

Resurrection Creek is the westernmost productive stream flowing into the south side of Turnagain Arm. Together with Bear Creek (which is properly a part of the same system although the two do not unite) it drains an area 21 miles long and 8 to 9 miles wide, comprising about 175 square miles. The side streams, with two or three exceptions, are short, the upper portions of the narrow valleys being above timber line. The mountains, though steep and at times covered with loose blocks and smaller débris, are much less rugged than any others seen during the season.

Sixmile Creek, which enters the arm 8 miles up from the mouth of Resurrection Creek, is formed by the union of two large branches, Canyon Creek and East Fork (Pl. VII, *B*), and drains an area of approximately 250 square miles. The valleys of the two branches, as well as that of the trunk stream, are broad and are floored with heavy deposits of gravel. From the forks of the stream to the town of Sunrise, at its mouth, the distance is 10 miles. Mills Creek, the most important tributary, joins Canyon Creek 8 miles south of "the forks." A majority of the small streams which compose this drainage system, like those of the Resurrection Creek system, occupy steep narrow valleys, but a decided difference between the two regions is found in the character of the topography, for the smooth rounded contours of the mountains west of Resurrection Creek here give place to the rugged outlines that characterize the whole eastern portion of the peninsula.

Glacier Creek flows into the north side of Turnagain Arm 9 miles east of Sunrise. It is about 8 miles long and flows in a broad flat-bottomed valley, whose floor is covered with a heavy growth of timber. The whole drainage area comprises about 45 square miles and is a region of very rough topography. Crow Creek is the most important tributary.

Other streams flowing into the arm have been prospected with little success. Their valleys are generally narrow and steep, and it is noticeable that the great deposits of gravel, such as are seen in Resurrection and Sixmile valleys, were either never extensively developed here or have since been partly removed.

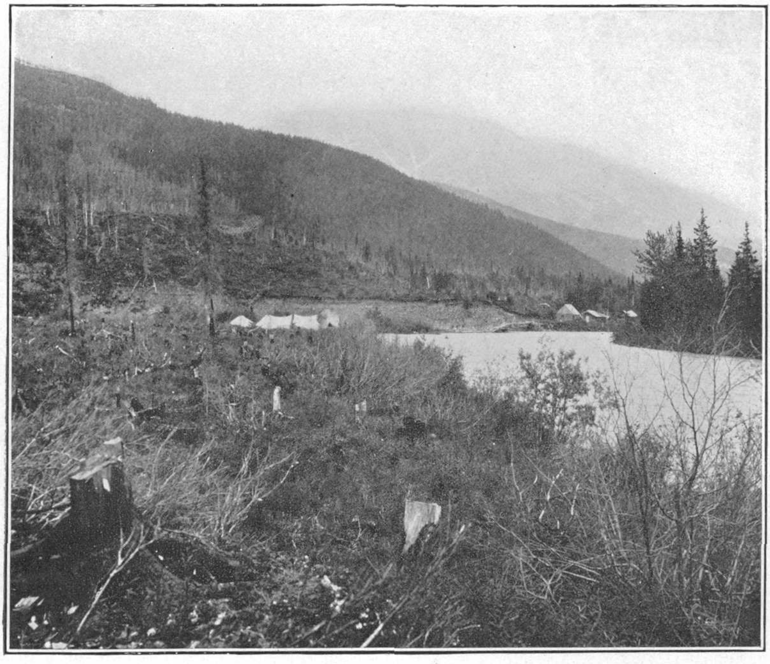
A description of Kenai River has been already given (pp. 14–15).

RESURRECTION CREEK VALLEY.

Resurrection Creek.—This stream, the earliest producer of the region, flows through a broad valley floored with a thick deposit of gravels, in which, throughout the greater part of its length, the waters have cut a deep, canyon-like channel. The portion from which gold has been taken, lying between Sixmile Point and Hope, has an average grade of 66 feet per mile, the grade of the lower 20 miles being about 100 feet per mile. Bed rock has not been reached on the majority of claims, for the stream cuts the country rock at only a few places and is working principally on gravels filling an old valley whose floor formerly stood at an elevation considerably higher than its present one. These valley gravels are roughly stratified and have been penetrated in one place to a depth of 50 feet below the stream level without reaching solid rock. They consist largely of slates and arkoses from the neighboring hills, but contain, in addition, an uncertain percentage of material, chiefly granitic in character, foreign to the valley. The bench deposits have never been worked, but are known to contain fine gold. A 60-foot bank 2 miles below Palmer Creek yielded colors from bottom to top, the best pan, about 2 cents, being taken from the upper 10 feet.

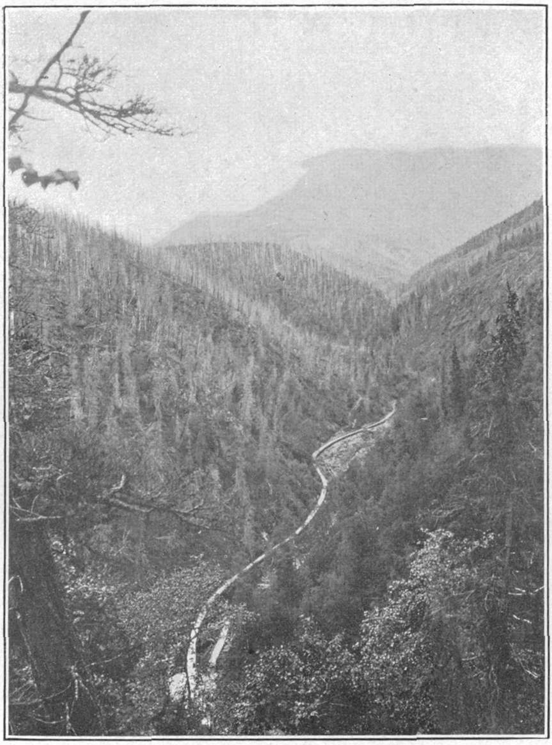
A. CANYON CREEK.

Showing the steep rock walls capped with gravels, and the remains of an old wing dam and China pump.



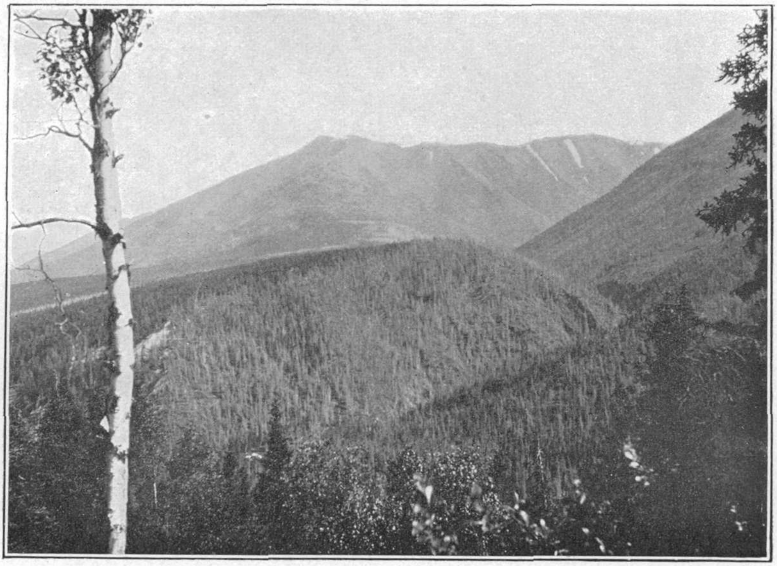
B. FORKS OF SIXMILE CREEK.

View down east fork. A bridge crosses Canyon Creek, on the left of which is the high gravel bank. A high bench is on the left.



A. CANYON OF PALMER CREEK.

High gravel bench on the left.



B. LOWER END OF PALMER CREEK.

Showing the deep rock canyon with gravel-capped walls.

Placer mining is confined to the channel gravels, which, however, must be derived, in part, at least, from the benches. The so-called bed rock on which pay is obtained is a gray glacial clay of variable thickness overlain by from 4 to 9 feet of stream wash containing some scattered gold. One claim on the creek yielded an average of 60 cents in gold to the cubic yard for a period of five years. This average was based on the assumption that a little over 4 yards of dirt per man per day were handled. From 4 to 5 yards is considered a good day's work.

The gold is fine and smooth, usually bright yellow in color, but at times whitish, and then of lower grade. Eighteen ounces of dust sent to the assay office contained $2 in silver.

Profitable mining on Resurrection Creek has been carried on entirely with pick and shovel. The method usually employed is to divert the stream into a new channel by a dam and then wash the uncovered gravels. All the material, excepting large bowlders, is sent through the boxes and the tailings are discharged into the stream below. A hydraulic elevator introduced at a point 9 miles south of Hope to handle channel gravels was not operated successfully, chiefly owing to the insufficient water supply and many bowlders. The former difficulty can be overcome without great expense, but derricks of some kind will always be necessary to handle the large material. Bowlders 2 or 3 feet through are not uncommon, and greater ones, with diameters of 5 to 6 feet, were also noted. A dredging machine shipped to this region on one of the late boats did not reach its destination and was unloaded at Valdez, to be brought in later. It is extremely doubtful, however, if there is any locality in the Resurrection Creek Valley where present dredging methods can be employed successfully, owing to the depth of the gravels and their irregularity in both the size of the material and the manner of its deposition. Bowlders form a large proportion of the deposits.

Palmer Creek.—Palmer Creek is the largest tributary of Resurrection Creek. Its upper portion flows for 6 miles through a broad, round-bottomed valley, while its lower part occupies a steep, narrow canyon cut through rock in some places and through gravel benches in others. (Pl. VIII, *A*, *B*.) Mining has been carried on chiefly in the lower 1.5 miles of the stream and has been confined entirely to the channel gravels. The country rock includes interbedded slates and arkoses, whose cleavage strikes a little east of north and dips at a high angle. The arkoses are frequently very much jointed and in weathering do not break into small pieces as easily as do the slates, a fact readily seen on examining the stream wash. The gravels resemble the country rock in their composition, and were undoubtedly derived from it in large part, although there are a few granitic bowlders which may not be of local origin. There is a large proportion of angular fragments and no small percentage of coarse material, possibly 5 per cent being over 18 inches in diameter. At the surface the gravels were laid down without definite arrangement, but are rudely stratified below. It is said that they yield about $1 per yard of material handled, but it should be stated that from 30 to 40 per cent of the gold is obtained from bed rock.

Palmer Creek gold is coarse and heavy, usually much flattened, and smooth. It passes at $16 per ounce at the local stores. In color the gold is bright yellow, but may be whitish. Pieces of native silver weighing as much as 1 pennyweight were seen, and also some black sand, which, however, is not abundant. No fine gold is saved. The claims on this stream were originally held by single individuals, but at present the whole of the lower canyon portion, 18 claims, is controlled by one company.

Two hydraulic plants were at work in 1904, employing in all about 10 men. The season was a wet one, and at the time of the writer's visit, in July, the stream was flowing not far from 3,000 inches of water, an amount sufficient for the present needs of mining. This quantity, however, is very much increased in time of high water, and may be considerably decreased during a dry season.

The greatest difficulty met in operating these plants arises from the presence of many large bowlders, which it is necessary to move by hand at least once. They are piled in a box provided with some dumping device and hoisted from the pit by a derrick, this operation consuming about twice the amount of time spent in piping, thereby decreasing greatly the efficiency of the plant. (Pl. IX, *B*.) When too large to be handled in any other way, the bowlders are reduced to convenient size with a few sticks of powder. It is the usual practice to operate the derrick with the stream from the giant, rather than to use a separate line of pipe for that purpose. With the present methods of mining, Palmer Creek should be a producer for several years to come.

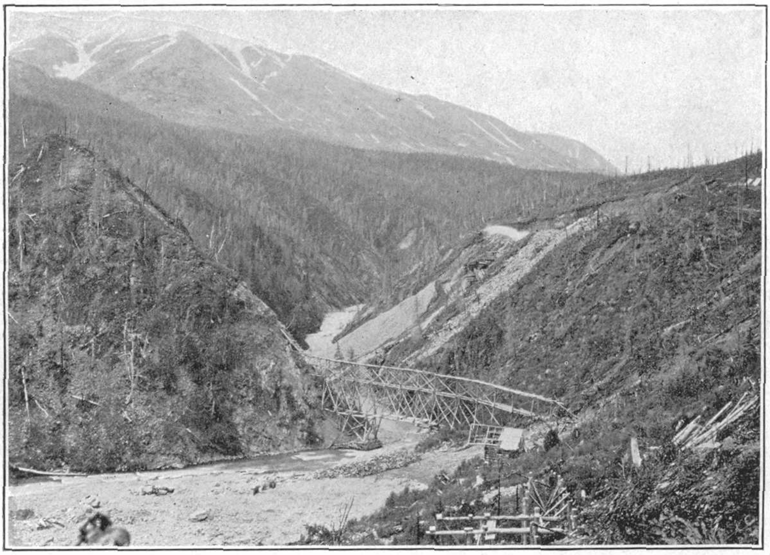
Bear Creek.—Bear Creek is the best known stream in this part of the field. It is about 5 miles long and has a fall of nearly 500 feet to the mile. Bear Creek Valley is narrower than Palmer Creek Valley, and, while resembling it in some ways, does not have the canyon features so well developed. The country rock is a succession of arkoses interstratified with bluish-black slates, the beds being so thin in one or two localities as to give to the outcrops a banded structure. These beds strike N. 20° E., or nearly at right angles to the general course of the creek, the cleavage, however, running more nearly north and south. The gravels are very irregular in distribution and are made up almost entirely of material like the country rock, but include, in addition, a few bowlders of granitic rock. In two places from 25 to 30 feet of unstratified deposits were seen. These contain a large quantity of coarse angular blocks mixed with sands and clays, the whole apparently dumped into its present position without having undergone any sorting by water. Bowlders 3 to 4 feet in diameter are plentiful. In some localities the surface wash is underlain by stratified sands and clays, which were probably deposited in small local basins, where they are sometimes found abutting against perpendicular rock faces or overlapping sloping surfaces. The hard gray clay locally underlying the surface wash and known as "glacial clay" rests on loose sands composed largely of slate particles and containing a large amount of water. It has been noticed in a few places that the rock surface above this clay is worn smooth, while below it is rough and unworn.

Bear Creek gold is lower in grade than any other from the Resurrection region. Like that from Palmer Creek, it is usually bright yellow in color, but may be whitish. Some native silver is found, and it is said that a small amount of native copper is also present. One large nugget of gold, valued at about $250, was found. The first claim staked on the stream yielded a little more than $2,000 the first year it was worked, but was not operated with profit in the following years. A second claim worked steadily, but in a small way, since the early days of Bear Creek's history has produced an average of $8 a day per man.

Two hydraulic plants have been installed on Bear Creek, but only one was in operation during the season of 1904, the other being involved in lawsuits. Although there has been sufficient water in the stream for the needs of these plants, the same difficulty with bowlders is encountered as on Palmer Creek. Bowlders are removed from the pit by derrick or cableway and are dumped at one side or carefully piled along the channel. It may be readily seen that the time lost in this way is great and that the cost of production is thereby very much increased. It can hardly be said that the future of the creek is bright, though with economical methods there are parts of the stream which can doubtless be worked at a profit.

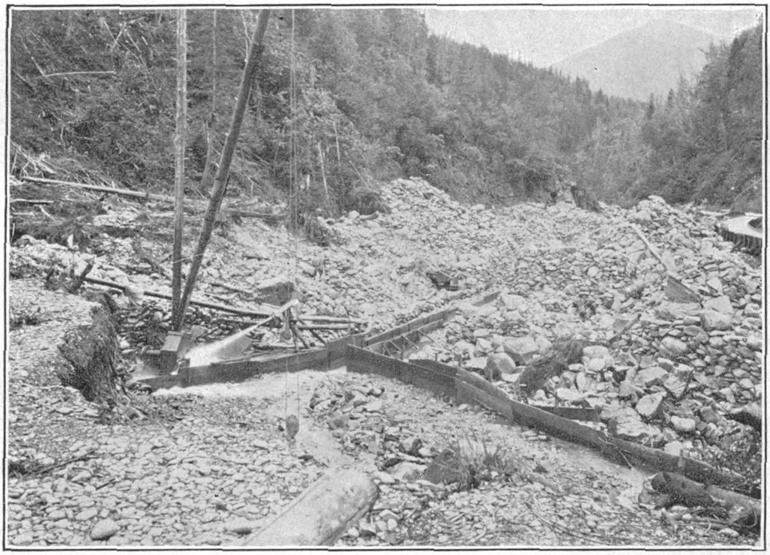
SIXMILE CREEK VALLEY.

The area of the drainage basin supplying the waters of Sixmile Creek and its branches is nearly half as large again as that of Resurrection Creek, and is much more irregular in outline. Probably the most noticeable feature of the topography in this area aside from the ruggedness of the mountains is the great development of gravel benches, which appear most prominently in the valleys of Sixmile Creek and



A. CANYON CREEK.

Showing the high gravels on the right. The trestlework formerly carried a flume.



B. HYDRAULIC MINING ON PALMER CREEK.

Shows the method of handling bowlders.

its two branches, Canyon Creek and East Fork. This basin contains the richest gold-bearing gravels yet found in the Turnagain Arm region, and mining operations have therefore been carried on here more extensively than elsewhere. The production of this part of the field is reported to be nearly $1,000,000, derived chiefly from Canyon, Mills, Lynx, and Gulch creeks.

Sixmile Creek.—Sixmile Creek has not been an important gold producer. It flows through a broad, flat-bottomed valley, but has not cut deep into the valley floor, so that the canyon features seen above on Canyon Creek are not here as well developed. Some mining has been carried on with fairly good results in one or two cases, but on the whole without marked success. A hydraulic plant was operated for some time on gravels said to carry about 40 cents per yard, but the work proved unprofitable and was finally given up. At present there is little or no mining on the stream.

Canyon Creek.—Canyon Creek flows for a distance of 8 miles through a narrow canyon ranging in depth from 100 to 200 feet or more, extending from "the forks" to a point just below Mills Creek. Above Mills Creek the valley is open and the waters have not yet had an opportunity to cut deeply into the gravels. A number of small lakes and considerable soft, wet ground make traveling in this part of the valley very disagreeable at times.

