THE COLD BAY DISTRICT.

By Stephen R. Capps.

INTRODUCTION.

LOCATION AND AREA.

The Cold Bay district, as here defined, occupies a part of the southeast half of Alaska Peninsula west of Kodiak Island and extending from the east side of Cold Bay southwestward to and including Kialagvik Bay. The local use of the term "Cold Bay district" to include an indefinite area in the vicinity of Cold Bay is inherited from the days of the oil excitement in 1903–4, when passengers, supplies, and drilling outfits were landed at Cold Bay, and several miles of wagon road was constructed to drilling sites in the "east field." At that time Cold Bay was the center of activity and supply point for the whole district. In 1920–21 prospecting and staking were extended over a larger area, particularly to the southwest, and Portage Bay was more generally used as a port, many persons even landing at Kialagvik Bay, yet the whole district is still generally referred to as the Cold Bay district. The present report is the result of a reconnaissance examination of the area reaching along the Pacific coast from Cape Kekurnoi, at the northeast entrance of Cold Bay, to the west end of Kialagvik Bay (or Wide Bay, as it is known locally) and extending inland to Becharof and Ugashik lakes. The area lies between latitude 57° 15′ and 57° 45′ north and longitude 155° 17′ and 156° 30′ west. (See Pl. II.) It includes about 740 square miles and comprises a part of the mountain range that lies along the Shelikof Strait shore line and a part of the inland lowland in which lie Becharof and Ugashik lakes.

HISTORY AND PREVIOUS SURVEYS.

The historical record of this district, though incomplete, dates back well toward the beginning of white settlement in Alaska. By 1762 the Russians had sent trading expeditions as far east as Kodiak Island, and in 1783 a permanent trading post was established at Three Saints Bay, on Kodiak Island. The rugged islets in the mouth of Cold Bay and elsewhere along the mountainous coast of the Alaska Peninsula furnished rich hunting grounds for the eagerly sought sea otter, and the Russian influence was soon felt among the native hunters and has continued ever since through the conversion of the natives to the Russian church. Even since the transfer of the territory to the United States the missionaries of the Russian church have still ministered to the spiritual needs of the natives.

A bibliography of the early publications in which reference is made to the presence of petroleum in Alaska was published in 1905,[1] and the publications that concern the Cold Bay district are cited here. The presence of petroleum in this part of Alaska was first recorded in print in 1869, by Davidson and Dall.[2] Dall[3] in 1896 also referred to the occurrences of petroleum on the portage from Katmai. An anonymous article[4] published in 1903 described briefly the occurrence of petroleum at Cold Bay and contained some notes on the geology of the area. In 1904 Martin gave an abstract[5] of the fuller report issued later,[6] in which he not only included the results of his own field studies but summarized the existing information concerning the Cold Bay district, as well as other petroleum fields. Other publications by Martin[7] and Stanton[8] were issued in 1905. In 1911 Atwood[9] in describing the geology of parts of the Alaskan Peninsula, summarized the previous reports of Martin and Stanton on the Cold Bay district. In 1921 Martin[10] made a general report on petroleum in Alaska, in which he reviewed the results of his earlier work in the Cold Bay district and advanced some new interpretations concerning the geology of the district. In 1921 Moffit[11] mapped the oil field of the Iniskin-Chinitna Peninsula on Cook Inlet, in detail.

[1] Martin, G. C., Petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 10–11, 1905.

[2] Coast Pilot of Alaska, 1st ed., pt. 1, pp. 36, 199, 1869.

[3] Dall, W. H., Coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, p. 799, 1896.

[4] The Cold Bay oil field: Eng. and Min. Jour., vol. 76, pp. 618–619, 1903.

[5] Martin, G. C., Petroleum fields of Alaska and the Bering River coal fields: U. S. Geol. Survey Bull. 225, pp. 365–382, 1904.

[6] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, 64 pp., 1905.

[7] Martin, G. C., Notes on the petroleum fields of Alaska: U. S. Geol. Survey Bull. 259, pp. 134–139, 1905.

[8] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 393–397, 401–402, 1905.

[9] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, 137 pp., 1911.

[10] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, 83 pp., 1921.

[11] Moffit, F. H., The Iniskin-Chinitna Peninsula, Alaska: U. S. Geol. Survey Bull. — (in preparation).

It is quite likely that the occurrence of petroleum on the Alaska Peninsula was known to the Russians nearly 100 years ago, but it was not until the closing years of the last century that any general interest was attracted to the Alaska oil fields. The first well was drilled at Katalla in 1901, and another was drilled in the Cook Inlet district, at Oil Bay, at about the same time. In 1902 to 1904 oil exploration was active throughout the Territory, and at that time the Cold Bay oil boom was at its height, and a large number of claims were staked in what were then known as the Cold Bay field, extending from the head of Trail Creek to Portage Bay; the Lake field, which lay between Bellim Bay of Lake Becharof and the northeast end of Cold Bay field; and the Becharof field, lying west of Becharof Lake and including what is now known as the West field. Four wells, of varying depth, were then drilled in the Cold Bay or East field, and although some paraffin-saturated beds were penetrated and a little oil was found, no commercially productive wells were brought in, and the excitement gradually died down. No important developments took place from 1904 to 1910, and in the fall of 1910, when all Alaska oil lands were withdrawn from entry, title had not been granted to any of the claims in the Cold Bay district. Then followed a long period of stagnation in oil prospecting and development in Alaska. A few prospectors of unusual perseverance had retained their faith in the ultimate development of the Cold Bay field and had kept their claims there. In 1918 a geologist made a private examination of the field for a group of claimants, and although his report was confidential, its contents became generally known in the district. The more intelligent prospectors were keenly alive to the relation of geologic structure to productive oil pools, and the most eagerly sought claims were those which lay along the crests of the anticlines or domes of the region.

In 1920 Congress passed an oil leasing bill permitting the staking and development of oil lands under certain restrictions. That act stimulated oil prospecting throughout the Territory, and those areas in which there were known indications of petroleum received particular attention, among them the Cold Bay field.

Soon after word was received that the oil leasing bill had become law, a considerable number of prospectors hastened to the Cold Bay district, and before the snow had disappeared in the spring of 1920 a large part of the most promising oil land had been staked. No drilling was done in the summer of 1921, but prospecting was continued energetically, the boundary lines of a large number of claims were surveyed, and a number of petroleum geologists representing strong producing companies in the western United States visited the field. The United States General Land Office also sent a party to this district to continue the work already begun of carrying out land surveys and to establish reference lines to which the claim surveys could be accurately tied.

PRESENT INVESTIGATION.

Realizing the importance to Alaska and to the country at large of a possible new oil field, the United States Geological Survey considered it wise to extend geologic and topographic mapping into this promising district and to make a study of the geologic structure and its relation to possible oil pools. Two parties were organized to carry out this work, one in charge of R. K. Lynt, consisting of five men and eight pack horses, to conduct the topographic mapping, and one in charge of the writer, including also W. R. Smith as geologic assistant, three camp hands, and eight pack horses, to map the geology and to study the structure and its relation to the possible accumulation of commercial petroleum pools.

The plans for these two parties were completed and preparations made to sail from Seattle on May 18, but at the last moment the officials of the steamship company decided that, owing to the reduced number of sailings to Alaska on account of the seamen's strike, only passengers and foodstuffs could be loaded, and that the pack horses, the only means of field transportation for the parties, must be left behind. Accordingly, Mr. Lynt sailed on May 18 with all the supplies for both parties and seven men. The writer and two packers remained in Seattle with all the horses and sailed on June 18. The horses were landed at Portage Bay on July 2, and were taken overland to Cold Bay on July 3. Field work for both parties commenced immediately and was continued until September 4; the men then returned to Kodiak by small power boat and thence to Seattle by steamship. Unfortunately, the weather during July and August was generally foggy and rainy, with only a few clear days, so that conditions were highly unfavorable for phototopographic mapping. With only four working days Mr. Lynt completed a topographic map of about 150 square miles on a scale of 1:180,000, and the geologic mapping was carried over an area of about 740 square miles. Considerable time was also spent in a study of the stratigraphic section and in a reconnaissance trip to Kialagvik Bay, but the results of this work can not be expressed in terms of area. At the time the field work on which this report is based was planned it was thought that the topographic party would be able to map an area of at least 1,000 square miles on a scale of 1:180,000 and thus furnish a base map upon which the areal geology could be accurately plotted. As a result of the unfavorable weather only a small part of the area was covered, and in consequence the geologists had no accurate topographic map for field use. It has therefore not been possible to present in this report a geologic map that shows the degree of refinement in mapping that could have been attained if an adequate base map had been available.

While the field work on which this report is based was being done independent explorations and examinations in the district were made by geologists representing at least three western oil companies. All these geologists showed the greatest cordiality and generosity in placing at the disposal of the Geological Survey the information they obtained. Especial acknowledgment is due to Mr. Ernest Marquardt, of the New York Oil Co., of Casper, Wyo., who furnished copies of his traverses, notes, and maps and supplied a number of valuable fossil collections and who alone is responsible for the topographic map of the Pearl Creek dome, published herewith; and to Mr. L. C. Decius, of the Associated Oil Co., and Mr. E. D. Nolan, of the General Petroleum Co., who furnished several geologic sections for comparison, as well as other useful information.

GEOGRAPHY.

DRAINAGE.

In the latitude of Cold Bay the Alaska Peninsula has a width of about 90 miles. Toward the north it widens, and toward the southwest it becomes narrower. Between Port Moller and the base of the peninsula the position of the divide is notably asymmetrical, for it lies much closer to the Pacific shore than to Bristol Bay. In the Cold Bay district the southeast coast is bordered by a mountain range which reaches elevations of about 2,000 feet near Cold Bay but which becomes increasingly higher to the southwest and at the west end of Kialagvik Bay culminates in a group of peaks that rise over 4,000 feet above the sea and contain vigorous glaciers. This mountain range forms the divide between the streams that flow in a southeasterly direction to Shelikof Strait and the Pacific and those that flow west or northwest to Bristol Bay. The area draining to the Pacific, however, is small, and the streams are in general short, swift, and of only moderate size. Most of them can be waded easily on foot during the summer, except at times of flood. The one notable exception is the glacier-fed stream that empties into the west end of Kialagvik Bay. This is a turbulent river during the season of glacial discharge and can be waded with difficulty even at favorable places.

The Bristol Bay drainage, by contrast, is characterized by large lakes and sluggish rivers. On the northwest flanks of the coastal mountain range many of the small streams are swift, but these descend quickly to the great lowland that occupies much of the peninsula. A remarkable feature of this lowland is the series of lakes that occur along the center line of the peninsula from its base to the constriction at Port Moller and Stepovak Bay, a distance of over 300 miles. Much of this area has not been accurately surveyed, but its general features are well known. These lakes lie against the northwest or inland front of the coastal mountains but are bordered on the northwest by a broad lowland that extends to Bristol Bay. Their elevation above sea level is generally less than 50 feet, and with one or two minor exceptions they drain to Bristol Bay through broad, sluggish rivers in which the effects of the Bering Sea tides are felt for long distances inland. These lakes and their tributary streams are favored spawning grounds for salmon, and an extensive salmon-canning industry has been established on Bristol Bay to utilize the fish that migrate from salt water to these great fresh-water lakes. Becharof Lake, the largest of the Alaska Peninsula lakes, is over 40 miles long and probably has an area of more than 450 square miles. Naknek Lake is about 45 miles long, though of smaller area, and the two Ugashik Lakes together are about 30 miles long. Naknek River, which drains Naknek Lake, Egegik River, the outlet of Becharof Lake, and Ugashik River, between the Ugashik Lakes and the sea, are all fairly large, rather sluggish streams that are easily navigable by small boats, and they with the lakes furnish convenient routes of travel through the lowland and from one coast to the other.

RELIEF.

As has been stated, the Pacific coast of the Alaska Peninsula in general is bordered by mountains that rise steeply from the water's edge, and the coast line is irregular and deeply indented with embayments. The visitor approaching from the southeast receives the impression that the entire peninsula is mountainous and rugged, but this is by no means the case. The mountain range along the coast, at least in the Cold Bay district, is narrow. Nearly all the southeastward-flowing streams head in low passes or in easily traversed divides, and after crossing the coastal range the traveler soon descends into a broad lowland area of slight relief, broken by isolated mountains and by large fresh-water lakes. In the immediate vicinity of Cold Bay the mountain ridges have rather smooth outlines and reach only moderate elevations, the highest peaks standing from 1,500 to 2,400 feet above sea level. Near Portage Bay the mountains are higher and more rugged, and at the southwest end of Kialagvik Bay there is a group of mountains whose peaks attain heights of 4,000 to 5,000 feet.

Northwest of the coastal mountains there are a few isolated mountains and at least one notable mountain chain that rises from the surrounding lowlands. The field work on which the present report is based covered only the coastal mountain strip between Cold and Kialagvik bays and a part of the interior lowland, and these interior prominences were not examined or their position accurately determined. One conspicuous ridge, however, the Kejulik (Garkulik) Mountains, forms a prominent topographic feature north of Cold Bay. This mountain ridge lies about 15 miles inland from the head of Cold Bay and extends from a point near Becharof Lake northeastward to merge with the coastal mountains in the Katmai region. Its crest line is conspicuously rugged, and its general character and topography suggest that the ridge has a core of granitic rocks, flanked by sedimentary beds. The highest peaks are probably little less than 5,000 feet above sea level.

The axial line of the Alaska Peninsula is marked at irregular intervals by volcanic peaks, of which some are still active and many others are of so recent origin that their topography still shows the conical shape characteristic of volcanic mountains. The high peaks of the Katmai region, with their smoke plumes, are visible on clear days from the Cold Bay district. Mount Peulik, an extinct volcano, forms a conspicuous topographic feature between Ugashik and Becharof lakes. Although sculptured somewhat by gulches, it still preserves its conical shape, and, rising to a height of about 5,000 feet above the lake, it dominates the lowlands to the northwest.

A feature less impressive but no less notable than the mountain ranges is the great lowland plain that occupies more than half of the Alaska Peninsula, on its northwest side. This plain stands, for the most part, less than 100 feet above sea level and consists of grassy meadows, marshes, and lakes. In summer travel in this lowland is confined to the rivers, which are sluggish and easily navigated by small boats. The lowland has little attraction for man, however, and is almost entirely uninhabited except for the fishing communities along the coast. In winter it is occasionally visited by trappers.

CLIMATE.

No systematic weather records have been kept in the Cold Bay district, and as the climate there is completely influenced by local conditions the weather records for Kodiak, the nearest important town, on Kodiak Island, more than 100 miles southeast of Cold Bay, are of little value for comparison. The following observations are therefore based on experience during the summer of 1921 and on information obtained from persons who have lived for considerable periods of time in the district. An understanding of the geographic position of the Cold Bay district, which lies in a range of mountains that extends along the axis of a peninsula separating two oceans, goes far to explain a somewhat unusual climate. This part of the Alaska Peninsula is especially notable for its prevalent high winds and for the frequency of cloudy and foggy weather. Any differences in barometric pressure that may exist between the Pacific Ocean and Bering Sea result in winds that blow across the peninsula either from the northwest or from the southeast, and a complete reversal in the direction of the wind often takes place suddenly. Furthermore, any wind that blows is a sea wind, and the air, having a high moisture content, is chilled on passing over the mountain barrier and forms fog or clouds. Thus windy days are generally cloudy or foggy, and as windy weather is the rule, the mountain tops are generally in clouds. The few clear days that occurred in the summer of 1921 were relatively calm.

Although the actual precipitation as rain or snow is probably moderate in amount, there are many days of drizzling rain or of driving wet fog in which travel is disagreeable. The temperature is cool in summer and cold in winter. The winter snowfall is said to be light on the average, though in the winter of 1920–21 it was unusually heavy, and in September, 1921, many gulches still contained heavy snow banks, even at low altitudes. It is said that there is often insufficient snow for good sledding until after Christmas. The winters are reported to be unusually severe, not so much on account of very low temperature as from the combination of cold and heavy wind. It is said that there are frequent intervals of several days each during the winter when the heavy cold winds make travel impossible and when even the wild animals lie in shelter and refuse to brave the weather.

VEGETATION.

The Cold Bay district is completely lacking in timber, and the problem of obtaining lumber for buildings and other structural purposes is a serious one, as is that of obtaining fuel. Willow and alder brush sufficient for the moderate needs of the camper can be found in most of the creek valleys at low altitudes, but camp sites must generally be chosen rather with a view to the availability of brush for fuel than for convenience in other ways. Most of the brush is small and crooked, and poles long and straight enough to serve as tent poles are to be had at only a few places and in a very meager supply. In most places along the shore there is abundant driftwood, especially at the heads of the bays, and this material is generally used as fuel and has furnished logs and timbers for building cabins. The Cold Bay field and the West field each contains a large patch of paraffin residue, the accumulation of the less volatile portions of petroleum that has seeped from the ground and saturated the peat and soil near by. This residue is somewhat plastic and may be cut and burned in stoves or under boilers. For camping or domestic use it is dirty and forms much soot, but it has been found to be a satisfactory fuel when used under boilers for power and will be a valuable asset as fuel for oil-drilling rigs in this country, where other fuel is lacking.

Grass for summer pasture for live stock is very abundant in most of the stream valleys, and thousands of acres of luxuriant grass are available during the summer months. The prevailing variety is the so-called redtop, which grows in thick stands to a height of 3 or 4 feet and furnishes excellent grazing from about the middle of May or the first of June until it is killed by frost some time in September. After it is frosted, however, it has little nourishment. It makes a fair grade of hay if properly cut and cured.

With the exception of the grassy valleys and their small areas of willow and alder brush, the surface of the ground is covered with a mantle of moss and heather everywhere except on the highest ridges and the steepest cliffs and talus slopes.

WILD LIFE.

This part of the Alaska Peninsula is not a particularly good game country. A few caribou formerly ranged through this district, but they have completely disappeared. There are no moose or mountain sheep or goats. The great brown bear is the largest wild animal and is abundant in those places where there are few people, but in the district here described the bears have been frightened away and are only occasionally seen. The ptarmigan vary in abundance from year to year; in 1921 they were numerous after a period of years during which they had almost disappeared. A few Arctic hare were seen during the summer. Ducks and geese breed in great numbers on the lakes and in the low marshy areas.

This region is notable for the abundance of its food fish. The lakes and streams are stocked with trout and grayling the year round, and in the summer they teem with salmon. The red salmon, the most desirable variety, come into Bristol Bay in the early summer and follow the rivers up to their spawning grounds in the lakes and smaller streams, and an extensive canning industry has been established on Bristol Bay. The Pacific streams have only a meager run of red salmon, though other varieties are present in abundance. There are prolific fishing grounds for halibut, cod, and herring, almost completely unexploited, and many other varieties of edible fish are obtainable.

The trapping of fur-bearing animals for their pelts is carried on each year by natives and by a few white trappers. Many red fox and a lesser number of silver-gray fox are taken, as well as mink, marten, ermine, and land otter. This coast was formerly a rich hunting ground for the highly prized sea otter, but they are now almost exterminated, and their capture is forbidden by law.

POPULATION.

The only permanent native settlement is the Aleut village of Kanatak, at the head of Portage Bay, with a population in the winter of 30 to 40 people. These natives scatter in the summer, many going to Bristol Bay to work in the salmon canneries, and others spending the summer at a temporary village near the head of Becharof Lake in catching and drying salmon. In August, 1921, there was only one family resident at Kanatak. These natives belong to the Russian church and indeed have a considerable admixture of Russian blood. They eke out a precarious living by fishing, hunting, and trapping and on occasion will perform services for wages, especially as guides and packers. Most of them are improvident and fail to cure enough fish during the summer, when salmon are easily caught and dried, to last through the cold months, and by late winter they are usually on the verge of starvation. On this coast, however, it is always possible to catch fish when the weather permits.

