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CHARLES D. WALCOTT, DIRECTOR

THE PETROLEUM FIELDS OF THE PACIFIC COAST OF ALASKA

WITH AN ACCOUNT OF THE BERING RIVER COAL DEPOSITS

BY

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LETTER OF TRANSMITTAL.

Department of the Interior,
United States Geological Survey,
Washington, D. C., May 5, 1904.

Sir: I beg to submit herewith the manuscript and illustrations of a report entitled "The Petroleum Fields of the Pacific Coast of Alaska, With an Account of the Bering River Coal Deposits," by Mr. George C. Martin, assistant geologist, and to recommend its publication as a bulletin.

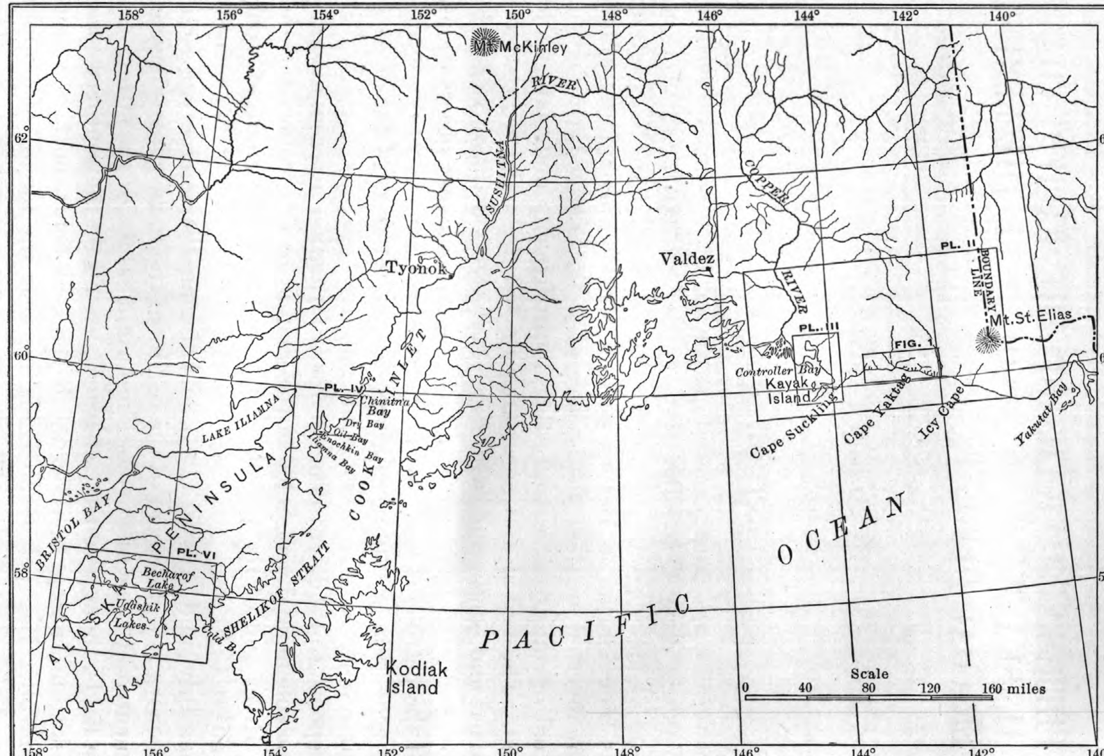
This report contains the result of a hasty examination of the structural and economic geology of the localities where indications of petroleum have been found. Though only a few wells have been drilled and it is too soon to predict an important future for the region as a petroleum producer, Mr. Martin's studies have shown that there is ample justification for further prospecting and that the region may yet be an important source of illuminating oil. In this connection it is of interest to note that the Bering River coal is the best that has yet been found on the Pacific coast of North America.

These coal and petroleum fields have been deemed of sufficient importance to justify the further investigation already begun, and it is hoped that this, together with the commercial development, will soon permit of more definite statements regarding the economic importance of this field.

Very respectfully,

Alfred H. Brooks,
Geologist in Charge Division Alaskan Mineral Resources.

Hon. Charles D. Walcott,
Director United States Geological Survey.



OUTLINE MAP, SHOWING GENERAL LOCATION OF OIL FIELDS AND AREAS OF LARGE-SCALE MAPS.

THE PETROLEUM FIELDS OF THE PACIFIC COAST OF ALASKA, WITH AN ACCOUNT OF THE BERING RIVER COAL DEPOSITS.[a]

By George C. Martin.

INTRODUCTION.

For several years indications of petroleum have been observed at Cape Yaktag,[b] near Controller Bay, on the western shore of Cook Inlet, and at many points on the Alaska Peninsula; and high-grade coal has been known on Bering River. A large amount of capital has been invested in these fields, several wells having been drilled, many coal openings made, and other improvements undertaken and projected. The verbal and newspaper reports from the region have been varied and conflicting, while such statements as have been published by geologists have not been based upon their own observations. Some of the petroleum and coal properties have been carefully examined by geologists or mining engineers in the interests of the owners, but their reports have not been made public.

In response to a general demand for information a reconnaissance of the petroleum and coal fields in the vicinity of Controller Bay and Bering River and of the petroleum fields on the west shore of Cook Inlet and at Cold Bay was made by the writer during the months of June, July, and August, 1903, and during the summer of 1904. The following is a statement of the results of the former investigation supplemented by some of the more important results of the latter.

These fields, though widely separated, are all on the southern coast of Alaska and, except the Bering River coal fields, on tide water. The Controller Bay petroleum fields are near the mouth of Copper River, and the Cape Yaktag fields are 75 miles farther east. The Cook Inlet fields are about 320 miles west of Controller Bay, in the

[a] See preliminary report, Petroleum fields of Alaska and the Bering River coal fields: Bull. U. S. Geol. Survey No. 225, 1904, pp. 365–382.

[b] Commonly spelled Yakatag or Yakataga.

middle part of the western shore of Cook Inlet, and the Cold Bay field is about 160 miles to the southwest on the southern coast of the Alaska Peninsula. The Bering River coal fields are from 20 to 40 miles from the coast, in the valley of Bering River, which flows into Controller Bay. (See Pl. I.)

All these regions may be reached directly by steamer from Seattle, except the Cape Yaktag field, where there is no regular steamer landing. Controller Bay is from seven to nine days' sail from Seattle, Cook Inlet is about three days farther, while Cold Bay is two days beyond this. In order to reach the Cape Yaktag fields it is sometimes necessary to secure a small boat for the trip, or to walk from Controller Bay.

The earliest reference in print to the occurrence of petroleum in Alaska was by Ivan Petroff,[a] who, in 1882, said: "In the vicinity of Katmai both coal and petroleum have been found, but not abundant in quantity or excelling in quality."

Dr. W. H. Dall[b] in 1896 referred to the occurrence of petroleum on the portage from Katmai. "The petroleum is said to be a dark lubricating oil which floats on the surface of ponds and lakes."

In 1898 Mr. F. H. Oliphant published a brief statement of the indications of petroleum[c] in the Cape Yaktag, Controller Bay, and Cook Inlet regions. The character of the oil is described and a few geologic notes are given, and in 1899[d] these notes were republished.

Mr. G. H. Eldridge published in 1899 some observations on the Bering coal field and on the Controller Bay and Cape Yaktag oil fields,[e] and in 1900 Mr. J. E. Spurr[f] called attention to the occurrence of coal and petroleum in the vicinity of Controller and Icy bays and published some facts, furnished by Mr. F. H. Shepherd, concerning the geology of the region and the composition of the coal.

A brief statement of the progress of development was made by Mr. F. H. Oliphant[g] in 1900, and republished[h] in 1901.

The same year Mr. John Kirsopp, jr.,[i] published an account of the petroleum and coal in the Controller Bay and Bering River fields.

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[a] Alaska, its population, industries, and resources: Tenth Census of the United States, vol. 8, p. 87.

[b] Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, p. 799.

[c] Petroleum, in Mineral Resources U. S. for 1897: Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6 (continued), 1898, p 110.

[d] Petroleum, in Mineral Resources U. S. for 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6 (continued), 1899, p. 123.

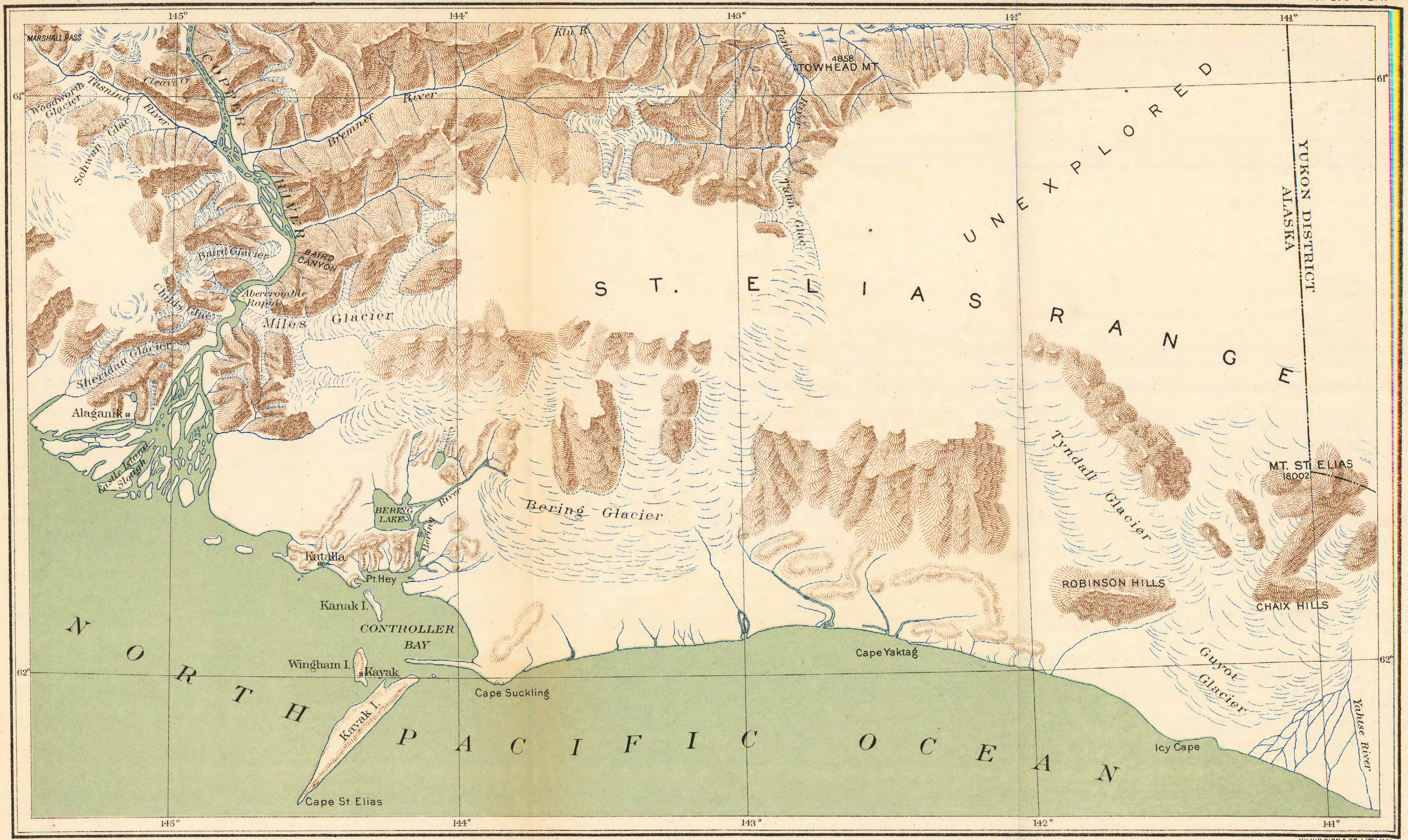
[e] The coast from Lynn Canal to Prince William Sound: In Maps and Descriptions of Routes of Exploration in Alaska in 1898; a special publication of the U. S. Geol. Survey, 1899, pp. 103–104.

[f] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 263–264.

[g] Petroleum, in Mineral Resources U. S. for 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 6 (continued), 1901, p. 167.

[h] Petroleum: Mineral Resources U. S. for 1900, U. S. Geol. Survey, 1901, p. 587.

[i] The coal fields of Cook Inlet, Alaska, U. S. A., and the Pacific coast: Trans. Inst. Min. Eng., vol. 21, pp. 536–538, 559.



MAP OF A PORTION OF THE PACIFIC COAST OF ALASKA

Scale

0 5 10 20 30 40 50 60 miles

In 1901 Mr. F. C. Schrader and Dr. Arthur C. Spencer [a] published an analysis of a sample of coal furnished them from Bering River, and a description of two samples of petroleum from the Controller Bay region. The facts in regard to the coal were summarized in 1902 by Mr. Alfred H. Brooks,[b] and he also made reference to the reported existence of petroleum between Yakutat and Controller bays, and on the west side of Cook Inlet. A statement of the operations in the Controller Bay and Cook Inlet petroleum fields [c] was made by Mr. F. H. Oliphant in 1902.

An account of the occurrence of petroleum [d] at Cold Bay, with notes on the geology of the region, was published anonymously in 1903, and Mr. F. H. Oliphant also described in considerable detail the progress of operations in the Controller Bay oil fields,[e] with references to the Cook Inlet fields. An abstract [f] of the following report was published in April, 1904, and the information therein contained was used by Mr. F. H. Oliphant [g] as the basis for his statement of the progress of operations in 1903.

CONTROLLER BAY REGION.

GEOGRAPHY.

Controller Bay, an indentation of the coast about 100 miles west of Mount St. Elias, is sheltered on the southeast by Cape Suckling and on the southwest by a group of islands of which the largest is Kayak (Pl. II). The area here to be discussed includes the shores of Controller Bay and the adjacent region, with an irregular group of low peaks having no uniform elevation or trend, which form the foothills of the Chugach Mountains to the north. These foothills are highest near the mountains and fall away irregularly toward the sea, where few points are more than 2,000 feet high. The eastern shore of Controller Bay and of Bering River is low and almost flat.

Bering River, with its tributaries, drains the central part of this region and flows through a lake of the same name, which is about 10 miles from the sea. Above the lake it receives Canyon Creek and Stillwater Creek, the latter draining Lake Kushtaka. Shepherd

[a] Geology and Mineral Resources of a Portion of the Copper River District; a special publication of the U. S. Geol. Survey, 1901, pp. 91–92.

[b] Brooks, A. H., Coal resources of Alaska: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 542, 549, 551, and 571.

[c] The production of petroleum in 1901: "Extract from" Mineral Resources U. S. for 1901, U. S. Geol. Survey, 1902, p. 208. (Not in bound volume.)

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

[e] The production of petroleum in 1902: Mineral Resources U. S. for 1902, U. S. Geol. Survey, 1903, pp. 582–584 (pp. 207–209 of separate).

[f] Petroleum fields of Alaska and the Bering River coal fields: Bull. U. S. Geol. Survey No. 225, 1904, pp. 365–382.

[g] The production of petroleum in 1903: Mineral Resources U. S. for 1903, U. S. Geol. Survey, 1904, pp. 690–692 (pp. 179–181 of separate).

Creek enters Bering Lake from the north at its northeast corner, while Nitchawak River enters Bering River from the east between the lower end of the lake and Controller Bay. Katalla River and a number of small streams drain the peninsula between the lake and Controller Bay. The region northwest of the valley of Katalla River drains into the Copper River delta. (See Pl. III.)

Most of the lowlands about Controller Bay are covered with a dense forest. Spruce and hemlock predominate among the larger trees and are of good size and fair quality. This heavy growth extends up the hillsides to an elevation of about 1,000 feet, where it gives way to less dense timber of the same species and grades into a zone in which scrub alders are far in excess of the other trees. In the lower part of the valley of Shepherd Creek and in the valley of Katalla River there are meadows covered with a luxuriant growth of grass.

The various companies interested in the development of this region have built trails from cabin to cabin, and land travel is confined to these and to a good wagon road which has been built for about 10 miles west from the mouth of Bering River to the wells 4 miles east of Katalla, with branches up the valleys of Chilkat, Burls, Mary, and Redwood creeks.

There are two short tram roads from the mouth of Redwood Creek and from the head of Katalla Slough to neighboring oil wells, and one tram road from the banks of Shepherd Creek to a neighboring coal opening. The network of rivers, however, makes it very easy to get about in small boats, so almost all travel is done in that way.