The country rock comprises shales and arkoses whose bedding and cleavage strike parallel with the course of the stream. In some of the narrower portions of the canyon the rock walls are seen to be capped with gravel deposits, but as a rule the

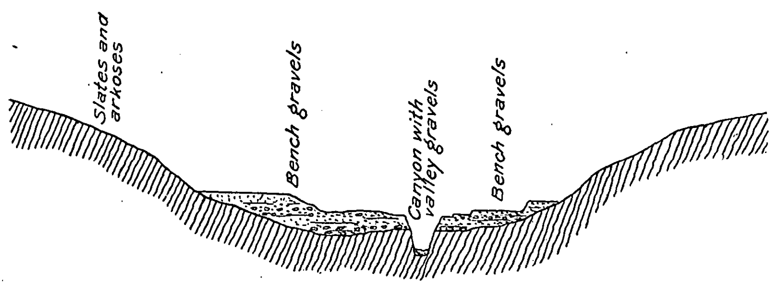


FIG. 3.—Diagrammatic sketch showing relations of creek and high bench gravels on Canyon Creek.

débris from above covers the rock faces, giving the impression that the height of the wall from the stream to the top of the bench represents the thickness of the gravels. Two principal gravel terraces at different elevations, besides a number of smaller ones, are seen below Mills Creek (fig. 3). In the localities most favorable for observing the high gravels near the stream, they were seen to have a thickness of about 50 feet, but the higher benches back from the creek may be considerably thicker. The bench gravels are made up chiefly of fragments like the country rock, but contain some material which was not seen in place south of the arm. Much of the gravel is rounded and well stratified, as is well shown in the benches near "the forks." In places it is cemented by iron oxide and gives difficulty in mining because it is not easily broken and often passes directly through the sluice boxes, carrying its gold into the dump. This gravel is locally known as "cement gravel."

The stream gravels are not stratified and the material is, in general, coarser and more angular than that of the benches. A section of gravel deposits at the flat near the mouth of Canyon Creek shows at the top from 6 to 8 feet of soil and coarse wash overlying 8 feet of sandy deposits, followed in turn by stratified clays and gravel.

The high gravels away from the channel have not been prospected, although gold is present in the high banks on the left side of Canyon Creek near "the forks," and the writer was told that a hole somewhere west of the stream showed good prospects. The only high gravels yet exploited are on the edge of the canyon, 3 miles above "the forks" (Pl. IX, *A*). Some gold is distributed through the gravel, but the greater portion comes from bed rock, which is here smooth, but shows hummock-like irregularities, due possibly to the action of ice, or, it may be, of running water. A well-defined rock channel, 40 feet wide and 12 feet deep, was uncovered by the removal of the gravels. This channel runs in a northwesterly direction, and is 150 feet above the present channel. In this channel was a bowlder weighing probably 15 tons. The gold from the bench is flaky and assays over $17 to the ounce. The largest piece yet found there was worth about 25 cents.

By far the greater part of the product of Canyon Creek has come from channel gravels. The swift current prevents any uniform distribution of gold, but the eddies behind rock points and large bowlders give an opportunity for the heavy particles to find lodgment, and at such places very rich pockets have been found. The stream has therefore been a good one for "sniping;" that is, for working the richest spots in a small way with very simple appliances.

The most evenly distributed gold occurs in the gravels of the flat at the junction of Canyon Creek and East Fork. This ground lies immediately below the canyons of both Canyon Creek and East Fork, making it a sort of dumping ground for the two streams. At this place the best pay comes from the clay bed rock, but fine gold is scattered through all the gravel.

Canyon Creek gold is generally coarse, as would be expected from the nature of the channel and swift current; that from "the forks" is finer. One hundred and six ounces of dust and amalgam, collected chiefly from claims on Canyon Creek, lost 4 per cent of its weight after melting at the mint; 0.8 per cent of the weight was silver and the combined value of gold and silver was $17.42 per ounce. The value before melting was $16.70 per ounce.

Mining on Canyon Creek has been carried on under difficulties, arising from the narrow channel and swift current. The more extensive operations always involve the construction of wing dams to confine the water to one side of the channel while the other side is being worked out (Pl. VII, *A*). Such operations are expensive and the results are uncertain, since in more than one instance the labor of an entire season has been destroyed by high water and loss of the dams. About two years ago a hydraulic plant was placed on the bench claims previously mentioned, and has met with some success, although with the present arrangement of sluice boxes some gold is probably lost. Yet this plant furnishes the only instance in the region of the use of undercurrents for saving fine gold. A head of about 300 feet is used in sluicing. The water supply during the season of 1904 was sufficient for all needs, but there was some trouble in getting water the previous year. This abundance of water resulted from a wet season and the fact that continued cool weather in the early summer prevented rapid melting of snow on the mountains. The obtainment of water for mining purposes is, however, a question of expense rather than of supply, for the region is peculiarly fitted for hydraulic mining. If it can be shown that the high gravels carry sufficient gold to permit hydraulic mining to be carried on in a large way with profit, the importance of the Sixmile region as a gold producer would be greatly increased.

Mills Creek.—Mills Creek has yielded more gold than any other stream of the Turnagain Arm field except Canyon Creek, and is probably better known than any other stream. It is nearly 5 miles long, but the important known gold-bearing gravels extend only from the mouth of the creek to the mouth of Juneau Creek, a distance of three-fourths of a mile. The stream here flows along the contact of the gravels and hard rocks, producing a canyon whose south wall is chiefly rock and whose north wall is chiefly gravel (Pl. X, *A*). The channel is cut principally in gravels, for the waters have not yet greatly attacked the underlying slates and arkoses.

The upper portion of Mills Creek lies in a round-bottomed valley, covered with gravels and bare of timber. High gravel benches are seen near the mouth of Juneau

A. GRAVEL BENCH NEAR THE MOUTH OF MILLS CREEK.

Looking across Canyon Creek. The valley of Mills Creek is seen on the right.

B. MILLS CREEK JUST BELOW THE MOUTH OF JUNEAU CREEK.

Juneau Creek once flowed through the gravel-filled channel over which the pipe line lies. Shows the manner in which bowlders are handled.

Creek and, as stated, form the north wall of the canyon below that point. Minor gravel benches are present in the upper valley. These high gravels have been described in the account of Canyon Creek, of whose benches they are a part. The stream gravels, as far as the writer could discover, were derived from the neighboring country rock, from which they differ in no way. They comprise slates and arkoses with occasional bowlders of conglomerate, consisting of rolled quartz pebbles in a fine-grained slaty cement. Such conglomerates were seen in place near the mouth of Canyon Creek..

The gravels of the canyon are unstratified or only rudely stratified. At the mouth of Juneau Creek (Pl. X, *B*) the work of the last two seasons has shown an old channel filled with gravels, the lower portion strongly cemented with iron oxide, resting on a tough, ill-smelling blue clay—the "bed rock." Part of the gold is scattered through the brownish cement gravel, but the best pay lies on the top of the blue clay. All the gold is heavy and flattened, but that from the cement gravel is the finer, averaging perhaps one-eighth inch in greatest diameter. Some of the larger nuggets found on bed rock are distinctly striated, as if rubbed against or dragged over a rough surface.

All of the mining in the canyon has been carried on with pick and shovel, and in this way all that portion of the gravels has been exploited. At present two hydraulic plants are in operation, one at the mouth of Juneau Creek, the other at the mouth of Mills Creek. The latter might better be regarded as being on Canyon Creek, although the ground is part of that belonging to the old Polly Mining Company. Water is obtained from Juneau Creek and is delivered at the mouth of that stream with a head of 280 feet. It was here found that this head was sufficient to tear out the cement gravel, but that it did not break it up enough to release all the gold, and that even small nuggets were carried through the boxes. The sluice boxes, usually having a grade of 5 to 6 inches to the box length (12 feet), are built with false sides and the riffles are covered with strap iron to protect them from wear. No mercury is used in the boxes. The tailings are dumped into the stream below; the bowlders are wheeled out and piled along the channel. A liberal use of powder to break large bowlders has proved economical.

The scarcity of white laborers in the spring resulted in the employment of natives during the season of 1904. They receive smaller wages than white men and when tactfully handled earn their pay, but in most cases can not be depended on to the same extent. It was said that the canyon of Mills Creek has been once worked over, yet there still remain small areas, at least, sufficiently rich to pay for sluicing. The banks have never been worked at all; no doubt they will receive some attention in the future.

East Fork.—East Fork is the larger of the two branches of Sixmile Creek. It has been worked only in the lower mile of its course, between the forks and the mouth of Gulch Creek. The production is about $16,000 to $17,000. This part of the stream lies in a shallow rock-walled canyon, cut through grits and arkoses, overlain by gravels. These gravels continue through the upper valley and appear as well-formed terraces in many places. None of these have been prospected.

The stream carries a larger body of water than Canyon Creek and the difficulties in handling gravels are the same as there. Wing dams are always necessary and china pumps run by the current are used to keep the pit dry. At the time of the writer's visit no mining was being done on East Fork.

Gulch Creek.—Gulch Creek is a small stream joining East Fork 1 mile above the mouth of Canyon Creek. Like the majority of the streams in this region its lower course is through a narrow canyon. The gravel benches, such as are seen in the larger valleys, are also present but are not so prominent. The creek gravels are made up of material like the bed rock, slates, and arkoses, and contain many large bowlders and angular blocks, usually arkose rather than slate. The gold production is about $25,000, nearly all of which was taken from the lower part of the creek by pick and shovel work. A hydraulic plant located three-quarters of a mile above the mouth of the stream proved unprofitable, and was in operation during the season of 1904 only long enough to complete the assessment work.

Lynx Creek.—Lynx Creek joins East Fork 7 miles above Canyon Creek, directly opposite the mouth of Granite Creek. It is about 3 miles long and occupies a narrow valley between high, rugged mountains. Deep gravel deposits are found at the mouth of Lynx Creek and continue well into the valley. Beside the usual slates and arkoses two or three large, rounded bowlders of altered diabase were seen in the gravels on one of the claims. These may have come from the neighboring hills, but no such rocks were seen in place by the writer. Two claims have furnished most of the gold taken from this creek to the present time (1904). These have been practically worked out and little in the way of placer mining is now done on the creek. The gold is heavy and contains numerous pieces of native copper whose probable source is the ledge now being opened up at the head of the creek. All work on Lynx Creek has been done with pick and shovel. Owing to the low grade of the lower part of the stream the gravels there have not been exploited. To overcome this difficulty a tunnel about 500 feet long and below the level of the water at its head is being driven to divert the stream. It is the intention to place sluice boxes in the tunnel and wash all the gravel through to the valley of Bench Creek. The production of Lynx Creek to the year 1904 was about $87,000.

Silvertip Creek.—Silvertip Creek has not been an important gold producer and presents no features of special interest. The entire output probably does not exceed $4,000. A hydraulic plant installed about a mile above the point where it joins East Fork did not prove successful, and the work was abandoned.

Granite Creek.—Granite Creek, one of the largest tributaries of East Fork, heads against Quartz Creek and thereby furnishes easy communication with the upper part of Turnagain Arm. Some work, more in the nature of prospecting than of mining, has been done on this stream or its tributaries for a number of years. The valley of Granite Creek below Bertha Creek is from one-quarter to one-third of a mile wide, and in many places is wet and marshy. Gravel terraces are seen here and there and the whole region presents the appearance of having been occupied by a lake or series of lakes, possibly at no distant time. A hydraulic plant, in operation for the last two years at the mouth of Bertha Creek, has been fairly successful. Here there are from 8 to 10 feet of coarse gravel and bowlders covered by 4 to 5 feet of finer wash. The gold is mostly taken from the coarse gravel, but the whole mass averages about $0.15 to the yard. Bed rock has not yet been reached. The gold is fine, bright yellow, and fairly smooth, the largest pieces being worth about 25 cents. Bertha Creek can be depended on for 400 inches of water, and if future developments warrant the expense, a flume can be constructed to bring water from the upper part of Granite Creek.

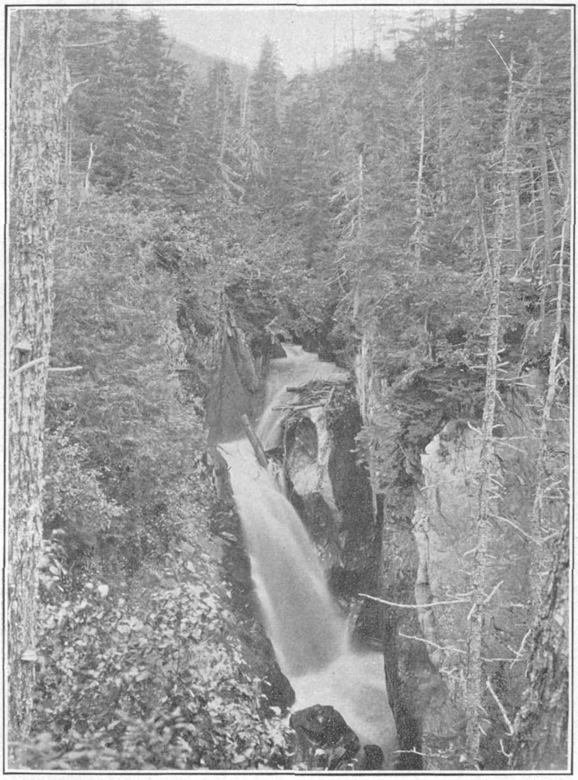
A rock carrier, driven by water power, for handling the bowlders, and a small homemade sawmill have been built. This mill is simply an ordinary whipsaw set in a square upright frame and driven by a water wheel with suitable gear; it will saw three times as much in a day as two men can saw by hand and is well worth the slight cost of construction.

GLACIER CREEK VALLEY.

Glacier Creek has never been a gold producer and is therefore important at the present time only because of its tributaries. It takes its name from several small glaciers at its head and flows on the broad, gravel-covered floor of a glaciated valley. Crow Creek, California Creek, and Winner Creek have yielded some gold. The production of Glacier Creek Valley—that is, of the three branches named—including the season of 1904, is over $51,000.

A. CROW CREEK JUST ABOVE THE CANYON.

Shows stone boat and wheel, run by the "giant," used in removing bowlders.



B. CANYON AND FALLS NEAR THE LOWER END OF CROW CREEK.

Such features characterize the lower portion of most streams on Kenai Peninsula.

Crow Creek.—Crow Creek is the largest tributary of Glacier Creek, and might properly be considered the head of that stream. It rises in the high mountains of the divide between this part of the Turnagain Arm drainage and Eagle, or Yukla, Creek, a tributary of Knik Arm. The lower half mile of the stream flows through a narrow rock canyon not over 5 feet wide at one point. (Pl. XI, *B*.) Above is a broader gravel-walled canyon or narrow valley extending northwestward to the mouth of Crow Gulch, where it broadens out suddenly to a basin three-quarters of a mile long, then, swinging abruptly northward, contracts to a narrow V-shaped valley and continues thus to the divide.

The bed rock comprises interbedded slates, arkoses, conglomerates, and banded quartzites, striking about N. 45° E., and cut by occasional dikes of light-colored granite.

The gravels are of three kinds, high-bench gravels, glacier deposits, and stream deposits. The first continue into the valley from Glacier Creek, and where most prominent have an elevation of nearly 1,000 feet. The top of the gravel bank east of Crow Creek at the head of the rock canyon is about 100 feet above the stream. On the west side a deep cut in the bank showed a perpendicular face 50 feet high in rounded gravels of fairly uniform size—that is, without large bowlders and with no marks of bedding. These high gravels were laid down in an old valley, whose stream was thereby forced to seek a new outlet and is now cutting the narrow canyon through the rock barrier which it encountered at its lower end. Near the middle of the rock canyon the work of the latter part of the season of 1904 disclosed the beginning of a well-developed, gravel-filled channel east of the present channel. This showed well-shingled stream gravels, and was expected to lead into the basin above the canyon. At the end of the season it had been followed in about 40 feet. The stream gravels show a large amount of material more recent than the bench gravels, consisting of angular blocks of arkose and slate, with many bowlders of light-colored granite, part of which are thought to be the product of erosion since the bench gravels were laid down. They are interbedded with finer clayey gravels and sands. A short distance above the rock canyon, mining has shown that here the base of the gravels must be considerably lower than at the head of the canyon; in other words, owing to the filling of the old outlet the deposits here appear to occupy a basin (fig. 4). The section includes loose sand resting on bed rock, overlain by blue clay, yellow clay, gray gravels, and surface wash. A few very large bowlders are present.

Another gravel-filled basin is seen farther up the stream. About one-quarter of a mile above Crow Gulch a long, curved "rock reef" extends across the valley and forms a well-marked ridge, with convex side downstream (fig. 4). A 60-foot cut had to be made through this "reef" in order to sluice the ground above, and it was found to be made up of immense bowlders and angular blocks, sometimes 10 to 12 feet in diameter, thrown down in greatest confusion. Plainly it is a terminal moraine left here by the retreating glacier, which still appears in contracted form in the high valleys to the north. Behind this barrier the gravels were confined and laid down with more or less regularity. The beds may be seen abutting against the upper side of the moraine, which cuts them off from the stratified gravels below. The section disclosed in piping the ground includes fine sandy beds, separated by beds of angular wash and coarse bowlders. These beds average from 2 to 3 feet in thickness. An interesting event, occurring at the time of the writer's visit to Crow Creek, may throw some light on the way in which these sandy and angular wash beds were formed. A very heavy rain brought down a large quantity of débris from points farther up the valley and filled the channel above the rock canyon—here from 75 to 100 feet wide—to a depth greater than the height of the sluice boxes, or over 2 feet. This material, as far as the writer could determine, was like that of the coarse, angular wash seen above. If this were followed by a period in which finer sands or clays were deposited and the whole process repeated, a similar series of beds would be formed.

Some gold has been panned from the bench gravels, but never in sufficient amount to encourage further work. The creek gravels are therefore the source of supply. Rich spots were found in the lower part of the rock canyon, and the old channel discovered last season yielded gold at the rate of 6.5 ounces per yard of gravel moved. Above the canyon the pay is irregular, and is taken chiefly from the yellow clay and the gray gravels. The former carries coarse gold; that from the latter is finer. Both

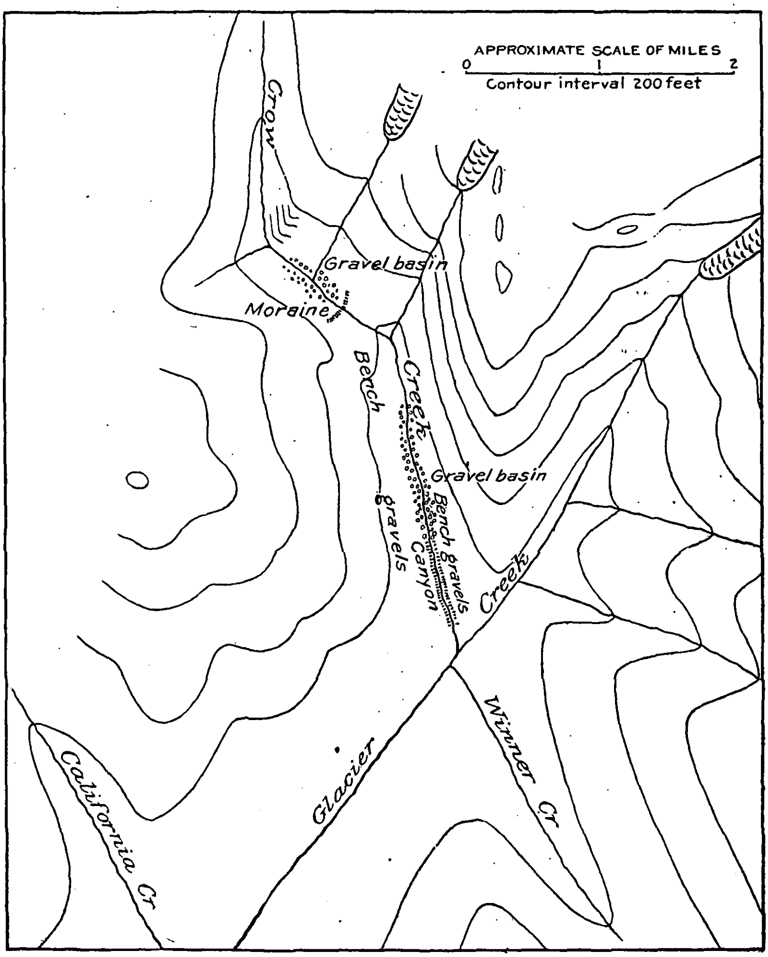


FIG. 4.—Sketch map of Crow Creek, showing terminal moraine and gravel basins.

these beds are tough and hard to pick, but the yellow gravel is the richer. In the upper part of the stream the pay is obtained almost entirely from the coarse wash, although the sandy beds carry some fine gold.