The white population of this district is extremely variable and depends in large measure upon the activity in the oil fields. In the period from 1902 to 1904, when active developments were under way near Cold Bay, a considerable number of white men were engaged in road building, drilling, and prospecting. A base camp was established on the west shore of Cold Bay, near its entrance, and several substantial frame buildings were constructed. These buildings are still intact and are now used as a trading station. A small stock of goods is kept at the store, and this has long been the supply point for the district.

From 1904 to 1920 the permanent white population was limited to one or two persons at the trading post, a very few holders of oil claims who retained their faith in the district, and a few trappers. In the spring of 1920, after the passage of the oil-land leasing law, there was a new influx to the district, and there has since been a variable population, depending upon the season and upon the activity of governmental and private surveys and examinations. In 1921 several new buildings were erected at the head of Portage Bay, near the native village of Kanatak, a small stock of goods for sale was landed there, and that point was generally considered the port of access to the oil fields of the district. Probably a dozen white men spent the winter of 1921–22 in the region. Plans were said to be under way for active drilling in 1922, and the future of the district will depend upon the degree of success in the oil-field developments.

ROUTES OF TRAVEL.

The Cold Bay district is invariably approached by sea from the east. A regular steamship service is maintained from Seattle by way of Alaska ports to the town of Kodiak, on Kodiak Island, with sailings scheduled about once a month, the trip requiring 10 or 12 days. From Kodiak the usual means of travel to the peninsula is by means of small motor boats that make occasional trips or that may be especially chartered. Most of these boats take about 24 hours for the run from Kodiak to Cold Bay or Portage Bay. A monthly mail boat leaves Seward and after stopping at a number of Cook Inlet ports calls at Cold Bay. This boat (1921) has accommodations for a few passengers, but its route to Cold Bay from Seward is indirect. In 1921 the steamship from Seattle made one call at Portage Bay to discharge passengers and cargo, and if active development work is begun in the district and there is sufficient traffic to justify it, some port in the Cold Bay district will no doubt receive regular calls from the through ships from Seattle. Plans were also under way to establish a better mail service.

In 1921 there were no wharves or other landing facilities anywhere in the district, the waters were largely uncharted, and so far as is known there was no anchorage for large vessels protected from south and east winds. Passengers and freight could be landed only by small boat or by lighter, and the only lighter available was a privately owned one that was at Portage Bay for part of the summer. If the oil fields are developed and prove productive some better landing facilities will have to be provided. At present Cold Bay seems to be the best harbor, for it is said to have plenty of deep water and offers fair protection from north and west winds, but in south and east gales ships can not safely enter or lie at anchor there, and the bay is inconveniently far from the promising West field. Portage Bay and Kialagvik Bay are about equally distant from the West field, but Portage Bay is better located with respect to the Cold Bay field. Portage Bay at present seems to have been generally selected as the port of the district, and in 1921 most of the passengers and supplies were landed there. Vessels drawing 4 or 5 fathoms can enter the bay, and a lagoon affords good protection for small craft. Most of the bay, however, is shallow. Large ships can not approach close to the village site at the head of the bay, and they have no protection from south winds. Besides the native village of Kanatak there were half a dozen small buildings at the head of Portage Bay, and trails radiate from the village to both the West and the Cold Bay oil fields.

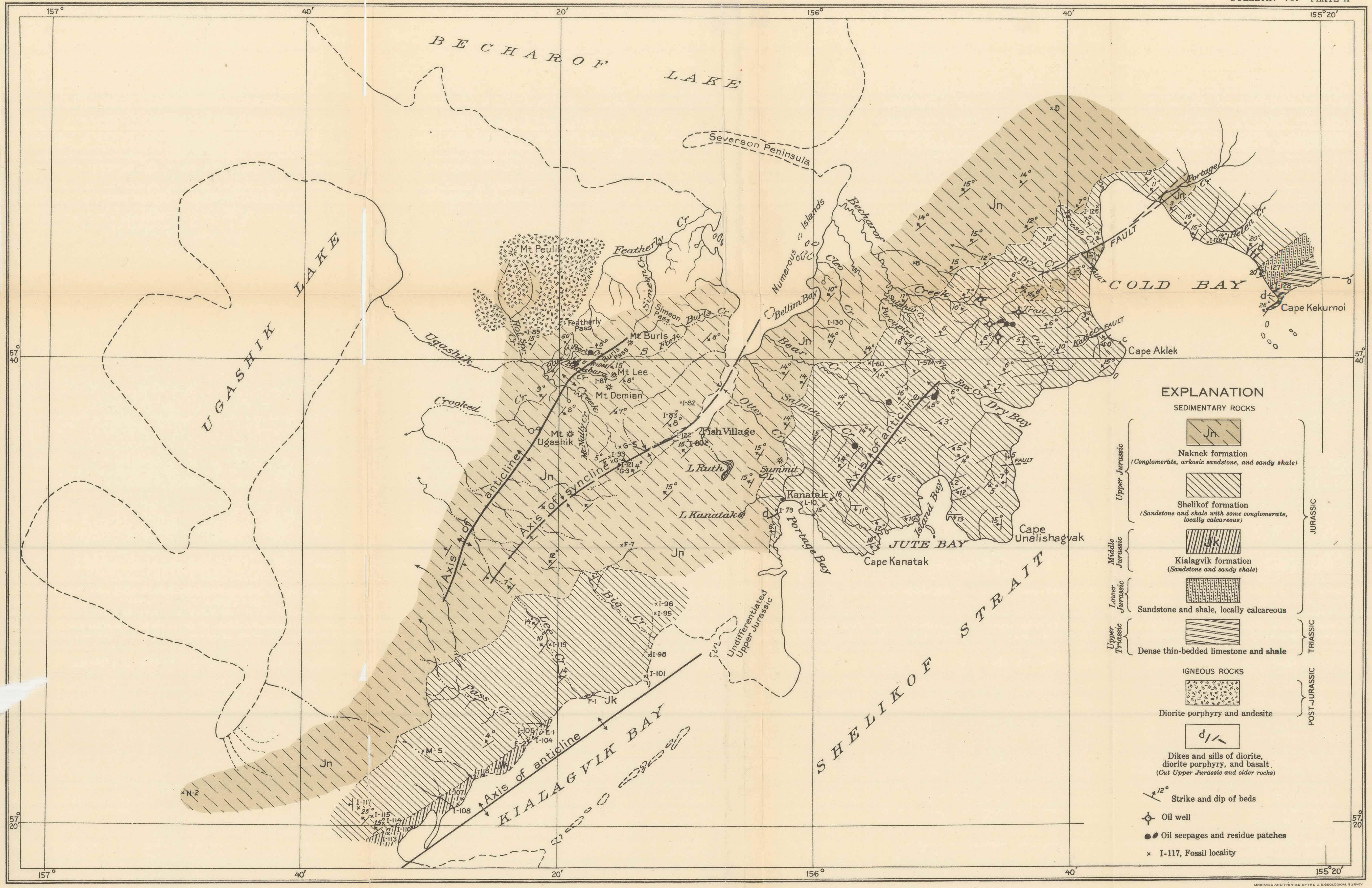
There is a lack of agreement among those interested as to whether Kialagvik Bay does not offer a better harbor and port for the West field than Portage Bay. The distance by trail is about the same, but the Kialagvik Bay route demands less climbing and offers better grades. It is said that Kialagvik Bay has an entrance channel containing deep water, has sufficient water inside the inclosing islands for anchorage, and gives protection in gales from any direction. The question as to which bay is more suitable for development into a port can be determined only when the waters have been adequately charted.

Within the district travel from place to place is fairly easy. There are many easy passes from the Pacific slope through the coastal mountains to the interior, and these passes and the large lakes and their outlets through sluggish rivers to Bristol Bay have long been used by the natives in their journeys from the Pacific coast to Bering Sea. From Cold Bay there are easy passes to the Kejulik (Garkulik) Valley, and a wagon road was built by way of Trail Creek to the well sites near the divide between Cold Bay and Becharof Lake, a distance of 7 or 8 miles. This road is now badly out of repair but can still be used for pack horses. From the end of the road an easy route is available to Becharof Lake. With the exception of the wagon road and a trail from Kanatak to a native fishing village on Becharof Lake, there were scarcely any discernible trails in the district in the spring of 1921. By fall, however, the pack trains and foot travelers had beaten out plain trails in many places. One trail could be followed continuously from Cold Bay to Portage Bay by way of Trail and Becharof creeks, across Bear and Salmon Creek valleys, and down Kanatak Creek to Kanatak. Another trail was broken from Kanatak around the head of Becharof Lake and thence across the hill to the head of Ugashik Creek and to the West field. Passable routes are available from Oil Bay up Oil Creek to the head of Becharof Creek; from Dry Bay up Rex Creek to Arvesta or Porcupine Creek; from Jute Bay into the valleys of both Bear and Salmon creeks; from Portage Bay by two routes to Becharof Lake; and from Kialagvik Bay by half a dozen passes through the mountains to the Ugashik Lake drainage basin. Pack horses may be taken to almost any place desired, and grass is sufficiently abundant everywhere during the summer to afford plentiful forage. There are few places in Alaska where land travel for horses and men is so easy.

GEOLOGY.

PRINCIPAL FEATURES.

In the lack of an accurate topographic base map in the field, it has been possible to delineate only a few of the larger geologic features on the geologic map (Pl. II). The present investigation



GEOLOGIC MAP OF THE COLD BAY DISTRICT, ALASKA

Scale, 1/250,000

0 1 2 3 4 5 6 7 8 9 10 11 12 MILES

was a reconnaissance only, with especial attention to study of the rock structure and of the possibilities of the district as a potential oil field. Little time was available for the tracing out of the contacts between lithologic units. It may be said, however, that this district is in many ways ideal for detailed geologic mapping, for exposures are generally abundant and good, the rocks are divided into rather distinct lithologic units, and from most of them fossils can be obtained. Furthermore, the attitude of the beds is such that although a thick series of rocks is exposed, the structural features are large and persistent and can be easily recognized, even from a distance. Even in a reconnaissance examination much more detailed information was obtained in places than can be shown on a map of the scale of Plate II.

In a study of the stratigraphy and structure of an area such as the Cold Bay district it is often difficult or impossible to trace the boundaries of a particular bed continuously, or to correlate the beds of one locality with those of another on the evidence of their similarity alone, for rock beds may vary greatly in thickness and character within short distances. In such places the fossil remains of animals and plants may prove invaluable in correlating the beds in one part of the area with those in another and with beds of the same age in distant areas. In the Cold Bay district the fossils collected were of the greatest aid in making such correlations. About 40 collections from as many localities were made by the writer and his assistant, W. R. Smith, and 10 collections made by Ernest Marquardt were generously turned over by him to the Geological Survey for identification and use. The localities from which all these collections were made are indicated on Plate II, and lists of the fossil forms as determined by T. W. Stanton are given in the descriptions of the rock formations.

The geology of the Mesozoic rocks of the Alaska Peninsula has already been discussed in some detail, and for a correlation of the rocks of the Cold Bay district with those of other parts of the peninsula the reader is referred to the original descriptions.[12]

A generalized section of the sedimentary rocks of the Cold Bay district is given on page 91. (See also fig. 5.)

[12] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 50–49, 1905; Notes on the petroleum fields of Alaska: U. S. Geol. Survey Bull. 259, pp. 134–139, 1905.

Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 393–397, 401–402, 1905.

Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, 1911.

Moffit, F. H., The Iniskin-Chinitna peninsula, Alaska: U. S. Geol. Survey Bull. — (in preparation).

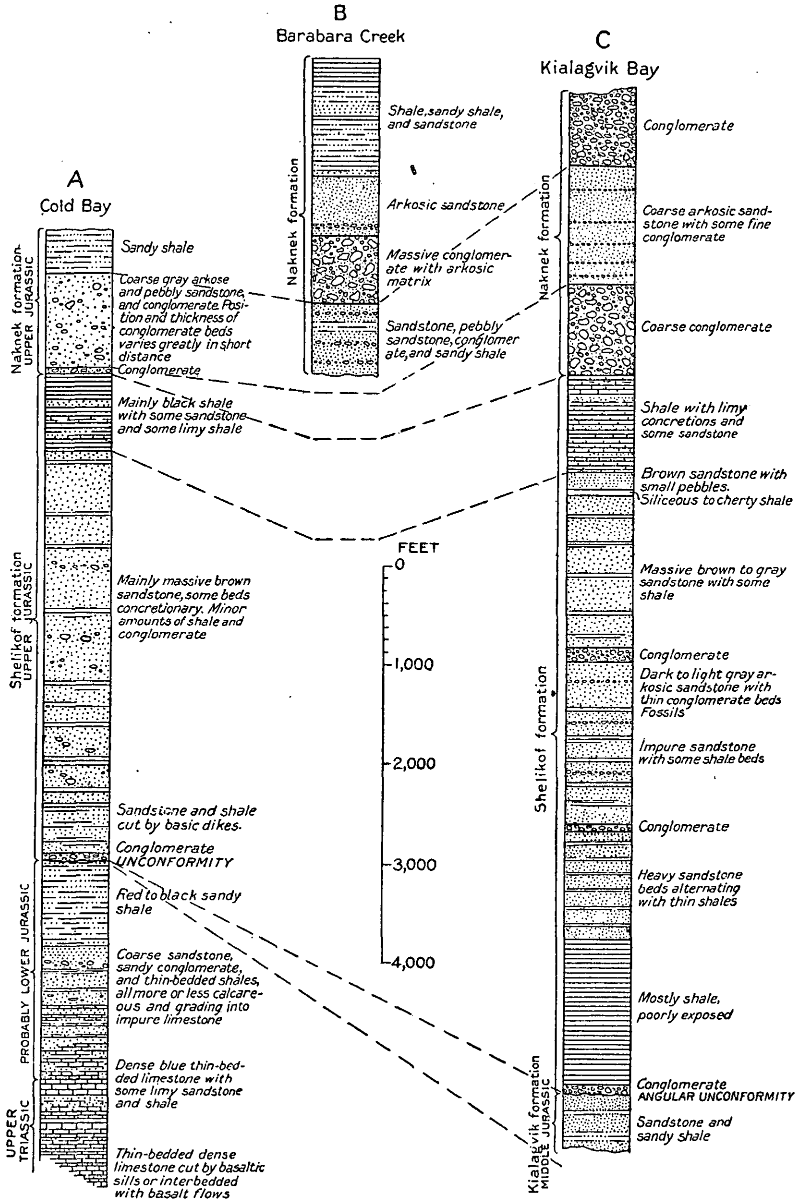


FIGURE 5.—Generalized geologic sections of the Cold Bay district.

Generalized section of the sedimentary rocks of the Cold Bay district.

	Feet.
Upper Jurassic:	
Naknek formation (conglomerate and arkosic sandstone from 1,000 to 3,000 feet thick, overlain by sandy shale)	5,000+
Shelikof formation (700 to 1,000 feet of black shale, with some limestone lenses at top, overlying a thick series of sandstone, with minor amounts of conglomerate and sandy to calcareous shale; carries the Chinitna fauna)	5,000–7,000
Unconformity.	
Middle Jurassic: Kialagvik formation (sandstone and sandy shale at Kialagvik Bay)	500+
Lower Jurassic (calcareous sandstone and sandy shale, with limestone at Cold and Alinchak bays)	2,300±
Upper Triassic (thin-bedded limestone and calcareous shale with basaltic dikes and sills at Cape Kekurnoi)	1,000+

The oldest rocks in the district include Upper Triassic sandstone, calcareous and sandy shales, and limestone, with basalt dikes and sills, that occupy the end of the peninsula back of Cape Kekurnoi, at the northeast entrance to Cold Bay. These rocks are in places highly contorted but in general dip 15°–25° NW. Apparently they either form the northwest limb of an anticline whose crest lies out in Shelikof Strait or are terminated in that direction by a fault. No older rocks are known on the Alaska Peninsula, and in fact these are the only Triassic rocks that have been recognized. Their total area on land is only a few square miles.

Next younger than the rocks of known Triassic age is a series that crops out along the north shore of Cold Bay and consists mainly of sandstone and shale that are in part highly calcareous and in places include beds of impure limestone. These beds are somewhat contorted and faulted, but apparently they lie conformably above the Upper Triassic sandstone. They have yielded fossils that are apparently of Lower Jurassic age. Their area is small, and they have not been recognized except on the peninsula back of Cape Kekurnoi.

Except in the small area of Triassic rocks near Cape Kekurnoi, all the sedimentary rocks of the Cold Bay district are of Jurassic age. Middle Jurassic beds are represented by a narrow belt of sandstone and sandy shale that occur along a part of the northwest shore of Kialagvik Bay, where they appear to lie unconformably beneath the Upper Jurassic beds. Only a part of the Middle Jurassic series that occurs farther north in Cook Inlet, at Tuxedni Bay, is present here, and on Cold Bay Middle Jurassic beds have not been recognized and are probably not present.

In by far the greater part of the Cold Bay district the prevailing rocks are of Upper Jurassic age. The entire thickness of Upper Jurassic beds is at least 10,000 feet and may be considerably more. These rocks have especial economic importance, for it is from them that the oil seepages of the district emerge, and they offer the most promising beds for oil exploration. On the accompanying map they have for convenience been divided into two portions. The lower portion consists predominantly of sandstone and shale and is overlain by a heavy conglomerate that forms the basal member of the upper portion, which also includes conglomerate, arkosic and tuffaceous sandstones, and sandy shale. No sedimentary rocks younger than the Upper Jurassic occur within the area shown on Plate II.

Igneous rocks are rather sparingly represented in this district. Some basaltic dikes and sills or interbedded lava flows occur in the Upper Triassic limestone of Cape Kekurnoi, and basic dikes cut beds of Upper Jurassic age on Cold Bay. On Portage Bay a few dikes also cut Upper Jurassic beds. An area of granitic rocks is reported on the west shore of Becharof Lake, but it was not visited, and its area and outline are unknown. These rocks, however, doubtless cut beds of Upper Jurassic age.

The most recent hard rocks in the district are the lavas and intrusive masses associated with the old volcano Mount Peulik. Nothing definite is known of the age of this volcano except that its lavas broke through Upper Jurassic rocks and were poured out over them. The present form of the mountain, however, and the relation of its lava flows to the topography indicate that the volcanic activity occurred in comparatively recent geologic time and that this volcano is to be correlated with the other volcanic peaks of the Alaska Peninsula, including Mounts Katmai, Douglas, Chernabura, Iliamna, and Redoubt, most of which are still smoking.

SEDIMENTARY ROCKS.

TRIASSIC SYSTEM.

The only known locality in the Alaska Peninsula in which Triassic rocks occur is at Cape Kekurnoi, where a small area extending from Cold Bay northeastward to Alinchak Bay is occupied by beds of this age. This formation includes a thickness estimated as well over 1,000 feet of hard, dense thin-bedded limestone and limy shale, cut by dikes and sills of basalt. There is evidence that some of the bodies of basalt are lava flows interbedded with the sediments, but this was not proved conclusively. Near Cape Kekurnoi the beds are locally much distorted and folded in several directions, and the included basaltic intrusives are metamorphosed and reticulated with a network of calcite veinlets. Farther northwest, along the shores of Cold Bay, the structure is less intricate, and the beds have a general northeasterly strike and dip 10°–20° NW. Calcite veinlets are abundant in the limestone.

Many layers of the limestone abound in fossil shells which consist almost exclusively of the single form *Pseudomonotis*. A collection from this locality was reported on by T. W. Stanton as follows:

10821. No. 1–128. North shore of Cold Bay half a mile northwest of mouth of bay:

Stoliczkaria sp. related to S. granulata (Stoliczka).
Pseudomonotis subcircularis (Gabb).
Upper Triassic.

