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PRELIMINARY REPORT

ON

PETROLEUM IN ALASKA

BY

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PREFACE.

By Alfred H. Brooks.

Though petroleum was among the first of the useful minerals found in Alaska, it has received relatively little attention. Except in the Katalla field, all attempts at systematic development were confined to a very brief oil boom that began in 1901 but soon collapsed, owing to the rapid oil developments in California. All the Alaska oil lands were withdrawn in 1910, and patent has been granted to only one claim, which is in the Katalla field. Since then nothing has been done on Alaska petroleum except some drilling in the Katalla field, where productive oil wells have been developed.

This condition persisted until the passage of the recent oil and gas leasing act of February 25, 1920. The provisions of this law applying to Alaska [1] appear to be liberal and will permit prospecting the fairly accessible localities near the Pacific where seepages have been found. These include all the areas that now give promise of being of commercial importance. There are, however, some indications of oil in the extreme northern part of Alaska (pp. 68–70), a region at present almost inaccessible. This region is nearly 1,000 miles from the nearest open port on the Pacific and 500 miles from the nearest point on the Government railroad. Obviously no one could be induced to furnish the capital for developing such a field unless there was promise of very large returns on the enormous investment required. Therefore, before entering upon such a project, capital will demand much more liberal conditions as to size of leaseholds and royalties than are permitted by the present act.

The approval of the oil-leasing law was the signal for starting small stampedes to all the accessible localities where oil seepages were known, and many claims were staked. Later the staking of oil claims was extended into several districts where no indications of oil had been found. Up to September, 1920, 178 applications for oil-leasing permits had been received by the Juneau land office, covering a total of 388,673 acres of land. This by no means includes all the claims that have been staked.

[1] Regulations covering oil and gas permits and leases (including relief measures) and rights of way for oil, gas, and pipe lines: General Land Office Circ. 672, 1920.

As in all oil booms, much the larger part of the land that has been staked will no doubt be found worthless, and there will be many disappointments. Yet, as Mr. Martin shows in this volume, there is good reason to believe that oil fields will be developed in Alaska. On the other hand, the geologic data do not indicate that any startling discoveries will be made. No doubt systematic drilling at localities in Alaska favorable for oil will be begun in 1921.

It is to be expected that with the legitimate enterprises that have for their purpose the search for oil will come the usual flood of stock-jobbing companies that are more energetic in selling stock than in developing an oil field. In the following pages Mr. Martin shows that in certain areas in Alaska there is good chance of finding productive oil pools. In other areas there is some chance of finding oil, though drilling in them must be regarded on present evidence as pure "wildcatting." On the other hand, the geology of much the larger part of Alaska gives no hope that it contains deposits of petroleum.

Those who are inexperienced in oil ventures are warned to be cautious in investing in Alaska oil stock without first obtaining full knowledge as to the character of the company and as to whether its holdings are in the region where petroleum seepages have been found. Wildcatting for oil in some parts of Alaska is perfectly legitimate, but the wildcatter should fully realize that his enterprise is a risky speculation. On account of the adverse local conditions that are set forth in this report, a company searching for oil in Alaska must have more capital than is needed for a similar enterprise in the States.

It is unfortunate that the limits set by the funds available have made it impossible to get complete surveys of the areas in Alaska which are the most promising for possible oil development. Additional surveys of prospective Alaska oil fields are, however, under-way and will be continued as fast as the conditions permit. Meanwhile, in view of the wide interest that is now taken in the oil resources of Alaska, this summary of the facts relating to it has been prepared.

Mr. Martin made his first investigation for oil in Alaska in 1903, and since then has from time to time devoted considerable attention to this subject. Other geologists have also made some field investigations bearing on the occurrence of oil in the Territory. The accompanying bibliography shows that the information relating to oil in Alaska is scattered through many publications, some of which are now out of print. This information has been assembled and coordinated by Mr. Martin. In addition to the facts published many others have been obtained from more or less confidential reports furnished by those who have been directly or indirectly connected with the development of oil in Alaska. For material of this kind special acknowledgment is made to Dr. A. M. Bateman, Messrs. J. L.

McPherson, Falcon Joslin, H. R. Harriman, and Capt. M. Manson. By using this material Mr. Martin has been able to present more detailed statements than those contained in the original publications.

In spite of the small developments Alaska has produced some 56,000 barrels of petroleum, all of which was taken from the Katalla field. This oil has found a ready local market. Most of the output made in recent years has been used by a small refinery near Katalla. The large use of petroleum and petroleum products in Alaska is shown by the following table of imports:

Petroleum products shipped to Alaska from other parts of the United States, 1905–1919, in gallons.[a]

Year.	Heavy oils, including crude oil, gas oil, residuum, etc.	Gasoline, including all lighter products of distillation.	Illuminating oil.	Lubricating oil.
1905	2,715,974	713,496	627,391	83,319
1906	2,688,940	580,978	568,033	83,992
1907	9,104,300	636,881	510,145	100,145
1908	11,891,375	939,424	566,598	94,542
1909	14,119,102	746,930	531,727	85,687
1910	19,143,091	788,154	620,972	104,512
1911	20,878,843	1,238,865	423,750	100,141
1912	15,523,555	2,736,739	672,176	154,565
1913	15,682,412	1,735,658	661,656	150,918
1914	18,601,384	2,878,723	731,146	191,876
1915	16,910,012	2,413,962	513,075	271,981
1916	23,555,811	2,844,801	732,369	373,046
1917	23,971,114	3,256,870	750,238	465,693
1918	24,379,566	1,086,852	382,186	362,413
1919	18,784,013	1,007,073	3,515,746	977,703
	237,949,492	23,605,406	11,807,208	3,600,533

[a] Compiled from Monthly Summary of Foreign Commerce of the United States, 1905 to 1919, Bureau of Foreign and Domestic Commerce.

PRELIMINARY REPORT ON PETROLEUM IN ALASKA.