Crow Creek gold is of two distinct grades—one coarse and pale yellow in color, the other fine and bright yellow. It assays $14.80, and with it are associated native silver, copper, and a little black sand. The largest nugget found was valued at $25.97. The conditions under which these gravels were probably laid down makes it appear that some places are decidedly more favorable for the deposition of gold than others and that consequently future developments will show the stream to be "spotted." It should be said, however, that careful prospecting in the upper basin and the results of last season's work in the lower basin above the canyon give an average of 46 and 44 cents in gold per yard of dirt moved. Most of the gold produced on Crow Creek has been taken with pick and shovel, but at present the whole of the creek is under two separate managements, both of which make use of hydraulic methods and have better equipment for such work than is found on the other streams in the field. The creek carries from 3,000 to 6,000 inches of water, according to the season, and above the canyon has a grade of 2.5 per cent. The extraordinary size and quantity of bowlders is the chief difficulty to contend with in mining, necessitating the use of considerable powder in reducing the blocks to a size which can be handled by the derrick. (Pl. XI, *A*.)

On the lower group of claims water is brought from the mouth of Crow Gulch by a ditch 460 rods long, and is delivered at the upper end of the canyon with a head of over 200 feet. A double tailrace is used, in which the water may be changed from one side to the other when repairs are necessary or when any other condition makes the change desirable. Tailings are dumped into the canyon.

On the upper group of claims nearly the whole of the season of 1904 was spent in making the cut through the moraine, or "reef," as it is called. Twenty men were employed during the early part of the season, but this number was cut down when it became too dark to run a night shift. A head of 250 feet of water is used. The gravels are sent through an 8-foot race having a grade of 4.5 inches to the rod. It is said that 1,500 to 2,000 yards a day can be handled. The tailings are dumped into the stream below, but after seeing how gravels are carried down by higher water one is led to think that this practice may seriously interfere with work on the lower claims unless some measures are taken to impound at least the coarse material. This ground has been well prospected by holes and a few crosscuts, so that the management feels justified in incurring the great expense which was necessary to open the ground. The working season is several weeks shorter here than at the lower end of the stream, since the claims are above timber line and are entirely unprotected from the cold winds of the valley.

California Creek.—This stream has cut a steep, narrow, V-shaped valley in the mountains west of Glacier Creek, which it joins 2 miles from the arm. Its bed rock comprises the same materials found on Crow Creek. The gravels are similar, also, but carry less granite and do not show in the same degree the effect of glacial action. A few thousand dollars were taken out in 1896 and 1897, but of late years nothing more than assessment work has been done. It was proposed to set up a hydraulic plant and build a sawmill last season, but for some reason the project was not carried out. There is some good spruce timber near the mouth of the stream, which may be of considerable value in the future.

Winner Creek.—Winner Creek joins Glacier Creek just below the mouth of Crow Creek. Its valley, bed rock, and gravels resemble those of California Creek. Like the latter, it was worked slightly in the early days of the field, several thousand dollars in gold being taken out in 1898 and 1899, but in the following year it produced little or nothing, and in 1904 no mining was carried on.

MISCELLANEOUS LOCALITIES.

Small tributaries of Turnagain Arm.—Gold is present in the gravels of nearly all, if not all, the other streams flowing into Turnagain Arm, but no one of those not already described has been an important gold producer. Not a little work has been done on Seattle and Quartz creeks, also on Sawmill Creek, and gold has been obtained, but in small quantity.

Kenai River Valley.—The immense deposits of gravel along Kenai River afford ground eminently suited to hydraulic mining and have been prospected at several points, in the hope of finding gravels of sufficient value to pay for working in that manner. Some of the tributaries have also been prospected. In the upper valley of Kenai River, False Creek, a small tributary of Trail Creek, was receiving some attention in the early part of the season of 1904. It flows in a steep, narrow valley, whose angular gravels are derived from the neighboring hills. At the time of the writer's visit several days' shoveling had yielded sufficient gold for a grubstake to enable the men to continue work.

An unsuccessful hydraulic plant was located on the north shore of Kenai River near the lower end of Lake Kenai in 1898, but was abandoned later. Some prospecting is now carried on in the upper valley of Juneau Creek, a tributary to Kenai River, not to be confounded with the stream of the same name tributary to Mills Creek. A second hydraulic plant is located on the high gravels south of Kenai River about 2 miles above Lake Skilak. It was not in operation last season. The writer learned, however, that the small quantity of gold procured during the previous year all came from a few inches of the top gravels.

The only gravels in the Kenai River Valley which have paid for working are found on Cooper Creek and a small branch—Stetson Creek.

Cooper Creek joins the river 2 miles below Kenai Lake. It rises in a small lake and is said to head against the upper part of Resurrection River, flowing into Resurrection Bay. Near the mouth it has cut through deep stratified gravels, showing a bank on the east side of the stream between 100 and 200 feet high. The stream gravels, however, are the present source of the gold. Most of the pay from the creek was taken from a single claim in a single year. It is said that a profit of 14 pounds in gold was made that year, which would indicate a total production of possibly $5,000 or $6,000. The product of the other claims and of Stetson Creek is small.

Tustumena Lake.—Prospecting on the small streams emptying into the eastern end of Tustumena Lake has shown the presence of gravels carrying gold in small amount. Some attempts have been made to exploit them, and for a number of years there has been a little mining on Indian Creek. A hydraulic plant was taken in by way of Kasilof River, and has been in operation, but the results of the work were not learned. It is known, however, that work will be continued. Access to the lake by way of the river is not difficult if one understands how to take advantage of the tides, and this is the route usually followed.

Anchor Point.—The beach sands at Anchor Point yield a few ounces of gold each year to prospectors looking for a "grubstake." This is all fine gold, and although locally said to be washed up by the waves of Cook Inlet, is probably derived by concentration from the gravels of the cliffs along the shore which are here rapidly undermined by the water. A hydraulic plant was formerly located at Anchor Point and much money was spent in the construction of ditches and buildings, but the whole undertaking proved a failure, except in that it has since furnished pipe and other material for several hydraulic plants on Turnagain Arm.

SOURCE OF THE PLACER DEPOSITS.

Placer gold is derived from an original supply contained in various ways in bed rock and is ordinarily found at a locality more or less distant from the place where it was freed from the rock. A discussion of the source of placer gold does not, however, necessarily involve a consideration of either the manner or form in which it was deposited in its previous condition, so that in this paper the occurrence of gold in bed rock is treated principally in its relation to the occurrence of gold in the gravels.

Among the miners of Turnagain Arm there are two opinions concerning the origin of the placer gold—first, that it is derived from a local source; second, that it has been brought from a distance by the transporting power of glacial ice. There can be no doubt that a large part of the gold is of local origin. It is more difficult, however, to show what portion, if any, has been derived from any distant source.

In two localities in the Turnagain Arm field gold-bearing quartz veins of sufficient importance to attract the attention of miners are present, and steps have been taken to determine their possible commercial value. Small mineralized quartz veins are also exposed along the rocky shores of the arm, and fragments of quartz veins showing chalcopyrite with peacock stain are not uncommon in the surface gravels in the upper valley of Crow Creek. On a steep talus slope south of Bench Creek and high above the stream the writer picked up pieces of arkose or fine conglomerate, on whose surface were flakes of free gold. At the time it was thought that the gold was contained in the rock, but more probably its presence there was due to the rubbing of the rough surface of the bowlder against fragments of the metal, either loose or still attached to their original matrix. It is stated that free gold has been found in the sluice boxes imbedded in small fragments of slate and with no attached quartz.

It appears that in this region the openings in the rocks resulting from the readjustment due to the various movements which effected them have been completely or partly filled by depositions of quartz. As far as the writer has observed the quartz occurs in the form of small veins or lenses which may branch or intersect, producing in places a kind of network. Occasionally the quartz deposits reach thicknesses of 3 to 4 feet, but none of those observed could be shown to be continuous for more than short distances; in other words, their horizontal extension on the surface was limited and they have the appearance of irregular lenticular bodies rather than continuous veins. Both the larger and the smaller veins may contain sulphide minerals, usually pyrite with arsenopyrite or chalcopyrite, or both, sometimes zinc blende and galena. Further, some of the veins are known to carry gold, at times visible to the eye, but more frequently revealed only by assays.

It has been seen that the gravel deposits, which have been exploited with profit, were found in stream channels and that much of the gold was obtained from the coarse, angular wash, especially where clay was present. Mining in the high gravels has not been carried on with even a small degree of success in more than one instance, although fine colors are frequently found scattered through them. Coarse gold, though it may be present, has not been found in the high gravels even when bed rock has been reached, as is the case on Canyon Creek, where, in the course of two years' mining on the bench east of the stream, the largest piece of gold obtained had a value of only 25 cents.

The writer would suggest, then, that the present stream-gold deposits are formed in two ways—first, by the breaking down and decomposition of mineralized veins in the country rock; second, by the concentration of the gold contained in the bench gravels. The gold in the bench gravels is itself a secondary deposit and may have been derived from two possible sources; like a part of the gold in the stream gravels, it may have had its origin in local deposits in the country rock, or it may have been transported to its present location from some place outside the present drainage basin. Evidence has already been given to show that the deep gravels of Sixmile and Resurrection creeks, and especially those of the country west of the Kenai Mountains, are not entirely local in origin but contain fragments of rocks that are not represented, or at least not found, in the Kenai Mountains—fragments that were probably brought by glacial transportation or by floating ice from the mainland on the north. It seems fair to suppose then that the ice which transported this material may have carried with it some gold, but even if this is true, the facts presented indicate that the gold in the deep gravels and to a still greater degree that in the stream gravels is of local origin.

Of far greater importance is the influence of glacial action on the deposition of gold. A most noticeable feature of the side streams of the region is the almost constant occurrence of broad, round-bottomed upper valleys, which give place to steep, narrow canyons below. These valleys were once occupied by ice, whose downward movement carried along both the débris falling on its upper surface and that lying on its bed. On some creeks this débris was moved only partly down the valley; on others it was carried entirely out of it. Frequently both operations must have taken place in the same valley, since a glacier that originally occupied all of a valley threw down, in its retreat, the transported material at successively higher and higher points. The effect of erosion would be to sweep the débris down the valley and localize it. Further, the grinding of the material within and beneath the ice would tend to free the gold which, at the same time, would be subjected to the concentrating power of waters derived from the melting glacier itself. The production of small local basins of quieter water, due to barriers formed by terminal moraines, permitted the finer particles of gold to come to rest. The former presence of such basins is most plainly seen in the gravel deposits of Crow Creek. It must be remembered that the glaciers whose workings have just been considered are local. Their sources are within the valleys where they occur, and while their general effect is to transport material from higher to lower levels, they do not ordinarily cross the high ridges between valleys. If the large number of granite bowlders seen on the shores of the lower Kenai Lake and along Kenai River and the great granite blocks of the coast at Kenai were brought to this region by glacial transportation from some locality farther north, the glacier must have been of far greater extent than those which recently occupied the valleys of the Kenai Mountains. Such a glacier might readily carry some gold in its load of rock waste.

Regarding the character of the gold itself, it may be said that the bright-yellow color of some and the pale yellow of other gold does not necessarily imply that the two were brought in at different times, although the fact that they are confined to a certain extent to different beds of gravel on Crow Creek would indicate that such is the case there. Such characters may result from differences arising at the time of the original depositions in the country rock, possibly indicating different solutions and different periods of deposition.

Whether the bench gravels contain gold deposits sufficiently concentrated to be profitably treated is an important problem, since on its solution depends, in a large degree, the future of this placer field. If the suggestions concerning the origin of the gold are true it seems not unlikely, when it is remembered that these gravels were laid down in an old valley produced by the erosion of a far greater amount of material than has been removed since their deposition, that there may be found old channels as rich or richer than any yet found. Indeed, one such appears already to have been discovered on Crow Creek.

AURIFEROUS LODES.

Since it is reasonable to suppose that placer gold is derived in most cases from the region drained by the stream in whose valley the gold-bearing gravels are found, there has been more or less effort on the part of the miners of Kenai Peninsula to find the source of the gold. At two localities in the Turnagain Arm region mineralized veins have been found, on Bear and Sawmill creeks. Besides these, other localities will be mentioned which were not visited by the writer.

BEAR CREEK VEINS.

The known gold-bearing veins on Bear Creek occur in the midst of the broad amphitheater at the upper end of the valley. Small quartz stringers were first found in the arkoses of the stream bed and on further investigation led to the initial steps in the development now in progress. At the locality where work began the arkoses are somewhat brecciated or closely jointed, and the openings formed were filled with quartz, appearing as veins from one-half to three-quarters inch thick. Samples of

QUARTZ LODE ON SAWMILL CREEK.

Shows the tunnel and the arrastre for treating gold ores.

the larger veins show sphalerite, galena, pyrite, and arsenopyrite, the peacock stain of copper, and a little free gold. The gangue is chiefly quartz, but contains some calcite. As the shaft was filled with water and the débris produced in enlarging the original opening, the writer did not see the veins from which these samples were taken, but was informed that the best ore was a 16-inch vein in a zone of mineralized rock 6 feet thick. No underground work other than the enlargement of the shaft had been undertaken at the end of July, 1904. This shaft has a cross section of 10 by 5 feet and a depth of 30 feet. There is a short drift at the bottom. The surface equipment consisted of a new head frame and a 4-ton boiler for operating the hoist and air compressor. A good road leads down the valley from the claims to Hope.

SAWMILL CREEK VEINS.

Gold-bearing veins were discovered on Sawmill Creek very early in the development of the region and occur at three localities, which, however, are probably not entirely unrelated to one another. These are on the shore of the arm a short distance east of Slide Creek, on Slide Creek about one-half mile from the beach, and on Sawmill Creek one mile from the beach. The three lie nearly on a straight line, corresponding in direction with that of a number of fault planes observed here. At the first locality a small quartz vein in slates lies along a fault plane, striking N. 70° E. and dipping 70° E. The rock surface of the hanging wall is smooth and highly polished. Samples of the quartz assayed $2 in gold per ton. On Slide Creek quartz veins occur along two fault planes, the first similar to that just described, the other striking N. 50° E. The strike of the bedding is N. 10°–15° E. Quartz from this locality carries a higher percentage of gold.

On Sawmill Creek the gold-bearing quartz is found along a fault zone running northeast and southwest. It is difficult to make out the structure of the slates and arkoses which are here greatly disturbed, for the fault is not a simple one, but apparently is made up of minor displacements, with no parallelism, which took place at different times. The walls are frequently striated and between them a thin gouge is usually present. An adit 60 to 70 feet long was started on a branching quartz vein having a maximum thickness of 4 feet but of very irregular dimensions. It appears to have been cut off by movements occurring after its formation, since the vein was lost and the extension of the adit did not rediscover it. The continuation, however, may possibly be found to be the quartz vein located a short distance north of the adit. This second vein is about 3 feet thick and is less disturbed than the other. It carries low gold values but no attempt has been made to extract them.

The first vein carries free gold in a quartz gangue containing arsenopyrite, pyrite, zinc blende, and galena. Crystals of arsenopyrite are also very abundant in the country rock. A small streak of rich ore, said to carry $90 per ton, pitched steeply northeastward under the creek and could not be followed because the water broke in and stopped the work. In order to save the expense of shipping ore a small arrastre (Pl. XII), driven by water power and capable of handling two 700-pound charges a day, was erected near the adit, and with it the ore is treated. Nineteen tons of picked ore put through this arrastre yielded $500, or a little more than $26 per ton.

MISCELLANEOUS VEINS.

During the early part of the season the writer was shown samples of quartz containing pyrite and said to carry gold. They were taken from a newly discovered vein about a mile southwest of Seward. The ground was staked and a little work was reported to have been done at the end of the season. A second locality is at Aurora, on the south shore of the upper end of Kachemak Bay. The rocks of the Kenai Mountains are here cut by dikes of porphyry and contain quartz veins. Some portions of the country rock are highly pyritiferous and carry a small amount of gold. Extensive preparations for mining pyritiferous deposits were made but finally discontinued and nothing beside assessment work has been done for the last two years. A wharf was constructed and one or two tunnels were started on the claims. A stamp mill also was landed, but was never set up, and is still stored at the beach.

COPPER.

Small pieces of native copper are found with the placer gold on several of the streams previously described. This copper was most abundant in the sluice boxes on Lynx Creek and led finally to the discovery of a ledge carrying copper sulphides, located on the mountain side at the upper end of the valley and well above the stream. Although the presence of the outcrop has been known for some time no steps toward determining its commercial value were taken till some time during 1904, when a company was raised for its exploitation. Much of the season was spent in preparation for opening the deposit and the field operations of the company did not begin until some time in August, so that comparatively little rock work had been done when the Survey party left the peninsula. An adit level, driven to strike the lode below the outcrop, had not cut it in the early part of October, but it was reported that work would be continued during the winter. At present supplies are brought to the camp from Sunrise by pack train, but if this prospect should develop into a paying mine connection with the Alaska Central Railroad could be established without serious difficulty.

ECONOMIC CONDITIONS.

ROUTES AND TRAILS.

Many of the first prospectors in the Turnagain field came into the region from Prince William Sound by way of Portage Glacier, for at that time there were no steamers making regular trips to Cook Inlet and, moreover, it was unsafe for boats to enter during a large part of the year because of ice. Winter mails continued to be brought in and sent out in this way for a number of years in the earlier history of the field until the overland mail routes from Seward were established. The passage over the glacier, though not very difficult at the proper season, is often dangerous because of the fierce storms which sweep through the gap and have caused suffering and death in a number of cases. At present this route is not frequently used.