In proceeding northwestward along the shore of Cold Bay, and so getting higher in the stratigraphic section and above the *Pseudomonotis*-bearing beds, the observer notes that the zone of limestone and calcareous shale gradually gives place to less calcareous and more sandy beds, and some distance farther northwest the sandy beds contain fossils of Jurassic age (fig. 5, A). The Upper Triassic beds are therefore considered to end at the point where the sandy phase begins to appear, but there is apparently perfect conformity between the Triassic and Jurassic beds, the transition having been marked by continuous deposition but a gradual change in the character of the material deposited.

At Alinchak Bay, the next indentation northeast of Cold Bay, the succession as reported by Martin[13] consists of basic igneous rocks at the bottom, succeeded by contorted cherts that have yielded no fossils, and these in turn overlain by shale and limestone yielding *Pseudomonotis*.

JURASSIC SYSTEM.

LOWER JURASSIC SERIES.

The only known Lower Jurassic rocks of this district, and in fact of the Alaska Peninsula, occur near Cape Kekurnoi in a narrow belt that extends from Cold Bay across the narrow peninsula to Alinchak Bay. The Triassic rocks at the cape, described above, become more sandy and less calcareous northwestward from the highest *Pseudomonotis* zone, although without any observed structural break. The transition from the Triassic limestone and limy shale to impure limestone, calcareous sandstone, and shale is gradual, and it is believed that deposition was here continuous. About 1⅓ miles from the cape a collection of fossils was made

[13] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, p. 58, 1921.

that has been determined by T. W. Stanton as probably of Lower Jurassic age. His determinations are as follows:

10820. No. 1–127. North shore of Cold Bay, 1⅓ miles northwest of mouth of bay:

Terebratula sp.
Rhynchonella sp.
Leda? sp.
Nucula? sp.
Pleurotomaria? sp.
Several genera of ammonites which in form and sculpture resemble Arietites, Aegoceras, Amaltheus, etc., but which do not show details of sutures and can not be positively identified.

This lot is probably from the Lower Jurassic and older than the oldest fauna from Kialagvik Bay.

The sandstone from which this collection was made and some similar conglomerates for some distance above and below the fossiliferous zone are characteristic in that they contain abundant grains of bright-red jasper and brightly colored greenstone particles, with larger fragments of carbonaceous shale.

Of the total thickness of about 2,300 feet of beds here included in the Lower Jurassic, the lower 1,500 feet is prevailing limestone and limy sandstone and shale at the bottom and prevailingly sandstone at the top. It was in the upper portion that the only fossils were found. Above the portion in which sandstone is dominant there is about 800 feet of beds that consist mainly of black to rusty weathered sandy shales with some thin beds of limestone. It is not certain that these shaly beds belong in the Lower Jurassic, but as they seem to lie conformably on the sandstone, they are here tentatively included with the Lower Jurassic. The shales are overlain by a conglomerate 75 feet thick which is believed to mark an unconformity between the Lower Jurassic and the overlying Upper Jurassic beds. It is possible, however, that these shales are to be correlated with the shales in the lower part of the Shelikof formation, as exposed in the Kialagvik Bay section (fig. 5, C); if so, they are of Upper Jurassic age.

The general structure of the beds above described is monoclinal, with a general northeasterly strike and dips of 10°–25° NW.

MIDDLE JURASSIC SERIES.

KIALAGVIK FORMATION.

The rocks here named the Kialagvik formation occupy a narrow belt along the northwest shore of Kialagvik Bay from a point near the mouth of Pass Creek to the southwest end of the bay. Their extent southwest of the bay is not known. They consist of a few hundred feet of sandstone, sandy shale, and conglomerate that form the bluffs along the beach and extend a short distance inland.

Little is known of the character or thickness of this formation, for the outcrops are scanty and are largely limited to rather widely separated exposures in the shore cliffs, in which massive sandstone, sandy shale, and conglomerate were seen. The exposures are so far from one another that it is not yet possible to construct the stratigraphic section. The contact with the overlying Shelikof formation is in most places concealed on the vegetation-covered benches between the shore and the mountains, but on the shore a short distance east of the mouth of Lee Creek a conglomerate was seen overlying with angular unconformity a series of sandy shales, and this unconformity is believed to mark the contact between the Shelikof formation and the Kialagvik beds. The Kialagvik formation is abundantly fossiliferous, and its fauna is somewhat different from any other known Alaska fauna. It is considered by Stanton to be either the correlative of the basal part of the Tuxedni sandstone of Tuxedni Bay or to be slightly older and is therefore of Middle Jurassic age and represents only the lower portion of the Middle Jurassic. At the type locality of the Tuxedni sandstone there is a thickness of several thousand feet of Middle Jurassic sediments that are not represented in the Cold Bay district. These missing beds may, in part at least, have never been laid down in the Cold Bay district. The presence of an angular unconformity at Kialagvik Bay, however, and the absence of most of the beds of Tuxedni age there and at Cold Bay indicate that there was an erosion interval of considerable duration in the Cold Bay district during Middle Jurassic time, and that some Middle Jurassic beds were then removed by erosion.

The following fossil collections from the Kialagvik formation were identified by T. W. Stanton:

10804. No. 1–104. Kialagvik Bay, about 9 miles northeast of southwest end of bay and 1 mile southwest of mouth of Pass Creek:

Ostrea sp.
Anomia? sp.
Pecten sp., smooth form.
Pecten sp., ribbed form.
Pecten sp., large, very coarse ribbed form.
Lima sp. related to L. gigantea Sowerby.
Cucullaea increbescens White.
Grammatodon sp.
Protocardia sp.
Venerids?
Pleuromya dalli (White).
Thracia? sp.
Turbo? sp.
Hammatoceras howelli (White).
Hammatoceras? kialagvikense (White).
Harpoceras whiteavesi (White).
Phylloceras sp.
Belemnites sp.

The named species in this list were all originally described by White as found in a collection from Kialagvik Bay, probably from the same locality as the present lot. Pompeckj has referred the fauna to the upper Lias, and Hyatt said that the nearest relatives to the fauna are found in the "lowest parts of the Inferior Oolite, in formations placed by many German and French authors in the upper Lias." It is either basal Tuxedni or slightly lower.

10806. No. 1–107. Kialagvik Bay, 3 miles from southwest end:

Pecten sp., ribbed form, same as in lot 1–104.
Inoceramus lucifer Eichwald?
Hammatoceras sp., related to H. howelli (White).
Hammatoceras sp., related to H. variabile (D'Orbigny).

These belong in the same general fauna with lot 1–104.

10807. No. 1–108. Same as 1–107, but 100 yards farther southwest along the shore:

Pecten sp., smooth form.
Lima sp., small costate species.
Pteria sp.
Grammatodon sp.
Trigonia sp., costatae group.
Trigonia sp., glabrae group.
Trigonia sp., clavellatae group.
Cypricardia? sp.
Pleuromya dalli (White).
Pleuromya? sp.
Tancredia? sp.
Cerithium sp.
Hammatoceras sp. related to H. howelli.
Hammatoceras ? sp. related to H.? kialagvikense.

Either basal Tuxedni or slightly lower.

10808. No. 1–110. Shore cliffs on point 2 miles from southwest end of Kialagvik Bay:

Pecten sp., smooth form.
Eumicrotis? sp.
Cucullaea sp.
Trigonia, three species.
Protocardia sp.
Hammatoceras? kialagvikense (White).

Same fauna as 10804.

10809. No. 1–113. On creek that enters Kialagvik Bay from the northwest at southwest end of bay. Lowest collection:

Ostrea sp.
Inoceramus lucifer Eichwald?
Pleuromya sp.
Sonninia? sp.
Belemnites sp.

This little collection permits pretty definite correlation with the lower part of the Tuxedni sandstone. The ammonite *Sonninia* and the *Inoceramus* are both identical with forms in No. 33 of Martin's Tuxedni Bay section (U. S. Geol. Survey Bull. 485, p. 61), which is 250 feet above the base.

11064, 11065. Nos. E–1, E–2. These collections contain only forms found in 10804.

In discussing the above collections as a whole, Stanton makes the following statement:

Lot No. 1–104 from Kialagvik Bay contains the fauna, rich in ammonites, described by C. A. White many years ago from the same locality. Lots 1–107, 108, and 110 also have the same or a closely related fauna. The ammonites of this fauna are all different from those of the Tuxedni sandstone, which also has a varied ammonite fauna, but some of the other mollusks of the Kialagvik Bay fauna are identical with species found in the lower part of the Tuxedni sandstone. A faunal zone in No. 33 of the type section of the Tuxedni sandstone, 250 feet above the lowest bed of the formation there exposed, seems to be pretty definitely represented in lot 1–113, which I am assuming to be higher than 1–104. I judge therefore that lot 1–104 is not much older than the lowest fossiliferous bed of the Tuxedni Bay section and that its horizon may well be included in the Tuxedni formation. I would refer it to the lower part of the Middle Jurassic rather than to the Lias or Lower Jurassic.

UPPER JURASSIC SERIES.

SHELIKOF FORMATION.

Rocks of Upper Jurassic age predominate in the Alaska Peninsula from Cape Douglas to Chignik, and in the Cold Bay district they occupy by far the greatest part of the land surface. Lithologically and on the basis of the fossil fauna these Upper Jurassic beds may be divided into two main divisions, of which the lower is here called the Shelikof formation and the upper the Naknek formation. The Shelikof formation is so named because it is the prevailing rock formation on the northwest shore of Shelikof Strait from Katmai Bay at least as far southwest as Kialagvik Bay, and in the Cold Bay district it forms nearly all the bold headlands and coastal mountains that are visible from the strait. A general idea of the lithology of the Shelikof formation may be obtained from the columnar sections shown in figure 5, A and C. Although the thickness and the relations of its different members vary considerably from place to place, some features are rather constant. Nearly every normal section shows that the uppermost member, lying immediately beneath the basal conglomerate of the Naknek formation, consists of a massive black shale from 700 to 1,000 feet thick which contains some limestone lenses and nodules. This shale is in places sandy and calcareous and is poorly fossiliferous. It has great economic significance in certain areas, for under proper structural conditions it should serve admirably as a cap rock to retain oil or gas.

A number of fossil collections were obtained from this shale and are described by T. W. Stanton as follows:

10791. No. 1–60. About 300 feet below the base of the Naknek on the Bear Creek-Porcupine Creek divide, 5 miles east-southeast of the mouth of Bear Creek:

Terebratula? sp.
Thracia sp.
Jurassic; formation not determined.

10792. No. 1–65. About 200 feet below base of Naknek on Bear Creek-Salmon Creek divide 4½ miles east-southeast of mouth of Salmon Creek:

Nucula sp. a.
Nucula sp. b.
Pteria sp.
Grammatodon sp.
Thracia? sp.
Dentalium sp.
Amberleya sp.
Jurassic; formation not determined.

10793. No. 1–79. About 300 feet below base of Naknek on shore of Portage Bay half a mile southwest of Kanatak village:

Serpula sp.
Grammatodon, two species.
Nucula sp.
Pteria sp.
Astarte? sp.
Undetermined gastropod.
Belemnites sp., fragment.
Jurassic; formation not determined.

Although the above faunas were not characteristic enough to warrant a close age determination from the fossil evidence alone, the field relations of the shale from which they came admit of no doubt that this heavy shale lies immediately beneath the persistent conglomerate that is believed to mark the base of the Naknek formation, and the shale is therefore included with little uncertainty in the Shelikof formation, which, at least in large part, is to be correlated with the Chinitna shale of Chinitna Bay.

Beneath the heavy shale member just described the Shelikof formation comprises 4,000 to 4,700 feet of beds that consist dominantly of massive brown to gray sandstones, with minor amounts of shale and of conglomerate. In many places the sandstone is concretionary, the concretions ranging from small hard well-rounded spherical bodies a few inches to a foot or more in diameter to large irregular, poorly defined masses with indefinite boundaries. The sandstone and included shale are locally calcareous and are in places so impure that they might well be called sandy shales. The only localities visited where the base of the Shelikof formation was seen are at Cold Bay and on the creeks tributary to Kialagvik Bay from the northwest. On Kialagvik Bay the lower 1,500 feet of the formation is mostly shale, with some limy lenses and concretions. At Cold Bay the lower limit of the formation is placed at a conglomerate below which is 800 feet of shale that has been tentatively placed in the Lower Jurassic, though it may correspond to the basal shale of the Kialagvik Bay section and therefore properly belong in the Shelikof formation.

The characteristic fossil of the Shelikof formation below the upper shale member is the ammonite *Cadoceras*, which correlates the lower part of this formation with the Chinitna shale of Chinitna Bay, of Upper Jurassic age. The following collections of fossils from this formation have been identified by T. W. Stanton:

10787. No. 1. Dry Bay, three-fourths of a mile north of the mouth of Rex Creek, at an elevation of 1,150 feet:
Cadoceras sp., fragment.
Phragmacone of belemnite.
Chinitna shale.

10788. No. 2. East shore of Jute Bay, half a mile south of head of bay:
Terebratula? sp.
Inoceramus sp., young shells.
Jurassic; formation not determined.

10790. No. 1–57. About 3½ miles above mouth of Rex Creek:
Terebratula? sp.
Pleuromya sp.
Cadoceras grewingki Pompeckj?
Chinitna shale.

10800. No. 1–95. About 1½ miles northeast of mouth of Big Creek, a tributary of Kialagvik Bay at its northeast end:
Terebratula sp.
Cadoceras? sp.
Belemnites sp.
Probably Chinitna shale.

10801. No. 1–96. Same as 1–95, but about 1,200 feet higher in section:
Cadoceras sp. related to C. schmidti Pompeckj.
Chinitna shale.

10802. No. 1–98. Shore of Kialagvik Bay 1 mile south of mouth of Big Creek:
Inoceramus sp. related to I. eximius Eichwald.
Belemnites sp., fragments.
Jurassic; formation not determined.

10803. No. 1–101. Kialagvik Bay near Barabara on point 1½ miles south of mouth of Big Creek:
Cadoceras doroschini (Eichwald)?
Belemnites sp., fragment.
Chinitna shale.

10805. No. 1–105. Kialagvik Bay stratigraphically 1,000 feet more or less above 1–104:
Inoceramus sp.
Cadoceras grewingki Pompeckj?
Belemnites sp.
Chinitna shale.

10810. No. 1–114. On creek that enters Kialagvik Bay from the northwest at extreme southwest end of bay. Higher in the section than 1–113:
Cadoceras? sp., a single crushed specimen.
If the genus is correctly identified, it indicates a horizon within the Chinitna shale.

10811. No. 1–115. Same as 1–113, but higher in section:
Grammatodon sp.
Phylloceras sp.

Cadoceras sp., numerous young shells.
Fragment of keeled smooth ammonite.
Belemnites sp.
Chinitna shale.

10812. No. 1-116. Same as 1-115, but higher in section:
Pecten sp., smooth form.
Astarte sp.
Pleuromya sp.
Thracia sp.
Amberleya sp.
Cadoceras wosnessenski Grewingk.
Belemnites sp.
Chinitna shale.

10813. No. 1-117. Same as 1-116 but higher in section:
Pteria sp.
Grammatodon sp.
Cadoceras stenoloboide Pompeckj.
Chinitna shale.

10814. No. 1-118. Shore of Kialagvik Bay, 4 miles from its southwest end; from a loose boulder:
Pecten sp., smooth form.
Inoceramus sp.
Pteria sp.
Pinna sp.
Astarte.
Pleuromya sp.
Amberleya sp.
Cadoceras? sp. with narrow umbilicus.
Belemnites sp.
Probably Chinitna shale.

10815. No. 1-119. Lee Creek, a tributary of Kialagvik Bay, collected 3 miles above mouth of creek:
Pteria sp., single imprint.
Cadoceras sp., imprint of fragment.
The *Cadoceras* indicates that the bed from which it came is in the Chinitna shale.

10818. No. 1-126. North shore of Cold Bay, 4 miles northwest of mouth of bay:
Cadoceras doroschini Eichwald.
Chinitna shale.

10819. No. 1-125. Head of Cold Bay, on west shore three-fourths mile southwest of mouth of lagoon:
Pteria sp.
Pleuromya sp.
Belemnites sp.
Probably Chinitna shale.

10822. No. 3. Head of creek above store, Cold Bay:
Pecten sp., smooth form.
Goniomya sp.
Tornatellaea? sp.
Phylloceras sp.

Cadoceras doroschini (Eichwald)?, probably immature shells.
Cadoceras grewingki Pompeckj?
Chinitna shale.

10824. No. C. Southwest shore of Cold Bay:
Turbo? sp.
Cadoceras doroschini (Eichwald)?
Cadoceras catostoma Pompeckj.
Belemnites sp.
Chinitna shale.

10826. No. E. Creek that enters Cold Bay at store:
Pteria sp.
Not sufficient for determining horizon.

11072. No. M-5. About 3 miles northwest of shore of Kialagvik Bay on creek that empties into bay 4 miles southeast of mouth of Lee Creek:
Pteria sp.
Burrow of a mollusk?
Cadoceras sp., fragmentary imprint.
Chinitna shale.

It will be seen from the above determinations that the portion of the Shelikof formation lying below the upper shale member is definitely correlated with the Chinitna shale of Chinitna Bay, of Upper Jurassic age, and it is believed to be probable that these *Cadoceras*-bearing beds and the overlying 700 to 1,000 feet of shale that together form the Shelikof formation are in a general way to be considered the correlative of the Chinitna shale of the type locality.

NAKNEK FORMATION.

The Naknek formation is extensively developed in the part of the Alaska Peninsula here discussed, though most of its area lies on the Bristol Bay side of the divide. The formation as originally described by Spurr [14] from observations in the vicinity of Naknek Lake and Katmai Bay consists of a series of granitic arkose and conglomerate that he estimated to be about 1,500 feet thick, and these beds are probably exposed continuously from Naknek Lake and Katmai Bay to and beyond the Cold Bay district. As here used, the term Naknek formation includes all the beds in the area mapped (Pl. II) that lie stratigraphically above the Shelikof formation.

The basal member of the Naknek in this district is generally a coarse conglomerate that lies with structural conformity upon the top of the upper shale member of the Shelikof formation. The conglomerate shows great variations in thickness from place to place. At the head of Cold Bay there is a basal conglomerate 70 feet thick overlying the black-shale member of the Shelikof formation and succeeded by gray arkosic sandstone containing scattered pebbles and

---

[14] Spurr, J. E., A reconnaissance of southwestern Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 169–171, 1900.

some thin beds of fine conglomerate (fig. 5, A). At the head of Dry Creek the conglomerate has thickened to 200 feet, at Bear Creek to about 300 feet, at the head of Portage Bay to 500 or 600 feet, and at the head of Lee Creek to about 900 feet. In most places a massive coarse conglomerate lies directly upon the top of the Shelikof shale. Elsewhere coarse arkosic sandstone or alternating sandstone and thin conglomerate constitute the base of the formation, with the thick conglomerate higher in the section. At the head of Lee Creek (fig. 5, C) a hastily studied section seems to show a lower conglomerate 900 feet thick overlain by about 1,200 feet of arkosic sandstone and conglomerate, which are in turn succeeded by a second conglomerate 800 feet or more in thickness. The Pearl Creek dome shows 1,500 feet of beds that include massive conglomerate, thin-bedded conglomerate, pebbly sandstone, and some shale, with the bottom of the formation not exposed.

The basal conglomerate of the Naknek consists of well-rounded pebbles and boulders of igneous rocks, the most conspicuous of which are gray granite and greenstone, in a matrix of coarse arkosic sand. In some places the boulders are of fairly uniform size. In others large and small boulders are mixed together. Granite boulders several feet in diameter are common, and well-rounded boulders 5, 6, and even 9 feet in diameter were seen. At one place on the trail near the main forks of Becharof Creek, on a débris-covered slope, a body of granite 10 feet wide and 30 feet long projects through conglomerate débris. It looks remarkably like an exposure of granite in place, but no other areas of granite are known for many miles from this locality, and granitic rocks intrusive into the Naknek formation are not known to exist in this district. The granite is of the same composition and texture as that composing the granite boulders that are so abundant in the conglomerate.