By GEORGE C. MARTIN.

INTRODUCTION.

Indications of petroleum have been found in five districts in Alaska (see Pl. I), four of which—the Katalla or Controller Bay field, the Yakataga district, the Iniskin Bay district, on Cook Inlet, and the Cold Bay district, on the Alaska Peninsula—are on the Pacific seaboard, and the fifth, which includes areas near Smith Bay, is on the Arctic coast. The Katalla field, the only one that is now producing oil, could be made tributary to Controller Bay or could be reached from the Copper River Railroad by an easily constructed branch 60 miles long. The Yakataga district is comparatively inaccessible for lack of a harbor. The Iniskin Bay district, on Cook Inlet, and the Cold Bay district, on Alaska Peninsula, are tributary to harbors that are free from ice throughout the year. Smith Bay, which is about 50 miles east of Point Barrow, is a shallow arm of the Arctic Ocean, which is locked in ice for at least 10 months of the year.

The petroleum of the Pacific coast of Alaska, as it is known from wells near Katalla and from seepages in the Yakataga, Iniskin, and Cold Bay districts, is a high-grade refining oil with a paraffin base. The petroleum found near Smith Bay appears to have an asphaltic base.

The oil seepages on Cook Inlet and Alaska Peninsula were apparently known during the period of Russian rule. The oil fields in Alaska began to attract considerable attention in 1896, when claims were staked under the placer law in the Katalla, Yakataga, and Cook Inlet districts. The first well at Katalla was drilled in 1901, and a well was drilled on Cook Inlet at about the same time. There was much activity in the supposed oil fields of Alaska from 1902 to 1904, when many claims were staked in all the fields on the Pacific coast of Alaska, and at other places where oil was supposed to exist, though its existence had not been confirmed. During this period most of the wells in the Katalla, Iniskin, and Cold Bay districts were drilled. This "boom" collapsed in 1904, and all active operations soon ceased. Drilling was stopped for several reasons, among them the failure to obtain oil in large quantities, the high cost and great difficulty of drilling under the peculiarly adverse geographic and geologic conditions existing in Alaska, the increasing supply of fuel oil from California, and later of refining oil from the Mid-Continent fields, and the difficulty of obtaining title to oil lands under the old law except by discovery of oil in wells.

All the oil lands in Alaska were withdrawn from entry November 3, 1910, but meanwhile patent had been granted to one claim of 151 acres in the Katalla field, and other claims were pending, on some of which oil seems to have been discovered. Assessment work has been continued on some of the claims that were staked before the withdrawal, especially in the Katalla field, and applications for patents have been made. Other claimants have doubtless acquired prior rights under section 22 of the new leasing law.

Drilling has been done only in the Katalla, Iniskin, and Cold Bay fields. About 40 wells, aggregating in depth about 35,000 feet, have been drilled, 31 of which, aggregating 28,431 feet, are in the Katalla field. Oil has been produced commercially only in the Katalla field, which has yielded since 1904 about 56,000 barrels of crude oil for use as local fuel and for distillation in a small local refinery that has been operated since 1912.

It is too early to forecast the possible ultimate extent of the Alaska petroleum industry, but some conclusions as to its probable future may nevertheless be given. The conditions in each field are discussed in greater detail farther on, but a summary of the conclusions will be given here.

The geologic conditions in the Katalla field are by no means encouraging, and none of the 31 wells have yielded a large output, yet the field has produced oil commercially for nearly 10 years, and a large proportion of the better-located wells have been productive. The results of drilling have on the whole been rather consistent and have proved the existence of moderate amounts of oil in at least a part of the district, especially within the area of the patented claim. The wells outside this claim are not numerous enough to determine the outlines of the productive areas or even to show whether oil exists in sufficient quantity to pay for exploitation. The widespread and copious seepages indicate that large areas may be regarded as possible oil land. The results obtained in the wells on the patented claim near Katalla probably give a fair indication of what may be expected near the other seepages. A large proportion of any new wells that may be drilled near these seepages will probably yield small quantities of oil, and some of them may be larger producers, but there is no reason to expect more favorable results at any special localities or at greater depths.

The geologic structure in the Yakataga district has been described as more regular than that in the Katalla field, but this seeming regularity is possibly due to the fact that a narrower section is exposed. The structure may be similar to that in the eastern part of the Bering River coal field, where the more massive and best exposed beds seemingly indicate regular structure but where the softer and less conspicuous beds show intricate folding, and where the folding has in places really been so close that many of the minor folds have been partly flattened out. The seepages in the Yakataga district are numerous and yield a large volume of oil. The Yakataga district is certainly worth testing with the drill, provided the difficulties of landing supplies and of shipping oil can be overcome, but there is doubt as to whether it is any more promising than the Katalla field.

The possible oil fields on Cook Inlet have not been adequately tested with the drill, but the stratigraphy, structure, and seepages indicate that some oil will probably be obtained, most likely along the easternmost anticline and belt of seepages in the peninsula between Iniskin and Chinitna bays. Favorable localities may be sought elsewhere within the areas of Jurassic rocks, but the larger part of these areas is less promising because of steep dips or of the profound depth of the probable oil sands or of difficulty of access.

The Alaska Peninsula has possibilities as an oil field. In parts of the Cold Bay district the stratigraphy, the structure, and the seepages give promise of future production. The few wells drilled near Cold Bay give no adequate test of any part of the field. Most of the Alaska Peninsula is unexplored, and possibly the most favorable localities for drilling have not yet been found.

In northern Alaska oil may be present in a wide area, but the difficulties of transportation and the very short open season make it doubtful whether commercial development is feasible at this time.

Future discoveries may reveal indications of petroleum in other parts of Alaska, but no localities are now known where drilling is warranted except in the regions described above.

KATALLA OR CONTROLLER BAY OIL FIELD.

LOCATION.