During the open season on Cook Inlet—that is, from the end of March to the beginning of November—the most convenient and customary means of reaching Hope or Sunrise is by the small steamer which connects with the ocean-going boats at Seldovia and carries mail, freight, and passengers to the upper end of the inlet. During the early days large boats occasionally went up the inlet in the summer months, touching at Tyonok, where it was necessary to transfer to small boats, often dories, in order to reach Turnagain Arm. At present these large vessels do not go farther north than Seldovia or Homer. The harbor at the former place is well protected, but small, while the anchorage behind Homer Spit, farther up Kachemak Bay, is swept by strong winds at certain seasons.

Large boats can not enter Turnagain Arm, but small ones of light draft reach Hope or Sunrise at high water and usually lie over until the next high tide to leave. At low water they are stranded on the mud flats. The completion of the Alaska Central Railroad will probably change the freight and passenger route into this region. Seward, the coastal terminus, possesses a splendid harbor, whose chief fault is its great depth. It is open all the year round and is well protected on every side. The railroad company has constructed a good wharf, at which steamers unload directly, without lightering, and had completed about 12 miles of track when work was shut down for the winter. Although the route chosen does not pass the camps on Sixmile

Creek, it crosses the upper end of the arm, from which connection with Sunrise can be readily established.

The trail from Seward to Sunrise along the east end of Lake Kenai and the Trail Lakes to Johnson and Bench creeks, and thence down East Fork of Sixmile, was the one followed by the Survey party in the trip across the peninsula. A very good trail leads from the forks of Sixmile to Mills Creek also, and thence to the lower end of Kenai Lake. This trail connects with the Trail Lakes trail by way of Moose Pass. Resurrection Creek may be reached from Sunrise by trail along the shore of Turnagain Arm from Mills Creek by way of Pass or Summit creeks. A good road has been constructed from Hope to the hydraulic plant 3 miles above Sixmile Point on Resurrection Creek, whence a trail leads to Pass and Fox creeks. There are also good roads up Bear Creek and from Hope to Palmer Creek. The camps on Crow Creek may be reached from the shore of the arm by a road lately completed, a large part of which is corduroy.

There is no trail for horses down Kenai River from the upper to the lower lake except the temporary one, most of which was cleared out by the Survey party. It followed the dryest ground and undoubtedly could be straightened somewhat. The horses of the Survey party were taken over the ridge north of Lake Skilak without packs, consequently little cutting was necessary, and there is practically no trail there at all. Moose River may be reached from the lower end of Lake Skilak without difficulty, but the writer would strongly advise against taking loaded horses from that point to Kenai. It was done by the Survey party late in the summer, when conditions were most favorable, but there is danger of losing the horses. Possibly by following the river bank a better though much longer trail could be found.

CLIMATE.

Climatic conditions on Kenai Peninsula are not the same over the whole area. The south slope of Kenai Mountains and the lower part of Cook Inlet are influenced more directly by the currents and winds of the Pacific, and the climate there is similar to that of southeastern Alaska. There is much rainy or foggy weather and extreme temperatures are not known. During the winter of 1903–4 a temperature of $-2°$ F. was reached only once at Seward, and the same was true at Seldovia.

The climate of that part of the peninsula that lies north and northwest of the divide is much like that of the interior, except that it is more changeable. The winter temperatures are much lower in this region than along the coast, the difference sometimes being as great as 30°, while in summer the temperatures are higher. Other weather conditions are more local. Clouds and rain may prevail for days on Turnagain Arm while the sun shines brightly on Cook Inlet; or these conditions may be reversed. On Turnagain Arm, in summer at least, the wind is either from the east or from the west, for the deep, straight valley of the arm seems to have a local controlling influence on its direction, regardless of whatever way it may blow outside. Fair weather usually accompanies the west winds, while east winds bring clouds and rain. Different temperatures prevail in different valleys. It is said that the temperatures on East Fork are lower than on Canyon Creek, and that in the coldest weather it is 10° warmer at Sunrise than at the Forks. On Sixmile Creek the snow lies 2 or 3 feet in the valleys, but is not so deep along Kenai River and on the west side of the peninsula.

Work is begun on the creeks about the first or middle of May and is continued till the first or middle of October. In 1904 gravels were washed on Crow Creek until November 15—an exceptionally long season.

Most of the claims of the Turnagain Arm field are well situated for hydraulic mining as far as water pressure is concerned, and water is obtained without great expense. The water supply is largely dependent on melting snows, consequently when the snow goes quickly in the spring a short flood period may occur, followed on small streams by scarcity of water, which continues till the July rains. The summer of 1904 was both cool and wet. Snow on mountains usually bare in July and August did not melt, and water was plentiful the whole season.

Some statistics may be of interest. During the time the survey party was in the field Mr. Hamilton kept a record of temperature observations taken twice each day, in the morning and evening. The averages of these observations were: June, 48.4° F.; July, 44.2°; August, 48.9°; September, 41.8°; first 18 days in October, 40.2°. Rain fell on 79 of the 140 days, nearly twice the number in the same period of the previous year, as determined from records kept by Mr. R. E. Oldham, on Crow Creek. The coldest day of 1904 on Crow Creek was −13°.

Records of temperatures and precipitation kept at Kenai show that during a period covering about eight years from 1882 to 1886, and from 1899 to 1902, the average yearly precipitation was 16.55 inches. Four times during that period the precipitation was as great as 1 inch in 24 hours, the greatest fall in 24 hours being 1.77 inches. The months of July, August, and September show the largest number of rainy days and the greatest precipitation. From 1899 to 1902 the highest recorded temperature was 80° and the lowest −43°.

TIMBER AND VEGETATION.

The Kenai Peninsula possesses a heavy growth of timber, which covers the whole area up to an altitude of 1,500 to 2,000 feet above sea level. This timber is chiefly spruce, but with it is found some hemlock, especially around Turnagain Arm. Cottonwood and willow grow along the streams; small poplars are abundant on the higher ground of the country west of the Kenai Mountains; birch and alders cover the mountain sides, the latter reaching well above the limit of spruce timber and making climbing very difficult. Near the coast the spruces are often hung with moss, while beneath the "devil's club" awaits the unwary. Lumber suitable for many purposes could be obtained at a reasonable cost near most of the camps. Till within the last year or two much of the lumber for sluice boxes was whipsawed by hand, but there is now a mill at Hope and another at Seward; the latter, however, has not yet supplied any lumber to the Turnagain Arm field. Better grades of lumber, especially that used for boats and other purposes where woods less brittle than spruce are required, are brought from Seattle, at a cost of from $35 to $50 per thousand. Many acres of valley lands have been burned over and are now strewn with the tangled trunks of fallen trees. These make traveling very difficult, and even dangerous at times, for on windy days the crash of falling trees is heard continually. In some areas the burning of this timber was accidental, or was the result of carelessness with camp fires; in others it was done purposely to kill the moss and destroy the breeding places of mosquitoes and flies. Without doubt these pests are less numerous in such areas than they were formerly. Other areas in the flats between the Kenai Mountains and Cook Inlet were burned over many years ago, and are now covered with a growth of young poplars and birch.

Good feed for horses is found in all the valleys visited by the survey party. Grass grows to an unusual height and is especially abundant about timber line, in the upper timberless parts of the valleys, and in places where the timber has been burned for a number of years. There is fine grass in the hills north of Homer, where horses and cattle have wintered without other feed. It is quite possible that with a suitable market these highlands could be utilized for cattle raising. The Department of Agriculture maintains an experiment station at Kenai with a view of determining the agricultural possibilities of this region.

Currants, cranberries, blueberries, huckleberries, and a few salmon berries are found at the proper seasons. Vegetables are grown successfully. Many miners have their own gardens, where potatoes, cabbage, turnips, rutabagas, and radishes were seen growing.

NATIVES.

The native inhabitants of the upper Cook Inlet shores, the Kenaitze, as they are called, are the only interior Indians (Athabascan) that reach the coast. The natives living about the southern part of Cook Inlet and along the Pacific coast to the east and west are related to the Eskimos. Besides these purely native inhabitants there is a people of mixed blood, the Russian creoles. The largest native settlements are at Kenai and Seldovia, where they have churches and schools. Smaller settlements or single families are found at Hope, Kasilof, Alexandrovsk, and a number of other places. Probably the entire native population, including those of mixed blood, is between 200 and 300, possibly over 300. Descriptions of these people have been given by Dall, Petrof, and others and need not be repeated. They are under the influence of the Russian Church, speak the Russian language, or a corruption of it, as well as their own, and have adopted many of the white man's habits, living partly by hunting, trapping, or fishing, and partly by working for the whites. They are employed by the canneries at Kenai and Kasilof and in one instance at the placer mines on Mills Creek. Under the direction of white men a considerable part of the lightering at Seldovia and Kenai is done by them, and for this work they are paid 10 cents an hour. A few make part of their living by supplying moose meat to the miners of Turnagain Arm. Their numbers are gradually decreasing, and several villages once occupied by them have been abandoned.

GAME AND FISH.

From the time of the first visit by Captain Cook to the discovery of gold on Resurrection Creek furs and fish were the only inducements bringing white men into the Cook Inlet region. The fur trade, after the purchase of Alaska by the United States, was largely in the hands of one company, whose trading posts were located at various points on the inlet and furnished the natives with such things as they desired in exchange for the furs they had taken. This trade was carried on with natives from Sushitna, Matanuska, and even upper Copper rivers, as well as the east and west coasts of Cook Inlet. The list of fur-bearing animals on Kenai Peninsula and Cook Inlet waters is a long one, in which the most valuable are black fox, sea otter, and silver-gray fox. Beside these, approximately in the order of their values, are martin, cross fox, black bear, brown bear, lynx, land otter, wolverene, black or brindle wolf, red fox, silver-gray wolf, and mink. "Ermine," muskrat, marmot, and parka squirrel also have an occasional market.

Brown and black bear are numerous in the Kenai Mountains, and after the salmon begin to run in the streams many bear tracks are found in the sands along the shores. The brown bear grows to large size, and is usually avoided by prospectors, especially when accompanied by her cubs. These bears have attacked men without apparent provocation. On Crow Creek a new tent was torn to pieces and a supply of groceries scattered all about the place by a bear, apparently with no other motive than a love for destroying. The black bear is a timid animal and molests no one. A third variety, called the "glacier bear," is said to be seen occasionally, but whether this is a distinct species or simply a variety of black or brown bear the writer was unable to determine.

Moose and mountain sheep furnish all the fresh meat used by the miners. It is the belief of many on Kenai Peninsula that the moose has increased rather than decreased in numbers during the last ten years, and they attribute this to several causes. The number of wolves has been greatly reduced through the use of poison, and in this way many moose calves are saved which otherwise would have been destroyed. It is believed that the number is slowly increased by migration from the mainland. Finally, the region west of the Kenai Mountains is a very favorable country for moose, since it produces an abundance of the food they require, especially birch, poplar, and willow. Moose from Kenai Peninsula furnish some of the largest antlers known, which are much in demand by trophy hunters. Undoubtedly many moose have been killed contrary to law, but it should be said that the miners are careful to observe the game laws and rarely take meat except when it is needed. Moose are most plentiful west of the Kenai Mountains, but signs were seen on Trail Lakes and Johnson Creek, around the heads of Canyon, Quartz, and Resurrection creeks, and along Kenai River. A few years ago mountain sheep were plentiful on the mountains east of Kenai Lake, east of Tustumena Lake, and in many other places, but are gradually being driven back from the more traveled ways. North of the arm, about the head of Eagle Creek, they may be seen at almost any time by those willing to climb the mountains in search of them. Spruce grouse and ptarmigan are not uncommon.

Fish are not plentiful in the smaller streams of the peninsula. Trout were taken at only a few places by the Survey party and none were seen in the glacier-fed streams of the Kenai Mountains. Salmon enter the streams flowing into Resurrection Bay and Cook Inlet in great numbers during the summer. There are three varieties, the king salmon, the silver salmon, and the red salmon, of which the first named is the largest and first to appear, but the less plentiful. They usually begin to run in Cook Inlet toward the middle of May, but did not appear in Resurrection Bay last summer till the middle of June. In September the shores of Lake Skilak and Kenai River were strewn with dead and dying fish, which furnished a feast for the bears, but gave rise to a very disagreeable odor. Canneries have been in operation at Kenai and Kasilof for many years and have shipped a great deal of fish. The one at Kenai was lately burned, however, and may not be rebuilt. Salmon formerly furnished the principal food of the natives of the peninsula, an average of about 190 pounds being prepared for winter use for each individual.

Codfish are found on the banks along the whole southern coast of Alaska, and were taken by members of our party at Kachemak Bay. Halibut are also taken in these waters.

CONCLUSIONS.

In conclusion it may be well to summarize briefly the favorable and the unfavorable conditions under which the prospector labors on Kenai Peninsula. The open season—that is, the length of time during which mining is not interfered with by cold weather—is longer than in either the Yukon country or Seward Peninsula. Compared with the interior of Alaska, ease of access is a condition favorable to the miner, as is also the lower cost of supplies and labor. When the region is considered as a whole, it may be said that the conditions tending to make hydraulic mining profitable are unusual in so far as water supply, water pressure, and thickness and extent of gravels are concerned. High stream gradients and consequent swift water aid in the disposal of tailings, and on the smaller streams sometimes make it possible to reach bed rock without great expense. An abundant supply of timber suitable for fuel and many other purposes is at hand and may be had for the cutting. On the other hand, gold in the stream gravels is very unevenly distributed, and in the high gravels has not been found sufficiently concentrated to be mined with profit. Although thickness of the high gravels is an advantage in hydraulic mining, yet the great thickness of gravels found along the larger streams, such as Resurrection and Sixmile creeks, is a decided disadvantage, especially when, as is always the case, the gravels are saturated with water, since it makes it impossible under ordinary circumstances to reach bed rock. Probably the most unfavorable condition encountered in rich as well as poorer deposits arises from the character of the gravels themselves, which are made up of an unusually large proportion of bowlders. These bowlders not only greatly increase the cost of mining as now carried on, but in many localities prohibit the use of labor-saving devices which might be employed if the gravels contained only a small amount of coarse material.

COAL FIELDS OF THE KACHEMAK BAY REGION.[a]

By Ralph W. Stone.

INTRODUCTION.

In continuance of the plan of the United States Geological Survey to investigate the mineral resources of Alaska, a party consisting of G. C. Martin, T. W. Stanton, and R. W. Stone spent the summer of 1904 on the coast of Cook Inlet and Alaska Peninsula. The investigation of the coal resources was assigned to the writer and opportunity was given to examine in detail the occurrence of coal beds in the Kachemak Bay and Port Graham regions. This report embodies the result of observations made in these two localities.

LOCATION.

Kachemak Bay is a large, northeastward-reaching arm of Cook Inlet which penetrates Kenai Peninsula near its southern end. The bay is funnel-shaped in outline, having a mouth 25 miles wide, extending from Anchor Point on the north to Dangerous Cape on the south. It is 35 miles long and tapers from a width of 6 miles at Homer to 3 miles at its head. Homer is at the outer end of Coal Point, a low, narrow spit composed of sand and gravel that projects 4 miles into the bay from the north shore. Its latitude is 59° 36′ 08″ and longitude 151° 23′ 37″. Homer was the scene of considerable activity several years ago, when 150 men were engaged in developing the coal field, but at present it contains only 2 men. Near the south entrance to Kachemak Bay, on its eastern shore, at the entrance of Seldovia Bay, is the village of Seldovia, which was the home of 7 whites and 75 natives in the summer of 1904. It is 12 miles southwest of Homer, and the first stopping point for steamers entering Cook Inlet.

Port Graham is a small bay 5 miles long that indents the west side of Kenai Peninsula south of the entrance to Kachemak Bay.

INVESTIGATION.

Cook Inlet ports can be reached from Seattle, Wash., in a week, by steamer direct or by transfer at Valdez. The party left Seattle May 22 and arrived at Seldovia May 29.

A trip to Port Graham, 8 miles southwest of Seldovia, was made in a 25-foot sloop. Homer is reached from Seldovia by steamer and was the writer's headquarters during the last three weeks of June.

[a] An abstract of this paper has been published under the heading Coal Resources of Southwestern Alaska, in Bull. U. S. Geol. Survey No. 259, 1905, pp. 151-171.

The work on the north shore of Kachemak Bay was begun in association with T. W. Stanton, who departed after three days for the west side of Cook Inlet. It was continued for two weeks with the assistance of Fred Reist, who served as oarsman and camp hand. The shore of the bay from Bluff Point eastward to a point 2 miles beyond Falls Creek (Pl. XIII), a distance of 28 miles, was traversed on foot, but camp was moved from point to point by means of a rowboat. A plane-table survey was made of the shore line from Coal Creek to Falls Creek, and of the south shore of the bay from Aurora to Gull Islands, opposite Homer. Later in the season E. G. Hamilton, topographer of the Moffit party, mapped the shore from Seldovia Bay nearly to Homer. These two maps, together with a plan of Seldovia Bay made by the writer, were combined with the Coast Survey chart and appear as Pl. XIII, accompanying this report.

In the prosecution of the work the writer received assistance from E. G. Wharf, of Seldovia, and many courtesies from S. T. Penberthy, of Homer.

MINING DEVELOPMENT.

HISTORY.

The existence of coal at Port Graham was reported by Portlock [a] in 1786, but it was not until the middle of the nineteenth century that coal mining was begun. In 1852 the Russian American Company undertook to mine coal at the locality discovered by Portlock and was actively engaged in its production for twelve years before Alaska was ceded to the United States. A long drift was run on one seam of coal and a shaft sunk to another. Coal was supplied to Russian steamers for a number of years, but it proved to be of low grade and was sold at a net loss. The enterprise was abandoned when ownership of the territory was transferred in 1867. A description of the developments at this locality will be given under the heading "Port Graham" (p. 66).

In 1888 the Alaska Coal Company began what was probably the first coal mining on the north shore of Kachemak Bay. Their operations, it is said, consisted in driving a tunnel on the Bradley seam near Fritz Creek, 6 miles north of Homer. It is not known how much work was done or whether any coal was shipped. The tunnel caved in long ago.