The relations of this granite mass to the structure of the surrounding sediments require that it must be either the sharp pinnacle of a granite mass buried by the conglomerate or the broken remnants of a remarkably large boulder. Well-rounded boulders of similar granite as much as 8 feet in diameter lie on the surface not far away, and in view of all the conditions it seems likely that this is an unusually large boulder weathered out from the underlying conglomerate.

The basal conglomeratic phase of the Naknek, which in this district locally includes also some sandstone and sandy shale, appears to correspond closely in position and character with the Chisik conglomerate on Chisik Island and Iniskin Bay, as described by Martin and Katz.[15] Its separation there was based solely on its lithologic

[15] Martin, G. C., and Katz, F. J., Geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 68–69, 1912.

character, for at the type locality, as in the Cold Bay district, these beds are almost devoid of fossils. It is characterized wherever it has been studied by its coarseness and by its great variability in thickness from place to place. It is desirable that this coarse basal phase of the Naknek should be separately mapped in the Cold Bay district, but time for this work was not available in the short field season on which this report is based. On the accompanying map (Pl. II) the basal conglomerate and the associated thinner beds of conglomerate and sandstone are included in the Naknek formation, in accordance with the earlier usage of that formation name.

Above the basal conglomeratic phase of the Naknek there is a variable thickness of light-gray to brownish-gray arkosic sandstone. Observed sections of this portion of the Naknek range in thickness from 500 or 600 feet to 1,600 feet, with an average of perhaps 800 feet. The sandstones generally contain pebbly beds and thin conglomerates, but very little shale. As described by Martin [16] the Naknek on the west shore of Cook Inlet contains arkosic sandstone, conglomerate, shale, and a considerable admixture of tuffs and andesite flows. In the Cold Bay district no igneous flows or tuffs were noted, and arkosic sandstone, derived from the disintegration of a granite mass, predominates in the part of the formation above the basal conglomeratic phase and below the upper sandy phase, described below. The arkosic sandstone is not generally very fossiliferous, but it has yielded enough collections to show that it should undoubtedly be included in the Naknek.

The highest part of the Naknek formation that has been recognized in the Cold Bay district consists of a heavy series of sandy shales that lie above the arkosic sandstone. These shales are well developed between the extreme head of Becharof Lake and Mount Lee, where they have an estimated thickness of 1,200 feet, although their upper part has been removed by erosion. They are believed to have a wide development in the basin of upper Becharof Lake and to extend northeastward into the Kejulik (Garkulik) Valley, as well as in the basin of the Ugashik Lakes. The shales are locally fossiliferous and have yielded many forms of shells, the most common and most characteristic of which are several species of *Aucella*. The collections from the Naknek have been studied by T. W. Stanton, who reports as follows:

10794. No. 1–80. Shore of creek between Lake Ruth and Becharof Lake at upper Indian village:

Pecten sp.
Aucella sp. related to A. bronni Lahusen.
Belemnites sp., fragments.
Phylloceras sp., fragments.
Naknek formation.

[16] Martin, G. C., and Katz, F. J., op. cit., pp. 69–74.

10795. No. 1–82. About 1,000 feet above the base of the Naknek shale 3 miles southeast of Mount Lee and 1 mile west of shore of Becharof Lake:

Aucella sp. related to A. erringtoni (Gabb).
Phylloceras sp.
Crustacean, genus undetermined.
Naknek formation.

10796. No. 1–83. About 1,000 feet above the base of the Naknek shale three-fourths of a mile southeast of 1–82:

Ostrea sp.
Aucella sp. related to A. bronni Lahusen.
Astarte sp.
Amberleya sp.
Phylloceras sp., same as in 1–82.
Perisphinctes sp.
Naknek formation.

10798. No. 1–89. Naknek, 5 miles southeast of Mount Peulik:

Pecten sp.
Astarte sp., same as in 1–83.
Aucella sp. related to A. bronni Lahusen.
Aucella sp. related to A. erringtoni (Gabb).
Turbo? sp.
Phylloceras sp., fragments.
Cardioceras sp. related to C. canadense Whiteaves.
Naknek formation.

10799. No. 1–93. 5 miles south-southwest of Mount Lee:

Aucella sp. related to A. bronni Lahusen.
Pteria sp.
Pleuromya sp.
Belemnites sp.
Naknek formation.

10817. No. 1–122. Southeast shore of Becharof Lake between extreme south end of lake and the fish village:

Pteria sp.
Aucella sp. related to A. erringtoni (Gabb).
Arca? sp.
Phylloceras sp.
Naknek formation.

10823. No. B. Oilwell Creek, Cold Bay:

Aucella sp. related to A. bronni Lahusen.
Naknek formation.

10825. No. D. Five miles northwest of head of Cold Bay:

Aucella pallasi Lahusen?
Naknek formation.

10827. No. 1–130. Two miles southeast of Bellim Bay, Becharof Lake:

Aucella pallasi Lahusen?
Eumicrotis? sp.
Tancredia sp.
Pleuromya sp.
Naknek formation.

11069. No. G–4. On summit of Crooked Creek-Becharof Lake divide:

Aucella sp. related to A. bronni Lahusen.
Naknek formation.

11070. No. G–5. On ridge three-fourths mile north of G–4.

Aucella sp. related to A. bronni Lahusen.
Pleuromya sp.

11073. No. N-2. About 3 miles south-southwest of south end of Ugashik Lakes:

Aucella sp. related to A. bronni Lahusen.
Naknek formation.

QUATERNARY SYSTEM.

The youngest consolidated sedimentary rocks of this district are of Upper Jurassic age, and the only geologic record now remaining here of the long time interval that elapsed between the Upper Jurassic and the Quaternary is to be found in the volcanic rocks of Mount Peulik. It should not be understood, however, that during this long period the Cold Bay district remained a land area and received no sediments. Farther to the southwest, at Herendeen and Chignik bays, there is a considerable thickness of Cretaceous sediments, and both southwest and northeast of the Cold Bay district there are beds of Tertiary age, and it is altogether likely that some of these sediments were once present in the Cold Bay district but have since been removed by erosion.

During Pleistocene time parts of this district were subjected to rather severe mountain glaciation. The limits of the glaciated area have not been determined, and morainal deposits are not conspicuous, but all the larger valleys in the higher mountains show evidence of vigorous glacial scour, and glacial ice once pushed down to the sea in all the bays of this district. Some idea of the development of these ancient glaciers is given by the fact that at one time ice accumulated on the inland slope of the mountains north and west of Portage Bay to so great a depth that although the main glacial movement was northward, into the basin of Becharof Lake, yet one lobe spilled southeastward across Kanatak Pass, at an elevation of about 850 feet. As Lake Ruth, on the inland slope, has an elevation of less than 50 feet above sea level, the glacier that moved into Becharof Lake must have been over 800 feet thick at Lake Ruth. The numerous islands in upper Becharof Lake are reported to consist chiefly of morainal material, and it is probable that glacial ice filled the Becharof Lake basin at least as far north as Severson Peninsula.

There are no glaciers now remaining in the area shown on Plate II, but in the high mountains southeast of the head of Kialagvik Bay there are many vigorous ice tongues, some of which are several miles long.

In addition to the morainal deposits, the materials of Quaternary age include the present stream gravels and beach deposits of sand and gravel. The rugged shore of the district is for the most part now subject to wave erosion, and erosion is more prominent than deposition. The shore line is a succession of wave-cut cliffs below which there is in most places a sand and gravel beach visible at low tide. At many places, however, sheer cliffs descend into the water with no beach visible, even at low tide. The only beach deposits of considerable area are at the heads of the bays, where the shores are somewhat protected from the violence of the waves, and where the beach sand and gravel merge with the delta deposits of the streams.

IGNEOUS ROCKS.

The only igneous rocks seen in the district, besides the few small dikes and sills that cut the beds of Upper Triassic, Lower Jurassic, and early Upper Jurassic age, are the volcanic rocks at and near Mount Peulik.

The vicinity of Mount Peulik has been a center of volcanic activity from at least the Pleistocene epoch up to comparatively recent geologic time. The mountain itself still retains a striking conical form, only slightly dissected by erosion. This peak, which no longer shows any signs of activity, is on the north edge of a much older crater which is outlined by the two forks of Hot Springs Creek. This older crater is deeply dissected and shows the upturned edges of the Naknek rocks, through which the volcano broke its way, forming a nearly circular rim around a central core of diorite porphyry. Over this rim lava flows extend to the east and to the southwest. Mount Peulik itself was not visited but is believed to consist of closely related rocks. It is reported that lavas from Mount Peulik extend north and northeast of the peak, covering a considerable area between the mountain and Becharof Lake. Other volcanoes along the axis of the Alaska Peninsula are reported to consist of rocks ranging in character from diorite to basalt.

It is reported that a considerable area on the west side of Becharof Lake, near the mouth of Featherly Creek, is occupied by granitic rocks, but this locality was not visited, and neither the outlines of the granite area nor the relations of the intrusive mass to the surrounding sedimentary rocks are known.

A specimen of an intrusive rock from Aniakchak Bay, some 50 miles southwest of Kialagvik Bay, proved to consist of quartz diorite porphyry containing abundant laths of hornblende. It is apparently intrusive into Jurassic sediments.

Near the head of Portage Bay a dike that cuts the Shelikof and Naknek formations is composed of diorite, in places heavily impregnated with small cubes of pyrite. The oxidation of the pyrite has locally stained both the dike and the inclosing sediments to a rusty red.

The igneous rocks near Cape Kekurnoi consist of dikes and sills of basalt that cut the Triassic, Lower Jurassic, and Shelikof (Upper

Jurassic) beds. The field relations suggest that some of the basalts may be lava flows interbedded with the Triassic limestones.

INDICATIONS OF OIL.

For many years it has been known that the Cold Bay district contains indications of the presence of petroleum, and it was these surface evidences that led to the staking of many claims and to the drilling of several wells near Cold Bay in 1903 and 1904. Plate II shows the location of these oil seepages that were visited or that were reported on reliable information. It will be noted that all these seepages occur along two structural uplifts—the anticline that extends from Salmon Creek northeastward to Rex Creek and flattens out at the northeast end, to be continued by the Dry Creek fault, and the Ugashik Creek anticline, in the vicinity of Pearl Creek, often called the Pearl Creek dome.

The most frequently visited seepages are those on the head of Oil Creek, about 5 miles west of Cold Bay. Here the largest seepage emerges from a smooth vegetation-covered slope in which no rock outcrops can be seen. The oil, accompanied by an abundant flow of water and considerable gas, bubbles forth as a strong spring, the surface of which is coated with a thick layer of brown oil. A rough estimate placed the volume of the oil flow at about half a barrel a day. The gas flows by heads and is of sufficient volume to support a strong flame for several seconds at a time. From this seepage the escaping water and oil flow down a long grassy slope in which most of the oil is entrapped. Similar conditions have existed for a long time, with the result of building up a large area of the less volatile paraffin residue of the oil, which has now hardened to a stiff, putty-like consistency. This residue, intimately intermixed with vegetation, covers an irregular but roughly triangular area, the base of which is 450 feet across and the long sides about 600 feet, in which the residue is from 1 to 6 feet thick. The material is stiff enough to bear a man's weight but soft enough to yield considerably under foot. This residue was utilized in 1903–4 as boiler fuel for the well rigs, and it is reported that the results were satisfactory. It will thus prove a valuable source of fuel for future drilling operations, at least until sufficient gas has been developed to supply fuel for the boilers.

A short distance below the Oil Creek residue patch a number of oil seepages emerge from Shelikof sandstone along the banks of Oil Creek. The quantities of oil emerging are small, and the disturbed condition of the outcrops makes it difficult to decipher the larger features of rock structure. It is apparent, however, that the locality in the vicinity of the seepages lies at about the point where the persistent northwest dip of the upper part of the Shelikof and the

Naknek formation gives way to a flattening or even slight southeast dip, and erosion has been deep enough to expose certain beds of the Shelikof formation in which there has been some concentration of oil. Oil-impregnated sands of the same formation crop out abundantly on upper Trail Creek.

A small oil seepage is reported in the valley of South Fork of Rex Creek, and another in a gulch tributary to Bear Creek from the northeast. On upper Salmon Creek a small quantity of heavy brownish-black oil appears in the stream gravels a short distance from the sandstone bluffs that border the stream flat. The location of these seepages is shown on Plate II. Although they all lie on the Bear Creek-Salmon Creek anticline, they are not on the crest of the fold but some distance down on the flanks. This indicates that the concentration of oil from which these seepages come is not in beds that lie below the lowest rocks exposed on the crest of the fold but is in sandstone beds some distance stratigraphically above the rocks exposed on the crest of the anticline in the valleys of Bear and Salmon creeks. A discussion of the possibility of commercial oil pools existing in this anticline is given in another section of this report.

The only other area in this district in which oil seepages are known to occur is in the so-called West field, in the headwater drainage area of Ugashik Creek, generally called the Pearl Creek dome. There, on the north side of Barabara Creek, near its mouth, is a large patch of residue similar in size and character to that on the head of Oil Creek. The point of emergence of the oil, of which the residue constitutes the less volatile remainder, was in a small tributary gulch, and from that point the residue extends down the gulch and out into the main valley a distance of about 1,200 feet, covering an area of about 1 acre. Its thickness was not determined but is doubtless irregular, being influenced by the irregularities of the surface on which it has accumulated. A small drainage line that runs through the residue contains depressions in which the water is covered with thick dark-brown oil, but no point could be located from which the oil could be seen emerging. This residue is somewhat softer than that on Oil Creek and like it contains a large percentage of vegetable matter as an impurity. The exposures of the bedrock near the residue are poor, but it is certain that the oil emerges from sandy or conglomeratic beds of the Naknek formation.

Another small patch of residue on the Pearl Creek dome occurs in the valley of Pearl Creek about 1 mile northeast of the large patch just described. It has an area of about 3,000 square feet and probably has a maximum thickness of not more than a few feet. The material closely resembles that on Barabara Creek. No oil was seen emerging from the rock, but a thick brown oil in considerable quantities oozes from the residue and flows down the creek. Several other small seepages are reported to occur in the valley of Pearl Creek near the residue but were not seen. The bedrock near the seepages consists of pebbly sandstone overlain by massive conglomerate, all belonging to the Naknek formation.

GEOLOGIC STRUCTURE.

PRINCIPAL FEATURES.

It is now generally recognized that there is a close relation between geologic structure and the accumulation of commercial petroleum pools, and that intelligent prospecting for oil, especially in unproved fields, can be done only after a close scrutiny of the character and structure of the rocks. In the present investigation, which was made primarily for the purpose of studying the possibility of valuable oil pools in the district, special attention was given to the structural features. It is outside the province of this paper to discuss in detail the types of geologic structure that have elsewhere been found to favor oil accumulation, but it may be stated that in this area the features most likely to contain oil pools of importance are domes, anticlinal folds, monoclines containing lenticular sands, terraces on monoclines, and important faults. The domes and anticlines should be first tested, and if they prove productive, drilling may be justified on structural features of other types. No sharp definition has been drawn to differentiate a dome from an anticline, for an anticline may have domes upon it, and a dome may merge into an anticline. Both, however, are the result of compression of the underlying rocks, which have yielded by bulging upward. If the fold so produced is long and a line drawn along its crest is a nearly straight line it is called an anticline. The term " dome " is self-explanatory, the bulge being oval or circular in general outline, with the beds dipping away from the center in all directions.

One of the most prominent structural features in this district is the anticline that crosses the headward basins of Salmon and Bear creeks into the valley of Rex Creek and is continued to the southwestward by the Kialagvik Bay anticline and to the northeastward by the Dry Creek fault. This fold is well exposed along the valleys of Bear and Salmon creeks, both of which cut across the anticline at right angles. On the northwest limb the beds dip uniformly to the northwest at angles of 12° to 15° as far as the head of Becharof Lake, which lies along the axis of a syncline, a distance of 8 miles. The southeast limb has much gentler dips and extends only 2 or 3 miles from the crest of the anticline before it is interrupted by a flattening or reversal of the dips.

South of the Salmon Creek basin this anticline plunges sharply to the southwest, beneath Portage Bay, but it rises again at Kialagvik Bay, which lies along the axis of the fold. To the northeast the fold flattens out in the basin of Rex Creek and is inconspicuous between Rex Creek and the head of Becharof Creek. At the low pass in which Becharof, Trail, and Dry creeks head compression similar to that which caused the formation of the Bear Creek-Salmon Creek fold started the formation of an anticline, but to the northeast this compression resulted in a fault. The Dry Creek fault probably had its greatest displacement at its intersection with the west shore of Cold Bay, where the base of the Naknek formation is displaced at least 2,500 feet, the northwest side of the fault having moved relatively upward. The fault plane appears to be almost vertical. This fault apparently dies out near the head of Dry Creek, and to the northeast it probably splits somewhere in Cold Bay, as two faults are apparent on the northeast shore of the bay.

BEAR CREEK-SALMON CREEK ANTICLINE.

The rocks exposed along the crest of the Bear Creek-Salmon Creek anticline comprise the sandstones and sandy shales of the Shelikof formation, with beds of the Naknek formation lying on the north limb. Near Cold Bay a few outliers of the basal part of the Naknek occur on the southeast side of the Dry Creek fault. The columnar section of the rocks at Cold Bay (fig. 5, A) shows the general stratigraphic sequence as exposed on the northwest shore of Cold Bay. The oil-saturated sands of upper Trail Creek lie in the Shelikof formation, a few hundred feet below the base of the heavy shale member that forms the top of the formation. The oil seepages at the head of Oil Creek emerge from the same sandstones, though at a somewhat lower stratigraphic horizon. The seepages on Rex, Bear, and Salmon creeks also all emerge from the sandstones of the Shelikof formation, though from a much lower part of it. On Bear and Salmon creeks the lowest beds exposed are approximately 5,000 feet stratigraphically below the base of the Naknek formation, and the oil seepages are about 4,000 feet stratigraphically below the base of the Naknek and 1,000 feet, more or less, above the lowest exposed beds. It is therefore apparent that if the oil-saturated sandstones of upper Trail Creek represent the horizon at which an accumulation of oil occurred, then the source of the oil seepages on Bear and Salmon creeks is much lower in the stratigraphic section. On Bear and Salmon creeks the beds at the horizon of the oil-bearing beds of both Trail and Oil creeks are so thoroughly exposed that any commercial oil accumulations that may once have existed there must have long ago escaped. The only chance of obtaining oil at this locality is therefore to find a lower oil sand than any yet known. Although the stratigraphic section shows great variability in the thickness of the formations from place to place, yet a study of the sections as exposed at Cold and Kialagvik bays (fig. 5, A, C) indicates that erosion on Bear and Salmon creeks has exposed the beds of the Shelikof formation well down toward its base. Furthermore, the lower 1,000 feet or more of the Shelikof formation at Cold and Kialagvik bays is composed predominantly of shale and would therefore not be expected to contain large accumulations of oil. In this district no evidences of oil have been found below the Shelikof formation. It is not intended to intimate here, however, that oil may not be found in lower formations On the west side of Cook Inlet, near Oil Bay, petroleum seepages emerge from the Tuxedni sandstone. The only place in the Cold Bay district where beds of Tuxedni age appear is at Kialagvik Bay, where only the lowest part of the Tuxedni formation appears to be represented in the Kialagvik formation. On Cold Bay the entire Tuxedni formation is missing. Whether or not the Tuxedni formation is represented below the Bear Creek-Salmon Creek anticline is not known, but probably most of it is missing there. Next lower than the Tuxedni is the Lower Jurassic, of which about 2,300 feet is exposed on Cold Bay. The upper 800 feet of this formation is composed of sandy calcareous shale with a few thin beds of limestone. The lower 1,500 feet is prevailingly limy sandstone at the top and limestone and limy sandstone beneath. At Cold Bay these beds show no evidence of being oil bearing. Below them lie the Triassic limestone and shale, which at Cold Bay are too dense and too lacking in pore space to offer a reservoir for the accumulation of petroleum in quantity.