The most important settlements are Kayak, on Wingham Island, which is the steamer landing for the entire region, and the town of Katalla, at the mouth of Katalla River. There are no other settlements except the camps of the various operating companies and several small Indian villages. Kayak and Katalla are post-offices.

GEOLOGY.

The rocks include a complex series of semimetamorphosed beds, some oil-bearing shales, a succession of coal measures, a series of Miocene sandstones, conglomerates, and shales, a few igneous rocks, and a large area of alluvial and glacial deposits. The map (Pl.III) is based on such facts as could be gathered during a hasty reconnaissance.

SEMIMETAMORPHOSED ROCKS.

Under this heading is placed a succession of slightly metamorphosed sandstone, limestone, and shale which vary in color from dark gray to dull shades of red and green, frequently with a mottled

JULIUS BIEN & CO. LITH. N.Y.

MAP OF THE CONTROLLER BAY REGION

COMPILED FROM THE CONTROLLER BAY CHART OF THE COAST AND GEODETIC SURVEY, FROM MAP BY J. L. McPHERSON AND FROM PLANE-TABLE SURVEY BY G. C. MARTIN

1904

Scale

0 1 2 4 6 8 10 miles

Sketch contours, interval approximately 250 feet

Geologic reconnaissance by G. C. Martin

appearance. The degree of metamorphism is slight, the alteration being apparently the effect of crushing and infiltration. None of the minerals show the effect of extensive recrystallization.

The series is best exposed west of Katalla (see map, Pl. III) and along the neighboring shore of the Pacific, where the beds are steeply folded, dipping almost 90°, and are also somewhat crumpled. There are excellent exposures, too, on the Fox Islands, which are made up of this same series, and it was apparently again observed at the extreme southwest point of Wingham Island. Rocks of the same general appearance were also seen about 3½ miles north of Kishtak Point, in Lone Baldy Mountain, and in the valley north of that region. At the latter place petroleum was noticed in the joints. The high ranges to the north and northeast of this point are apparently composed of this formation, or of one very similar in character dipping at a high angle.

There is no evidence of the age of these rocks, or of their relation to the others to be described, except that they are apparently older than all the latter. It is possible that they represent part of the Orca or Valdes series of the Copper River region.

KATALLA FORMATION.

The Katalla formation is a series of dark argillaceous and carbonaceous shales, with occasional bands of sandstone, limestone, conglomerate, and volcanic ash. It is the series through which the petroleum of the region reaches the surface. The formation is typically exposed in the region to the northeast of Katalla, along the banks of Katalla River, and in the range of hills to the southeast. From this point it extends eastward, occupying the whole of the peninsula between Bering Lake and Controller Bay and outcropping in most of the hills south and east of Bering River. Good exposures were seen on the west shore of Bering Lake, and it is possible that some of the shales and sandstones of Kayak and Wingham islands represent the same formation. No estimate could be made of the thickness of the formation because of the complicated structure in all the districts where it is exposed.

The few fossils that have been obtained indicate that the Katalla formation is of Tertiary age. Several specimens of a crab and fragments of a gastropod were collected on the west shore of Bering Lake, and fragments of a pelecypod were seen at the mouth of Bering River, and a fossiliferous limestone concretion with many fragmentary pelecypods was collected in the bed of Chilkat Creek. These were submitted for determination to Dr. T. W. Stanton, who reports as follows: "The very small lots from the neighborhood of Bering Lake and Controller Bay are probably of Tertiary age." The following lists give the preliminary determinations of fossils from each locality.

2938. West end of Bering Lake, in concretions. Several specimens of a crab apparently belonging to the group Catometopa and related to the modern genus *Pilumnoplex* of the family Gonioplacidæ. The Catometopa range back only to the Eocene according to Zittel. It seems probable, therefore, that these specimens are not older than Tertiary.

A fragment labeled "Camp of June 27 to 29, west end of Bering Lake," shows an imprint of a small costate gastropod not well enough preserved for identification.

2939. North end of Bering Lake, Alaska. Fragment of a gastropod that may be a *Turbo* or a related form. Small indeterminate bivalve, possibly a venerid.

2940. Mouth of Bering River, Controller Bay. Fragments of an undetermined bivalve.

2946. Chilkat Creek near Controller Bay. Fossiliferous limestone nodule with many fragmentary bivalves. Nothing determinable.

Point Hey, Controller Bay,[a] *Phacoides* (?) sp., *Callista* (?) sp., *Conus* sp., *Fusus* sp. A (medium), *Fusus* 2 sp. (small), *Turritella* sp., *Dentalium* sp. "Poor material, but the *Conus*, *Fusus*, and *Dentalium* look like Eocene forms."

Between Point Hey and Strawberry Point.[a] *Astrodapis* (?) sp., *Semete* (?) sp., *Dentalium* sp.

The paleontologic evidence concerning the position of the formation is therefore rather indefinite, but indicates that the age is certainly Tertiary and probably Eocene. There is no stratigraphic evidence on this question, for the exact age of neither of the adjacent formations has been determined with certainty. While the Katalla shales are evidently younger than the semimetamorphosed rocks, which may be the equivalent of the Paleozoic or Mesozoic Orca or Valdes formation, they are probably older than the Kushtaka coal measures, which are doubtful, but probably of Oligocene age.

KUSHTAKA FORMATION.

This name is here proposed for a coal-bearing series of strata, exposed in the valley of Bering River and its tributaries and on the shores of Lake Kushtaka, and consisting of an unknown thickness (at least many hundred and probably several thousand feet) of shale, arkosic sandstone, and coal seams. No detailed section of the formation has been found. Its areal extent, so far as now known, has been indicated in a preceding paragraph and is shown on the accompanying map (Pl. III). Its lower boundary may be taken at the base of the lowest coal in this region or at the first mappable stratigraphic break below that. Its upper limit may be taken at the top of the highest coal or at the next succeeding mappable stratigraphic break.

The formation is distinguished from the Katalla formation, which

[a] Determined by Dr. W. H. Dall and Dr. Ralph Arnold.

lies in an adjacent belt to the south of it, by the presence of coal seams, the predominance of sandstone over shale, and the coarseness of the sediments. It evidently adjoins on the north a belt of crystalline formations, of which numerous fragments have been transported into this region by streams and glaciers. The stratigraphic relation to the formations existing in the adjacent areas is not known, except that the general structure of the region is such as to indicate that it overlies the Katalla formation, which probably occupies a low horizon in the Tertiary.

The formation has yielded the following fossils (as determined by Dr. F. H. Knowlton): *Salix* sp. cf. *S. varians*, *Corylus macquarrii*, *Betula prisca*, and *Betula grandifolia.* All of these occur also at Port Graham in the Kenai formation, and are representative of the so-called Arctic Miocene or Oligocene. Poorly preserved fragments, which probably represent species of *Zizyphus* and *Laurus* were also found.

MIOCENE ROCKS.

The rocks exposed on the north shore of Kayak Island consist of beds of conglomerate, sandstone, and shale, with a marine fauna in which Dr. W. H. Dall and Dr. Ralph Arnold have identified the following species: *Leda* sp. A. (smooth), *Yoldia* aff. *scissurata* Dall, *Yoldia* aff. *thraciaformis* Dall, *Macoma* cf. *calcarea* Gmel., *Callista* sp., *Natica* sp., *Chrysodomus* sp. A., *Chrysodomus* sp. B., *Rostellites* cf. *indurata* Conrad. They are of the opinion that this fauna is upper Oligocene or lower Miocene, and is the equivalent of the marine faunas at Unga and Cape Yaktag.

IGNEOUS ROCKS.

Several igneous masses were seen on the west shore of Bering River near its mouth, and include dikes of a light-colored, fine-grained rock, tentatively determined under the microscope to be a micro-granite. About one-half mile above this point and just below the Chilkat Indian village are numerous exposures of a fine-grained, dark-green, igneous rock, which upon examination proves to be a chloritized tuff.

A massive, light-colored, medium-grained rock is exposed in the north bank of Bering River at the south end of Carbon Mountain, and the island in the river at this point is perhaps of the same composition. It is possibly of igneous origin and may have furnished the heat that produced the coke occurring in the vicinity. Specimens of this massive rock were collected but were lost in shipment, and no determination of either its name or its general character can be made. Several large masses of a basic glassy rock have broken up through the Miocene rocks on the north shore of Kayak Island.

The extreme southern end of Kayak Island, known as Cape St. Elias, rises in a high peak, having the appearance of a volcanic plug. The rock is of light color, has a columnar jointing, and is somewhat exfoliated and has been identified microscopically as a trachyte.

PLEISTOCENE AND RECENT DEPOSITS.

At the southern end of Wingham Island are good exposures of horizontal or gently dipping unconsolidated sand, clays, and gravels. These strata rest unconformably upon the upturned edges of the shales, which make up the larger part of the island. They are fossiliferous, containing *Ostrea* and a variety of other pelecypods and gastropods, which are surely not older than Pliocene. It is possible, and from the structural relations of these beds as compared with the other Tertiary and Quaternary deposits of the coast of Alaska, it seems probable that these beds are, indeed, very late Tertiary or post-Tertiary. They are exposed at an elevation of from 10 to 30 feet, and possibly date from the most recent elevation of the coast. Gravels which are accompanied by finer deposits and carry no fossils are exposed in a similar position along the bluffs near and to the west of Fox Islands, and probably also represent the most recent elevation.

The eastern shore of Bering River and Controller Bay, from a point slightly below the mouth of Stillwater Creek to the ocean, is a flat plain of sand and mud, constantly growing by the addition of sediment which the streams from the southwestern margin of the Bering Glacier carry and deposit along their courses and at their mouths. Mount Nitchawak, Mount Campbell, Mount Gandil, and other peaks rise like islands from this plain, and it seems certain that a very short time ago they were islands in an older extension of Controller Bay, then as now being filled by the sediment of these glacial streams. This younger fluviatile Quaternary formation extends along the northern bank of Bering River from a point about 3 miles below the mouth of Stillwater Creek to Bering Lake. It also extends up the valley of Shepherd Creek for a distance of about 4 miles above the lake, and apparently to the southern end of Lake Kushtaka. The valley of Katalla River and of the stream which heads near it and flows into Bering Lake is floored with the same material, as are also the lower courses of most other streams which enter Controller Bay. The deposits are known to have a thickness of over 580 feet at one point on Bering River, and of over 240 feet in the Katalla Valley.

Another series of deposits contemporaneous with the last, yet different in origin, are the beaches, islands, and bars which the waves of the ocean are building along these shores. Okalee sand spit and the long beach extending from Strawberry Harbor to the mouth of Katalla River are good examples. Others, which extend out of the region here described, are Softuk Bar and the line of bars and sand hills extending in line with it across the margin of the Copper River delta.

GLACIERS AND GLACIAL DEPOSITS.

The Bering Glacier, previously mentioned as supplying Bering and other rivers, is a large glacier of the Piedmont type, and, if considered independently, is second in size, among glaciers of this type, only to the Malaspina Glacier. It is a large field of stagnant ice, which has overflooded the eastern extension of the zone of coastal foothills described above, and it is considered by many as merely the western lobe of the Malaspina Glacier. It is, however, in all probability entirely separate from the latter. A great many valley glaciers coming from the Chugach Range enter it as tributaries. It is fringed along its southwestern border by a wide moraine, while the ice itself is thickly covered with rock débris for a distance of several miles from its front, and, as in the case of the Malaspina Glacier, this covering is so thick that it is often impossible to determine the margin of the glacier itself. During the warm summers large lakes are formed on the surface of the ice, which later in the season break loose and subject the valleys of the Bering, the Nitchawak, and other streams draining the ice front to severe floods. The entire region from the lower tidal channel of Bering River eastward to the ice front, a distance of over 10 miles, is a great flood plain formed of the débris which these rivers are depositing.

In the region north of Bering River there are a number of valley glaciers not tributary to the Bering Glacier, the best known of which is the Martin River Glacier, which flows northward behind the coal field, and one lobe of which is the Kushtaka Glacier, entering the lake of the same name. There are others to the northwest which have received no names and are unmapped.

STRUCTURE.

DETAILS.

An anticline extends through the Katalla Valley in an average direction of N. 38° E. Exposures on the western flank showed strikes of N. 55° E. and N. 85° E., with dips varying from 18° to 65° NW., on the west shore of Bering Lake; and a strike of about N. 40° E., with a dip of 70° NW., near the mouth of Deep Creek. The strata are almost continuously exposed along the eastern flank in the high ridge forming the eastern side of the valley. The strike varies from north to N. 40° E. and the dip from 32° to 60° SE. The outcrop in the high southern peak of this ridge is an unexplained irregularity, for the strike is N. 30° W., with a dip of 35° SW. From this point a ridge extends northeastward along the eastern side of the Katalla Valley. The strike and dip last mentioned are apparently confined to the southern peak of this ridge, for beyond the first saddle which separates it from the continuation of the ridge the strike is along the crest of the ridge, N. 40° E., with a dip of 35° SE. (See Pl. III.) This ridge is, then, apparently monoclinal, with the exception of its southwestern peak, where the strata have been abruptly flexed or faulted, striking almost at right angles to those in the rest of the ridge.

The exposures on the western shore of Bering Lake show greater uniformity of strike than those hitherto described. The strike varies from N. 55° E. to N. 85° E., while the dip is from 18° to 65° NW. This strike if continued southwestward would carry the same strata and the same structure into the hills on the northwestern side of the Katalla Valley, and would thus make Katalla River occupy an anticlinal area with a northeast-southwest direction. This strike does not seem to continue northeastward across Bering Lake, for the strata on the north shore of the lake apparently belong to a different formation and have a different structure. It is possible, then, that the northwestern arm of the lake occupies the position of a fault which extends north and south parallel to the western shore of the lake. If this fault is continued southward into the region of the hills on the western side of the Burls Creek Valley, it may explain some of the apparently strong variations in the structure within short distances, which have been alluded to above.

In the valley of Burls Creek, however, a great complexity of structural relations exists, almost no two outcrops agreeing, even in the general direction of the strike or dip. The outcrops nearest the shore of Bering Lake, on the western slope of the creek's valley, have a strike of N. 30° E. and a dip varying from 45° to 60° SE. This corresponds in general direction and amount with the strike and dip of the ridge forming the eastern slope of the Katalla Valley, and inasmuch as this hill is in a general way the most northeasterly outlier of this ridge it is possible that it is a part of the same anticlinal fold. In a peak 1 mile to the south an approximate north-south strike was observed, with a dip of 45° to the west. This would seem to lie upon the eastern flank of a syncline whose axis corresponds in a general way with the position of the group of hills occupying the area between Redwood Creek and Mary Creek. This syncline might be considered the northern prolongation of the one shown in the crescent-shaped ridge bordering the northern shore of Strawberry Harbor.

The peninsula from Point Hey to Cave Point consists of a crescent-shaped ridge, its concave face toward the sea, and forming the northern shore of Strawberry Harbor (Pl. III). The dip is everywhere toward this concavity, changing from southwest at Point Hey to southeast at Cave Point, indicating the presence of a pitching syncline, of wihch only the nose is on land.

An outcrop at the lower edge of the abrupt slope rising from the tidal flat about halfway between Burls Creek and Mary Creek has a strike N. 55° E. and a dip of 52° NW. This would not seem to readily fit into any of the general structure hitherto described, and can only be explained at present as a local variation in the eastern flank of the above-mentioned syncline. (See Pl. III.)

Chilkat Creek, which occupies the valley between Bering River and Burls Creek, has exposed a great many excellent outcrops. It is evident that a sharp anticline extends along the general line of this valley from northeast to southwest, the dip of the flanks averaging about 45°. The center of the anticline is very steep and locally crumpled. The ridge east of this valley, between it and Bering River, is apparently synclinal, with a strike of about N. 40° E. This fold is very sharp along its axis, for the rocks at the mouth of Bering River stand vertical, though farther up the river the dip is 40° NW.

The strike of the coal formation is, in general, from northeast to southwest; and the dip is to the northwest. There are certain variations, but they appear to be due to local disturbances. The structure of the region as now known is chiefly monoclinal. The continuation of this feature to the southwest would carry the coal into the hills on the west shore of Bering Lake and on the west bank of Katalla River. No coal is known, however, in these hills, and the shales exposed on the west shore of the lake appear to be identical with those on the south shore, which have been described in the preceding chapter as the Katalla formation. It is evident, therefore, that there is a line of faulting through the north end of the lake and parallel to the west shore. The coal is apparently absent to the west of this fault. It would appear from the dip that the Kushtaka formation overlies the Katalla formation; there is, however, no positive proof that such is the case. No contact of the two has been observed, and there is no reason why other explanations of the existing phenomena may not be found.