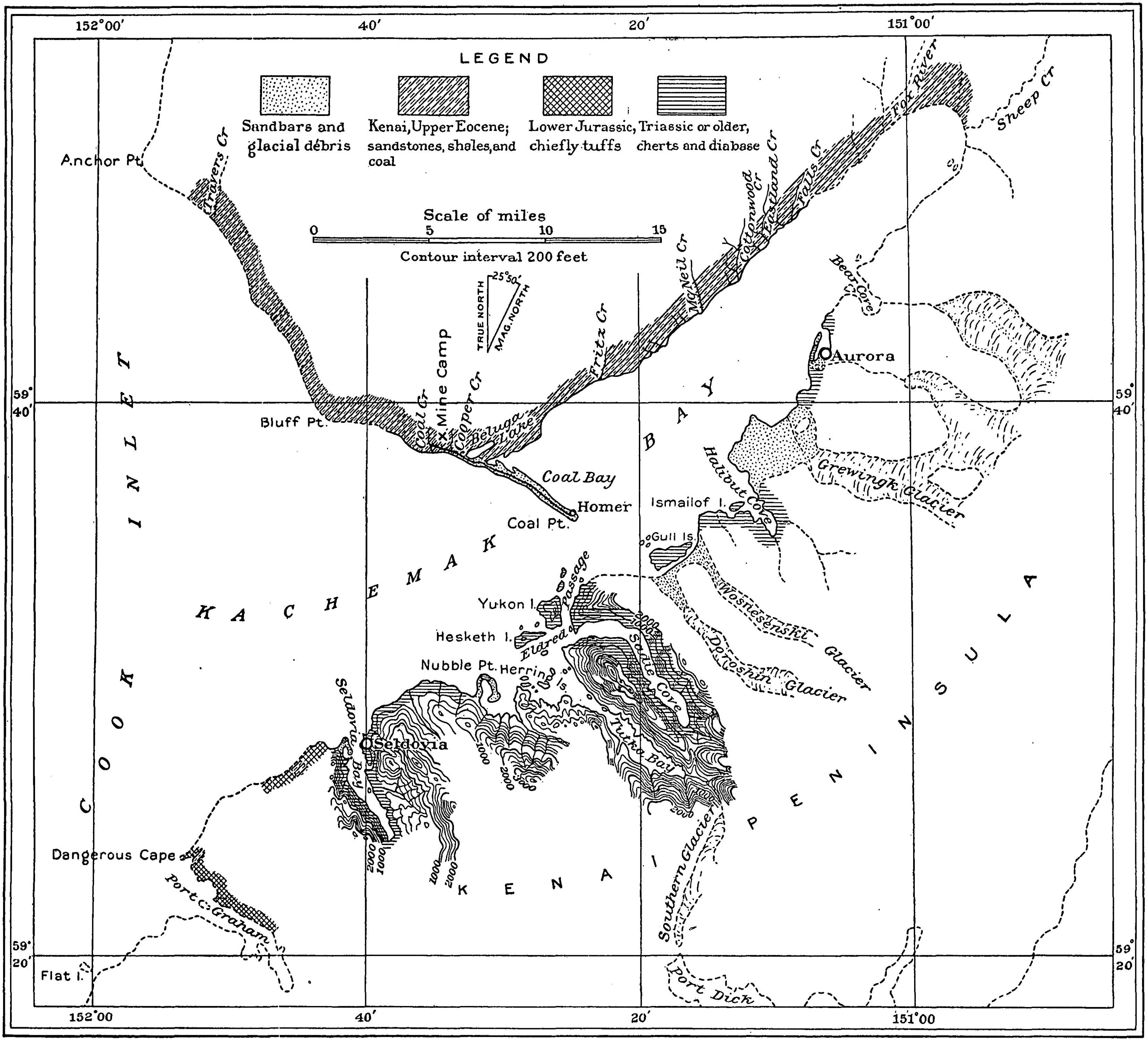
Lieut. R. P. Schwerin, U. S. Navy, on behalf of New York parties, took 200 tons from Kachemak Bay in 1891. This coal was shipped to San Francisco and submitted to a series of tests, the results of which are given on page 71. The results were not sufficiently satisfactory to warrant the development of the field under existing difficulties.

In December, 1894, the North Pacific Mining and Transportation Company began exploration in Eastland Canyon, about 14 miles northeast of Homer, under the supervision of M. B. Curtis. Three buildings and a short pier were erected at the mouth of the canyon, and a tramway was constructed from the pier to a tunnel driven on a coal seam half a mile up the canyon. The buildings are still standing, but the tramway, which follows the east bank of the creek, is undermined in many places. At least 650 tons of coal were taken out, lightered to the steamer *Theobald*, which lay at anchor in Bear Cove, and sent to San Francisco to be tested.

This company and the Alaska Coal Company continued prospecting in Eastland and McNeil canyons from 1894 to 1897. During this time two short tunnels were driven on a 4-foot coal seam 400 yards west of McNeil Canyon and 45 feet above the beach. This is called the Curtis seam. A short wharf and coal bins were built and still remain, though in a dilapidated condition. The horizontal dark bands seen in

---

[a] Portlock, Nathaniel, A Voyage to the Northwest Coast of America, London, 1789, pp. 102-110.



MAP OF KACHEMAK BAY.

Pl. XVII, *A*, represent lignite beds. The outcrop of the Curtis seam is covered by a slide above the bin and appears only at the extreme right and left of the view. A frame house at the mouth of McNeil Creek and a log cabin at the mouth of Cottonwood Creek, built by these companies, were standing in 1904, but were out of repair.

Since 1899 the Cook Inlet Coal Fields Company has held possession of the most desirable part of the coal field on the north shore of Kachemak Bay. This is the portion which lies to the west and within 3 miles of the base of the long spit known as Coal Point.

Under the management of this company a large dock was built on the east side of Coal Point, where there is protected anchorage. A 42-inch gage railroad was constructed from the dock along the spit to the mainland, where it rises to the top of the bluff about 200 feet above the beach, and ends at Coal Creek. Two shafts were started and three tunnels were driven on a 6½-foot coal seam which outcrops in the sea bluff between Cooper and Coal creeks. Underground work was begun in the fall of 1899 by driving the first of these shafts, which is known as the Kirsopp slope, because it was excavated under the direction of John Kirsopp, an English mining engineer. This shaft had three compartments and was carried 125 feet, when it was discovered that the slope of the shaft was so nearly parallel with the dip of the coal

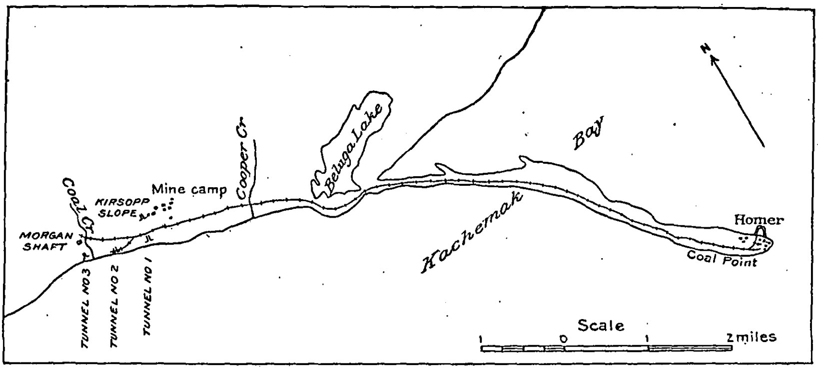


FIG. 5.—Sketch map showing location of Cook Inlet Coal Fields Company's operations.

that it would have to be driven nearly 1,800 feet to reach the coal. In 1900 tunnel No. 1 was driven in the face of the bluff on a seam of coal 6½ feet thick. It proved to be very wet and was abandoned. Tunnel No. 2, on the same seam, was driven 350 feet and had to be pumped to keep it dry. Coal was brought to the mouth of the tunnel in mine cars, dumped into a skip, and hoisted over the bluff by a square-framed derrick which spilled into a railroad car standing on the spur track. At the west end of the railroad a vertical 3-compartment shaft, known as the Morgan shaft and contemporaneous with tunnel No. 1, was sunk over 25 feet, and a tunnel was started on coal in the sea bluff near Coal Creek to connect with the shaft. This third, or Ray, tunnel was driven 125 feet when work at that end of the field was discontinued and efforts were concentrated on getting out coal from tunnel No. 2. During the winter of 1901–2 the mail steamer *Discovery* was supplied continuously with fuel and other vessels occasionally. All work on this property ceased in March, 1902, but the company holds possession by retaining a representative on the ground. No money or effort is being expended, however, in keeping the railroad or mine tunnels in repair. Eight buildings at the mine camp and 20 on Coal Point at Homer, which was the company's headquarters, are in good condition. Fig. 5 shows the location of the development work done by this company.

PRODUCTION.

The production of this region is estimated as follows:

Coal output of the Kachemak Bay region.

	Tons.
Port Graham	2,700
Kachemak Bay:	
Taken by Schwerin	200
Mined by Curtis	650
Taken by tug *Kodat*	15
On cars at Homer	80
Heap at Cook Inlet Coal Fields Company's mine	20
Sold at Homer	125
Total	3,790

TOPOGRAPHY.

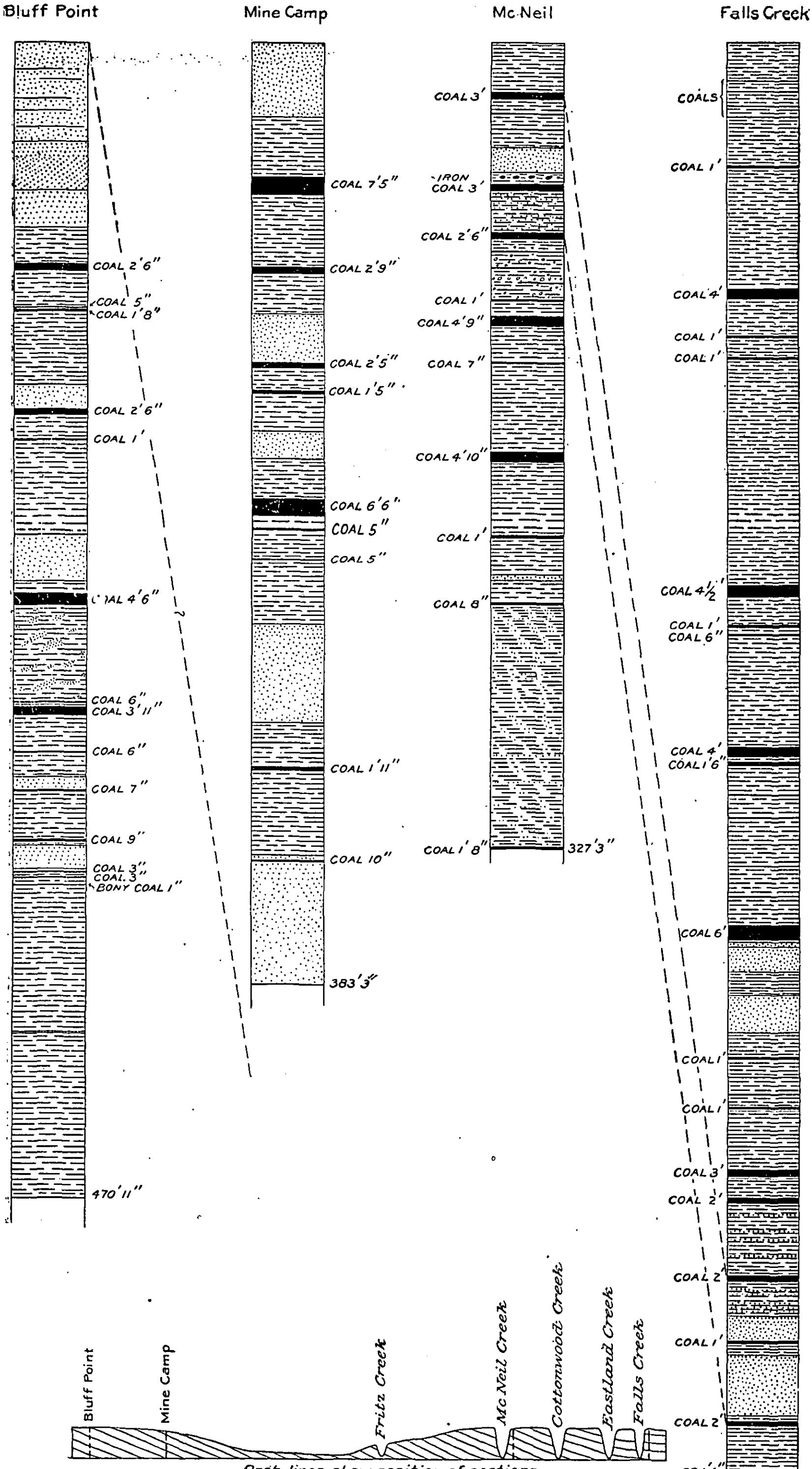
The mountain range which forms the backbone of Kenai Peninsula rises abruptly from the east and south shores of Kachemak Bay, its crest being marked by rugged snow-capped peaks having an elevation of 3,000 to 5,000 feet. In places a narrow belt of foothills covered with forest intervenes between the mountains and the shore. Cliff-like walls, sharp peaks, and narrow spurs are characteristic details of this section of the range, and six glaciers descend nearly to sea level and discharge their waters into the bay.

North of Kachemak Bay is the Kenai Plateau, which lies west of the Kenai Mountains and extends from this bay on the southwest to Turnagain Arm on the northeast. This area varies in width, but the average distance from the mountains to the shore of Cook Inlet is 25 miles, and its length is nearly 100 miles, so that it covers over 2,000 square miles. The plateau has its greatest elevation on Kachemak Bay and slopes gradually northward. The Kenai formation probably underlies the entire area, the lower and more densely consolidated coal seams being exposed in the sea bluff between Coal Point and Anchor Point. Thence northeastward the strata lie in broad, gentle folds, which finally carry the coal seams below sea level at Cape Kasilof.

The upper surface of the plateau is undulating and is cut by a number of westward-flowing streams, which, in the northern part of the area, have formed broad valleys in the soft Tertiary rocks. Many small shallow lakes are scattered over the surface, and in wet seasons large marshy areas are numerous. Meadows of considerable extent are interspersed through areas heavily wooded with spruce and poplar.

On the north side of Kachemak Bay the Kenai Plateau comes to the sea in steep bluffs ranging in height from 50 to 400 feet. The narrow beach at the base of these is kept free from talus by the constant action of the waves, and in some places is impassable at high tide. The bluffs are notched by sharp canyons, some of which are only a few hundred yards long, while others, such as those cut by McNeil, Cottonwood, Eastland, and Falls creeks, are from 1 to 2 miles long.

The shore line of the north and west side of Kachemak Bay is composed of long, straight, or slightly curved stretches of beach, usually overlooked by a bluff. Coal Point is the only marked projection. Shallow water is found all along the north shore, and when the tide runs out mud flats half a mile wide are exposed from Coal Point to the head of the bay. At Homer the range of tide varies from 16 to 28 feet. The east and south shore of the bay is indented by a number of bays and coves and flanked by numerous islands, of which Yukon, the blue-fox farm island, is the largest. Tutka Bay, which lies south of Yukon Island, is the deepest indentation, extending 8 miles. Seldovia Bay, lying near the southern entrance to Kachemak



COLUMNAR SECTIONS OF THE KENAI FORMATION.

Bay, is smaller, but more important, because a salmon stream empties into it and a village is located on its northern shore. This bay is shallow, and steamers do not go in farther than Seldovia, which is near the entrance. The streams flowing from Grewingk Glacier, which lies between two spurs of the Kenai Mountain Range, have built a broad delta out into the bay, and the terminal moraines of Wosnesenski and Doroshin glaciers unite in filling what would otherwise be a cove southeast of Homer. The south side of Kachemak Bay is navigable for steamers up to Bear Cove, where there is a protected anchorage.

GEOLOGY.

GENERAL STATEMENT.

The general geology of the Kachemak Bay region is discussed elsewhere in this report by Mr. Moffit (p. 16). On the south side of the bay it is complex and can be described briefly as exhibiting pre-Jurassic diabase and cherts, a lower Jurassic formation composed of tuffs, sandstone, and calcareous beds, and small isolated areas of Tertiary coal-bearing beds, known as the Kenai formation, lying unconformably on the other rocks. The Kenai formation makes the entire north shore of Kachemak Bay, and is overlain unconformably by gravels and clays of glacial origin. This paper is concerned only with the Kenai formation, which will be described in some detail.

KENAI FORMATION.

DISTRIBUTION.

The formation was named by Dall[a] from its occurrence on Kenai Peninsula, especially at Port Graham, and on the north side of Kachemak Bay. It first attracted attention by reason of the presence of coal on the north shore of Port Graham, where the formation is exposed for about 1,000 feet along the beach. In Kachemak Bay the Kenai formation is exposed continuously for 45 miles along the north shore from Anchor Point to the head of the bay, and it probably underlies an area of at least 2,000 square miles northeast of Kachemak Bay, known as Kenai Plateau. This formation occurs also at Tyonok, near the head of Cook Inlet, where there is a continuous outcrop along the beach for at least 4 miles;[b] its extent in this field has not been investigated. The Kenai formation has a wide distribution throughout Alaska.

CHARACTER.

The Kenai formation as exposed in Kachemak Bay is composed of soft, light-gray sandstones and clay shales, with numerous interspersed coal seams. Four partial sections of the formation, aggregating 1,763 feet of strata, are given on pages 60–66. These sections are represented diagrammatically in Pl. XIV, and show that coal seams ranging in thickness from a few inches to 7 feet are distributed throughout the portion of the formation represented. It appears also that 350 feet at the top of the Falls Creek section, which is the highest geologically, contain no sandstone, but are composed entirely of shale and coal. It can not be said with certainty that the lower portion of the formation is characterized by an abundance of sandstone and the upper part by a lack of it, although there is a suggestion that this may be the case. The sandstones are medium-grained, soft, light gray, sometimes iron stained, and occur in beds from a few inches to 30 feet thick. Cross-bedding was noted at one horizon. Some portions of the heavier beds of sandstone are hard and weather out in nodular blocks. In these blocks the best preserved fossil plants are sometimes found. In one locality lenses of grit occur in a sandstone mass. The pebbles in the grit are

[a] Dall, W. H., and Harris, G. D., Correlation papers—Neocene: Bull. U. S. Geol. Survey No. 84, p. 234.
[b] Eldridge, G. H., A reconnaissance in the Sushitna basin, Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, p. 21.

smaller than one-half inch in diameter and are mostly quartz. Dall[a] reports conglomerates in the Kenai series on Kachemak Bay, but the author found none in the portion he visited. Sandstone at places grades into sandy shale.

The shales of the Kenai formation on Kachemak Bay are all light-colored clay or mud rocks, grading on one side into arenaceous shale and on the other into clay. The shales are soft and crumbly, on the outcrop, and when wet become plastic. Beds of clay that have been baked by the burning of coal seams are red and hard. Small blocks of gray, hard limestone were found at one locality and suggest that calcareous sediments in small amount may be contained in the formation. Limestone was not seen in place.

The abundant coal seams in the Kenai rocks of this field are all lignite. They vary in thickness from mere streaks to beds several feet thick. Eldridge[b] counted 36 seams along the beach at Tyonok, varying in thickness from a foot to 15 feet, and Kirsopp[c] figures 73 seams on the north shore of Kachemak Bay. Much of the Kachemak Bay lignite, especially that in the lower beds, is hard and glossy, clean to handle, and tends to break cubically. The higher beds, however, are dull and lighter and show more woody fiber.