The immediate vicinity of the patch of residue and the oil seepages of upper Oil Creek does not appear to have particularly favorable prospects of containing large oil pools, though there is a chance that such pools exist there. The monoclinal beds that dip very uniformly 12°–15° NW. from the head of Becharof Creek to Becharof Lake give way at the heads of Trail and Oil creeks and as far to the southwest as Rex Creek to nearly flat-lying beds. At the head of Dry Creek there is a slight anticlinal fold, with the southwesternmost outlier of the Naknek formation lying in the trough of a small syncline. This anticline is short and is narrow on its southeast limb, though the northwest limb extends far out toward Becharof Lake. The anticline apparently does not extend southwestward across the trail, and to the northeast it is continued by the Dry Creek fault. The beds at the horizon of the oil-saturated beds in the Shelikof sandstone on Trail Creek are exposed on Dry

Creek, so that any oil concentrations there must occur at a lower stratigraphic horizon than the oil showings on Trail and Oil creeks. No seepages were seen or reported on Dry Creek.

If it is shown that considerable concentrations of oil occur far down in the Shelikof formation, there is a possibility that oil pools may be found on the northwest side of the Dry Creek fault. The maximum observed displacement of that fault, at the west shore of Cold Bay, is about 2,500 feet, and the upper 2,500 feet of the Shelikof formation is there exposed. No oil indications were seen there, and any oil that may have existed in the upper 2,500 feet of the Shelikof beds at that place has had ample opportunity to escape. It is possible, however, that some lower oil-bearing bed, beneath an impervious shale, has been sealed off at the fault against the thick shale at the top of the Shelikof formation.

KIALAGVIG BAY ANTICLINE.

The Kialagvik Bay anticline is a continuation of the same general structure as that which makes up the Bear Creek-Salmon Creek anticline and the Dry Creek fault, but it is separated from the Bear Creek-Salmon Creek fold by an interruption at Portage Bay. The ends of the Kialagvik Bay anticline were not examined in detail, and little is known concerning their structure. No folding is conspicuous along the west shore of Portage Bay, in line with the anticlinal axis. Farther southwest it could be seen that the anticlinal structure extends several miles beyond Kialagvik Bay, but no examination was made beyond the borders of the area mapped (Pl. II).

As seen from the shore of Kialagvik Bay it is apparent that the axis of the Kialagvik Bay anticline lies between the shore and the line of islands that nearly incloses the bay. The islands, which were not visited, can be plainly seen to consist of sediments that dip to the southeast. The prevailing dips on the mainland are to the northwest. It is highly probable that the islands are composed of the rocks of the Shelikof formation. All the rocks exposed along the shore from the vicinity of Lee Creek to the southwest end of the bay belong to the Kialagvik formation, of Middle Jurassic age, and are therefore older than any other rocks of the district except the Lower Jurassic and Triassic beds that occur only in a small area at Cape Kekurnoi. The Kialagvik formation, as has been shown, is probably the equivalent of the lowest part of the Tuxedni formation of Cook Inlet and is of Middle Jurassic age. Its base is not exposed. It is overlain to the northwest by more than 6,000 feet of beds of the Shelikof formation, which is in turn overlain by the Naknek formation.

Little information is at hand upon which to base an opinion concerning the oil possibilities of the Kialagvik Bay anticline. The

Tuxedni formation contains oil seepages at Oil Bay, but they emerge from beds at a higher stratigraphic horizon than is represented by any part of the Kialagvik formation. It is not known how thick the Kialagvik formation is below the lowest exposures on Kialagvik Bay, nor what beds would be reached by the drill below the Kialagvik formation. It can only be stated that if strata sufficiently porous to form a reservoir for oil exist below the exposed portion of the Kialagvik formation and have an impervious cover, the structural conditions at Kialagvik Bay are favorable for the accumulation of oil.

UGASHIK CREEK ANTICLINE.

A strongly developed anticline roughly paralleling the Kialagvik Bay and Salmon Creek-Bear Creek folds but 8 to 14 miles inland from them occurs in the drainage basin of the Ugashik Lakes. It extends from Mount Burls, between upper Becharof Lake and Mount Peulik, southwestward for at least 15 miles, crossing the basins of Ugashik, Crooked, and a number of smaller unnamed creeks. Near its northeast end this anticline, which as a whole is here called the Ugashik Creek anticline, is sharply domed, and that part is commonly referred to as the Pearl Creek dome. On this dome there are two patches of oil residue and several seepages. The Ugashik Creek anticline apparently flattens out to the northeast, beyond Mount Burls, and although it has been traced continuously for 15 miles to the southwest, its amplitude diminishes in that direction, and it apparently fades out somewhere between the west end of Kialagvik Bay and the head of the Ugashik Lakes. The entire area of this anticline is covered by rocks of the Naknek formation, except in the vicinity of Mount Peulik, an old volcano that has broken through the Jurassic sediments and has a core of dioritic material, with some andesite lava flows that were poured out over the Naknek formation. Mount Peulik is on the northwest flank of the anticline and is a comparatively young cone standing on the rim of an older crater that is roughly outlined by the forks of Hot Springs Creek. The eruptions that formed this old crater, breaking through the northwestward-dipping Jurassic beds, bowed them up around its margin and so interrupted at that place the prevailing northwesterly monoclinal dips.

The Ugashik Creek anticline as a whole is a symmetrical fold, the beds on the northwest flank dipping 12°–14° NW., toward the Ugashik Lakes, and those on the southeast flank dipping about 12° SE., toward Becharof Lake. At the Pearl Creek dome the southeast limb extends for about 5 miles to the synclinal axis in upper Becharof Lake. Farther southwest, as the size of the fold diminishes, the anticline and the syncline converge. The northwest flank has not been completely outlined but probably extends to a syncline in the Ugashik Lakes.

The Ugashik Creek anticline, on which no wells have yet been drilled, gives promise of containing oil in commercial quantities. The accompanying topographic map of a part of the Pearl Creek dome (fig. 6) was made and generously furnished by Mr. Ernest Marquardt and shows accurately the topography of the central por-

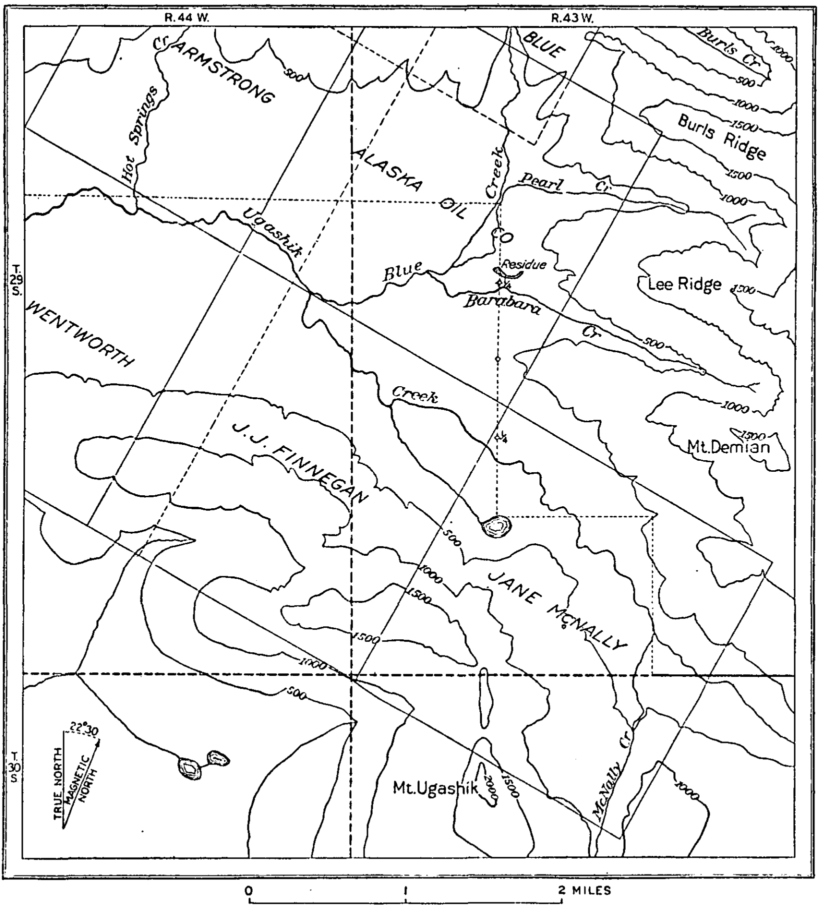


FIGURE 6.—Topographic map of Pearl Creek dome. By Ernest Marquardt.

tion of the dome. Here, where the lowest beds along the axis of the fold are exposed, seepages emerge from the conglomeratic sandstone that forms the lowest part of the Naknek formation exposed, but the base of the Naknek does not appear at the surface. It is of course important to determine the thickness of the Naknek beds that remain to be penetrated by the drill on the top of the Pearl Creek dome, but the problem involves certain unknown factors which can not be accurately determined in advance of drilling. From the hasty study of this area that was made in the field, it appears that the point within the dome at which the underlying Shelikof formation approaches nearest to the surface is on Barabara Creek about 2 miles above its mouth, or about 1 mile above the lower end of the residue patch. The stratigraphic horizon at that place is about 1,500 feet below the top of the massive conglomerate of the Naknek. This conglomerate, which probably corresponds to the Chisik conglomerate of the Cook Inlet section, normally occurs at the base of the Naknek formation. In the Cook Inlet field it has a maximum thickness of 400 feet or more and thins out to nothing laterally. In the Cold Bay district its variability in thickness and character is even more striking. At Cold Bay this basal conglomerate is about 70 feet thick and is underlain by the Shelikof formation, of which the upper 800 feet is shale. From Cold Bay to Portage Bay the basal conglomerate increases to about 600 feet in thickness, and in the Kialagvik Bay section, at the head of Lee Creek, it is about 900 feet thick and is apparently overlain by about 1,200 feet of coarse, pebbly sandstone, which is in turn overlain by another massive conglomerate about 1,000 feet thick.

If this hastily studied section is correctly interpreted, there seem to be two very heavy conglomerates separated by about 1,200 feet of pebbly sandstone, and this whole assemblage corresponds to the 70-foot conglomerate at Cold Bay. It is apparent, therefore, that, with a variation in thickness of more than 3,000 feet in 36 miles, any estimate of the total thickness of the coarse basal beds of the Naknek formation on the Pearl Creek dome, at a distance of 10 miles from the nearest outcrop of the underlying Shelikof formation, can be little better than a guess. At a well location 1,500 feet stratigraphically below the top of the basal conglomerate of the Naknek the depth to the upper Shelikof shale may not be great, or it may be as much as 1,500 feet if the section corresponds to that on Lee Creek and if the Lee Creek section has been properly interpreted. Once in the Shelikof formation the drill should penetrate 800 to 1,000 feet of shale, below which the Shelikof sandstones should be reached. It seems likely that there are oil-bearing beds in these sandstones. Oil-saturated sands of this formation occur on Trail Creek not far below the base of the shale, and the oil seepages of Oil Creek emerge from them. It would be wise, therefore, for anyone preparing to drill on the Pearl Creek dome to be equipped to drill to a depth of at least 3,000 feet, although there is a good chance that oil-bearing beds may be encountered at considerably shallower depths.

If commercial oil pools exist on the Ugashik Creek anticline, wells drilled on the Pearl Creek dome should demonstrate that fact, for conditions there are most favorable for the concentration of oil. When it has been shown that this dome contains commercial oil pools, other parts of the anticline may be worth drilling. The log of a well on the dome should give highly valuable information as to the thickness of the basal conglomerate of the Naknek formation in that vicinity and the depth within the Shelikof formation of the oil-bearing beds. With that information in hand, a geologic study of any particular well site should furnish a fairly accurate estimate of the depth of the oil sands at that place.

CONCLUSIONS.

Geologic surveys have been made of only a relatively small area in the Cold Bay district, and these are only of a reconnaissance type. Some of the dominating structural features in the district are described above, but few structural details have been determined. There is almost no information at hand in regard to the structure in the unsurveyed part of the district. The oil seepages in the Cold Bay district have been described; others are reported in adjacent parts of the Alaska Peninsula. There appears to be definite evidence of an oil seepage on Aniakchak River, 60 miles south of Cold Bay. The reports of oil seepages near Chignik Bay have not been officially verified.

The outlook for the finding of petroleum in commercial quantities in this general region is good, because certain structural features in this district and probably in other parts of the Alaska Peninsula are favorable for the accumulation of oil and are of dimensions indicating the possibility that they may contain large oil pools.

THE INISKIN BAY DISTRICT.[1]

By Fred H. Moffit.

INTRODUCTION.

The district described in this paper is on the west side of Cook Inlet between Iniskin and Chinitna bays. It is a peninsula with an area of about 150 square miles separated from the mainland mountains on the west by a narrow valley extending from the right arm of Iniskin Bay northeastward to the head of Chinitna Bay. For convenience it may be called the Iniskin-Chinitna Peninsula. Seldovia, on the southwest end of Kenai Peninsula, is directly across Cook Inlet from Chinitna Bay and is the nearest white settlement and post office except Iliamna, a native village on Iliamna Lake.

Oil Bay, on the south side of the Iniskin-Chinitna Peninsula, at one time received considerable attention because of its petroleum seeps and was the scene of drilling for a number of years. Shortly before the Alaskan oil lands were withdrawn from entry in 1910 the oil properties were abandoned, and no further attention was paid to them till the new leasing law was passed in 1920. This law renewed interest in the district, so that much ground was restaked, and it became necessary, in order to carry out the provisions of the law, to collect information regarding the areal geology and structure of the area likely to be prospected for oil.

Oil Bay was visited by Martin in 1903 and by Martin and Stanton in 1904, and the results of their work, published in different papers from time to time, have been summarized by Martin[2] in a recent bulletin.

The investigations of the summer of 1921 on the Iniskin-Chinitna Peninsula include surveys by C. P. McKinley for a topographic map to be published on the scale of about 1 inch to the mile and a study of the areal and structural geology of the same area by Arthur A. Baker and the writer.

[1] This paper is a preliminary report on surveys made in the Iniskin Bay district in 1921. A more detailed report containing the topographic and geologic maps resulting from these surveys is in preparation.

[2] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, 1921.

The Cook Inlet side of the peninsula (Pl. III) is bordered by a curving belt of rugged mountains extending from Chinitna Bay to Iniskin Bay and decreasing from a maximum height of 3,130 feet on the north to 2,410 feet on the south. The west side is bordered by a lower, less rugged belt extending about north-northeast. The central area is occupied by rounded hills. Three principal streams heading near the center of the area take care of most of the drainage. Bowser and Brown creeks cut through the coast mountains at Oil and Dry bays, and Fitz Creek flows northward into Chinitna Bay.

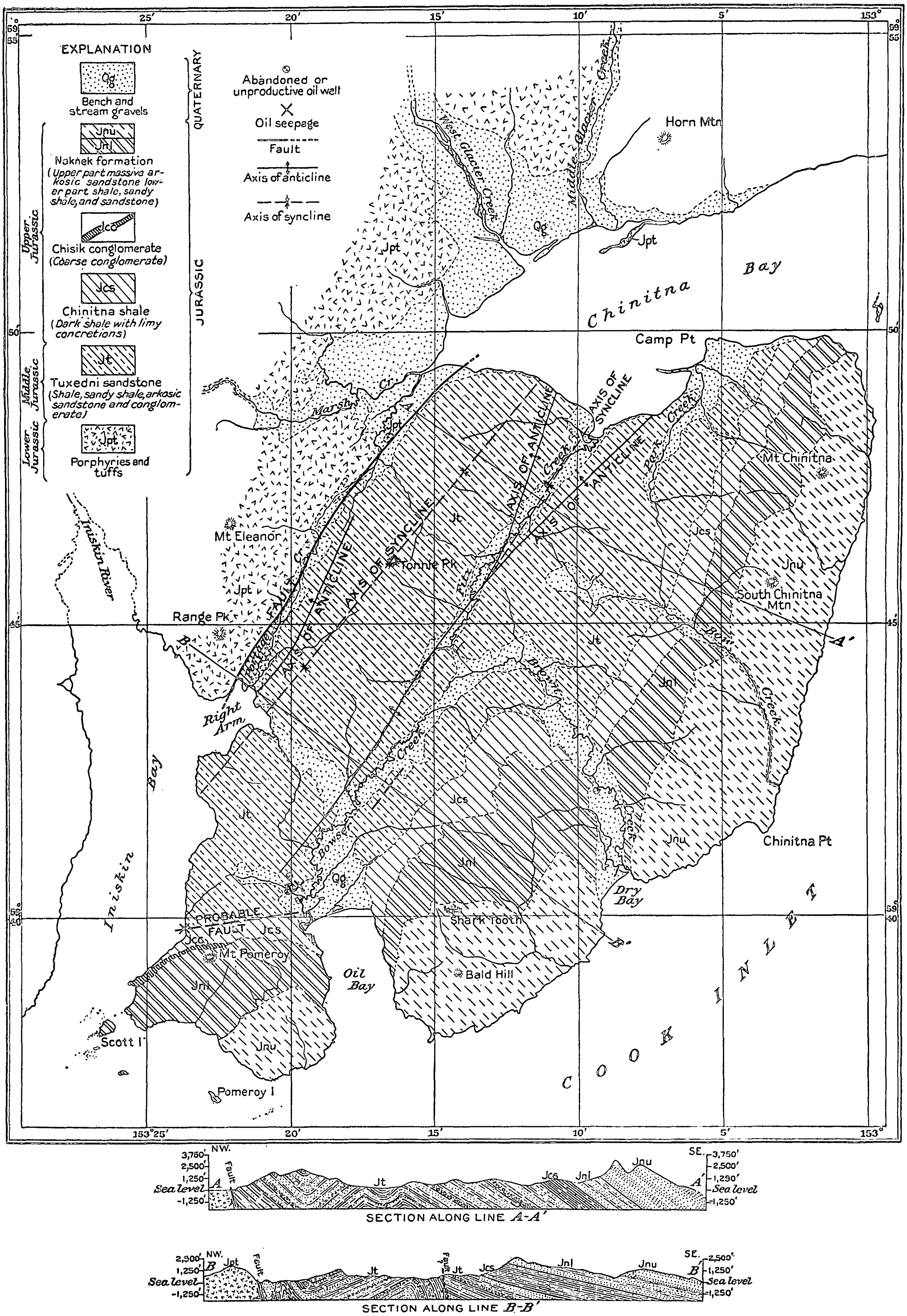
At present the peninsula is without roads or trails, for those established during the time of the earlier oil excitement are now grown up to alders and willows or are washed out by the streams. Some of the old trails, however, could be reestablished without great labor or expense. The peninsula not only is without trails but is inconvenient to reach because it lacks direct steamship communication. Iniskin Bay has deep water with protection for vessels on its lower west side and is the only place where vessels can enter and discharge freight, for Oil Bay and Chinitna Bay are both shallow and Dry Bay is a mere indentation in the shore line.

Spruce timber sufficient for local demands is present in the interior valleys and in places is of excellent quality. Many fine trees were seen in the vicinity of Oil Bay. Piling for fish traps and the wharf at the cannery on Chisik Island have been cut on Chinitna Bay for a number of years. Cottonwood also grows in the district but is not likely to have much value for building or similar uses. All of the peninsula is abundantly supplied with grass suitable for pasture and for hay, so that during the days when drilling was in progress at Oil Bay native grass was cut and cured as winter feed for horses.