The monoclinal dip, which has been observed as continuing for several miles up the valley of Canyon Creek, would seem to indicate a thickness of many thousand feet in the Kushtaka coal measures. Several faults, however, were observed in the banks of Canyon Creek, and it may be that these are numerous enough or of sufficient displacement to cause the thickness of the formation to appear greatly increased.

This monoclinal dip is apparently modified by only two folds within the region hitherto explored. There is one fault which probably has considerable length and displacement, and an undetermined number of smaller ones.

One of these folds is an incline exposed near the headwaters of Queen Creek on the divide between the Shepherd Creek and Lake Kushtaka valleys. The rocks here have a strike of N. 64° to 66° E., with a dip of 42° NW. on the northwest flank of the fold, and 58° SE. on the southeast flank. The latter is cut by a fault of unknown but probably of considerable magnitude. The other is a sharp syncline, which apparently lies in the hills east of Lake Charlotte. Its presence is indicated by the fact that the dip of the Charlotte seam at the openings above the lake is southeast. It is not known how far in either direction this southeast dip continues.

A northeast strike and a northwest dip, corresponding to many of those alluded to above, may be seen on Kayak and Wingham islands and in the hills of the Nitchawak region. Each of these areas considered independently is therefore monoclinal. The intervening areas, where the solid rock is concealed by water or lowland, are so broad that the general structure can not be made out.

The rocks on the shore of the mainland near Fox Island, and apparently those of the islands themselves, have a strike of N. 70° W., parallel to the shore, with a steep seaward dip. The high ridge northeast of this point seemingly consists of rocks standing almost vertical, with a north-south strike parallel to the ridge. On Lone Baldy Mountain, about 3 miles north of Fox Islands, the strike is N. 80° E. and the dip 80° NW. The high ridge about 2 miles north of this point apparently has a strike parallel to this and a steep dip. The relation of this dip to that observed at Fox Islands and on the ridge northeast of them has not been determined.

GENERAL FEATURES.

It can be seen from the statements given above that the structure of this region is very complex, at least so far as the minor details are concerned. The outcrops are almost wholly confined to the higher ridges and to the deep canyons. Many of the latter were almost inaccessible to the author on account of the amount of snow and ice at the time of his visit. The observations are, therefore, not numerous and are widely scattered. It is probable that a large proportion of these observations do not represent the major structure of the region, but rather a minor crumpling which is attendant upon the dominant, simpler, structure. This major structure can be made out only by platting so large a number of observations that the entire structure will be evident, both in its broader features and in its less essential and diverse details, or else by determining some characteristic strata whose general position of outcrop can be readily followed, and which can be made to thus give the key to the major structure. Unfortunately the rocks of the Katalla formation are so homogeneous throughout that no strata have been so far observed which are characteristic enough to make the dominant structure evident, and the observations which have been made are not abundant enough to determine the complete structural relations as suggested for another method.

There appears to be a larger folding, modified by a minor folding, that often reveals itself merely as a crumpling in the softer shales but which is locally so strongly developed as to obscure the major folding. There are thus two sets of structural features, one of which reveals itself in an east-west and the other in a northeast-southwest strike. The first is well shown in the great anticline which is described below as extending along the coast at Cape Yaktag; and it again appears in some of the exposures of this region, especially along the coast near Katalla. Of the second series of folds, those extending in a direction from northeast to southwest, one of the most illustrative is the anticline which apparently extends along the center of the Katalla Valley. This is paralleled by a number of other folds east of it in the peninsula between Bering Lake and Controller Bay, one of the most distinct being the anticline in the little valley nearest Bering River. The central part of the peninsula appears to consist of a succession of folds, several of which are exposed in the valley of Burls Creek.

The structure of this region appears at first sight to be extremely complex, the strikes and dips being of almost indescribable irregularity. More careful studies made during the summer of 1904, have, however, shown that part of the irregular outcrops are of large blocks which have been displaced by gravity on the steep hillsides, while part of them may be assigned to a minor crumpling in the softer beds. Others may be due to faulting, but the amount of influence of this factor is not known.

After the irregularities due to the above-mentioned cause have been eliminated, the following structural features distinctly appear. The prevailing strike is northeast and southwest and the prevailing dip is from 35° to 60°. The region between Bering Lake and Controller Bay consists of an undetermined number of parallel, closely folded anticlines and synclines, with pitching axes of which the average direction is N. 35° E. The most plainly developed of these folds are the Katalla Valley anticline, the Strawberry Point syncline, and the Chilkat Creek anticline.

The structure of that part of the coal area which was visited by the writer is rather simple. The strike is fairly regular in direction (northeast and southwest), and the dip is chiefly northwestward. The uncertain factor is the total amount of influence of the faults.

ECONOMIC MATERIALS.

PETROLEUM.

Petroleum seepages.—Petroleum seepages are very abundant in the Controller Bay region. Those which are best known are situated about 4 miles east of Katalla. The flow of oil here is very large, and good-sized pools have collected on the surface. Another group of seepages is on the headwaters of Burls Creek, where the petroleum may be seen oozing from the joints and bedding planes of the carbonaceous shales and volcanic ash beds which are exposed in the deep ravines. The quantity of petroleum here showing is not so large as at the seepages east of Katalla, but it is more widespread. The small stream between Burls Creek and Bering River has several seepages along its bank. Seepages occur, too, in other parts of the peninsula between Bering Lake and Controller Bay and in the region west of Katalla. The so-called "Nitchawak region," which is situated on the banks of the various branches of Nitchawak River and in the vicinity of Mount Nitchawak, also presents a number of seepages. Some of these are located on the banks of a small lake, which is reported to be at times covered with petroleum. The small creeks which enter Little Nitchawak River from the north have a number of seepages on their banks, in some of which oil issues directly from the rock, which is here a shale. The canyon north of Lone Baldy Mountain and between it and Ragged Mountain contains a number of seepages, in which the oil may be seen oozing from the cracks of the rock.

A strong flow of gas bubbles to the surface of the water at a number of places along the lower course of Katalla River. In places this flow is so strong that it can be heard for a distance of several hundred feet. The composition of the gas is not known. Several large sulphur springs issue from the northern bank of Bering River within a mile on either side of the Indian village.

Most of the seepages between Katalla and Bering River fall approximately on three straight lines, each having a general northeast-southwest direction. These lines are nearly parallel to the strike in their vicinity, and are undoubtedly influenced in position and direction by the structure. They probably represent the outcrops of oil-bearing strata. The easternmost of them is on the western flank, but very close to the crest of the Chilkat Creek anticline. The westernmost is on the eastern flank and about halfway down the Katalla anticline. Those in the valley of Burls Creek are in a less certain structural position.

The gas springs on the banks of Katalla River are probably located on or near the crest of the Katalla anticline.

Petroleum wells.—The first well in the Controller Bay region was drilled in the summer of 1901. Work upon it was stopped owing to the loss of tools. The same company drilled another well in the summer of 1902, which at a depth of about 250 feet yielded some petroleum. At a depth of 360 feet the tools appeared to break through into a cavity of the rock and a large flow of oil began, spouting, it is reported, many feet above the top of the derrick. No estimate of the amount of the flow has been made. This well was immediately capped, to be reopened in July, 1903, and drilled deeper, and it is now reported to have a total depth of 550 feet.

The following is a record of the well as reported by the Alaska Steam Coal and Petroleum Syndicate, and published by Mr. F. H. Oliphant:[a]

Well record near Controller Bay.

	Depth, in feet.
6 feet surface drift	6
10 feet decomposed shale	16
140 feet light-colored shale	156
18 feet fine-grained sandstone	174
One-half foot coal contained in the sandstone	174½
190 feet dark shale, very hard	364½
One-half foot quartz containing iron pyrites, and contained in the shale	365
1 foot oil sand and flow of oil	366
Total	366
Length of 12-inch casing	220
Length of 9⅝-inch casing	340

Numerous small showings of petroleum and natural gas were encountered as the drill proceeded, and at 366 feet a large flow of oil was developed. The well is said to have continued to flow until capped.

Another company began work in the spring of 1903 on a well about 4,000 feet south of the first producing well mentioned above. In July this well was abandoned at a depth of 1,700 feet, that being as far as it was possible to drill with the light rig which was used. No flow of oil was encountered, but a little was brought up in the bailer from time to time.

It should be noted, in comparing the results obtained in these two wells, that the location of the second with reference to the first is in the direction of the dip. The dip is very steep in the interval of 4,000 feet between the wells, and while the exact amount is undetermined it is surely enough to carry the oil sand that was tapped in the first well to a depth considerably exceeding 3,000 feet at the location of the second.

[a] The production of petroleum in 1902: Mineral Resources U. S. for 1902, U. S. Geol. Survey, 1903, p. 583.

Another well on the north bank of Katalla River, about 2 miles above the town of Katalla, was begun by the same company during July, 1903. The latest information which the author has received is that it was drilled to a depth of 240 feet without reaching solid rock. A third company began drilling in July 1903, about 7 miles above the mouth of Bering River. At last reports this well had attained a depth of 580 feet and bed rock had not been reached.

Fifteen wells had been drilled or were drilling in this region in September, 1904. Of these, two are in the Katalla Valley, one is 3 miles east of Katalla near Cave Point, two are on Strawberry Harbor, nine are between the head of Katalla Slough and the mouth of Bering River, and one is on Bering River about 4 miles above its mouth. Of these wells, three (one in the Katalla Valley, one on Strawberry Harbor, and one on Bering River) were abandoned before reaching bed rock. Four of them (one in the Katalla Valley, one at Strawberry Harbor, and two west of the mouth of Bering River) are still drilling. Of the remaining eight wells, three were mentioned in an earlier report.[a] One of these is now furnishing oil which is used as fuel at the other wells of the same company. No statistics regarding the present production of the well are at hand, nor is it known how much greater the yield might be if the well were pumped continuously.

The amount of authentic information which has been given out for publication regarding these wells is extremely small.

It is reported that none of the remaining five wells has produced oil in commercial quantities. But it is furthermore said that none of them has reached a depth exceeding 1,100 feet, in which case it may be assumed that the possibilitites of the field have not yet been conclusively tested.

Mr. F. H. Oliphant, in summarizing the developments during 1903, said of this field:[b]

"The developments in Alaska during 1903 have not resulted in any commercial production of petroleum, notwithstanding the numerous surface indications and the wells that have been completed in the supposed productive territory. The prospectors should not, however, be discouraged, although it may require patience and careful prospecting with the drill to tap the reservoirs, whose existence seems to be indicated by remarkable surface shows of both petroleum and natural gas."

Great difficulty has been experienced in all parts of the field in keeping the holes straight and free from water. This has made progress very slow and deep drilling sometimes impossible. Perhaps

[a] Bull. U. S. Geol. Survey No. 225, 1904, pp. 368–369.

[b] The production of petroleum in 1903: Mineral Resources U. S. for 1903, U. S. Geol. Survey, 1904, p. 690.

some of the wells would have been more successful if they could have been continued to greater depths.

Three wells which were located on mud flats at some distance from high land or from exposure of solid rock had difficulty or did not succeed in reaching bed rock. In two cases the drivepipe was sunk to depths of 240 and 580 feet through mud without reaching solid rock. These instances show conclusively the inadvisability, in the present stage of development, of attempting to locate wells on the flats. After a field is proven, then the mud flats adjoining it longitudinally may be considered to have a speculative value. At present there is no indication that they are worth anything.

Another instance illustrating the folly of investing in the low grounds, and also of investing without thorough investigation, is the case of a tract which was staked and sold for $1,700 during the past winter. In the spring the supposed land floated and melted entirely away, the stakes having been driven in the ice off the shore of Controller Bay. It is generally believed in the region that there was no intent to defraud.

Structural relations of the petroleum.—The conditions believed by the majority of observers to be necessary to the occurrence of petroleum in commercial quantities are, first, the presence, originally, of a large amount of organic matter in the sediments from which the oil was derived; second, the existence of a porous rock, in the aggregate very considerable, in which the oil could accumulate, and, third, the protection of this rock in such a manner that the oil can not escape. The condition generally regarded as affording the most efficient protection is the presence of an overlying stratum of fine compact rock which the oil can not penetrate and the flexure of the strata into a gentle anticline, so that escape of the oil is cut off both in an upward direction and laterally—in the latter case, it may be, by the body of water behind it. Other conditions which govern the accumulation and distribution of oil are changes in the porosity of the containing bed, either from variation in the coarseness of sediment or from the filling of the interstices with mineral deposits, such as carbonate of lime. Underground water also doubtless plays a part in the accumulation and distribution of oil.

From the size and distribution of the seepages it may be reasonably inferred that a vast amount of organic matter which was subsequently converted into petroleum was incorporated with the sediments now constituting the oil-bearing shales of the Controller Bay region; the appearance of the rocks is evidence that there are numerous horizons in the series sufficiently porous to afford reservoirs for the accumulation of oil, and the successful wells show that the conditions are favorable for at least one productive field. Conditions below the surface are, however, frequently very difficult even to surmise, and the aid ordinarily derived from well records is not yet sufficient in this field to show conclusively the relation in depth between the occurrence of the oil and the structure and stratigraphy of the containing series. The structure of the field is complex, but if drillings are made after a careful consideration of all geologic details the existence of valuable oil areas may perhaps soon be proved and their definition safely suggested.

CAPE YAKTAG PETROLEUM FIELD.

Cape Yaktag is situated about 75 miles east of Controller Bay. The shore line is here straight, and there is no harbor which affords shelter for any kind of boat. (See fig. 1.) A strip of land from 5 to

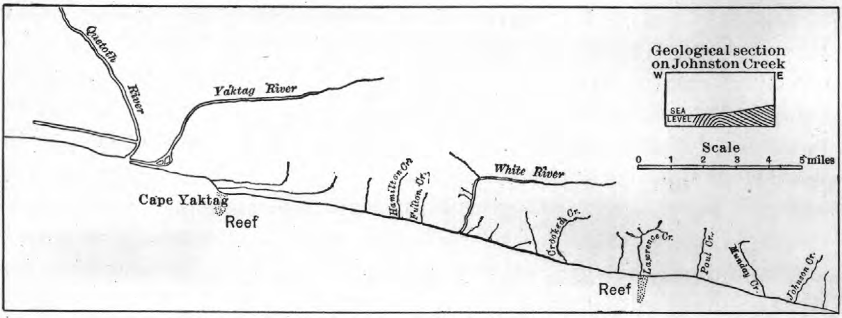


FIG. 1.—Sketch map of Cape Yaktag petroleum field.

10 miles in width lies between the coast and Bering Glacier. The ice front is marked by a line of hills which are parallel to the coast and from which a steep slope descends to the sea. This slope is drained by many short parallel streams, some of which head in the ice. The Cape Yaktag oil field extends eastward for about 25 miles from the mouth of Yaktag River, which is the easternmost of the longer streams reaching the ocean near Cape Yaktag (fig. 1).

Geology.—The writer was not able to visit this region, so that the following observations are based upon the statements of others: The structure, it is said, is anticlinal, with the axis parallel to and very near the shore line. The dip on the southern flank of the fold is very steep, the rocks standing vertical along the beach. The dip on the northern side in much gentler, seldom exceeding 20°. This continues inland as far as the region has been explored. The rocks consist of shales with interbedded sandstone and limestone, the whole resembling very closely in lithologic character some of the rocks of the Controller Bay oil field. They here carry fossils which show them to be of Miocene age. A list of these fossils was published by Mr. J. E. Spurr.[a] The structure of the region is very uniform, and no marked variations from the strike and dip recorded above were noticed.

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

Occurrence of the petroleum.—There are said to be good seepages in several of the creeks in this belt, and the petroleum is regarded as similar in character to that of the Controller Bay field. It oozes from the rocks along the crest of the anticline. No development work has been done, due to the difficulty of transporting machinery, which it would be necessary either to land through the surf on the open coast or to transport overland for a distance of 75 miles from Controller Bay. The latter will be an impossibility until roads are constructed.

COAL.

BERING RIVER COAL FIELD.

The field.—The Bering River coal field lies from 12 to 25 miles inland from Controller Bay. The coal area, as far as known, is restricted to the region north of Bering Lake and Bering River. Its southern boundary appears to coincide approximately with the position of Bering Lake and with Bering River above the lake. The western boundary, although not definitely known, is assumed to lie along a north-south line extending through the northwest arm of Bering Lake parallel to its western shore. The northern and eastern boundaries are also uncertain, but are probably at a considerable distance beyond the region as now known. The coal area as at present recognized includes about 120 square miles. (See Pl. III.)