THICKNESS.

The thickness of the formation exposed in Kachemak Bay has not been determined, and is almost impossible of determination because there are stretches over which the beds can not be traced. Anchor Point is near the base of the formation, but it is not known how far the coal-bearing rocks extend beyond the head of the bay, except that coal has been found 15 miles up Sheep Creek. Kirsopp[d] published a section from Anchor Point to the head of the bay, including 2,683 feet of coal-bearing measures. This section contains at least 126 feet of lignite in seams over 2 feet thick. The author did not go west of Bluff Point nor more than 3 miles east of Falls Creek, and can only guess at the thickness of the strata exposed between these two points. Estimated roughly, there probably are about 1,500 feet of strata between Bluff Point and the base of Coal Point. From Coal Point to McNeil Creek the dip is strong and 3,000 feet may be a low estimate. From McNeil Creek to the top of the bluff at Falls Creek at least 1,000 feet are exposed. Hundreds of feet of strata probably overlie the section measured at Falls Creek and outcrop in the bluff north of the head of the bay. The writer is inclined to think that 10,000 feet may not be a high estimate for the thickness of the Kenai formation in the Kachemak Bay field.

AGE.

The determination of the age of the Kenai is dependent chiefly on its fossil flora, which was originally described as Miocene, but is now considered more probably Upper Eocene.[e] Collections obtained by Dall from the shore immediately north of Coal Point, now deposited in the National Museum, were examined and in part reported on by Lesquereux.[f] This collection, with a more recent one obtained by Dall from Eastland Canyon, has recently been reexamined by F. H. Knowlton, who makes the verbal statement that it unquestionably belongs to the so-called Arctic Miocene flora of Upper Eocene age. Dall[g] has provisionally assigned the Kenai to the Oligocene, chiefly because its stratigraphic position is apparently similar to that of Oligocene beds in Oregon.

[a] Dall, W. H., Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, p. 789.
[b] Eldridge, G. H., op. cit., p. 21.
[c] Kirsopp, J., jr., Coal fields of Cook Inlet, Alaska: Trans. Inst. Min. Eng., London, 1901.
[d] Kirsopp, op. cit., p. 3.
[e] Alaska, geology and paleontology: Harriman Alaska Expedition, vol. 4, p. 162.
[f] Proc. U. S. Nat. Mus., vol. 5, 1882, pp. 443-449. The species there cited as from "Chugachik Bay" are from this locality.
[g] Dall, W. H., Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, p. 842.

The Kenai formation includes the following species of fossil plants: *Alnus corylifolia* Newby, *Fagus antipofi* Heer, *Fagus deucalionis* Ung., *Salix varians* Goeppert, *Salix raeana* Heer, *Ulmus sorbifolia* Goeppert, *Cornus orbifera* Heer, *Diospyros anceps* Heer, *Quercus Dallii* Lesq., *Corylus MacQuarrii* (Forbes) Heer, *Taxodium distichum miocenum* Heer, *Carpinus grandis* Ung., *Vaccinium reticulatum* Al. Br., *Andromeda grayana* Heer.

T. W. Stanton and the writer collected many of these species along the beach on the north shore of Kachemak Bay, from the mine camp near the base of Coal Point west to Bluff Point, but the collection was lost.

STRATIGRAPHIC RELATIONS.

It is reported[a] that fossil "oysters" (*Inoceramus*) are found at extreme low water off Anchor Point, but the report has not been verified. If it be true, the Kenai formation of upper Eocene age, is directly underlain by the same Cretaceous rocks that occur on the west side of Cook Inlet. In the vicinity of Seldovia Bay and at Port Graham the Kenai formation lies unconformably in steep-sided basins in the Lower Jurassic, or upon diabase of unknown age. The Kenai in the Cook Inlet region is overlain by unconsolidated gravels and clays.

For a more complete description of the stratigraphic relations of the Kenai formation in this vicinity, reference should be made to the accompanying paper by Mr. Moffit.

DEFORMATION.

The Kenai formation in Kachemak Bay and vicinity is very gently folded and has suffered but little faulting. North of the bay four broad folds, which probably trend generally east and west, are described by the coal-bearing beds under the Kenai Plateau. Along the shore of the bay the strike is generally about N. 65° W. and the dip is northeast at low angles. The few faults which were noted seemed to be small.

THE COAL.

OCCURRENCE AND DEVELOPMENT.

The Kenai formation, which carries the coals found on the east side of Cook Inlet, outcrops along the entire north shore of Kachemak Bay and in a small cove at Port Graham. The coal beds are not confined to any one definite horizon in the formation, but seem to be rather evenly distributed throughout many hundreds of feet of strata. In this region they are all lignites, or at least lignitic in character.

In discussing the occurrences of the Kenai formation, localities on the north shore of Kachemak Bay will be described in geographic order eastward from Anchor Point.

NORTH SIDE OF KACHEMAK BAY.

Anchor Point.—It is reported that several seams of coal outcrop between high and low tide one-half mile south of Anchor Point. One seam[b] is said to be 8½ feet thick and harder than coal found elsewhere in this bay. These coal beds off Anchor Point are probably in the lowest Kenai exposed in Kachemak Bay. Coal also occurs a few feet above high tide at the mouth of Travers Creek, 3 miles east of Anchor Point. The seam is 5 feet thick, and the middle portion, about 2 feet thick, is a hard, shiny coal which is considered by those who have used it[c] to be of higher grade than that found farther east. Some of it is said to melt and cake like Pittsburg coal when ignited. This coal is bright, blocky, ignites quickly, and does not soil the hands.

---

[a] Dall., op. cit., p. 788.
[b] Reported verbally by Mr. Fred Reist, prospector.
[c] Messrs. Fred Reist and Fred Barker, prospectors.

Bluff Point.—At Bluff Point, 12 miles northwest of Homer, a cliff has been formed by a landslip extending parallel to the coast for a mile. In this cliff the Kenai formation is beautifully exposed. The top of the bluff, which is one-eighth mile back from the beach and 600 feet high, is a broad meadow bordered with spruce. A section of the formation measured at this point by T. W. Stanton and the writer is as follows:

Partial section of Kenai formation at Bluff Point.

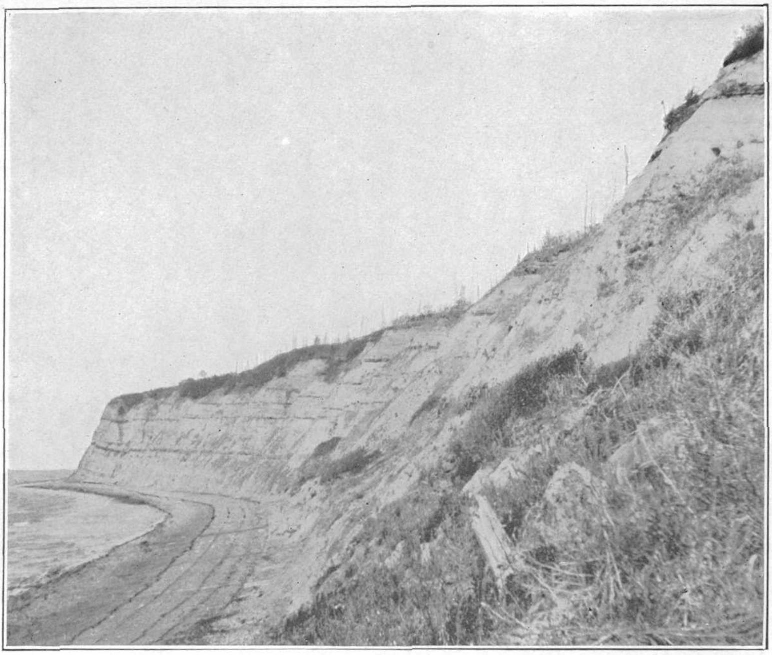
	Ft.	In.		Ft.	In.
Sandstone with thin coal streaks	40	0	Coal (section below)	3	11
Massive cross-bedded sandstone	20	0	Clay shale	15	0
Massive sandstone	15	0	Bony coal	0	6
Arenaceous shale	15	0	Clay shale	10	0
Coal	2	6	Sandstone	5	0
Bluish clay shale	15	0	Coal	0	7
Coal	0	5	Clay shale	20	0
Carbonaceous clay shale	1	3	Coal	0	9
Coal	1	8	Clay shale	1	3
Clay shale	30	0	Sandstone	10	0
Sandstone	10	0	Clay shale	1	0
Coal	2	6	Coal	0	3
Clay shale	10	0	Clay shale	2	0
Coal	1	0	Coal	0	3
Clay shale	35	0	Clay shale	3	6
Sandstone	20	0	Bony coal	0	1
Clay shale	5	0	Clay shale	60	0
Coal (section below)	4	6	Sandstone lenses	0	10
Clay shale with sandstone lense	40	0	Clay shale	65	0
Coal	0	6	Beach	---	--
Clay shale	0	10			
Carbonaceous shale	0	10	Total	470	11

In this bluff the strata strike about N. 65° W., or parallel with the coast line, and dip northeast. The sandstones are medium coarse grained, soft, quartzose, and often somewhat iron stained. Shale which is so soft that it crumbles readily forms the greater part of the bluff. Eighteen feet of coal in 13 seams ranging in thickness from 3 inches to 4½ feet are interbedded with the shale and sandstone, all of black, glossy lignite. Detailed measurements of the two largest seams in the section given above are as follows:

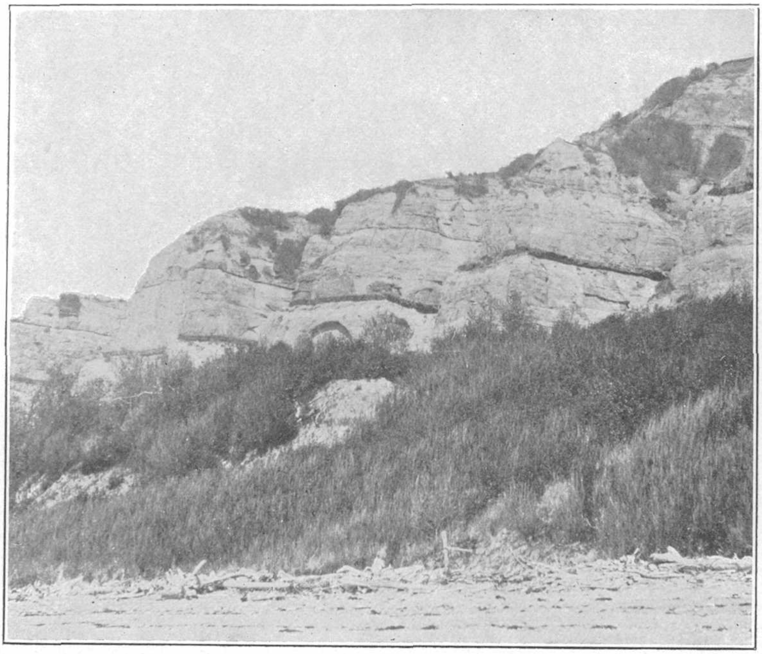
Section of coal seam at Bluff Point.

	Ft.	In.
Coal and shale	0	10
Coal	0	11
Shale parting	0	3
Coal	0	9
Shale parting	0	1
Coal	0	3
Shale parting	0	2
Coal	1	3
Total	4	6

A thinner seam 42 feet below the one just given and about 180 feet above the beach has about the same amount of coal with less waste.



A. SITE OF COOK INLET COAL FIELDS COMPANY'S TUNNELS NEAR THE MINE CAMP.



B. KENAI FORMATION NEAR BLUFF POINT.

The dark band in the bluff is a bed of coal.

Section of coal seam at Bluff Point.

	Ft.	In.
Coal	2	6
Shale parting	0	2
Coal	1	3
Total	3	11

Pl. XV, *B*, gives a general view of the coal seams in the cliff near Bluff Point. An appearance of step faulting is due to a number of sharp gullies which in the perspective view hide a portion of the outcrop of the thick coal seam.

Mine camp.—That portion of the north shore which lies just west of Coal Point may be called the mine-camp district. It lies at the west end of the Cook Inlet Coal Fields Company's railroad, 7 miles from Homer. The coal-bearing series is exposed in a cliff which is 250 feet high at a point three-fourths mile west of the mine camp but which decreases in elevation toward the east and disappears before reaching the base of Coal Point. A view of this cliff showing a number of coal seams is given in Pl. XV, *A*.

A section whose base is as high stratigraphically as the top of the one at Bluff Point was measured near the mine camp. The lower part was obtained at the point near Coal Creek and the upper part one-half mile farther east. The combined section is as follows:

Partial section of Kenai formation at the mine camp, Kachemak Bay.

	Ft.	In.		Ft.	In.
Sandstone	30	0	Clay shale	3	7
Clay shale	25	0	Coal	0	5
Coal (section below)	7	5	Clay shale	12	0
Clay shale	30	0	Coal	0	5
Coal (sample No. 3)	2	9	Clay shale	26	0
Shale	16	0	Sandstone	40	0
Sandstone	20	0	Clay shale and coal streaks	18	0
Coal (section below)	2	5	Coal	1	11
Clay shale	9	1	Clay shale	34	0
Coal	1	5	Sandstone	2	0
Clay shale	15	3	Coal	0	10
Sandstone	11	10	Sandstone to beach	50	0
Clay shale	16	0			
Coal (Cooper seam, sample No. 4)	6	6	Total	382	10

Between the two places where the section was measured there is some variation in the character and sequence of the strata. At the point the section seems to be composed more largely of sandstone, and the coal 42 feet above the Cooper seam appears to be absent. The sandstones are only partly consolidated and are less resistant to weathering than the coal, while the shales, which are soft and crumbly, sometimes contain hard lenses and a few clay ironstones.

Exposed in this cliff are three coal seams, whose position in the preceding section can be recognized by their total thickness. The first and thickest seam, which is more than 50 feet below the top of the bluff where the section was measured at the end of the railroad spur, is composed of the following beds:

Coal seam at the mine camp, Kachemak Bay.

	Ft.	In.
Bony coal and clay	2	0
Clay shale	1	8
Coal	2	6
Clay parting	0	2
Coal	1	1
Total	7	5

The next section is the third seam from the top of the bluff:

Coal seam at the mine camp, Kachemak Bay.

	Ft.	In.
Coal	1	7
Clay parting	0	4
Coal	0	6
Total	2	5

Following is the section of the Cooper seam, on which three tunnels were driven by Cook Inlet Coal Fields Company:

Cooper seam at the mine camp, Kachemak Bay.

	Ft.	In.
Coal	3	0
Clay parting	0	½
Coal	1	11
Clay parting	0	1½
Coal	1	5
Total	6	6

An outcrop of the Cooper seam is shown in Pl. XVI, *B*.

Other seams of coal lying lower than those given in the section on page 61 are found below high tide at the point near Coal Creek. The first one outcrops about 350 feet from the base of the point and appears to be about 6 feet thick. It has an upper bench at least 15 inches and a lower one 30 inches thick. The strike of this seam across the beach is N. 58° W. and the dip north. The interval between this coal and the base of the formation section given above (p. 61) seems to be occupied by sandstone. Outcropping parallel with it and 130 feet farther offshore is another seam, which is 4 feet 5 inches thick and strikes N. 80° W. Still farther offshore and exposed only at very low tide is a 1-foot seam.

The coal in these seams is hard, compact, glossy lignite. It is clean, does not smut the hands, and tends to break in cubical fragments. When exposed to the weather its high content of moisture causes it to slack down to fine chips. Carloads of coal that have been standing at Homer for three years are shown in Pl. XVI, *A*. Only a small amount of disintegration is apparent in the picture, but the blocks are so deeply weathered that they easily break to pieces. The composition of these coals will be discussed later.

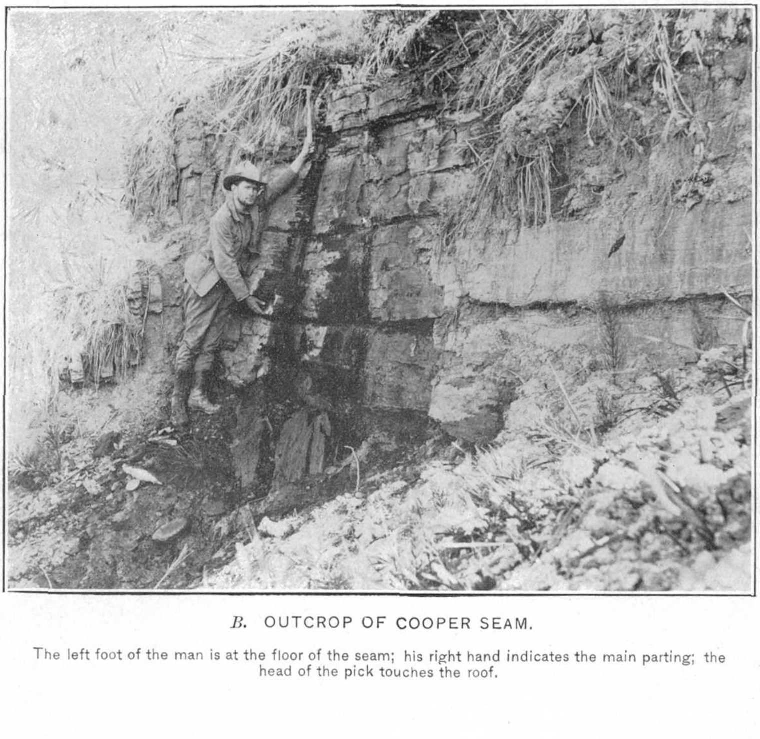
The rocks dip slightly to the east along shore and at an angle of 15° or 20° into the bluff. There are nine coal seams in the mine camp bluff, having a total thickness of 24 feet, as shown in the section on page 61. The smallest seam in the section is 4 inches and the largest 7 feet 5 inches thick.

This portion of the Kachemak Bay coal field, lying just west of Coal Point, was the scene of considerable development work by the Cook Inlet Coal Fields Company, as described on page 55.

Fritz Creek.—The first prominent coal locality inside Coal Point is at the outcrop of the Bradley seam on the beach halfway between Fritz Creek and the base of the spit. The Bradley seam runs from the bluff obliquely across the beach with an average dip of about 15° N. Although this seam aggregates about 7 feet, there is only 18 inches of clear coal, the greater portion of the bed being made up of thin seams interbedded with leaf-bearing shale. It is said[a] that the Alaska Coal Company explored this seam in February, 1888, and that Mr. J. A. Bradley drove a tunnel at this place several years ago which is now caved in. Part of the outcrop of the

[a] Dall, W. H., Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, p. 791.

A. CARLOADS OF LIGNITE AT HOMER AFTER THREE YEARS' EXPOSURE TO THE WEATHER.



B. OUTCROP OF COOPER SEAM.

The left foot of the man is at the floor of the seam; his right hand indicates the main parting; the head of the pick touches the roof.