GEOLOGY.

OUTLINE.

The rocks of the peninsula between Iniskin and Chinitna bays are almost exclusively marine sedimentary deposits but are composed of clastic material derived in large part from older igneous rocks, among which granite and related granitic rocks were abundant. The sedimentary rocks are cut by a few dark-colored dikes or are intruded by light-colored sills and are separated by a great fault from the volcanic rocks of the mountains between the heads of the two bays. Named in the order of their age from the oldest to the youngest, they are the Tuxedni sandstone, which is Middle Jurassic, and the Chinitna shale, Chisik conglomerate, and Naknek formation, which are Upper Jurassic.



GEOLOGIC MAP OF INISKIN-CHINITNA PENINSULA.

By F. H. Moffit.

The Tuxedni sandstone is composed of sandstone, arkose, conglomerate, and sandy shale and reaches a thickness of probably 8,000 feet. In the lower part of the formation the sandstone and other coarser-grained beds predominate over shale, but in the upper part shale predominates greatly over sandstone. The shale is commonly more or less sandy except at the top of the formation, where it is argillaceous instead of arenaceous and grades into the overlying Chinitna shale.

The Chinitna shale is a fairly homogeneous formation of gray, black, and reddish shales with subordinate sandstone and calcareous beds and is approximately 2,300 feet thick.

The Chisik conglomerate overlies the Chinitna shale. This formation in its largest and most typical exposure is 290 feet thick and includes boulders and cobbles of igneous rock, especially granitic rocks. It is of variable thickness and character, however, and throughout most of the district either is represented by beds of grit and arkose or is absent altogether.

The Naknek formation, which overlies the Chisik conglomerate, includes possibly 4,500 feet of shale and sandstone and is the youngest formation in the district. At its base is about 1,500 feet of shale with subordinate sandstone. This is overlain by beds of white or light-colored sandstone which are the conspicuous cliff-forming rocks of the mountains bordering Cook Inlet in this peninsula.

These four formations succeed one another without structural unconformity so far as is known. They are in places abundantly fossiliferous, so that their age is well determined.

The beds are folded rather closely on the west side of the peninsula near the volcanic rocks of the main mountain chain of the mainland but are less compressed toward the east and dip in a great monocline beneath the waters of Cook Inlet. The strike in general is about N. 30° E. in the central part and west side of the peninsula but is parallel with the coast line on the east side and changes from N. 30° E. near Chinitna Bay to nearly due east on Iniskin Bay.

Deposits of gravel are present along the streams and on the coast, but bench gravels and glacial deposits are uncommon. Erratic boulders of rock not present in the bedrock of the peninsula, however, bear evidence that the glaciers brought in and left morainal material, but apparently the glacial deposits were reworked by streams or the sea, so that typical glacial deposits were not seen.

The character and relations of these rocks are summarized in the following table:

Rocks of the west side of Cook Inlet.

Age.	Formation.	Lithologic character.	Thickness (feet).
Quaternary.		Stream and coastal gravel and sand. Glacial deposits: Sand, gravel, and erratic boulders.	
Upper Jurassic.	Naknek formation.	Massive light-colored sandstone, arkose, and tuff.	3,000
		Gray shale with sandstone beds.	1,500
	Chisik conglomerate.	Massive conglomerate with boulders, possibly represented in many places by grit and arkose.	290
	Chinitna shale.	Fairly homogeneous argillaceous gray, black, and reddish shales with subordinate calcareous and arenaceous beds.	2,300
Middle Jurassic.	Tuxedni sandstone.	Arenaceous gray shale with subordinate sandstone beds. Sandstone, shale, arkosic sandstone, and conglomerate.	8,000
Lower Jurassic.		Volcanic rocks; porphyry and tuff (basaltic and andesitic lavas and tuffs).	1,000?

MIDDLE JURASSIC ROCKS.

TUXEDNI SANDSTONE.

Character and distribution.—The Tuxedni sandstone is not a homogeneous sandstone formation. It consists principally of sandstone and sandy shale but includes also conglomerate, grit, arkose, and, in the type locality, limestone. In general the lower part of the formation shows all the rocks mentioned, but the upper part is made up of sandy shale with which thin beds of sandstone in subordinate amount and rare conglomerate beds are interstratified. A generalized section based on observations of the formation in different parts of the district follows.

Generalized section of the Tuxedni sandstone in the Iniskin-Chinitna Peninsula.

	Feet.
Shale	1,075
Coarse gray sandstone	75
Shale	1,000
Coarse conglomerate.	
Shale	300
Gray sandstone.	
Shale	1,000
Coarse conglomerate	20
Thin shale.	
Heavy sandstone.	
Dark shale	1,200
Fine-grained gray sandstone with small beds of shale and sandy shale	1,500
Conglomerate	30
Sandy beds, including sandstone, sandy shale, and conglomerate. Dark shale, sandy shale, and thin sandstones	1,800
	8,000+

Thickness and structure.—Study of the Tuxedni sandstone during the summer of 1921 shows that the formation is much thicker than earlier work in Cook Inlet seemed to indicate. No single section is known where the thickness of all the beds can be measured consecutively. The evidence of the thickness is therefore obtained from a number of incomplete sections in different localities and is subject to errors arising from incorrect correlation of beds in these sections and also from possible duplication of beds through faulting or folding. Furthermore, the base of the Tuxedni sandstone has never been unmistakably recognized in this district, although the top, determined solely on paleontologic evidence, was seen in a few places. The combined sections from all the localities indicate a maximum thickness of 8,000+ feet for the formation. These figures are large and represent a thickness much greater than the formation attains elsewhere on Cook Inlet, so that some doubt is felt as to their correctness, although they are comparable with the thickness of the overlying Upper Jurassic rocks in that region.

The structure of the Tuxedni sandstone is shown on the map (Pl. III) and is of particular importance to those interested in the problem of finding petroleum in the district, for the known seepages and the holes that were drilled and produced oil or gas are within the area of this formation.

The valley of Portage Creek, extending northeastward from the Right Arm of Iniskin Bay to Chinitna Bay, marks the course of a great fault and the axis of a closely compressed anticlinal fold which meet each other at a slight angle. All the rocks on the west side of the valley, except a small area on the Right Arm, belong in the belt of volcanic rocks bordering the main mountain range. The great fault that brought the Tuxedni sandstone into contact with the volcanic rocks appears to lie on the west side of the anticlinal axis at Right Arm but possibly crosses to the east side in the valley farther north, for it cuts off the west limb of the anticline. The valleys of Bowser and Fitz creeks mark the position of a second anticlinal fold, parallel to and somewhat less compressed than the fold previously described, which extends from a point near the head of Oil Bay to Chinitna Bay. This fold is compound and divides into two minor anticlines in the Fitz Creek valley. East of Bowser and Fitz creeks the Tuxedni sandstone dips toward the coast and passes beneath the Chinitna shale in a monocline that is interrupted in places by small local folds.

The western anticline is hidden on the south by the waters of Right Arm and Iniskin Bay, so that its character there is not known, but the anticline of Bowser and Fitz creeks and the synclinal trough between it and the Right Arm anticline flatten out toward the south and pitch or dip beneath the younger rocks of the mountains between Iniskin and Oil bays. The relation of the Tuxedni sandstone to the Chinitna shale between Iniskin and Oil bays is not simple, however, for faulting disturbs the normal relation and is known from the exposures on Iniskin Bay and the absence of the higher beds of the Tuxedni sandstone. Unfortunately, the low shale hills between Oil and Iniskin bays are so thickly covered with timber and particularly with alders that only scanty information about the faulting was obtained, in spite of the realization that such information may have an important bearing on the accumulation of oil.

Age.—The Tuxedni sandstone is the most highly fossiliferous formation in the district and contains abundant fossils at many horizons. Good collections were accordingly made to supplement those of earlier workers in this and in other localities. On the evidence of all these collections the Tuxedni sandstone is assigned to the Middle Jurassic.

Intrusive rocks.—The intrusive rocks in the Tuxedni sandstone are rare and, so far as they were observed, are confined to the vicinity of Iniskin Bay. They include sills of quartz diorite and basaltic dikes.

Two sills of quartz diorite, one of them 10 feet thick and the other 50 feet thick, were seen on the shores of the Right Arm of Iniskin Bay. The rock is soft, is of a dark greenish-gray color, and is speckled or mottled with small blotches of altered feldspar, but it is so dense and fine-grained that the other minerals can not be identified with the unaided eye. In the surface exposures the rock is weathered and much altered, so that it is soft and breaks easily. The sills crop out on both shores of the Right Arm and are structurally conformable with the beds of sandstone and conglomerate with which they are associated. Under the microscope it is seen that the rock owes its green color to chlorite.

Several dikes cutting Tuxedni beds are exposed on the east shore of Iniskin Bay. They are not conspicuous, for the color of the dikes is much like that of the including shale. The dikes consist of dense fine-grained black basalt and reach a maximum thickness of 10 feet. One small dike, 10 inches thick, is vesicular, and the vesicles are filled with a white secondary mineral resembling heulandite. The microscope shows phenocrysts of feldspar, augite, and olivine in a groundmass of feldspar and augite.

Neither the sills nor the dikes are indicated by topographic features. No direct evidence of their age was found aside from the fact that they are manifestly younger than the Middle Jurassic rocks which they intrude.

UPPER JURASSIC ROCKS.

The Upper Jurassic rocks include the Chinitna shale, the Chisik conglomerate, and the Naknek formation. These formations succeed one another and the Tuxedni sandstone without structural unconformity and form a belt of high mountains, averaging less than 4 miles in width, along the coast of Cook Inlet from Chinitna Bay to Iniskin Bay. About 50 per cent of the area mapped is occupied by Upper Jurassic rocks.

CHINITNA SHALE.

Character and distribution.—The Chinitna shale consists of gray, black, and reddish argillaceous shale, in which are interstratified some sandy and calcareous beds and rare beds of grit. This formation is of fairly homogeneous character and differs from the prevailing shales of the upper part of the Tuxedni sandstone in that it is argillaceous rather than arenaceous, yet the shales of both formations at their contact are similar in appearance and composition and are distinguished from each other on paleontologic and not on lithologic evidence. Lines of fossiliferous concretions indicating the bedding planes are numerous in the lower part of the formation, and in most places where exposures are good they make it possible to determine within narrow limits the boundary line between this and the underlying formation. The upper part of the Chinitna shale, on the other hand, yields few fossils, yet it is characterized by discontinuous thin calcareous beds which are shaped like much elongated lenses and have a conspicuous yellowish color where weathered. These yellowish bands, although present throughout the upper 500 feet of the shale, give much assistance in determining the position of the formation boundary.

The Chinitna shale occupies the intermediate slopes of the landward side of the coast mountains, overlying the Tuxedni sandstone of the foothills and lower slopes and underlying the Chisik conglomerate and Naknek formation, which form the brow and crest of the ridge. It thus appears on the map as a narrow band nowhere more than a mile wide.

Thickness and structure.—The thickness of the Chinitna shale in its type locality, as measured by Stanton, is 2,315 feet, and that of the partial sections on Iniskin and Oil bays is 1,308 feet and 1,294 feet, respectively. The base of the shale is not included in either of these partial sections, yet the thickness represented by them is nearer the thickness of some other sections between Iniskin and Chinitna bays than that of the type section. A section at the head of Bowser Creek gives 1,425 feet as the thickness of the Chinitna shale at this locality.

So far as is known, this figure is not made questionable by folding and faulting, although faulting might be difficult to detect. Such a thickness would contrast strongly not only with that of the type section, but especially with that of the formation on the Alaska Peninsula, where it reaches a maximum of 7,000 feet.

The Chinitna shale nearly everywhere shows a seaward dip, although at one locality a small fold with reverse dips was seen. In general, then, the formation has a monoclinal structure with dips that range from 15° to 35° and strikes that approximate the trend of the coast line.

Age.—The Chinitna shale was at first included by Martin in the "Enochkin formation," together with the Tuxedni sandstone, and regarded as of Middle Jurassic age. Later studies, however, led to the separation of the "Enochkin formation" into two formations and the assignment of the Chinitna, or upper part, to the Upper Jurassic.

This formation is less fossiliferous than the Tuxedni sandstone but yields numerous fossils at some horizons in its lower part, especially certain ammonites, among which several species of *Cadoceras* are predominant. These forms were regarded as diagnostic in mapping the formation boundary.

CHISIK CONGLOMERATE.

Character and distribution.—The Chisik conglomerate is typically a coarse, massive conglomerate made up of cobbles and boulders of granite or diorite and other igneous rocks in a tuffaceous andesitic matrix. The only locality within the area mapped where it is found with the character described is on the east shore of Iniskin Bay and the adjacent mountain, where, as measured by Martin, it reaches a thickness of 290 feet. It lies with structural conformity on the Chinitna shale and is overlain conformably by the coarse sandy beds of the lower part of the Naknek formation.

On the geologic map the Chisik conglomerate is represented as a narrow band extending only part way between Iniskin and Oil bays, for the beds resting on the Chinitna shale on both sides of Oil Bay are grits or fine conglomerate and arkosic sandstone and bear no resemblance to the beds occupying this position on Iniskin Bay. In all other places from Oil Bay to Chinitna Bay where the base of the Naknek formation was examined the beds consist of coarse arkose and fine grit. It therefore appears that the Chisik conglomerate of Iniskin Bay is probably a local phase of the basal Naknek. It is separated from the Naknek on the map because of its lithologic character and its conspicuous outcrops, although a somewhat similar conglomerate of less thickness within the Tuxedni sandstone was not separately mapped. Blocks of the conglomerate have fallen from the cliffs on the east shore of Iniskin Bay and have been worn by the sea waves into the peculiar shapes that gave them the name Mushroom Rocks, a name also applied to certain small islands near the entrance to the bay.

Age.—The Chisik conglomerate has furnished no fossils, but its age is known from the fact that it lies between the Chinitna shale and the Naknek formation, both of which are Upper Jurassic.

NAKNEK FORMATION.

Character and distribution.—The Naknek formation, like the Tuxedni sandstone, includes a heterogeneous mixture of shale, sandstone, arkose, andesitic tuff, and conglomerate and may be separated into a lower and an upper part with distinctive lithology and conspicuous differences as expressed in topography and the landscape. In the area between Chinitna and Iniskin bays the lower part of the formation, ranging from about 1,500 to 1,645 feet in thickness, consists of gray shale with dark arkosic beds and fine conglomerate or grit at the base and thin sandy beds scattered through it. The overlying sediments are white or light-colored sandstones containing an abundance of igneous material, in part tuff, in part clastic material derived from granite or granite-like rocks, and in part intrusive sills. This upper part includes the remainder of the formation as exposed in the district. These rocks are confined to a curving belt from 2 to 4 miles in width and extend along the whole seaward side of the peninsula from Iniskin Bay to Chinitna Bay.

The basal arkosic beds are also made up of material from a land mass where granite or granitic rocks supplied an abundance of waste for the formation of new sediments and are believed to be the time equivalent of the Chisik conglomerate of Iniskin Bay, for no conglomerate comparable to the Chisik conglomerate of Iniskin Bay was seen elsewhere in the district. The thickness of the coarse-grained basal beds is 147 feet on the east shore of Oil Bay and is approximately the same in other places where the beds were examined. Sandy shales with beds of sandstone succeed the basal beds and together with them make up the lower part of the Naknek formation below the light-colored cliff-forming beds. This part of the Naknek reaches a thickness of 1,645 feet in the section measured by Martin at Oil Bay.

The upper part of the Naknek formation is conspicuous wherever it crops out because of its light color and because it resists erosion better than the underlying beds. It forms the dip slope on the seaward face of the mountains along the coast. Its scarp makes the white cliffs along most of the crest of the mountains as seen from the landward side. This part of the Naknek formation reaches a thickness of at least 3,000 feet. The beds are prevailingly hard and massive but in large exposures show distinctly the bedding lines. They include hard arkosic sandstone, andesitic tuff, coarse and fine sandstone, shale, and conglomerate. Thin sills of quartz diorite are intruded into the sedimentary beds and are distinguished from them only on close examination. The strike of beds of the Naknek formation ranges from about N. 30° E. on Chinitna Bay to nearly due east on Iniskin Bay. The dips are everywhere toward the sea and decrease from an average of about 35° on Chinitna Bay to about 15° between Oil and Iniskin bays and on the Iniskin shore. Local variations of dip are found, as at Mount Chinitna, where the beds are tilted to an angle of nearly 45°, but no such high dips were seen in the Naknek formation farther south.

Age.—Fossils are less numerous in the sedimentary beds of the Naknek formation than in the underlying Chinitna shale and Tuxedni sandstone. They are abundant at certain horizons, however, and yield conclusive evidence that the formation is of Upper Jurassic age.

QUATERNARY SYSTEM.

The unconsolidated deposits of the Iniskin-Chinitna Peninsula include coastal-plain deposits, stream and bench deposits, and glacial deposits. The coastal and stream deposits are much more extensively developed than those resulting from glaciation.

Coastal gravel and sand form a narrow band limited by high tide along the outer shores of the peninsula but are somewhat better developed within the bays, where they are protected from the strong currents of the inlet. The marshy flats on the south side and around the head of Chinitna Bay are in part built up of marine shore gravel intermingled with gravel and sand contributed directly by streams and with accumulations of vegetable matter. The flats around Camp Point are of this nature, as are probably also the lowlands at the heads of Oil and Dry bays. Without doubt the sea at no distant geologic time extended much farther into valleys like that of Bowser Creek, probably cutting off the mountains between Oil and Iniskin bays from the rest of the peninsula and leaving marine deposits on the valley floors on its retreat. Deposits of this kind, however, would be subject to more or less redistribution by streams and possibly by glaciers and may no longer remain. No gravel of marine origin was recognized except along the shore line.

Stream and bench gravels are here considered together because the only deposits of bench gravel seen are but a few feet above the level of the near-by streams and were evidently laid down by the streams. Deposits of gravel and sand are less common in this area than in much of interior Alaska and are restricted to the flood plains of the streams and to the adjacent valley floors. The deposits are mostly of local origin but contain erratic boulders, which were doubtless brought to their present resting places by ice moving from the high mountains west of this area. Owing to the rapid weathering of the shale that occupies a large part of the peninsula within the bounding zone of the sandstone at the top of the Naknek formation, the stream and bench gravels contain much argillaceous material and pack down so as to give firm footing for horses, except where they are poorly drained, as in the grass-covered flats at the head of Chinitna Bay. Quicksands were not found in any of the streams traversed during the summer. So far as is known, the stream gravels contain no gold or other valuable minerals. The readiness with which the shale and sandstone disintegrate and the ease with which the resulting loose material is carried away by the streams are probably the principal reasons for the lack of conspicuous gravel deposits in the district.

In spite of the fact that ice must have once covered most of the peninsula, glacial deposits are conspicuously uncommon and were recognized only where foreign material was seen in the local stream gravel. The common topographic expressions of glacial deposits were not observed, although they are evident in neighboring areas and may once have been here.

PETROLEUM.

As far as is now known petroleum is the only mineral resource of the Iniskin-Chinitna Peninsula that offers a possibility of profitable commercial development. In earlier years a few prospectors panned the stream gravel in the search for placer gold and examined the hills in the hope of finding gold lodes, copper, or other metals, but without success. Petroleum seepages, however, were known in the vicinity of Oil Bay many years before the great rush of gold seekers who came to Alaska after the early discoveries in the Klondike, and attempts were made to prove or disprove the presence of an oil pool. The work met with inconclusive results, although a number of wells were drilled, and was finally abandoned, probably from lack of means to continue it.

SEEPAGES.

The indications of petroleum that first directed attention to the possibility of producing oil in this part of the Cook Inlet region are springs or seepages of oil and gas. Many such springs have been reported and have led to the staking of numerous claims in the earlier days, before the oil lands were withdrawn from entry, and again in recent years, after the leasing law of 1920 was passed. An attempt was made to examine all the seepages that have been reported, but in the absence of anyone familiar with their exact location this was not fully accomplished.