The coal is known to extend as far north as the Martin River Glacier and as far east as the valley east of Carbon Mountain. It is possible that further exploration will reveal the presence of coal north of the Martin River Glacier in the foothills of the Chugach Mountains or in the region to the east of Carbon Mountain.

The lowlands which border the northeast shore of Bering Lake and extend up Shepherd Creek, Bering River, and other streams are doubtless underlain by coal. The covering of mud and other soft deposits is probably very thick, and the uncertainties of deep mining below it are so great that these lands are now of very doubtful value. The same applies to the area covered by the Bering, Martin River, and Kushtaka glaciers. The above estimates of the coal area include only the high land lying above and between the tidal flats and river flats and the glaciers.

Geologic occurrence of the coal.—The coal is restricted to the rocks of the Kushtaka formation described above. The following local sections have been measured by the writer:

Section in lower tunnel on east bank of Carbon Creek.

	Feet.
Dark shale	2
Coal	20
Massive, arkosic, cross-bedded sandstone with many thin carbonaceous streaks	10

The strike at this point is N. 65° E. The roof of the seam dips 60° NW., the floor 78° NW.

About 100 yards northwest of this point a seam containing about 3 feet of clean coal has been exposed. One mile northwest, at what is known as Doyle Camp, a coal 20½ feet thick is exposed. The strike of the roof is N. 10° E., of the floor N. 30° W.; the dip is from 75° to 85° E. Both roof and floor are very irregular and the coal has been found to be entirely cut off by a fault.

Several seams have been opened near the headwaters of Shepherd Creek, of which the most promising is the Charlotte seam, on the hillside southeast of Lake Charlotte.

Section of the Charlotte seam.

Shale roof	10 ft.+	
Coal		2 in.
Shale		5 in.
Coal	9 ft.	6 in.
Shale and coal	6 ft.	

Strike, N. 12° E.; dip, 72° SE.

The same seam has been opened again about half a mile south of this point. The coal in this seam is firmer and should stand shipment with less crushing than any other seen by the writer in this field.

Section 1 mile northwest of Canoe Landing on Shepherd Creek.

	Ft.	In.
Coal	3	0
Shale	0	2
Coal	4	4

The strike at this point is N. 20° E., the dip 65° NW. The opening is on the west side of the valley of Shepherd Creek, at an elevation of about 200 feet above Bering Lake.

The region adjoining the north shore of Bering Lake has been exploited to a considerable extent during the past season and a small amount of coal mined for local use. The seams so far discovered in this region are smaller than those described from other parts of the field.

The high ridge between Lake Kushtaka and Shepherd Creek contains a large number of seams. There are probably at least 20 of these seams which are 5 feet or more in thickness and several which are over 20 feet thick.

The western slope of this ridge is drained by Queen Creek and other branches of Carbon Creek. Queen Creek has cut into the crest of a sharp anticline, which is probably faulted on its southeastern flank, and on both flanks of which coal seams are exposed. The coals in this locality are of extraordinary thickness, perhaps having swollen into pockets near the crest of the field. (See fig. 2.)

Section of coal on northwest bank of Queen Creek.

	Feet.
Shale roof.	
Coal	27
Shale (pocket?)	7
Coal	2
Shale	10
Coal	31
Shale floor.	

Section of coal on southeast bank of Queen Creek.

	Ft.	In.
Coal	14	0
Shale	4	0
Coal	7	0
Shale	0	3
Coal	2	0
Shale	0	2
Coal	10	0

FIG. 2.—Section on Queen Creek, showing structure and coal seams. Scale, 1 inch = 75 feet.

Several prospect openings and a well-constructed tunnel have been driven into the banks of Carbon Creek. The latter intersected two seams, the larger of which has a thickness of 8 feet of clean coal. This is not the same as the Carbon Creek tunnel mentioned above.

The valley of Stillwater Creek and Lake Kushtaka has been shown to contain a great deal of valuable coal. A trail recently built northward from the western shore of Lake Kushtaka exposes 15 or 16 seams. The writer has seen one seam on the west side of Lake Kushtaka which has a thickness of over 22 feet, and several others with thicknesses of from 8 to 15 feet. It is reported that a thickness of over 60 feet of coal was found in a tunnel in one of the valleys on the north side of Stillwater Creek.

The following section is exposed in the west bank of Trout Creek, 2 miles above its juncture with Stillwater Creek and 6 miles above the mouth of the latter:

Section on Trout Creek.

	Feet.
Shale	4
Coal	6½
Sandstone	5

The strike is N. 40° E., the dip 38° W.

Several valuable seams have recently been opened in the valley of Canyon Creek and on the opposite (east) side of Carbon Mountain. It is said that of fifteen openings in the same seam on Carbon Mountain which showed a range of thickness from 9 to 25 feet, nine revealed a thickness of 14 feet or more. About a dozen workable seams have been reported from this region. The writer has already published the following sections of the coal and coke seen by him in this vicinity,[a] which were all that were accessible when he was there in 1903.

Four seams are exposed on the east bank of Canyon Creek. Three miles above the mouth the coal has a thickness of 2 feet 9 inches, is overlain by sandstone, and has a shale floor. The strike is N. 80° E., the dip 35° W. The section was measured at the level of the valley floor. This seam is variable in thickness, pinching out somewhat higher in the bluff.

Four miles above the mouth of Canyon Creek a coal has a thickness of 4 feet 2 inches; it strikes N. 10° E. and dips 60° W., and has a shale roof and floor.

At the south end of Carbon Mountain there is a high bluff where Bering River has been pushed against the end of the mountain by the Bering Glacier, and here the following section was measured:

Section at south end of Carbon Mountain.

	Feet.
Sandstone	30
Coke	1
Sandstone	20
Coke	2
Sandstone	2 to 5
Coke	1 to 5
Sandstone	3
Coke	1
Sandstone	8
Coke	1¾ to 2¼

The strike at this point is N. 80° W., the dip from 20° to 25° N.

It is the opinion of the writer that the foregoing sections represent distinct coals, and that, furthermore, from the smut observed by him, many additional ones will be discovered in the development of the country which are now concealed beneath the soil and the dense vegetation.

[a] Bull. U. S. Geol. Survey No. 225, 1904, p. 372.

Owing to the general northerly dip throughout the coal field, the northern portion of it, as at present recognized, is underlain by a far greater number of seams than the southern. But the northward extent of the field, the nature of its structure, and the manner of its termination remain unknown.

The features to be considered by the mining engineer embrace faults and their attendant problems, steep dips, the proportion of the seams above water level, accessibility, and the physical properties of the coal as affecting its shipment and market value, a tendency to crush being especially noticeable.

The lands within the region noted above as known to be coal bearing have for the most part, if not entirely, been located, and it is understood that some of the holders are about to secure patents. It seems probable that there are unlocated coal lands in the unexplored area to the east and northeast.

The work which has been done in the development of this field is entirely pioneer development work. Land surveys have been made of most of the larger holdings. Several railway routes have been surveyed. Many miles of good trails have been built, and a large number of cabins erected. A large number of prospect openings have been made and several more extensive tunnels dug. There is a tramroad and a gravity plane from Shepherd Creek to a tunnel on the hillside to the westward. A small amount of coal is being mined for local use in stoves and as blacksmith coal at some of the neighboring oil wells.

More extensive mining will be delayed until shipping facilities are provided at Controller Bay or elsewhere, and a railroad is built from the harbor to the mines.

Character of the coal.—The physical properties of the coal are very much alike in all the seams and in all parts of the field visited by the writer. The coal resembles the harder bituminous coals of the East more than it does anthracite. It is doubtful, too, if much of the coal could be sized so as to compete with anthracite coal for domestic use; and again, under ordinary handling it will probably crush to almost the same extent as the harder grades of semibituminous coal, which will not, of course, impair its value for steam purposes, but will necessitate careful handling if it is to at all compete with Pennsylvania or Welsh anthracite as a domestic fuel.

The following table includes all the analyses and calorimetric tests which have been made of the Bering River coal. The first nine samples were collected by the author and represent the composition of the entire seam; that is, coal was cut evenly from the seam, from roof to floor.

Analyses and tests of Bering River coals.

Locality.	Thickness of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Color of ash.	Calories.	Recalculated. Fuel elements. Volatile matter.	Recalculated. Fuel elements. Fixed carbon.	Recalculated. Fuel ratio.
	Feet.										
1. Carbon Creek[a]	20	2.41	15.03	79.24	3.32	0.51	Reddish	8,345	15.94	84.06	5.27
2. Shepherd Creek[a]	7⅓	1.54	14.58	72.99	10.89	.69	Yellow	7,664	16.65	83.35	5.01
3. Trout Creek[a]	6½	2.36	18.12	71.87	7.65	.73	Reddish	7,819	20.14	79.86	3.97
4. Canyon Creek[a]	4⅙	3.24	9.79	62.97	24.00	1.94	Yellow	6,502	13.45	86.55	6.43
5. South end of Carbon Mt. (coke).[a]	5	1.34	6.30	84.57	7.79	.77	Very red.	7,776	6.93	93.07	13.43
6. Queen Creek[b]	31	1.20	17.28	77.69	3.83	.78	Reddish	8,310	18.20	81.80	4.49
7. Queen Creek[b]	27	.56	16.61	78.71	4.12	1.25	Reddish	8,310	17.43	82.57	4.74
8. Lake Charlotte[b]	9½	.68	17.87	60.73	20.72	.55	Gray	6,883	22.74	77.26	3.40
9. Carbon Creek[b]	8	.38	16.97	77.48	5.17	1.02	Gray	8,248	17.97	83.03	4.57
10. Bering River[c]	------	.83	7.18	87.57	4.42	------	----------	------	7.58	92.42	12.19
11. Bering River[d]	------	1.00	14.30	81.10	3.60	------	----------	------	14.99	85.01	5.67
12. Controller Bay[e]	------	.75	13.25	82.40	3.60	.69	----------	8,376	13.85	86.15	6.22
13. Controller Bay[e]	------	.78	13.22	80.30	5.70	2.90	----------	8,043	14.13	85.86	6.07
14. Bering River[f]	------	.77	13.79	82.36	3.08	2.68	Brownish.	8,289	14.34	86.66	5.97

[a] Sample collected by G. C. Martin. Analysis and calorimeter test by Penniman and Browne.

[b] Sample collected by G. C. Martin. Analysis by E. C. Sullivan.

[c] Analysis by William H. Fuller, Fairhaven, Wash. Published by John Kirsopp, jun., The coal fields of Cook Inlet, Alaska, U. S. A., and the Pacific coast: Trans. Inst. Min. Eng., vol. 21, 1901, p. 570.

[d] Analysis by W. F. Robertson, Victoria, B. C. Published by John Kirsopp, jun., as above.

[e] Analysis furnished by F. H. Shepherd. Published by J. E. Spurr, A reconnaissance in southwest Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, p. 263. (No. 13 is not from Icy Bay as hitherto reported.)

[f] Sample collected by W. M. Carless. Analysis by W. F. Hillebrand. Published by Schrader and Spencer, Geology and Mineral Resources of a portion of the Copper River District, Alaska, p. 91.

NOTE.—The calories of Nos. 6 to 14 are computed from the analysis by the author.

The above coals vary greatly in composition and in heating power, and it seems likely that this field, as elsewhere, each seam will be found to have a characteristic composition. The source of Nos. 10–14 is not known, but possibly some of them are from the opening on Carbon Creek from which No. 1 was obtained. The difference between the amount of moisture in these samples and that in sample Nos. 1–5 is probably due to the fact that the latter were placed in sealed cans as soon as taken and no opportunity was given for the coal to dry out. The very high percentage of sulphur in Nos. 13 and 14 is probably due to their having been taken, not from the entire thickness of the seam, but from pieces of coal which were picked for their hardness and apparent cleanness. The one who took the samples evidently overlooked the fact that their exceptional hardness was not due to the coal being nearer anthracite, but to its containing a large amount of pyrite (sulphide of iron).

Analyses of other coals for comparison.

Locality.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Calories.	B. T. U.	Recalculated.		
								Fuel elements.		Fuel ratio.
								Volatile matter.	Fixed carbon.	
Pennsylvania, anthracite (average of 9) [a]	3.389	3.812	83.790	8.417	0.592	-------	--------	4.35	95.65	21.99
Wales, anthracite (average of 4) [b]	-------	5.94	91.42	2.62	-------	-------	--------	6.11	93.89	15.80
Loyalsock, semianthracite (average of 4) [c]	1.488	11.074	78.883	7.695	.861	-------	--------	12.31	87.69	7.12
Pocahontas, semibituminous (average of 38) [d]	.73	17.43	77.71	4.63	.62	8,403	15,178	18.32	81.68	4.46
Georges Creek, semibituminous (average of 12) [e]	.69	18.95	74.11	6.08	.67	7,984	--------	20.36	79.64	3.91
Georges Creek, semibituminous (No. 9023) [e]	.65	17.89	74.28	6.18	.60	-------	--------	19.41	80.59	4.15
Georges Creek, semibituminous (No. 9011) [e]	.72	18.61	75.06	5.61	.71	8,144	--------	19.87	80.10	4.03
Georges Creek, semibituminous (No. 9004) [e]	.67	18.19	72.41	8.73	.66	7,708	--------	20.08	79.92	3.98
Georges Creek, semibituminous (No. 9002) [e]	.69	20.16	71.59	7.56	.55	7,983	--------	21.97	78.03	3.56
Pocahontas (Quinnemont), semibituminous (average of 17) [f]	.60	19.93	75.20	4.27	.67	8,415	15,202	20.95	79.05	3.77
New South Wales (southern coal fields), bituminous (average of 21) [g]	.97	23.10	65.26	10.67	.462	-------	--------	26.14	73.86	2.83
Wales, bituminous (average of 37) [h]	-------	27.00	68.09	3.22	1.43	8,402	--------	28.39	71.61	2.52
Comox, bituminous (average of 4) [i]	1.30	28.63	62.73	6.96	-------	-------	--------	31.35	68.65	2.19
Naniamo, bituminous (average of 4) [i]	2.19	30.76	56.52	10.53	-------	-------	--------	35.24	64.76	1.84
New South Wales (western coal field), bituminous (average of 13) [j]	1.87	31.49	52.61	14.03	.626	-------	--------	37.44	62.56	1.67
New South Wales (northern coal field), bituminous (average of 77) [j]	1.92	35.09	54.08	8.91	.541	-------	--------	38.23	61.77	1.62

[a] Ashburner, C. A., Ann. Rept. Geol. Survey Pennsylvania, 1885, p. 313.

[b] Lozé, Ed., Les Charbons Britanniques et leur Épuisement, vol. 1, p. 386.

[c] Ashburner, C. A., Ann. Rept. Geol. Survey Pennsylvania, 1885, p. 318.

[d] White, I. C., Geol. Survey West Virginia, vol. 2, pp. 695, 696, 700.

[e] These are furnished by Dr. W. B. Clark, State geologist of Maryland, and will be published in a forthcoming report of the Maryland Geological Survey on the coal of that state.

[f] White, I. C., Geol. Survey West Virginia, vol. 2, p. 670.

[g] Pittman, E. F., Mineral Resources of New South Wales, 1901, pp. 324–348.

[h] Poole, H., The Calorific Power of Fuels, 1898, p. 223.

[i] Dawson, G. M., Mineral Wealth of British Columbia: Geol. Nat. Hist. Survey Canada, new ser., vol. 3, pt. 2, p. 98 R.

[j] Pittman, E. F., Mineral Resources of New South Wales, 1901, pp. 324–348.

The seams now exposed in the valley of Shepherd Creek are the most promising coals seen by the writer. They not only possess the greatest thickness and are largely free from bands of shale and other impurities, but, as the above table shows, are the purest coals and have the highest heating power. Its composition shows it to be nearly semianthracite, of somewhat the composition of the coal of the Bernice basin (Loyalsock) in Pennsylvania, although it is purer and has a higher heating power than that coal. It differs from the anthracite of Pennsylvania and Wales in having more volatile matter in proportion to the amount of fixed carbon. In the ratio of fixed carbon to volatile matter it is nearer to the Bernice basin coal than to any other coal that reaches the general market. It is almost identical in heating power, as well as in the low amount of impurities, with the Pocahontas steam coal of West Virginia, but excels this coal by having a higher proportion of fixed carbon. There is no other coal with which it is likely to come into general competition with which it is to be compared, for it is far higher in heating power and in purity than any coal that is mined on the Pacific coast, whether in the United States, in Canada, or in Australia.