The Katalla or Controller Bay oil field is on the Pacific coast of Alaska near latitude 60° 10′ N., longitude 144° 20′ W. The localities at which there are known indications of petroleum are confined to a belt that is about 25 miles long (from east to west) and 4 to 8 miles wide (from north to south). (See Pl. IV.) This belt is bounded on the north in part by the Bering River coal field, on the south by Controller Bay, the Pacific Ocean, and the alluvial flats on the east shore of Controller Bay, on the east by Bering Glacier, and on the west by Copper Delta.

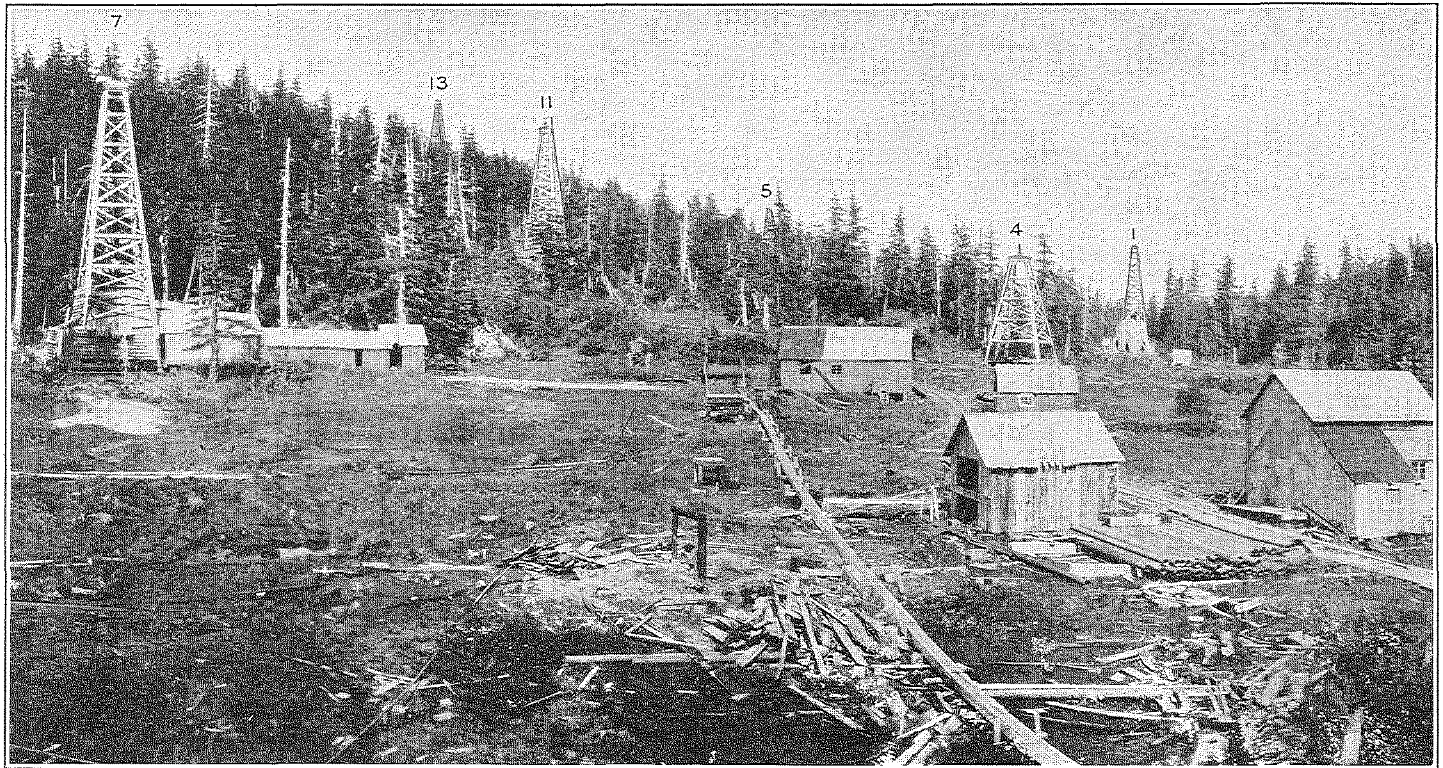
Katalla, the distributing point for the oil field, is a small settlement about six days' sail from Seattle and about 50 miles in an air line east of Cordova. Katalla can be reached either by direct landing from Seattle steamers or by launches from Cordova. Passengers and freight are landed at Katalla by means of scows and launches when the wind is favorable. During the period of excitement resulting from the discovery of oil some use was made of Controller Bay, 15 miles east of Katalla. Within its shelter ships discharged on scows, which were landed at Katalla or at the mouth of Bering River. Plans have been formulated for developing the Bering coal field by building a branch from the Copper River Railroad to connect with tidewater at Cordova, on Prince William Sound. (See Pl. III.) Another plan contemplates the building of a railway from a terminal on Controller Bay. Either plan could be made to serve the Katalla oil field with but little additional expense. Controller Bay could also be used as a shipping point for petroleum without a railroad by building short pipe lines to tidewater. The available timber is ample for construction. Fuel and blacksmith coal can be obtained in the Bering River coal field, which is only a few miles north of the oil field.

Passengers and freight are carried from Katalla to all parts of Controller Bay and to Bering Lake by launches, and much of the rest of the region is accessible by canoes. Bering River as far as the mouth of Canyon Creek, Gandil, Nichawak, and Katalla rivers, and other large streams are navigable for canoes and poling boats, which carry most of the local freight and passengers.

Land travel is practicable only where trails have been built, because the vegetation is dense, the flats are swampy, and the streams are numerous and many of them are hard to cross. Most of the trails are indicated on Plate IV. The trails that are most used are those from Katalla to Mirror Slough, from Katalla along the beach to Strawberry Harbor and to the head of Katalla Slough, and from the mouth of Bering River to the head of Katalla Slough. The last is a well-built wagon road. Other shorter trails reach practically all the camps that are not accessible by water. Short tramroads have been built from the head of Katalla Slough and from the mouth of Redwood Creek to neighboring oil wells. Telephone lines are in operation from Katalla to Cordova, where they connect with the Government cable and wireless systems, and to some of the local coal and oil camps.