Martin reports a strong seepage between high and low tides on the east shore of Iniskin Bay about 1,000 feet below the lower cabin, which produced an intermittent flow of oil, at one place coming from a crevice in the shale of the upper part of the Tuxedni sandstone. No sign of this seepage was seen by the writer, and it is suggested that the seepage either has been diverted or is exhausted.

One of the oil seepages at Oil Bay is at the foot of the hill about 100 feet east of the place where the old road from the cabin starts up the hill to the fourth well. The oil rises in a water spring and collects on the surface of the water in a small pool. At the time it was visited in 1921 not more than an ounce or two of oil could be taken from this pool in a day.

A strong flow of gas bubbling up through water about 2 miles west of Dry Bay was the inducement that led to drilling at that locality.

Oil claims have been staked recently on the shores of Chinitna Bay, where oil seepages are also reported. Although the south shore of Chinitna Bay was examined rather carefully, no seepages were found there by the surveying parties in 1921. Oil springs might easily be missed, however, unless their locations were fairly well known, for the vegetation by midsummer is so rank as to hide them.

The seepages, with the probable exception of the gas spring at Dry Bay, are within the area of the Tuxedni sandstone. Some of them appear to be near or at places where the dip of the sedimentary beds increases toward the coast. Such places would be favorable for the accumulation of oil, but probably the presence of the seepages is more dependent on the fact that they are near places where the rocks are faulted or conspicuously jointed, thus giving an opportunity for oil and gas to escape to the surface.

EXPLORATION FOR PETROLEUM.

Oil Bay and its vicinity were visited by Martin[3] in 1903 and again in 1904 during the time when drilling operations were in progress. Martin's reports on the investigations he then made are the best available source of information on the development of the district and the character of the oil seeps.

Martin states that indications of petroleum were discovered in the Iniskin Bay region in 1853 and that the first samples of petroleum

[3] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 37–49, 1905. Martin, G. C., and Katz, F. J., Reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 126–130, 1912. Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 51–55, 1921.

were taken by a Russian named Paveloff in 1882. A Mr. Edelman staked claims near the heads of Bowser and Brown creeks in 1892, but these claims were not drilled, and apparently no work of any kind was done on them. Pomeroy and Griffen staked claims near the head of Oil Bay in 1896, organized the Alaska Petroleum Co. in 1897, and began preliminary work on the ground in 1898.

Drilling is reported to have been in progress in 1900, although Oliphant[4] says that the well at Oil Bay was started in 1902 after unsuccessful attempts had been made in 1899 to land machinery and in 1901 to begin drilling. Work on the first well was ended in 1903.

Martin was unable to get authentic information about this well but states that it was said to be more than 1,000 feet deep, that gas was encountered all the way below 190 feet, and that considerable oil was found at a depth of either 500 or 700 feet. It seems improbable that the reported flow of 50 barrels a day was obtained, although oil was undoubtedly present. When the well was drilled deeper a strong flow of salt water was met and shut off the flow of oil. Efforts to recover the oil or to drill deeper were not successful. At present water flows from the pipe and gas bubbles continually through it, but practically no oil accompanies the water.

A second hole was drilled in 1904 near the base of a hill three-tenths of a mile northwest of the first well and nearly 400 feet north of the road to Iniskin Bay. When this well had reached a depth of 450 feet it was abandoned because of caving shale. The log of the well, as furnished by Mr. August Bowser, who had charge of the drilling, is as follows:

Record of well No. 2 at Oil Bay.

	Feet.
Sandstone	200
Shale	120
Oil and some gas	1
Shale (caving)	129
	450

A third well was started in the same year almost directly south of the second well and about 150 feet from the road. It was sunk to a depth of 900 feet but was cased for only 630 feet. Caving ground was encountered at 830 feet. At 770 feet three oil sands 6 to 8 inches thick and 4 or 5 feet apart were passed through. It is said that the well produced about 10 barrels of oil a day and had a gas pressure sufficient to blow water into the derrick to a height of 20 feet.[5] Water now flows from the pipe in this well but in less amount than from the first well. A little gas and oil also come up the pipe with the

[4] Oliphant, F. H., Petroleum: U. S. Geol. Survey Mineral Resources, 1903, p. 691, 1904.
[5] Information furnished by Mr. August Bowser.

water, but the quantity is less than that in the natural seepage at the foot of the hill a short distance to the east.

A fourth hole was started on the low hill half a mile north of the cabin at the first hole. The derrick is still standing, but no information concerning this hole is at hand. The pipe was plugged, and no evidence of oil, gas, or water was seen when the place was visited in 1921. No drilling was done at Oil Bay after 1906, and in 1908 the claims were abandoned.

Drilling operations at Dry Bay began at about the same time as at Oil Bay. They were undertaken by the Alaska Oil Co., which was organized in 1901 and began drilling in 1902. The first well was put down that year, but the tools were lost at a depth of 320 feet without having encountered oil and the hole was abandoned. The well had a diameter of 8 inches to a depth of 212 feet and of 6 inches below that. A second well near the first was started in 1903 but was soon given up because of an accident to the machinery. No other drilling was undertaken at Dry Bay after 1903.

CHARACTER AND OCCURRENCE OF THE PETROLEUM.

Samples of the seepage petroleum from Oil Bay were collected by Martin for analysis. The oil when it first rises to the surface of the water is dark green, but it turns dark brown after it has been exposed to the air for a time and has lost part of its volatile constituents. It has a paraffin base and would doubtless be a refining oil.

It was pointed out that the oil seepages and drill holes showing oil are within the area of the Tuxedni sandstone. So far as is known none of the seepages, except possibly the gas spring at Dry Bay, are within areas of the Chinitna shale or the Naknek formation. It is therefore believed that the source of the oil is within the Tuxedni sandstone or at some lower horizon. Two of the drill holes at Oil Bay are reported to have penetrated oil-bearing sands at depths ranging from 500 to 770 feet and to have shown a considerable quantity of oil. No other direct evidence for the depth at which the oil originated was observed.

The relation of the oil seepages and wells to the geologic structure of the formation in which they are situated is of importance in predicting the location of a possible oil pool. The seepage on Iniskin Bay is near a fault, and the principal seepage at Oil Bay is in a zone of jointing and faulting. The east and west shores of Oil Bay were determined by a system of vertical faults and closely spaced joints, which in general strike N. 20° W. A glance at the geologic map shows clearly that the seepage and drill holes at Oil Bay are in line with the west shore of the bay and that unless the fracturing does not extend that far northward the position of the seepage may readily have been controlled by the same structure that controlled the form and location of Oil Bay.

The accumulation of oil, however, would be determined by other structural features than these and may be related to either one or both of two types of folds. The rocks of a narrow curving belt along the Cook Inlet coast dip eastward in a monocline that carries them from view beneath the water. This structure is so pronounced that it suggested for the mountains of this belt the name Tilted Hills. The landward margin of the belt is marked approximately by the boundary line between the Tuxedni sandstone and the Chinitna shale. This boundary line in turn marks the locality of a slight change in dip between the rocks of the Tilted Hills and those of the interior of the peninsula. This change is not everywhere noted, but in places the dip of the rocks along the coast is greater than that of the interior beds and thus produces one of the types of structure well known in some oil fields as favorable for the accumulation of oil.

The Tuxedni sandstone of the interior of the peninsula has been thrown into a succession of folds with axes running about N. 30° E. The position of these folds is indicated on the geologic map, where it is shown that one of the two principal anticlines follows the valleys of Bowser and Fitz creeks. This anticline divides into two minor anticlines in the lower part of the Fitz Creek valley and flattens out on the south near Oil Bay, losing its identity and pitching beneath the southward-dipping beds of Mount Pomeroy.

These two structural features—the line of changing dip along the inner slopes of the coast mountains and the anticline marked by the valleys of Fitz and Bowser creeks—are believed to be more favorable for the accumulation of oil than others in this district. One possible unfavorable condition in the Bowser-Fitz Creek anticline should be pointed out. Fitz Creek has cut its valley deep into the Tuxedni sandstone near Chinitna Bay, so that the rocks exposed there are probably lower in the formation than the beds at Oil Bay. It is thus possible that the lowest beds exposed on Fitz Creek are below the horizon of the oil-producing bed and therefore that no oil will be found in them. Whether or not this is true can not be determined till more is known about the source of the oil.

The valley of Portage Creek would seem to offer a less favorable locality to test for oil because the rocks are so closely compressed that the limbs of the narrow fold are almost parallel in places and because the fold is affected by a profound fault which cuts off its north end completely.

Oil may be found in other structural features than the two types of folds already mentioned. One such feature is a porous sandstone bed capable of holding oil inclosed in a shale bed tight enough to prevent the escape of the oil. Beds of this nature are doubtless present in the upper shaly part of the Tuxedni sandstone, but their presence at a particular locality could not ordinarily be predicted from surface indications and could be determined only by the drill.

A tilted sandstone bed cut off by a tight fault might also provide a reservoir capable of holding oil, but here again the difficulty of finding it would usually be great in an undeveloped field.

It seems evident to the writer that if other drill holes are put down in the search for oil in this district they should be located with reference to one or the other of the two principal structural features just described. The anticline in Fitz and Bowser Creek valleys is in reality the crest of an unsymmetrical fold, of which the monocline along the Cook Inlet shore is the eastern limb. In at least one place there is a small minor fold between the crest and the monocline, but in other places no such minor fold was found. If oil in considerable quantity were moving up along the beds of the monocline it would probably in places find its way past the line of decreasing dip into the crest of the anticline. The tilted sedimentary beds bordering Cook Inlet would seem to provide a good gathering ground for oil and conditions favorable for its accumulation, but the presence of oil can not be predicted and can hardly be determined by any other means than the drill.

In summarizing it may be said that the Iniskin Bay region includes a number of long, narrow anticlines, which are adjoined on the seaward side by a great monocline. This monocline should have afforded a considerable underground drainage area for oil and may contain valuable pools.

A PETROLEUM SEEPAGE NEAR ANCHORAGE.

By Alfred H. Brooks.

Prior to 1921 no evidence of petroleum near Anchorage had been found. Some shallow drilling had been done, but it did not reach the hard rock, and the character of the nearest exposed formations gave no encouragement to the hope of finding oil at greater depths. In July, 1921, however, a small petroleum seepage was found in sec. 24, T. 23, R. 3, about a mile southwest of the town of Anchorage. This locality was visited in August, and oil seeping from a gravel bank on top of a clay layer at about sea level was found. The seepage was estimated to yield about 2 fluid ounces a day. Its location precluded the possibility of its being due to an accidental leakage from an oil tank. Other reported seepages in the district were not seen. A sample of the petroleum was collected and submitted for examination to the Bureau of Mines, which reported as follows:

The sample consisted of a mixture of oil, water, and sediment. By simple filtration and separation it was possible to obtain about 30 cubic centimeters of the oil. This quantity, of course, is not sufficient to permit a complete analysis, but the following results were obtained:

Bureau of Mines No. 0088:
- Specific gravity, 0.880.
- Degrees Baumé, 29.1.
- Sulphur, 0.50 per cent.
- Viscosity (Saybolt Universal at 100° F.), 45 seconds.

The gravity and viscosity indicate that this is a genuine crude oil of fairly high grade. The sample was distilled with the following results, which, however, are only approximate:

- First drop, 196° C.
- Boiling below 225° C., 30 per cent.
- Boiling between 225° and 250° C., 22 per cent.
- Boiling between 250° and 275° C., 12 per cent.

In all 64 per cent was recovered by boiling between 196° and 275° C., which would indicate that the distillate consisted almost entirely of kerosene. No gasoline was present. An approximate analysis of the oil could be given as:

- Gasoline, none.
- Kerosene, 64 per cent.
- Gas oil, lubricating oil, and residuum, 36 per cent.

The fact that the petroleum has without doubt traveled a long distance from its bedrock source may account for the absence of gasoline.

There is no positive evidence of the source of the petroleum of this seepage. The surface of the region for several miles is mantled with a cover of gravel and sand, probably at least 300 feet thick. Soft sandstones containing a little lignitic coal occur on the shores of Knik Arm, not far from the seepages. So far as known these beds are only gently tilted. Even if oil might be distilled from the vegetable remains in these beds, the fact that the formation is nearly unaltered except for slight cementation of sandstone seems to preclude the idea that the physical conditions have been favorable to distillation. Moreover, the same Tertiary lignite-bearing beds occur in large areas both north and south of this locality. These beds have been examined in considerable detail, but nowhere have they revealed any evidence that they contain petroleum, and they can with confidence be excluded as a possible source of this oil. This seepage occurs near the eastern margin of the great Susitna lowland, which covers over 1,500 square miles and is filled with silts, sands, and gravels to an unknown but probably great depth. These delta deposits undoubtedly contain some vegetable remains and possibly some animal remains. It is not impossible that such deposits might afford favorable conditions for the formation of petroleum, but such an explanation of the facts in hand is a mere speculation. Moreover, the unconsolidated silts, sands, and gravels certainly do not afford favorable conditions for the formation of oil pools.

With regard to a possible hard-rock source for this oil the available facts obtainable from outcrops are all negative. The gravel bench from which the oil emerges stretches eastward for 7 miles to the base of the mountains, mantling all rock exposures. In the mountains the formations consist of closely folded and faulted altered sediments and igneous rocks,[1] possibly of Mesozoic age, but entirely unfavorable to the presence of petroleum and so much altered and disturbed as to preclude the possibility that they contain oil pools.

The outcropping bedrock in the vicinity of Anchorage therefore affords no clue to the source of the seepage oil. The great lowland described is occupied almost entirely by alluvial deposits, the only bedrock being a few outcrops of the Tertiary lignite-bearing beds. Neither of these formations is a promising source of petroleum. The formations in the highland bounding this alluvium-covered

---

[1] Capps, S. R., The Turnagain-Knik region: U. S. Geol. Survey Bull. 642, pp. 152–165, pl. 8, 1916.

lowland are not believed to be oil bearing, yet this lowland tract may itself contain oil-bearing rocks. The nearest known oil-bearing rocks are those of Iniskin Bay, 150 miles to the south, which are of Jurassic age. The extension of the strike of these distant formations would carry them into the lowland region near the eastern margin of which the Anchorage seepage is situated. If the Anchorage seepage is derived from such buried oil-bearing rocks, a careful search in the lowland region should lead to the discovery of other seepages, if they have not already been found.

Evidently, therefore, the presence of oil in this region, except for the small seepage described or others that may be found, can be proved only by drilling. In the absence of bedrock exposures, geologic examinations are of little or no value. The fact that the region is readily accessible by steamer, railroad, and wagon road will make it far less expensive to drill than other parts of Alaska. It should be added, however, that in the absence of any clue to the structure and any knowledge of the depth of the oil-bearing formations, even if they are present, all drilling in this region must be classed as wildcatting.

A SUPPOSED PETROLEUM SEEPAGE IN THE NENANA COAL FIELD.

By George C. Martin.

INTRODUCTION.

During the last two years the discovery of several supposedly genuine petroleum seepages have been reported from the Nenana coal field, Alaska, and several prospecting claims have been staked. The reports of seepages were sufficiently definite to justify a field examination, and therefore the writer visited one of the localities in August, 1921. The evidence obtained in the field and from laboratory investigations of material collected appears to indicate that the supposed petroleum residue is not derived from petroleum but is a tar distilled from burning coal beds.

It is the duty of official geologists not only to indicate the areas that are favorable for the finding of oil pools or other mineral deposits but also those that are unfavorable. Much of the most valuable results of geologic work, including the work of both official geologists and of those in private employment, consists in reducing the expense and hazard of mining investment by pointing out the localities or regions where mining operations are not justified. The supposed Nenana oil seepages have attracted enough public attention to make it imperative to give in full the reasons why they have proved not to be true petroleum seepages. This presentation will, it is hoped, discourage any further expenditures in this region in search for petroleum.

Petroleum seepages and residues are generally and rightly regarded as among the most useful and reliable indications of oil pools. Although those who are not familiar with oil seepages sometimes mistake iron stains, mineral salts, and living organic slimes for them, it is generally considered that a true oil seepage is unmistakable. It is important, therefore, to describe a material which has some of the generally accepted characteristics of a petroleum residue but which is believed to be something else. The purpose of the present paper is not merely to report a supposed oil discovery that is believed to be based on misleading indications but to call attention to the broader question of the possible general inadequacy of a commonly accepted class of evidence.

It was reported in the summer of 1920 that a petroleum seepage had been discovered[1] in the vicinity of Healy Creek, near the southern margin of the Nenana coal field. There are also reports, which apparently have not been referred to in print, of indications of petroleum in other parts of the Nenana coal field, notably on Totatlanika Creek in the northeastern part of T. 11 S., R. 5 W. A sample of sand impregnated with bituminous material that was supposed to be petroleum or petroleum residue was taken from the Healy Creek locality in 1920 and is said to have been subjected to tests in which oils bearing some resemblance to petroleum were extracted by solution. Considerable interest in the possible occurrence of petroleum was aroused thereby, and application has been made for several oil leases in this vicinity. A brief visit to the supposed seepage was made in August, 1921, by the writer, who, although he had never seen the precise locality before, was thoroughly familiar with much of the neighboring territory. While in the field the writer suspected that the supposed petroleum residue was really a natural coal tar produced by the distillation of burning coal beds. Chemical tests made in the laboratory of the United States Geological Survey by E. Theodore Erickson tend to confirm this suspicion.

The reasons for believing that this material is not a petroleum residue are as follows:

No adequate original source of petroleum is known in the strata that crop out at and near the supposed seepage or in the rocks that underlie them.

The structure is not favorable for the accumulation of bodies of oil in the vicinity nor for its escape at this point.

If petroleum were escaping at this locality it would almost certainly escape at many other places in the Nenana coal field where it would probably not have been overlooked by the writer and his associates in the detailed investigation which they made in 1916 or by the several other geologists and many engineers and prospectors who are familiar with the district.

The material differs in odor and chemical composition from most petroleums and contains substances that are generally regarded as characteristic of coal tars.

An adequate source for natural coal tar is found in distillation from coal beds that are known to have burned at many places throughout the field and that are believed to have burned at this very spot.

---

[1] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, p. 73, 1921.

THE BITUMINOUS DEPOSIT.

The locality of the supposed seepage is just inside the southern border of the Nenana coal field, which lies in the northern foothills of the Alaska Range, in the central part of Alaska. (See fig. 7.)