The seams opened 1 mile northwest of Canoe Landing on Shepherd Creek, and also near the headwaters of Trout Creek, are probably representative of the thinner seams of this region. These coals differ from the coal of the 20-foot seam in having a less amount of fixed carbon in proportion to the volatile matter and in having a higher percentage of ash and sulphur. The heating power is consequently less. They resemble coals of the semibituminous type that enter the market as high-grade steam coals. They correspond in texture, composition, and heating power to the high-grade Pocahontas (West Virginia) and Georges Creek (Maryland) steam coals, and also to some of the semibituminous coals of Wales.

The coke exposed in the southern end of Carbon Mountain is an interesting deposit, which may prove of considerable value. The analysis shows it to be of great purity and high heating power. It will be seen from the section given on page 30 that it is broken up by partings into a number of thin seams, which vary considerably in thickness within short distances. It may be that some of these will be found sufficiently thick and persistent to be of economic importance. Part of the coke is dense and hard and shows a well-marked columnar structure. The latter will break into fine fragments on handling, and will thus be at a disadvantage from the market standpoint. The product should be carefully screened and then the lump will make a domestic fuel of high grade.

Methods of shipment.—There is now no local market for the coal of this field, which therefore necessitates shipping for long distances. It is out of the question to think of building railroads to a market, because of their length, the difficulties and expense of railway construction, and the ease of water transportation. The available harbors are Controller Bay and Katalla Bay, and each of these has its disadvantages. The water of Katalla Bay is apparently very deep to a short distance from the shore, though it is said to be obstructed by an uncharted bar, and it is at present not known how firm the anchorage would be. The bay is, however, exposed to winds from the south. It is said that even the largest ships can run in close to the eastern shore of Fox Islands, where they would be sheltered from all winds except those coming from a little east of south.

Controller Bay has the disadvantage of being shallow over a large part of its area and of being filled, at certain seasons of the year, with drift ice brought down Bering and other rivers from the Bering Glacier. The present steamer landing is at the village of Kayak, on the eastern shore and near the southern end of Wingham Island. The ships enter through a narrow passage between Kayak and Wingham Island, over a bar only to be crossed at half or full tide. There is another anchorage off the northern end of Wingham Island; though accessible at all times, it is farther from shore and directly in the track of the drift ice.

There are several possible routes of transportation from the mines to the harbors. The most direct route from Katalla Bay to the coal fields would be in a straight line up the western side of Katalla Valley, over Katalla Pass (only a few scores of feet above tide), along the west shore and northern end of Bering Lake, and up the western side of the valley of Shepherd Creek. From the coal openings in the headwaters of Shepherd Creek the road could be extended, around the edge of the flat land which forms the peninsula between Shepherd Creek and Bering River, into the valley of Lake Kushtaka; thence down the valley of Stillwater Creek, up Trout Creek, and finally up Bering River and Canyon Creek. Such a road, with branches to reach all the existing coal openings, would be about 44 miles in length, divided as follows:

Routes of transportation between mines and harbor, Katalla Bay.

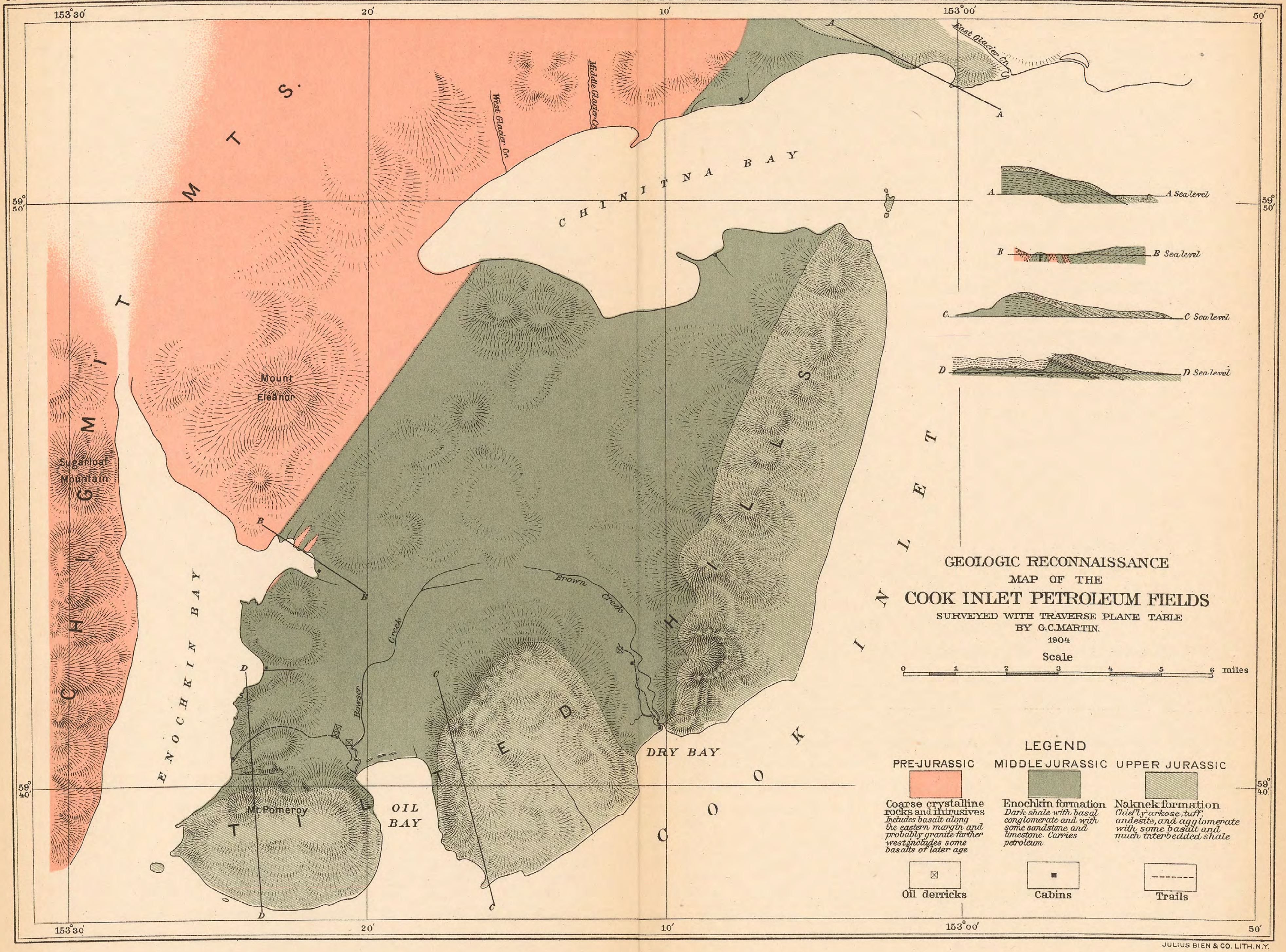
	Miles.
Fox Islands to mouth of Shepherd Creek	20
Mouth of Shepherd Creek to coal openings on Carbon Creek	6
Mouth of Shepherd Creek to mouth of Stillwater Creek	8
Mouth of Stillwater Creek to coal openings on Trout Creek	4
Mouth of Stillwater Creek to coal openings on Canyon Creek	6

This route would have the advantage of a deep (though not very secure) harbor free from glacial drift ice, of distance, of a low grade from the harbor to the mines, and of the absence of bridges over large streams which are liable to severe floods.

Another route would be from a long pier extending into Controller Bay from Point Hey over Kanak Island. This route would extend from Point Hey northwestward to Katalla River; thence up the east side of that river to Bering Lake, where it would join the route outlined above. It would be 1 to 2 miles longer than the first route. A third route would extend from a long pier on the eastern side of Controller Bay up the tidal flats east of Bering River, past the east end of Bering Lake and across Bering River above its entrance into the lake; from here branches could be built up the east side of Shepherd Creek and up the northern bank of Bering River on the extension of the first route. The length of this road would be 15 miles from the pier to the junction on the north bank of Bering River. The distances from this point to the coal openings on Carbon Creek, and to the mouth of Stillwater Creek, are 17 miles. This route would have the advantage of a more secure harbor than the first one, and also the advantage of a saving in distance. It would have the disadvantage of crossing Bering, Nitchawak, and other rivers, which are liable to severe floods every year, and the further disadvantage of having its harbor liable to be blocked with ice during some of the winter months.

Another possible route would extend from the eastern shore of Controller Bay northeastward until it reached the dead moraine of the Bering Glacier; thence northward along the moraine to the shore of Bering River at or near the mouth of Stillwater Creek. From this point branches could be built up Bering River to Canyon Creek, up Stillwater Creek to the coal openings on Trout Creek and Lake Kushtaka, and either from the lake to Carbon Creek or by an independent route down Bering River and up Shepherd Creek to Carbon Creek. This route would have the advantage of easy and cheap grading over the dead gravel moraine and of crossing the rivers nearer their sources by a larger number of small bridges rather than by a few large ones. It would have the disadvantage of being somewhat longer than the last route. The petroleum could be shipped from the same harbor as the coal, and as the petroleum belt is nearer the coast the problem of transportation prior to water shipment would not be a serious one. The wells which have been drilled up to the present time, and probably those which will be drilled in the immediate future, are near the coast, so that transportation to the piers could be effected by very short pipe lines. The prospective railroad to the coal mines would not at all be needed for the petroleum.

If a field should be developed on Nitchawak River or to the eastward in the Yaktag region a long pipe line would be necessary, and shipments would have to be effected either from the eastern shore of Controller Bay or the pipe line could be carried across Bering River. It is said a company owning claims in this region has made surveys for a pipe line from Controller Bay to Cape Yaktag, a distance of about 75 miles.



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COOK INLET PETROLEUM FIELDS.

GEOGRAPHY.

The region under discussion occupies the western shore of Cook Inlet from the foreland on the north side of the entrance of Chinitna Bay, southwestward for about 40 miles, to the mouths of Enochkin[a] and Iliamna bays, and extends inland, with a maximum width of about 10 miles, to the crystalline rocks at the eastern front of the Chigmit Mountains. Its coast includes the deep indentations of Chinitna, Enochkin, and Iliamna bays, and the lesser ones of Oil and Dry bays (Pl. IV).

The region includes a high mountain range, a range of lower hills, and an intervening valley region. The rugged Chigmit Mountains have an average elevation of about 3,500 feet, and are parallel to the general shore of the inlet. The Tilted Hills from the mouth of Enochkin Bay northeastward to Snug Harbor run parallel to the coast at the distance of a mile, and have a general elevation of about 2,200 feet (Pl. V). An area of depression occupies the position between these two ranges, and consists of many valleys drained by streams flowing into the bays named above, and of irregular, low, rounded hills. The divides between the drainage systems are low and permit easy portages. The streams are all small, for the most part unnamed, and entirely unnavigable.

The lowlands are covered with dense vegetation and consist of about half meadow and half forest. The meadows are deeply grassed and are dotted with groves of cottonwood and thickets of alder and willow. The forests consist of a fair growth of spruce and hemlock, and though trees are not large, they are straight and sound.

A wagon road has been built from the lower landing point of Enochkin Bay to the head of Oil Bay, and there are cleared trails from the head of Oil Bay to Dry Bay, to the head of the eastern arm of Enochkin Bay, and to a point on the shore of Enochkin Bay 2 miles above the lower landing. There are also two trails from Dry Bay to the shores of Chinitna Bay, and a portage trail from the head of Enochkin Bay to the head of Chinitna Bay. (See Pl. IV.)

GEOLOGY.

The rocks of this region consist of a zone of massive crystallines, exposed in the Chigmit Mountains; a sedimentary formation of Jurassic age in a belt east of them, and a series of overlying agglomerates, shales, and bedded volcanic flows, which are exposed in the

[a] This has been variously spelled as Inerskin, Innerskin, Inischen, and Innisken, but that here given is said to be the correct spelling of the Russian name.

Tilted Hills. The formations lie in belts parallel to the coast. The relation of the sedimentaries to the crystallines is complex and obscure, but the remainder of the series is conformable throughout (except for an unconformity between the Jurassic and the Tertiary) and is gently and simply folded. The general section is as follows:

General section of the Cook Inlet petroleum fields.

	Feet.
Tertiary:	
Sandstone, shale, and conglomerate with fossil trees and leaves	100?
Upper Jurassic:	
Naknek formation: Interbedded sediments and volcanic rocks (arkose, andesite, tuff, sandstone, and shale)	5,000
Agglomerate (best developed on Enochkin Bay)	300
Middle Jurassic:	
Enochkin formation (shale and sandstone with some conglomerate)	3,000?
Pre-Jurassic:	
Coarse crystalline rocks.	

PRE-JURASSIC CRYSTALLINES AND INTRUSIVES.

The crystalline rocks of the Chigmit Mountains extend along the entire western shore of Enochkin Bay and both shores of the northern arm of that bay. There is considerable variety in the series, but granite and rocks similar in texture and general appearance predominate.

The exposures along the eastern margin of this belt consist of basalts varying considerably in appearance. The eastern side of the point between the arms of Enochkin Bay contains good exposures of a reddish porphyritic rock. A greenish rock is exposed east of this on the northern shore of the eastern arm of the bay, and a rock of similar color and appearance is exposed on the north shore of Chinitna Bay. These rocks were shown by microscopic study to be of identical mineralogic composition, and were determined to be basalt.

The basalt may be either a member of the pre-Jurassic crystalline complex which forms the main mass of the Chigmit Mountains and the backbone of the Alaska Peninsula, or a post-Jurassic intrusive. The writer is inclined toward the former view.

MIDDLE JURASSIC ROCKS.

Enochkin formation.—The rocks overlying the crystallines consist of a thin conglomerate at the base, followed by more than 3,000 feet of dark sandy shales with occasional bands of sandstone, conglomerate, and limestone and many fossil beds; they are well exposed in the cliffs on the east shore of Enochkin Bay. Rocks of the same lithologic character extend along the strike northward from these exposures, passing the heads of Oil and Dry bays to Chinitna Bay. They have not been followed by the writer beyond the north shore of

LANDWARD FACE OF TILTED HILLS, CHINITNA BAY.

Enochkin formation overlain by Naknek formation.

Chinitna Bay, but from the great thickness exposed it is evident that they must extend thence a considerable distance. Rocks of similar lithologic character have been reported from the vicinity of Snug Harbor.[a] Fossils are distributed throughout the entire thickness of the formation, and show the age to be middle Jurassic.

A generalized section of the Enochkin formation is as follows:

Generalized section[b] of Enochkin formation.

	Feet.
Dark-drab shale with abundant limestone concretions and with numerous fossils (zone D)	1,283
Concealed	25
Sandy shale with many fossils (zone C)	50
Concealed	20
Shale with some sandstone	150
Conglomerate	10
Concealed	
Shale with several fossil bands (zone B)	50
Concealed	
Shale with one or more fossil bands (zone A)	30
Concealed	
Shale	12
Coarse conglomerate	20
	1,650+

The lowest bed is a basal conglomerate about 20 feet thick. The pebbles are large (averaging several inches in diameter) and were derived from crystalline rocks, principally granite. The shales at their very contact with the conglomerate are fossiliferous.

The point at the south side of the entrance to the eastern arm of Enochkin Bay[c] shows several outcrops of shale, with several beds abundantly filled with fossils, each bed being from 10 to 25 inches thick. About 30 feet of shale is exposed. The strata immediately above and below are concealed, and there are no good exposures between this point and the contact 1 mile northeast, described above, nor for a distance of 1 mile below it. At the latter point good exposures again begin and are continued along the shore for a distance of about 3 miles, the strata exposed in this interval being dark, sandy, fossiliferous shales. Fossils were collected from these zones, but were mixed in transportation, and it is consequently not possible to give the faunal lists separately. The specimens of the combined faunas have been submitted to Dr. T. W. Stanton, who determined the following species and assigned the faunas to the middle Jurassic.

[a] These beds were traced as far north as Snug Harbor during the summer of 1904.

[b] The concealed intervals in this section are very large. The total thickness probably exceeds 3,000 feet.

[c] On this point are also large masses (not in place) of brown sandy shale; there are numerous bowlders of this rock, but no exposures in place. The bowlders are always near the basal contact of the Enochkin formation and can not have been transported far. The sandstones from which these probably came were seen during the summer of 1904 in the region to the northward.

Specimens from sandy fossiliferous shales, Enochkin Bay.

2919.—East shore of Enochkin Bay, Cook Inlet, above lower cabin, zones A and B in lower part of Enochkin formation.