SURVEYS AND INVESTIGATIONS.

Geologic reconnaissance surveys of the Katalla oil fields were made by the writer in 1903 and 1904, and detailed topographic surveys were extended over the more promising part of the field in 1905. Detailed



OIL WELLS NEAR KATALLA.

Numbers correspond to those in text and on figure 1.

geologic surveys were made in 1905 and 1906. The reports on these surveys have already been published[2] but are no longer available for free distribution. The information herein presented is based chiefly upon these surveys and upon supplemental investigations made by the writer in 1917. The detailed topographic map[3] of the region can still be obtained on application to the Geological Survey.

DEVELOPMENT.

The seepages near Katalla became known about 1896. The first well, known as well A, on the banks of Oil Creek, on claim No. 1,[4] now patented, was drilled in 1901 by an English company known by different names and operating under lease from the Alaska Development Co. This well[5] was drilled to a depth of 270 feet and was abandoned because of the loss of the tools, without obtaining any oil.

In 1902 the lessees of the Alaska Development Co. drilled well No. 1 to a depth of 366 feet and obtained a flow of oil.

In 1903 the lessees of the Alaska Development Co. deepened well No. 1 to 550 feet without obtaining additional oil and drilled well No. 2 on the same claim, obtaining some oil; the Alaska Petroleum & Coal Co. drilled its first well (No. 110) near the head of Katalla Slough and its second well (No. 111) on Katalla River without obtaining any oil; and another company began a well (No. 102) on the east bank of Bering River.

In 1904 the lessees of the Alaska Development Co. drilled well No. 3 and well B and erected a derrick for well C and possibly drilled it, all on claim No. 1. (See fig. 1.) Some oil was obtained in well No. 3. The same company drilled a well (No. 108, Pl. IV) on Redwood No. 11 claim, a well (No. 103) on the bank of Chilkat Creek, on Chilkat No. 10 claim, two wells (Nos. 104 and 105) on Chilkat No. 11 claim, along the wagon road west of Chilkat Creek, and erected a derrick but did not drill on Barrett No. 1 claim, a mile west of Burls Creek. Some oil was obtained in the well on the Redwood claim, and in one or both of the wells on Chilkat No. 11 claim. One or more of the wells on claim No. 1 were pumped to supply fuel for use at the wells that

[2] Martin, G. C., Petroleum fields of Alaska and the Bering River coal fields: U. S. Geol. Survey Bull. 225, pp. 365–382, 1904; The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: U. S. Geol. Survey Bull. 250, 64 pp., 1905; Notes on the petroleum fields of Alaska: U. S. Geol. Survey Bull. 259, pp. 128–139, 1905; Petroleum at Controller Bay: U. S. Geol. Survey Bull. 314, pp. 89–103, 1907; Geology and mineral resources of the Controller Bay region, Alaska: U. S. Geol. Survey Bull. 335, 141 pp., 1908.

[3] Topographic map of Controller Bay region, Alaska (No. 601A); scale 1:62,500; by E. G. Hamilton and W. R. Hill. Price, 35 cents retail or 21 cents wholesale.

[4] For the positions of the wells see Pl. IV and fig. 1, where they are indicated by the numbers here given.

[5] Further information concerning each well is given on pp. 21–25.

were being drilled. The Alaska Petroleum & Coal Co. drilled its third well (No. 112) near Katalla but obtained no oil. Two wells (Nos. 106 and 107) were drilled on Strawberry Harbor by Clarence Cunningham, but no oil was obtained.

In 1905 the lessees of the Alaska Development Co. did no drilling and their wells were not pumped. The Alaska Petroleum & Coal Co. drilled its fourth well (No. 113) near Katalla, and the so-called Rathbun well (No. 101) was drilled on the west shore of Bering Lake.

In 1906 drilling was continued at the two wells begun in 1905, but no oil was obtained. Patent was granted for claim No. 1 of the Alaska Development Co.

In 1907 the Alaska Petroleum & Coal Co. drilled its fifth well (No. 114). Two wells on the patented claim were pumped to supply fuel for use in local railroad construction.

In 1908 and 1909 no wells were drilled. Some oil was pumped for local use in 1908 from the wells on the patented claim.

In 1910 the Amalgamated Development Co. obtained control of the patented claim and of the rights and other property of the Alaska Development Co. The wells previously drilled by the lessees of the Alaska Development Co. were cleaned out and tanks and a pipe line were built. All oil lands in Alaska were withdrawn from entry November 3, 1910.

In 1911 a well (No. 115) was drilled by the Alaska Coal Oil Co. on Mirror Slough, which is said to have struck some oil and gas at a depth of 700 feet. Derricks were probably erected about this time at other localities, but it is not known that any further drilling was done. Preparations were made for utilizing oil from the wells on the patented claim, a small experimental refinery was built on Katalla Slough, and possibly some oil was pumped or refined.

In 1912 four wells (Nos. 4, 5, 6, and 7) were drilled on the patented claim. Oil was obtained in wells 4, 5, and 7. The refinery was placed in regular operation and supplied gasoline and other products for local use. Drilling was continued at the well (No. 115) on Mirror Slough in 1912 and for some time thereafter.

In 1913 well No. 8 was drilled on the patented claim, the older wells on this claim were pumped, and the refinery was operated.

In 1914 and 1915 the refinery was operated, but no new drilling was undertaken. In 1915 the company that had been operating the refinery went into the hands of a receiver.

In 1916 the patented claim and the refinery were bought by the St. Elias Oil Co. Production was increased somewhat by cleaning out the old wells, but no new wells were drilled.