Bradley seam is covered at high tide, but at low tide the water runs out half a mile or more, exposing broad mud flats, into which the coal outcrop can be traced. The Dall and Becker party in 1895 broke out about 15 tons of this coal with crowbars and used it for steam purposes and galley fuel on the steam tug *Kodak*.

Near Fritz Creek the sea bluff is about 50 feet high. The top is a fairly level belt of wooded land, which reaches back to a bluff several hundred feet high and 2 or 3 miles distant from the shore. The clean cliffs of this higher bluff show numerous coal seams, some of which are usually on fire. Being harder than the sandstone and shale with which they are interbedded, the lignite seams always form small ledges in the cliffs and in the beds of streams cause cascades. This is well illustrated in Pl. XVII, *B*, reproduced from a photograph taken on the north shore of Kachemak Bay, near Cottonwood Creek, where a rill is seen jumping down over 7 small coal seams in the sea bluff.

From Fritz Creek eastward to McNeil Creek the coal seams exposed in the sea bluff are mostly thin. In one stretch of 2 miles the section is almost entirely sandstone, hard nodular blocks of which lie along the beach and often show fossil leaves. In places a few feet of pebble sand or grit is interbedded with the sandstone. This barren section soon dips below sea level, and where the bluff becomes higher gives place to a 100-foot section containing half a dozen lignite seams, the thickest of which is 27 inches. The highest bed in the bluff soon comes down to the beach, the dip along shore being 8° or 10°.

McNeil Creek.—Ten miles northeast of Homer a small stream, known as McNeil Creek, has cut a sharp canyon through the bluff, making excellent exposures of the formation. Four hundred yards west of the canyon two short tunnels were driven on a 4-foot coal seam a few feet above the beach. This work was done ten years ago by Mr. M. B. Curtis, and the seam is called the Curtis seam. (Pl. XVII, *A*.)

Section of Curtis seam, Kachemak Bay.

	Ft.	In.
Coal	0	7
Parting	0	¼
Coal	0	9
Parting	0	¼
Coal	0	6½
Parting	0	1
Coal	0	8
Parting	0	¼
Coal	1	5
Total	4	1¼

Iron-stained sandy clay forms the roof, and the floor is of gray clay. Timbering would be necessary to avoid caving in if coal were taken out to any extent. The coal is compact and tends to break cubically. In the bluff above the Curtis seam there are three other seams, separated by thick beds of clay or soft sandstone. The lowest of the three is nearly 4 feet thick, and was measured about 300 yards up the canyon and 35 feet above high tide, at a spot where it outcrops and causes a small cascade. This outcrop is illustrated in Pl. XVIII, *B*, and the section is given below:

Section of coal in McNeil Creek, Kachemak Bay.

	Ft.	In.
Coal	0	8
Parting	0	2
Coal	0	7
Parting	0	2
Coal	2	4
Total	3	11

A short distance farther up the creek and 60 feet above tide a 20-inch coal seam causes another cascade. From this seam to the top of the bluff the section measures 327 feet and contains 21 feet 4 inches of coal. Four of the coal seams are 3 or more feet thick.

The section of the Kenai formation exposed along this creek, as measured by the writer, is given below:

Partial section of Kenai formation in McNeil Canyon.

Top of bluff.	Ft.	In.		Ft.	In.
Clay shale	20	0	Clay shale	14	0
Coal	3	0	Coal	0	7
Clay and coal streaks	20	0	Clay shale	36	0
Sandstone	10	0	Coal (section below)	4	10
Clay and ironstone	5	0	Clay shale	26	0
Coal	3	0	Coal	1	0
Sandy clay	17	0	Clay shale	16	0
Ironstone	0	3	Sandstone	2	0
Coal	2	6	Clay shale	8	0
Clay, coal streaks, and sandstone nodules	25	0	Coal	0	8
Coal	1	0	Clay and sandstone	99	0
Clay shale	6	0	Coal	1	8
Coal (section below)	4	9	Total	327	3

Two of the coal beds exposed here are over 4 feet thick. The details follow:

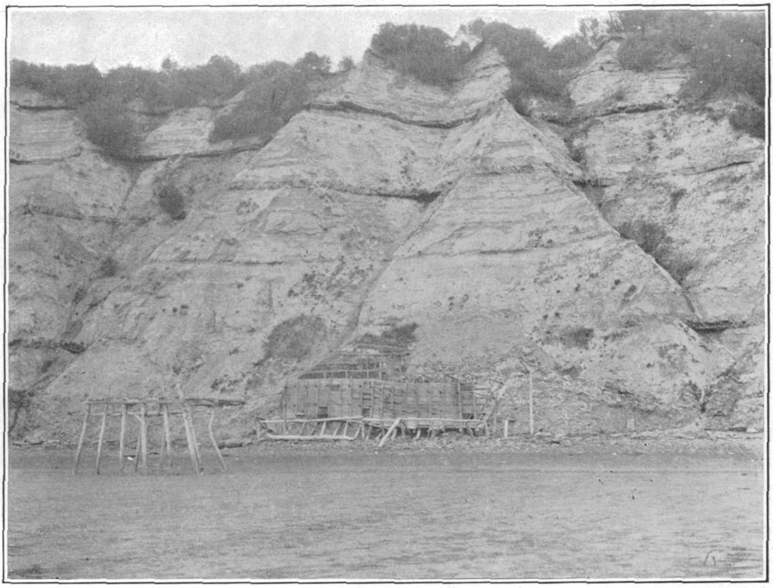
Section of coal seams in McNeil Canyon.

	Ft.	In.
Coal	2	0
Clay	0	7
Coal	0	5
Clay	0	2
Coal	0	4
Clay	0	2
Coal	0	2
Clay	0	3
Coal	0	8
Total	4	9
Coal	0	6
Clay	1	0
Coal	3	4
Total	4	10

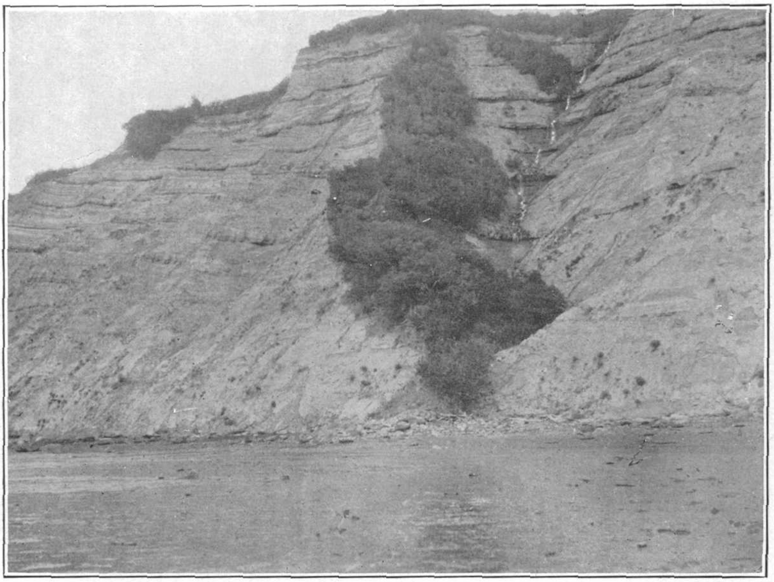
All of the coal in this canyon is bright, glossy lignite, of light weight, having a cubical fracture, and a tendency to slack on drying.

In 1891, Lieut. R. P. Schwerin, U. S. Navy, prospected for coal in this vicinity and took out 200 tons, 50 tons each from four localities, which were shipped to San Francisco and submitted to a series of tests. One of the 50-ton samples was taken from McNeil Canyon.

Cottonwood Creek.—Cottonwood Creek is 2 miles northeast of McNeil Creek and opposite Aurora. It enters the bay by a sharp canyon, which is not so narrow as that of McNeil Creek and has no distinctive landmark, the roofless log cabin at the mouth being hidden among the trees. The dip of the strata between the two creeks



A. OUTCROP OF CURTIS SEAM, RUINS OF WHARF AND BUNKER.



B. CASCADES OVER LIGNITE SEAMS IN SEA BLUFF.

is slight. A coal seam halfway up the bluff at the mouth of McNeil Creek can apparently be traced to a bed 50 feet above tide on Cottonwood Creek. This correlation is not certain, however, because there appears to be a fault about halfway between the two canyons, and a landslip at the west side of Cottonwood Creek also displaces the strata.

At a distance of three-fourths of a mile from its mouth Cottonwood Creek runs nearly parallel with the shore. A mile from the bay the small branches cascade from a height of 500 feet, and the main stream cascades 200 or 300 feet not more than 2 miles from its mouth. In the cascades the strata are well exposed, the coal seams making the ledges over which the water falls. No coal seams over 2 feet thick were seen in the canyon below an elevation of 300 feet. At this height a bed outcrops which appeared at a distance to be 3 feet thick. The coal in this canyon is lighter, perhaps less compact, and dull. Some of it preserves its woody structure so perfectly that it will split in slabs and chips like wood.

Clay forms a considerable part of the section in this canyon. A few limestone cobbles, 6 to 8 inches thick, showing yellowish white on the weathered surface and gray inside, were noticed in the stream bed. The limestone is hard, rings under the hammer, and contains carbonaceous spots or woody fragments. It was not found in place. A quantity of iron carbonate nodules, noticeably heavy and brown, were also seen in a layer 5 inches thick overlying a coal seam about one-third mile from the beach.

Eastland Creek.—This creek is 1½ miles beyond Cottonwood Creek. A sandstone layer conspicuous near the top of the bluff at Cottonwood Creek seems to be almost as high above the beach at Eastland Creek. The tide runs out nearly a mile, but high tide reaches the base of the bluff and keeps it free from talus. At the mouth of the canyon there are the ruins of three cabins, a short dock, and a small tramway which runs up the creek 2,000 feet. Active mining exploration work was done here by M. B. Curtis, engineer in charge for the North Pacific Mining and Transportation Company from 1895 to 1897. One-half mile up the canyon a coal seam shows the following section:

Section of coal in Eastland Canyon, Kachemak Bay.

	Ft.	In.
Coal	1	3
Clay	0	2
Coal	0	4
Clay and coal	1	3
Coal	2	6
Total	5	6

This seam is about 250 feet above tide, has a sandstone roof and clay floor, and dips 4° N. A tunnel driven at the end of the tramway on the seam is choked at the mouth and access was not obtained. Measurement was made and a sample taken where the creek cascades over the outcrop. On the east fork of the creek a coal seam 3 feet 2 inches thick is found at an elevation of 360 feet, and a vertical fault trending N. 70° W. The coal here has a duller fracture and sound under the hammer than have those farther down the bay. Some of it seems to resemble brown coal.

Falls Creek.—One mile northeast of the mouth of Eastland Creek a small stream enters the bay by a deep canyon. The name Falls Creek is given by the writer because there is a 20-foot waterfall within a few rods of the beach. This fall, like many in the streams on the north side of Kachemak Bay, is caused by a coal seam. The face of the bluff on the east side of Falls Creek is bare and light colored, and is noticeable for a long distance. A large number of coal seams 1 to 2 feet thick which appear in the bluff (see Pl. XVIII, *A*) are also exposed in the bed of the stream. The first is 2 feet thick and causes the waterfall. There is a 3-foot seam containing 6 inches of clay at an elevation of 90 feet. Eighty feet higher is a 6-foot seam, the upper half of which consists of interbedded layers of clay and coal. A 4-foot seam, 240 feet above tide, has a 4-inch clay parting 3 feet from the floor, and another seam at an elevation of 300 feet is 4½ feet thick with only one parting, which is 5 inches thick and 30 inches from the floor. There are several other beds above this, the thickest of which is 4 feet. The coal in this canyon is fairly solid, but light and woody; it has a dull fracture and resembles that in Eastland and Cottonwood canyons. The more woody character and better preservation of the vegetable fiber in the coals from McNeil Creek eastward give the impression that they are as a whole of a different quality and a lower grade than the lignites west of Coal Point.

The section below was measured from the plateau at an elevation of about 520 feet down to the beach. It is higher stratigraphically than the section in McNeil Canyon given on page 64, and it is possible that the two sections overlap about 100 feet.

Partial section of Kenai formation in Falls Creek Canyon.

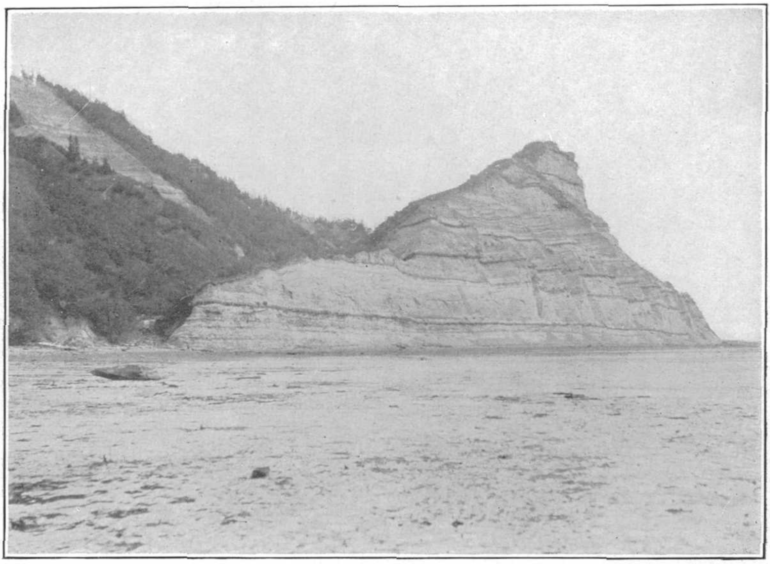
	Ft.	In.		Ft.	In.
Clay shale	15	0	Sandstone	10	0
Shale and 4 thin coals	15	0	Clay and coal streaks	10	0
Clay shale	20	0	Sandstone	15	0
Coal	1	0	Clay shale	10	0
Clay shale	50	0	Coal	1	0
Coal	4	0	Clay shale and coal streaks	20	0
Clay shale	15	0	Coal	1	0
Coal	1	0	Clay shale and coal streaks	25	0
Clay shale	8	0	Coal	3	0
Coal	1	0	Clay shale	8	0
Clay shale	90	0	Coal	2	0
Coal	4	6	Clay shale and sandstone	30	0
Clay shale	12	0	Coal	2	0
Coal	1	0	Sandy clay shale	15	0
Clay shale	3	0	Sandstone	10	0
Coal	0	6	Coal	1	0
Clay shale	45	0	Clay and coal streaks	5	0
Coal	4	0	Sandstone	25	0
Clay shale	2	0	Clay shale	2	0
Coal	1	6	Coal	2	0
Clay shale and coal streaks	65	0	Clay shale	20	0
Coal	6	0			
Clay and shale	1	0	Total	584	6
Carbonaceous sandstone	2	0			

From Falls Creek to the head of the bay the strata dip at a low angle to the north. Clay beds baked hard and red by the burning coal seams color the upper part of the bluff for some distance.

The coal-bearing formation is visible in the bluffs as far as the head of the bay, and a 3-foot seam of coal is reported 15 miles beyond the head of the bay, 200 feet above tide on Sheep Creek.

PORT GRAHAM.

Lignite beds of the Kenai formation are exposed near the mouth of Port Graham. This small bay on the east side of Cook Inlet is long and narrow, penetrating about 8 miles. Dangerous Cape marks the northern entrance, and the native village of



A. KENAI FORMATION AT THE MOUTH OF FALLS CREEK.

B. OUTCROP OF LIGNITE SEAM IN McNEIL CREEK.

Alexandrovsk stands at the southern entrance. The small cove at Alexandrovsk is sometimes called English Bay to distinguish it from Port Graham. The cove on the north side of Port Graham, under Dangerous Cape, was called Coal Bay by Portlock, who discovered coal here in 1786. [a]

At the western end of a crescent-shaped beach behind Dangerous Cape is a low bluff exposing sedimentary rocks lying nearly horizontal between two masses of igneous rock about 1,000 feet apart. The series is composed of sandstone, clay shale, and coal, and appears to have been deposited unconformably in a steep-sided erosion valley in the older rocks. This section at Port Graham must be considered one of the type localities of the Kenai formation, which was the name giv. n by Dall to the coal-bearing Tertiary beds "best exhibited on the shores of Kachemak Bay, Kenai Peninsula, Cook's Inlet," because it was one of the earliest describe.l localities and because it yielded a large proportion of the so-called Miocene flora described by Heer, [b] which has furnished the paleontologic characterization of the formation. At the time of the writer's visit the fossiliferous strata were not accessible, and the following statement concerning the fauna and flora is quoted from Dall: [c]

> The plants are all terrestrial or fresh-water species. One of the most common is a species of *Trapa* represented by many fruits. With them are found *Unio* (*Margaritana*) *onariotis* Mayer, a species probably related to *Margaritana margaritifera* L.; *Amicola abavia* Mayer; and *Melania* (*Goniobasis?*) *furuhjelmi* Mayer, together with elytra of a beetle described by Heer under the name of *Chrysomelites alaskanus*. Among the plants are both Coniferæ and broad-leaved trees, the total number of species amounting to forty-four. The deposit appears to have been formed at the bottom of a lake. The leaf-bearing strata crop out below the level of the sea and are accessible only at extreme low water.

Two outcrops of coal were seen, one on the beach between tides, and the other at high-tide mark, near the west end of the gravel beach. A tunnel driven on the coal at the latter outcrop is now caved and inaccessible. At the mouth of the tunnel there are between 8 and 9 feet of coal, some of which is good and some bony. Clay underlies the bed and the roof is shaly sandstone. On top of the bluff, a short distance back from the beach and about in line with this tunnel, is the mouth of a large shaft. Its dump is small and shows no coal, from which it is concluded that sinking ended at no great depth. On the beach at the end of a log crib is the framework of a 6 by 10 foot shaft, in one corner of which are hollow upright logs which may have been pump columns. A Russian miner, who lived for many years at Seldovia and died there in May, 1904, at the age of about 95, said he had worked in this shaft. As he remembered it, the shaft was 180 feet deep and passed through 5 seams of coal, of which the first was about 5 feet thick, the three succeeding ones smaller, and the fifth, at the bottom of the shaft, about 9 feet thick. [d] Nothing is known of the workings in this shaft.

Ruins of several large log buildings situated on the hill a few hundred yards back from the shafts are hidden in the long grass and second growth of spruce which covers the top of the bluff. A blacksmith shop, tool house, church, cook house, and barracks were recognized. Connection between these log buildings and the abandoned mine is shown by their proximity, and by the quantity of iron ax and pick heads and other tools and machinery found in the buildings. At low tide a long line of large stone blocks, apparently the ruins of a stone pier, can be seen extending from the mouth of the tunnel at least 100 yards into the bay.