Belemnites sp. Fragments.
Thracia sp.
Trigonia doroschini Eichwald. Abundant.
Trigonia sp. Belongs to Clavellatæ group.
Grammatodon? sp. a.
Pseudomonotis? sp.
Pecten sp. A single very small, smooth form.
Ostrea sp. Fragmentary specimens of a small irregular species.

A total thickness of the foregoing beds of probably 150 feet is exposed, and then the continuity is broken by a fault having a displacement of at least 25 feet, beyond which the following section is exposed:

Section of part of Enochkin formation.

	Feet.
Soft shale	20
Dark-drab shale with scattered fossils	33
Hard calcareous shale full of fossils, principally pelecypods	2
Black sand	1
Dark shale	5
Black sand	1
Dark shale with many fossils	12
Reddish limestone	½
Dark shale with many fossils	14
Dark shale with scattered fossils	62
Soft dark sandstone with streaks of conglomerate	10
	160½

A concealed interval of about 20 feet in thickness succeeds this section. Then there is an exposure of about 50 feet of fossiliferous shale, followed by another concealed interval of about 20 feet. A richly fossiliferous zone is exposed here, from which a representative collection was made. The following forms have been identified by Dr. T. W. Stanton, who considers the fauna to be of middle Jurassic age.

Specimens from richly fossiliferous shale, Enochkin Bay.

2090.—East shore Enochkin Bay, below and near lower cabin, zone C, about 800 feet above base of Enochkin formation.

Stephanoceras sp.
Belemnites sp. a.
Belemnites sp. b. Abundant.
Belemnites sp. c.
Grammatodon? sp. a.
Grammatodon? sp. b.
Inoceramus eximius Eichwald.[a] Abundant.
Pecten sp. Small form, same as in lot 2919.
Pecten sp. Large individual that may be adult of last named.

[a] The forms described by Eichwald as *I. eximius, I. ambiguus,* and *I. porrectus* may all belong to one species.

Good exposures continue from this point to the mouth of the bay. This shows not only the upper part of the Enochkin shales but also much of the overlying strata. The upper part of the Enochkin formation as here exposed is as follows:

Section of upper part of Enochkin formation.

	Feet.
Dark-drab shale, with numerous bands of limestone concretions filled with well-preserved specimens of Cadoceras, Belemnites, etc., and with occasional sticks of fossilized wood	146
Concealed by talus at "Mushroom Rocks" (computed)	77
Dark shales, as above, with same concretions, wood, and fossils	190
Dark shales, as above, with Cadoceras	6
Limestone	1
Dark shales, as above, with fossils	68
Shales, as above	295
Concealed by talus (computed)	300
Shales, as above, with Cadoceras	200
	1,283

Fossils were collected from the entire thickness of these beds. Dr. T. W. Stanton has identified the following forms, which show relationship with the Callovian fauna occurring in Europe near the top of the middle Jurassic.

Fossils from upper part of Enochkin formation, Enochkin Bay.

2921.—East shore of Enochkin Bay for a mile below lower cabin, zone D, uppermost 1,200 feet of "Enochkin shales:"

Cadoceras doroschini (Eichwald). Abundant.
Cadoceras wosnessenskii (Grewingk).
Cadoceras schmidti Pompeckj.
Cadoceras catostoma Pompeckj?
Cadoceras sp.
Macrocephalites? sp.
Phylloceras subobtusiforme Pompeckj?
Stephanoceras sp. Form figured by Eichwald as Amm. astierianus d'Orb. aff.
Belemnites sp. a. One specimen.
Goniomya sp. One small specimen.
Lima sp.
Pecten sp. Small, smooth form.
Pleuromya? sp. One specimen.
Serpula? sp. Small discoidal form abundant in one rock fragment.
Several undetermined bivalves represented by imperfect material.

Compiled detailed section of the Enochkin formation.

	Feet.
Zone D:	
Dark-drab shale, with numerous bands of limestone concretions filled with well-preserved specimens of various cephalopods and belemnites and with occasional sticks of fossilized wood	146
Concealed by talus (all shale as above), thickness computed	77
Shales as above, with same concretions and wood	196
Limestone	1
Shales as above	363
Shales (partly concealed by talus), thickness computed	300
Shales as above	200
Concealed	25+
Zone C:	
Sandy shales with many fossils	50
Concealed	20
Soft shale	20
Dark-drab shale with scattered fossils	33
Hard calcareous shale full of fossils, principally pelecypods	2
Black sand	1
Dark shale	5
Black sand	1
Dark shale with many fossils	12
Reddish limestone	½
Dark shale with many fossils	14
Dark shale with scattered fossils	62
Dark soft sandstone with streaks of conglomerate	10
Concealed	
Zone B:	
Shale with several fossil bands	50
Concealed	
Zone A:	
Shale with one or more bands packed with fossils, each fossil bed 10 to 25 inches thick	30
Concealed	
Shale	12
Coarse conglomerate	20
Unconformity	
Greenish basalt	

The following section was measured at Oil Bay. It is the opinion of the writer that the lower 1,294 feet represent the upper part (zone D) of the Enochkin formation:

Section on north shore of Oil Bay.

Naknek formation:	
Arkose, andesite, sandstone, conglomerate, and shale	2,000
Sandy shale with Aucella near base	600
Shale with fossils	380
Coarse sandstone	3
Shale with fossils	165
Concealed	40
Sandstone and sandy shale with plant impressions	310
	3,498
Naknek formation?:	
Agglomerate with an abundance of small pebbles one-twelfth to one twenty-fifth inch in length, and with numerous poorly preserved plant impressions	7
Sandy shale and sandstone	85
Agglomerate with pebbles as above	3
Shale	1
Fine agglomerate of same pebbles as above	7
Fine agglomerate of same pebbles as above, but interbedded with shale	14
Olive shale[a] with an abundance of small pebbles as above	30
	147
Enochkin formation:	
Dark shale with concretions	690
Hard dark sandstone	½–¾
Dark-drab shale with numerous concretions	530
Calcareous shale with Cadoceras schmidti Pompeckj, Cadoceras, sp. cf. stenoloboide Pompeckj, and Phylloceras	1
Dark shale	60
Soft green sandstone	½
Dark-drab shale	12
	1,294

The cliffs on the north shore of Chinitna Bay expose a thickness of many hundred feet of the upper part of the Enochkin shales. Exact measurements were not made here, so it is impossible to tell what proportion of the formation remains below water level. The cliffs south of the bay, on the landward escarpment of the coast range, also show a thickness of many hundred feet of the same rocks. Neither section has been studied in detail.

Fossils are distributed throughout the entire thickness of the Enochkin formation, and show the age to be Jurassic. It consists of at least two well-marked paleontologic subdivisions. The lower 800 or 1,000 feet contain several faunules, in which the pelecypods predominate (zones A, B, and C), and which Dr. T.W. Stanton considers middle Jurassic. The upper 1,300 feet (zone D) are characterized

[a] Indeterminate fragments of a crustacean, evidently not related to the one from Bering Lake (see p. 14), were collected 5 feet above the base of this.

by the abundance of large cephalopods, especially several species of *Cadoceras*, which, with the *Belemnites*, predominate over all other forms. Dr. Stanton places this fauna near the top of the middle Jurassic, it possibly being the equivalent of the Callovian. It is to be compared with the Jurassic rocks from Cold Bay described by Dr. W. H. Dall and also in this report, and with those described by Doctor Dall from Tuxedni Harbor (Snug Harbor), Kamishak Bay, and other localities on the Alaska Peninsula.

UPPER JURASSIC ROCKS.

The Enochkin shales are overlain by a series of volcanic flows of andesite and basalt, and by coarse agglomerate, with much interbedded tuff, arkose, and shale. While the agglomerate seems to be confined to the shore of Enochkin Bay, the series as a whole forms the high coastal ridge which extends from Enochkin Bay to and beyond Chinitna Bay, the total thickness being probably more than 5,000 feet.

Agglomerate.—The Enochkin shales as exposed in the type section are overlain with apparent conformity by a bed of agglomerate having a computed thickness of 290 feet. The pebbles vary in size from less than an inch to 6 or 8 inches in diameter, are well rounded, and composed principally of granite, though occasional pebbles of some other crystalline or of schistose rocks are seen. The cement is evidently a volcanic ash of andesitic character.

The thick beds of coarse agglomerate have been seen by the writer only in the section described above, and it is probable that they are a local facies of the series of igneous flows which outcrop at the mouth of Chinitna Bay and along the shore of Cook Inlet, both north and south of that point. If such be the case, then the very fine tuffaceous agglomerate described in the Oil Bay section (see p. 43) is probably the equivalent of the coarser agglomerate exposed a few miles southwestward on Enochkin Bay.

Naknek formation.—In the section on the east shore of Enochkin Bay the bed of agglomerate is overlain by a series of very homogeneous, dark, sandy shales, with a computed thickness of 583 feet. No fossils were seen in these shales at their exposure on the shore of Enochkin Bay.

The shales are overlain by an alternating series of andesite flows and beds of agglomerate, the thickness exposed on the shore of Enochkin Bay being computed at 270 feet. Beyond the mouth of Enochkin Bay, in the cliffs on the shore of Cook Inlet, higher beds are exposed. The entire thickness is not known.

The Enochkin shale exposed on the shores of Chinitna Bay and in the Dry Bay and portions of the Oil Bay regions is overlain conformably by a series of arkose and other sediments interbedded with andesitic flows (fig. 3). These with their relation to the underlying shales are well exposed on the southern shore and near the mouth of Chinitna Bay. From this point, along Cook Inlet to Oil Bay, a continuous section of the series of flows is to be seen, the total thickness of which has not been measured, but is probably about 3,500 feet. The igneous rock is occasionally interbedded with shales, which in the cliffs between Oil Bay and Dry Bay contained *Belemnites*. They are thus shown to be of Mesozoic age. Probably the igneous rocks with their interbedded shales are to be referred to the upper Jurassic.[a] This series is certainly allied in age and is the equivalent of the Naknek formation which Spurr[b] described from the shores of Naknek Lake. It would appear from Spurr's description of this formation, as well as from the writer's observations, that it contains more arkosic material and less fine, well-assorted sediments than the shales of the Enochkin formation. Enough fossils have been collected from the Naknek formation to determine from paleontologic

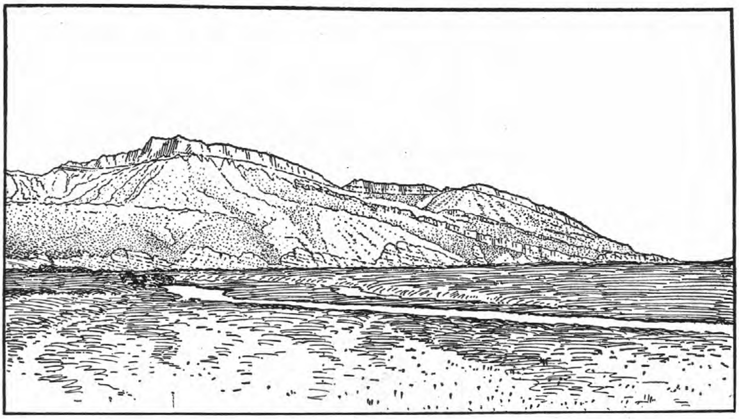


FIG. 3.—Enochkin formation, capped by Naknek formation, Oil Bay.

evidence the exact faunal equivalency. It seems best, therefore, in view of the lithologic similarity and the relations of the faunas, to use the same for the rocks exposed on the western shore of Cook Inlet.

POST-JURASSIC ROCKS.

North of the mouth of Chinitna Bay is a belt of lowland which extends eastward for several miles. The shore consists of alternate bluffs and beaches, the latter thrown across the ends of swamps and one or two forming lagoons behind them. A number of the bluffs are

[a] Abundant fossils, including *Aucella* and other characteristic upper Jurassic forms, were collected from these beds during the summer of 1904. Doctor Stanton considers the evidence of these fossils sufficient both for the reference of these beds to the upper Jurassic and for correlation with the Naknek formation of the Alaska Peninsula region.

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

roc' cliffs (igneous rock, bedded, as on south shore of the bay), while th others are composed of angular fragments of the same rock. The mo asterly ones are all of the latter kind.

The most easterly of the rock cliffs shows the following section:

Section on north shore of Chinitna Bay.

	Feet.
Conglomerate with interbedded shale and sandstone, the last two carrying fossil sticks and fragmentary leaf impressions	15
Dark-gray shale, with upright tree trunks	20

The strata here are almost or quite horizontal. The trees are between 1 and 2 feet in diameter, are silicified, and show the structure of the wood very distinctly, while numerous small sticks lie in the bedding of the shale. The leaves are Tertiary species.

STRUCTURE.

The structure of this region consists of a broad, low, somewhat undulating anticline parallel to the shore of Cook Inlet and to the general line of the eastern front of the Chigmit Mountains, followed on the west by a narrow syncline, beyond which is a second very closely folded and probably faulted anticline. The dip in the broad easternmost anticline is moderate in amount and very regular, except on the crest of the fold, where it is undulating, but not in excess of 10°. On the eastern limb the dip varies from 20° to 28°, diminishing as the shore is approached, and on some of the long points and islands becoming almost or quite horizontal. The steepest dip in the southwestern part of the field was observed on the shore of Enochkin Bay, where the rocks are inclined southeastward at an angle of 28°. The greatest dip at the northern end of the field is between half a mile and a mile southeast of the entrance to Chinitna Bay, where it varies from 25° to 45° SE. On the western flank of this anticline the dip is about 17°.

The nature of the undulations at the crest can be seen in the cliffs on the eastern side of Enochkin Bay. The dip is southeastward for the first 4 miles above the mouth of the bay, measured along the shore, and averages about 20°. There is then a low anticline at the mouth of a small creek, 4 miles above the entrance to the bay and half a mile below the lower cabin, which is situated at the end of the wagon road to Oil Bay. A small syncline is crossed at the lower cabin or just below it. The dip is southeastward for about 2,000 feet along the shore above the cabin, where the rocks bend over the top of another low anticline and dip to the northwest. Just below this point a fault, with a displacement of at least 25 feet, extends into the cliff at right angles to the shore. The fault plane is perpendicular to the bedding, which dips 10° SE. A crevice 6 feet wide is opened along the fault plane. For about 3 miles north from this fault the strata undulate somewhat, but have a general dip to the northwest, which finally becomes very pronounced and is constant at an angle of from 15° to 17° for a distance of over a mile, thus forming the general western flank of the greater anticline.

The syncline which adjoins this anticline on the west is a much narrower and simpler fold. It is characterized by a steeper dip on the western than on the eastern flank. It appears to die out toward the northeast and was not recognized on Chinitna Bay. West of this syncline is an anticline in which the rocks are badly crumpled and faulted. The crystalline rocks are exposed on its western side and at places within it. The contact of the westernmost outcrops of the shales with the crystalline rocks appears to be along the line of a great fault.

The amount of pitch of the axes of these folds is not known.

The contact of the Enochkin formation with the underlying crystallines has been seen only on the east side of Enochkin Bay. The locality on the south shore of the northeast fork of the bay would seem to show that the formation rests unconformably upon the green porphyritic rock, though, on the other hand, the locality across the bay, on its northern shore, suggests that the green rock may be younger and intruded. Another hypothesis may also be considered, namely, that the Enochkin formation is unconformable upon the green rock and that the western line of outcrop of the former is along a zone of faulting which has thrown a block of the green rock into the dike-like position seen on the north shore. The crushed zone west of this locality favors this hypothesis, as does also the fact that on Chinitna Bay, some distance northeast of this point, the contact of the Enochkin formation with the green rock has transgressed eastward across the series of folds in the former, so that there is only one anticline instead of two, as on Enochkin Bay. This hypothesis is favored also by the occurrence of abundant fragments of brown, sandy, shale or shaly sandstone along the western border of the belt occupied by the Enochkin formation.

OCCURRENCE OF PETROLEUM.

Surface indications.—The surface indications of petroleum in this region consist of seepages or oil springs and the so-called "gas springs." In the first, the petroleum may be seen oozing from the cracks in the rock or coming out of the soil. On the east shore of Enochkin Bay a good seepage was seen about 1,000 feet below the lower cabin, although the spring is covered at high tide. The flow is often so strong that the petroleum collects in large blotches on the pool, or even covers its entire surface. At one point it issues from a crevice in the shale of the Enochkin formation.

In the vicinity of the cabin at Oil Bay are a number of large springs. From the bottom of one the petroleum is almost continually rising, the flow varying, however, from time to time, now almost ceasing, now becoming very strong. It is frequently possible to skim several quarts of petroleum from the surface of the pool.