In 1917 the St. Elias Oil Co. drilled well No. 9 on the patented claim and well No. 10 (same as No. 109, Pl. IV) on Redwood No. 12 claim. The refinery was operated as usual. The Alaska Coal Oil Co. continued its efforts to shut off the water and recover the oil in its well on Mirror Slough. Some of the pending claims were surveyed preparatory to application for patent.

In 1916 two productive wells (Nos. 11 and 12) were drilled on the patented claim and well No. 13 was begun.

In 1919 well No. 13 was finished and well No. 14, also on the patented claim, was drilled to a depth of 1,410 feet.

From 1901 to 1919, inclusive, 31 wells have been drilled in the Katalla field. On the patented claim (see Pl. II) 16 wells have been drilled to depths of 200 to 1,810 feet. Oil was obtained in 10 wells (Nos. 1, 2, 3, 4, 5, 7, 8, 11, 12, and 13), of which Nos. 8 and 2 ceased to be pumped in 1907 and 1919, respectively. Three wells (Nos. A, C, and 6) were abandoned at shallow depths because of accidents. Two wells (Nos. B and 9) should be classed as dry holes, and one well (No. 14) has not yielded any oil but is not yet finished. On the claims formerly held by the Alaska Development Co. between the patented claim and the mouth of Bering River 5 wells (Nos. 103, 104, 105, 108, and 109, Pl. IV) have been drilled. The well on Redwood No. 11 claim (No. 108) and one of the wells (No. 105) on Chilkat No. 11 claim are probable producers. There is some oil and gas in the other well (No. 104) on Chilkat No. 11 claim. The well (No. 103) on Chilkat No. 10 claim was probably abandoned at a shallow depth because of accident. The well (No. 109) on Redwood No. 12 claim is nonproductive. The remaining 10 wells were drilled by five companies in various parts of the field. Three of them (No. 111 on Katalla River, No. 106 on Strawberry Harbor, and No. 102 on Bering River) are situated on the mud flats and were abandoned without reaching bedrock. The well on Mirror Slough (No. 115), which has encountered some oil and gas, is not regarded by the owners as finished. The remaining six wells (Nos. 101, 107, 110, 112, 113, and 114) are all nonproductive and were abandoned at various depths down to 1,710 feet. Descriptions of the wells are given on pages 21–25. The total petroleum output of the Katalla field from 1904 to the end of 1919 is believed to be about 56,000 barrels, valued at about $270,000.

Casing-head gas is obtained from most of the productive wells on the patented claim. It is used for power and domestic heat and light at the oil camp. The quantity of gas is probably in excess of these needs, but no further use is now feasible because of the lack of a local market.

GEOLOGY.

GENERAL FEATURES.

In the Controller Bay region (see Pl. IV) there are some igneous and metamorphic rocks probably of pre-Tertiary age, a great thickness of thoroughly consolidated and highly folded Tertiary sedimentary rocks, which include the oil-bearing strata, and a large area and great thickness of Quaternary alluvial deposits. The general succession of rocks in the Controller Bay region, including both the Katalla oil field and the adjacent Bering River coal field, is shown in the following table:

General section of rocks of the Controller Bay region.

Age.	Formation.	Character of rocks.	Thickness.
			Feet.
Quaternary.		Stream deposits, probably in part underlain by marine sediments.	0-500±
		Sediments and abandoned beaches of glacial lakes.	0-200±
		Morainal deposits.	0-100±
		Marine silt and clay.	100
Tertiary or later.		Diabase and basalt dikes.	
Tertiary.	Tokun formation.	Sandstone.	500
		Shale.	2,000+
	Kushtaka formation.	Arkose with many coal beds.	2,500±
	Stillwater formation.	Shale and sandstone.	1,000±
	Katalla formation.[a]	Conglomerates, and sandstones and shales, some of which are conglomeratic.	2,500
		Sandstone.	500
		Shale, concretionary and with a glauconitic bed at the base.	2,000
		Sandstone.	1,000
		Shale.	500+
Pre-Tertiary.		Graywacke, slates, and igneous rocks.	

[a] The position of the Katalla formation with reference to the other Tertiary formations is not definitely established.

PRE-TERTIARY ROCKS.

The metamorphic rocks of the Controller Bay region crop out in two areas. One of these areas covers all of Wingham Island except its narrow southeastern point, and the other is west of Katalla, in Ragged Mountain. The rocks consist of black slates having well-developed cleavage, graywacke, chert, a variety of highly colored fine-grained rocks of uncertain origin, and greenstone and other igneous rocks, which probably include both bedded and intrusive masses.

The observed contacts with the Tertiary rocks are faults, and these rocks are probably in both areas overthrust upon the Tertiary sediments.

TERTIARY ROCKS.

Most of the consolidated rocks of the Katalla oil field have been included in the Katalla formation, which occupies the hilly area south of Bering Lake between Bering and Katalla rivers and the low hills between the base of the steep eastern slope of Ragged Mountain and Katalla River. Rocks that are probably, in part at least, equivalent to these crop out in Gandil Mountain, Nichawak Mountain, Mount Campbell, and the neighboring small hills of the Nichawak region, on Kayak Island and on the southeastern point of Wingham Island, in the low hills west of Bering Lake, possibly in parts of the region north and northeast of Bering Lake, and in the low hills between Ragged Mountain and the mouth of Copper River.

The Katalla formation is composed of shales, sandstones, and conglomerates. The section has not been definitely established but seems to be as follows:

Generalized section of Katalla formation in hills south of Bering Lake.

	Feet.
Conglomerate and conglomeratic sandstone interbedded with shale and sandstone	2,500
Flaggy sandstone	500±
Soft shale with calcareous concretions and with bed of glauconitic sand near base	2,000
Sandstone	1,000
Soft shale	500+

The shales that constitute the bulk of the formation are soft, dark, and argillaceous, in places with many limestone concretions and with at least one bed of glauconitic sand.