Russian occupancy of this bay extended from 1855 to 1867. In April, 1855, the bark *Cyane*, Captain Kinzie, left San Francisco for Port Graham, where miners and machinery were landed. [e] Mining operations continued about ten years and supplied Russian steamers with coal. Bancroft [f] says of the operations in this bay:

---

[a] Portlock, Nathaniel, A Voyage to the Northwest Coast of America, London, 1789, pp. 102–110.
[b] Heer, Flora fossilis Alaskana, 1869.
[c] Op. cit., p. 787.
[d] Information furnished verbally by E. G. Wharf, Seldovia.
[e] Dall, op. cit., p. 786.
[f] Bancroft, H. H., History of Alaska, p. 694.

In 1857 shafts had been sunk and a drift run into the vein for a distance of nearly 1,700 feet, nearly all of which was in coal. During this and the three following years over 2,700 tons were mined, the value of which was estimated at nearly 46,000 roubles, but the result was a net loss. The thickness of the vein was found to vary from 9 to 12 feet, carrying 70 per cent of mineral, and its extent was practically unlimited; but the coal was found to be entirely unfit for use of steamers, and a shipment of 500 tons forwarded to San Francisco realized only 12½ roubles per ton, or considerably less than cost.

It is likely that as the shafts increased in depth water came in faster than primitive pumps could handle it, and in addition, as the coal was found to be an inferior quality of lignite, operations were discontinued. The mine was finally abandoned when Alaska was sold to the United States.

Port Graham coal is lignite—black, brilliant, clean to handle, and with slabby cleavage. The blocks into which it breaks are fairly strong, although like most lignites they lose luster and slack on long exposure to the weather. It burns well and makes little ash. An analysis is given on page 70. The limited extent of the coal beds, their position below sea level, and other disadvantages make this field of little more than historic interest.

SOUTH SIDE OF KACHEMAK BAY.

At a number of localities on the south side of Kachemak Bay there are sedimentary rocks, supposedly of the Kenai formation. In a high sea bluff about 2 miles north of Seldovia there is an exposure of finely laminated clays and partly indurated sandstone, which rest unconformably on diabase. A few plant impressions found in the clay and the conspicuous contact near the bottom of the bluff show that these beds are the base of the Kenai formation.

According to Mr. H. D. Reynolds, of the Reynolds Alaska Development Company, and Mr. Ritchie, of Yukon Island, there is coal on the mainland east of Yukon Island and north of Sadie Cove. Mr. Reynolds saw abundant float, but did not find the coal in place. It is not unlikely that some of the lower members of the Kenai formation may be caught in the mountain and thus account for the presence of the coal.

At a point 2 miles southwest of Seldovia Bay tilted Jurassic tuffs and sandstones abut against horizontal conglomerates. A mile farther along shore the Jurassic beds are found again. The horizontal conglomerates have a very youthful appearance, being only partly consolidated, and probably belong to the Kenai formation. They seem to have been deposited unconformably in steep-sided, comparatively narrow valleys in the older rocks. No fossils were found in them, and the character of the beds seemed unfavorable for the preservation of any. No other occurrences of the Kenai formation are at present known in the vicinity of Kachemak Bay.

CHARACTER OF THE COAL.

ANALYSES.

A study of analyses of samples throws light on the character of the coal and forms a basis of comparison between different seams and fields. Five analyses of Kachemak Bay coals were made by George Steiger in the chemical laboratory of the United States Geological Survey for W. H. Dall in 1895, and were published in the latter's report on coal and lignite of Alaska. Dall's samples were "taken from the seam and tied up in bags of stout duck, and analyzed immediately on arrival at headquarters."[a] This method of treatment resulted in a very appreciable loss of moisture, and for that reason the analyses will not be repeated here. Six samples were taken at Kachemak Bay by the writer and analyzed in the same laboratory by W. T. Schaller.

---

[a] Dall, op. cit., p. 827.

These samples were taken under greatly differing conditions, but all are intended to represent the marketable portion of the seams. One was taken inside a tunnel, another below high tide, and the others on the outcrop, which in some cases was dry and in others a stream bed. Each sample was washed piece by piece and dried several hours in the open air before crushing and quartering. They were packed in tin cans with tight covers, so there was little chance for evaporation during the six months which elapsed before they were analyzed. Two sets of analyses were made, one from samples ground in a coffee mill and the other from specimens ground to powder in an agate mortar. The analyses of the coarse-ground samples are believed to represent more closely the condition of the coal as it would be mined and marketed, and are given below:

Analyses of coarse-ground Kachemak Bay coal.

No. of sample.	Locality.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
3	Mine camp, below hoist	20.87	40.71	33.29	5.13	0.36
4	Mine camp, No. 3 tunnel	19.26	43.95	28.74	8.05	.32
7	Mine camp, below tide	19.22	41.22	31.96	7.60	.38
8	Curtis seam, McNeil Canyon	18.92	37.62	28.59	14.87	.46
9	McNeil Canyon	21.54	39.10	30.26	9.10	.34
10	Eastland Canyon	19.29	40.31	33.11	7.29	.27

Sample No. 3 in the above table was taken from the outcrop of the 2-foot 9-inch seam near the end of the railroad spur at the mine camp; No. 4 came from 50 feet inside of tunnel No. 3; No. 7 represents 30 inches of a 4½-foot bed occurring below tide about 500 feet offshore at the point west of Coal Creek; No. 8 was cut from the outcrop of the Curtis seam 400 yards west of McNeil Canyon; No. 9 was from a 4-foot seam found 300 yards from the beach up McNeil Canyon; No. 10 was from the lower 30-inch bench of a 5½-foot coal seam on which a tunnel was driven in Eastland Canyon.

Analyses of the same 6 samples ground fine showed a much lower percentage of moisture, and in that respect compare closely with those published by Dall for the same locality. The loss was due probably to evaporation during manipulation in a finely pulverized condition.

The averages of the 6 analyses given above, of the 6 analyses of the same fine ground, and of the 5 analyses published by Dall are shown in the following table:

Average analyses of Kachemak Bay coal.

	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Six analyses given above	19.85	40.48	30.99	8.67	0.35
Same material fine ground	11.07	44.90	34.39	9.63	.39
Five analyses given by Dall	11.59	49.03	31.64	7.73	.35

These analyses show that this lignite has a low percentage of sulphur and not an excessive amount of ash. It is probable that the marketed coal would contain 15 or 20 per cent of moisture.

The writer took a sample of Port Graham coal from blocks dug at the outcrop between tides. It was washed to remove dirt and barnacles and packed in a tight tin can. On arriving at the United States Geological Survey laboratory it was analyzed by W. T. Schaller, with the following result:

Analysis of Port Graham coal.

	Per cent.
Moisture	16.87
Volatile matter	37.48
Fixed carbon	39.12
Ash	6.53
Sulphur	.39

From this analysis it appears that the content of moisture is high and the ash moderately low.

The following table offers a comparison of Kachemak Bay lignites with coals from other points on the Pacific coast:

Averages of analyses of Pacific coast coals.

No.	Locality.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Fuel ratio.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
6	Kachemak Bay, Cook Inlet	19.85	40.48	30.99	8.67	0.35	0.76
1	Port Graham, Cook Inlet	16.87	37.48	39.12	6.53	.39	1.04
2	Unga Island, Shumagin Islands[a]	10.92	53.36	28.25	7.47	1.36	.53
5	Bering River, Controller Bay[b]	2.18	12.76	74.33	10.73	.93	5.82
12	Cape Lisburne (Jurassic)[c]	9.46	38.42	46.83	5.24	.38	1.21
3	Cape Lisburne (Carboniferous)[c]	3.66	17.47	75.94	2.92	.96	4.46
5	Comox, Vancouver Island[d]	1.25	26.87	58.74	11.76	1.38	2.19
4	Nanaimo, Vancouver Island[d]	2.10	34.68	54.47	8.09	.66	1.57
10	Washington[e]	4.43	31.60	56.01	7.45	....	1.77
17	Coos Bay, Oregon[f g]	10.22	44.19	38.91	7.35	.90	.88

[a] Dall, W. H., Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, p. 828.
[b] Martin, G. C., Bering River coal fields: Bull. U. S. Geol. Survey No. 225, p. 374.
[c] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: Bull. U. S. Geol. Survey No. 278, p. 48.
[d] Annual Report of Minister of Mines, British Columbia, 1902, p. H-262.
[e] Smith, G. O., Coal fields of the Pacific coast: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, p. 490.
[f] Smith, G. O., op. cit., p. 510.
[g] Diller, J. S., Geology of northwestern Oregon: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, p. 504.

From this table it appears that Kachemak Bay coal has a high percentage of moisture and volatile combustible matter, a moderate amount of ash, and remarkably little sulphur. Judging from the chemical analyses its fuel value is lower than that of Port Graham coal, and both are low in comparison with that of the Vancouver Island and Bering River coals.

TESTS AND CONCLUSIONS.

Aside from chemical analyses and theoretical conclusions regarding the value of Kachemak Bay coal some data have been collected from experiments in its use. Dall obtained some information in regard to tests made with it, and the following is quoted from his report: [a]

[a] Dall, op. cit., pp. 830-832.

During part of the expedition of twenty-eight days' cruising on the steam tug *Kodat*, in July and August, 1895, we were obliged to burn coal from the Bradley seam, Kachemak Bay, Cook Inlet, which was dug out of the beach at low water with crowbars and burned as it was, covered more or less with barnacles and seaweed. This coal, being under water most of the time, must have had a larger percentage of moisture than the normal amount belonging to it. The opinion of the engineer of the *Kodat* was to the effect that this lignite did from 60 to 75 per cent of the duty of Wellington (B. C.) coal.

Several hundred tons of coal from Eastland Canyon, Kachemak Bay, were imported into San Francisco by the Alaska Mining and Transportation Company in 1895, and distributed to various manufacturing establishments for trial. Among these was the foundry of Messrs. W. T. Garrat & Co., well known as the principal brass founders of the Pacific coast. I was informed by their manager that this coal, to the amount of 50 tons, had been in use for making steam in their establishment, and was regarded by them as a very fair steaming coal. When a good fire was kept up they used 2,600 pounds in a given time, during which they would have used 2,200 pounds of Comox (B. C.) coal. With a low fire and small pressure of steam the amount used was 2,240 pounds to 1,350 of Comox. They stated that if the Cook Inlet coal could be furnished at a price corresponding to its relative efficiency compared with the British Columbia coal they should be glad to make regular use of it.

By permission of the Secretary of the Navy, and at the request of some New York parties, Lieut. R. P. Schwerin, in April, 1891, proceeded to Cook Inlet to examine the coal fields. The party was provided with a diamond drill and examined numerous seams. From four localities in particular, one of which was McNeil Canyon, Kachemak Bay, 50 tons of coal each were mined and brought to San Francisco. Lieutenant Schwerin informed me that during the entire summer this coal was used under the boiler and for cooking in camp and aboard ship. It gave very satisfactory results for stationary purposes, though the coal slacks into chiplike fragments rather rapidly after exposure to a dry atmosphere. He induced the Southern Pacific Company of California to make a test of the coal on their locomotives, a purpose for which it proved unfit owing to its sparking tendency, which, under forced draft, was very pronounced in spite of the use of fine netting over the stacks. There was no trouble of this kind when used under stationary engines or in a cooking stove.

The following summary of the data of the test, prepared September 29, 1891, was kindly furnished to Dr. Becker by Lieutenant Schwerin, who is now one of the staff of the Southern Pacific Railway organization. The kinds of coal with which the Cook Inlet lignite was compared were the ordinary Nanaimo coal from Vancouver Island and bituminous Cardiff coal imported as ballast by wheat ships.

Comparative tests of Cook Inlet, Nanaimo, and Cardiff coals.

	Cook Inlet.	Nanaimo.	Cardiff.
Number of trips	2	2	4
Average number of miles per trip	86	168	86
Average gallons water used per trip	3,734	13,836	2,989
Average pounds fuel per trip	6,982	18,551	3,601
Average number loaded cars per trip	6.2	11.98	6
Average number empty cars per trip	....	1.401	75
Average tons weight loaded cars per trip	155.35	....	139
Average tons weight empty cars per trip	....	....	21.25
Average tons weight train without the engine and tender	155.35	301.47	160.25
Gallons water used per ton of train	24.04	45.895	18.653
Pounds fuel used per ton of train	44.94	61.535	22.473
Water evaporated per pound of fuel	4.46	6.215	6.917
Fuel burned per gallon of water evaporated	1.87	....	1.205
Average steam pressure, pounds	130.5	143	150.3
Average temperature of air, degrees	....	....	52
Average temperature of feed water, degrees	68	....	57
Average temperature of steam, degrees	355.6	....	365.7
Area of grate, in square feet	16.87	25.6	16.87
Average fuel per hour per square foot of grate, pounds	....	....	54.215
Total heating surface	1,325	1,288	1,325
Pounds fuel burned per hour per square foot of heating surface	....	....	.69
Pounds fuel burned per ton per mile	.5226	.3663	.2613
Equivalent evaporation from temperature of feed water	5.33	7.507	8.369
Average number of miles run per ton fuel burned	24.635	18.112	47.762
Per cent value of fuel from evaporation	63.678	89.7	100

It thus appears that the Cook Inlet coal, under these conditions, has 71 per cent of the heating effect of Nanaimo coal and 63.7 per cent of Cardiff bituminous, a result which agrees fairly well with that derived from the other tests above mentioned.

The following table, adapted from Goodyear,[a] shows the relative value as fuel of the Pacific coast lignites, to which I have added the Cook Inlet variety:

Table of relative values of Pacific coast lignites.

Locality.	Value.
Mount Diablo, Black Diamond (best)	1.000
Bellingham Bay, Washington	1.148
Seattle, Wash., average of 3 tests	1.229
Nanaimo, British Columbia (2 tests)	1.306
Wellington, British Columbia (2 tests)	1.351
Cook Inlet, average of 4 tests	.927

A series of tests made on the steamer *Dora*, which at present plies between Valdez and Dutch Harbor, is reported by James D. Garvey, chief engineer, in the following letter to Alfred Ray:

I received some of your Homer coal July 21 [1899], and as it gave good results I thought I would make a test and compare it with other brands of coal we have been using on this ship. The tests were made under the following conditions, viz, consumed in Scotch marine boiler with straight double grate bar, natural draft, and fair steaming weather.

Wellington: 5⅓ tons per 24-hour day (2,000 pounds per ton); ashes, 1,170 pounds, mostly heavy clinker; 10.6 per cent waste; good steam coal; black smoke.

Seattle Franklin coal: Very dirty; can not get steam over 100 pounds for any length of time; thick black smoke; 6½ tons per day (2,000 pounds per ton); ashes, 2,250 pounds, like black sand; 10.57 per cent waste.

Newcastle, N. S. W.: 5 tons per day (2,000 pounds per ton); ashes, 768 pounds, with little clinker, very thin; 7.68 per cent waste; light-gray smoke (good coal).

Tyonok, Cook Inlet lignite: 9 tons per day (2,000 pounds per ton); ashes, 1,300 pounds, with little clinker; 7.22 per cent waste; a little gray smoke; makes steam easy, but very smoky smell.

Homer fuel: 4 tons 14 hours running time (2,000 pounds per ton); ashes, 420 pounds (equivalent to 6⅞ tons 24-hour day and 720 pounds ashes); a pure fine white ash; 5.25 per cent waste; makes a very hot and lasting fire, no smoke, and no trouble to make all the steam we want, and to clean fire only use poker the same as in house grate, and I can truthfully recommend it to large steam plants as a good, clean, and lasting fuel.

The experience of the writer, who was at Homer three weeks, is that the general run of Kachemak Bay coal is excellent for use in heating and cooking stoves. It is clean to handle, ignites easily, makes a hot fire, does not soot the bottom of cooking utensils, makes very little smoke, and leaves only a moderate amount of ash. It slacks on exposure, but this does not seriously affect its fuel value. In drying it loses its brilliancy and takes on a dull, shaly appearance, in which condition doubtless many would scorn it as an unpromising fuel. The loss of moisture may not be to its disadvantage, but still there was no perceptible difference in heating qualities between coal which had been under shelter for two years and that which was washed up on the beach at Homer after migrating several miles in the longshore currents.

Other things than the quality of the fuel itself must be considered in discussing the economic value of a coal deposit. Among these are the undisturbed or broken condition of the strata as a whole, the thickness of the seams, the character of roof and floor, the accessibility of a supply of good lumber for timbering, the ease or difficulty of getting the fuel to market, the availability of mining labor, and the demand for the fuel.

The coal strata just west of Coal Point outcrop in a bluff above the sea beach, dip inland at a low angle, and so far as observed are evenly bedded and undisturbed

[a] Goodyear, W. A., Coal Mines of Western Coast of United States, 1877, p. 164.

by flexures or faults. Several of the seams are thick enough for economic mining. Unfortunately the roof rock is generally weak, which would necessitate timbering. The floor is often clayey and probably would have a tendency to swell. There is sufficient and suitable timber close at hand for all mining purposes. An excellent harbor, open at all seasons of the year, is reached by a light railroad, extending from the mine to deep water, at the outer end of the spit. The region is subject to severe storms during the spring and fall.

FUTURE PROSPECTS.

There is no available local labor, and any that might be imported would possibly be affected by a rush for a new gold field. It seems probable that the natural demand for this coal under present conditions can not be large. Its quality is fairly good for steaming purposes and household use, but the steamers which might make use of it are not fitted with grates fine enough to burn this coal without a considerable loss into the ash pit. There are at present no stationary engines requiring such fuel in the region, and the population for hundreds of miles is extremely scanty, mostly penniless natives, and, therefore, the demand for household uses is almost nil. If the Kachemak Bay lignite could be mined in large quantities by economical methods and placed on the market in the Pacific coast towns at a price commensurate with its relative efficiency, compared with the coal now being supplied to those markets, it might compete. But it is doubtful if it can be supplied at such a price.

SUMMARY.

In the foregoing pages a history of coal mining in the Kachemak Bay region has been given, and the Kenai formation, which occurs on the shores of Kachemak Bay and Port Graham, has been described. The Kenai formation contains a large number of lignite beds, and their occurrence has been described in detail. Four sections of the formation, having an aggregate thickness of 1,765 feet, and 10 detailed sections of the thicker coal seams are given. Proximate analyses showing the character of the coal in different seams in this locality are compared with analyses of other Pacific coast coals. It is shown that the lignite at Port Graham is probably of a slightly higher grade than that on the north shore of Kachemak Bay, but that the Port Graham field is very limited and lies largely below sea level. Although the Kachemak Bay lignites constitute an extensive field and occur in beds ranging up to 7 feet in thickness, their average fuel ratio is only 0.76. In comparison with Vancouver Island bituminous coals, having an average fuel ratio of 1.88, and with semibituminous coals from Bering River, Controller Bay, whose ratio is 5.82, the lignites here described can at present create no great demand for their use.

INDEX.