About 2 miles west of the beach at Dry Bay is a so-called "gas spring," gas of unknown composition rising in a continuous stream of bubbles to the surface of the water. From the north shore of Chinitna Bay both oil and gas springs have been reported, but they were not seen by the writer.

The geologic structure of this region has already been outlined. It consists of a long anticline bending from an east-west direction at the southern end to a northeast-southwest direction at the northern end, and so keeping parallel to the coast. The dip on each flank is regular and comparatively moderate, seldom exceeding 20°. Although in the actual region of the fold the strata are faintly undulating, the crown of the arc is almost flat. Other things being equal, the fold is such, indeed, as should yield a good flow over a considerable arèa, granting the existence below of a porous reservoir capped by impervious beds and filled with oil. The center of the zone, which at the present seems to be the most promising, lies on a line extending from a point about a mile above the lower cabin on the shore of Enochkin Bay to a point a half mile northwest of the beach at Oil Bay, thence through a third point 2 miles above the beach at Dry Bay to the center of the high cliff on the north shore of Chinitna Bay. The oil sand would probably be found nearer the surface along this line than either to the southeast or the northwest.

As in all cases, however, drilling is necessary to obtain a knowledge of the underground conditions, as well as to estimate the economic and commercial value of the field. Thus far this has been insufficient. As regards the entire Enochkin Bay region, it is almost certain that the oil will be confined to the easternmost anticline.

Development.—Indications of petroleum were discovered in this region about fifty years ago. The first was taken out in 1882 by a Russian named Paveloff. A Mr. Edelman staked ground in 1892. His location was near the divide at the head of the creeks entering Oil and Dry bays, but the claims were subsequently abandoned. In 1896 Pomeroy and Griffen also staked property at Oil Bay, and during the next year organized the Alaska Petroleum Company. Work was begun in 1898. The Alaska Oil Company was organized in 1901, and in 1902 began drilling at Dry Bay.

The first well at Oil Bay was begun in 1898 and has been drilled to a depth of somewhat over 1,000 feet. No log of this well or any very authentic information can be obtained, as the property has changed management several times. It is reported that gas was encountered all the way below 190 feet, and that considerable oil was found at a depth of 700 feet. The flow of oil is reported as having been estimated at 50 barrels. On drilling deeper a strong water pressure was encountered, which shut off the flow of oil. The well is now over 1,000 feet in depth and affords a continuous flow of gas, which at times becomes very strong. Attempts have been made to shut off the flow of water and either recover the lost oil or drill deeper, but without success.

A second well, located about a quarter of a mile west of the older one at Oil Bay, was drilled during the summer of 1904.

Record of well at Oil Bay, as reported by Mr. August Bowser.

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

The well was abandoned at a depth of 450 feet because the shale caved so badly.

A third well located about 250 feet south of the last was also drilled during the summer of 1904.

The general sequence of strata was the same as in the last well, the shale continuing to the bottom of the hole. The well was cased to a depth of 630 feet. Oil and gas were encountered at a depth of 770 feet, there being three small oil sands, each 6 to 8 inches thick and 4 or 5 feet apart. The well was estimated at 10 barrels. The caving rock was encountered at 830 feet. Work was stopped at a depth of 900 feet at the end of the season. Considerable gas was encountered at various depths, at times the pressure being strong enough to blow the water up in the derrick to a height of 20 feet.

A well at Dry Bay was drilled to a depth of 320 feet in the summer of 1902 without encountering oil. The tools were then lost and the hole was abandoned. In August, 1903, a new well was started in close proximity to the first, but not much was accomplished, and work was discontinued a few months later because of an accident to the machinery. Nothing has been done during the past season.

The shipment of petroleum from this field would probably be from Enochkin and Chinitna bays, which are harbors affording safe anchorage to large vessels in all weather, as well as good wharf sites. Ships can, however, anchor in the mouth of Oil Bay and off Dry Bay except during very bad weather. If the docks should be built either at Enochkin or Chinitna, it would be necessary to build pipe lines and pumping stations to transfer the product from the field to the shipping point. This would not, however, be a serious matter, as divides are low and construction and operation would be easy.

COLD BAY PETROLEUM FIELD.

GEOGRAPHY.

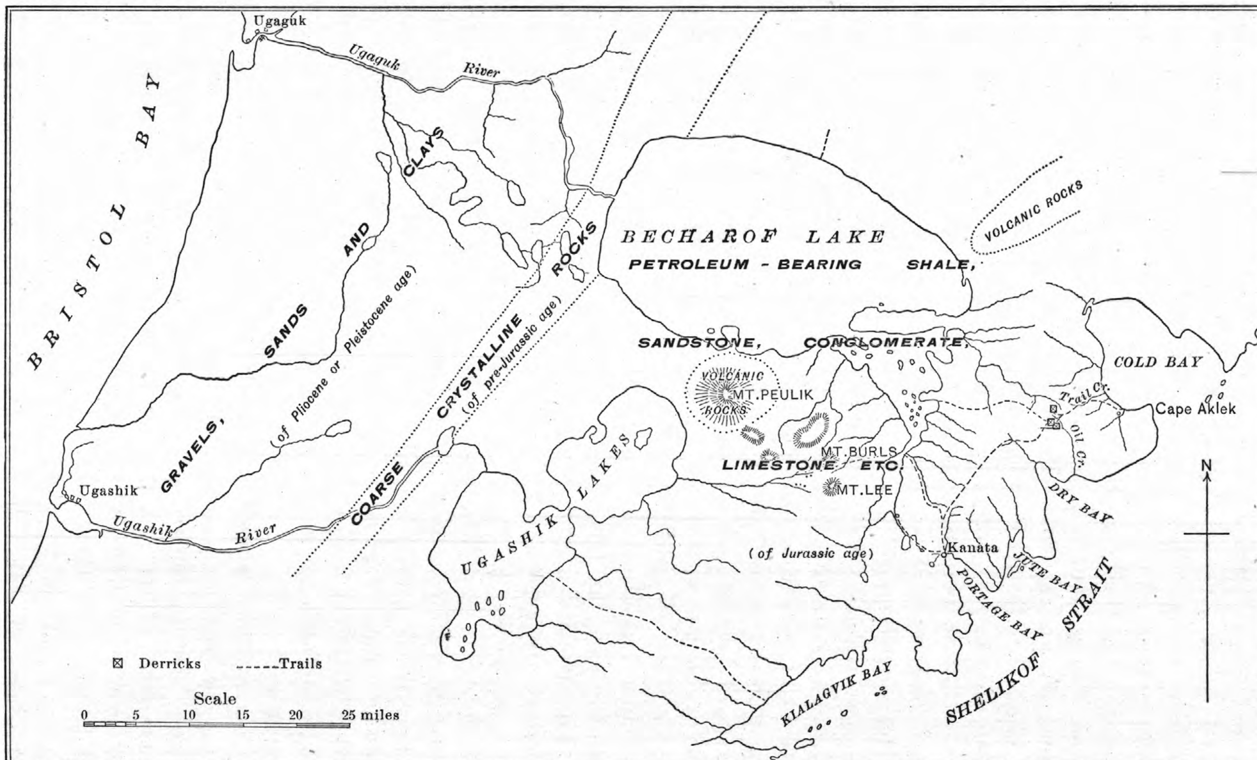
Cold Bay is situated on the south shore of the Alaska Peninsula at the southwest end of Shelikof Strait and opposite the west end of Kodiak Island. (See map, Pl. I.) It may be reached by steamer from Seattle either direct or by transfer at Valdes or Kodiak, or from Dutch Harbor. From Seattle the time is about fifteen days; from Valdes, four. It may also be reached from Bristol Bay by a canoe and portage route across the peninsula.

The southern shore of the Alaska Peninsula is very sinuous, with deep indentations and long rugged forelands. Cold Bay, one of the best of the harbors, is roughly triangular in shape, about 10 miles long by 7 miles wide at the mouth, and contains a very large area of deep water. (See map, Pl. VI.) The surrounding country consists of an elevated upland with gently rounded or flat-topped hills rising above it, and its general level is about 750 feet above tide. The higher peaks rise to an elevation of about 1,500 feet, but farther back from the coast, in the central part of the peninsula, are mountains 5,000 feet or more in height. Among these is the volcano Peulik (about 5,000 feet), situated on the western shore of the southern arm of Becharof Lake, about 35 miles west of Cold Bay. This is one of the chain of volcanoes which extends the entire length of the Alaska Peninsula and the Aleutian Islands.

The streams emptying into Cold Bay and into the other bays in the vicinity are short and swift, carrying no very large amount of water. It is a striking fact that in this part of the peninsula the divide between the Pacific drainage and the Bering Sea drainage is situated in close proximity to the southern shore. For example, near Cold Bay, where the peninsula has a total width of about 90 miles, the divide is nowhere more than 10 miles from the southern shore, and is, in some cases, within a mile or two of the heads of the bays. These short, swift streams are characteristic of the entire southern slope of the peninsula.

The northern slope of the peninsula, on the other hand, is drained by a comparatively small number of fairly large rivers, which empty either into shallow bays or directly into the sea. All of these rivers have lakes at their headwaters or along their courses. Lake Becharof, the head of which is situated about 15 miles from the landing at Cold Bay, is one of the largest. The presence of such lakes and rivers throughout almost the entire area of the peninsula makes navigation in canoes or other small boats very easy, and almost all travel is accomplished in this way.

Timber is entirely lacking in this region, the only trees being a few small cottonwoods, willows, and scrub alders along the banks of the



SKETCH MAP OF COLD BAY PETROLEUM FIELD.

streams. The flat lowlands along the shores of Cold Bay are covered with deep grass, but the hillsides and upland region have no vegetation except scattered tufts of grass and moss (Pl. VII). This vegetation is characteristic of the greater part of the Alaska Peninsula.

There are no natives in the immediate vicinity of Cold Bay. The two oil companies which are operating in the region have brought their native employees from settlements at various points along the shores of Shelikof Strait.

GEOLOGY.

The region in the vicinity of Cold Bay has been visited by many geologists from time to time and a good deal of scattered information is published.

On one end of the promontory at the eastern entrance to Cold Bay Pinart obtained a number of specimens of *Monotis salinaria*, which was subsequently identified and figured by Fischer, and which is a characteristic Triassic form.

The promontory at the southwestern entrance to Cold Bay, which has been called by many names, but is now known as Cape Aklek, was visited by Doroschin, who collected *Belemnites*. Plant impressions which resemble and have been considered *Calamites*, but which have been shown to be reeds of a more modern type, occurred in sandstones just above.

The region was visited in 1895 by Dr. W. H. Dall, who says of it:

Though no strata evidently of Kenai age were found in this bay, yet there were in several places fossil wood and vegetable remains. Near the northeast part of the harbor, east of a stream which comes in here, the rocks consist chiefly of calcareous sandstones, or sandy limestones, containing numerous concretionary nodules and some pebbles. In this nearly horizontal limestone, which is very massive and weathers into most bizarre shapes near the shore, we found a small seam of carbonaceous shale with occasional thin laminæ of clear coal. This shale is only a few inches thick. In shaly streaks of the limestone were vegetable impressions resembling those noted at Cape Douglas. On the other side of the stream, above the anchorage, these strata were arched and dipped 30° NW. On the opposite side of the main bay, well up on the hillside, was found a calcareous shale with impressions of pine needles, above which was a heavy bed of conglomerate covered by a hard, perhaps andesitic, rock of igneous origin. From fragments fallen from above it seemed that this rock is more coarse grained and friable higher up. It is unconformable with the other rocks. In the limestones near the south point of entrance impressions of reedlike plants and much fossil wood were observed. No coal seams were observed in this vicinity.[a]

Well up on the northeastern side of the bay is a valley which a stream drains, off the mouth of which is anchorage. Westward of the stream is a rather high (2,000–2,500 feet) ridge, recalling the Mesozoic mountains about Tuxedni Harbor, eroded in benches and having a singularly artificial aspect. From the first bench on this ridge Mr. Purington obtained a few Mesozoic fossils,

[a] Dall, W. H., Report on coal and lignites of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, p. 801.

the most noticeable of which was a Rhynchonella, and a few others were obtained at high-water mark where the same ridge came down to the beach. The matrix was coarse and friable and the specimens were few, but it seemed certain that the two lots belonged to the same fauna, which must range through at least 1,000 feet of strata. The rock is chiefly a calcareous shale, barren of fossils, which disintegrates into small angular fragments, forming enormous and extremely regular talus slopes. Where a seam of sand and gravel or coarse sandstones is interleaved with the shales, there the fossils are found, but these seams are rare.[a]

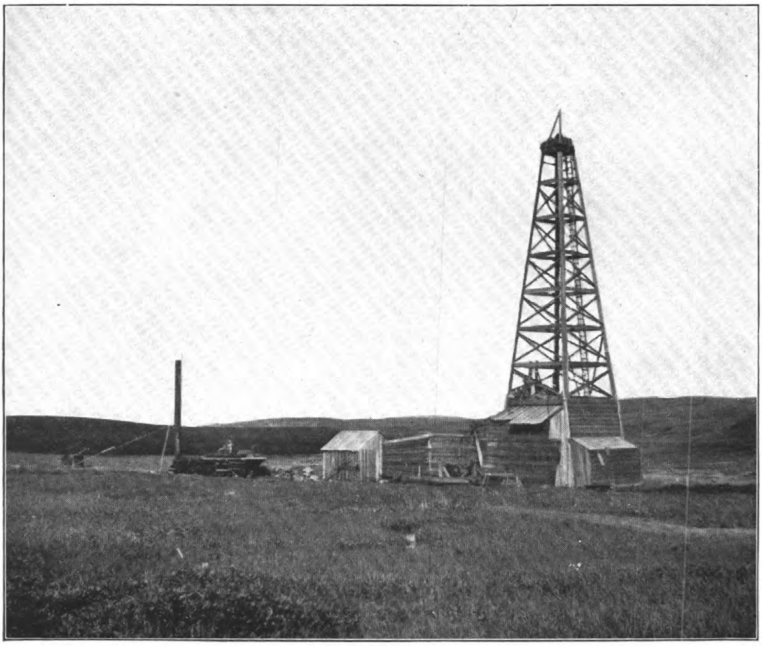
The rocks seen by the writer in the vicinity of Cold Bay consist of dark-brown arkosic sandstone alternating with conglomerates, and a few thin limestones and dark shales which break on the weathered surface with a conchoidal fracture.

Fossils were collected at several localities. The low sandstone cliffs extending for about 1 mile above the store at the lower landing carry abundant specimens of *Belemnites*. Dr. T. W. Stanton has examined the specimens and is of the opinion that three species, indicating a horizon in the middle Jurassic, are present. He compares them with the faunas of the middle and upper zones of the Enochkin formation of the Cook Inlet region. Fragments of a small belemnite were collected at the base of the cliffs 2 miles northwest of Cape Aklek. Doctor Stanton considers that the horizon of this is Jurassic, but the fossils are too scanty and fragmentary for precise reference of the strata. The rocks at this point consist of arkosic sandstones well exposed in high cliffs. An ammonite was seen in the face of the cliff near the top, showing that the entire series is Mesozoic. Four miles southwest of this point, where Oil Creek flows into Dry Bay, specimens of *Cadoceras schmidti* Pompeckj were obtained. Doctor Stanton believes these fossils belong at the same horizon as those already referred to from the shores of Cold Bay.

General section in the Cold Bay–Becharof Lake region.

Name of formation.	Age.	Lithologic character.	Thickness.
	Post-Jurassic	Volcanic rock, probably andesite or basalt.	
Naknek formation.	Upper Jurassic	Arkose, conglomerate, sandstone, and shale.	3,000 to 5,000 feet.
Enochkin formation.	Middle Jurassic	Shale, sandstone, and a little limestone.	2,000 feet.
	Triassic	Shale, limestone, and chert.	
	Pre-Jurassic	Granite, syenite, etc.	

[a] Op. cit., p. 870.