The formation seems to include two massive and prominent beds of sandstone. One of these overlies the thickest and most prominent bed of shale; the other underlies the same bed and is in turn underlain by a bed of shale that resembles the thicker shale above it. It is possible, however, that the beds are duplicated by faulting and that the supposed lower sandstone and shale are a repetition of the sandstone and shale above.

The upper sandstone is overlain by conglomerates, sandstones, and shales, apparently of great thickness. The conglomerates, though massive, are irregular in extent and position and grade locally into pebbly sandstone or shale or into rock containing no pebbles. The more typical of the conglomerates contain usually well-rounded but unsorted pebbles and boulders of granite, greenstone, gneiss, and other rocks and minerals. The material making up the conglomerate ranges in size from that of very coarse sand to that of large boulders, but most of it is less than 6 inches in diameter. The boulders examined show no glacial facets or scratches. The matrix consists of fine shale, sandstone, and arkose.

The Katalla formation contains numerous poorly preserved fossils, which are clearly Tertiary but which do not indicate with certainty any precise horizon within the Tertiary, though they are probably Miocene. The paleontologic evidence of the age of the Katalla formation that was gathered when the detailed survey of the region was made has already been published.[6] The only additional evidence was obtained from a small lot of fossils contained in a boulder, probably derived from the Katalla formation, which the writer found in the bed of Redwood Creek in 1917 and on which W. H. Dall has reported as follows:

The shells (contained in the fragments of a concretion) are all of one species of *Pseudamusium*, namely, *P. peckhami* Gabb, of the Miocene Monterey horizon. They appear to be identical with California specimens.

The rocks on the shore of Mirror Slough consist chiefly of graywacke or highly indurated arkosic sandstone interbedded with some shale or slate. Most of the observed exposures consist of graywacke or arkose. This may mean either that the graywacke or arkose is the dominant rock in the area or that, being more resistant than the argillaceous beds, it makes most of the outcrops. These rocks, in the writer's opinion, were originally not unlike the more sandy beds of the Katalla formation and may possibly be correlated with them. They differ from those beds chiefly in being slightly more metamorphosed. They are also not unlike some of the less metamorphosed graywackes of the Orca and Valdez groups of Prince William Sound. No evidence of the age of these rocks has been obtained, except from several small lots of fossil plants collected by the writer in 1917 from exposures of arkose and argillite near the mouth of Mirror Slough. F. H. Knowlton has submitted the following statement concerning these fossils:

This material includes about a dozen pieces of hard arkosic matrix exhibiting only pieces of bark, fragments apparently of monocotyledonous stems, and fragments of some grasslike leaves. The question to be decided is whether this material is Mesozoic or Tertiary in age. It is absolutely impossible to decide this point with certainty, but from the resemblance of the grass leaves to many I have seen from the Kenai formation I might hazard the guess—it can hardly be more—that it is probably Tertiary. If it belong in the Mesozoic at all I should presume it to be late Mesozoic. I must add that very little weight should be attached to this report.

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[6] Martin, G. C., Geology and mineral resources of the Controller Bay region, Alaska: U. S. Geol. Survey Bull. 335, pp. 28–30, 38–41, 1908.

Several small basalt or diabase dikes have been found in the hills south of Bering Lake. A diabase dike on the crest of the hill between Katalla River and Clear Creek is about 20 feet wide and several hundred feet long. It is the largest dike seen in the Tertiary rocks of the mainland.

QUATERNARY DEPOSITS.

The east shore of Bering River and of Controller Bay from the margin of Bering Glacier to the ocean is a flat plain of mud, sand, and gravel, which is constantly growing by the addition of sediment deposited by glacial streams along their courses and at their mouths. Nichawak Mountain, Mount Campbell, Gandil Mountain, and the Suckling Hills rise like islands from this plain, and a very short time ago they were islands in an older extension of Controller Bay that has been filled by the sediment of these glacial streams. These fluviatile deposits cover large areas in the Copper River delta, which extends into the west end of the district here described. The valley of Katalla River and of the streams that head near it and flow into Bering Lake is floored with similar material, as are also the lower courses of most of the other streams that enter Controller Bay. These unconsolidated deposits, some of which are of fluviatile origin, are known from well borings (see pp. 24–25) to have a thickness of more than 580 feet at one point on Bering River and of more than 280 feet in the Katalla Valley.

The beaches, bars, and islands which the ocean waves are building along these shores are composed largely of reworked fluviatile and glacial material and are in part contemporaneous with the stream deposits. They include Okalee Spit, Kanak Island, the beach from Strawberry Point to Katalla, Softuk Bar, and the long line of islands that extend across the front of the Copper River delta.

STRUCTURE.

The rocks of the Controller Bay region are much folded and in some places faulted. They have a general northeast strike and a northwest dip, but the strike and dip vary sharply and irregularly from place to place, the rocks having evidently been involved in violent crustal movements. Though the structure in areas of uniform monoclinal dip appears at first to be simple, a closer study shows that much of the simplicity is only apparent and that the structure is extremely complex. The problems involved are difficult, and it must be admitted not only that our present knowledge of the structural details in most of the area is incomplete and unsatisfactory but that even the broader scheme of the structure is not definitely known. Numerous faults were noted and there are doubtless others, and faulting has probably played a large part in the development of the structure.

The peninsula south of Bering Lake shows considerable diversity of structure. In the region east of Burls Creek the strike is north and northeast and the dips are both east and west. An anticline extends along the canyon of Chilkat Creek, and its western flank is broken by a fault. East of this anticline there are several minor folds, the most noticeable being a closely compressed syncline, which extends diagonally across the south end of the ridge east of Chilkat Creek and is shown on the map by the position of a belt of sandstone. The west bank of Bering River in its lower course is probably on the line of a fault.