The Nenana coal field, which has been described by Prindle,[2] Brooks and Prindle,[3] Capps,[4] and Martin,[5] contains a thick section of Tertiary (probably Eocene) coal-bearing rocks resting unconform-

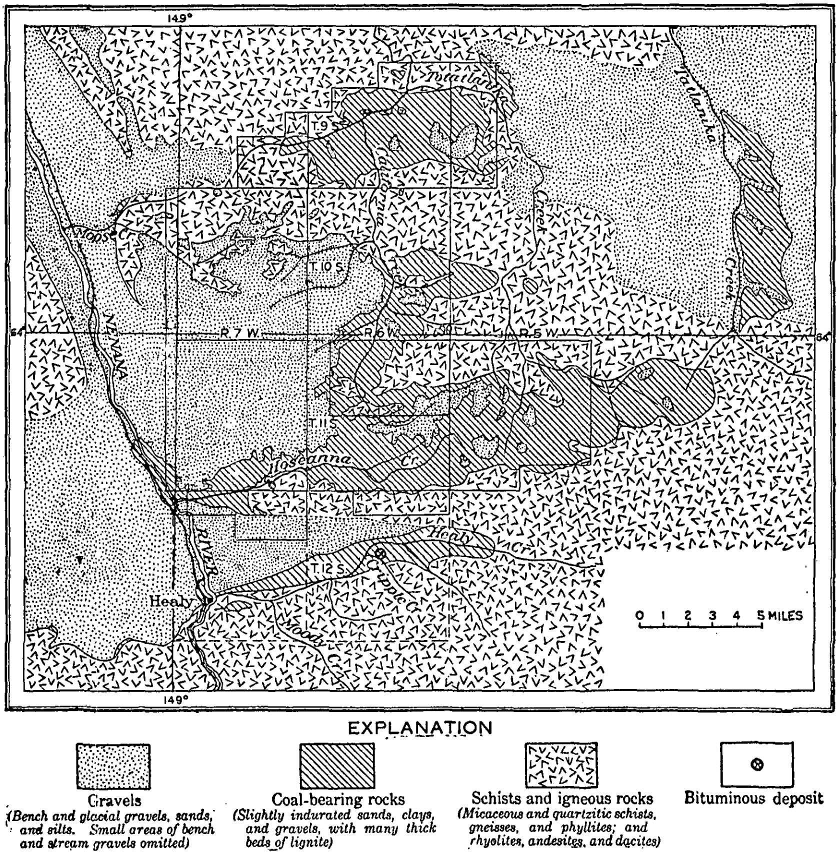


FIGURE 7.—Geologic map of the Nenana coal field.

ably on igneous and highly metamorphic rocks and overlain by Quaternary gravel. The coal-bearing strata are at least 1,200 feet and possibly 1,500 or 2,000 feet thick and consist of slightly consoli-

---

[2] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, pp. 205–226, 1907.

[3] Brooks, A. H., and Prindle, L. M., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 188–192, 1911.

[4] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, 64 pp., 1912.

[5] Martin, G. C., The Nenana coal field, Alaska: U. S. Geol. Survey Bull. 664, 54 pp., 1919.

dated sand, clay, and gravel with numerous beds of lignite, there being at least 12 coal beds of workable thickness, six or more of which measure 20 feet each and several of them 30 to 35 feet. No organic matter, other than the coal and the disseminated vegetable detritus which it is customary to find in the sandstones adjacent to coal beds, has been seen.

The supposed seepage is in sec. 15, T. 12 S., R. 6 W. Fairbanks meridian, on the east bank about a mile above the mouth of Cripple Creek, which flows northwestward into Healy Creek, one of the larger eastern tributaries of Nenana River. (See fig. 7.)

Cripple Creek has cut a discontinuous series of exposures of Tertiary coal-bearing rocks dipping about 20° N. The rocks are clearly exposed only where the creek washes the bases of the steep bluffs, the intervening areas being more or less mantled with talus. About half a mile south of the supposed seepage Cripple Creek emerges from a narrow canyon in which igneous rocks and highly metamorphosed schist are exposed underlying the coal-bearing rocks.

The bituminous deposit or supposed "oil seepage" is near the top of a steep bank, about 150 feet above the creek. The coal-bearing rocks do not clearly crop out at this point, the exposure consisting of hillside wash, more or less mantled with gravel from a terrace on the top of the bank. The gravel and talus are laid bare in a small area where the soil and vegetation have been swept away, partly by landslides and partly by wind erosion. Here the sand and soil are more or less generally impregnated with tarry and oily material, which bears some resemblance both in appearance and in odor to petroleum residue, though the odor is somewhat different from that at any oil seepage which the writer has ever visited. Shallow trenches have been dug into the soil at this place without revealing any strata that were absolutely undisturbed, but showing considerably more of the bituminous material than was apparent on the natural surface. The oil or tar is possibly disseminated throughout the exposed material, but it is not uniformly distributed. Small irregular masses of sand seem to be completely saturated with black tarry and oily material, so that they have about the appearance and consistency of the tarry sands that were formerly used in laying sidewalks. The odor of the material was noticeable to one walking over the area and is said to have led to the discovery. The accompanying sketch (fig. 8) shows the relation of the bituminous deposit to the gravel and to the underlying lignite-bearing beds. This sketch is a copy of a rough diagram furnished by Mr. W. E. Dunkle, who is thoroughly familiar with the locality, although he did not have his detailed notes at hand when he prepared the diagram. The sketch indicates conditions substantially in accord with the observations of the writer and supplies evidence in confirmation of the theory here set forth, although it was prepared by one who did not have that theory in mind. It should be noted that the 5-foot bed of lignite has its position merely indicated in the lower left corner of the sketch. This is where the writer saw no exposure of the lignite but only fragments of clinker indicating that a bed had been burned. Only the upper part of this lignite bed is drawn solid in the sketch. This would seem to indicate that the fire did not extend to the base of the gravel but was probably drowned out a short distance below. The bituminous deposit is shown as lying wholly in the gravel, a position which is in accordance with the belief of the writer, and it is directly above the place where the fire is believed to have died out. This is the very place where, in accordance with the theory here presented, the tars and oils would condense in greatest amount.

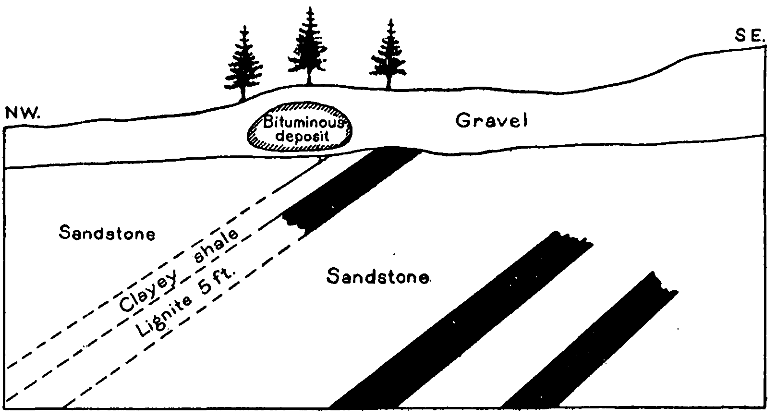


FIGURE 8.—Sketch showing relation of bituminous deposit on Cripple Creek to gravel and lignite-bearing beds.

GEOLOGIC EVIDENCE THAT THE MATERIAL IS NOT PETROLEUM RESIDUE.

The only sedimentary strata known near this locality, or anywhere else in the Nenana coal field, which might be considered as a possible source of petroleum are the Tertiary lignite-bearing beds. These beds are composed of slightly consolidated sand, gravel, and clay, with numerous beds of lignite. Their organic constituents include only the beds of lignite and the vegetable detritus which is common in sandstone associated with coal beds. The intervening strata are dominantly sand and gravel, with no observable organic constituents. The argillaceous members (clay) are relatively few and thin, probably being subordinate to the lignite in amount, and they consist of light-colored clay which is notably lacking in organic matter. Carbonaceous or bituminous clay or shale is relatively scarce if not wholly lacking. No beds of limestone or of diatomaceous or infusorial earth or any marine or brackish-water beds are known. The strata, in brief, contain little or no organic matter from which petroleum might be derived unless it may be the remains of the higher forms of vegetable life in and associated with the lignites, and these remains are not generally regarded as a possible source of petroleum. It may therefore be considered certain that the lignite-bearing strata of the Nenana field are not a probable source of petroleum.

In discussing the question as to whether petroleum could have been derived from strata beneath the lignite-bearing beds, brief consideration must first be given to the general structure and distribution of the beds. The Nenana coal field (see fig. 7) consists of a group of narrow and gently warped basins. The combination of shallow basins having a dominant east-west structural trend with deeply incised north-south drainage reveals the basal contact of the lignite-bearing beds very thoroughly in all parts of the field. For example, at no place in the portion of the field covered by the detailed surveys of 1916 are there exposures of the lignite-bearing beds at a horizontal distance greater than 2½ miles from the exposures of the underlying rocks. Consequently, there is little chance that the lignite-bearing beds are underlain anywhere in this area by rocks of unknown character.

The rocks exposed beneath the lignite-bearing beds include the Birch Creek and Totatlanika schists and intrusive igneous rocks, chiefly andesite and dacite. It is clearly hopeless to look to these rocks for a source of petroleum. Moreover, at no place in this general region are there any rocks known which might be considered as possibly oil-bearing. The northern foothills of the Alaska Range are known geologically for 100 miles or more both east and west of this locality, and throughout this belt the rocks beneath the Tertiary lignite-bearing beds are almost wholly crystalline. It should be noted that relatively unaltered Devonian limestones and Ordovician shales occur on the north flank of the Alaska Range, but they have not been seen within a great many miles of this locality and are known only in the mountains and not in the extension of the foothill belt. The marine Jurassic and Tertiary strata that contain the known petroleum of Alaska have not been found north of the Alaska Range, except in the Arctic coastal province, and are believed never to have been deposited there.

GEOLOGIC EVIDENCE THAT THE MATERIAL IS TAR.

The belief of the writer that this material is a natural coal tar produced by distillation from burning coal beds finds geologic support in the fact that coal beds have burned at many places throughout the field and have probably burned at this very spot. This is, moreover, one of the places where the geologic conditions are especially favorable for a trapping and condensation of the liquids and gases that must inevitably be given off whenever a coal bed is burned.

The lignite beds throughout the Nenana field have been extensively burned from unknown natural causes. There is hardly a single large exposure anywhere in the western part of the field in which one or more of the coal beds have not been burned in greater or less degree. The burning of the lignite in the Nenana field was first described by Prindle,[6] who states that on Healy Creek "some beds in almost every section have been destroyed by fire." The burned coal beds are also described by Capps,[7] who says that on Healy Creek "some beds of coal have burned out in almost all sections examined."

Reference to the burning of the coal beds has also been made by the writer,[8] who has given many details concerning localities at which there is evidence of burning and who states that "the coal beds have been extensively burned in many parts of the field, especially in T. 9 S., R. 6 W., where only about half a dozen unburned outcrops were observed." The burning began at an unknown date, in some places certainly before the deposition of the Quaternary gravels, and some beds are burning now. The extensiveness and the antiquity of the burning are indicated by the fact that one of the most trustworthy criteria used in the detailed survey of the coal field for distinguishing, in poor exposures, between the Quaternary gravel and the somewhat similar gravel that is intercalated between the coal beds is the almost universal presence of minute chips of burned clay, resembling pieces of brick or tile, in the Quaternary gravel. Similar pieces of burned clay, which doubtless came from the Nenana coal field, have been found by the writer in the gravel of the low terraces along Tanana River. It may be noted that the burning of lignite in past geologic time, as shown by the presence of pebbles of clinker in terrace gravel, has also been observed in Montana.[9]

Although no burned coal beds have been seen at the bituminous deposit, the coal beds and accompanying strata not being actually exposed at the place, abundant fragments of burned clay and also masses of scoriaceous material resulting from the complete fusion of the rocks were seen by the writer in the soil immediately below

[6] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, pp. 222–244, 1907.

[7] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 55, 58, 60, 61, 1912.

[8] Martin, G. C., The Nenana coal field, Alaska: U. S. Geol. Survey Bull. 664, 54 pp., 1919.

[9] Allen, J. A., Metamorphism produced by the burning of lignite beds in Dakota and Montana Territories: Boston Soc. Nat. Hist. Proc., vol. 16, pp. 258–259, 1874. Collier, A. J., and Smith, C. D., The Miles City coal field, Mont.: U. S. Geol. Survey Bull. 341, p. 45, 1909.

the deposit. It may therefore be confidently assumed that the coal beds have been burned at this very place. There is no conclusive evidence as to when the burning took place here. This fire is not burning now, but the fact that volatile material still remains in the bituminous deposit is perhaps an indication that the burning was of comparatively recent date.

It is evident that whenever a coal bed is burned in the ground there will be distillation of liquid and gaseous hydrocarbons in advance of the actual combustion. When the coal is heated to a sufficient temperature, liquids and gases will be driven off in the same way as they are in the manufacture of coke or in the artificial distillation of tars and oils from coal and lignite.[10] These liquids and gases will, for the most part, burn or escape into the air, but part of them will migrate through the rocks, and if they reach cool or damp places they will undoubtedly condense there. The gases given off near the margins of the burned areas are the more likely to escape combustion. If the margin of the burned area approaches the surface of the ground without actually reaching it, the gases are likely neither to be burned nor to escape into the air but will be in part condensed in the damp, cool soil.

The special conditions favorable for the trapping and condensation of distillation products at this locality are the presence of a nearly horizontal bench of Quaternary gravel lying unconformably across the beveled edges of the Tertiary lignite beds. (See fig. 8.) The surface of this bench, if it is like the similar neighboring benches, is dotted with marshy areas and pools of water. The materials composing the bench are doubtless either wet or frozen. The burning of the coal beds would probably approach without reaching the base of the bench gravel. The gases and liquids given off from the combustion and distillation of the coal would be trapped beneath the wet or frozen gravel and would in part condense there.

The natural burning of coal beds is a well-known phenomenon which has been described by many observers. Only a few of the more comprehensive descriptions need be cited here.[11] The published descriptions deal with the destructive effects on the coal beds and with the effect of heat on the overlying rocks, with special reference to the fusion of the rocks and the development of glass,

[10] Scheithauer, W., Shale oils and tars and their products (English translation by Charles Salter), 183 pp., 1913.

[11] Allen, J. A., Metamorphism produced by the burning of lignite beds in Dakota and Montana Territories: Boston Soc. Nat. Hist. Proc., vol. 16, pp. 246–262, 1874.

Collier, A. J., and Smith, C. D., The Miles City coal field, Mont.: U. S. Geol. Survey Bull. 341, pp. 45–46, 1909.

Bowie, Alexander, The burning of coal beds in place: Am. Inst. Min. Eng. Trans., vol. 48, pp. 180–193, 1915.

Rogers, G. S., Baked shale and slag formed by the burning of coal beds: U. S. Geol. Survey Prof. Paper 108, pp. 1–10, 1918.

slag, and silicate minerals. No reference has been made in print, as far as the writer knows, to condensation products from the distillation of the coal. The reason for this omission is believed to be that in most regions the coal has burned vigorously to the very outcrop and that consequently the distillation products have either burned or escaped into the air at the places where they might otherwise be most easily observed. The gases given off at great depth will as a rule be diffused through buried rocks, where their condensation products will not be observable till these buried rocks are laid open by natural or artificial excavation. The fact that natural tars have not been commonly noted in connection with the natural combustion of coal beds may also be due to the lack of a wet or frozen cover. Generally either the rocks are wet to great depths, so that the coal beds do not burn, or else they are dry to the very surface, so that they heat to the surface and the gases escape.

CHEMICAL TESTS.

In order to obtain more positive evidence as to whether the organic matter of this place was actually derived from the distillation of coal beds, samples have been studied by E. Theodore Erickson in the chemical laboratory of the United States Geological Survey. The following report has been submitted on three samples collected by the writer, all from the same locality. Sample A was a selected sample made up of numerous small samples of the more bituminous black sand. Samples B and C were representative selections of the less bituminous (average) finer and coarser material.

Sample A: A chloroform extract indicated a small part of bitumen together with considerable soluble sulphur. The bitumen when heated with alkali solution and likewise the sample when so directly treated yielded strong odors of the pyridine series of compounds. Red litmus paper in the emitted odors readily turned blue. The intensity of these results is sufficient to indicate that considerable quantities of these substances are present in the comparatively small amount of bitumen in the sample.

Phenol-like compounds were detected by the following procedures: The sample was treated directly with strong boiling alkali solution. The alkali extract after filtration from insoluble matter was acidified with HCl, boiled gently, and again filtered. The final filtrate was colored reddish with organic matter, an ether extract was made, and upon evaporation of the ether a small amount of reddish organic matter remained. It possessed a phenol-like odor, and when dissolved with a small amount of water the aqueous solution gave with dilute ferric chloride solution a positive reddish-violet color. Pure phenol under the same conditions gave a bluish-violet color. The phenol-like residue when heated in the usual way with a small quantity of a mixture of two parts of H_2SO_4 and one part of HNO_3 gave the yellow color of the picric acid test. The characteristic phenolic results of a moderately colored yellow solution in water, which deepened much upon the addition of ammonia, were obtained. Phenolic compounds were detected in the phenol-like residue by dissolving in

20 centimeters of normal NaOH solution and adding a small amount of diazobenzene chloride solution. A reddish color and precipitate were obtained, identically as for small amounts of pure phenol. Under the same conditions negative results were obtained in a blank test and in a second blank test containing a small amount of pyridine.

There is also present some pyrobitumen or chloroform-insoluble bitumen in the sample. A trace of arsenic and considerable free sulphur were detected.

An approximate determination of the amount of soluble material in sample A showed 3.6 per cent of bitumen and 7 per cent of soluble sulphur. In this test carbon disulphide was used as the solvent, instead of chloroform, because it was found to yield a sharper separation of sulphur and bitumen upon evaporation.

Sample A was heated for 10 days at 105° C., when it showed a total loss of 10.42 per cent, which is believed to be chiefly moisture, as considerable water and no observable oils condensed. The sample gave an odor of volatile substance both before and after the heating.

Sample B: A chloroform extract indicated a small amount of brittle bitumen. It gave pyridine and phenolic indications, but not as intense as in sample A. Free sulphur did not separate out from the chloroform-evaporated extract, as in sample A. It contains practically no arsenic and a slight amount of pyrobitumen.

Sample C: The amount of bitumen obtained from sample C was intermediate in amount between that from samples A and B. The free sulphur obtained was less than in sample A. The pyridine and phenolic indications are also intermediate between those of samples A and B. The sample contains not over a trace of pyrobitumen and practically no arsenic.

The detecting of the pyridine series of compounds together with appreciable amounts of phenol-like compounds in the organic matter in sample A may be considered as evidence of the presence of coal-tar products that have resulted from the destructive distillation of coal. To differentiate the bitumen from a natural petroleum bitumen and asphalt on this ground becomes tenable when it is considered that petroleum in general contains small amounts of these substances, especially the phenol-like bodies. The diazobenzene chloride test is considered by Marcusson[12] to give for natural asphalt and petroleum pitch a yellow or orange color and not the reddish-colored results above noted, which are obtained from lignite-tar pitch that contains phenol.

Loebell[12] uses the diazobenzene chloride test to differentiate coal-tar pitch from natural or petroleum asphalt, the latter giving negative results with this test.

Of the nitrogen constituents in petroleum it appears likely that allowance must be made for the presence of hydrochinolines other than the pyridine series of compounds, as is evident in Mabery's work on the California petroleums.

It is understood that the samples here tested are directly connected with the natural combustion of coal, with which the results here reported accord.

Mr. Erickson has shown above that the customary tests for distinguishing coal-tar pitch from petroleum pitch or natural asphalt indicate that all three samples contain coal-tar pitch. These tests are based on the presence in coal tars of certain compounds, notably compounds related to phenol and pyridine, which are rare or lacking

[12] Holde, D., The examination of hydrocarbon oils and of saponifiable fats and waxes (English translation by Edward Mueller), p. 222, 1915.

in most petroleums. The tests show that substances related to phenol and pyridine are present in comparatively large amounts in the material under consideration and indicate very strongly that the material is a coal tar rather than a petroleum residue. These chemical tests are possibly not absolutely conclusive, as phenol and pyridine have been recognized in small amounts in a few petroleums, notably in some from California. Moreover, the writer would suggest that perhaps these substances may occur in larger quantities in natural petroleum residues than they do in live oils. The large quantity of sulphur is perhaps a further indication that the material was derived from burning coal beds, because although sulphur is a common constituent of petroleum, it usually occurs in only small quantities. Sulphur occurs also in all coals and lignites, from which it would be easily volatilized and condensed, and it is a common and troublesome constituent[13] of the tars that are artificially distilled from lignites. As Mr. Erickson's studies tend to confirm the conclusions drawn from the geologic field relations it is believed that this material is with little doubt a natural coal tar and not a petroleum residue.

[13] Scheithauer, W., Shale oils and tars and their products (English translation), pp. 142–143, 1913.