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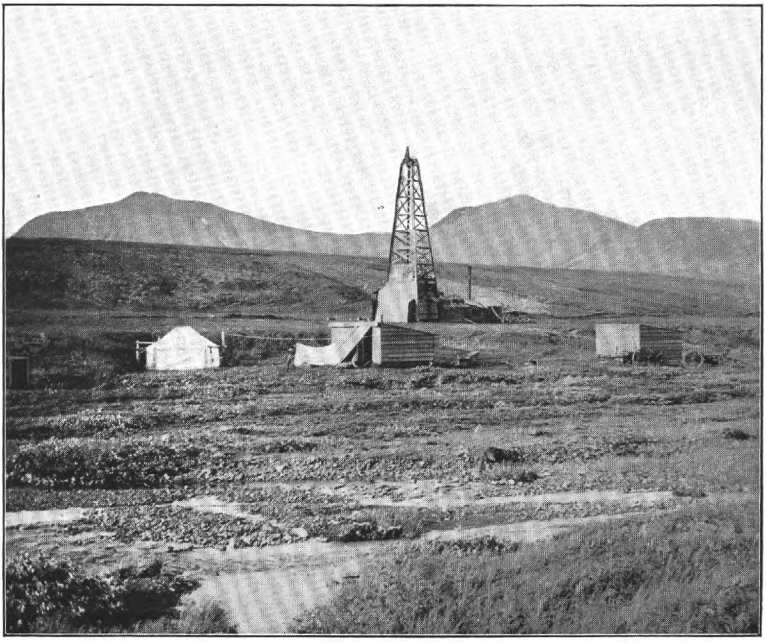

B

OIL DERRICKS AT COLD BAY.

The coarse crystalline rocks (granite, syenite, and rocks of similar texture) occur in a belt parallel to the length of the Alaska Peninsula. They cross the lower end of Becharof and Naknek lakes and possibly underlie the Cold Bay region.

The Triassic rocks occur on Cape Kekurnoi at the eastern entrance to Cold Bay, and on some of the capes and islands to the northeastward. They doubtless underlie the Jurassic throughout the Cold Bay region.

The Enochkin formation occupies both shores of Cold Bay, except at the northeastern promontory (Cape Kekurnoi) and at the head of the bay. It also extends in a belt along the shore of Shelikof Strait from Cold Bay to Dry Bay and probably as far beyond as Portage Bay.

The Naknek formation forms the shore of the head of Cold Bay and occupies the entire interior region as far west as Becharof Lake and as far north as Katmai.

The following section was measured on the east side of Rex Creek about 1 mile above the head of Dry Bay:

Section on Rex Creek, Cold Bay region.

	Feet.
Naknek formation:	
Arkose, sandstone, and shale	600+
Enochkin formation:	
Shale and sandstone	500
Sandstone	90
Argillaceous shale	400
Sandstone, shale, and conglomerate	300

The post-Jurassic volcanic rocks occur in a discontinuous belt near the center of the peninsula. This belt includes several volcanoes which have been active in comparatively recent time. The lavas are probably all either andesite or basalt.

It may thus be seen both from the previous observations quoted above and from the work of the writer that the rocks exposed in the immediate vicinity of Cold Bay are entirely Mesozoic. They carry Jurassic fossils everywhere except at the promontory on the east side of the bay, where Triassic fossils have been found.

Mount Peulik, the high peak on the southern shore of Becharof Lake, is a volcano that has probably been active in comparatively recent times. It is one of the many volcanic mountains which extend along the central axis of the Alaska Peninsula, and has apparently broken through the Jurassic sediments. Other similar mountains extend in a northeasterly direction from the north shore of Becharof Lake to and beyond the head of Naknek Lake.

Glacial deposits are probably entirely lacking in this region, except as they are reported in the moraines of small living glaciers on the higher mountains.

STRUCTURE.

The rocks in the vicinity of Cold Bay are very gently folded. The dips are low over wide areas and the zones of steep dip are narrow and infrequent.

It has been stated that there is a great anticline seaward, parallel to the southern coast, that has its axis near the ends of the forelands. This view is sustained by the fact that on at least one of these promontories rocks older than the Jurassic are exposed, but the writer has not seen any evidence which would show how far seaward the southeast dip may extend. This fold extends from Katmai to the cape at the east entrance to Cold Bay. No land extends far enough seaward below Cold Bay to reach the axis of this fold. The strike and the direction of the axis average about N. 45 E. The northwest dip seldom exceeds 6° on the forelands. It is considerably steeper on the east shore of Cold Bay.

There is a syncline parallel to this and northwest of it which extends from near the mouth of Dry Bay along the west shore of Cold Bay to the high bluffs above the mouth of Teresa Creek. At this point it is cut off by a fault which crosses the head of the bay and extends up the valley of Dry Creek.

A long anticline is exposed in the hills southwest of the bay, the axis reaching the shore a short distance from Portage Bay and extending thence inland in a general northeast direction. The maximum dips observed on the southern flank of this fold were about 2° to 10°; on the northern, 12° to 16°. Strikes of N. 2° E. and N. 10° E., respectively, were noted. The steeper dips were apparently confined to a narrow zone, beyond which a dip of 8° continued for a considerable distance. These observations of the writer show a structure corresponding to that which has been reported from the region of Portage Bay, where an anticline with a northeast axis is said to parallel the south arm of the lake in such a position that, if continued to the location of the oil derricks west of the shore of Cold Bay, it would coincide with the anticline seen by the writer and described above. The rocks exposed in the immediate vicinity of the oil derricks lie almost or quite horizontal. The dip in the hills south of the derricks is southwest at a low angle, while in the hills north of the derricks it is northerly at an average angle of 8°. According to report, the northwest dip is reversed near the center of the peninsula, so that part of Becharof Lake lies in a syncline, while near its northwestern shore a sharp anticline is said to rise, which brings to the surface not only the entire sedimentary series, but also a mass of crystalline rocks that form the core of the peninsula throughout most of its length.

It may be seen from the descriptions given above that the most striking structural features are an anticline with a northeast-southwest axis extending from a point 3½ miles above the mouth of Oil Creek to Kanata, and a syncline extending from near the mouth of Oil Creek northeastward into Cold Bay. The northern end of this syncline is cut off by a fault which extends up the valley of Dry Creek. The anticline terminates by flattening out.

The dips are quite uniformly northwestward on the north shore of Cold Bay and on the north side of Dry Creek. Along the southeastern side of Becharof Lake it is northwestward and westward. On the western shore of Cold Bay it is northwestward or horizontal. On Dry Bay it is southeastward. The dips seldom exceed 15° except toward the mouth of the bay, and are quite low and regular over wide areas. The region between Becharof Lake and the Becharof-Cold Bay divide has a uniform westward and northwestward dip.

INDICATIONS OF PETROLEUM.

Seepages.—There are several seepages at the north end of the anticline near the oil wells. In all of these the flow of petroleum is large and constant. One of them furnishes lubricating oil for use at the wells. There is also a considerable flow of gas at one of these seepages. Other seepages not seen by the writer are reported from various places along the crest of this same fold, near the head of Dry Bay and elsewhere between that point and Kanata. There is said to be even more important seepages on the west shore of the south arm of Becharof Lake.

Developments.—Three wells were begun in the summer of 1903. They are located about 5 miles from the landing on the west shore of Cold Bay, at an elevation of about 750 feet above tide, and are distant about 9 miles in an air line from Becharof Lake. (Pl. VII.)

One of the wells begun during the summer of 1903 was abandoned in the autumn at a depth of several hundred feet, and the derrick was moved to a new site a few hundred feet distant. Very little drilling had been done at this point up to the time the writer left Alaska.

The second well, mentioned in an earlier publication,[a] was drilled to a depth of about 1,400 feet. The drill is said to have penetrated several strata filled with thick residual oil having about the consistency of warm pitch. This well was finally abandoned during the summer of 1904, because of the strong continual flow of fresh water. It is now certain that this well is situated near a fault, which fact would seem to explain the presence of a large amount of fresh water at all depths and also the absence of the more volatile and fluid constituents in the oil. The machinery from this well has now been moved to a new location about 2¼ miles southeastward on Trail Creek. At last reports it had reached a depth of 1,500 feet.

[a] Bull. U. S. Geol. Survey No. 225, 1904, p. 381.

Record of well at Cold Bay.

	Feet.
Sandstone	76
Hard sand with crevices	39
Sand with hard streaks	85
Oil sand, not hard	40
Sandstone with hard streaks	60
Oil sand, soft	8
Sandstone with hard streaks	82
Oil sand	25
Soft argillaceous sandstone	15
Soft blue sandstone with oil	5
	435

If petroleum is stored within the series of rocks about Cold Bay, other things being equal, the very gentle folding which the strata have undergone should be favorable to the formation of large pools. It is impossible, however, to tell at present how far the influence of the volcanic belt and faults may extend.

The petroleum from this field has a paraffin base and is probably similar to the Controller Bay petroleum. (See p. 58.) If petroleum should be discovered in commercial quantities in this region it can be piped from the wells to Cold Bay by gravity and shipped thence to San Francisco or to Puget Sound ports.

PETROLEUM RESIDUE.

On some of the hillsides near the oil derricks 5 miles inland from Cold Bay are seepages of petroleum that are in some cases continuous, in others intermittent. The petroleum runs down the hillsides in the watercourses, collecting at the bottom in peat bogs. Losing enough of its volatile constituents by evaporation to render it immobile, it remains there, impregnating the peat and forming over its surface a thick coating of black paraffin wax.

These deposits have already been of considerable importance in the development of the region, for the peat, impregnated with the paraffin wax, has proved a fuel of the greatest value, replacing even the coal from the mines of Puget Sound, which is imported in large amount for use under the boilers in drilling operations. The deposit which has furnished this fuel for the past season has an area of about 1½ acres. The material has been dug to a depth of about 3 feet without, in some cases, reaching bottom. This deposit alone contains enough of the residue to supply all local needs for fuel for some time to come. Another deposit has, however, been discovered in the vicinity, which has an area of 3 acres and a thickness of at least 10 feet. Many more also will doubtless be brought to light.

Chemical and calorimetric tests of petroleum residue have been made by Penniman & Browne, of Baltimore. The result of their tests is as follows:

Chemical and calorimetric tests of petroleum residue.

	Per cent.
Moisture	None.
Volatile matter	85.40
Fixed carbon	7.76
Ash	6.84
Total	100.00
Sulphur	.36
Soluble in gasoline	68.20
Calories	8,193

The table shows a material that compares favorably with most of the coals sold on the Pacific coast. It is, indeed, their superior as regards calorific power, ash, and amount of sulphur. The amount indicated in the table as soluble in gasoline represents the petroleum residue present, the remaining 31.80 per cent consisting of peat and earthy material.

PROPERTIES OF THE ALASKA PETROLEUM.

Controller Bay petroleum.—A sample of the petroleum from the well near Katalla has been tested by Penniman & Browne, of Baltimore, with the following results:

Test of petroleum from Katalla.

Specific gravity	(0.828 at 15.5° C.) 39.1° B
Distillation by Engler's method:	
Benzine (80°–150° C.)	21%, 54.9° B. (0.7573)
Burning oil (150°–300° C.)	51%, 40.6° B. (0.8204)
Residium (paraffin base)	28%, 23.9° B. (0.9096)
Sulphur	Trace

The burning oil was purified by concentrated sulphuric acid and soda, the volume of acid used up being too small to measure. The purified burning oil was put into a small lamp, where it burned dry without incrusting the wick or corroding the burner, and without any marked diminution of flame. The burning oil compares very favorably in these respects with Pennsylvania oil prepared in the same way.

The following analysis of this petroleum was published by Mr. Oliphant:[a]

Analyis of petroleum from Katalla Bay well.

Specific gravity at 60° F., 0.7958, equal to 45.9° Baumé.

Cold test did not chill at 3° F. below zero.

	Per cent.
Distillation below 150° C., naphtha	38.5
150° to 285° C., illuminating petroleum	31
Above 285° C., lubricating petroleum	21.5
Residue, coke and loss	9
Total	100

[a] The production of pretroleum in 1902: Mineral Resources U. S. for 1902, U. S. Geol. Survey, 1903, p. 583.

The results of the tests may be compared with those of other petroleums in the following table:

Tests of petroleum from Alaska and other fields.

	Alaska.[a]	Alaska.[b]	Pennsylvania.[c]	Ohio.[d]	Colorado.[e]	Mexico.[f]	Beaumont, Tex.[g]
Benzine (80°–150° C.)	21	38.5	16.5	10	16	10	2.5
Burning oil (150°–300° C.)	51	[h]31	54	50	40	60	40
Residuum	28	[h]30.5	29	40	44	30	57.5
Sulphur	Trace.						1.7
Gravity	39.1° B.	45.9° B.			43° B.		22°B.

[a] Penniman & Browne for this report.
[b] Oliphant, F. H., The production of petroleum in 1902: Mineral Resources U. S. for 1902, U. S. Geol. Survey, 1903, p. 583.
[c] Peckham, S. F., Report on Petroleum, p. 365.
[d] Woodman, Durand, Jour. Am. Chem. Soc., vol. 13, p. 168.
[e] Oliphant, F. H., Petroleum: Mineral Resources U. S. for 1901, U. S. Geol. Survey, 1902, p. 560.
[f] Stillman, T. B., Engineering Chemistry, p. 364.
[g] Hayes and Kennedy, Oil fields of Texas-Louisiana coastal plain: Bull. U. S. Geol. Survey No. 212, 1903, pp. 146–151.
[h] See above (p. 57).

The petroleum is clearly a refining oil of the same general nature as the Pennsylvania petroleum. It resembles the latter in having a high proportion of the more volatile compounds and a paraffin base and in containing almost no sulphur. The proportions of the several constituents given in the table above do not necessarily represent the full amounts that could be obtained in practice by different treatment.

Oil Bay and Cold Bay seepages.—Samples of the seepage petroleum from Oil Bay and Cold Bay have been collected by the writer. They were obtained by skimming the petroleum from the surface of the pools of water where it was continually rising from the bottom of the pool. An effort was made to obtain as much of the fresher oil as possible. Vegetable and earthy impurities were removed by straining through coarse cloth. Water could not be entirely removed. Oil for lubricating purposes at the neighboring wells is obtained from these pools in this manner.

The fresher oil is dark green. That which has remained on the surface of the pool for some time is dark brown.

The oil has doubtless lost a large part of its volatile constituents. The analyses therefore do not represent the composition which could be expected of the live oil from wells in this region. Such oil would have a lower specific gravity, higher percentage of the more volatile constituents, and lower percentage of the less volatile constituents, residue and sulphur. It would certainly be better than these samples in all respects, and would resemble them in having a paraffiin base. It might not be of so high quality as the Controller Bay petroleum, but nevertheless it would be a refining oil.

The samples were submitted to Penniman & Browne, of Baltimore, who return the following report on their tests.

Tests of samples of seepage petroleum from Oil Bay and Cold Bay.

	Oil Bay.	Cold Bay.
Specific gravity at 60° F	0.9557 (16.5° B)	0.9547 (16.6° B)
Distillation by Engler's method:		
Initial boiling point	230° C	225° C.
Burning oil (distillation up to 300° C., under atmospheric pressure)	13.2% (29.5° B)	13.3% (29.6° B)
Lubricating oils (spindle oils) (120 mm. pressure, up to 300° C.)	39.2% (22.6° B)	28.3% (23.8° B)
Lubricating oils (120 mm. pressure, 300° C.-350° C.)	19.6% (17.9° B)	18.3% (18° B)
Paraffin oils (by destructive distillation under atmospheric pressure)	22.4% (20.4° B)	32.0% (20.4° B)
Coke and loss	5.6%	8.1%
Total sulphur	0.098%	0.116%

The distillation of the lubricating oils under diminished pressure, corresponding to refinery practice, was carried on until signs of decomposition set in. The resulting residue was unsuitable for making cylinder stock, and was therefore distilled for paraffin oils. These paraffin oils contain a considerable quantity of solid paraffin. It was not practicable to determine the amount of the material with the small amount of oil at our disposal.

The iodine absorption of the oils and distillates has been determined by Hanus's method (solution standing four hours), and is here tabulated:

	Oil Bay.	Cold Bay.
Burning oil	17.8% iodine	17.2% iodine
Lubricating oil	26.2% iodine	27.2% iodine
Heavy lubricating oil	35.8% iodine	35.2% iodine

These iodine numbers upon the lubricating oils were obtained upon the samples. For comparison, samples of similar oils were obtained from the Standard Oil Company, and the iodine numbers determined as follows:

Light distilled lubricating oil (spindle oil)	32% iodine
Dark lubricating oil (engine oil)	45.4% iodine

The burning oils were tested in a small lamp and found to give a good flame. All the oil was consumed without incrusting the wick or corroding the burner.

The sample of crude oil from Cold Bay was distilled in such a way as to give the maximum yield of burning oil; under these conditions 52.2 per cent of fair quality burning oil was obtained.

The oils are entirely similar; both have paraffin bases, and the products of distillation are "sweet." We are informed that these samples are "seepage oils." If a sufficient yield can be obtained by drilling, a very suitable oil for refinery purposes may be expected, containing a very much larger quantity of the more desirable lighter products.

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