The valley of Burls Creek and the hills northeast of it contain several folds, which are revealed by the sinuous boundary of the shale and sandstone. These folds descend into the valley of Burls Creek and die out or are cut off by a fault along the steep western side of the valley.

On the hills between Burls and Redwood creeks an anticline extends northeastward through the headwaters of Split Creek. North of this anticline is a spoon-shaped syncline, which is separated from the anticline by a fault. South of the anticline the monoclinal southerly dip continues to the edge of the flats bordering Controller Bay. The structure of this area is shown on Plate IV. Possibly the valley of the upper east fork of Redwood Creek contains a fault that has caused a repetition of the shales and sandstones. If this fault exists, the shale in the valley of Split Creek is the same as that on the headwaters of Redwood Creek, and the sandstone on the ridge north of Redwood Creek is the same as the sandstone underlying the conglomerate on the ridge south of it. Another possibility is that the upper valley of Redwood Creek and the ridge north of it each contain a closely compressed and overturned anticline and syncline which would cause a repetition of the beds similar to that which would be made by faulting. The shales and sandstones are near enough alike to admit of this possibility, but the fault or folds have not been found, and the presence of two shales and two sandstones is indicated in other localities.

The fact that the sandstones and conglomerates east of Redwood Creek are not found west of it indicates that a large fault extends along the course of the creek. At the south end of the range of hills between Redwood Creek and Katalla River there is an irregular syncline, and immediately west of it there are several small, closely compressed folds.

An anticline possibly lies southeast of this fold extending southwestward from a point near the oil drillers' camp at Redwood, where it is probably cut off by the Redwood Creek fault to a point near the head of Katalla Slough. The north end of the ridge west of Redwood Creek has a monoclinal southeasterly dip.

The rocks of the crescent-shaped hill that extends from Cave Point to Point Hey have a curving strike parallel to the crest of the hill and a dip toward its concave seaward face. This appears to be the end of a seaward-pitching syncline, of which only the nose remains above the ocean.

The rocks between Katalla River and the base of the steep eastern slope of Ragged Mountain have a general northeast strike and a diversity of dips which have not been interpreted. The base of the steep mountain slope mentioned above lies on the line of contact between the Katalla formation and the metamorphic rocks. The latter strike east, have steep and diverse dips, and are considered to be overthrust upon the younger shales of the Katalla formation.

PETROLEUM.

WELLS.

Oil has been obtained in 12 or 14 of the 31 wells that have been drilled in the Katalla field (see pp. 21–25), 10 of which have produced it in commercial quantities. Seven of these 31 wells were abandoned at shallow depths and 10 or 12 were nonproductive. Most of the systematic search for petroleum has been made within the small area (151 acres) of the single patented claim (see Pl. II), where there are 16 wells, which include all that have been pumped and most of those that have encountered oil. About 28,431 feet of drilling has been done in the field, 13,308 feet of which was on the patented claim. The 31 wells in the field range in depth from 100 to 1,810 feet and average 917 feet; the 12 productive wells range in depth from 366 to 1,130 feet and average 885 feet. Neither the field as a whole nor any part of it, except possibly the patented claim, has been adequately tested with the drill.

In the following account of the wells drilled in the district the numbers and letters by which the wells are designated correspond to numbers and letters on Plate IV and figure 1, showing the geographic positions of these wells. (See also Pl. II.)

No. A. Near head of Katalla Slough. Drilled in 1901 to a depth of 270 feet[7] and abandoned because of loss of tools, without producing oil, although it has been stated[8] that some oil was found.

No. 1. Near head of Katalla Slough. Drilled in 1902 to a depth of 366 feet, where a flow of oil was obtained. Drilled to 550 feet in 1903, without further

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[7] Oliphant, F. H., The production of petroleum in 1901: U. S. Geol. Survey Mineral Resources, 1901, p. 208, 1902 (not in bound volume).

[8] Oliphant, F. H., Petroleum: U. S. Geol. Survey Mineral Resources, 1903 p. 691, 1904.

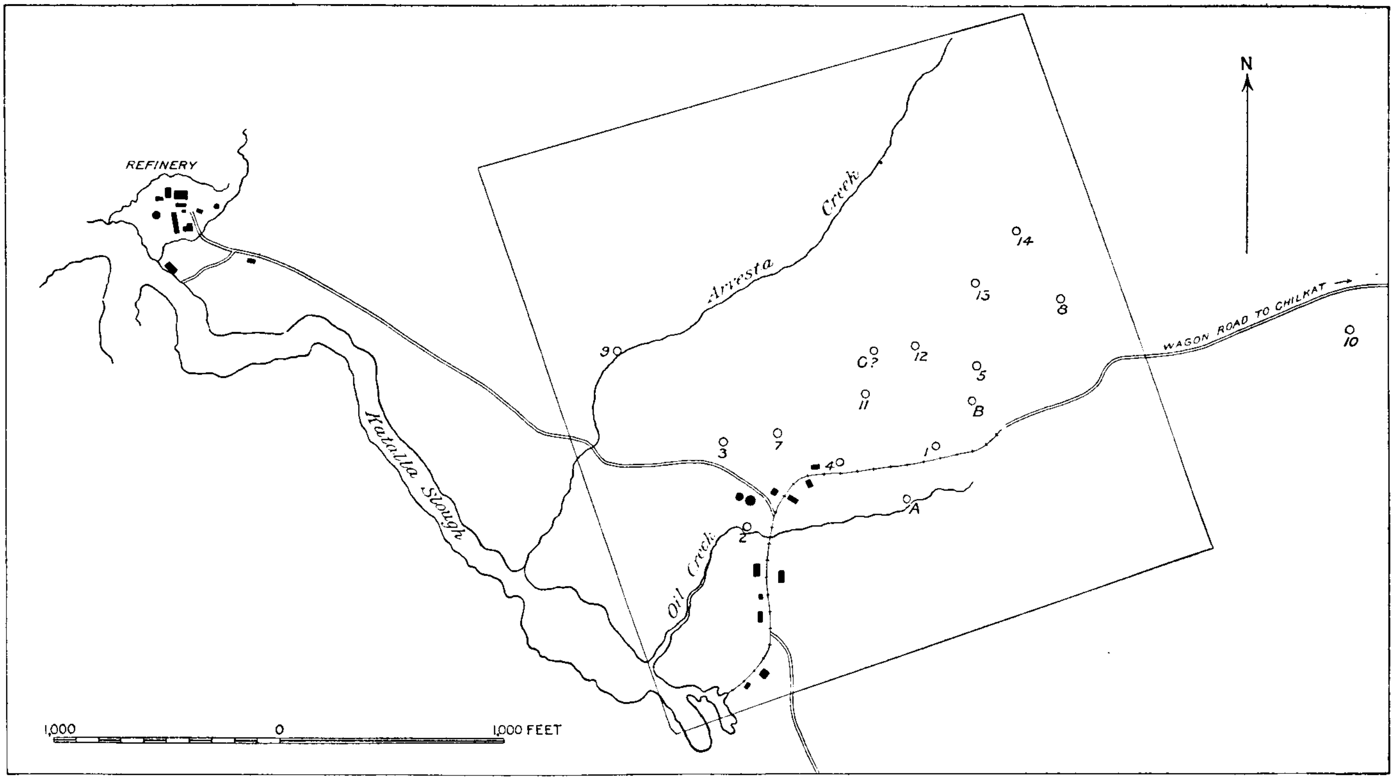

FIGURE 1.—Map showing productive oil wells near Katalla and outline of the patented claim.

results. In 1904 this well was pumped to obtain fuel for use at the other wells of the same company. In 1905 and 1906 the well remained capped, but the oil oozed from around the casing. The well was pumped to get local fuel in 1906 and 1907, and it has been a continuous producer since the refinery was placed in operation in 1912. It yields considerable gas.

The following is a record of this well given by the Alaska Steam Coal & Petroleum Syndicate and reported by F. H. Oliphant:[9]

Record of well No. 1, near head of Katalla Slough.

	Thickness.	Depth.
	Feet.	*Feet*
Surface drift	6	
Decomposed shale	10	16
Light-colored shale	140	156
Fine-grained sandstone, containing 6-inch bed of coal	18½	174½
Dark shale, very hard, including 6 inches of quartz containing iron pyrites	190½	365
Oil sand; flow of oil	1	366
Length of 12-inch casing		220
Length of 9⅝-inch casing		340

According to Mr. Oliphant the drill encounters numerous small showings of petroleum and natural gas and at 366 feet struck a large quantity of oil, which flowed. The well is said to have continued to flow until it was capped.

No. 2. Near head of Katalla Slough. Drilled in 1903 to a depth of about 1,000 feet. Said to have obtained oil at a depth of about 700 feet. Pumped from 1912 to 1919, yielding a small quantity of oil but no gas. Abandoned in 1919.

No. 3. Near head of Katalla Slough. Drilled in 1904 to about 900 feet. In 1905 and 1906 this well remained capped, but the oil squirted at times in strong jets from the casing. The well was pumped for fuel in 1907 and 1908 and has been a constant producer since 1912. It yields a small amount of gas.

No. B. Near head of Katalla Slough. Drilled to an unknown depth in 1904. No oil so far as known.

No. C. In 1903 a derrick was erected on this site and in 1904 a well was probably drilled. No oil was obtained.

No. 4. Drilled in 1912 to a depth of 690 feet, obtaining oil between 400 and 500 feet. The well has been pumped since 1912, yielding both oil and gas.

No. 5. Drilled in 1912 to a depth of about 1,000 feet. A small quantity of oil was obtained at 650 feet and the main flow at 800 feet. This well is one of the larger producers of oil on the patented claim and it also yields some gas.

No. 6. Drilled in 1912 to a depth of 100 or 200 feet and abandoned without obtaining oil because of the loss of the rotary bit.

No. 7. Drilled in 1912 to a depth of 645 feet. Small showings of oil were obtained from 300 to 450 feet and the main flow was struck at 450 feet. Yields both oil and gas.

No. 8. Drilled in 1913 to a depth of about 1,100 feet. A small quantity of oil was obtained between 700 and 800 feet. The well was pumped in January, 1917, but not since then. It yielded some gas.

No. 9. Drilled in 1917 to a depth of 1,810 feet. Some oil was obtained at 650 and 1,000 feet, but not enough for pumping. The well yields a small quantity of gas from a depth of 350 feet.

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

No. 11. Started June 6, 1918, and finished July 9, 1918. Drilled to a depth of 1,130 feet, entirely in shale. Produces about 3 barrels a day. The well is on claim No. 1 and is about 350 feet from well No. 4 and in line between well No. 4 and the northeast corner of the claim. Oil was obtained at 490 feet and from 590 to 1,000 feet, and gas at 380 and 475 feet.

No. 12. Started July 27 and finished September 7, 1918. Drilled to a depth of 903 feet, entirely through shale. This well produced about 8 barrels a day. It is about 350 feet northeast of well No. 11, on claim No. 1. It struck a slight showing of oil at 330 feet, a slight increase at 430 feet, and a big increase at 590 feet.

No. 13. Started in September, 1918, and finished in June, 1919. Drilled to a depth of 900 feet, entirely through shale. Produces about 20 barrels a day. This well is 350 feet northeast of well No. 12, on claim No. 1. The first oil obtained in this well was struck at 635 feet and a strong flow at 770 feet. Gas was obtained at 637 feet.

No. 14. Started in July, 1919, and drilled to a depth of 1,410 feet. Drilling discontinued November 1, 1919, for the winter. This well is about 350 feet northeast of well No. 13, on claim No. 1, and is drilled entirely through shale. A little gas and a showing of oil were found in this well, but no "pay." This well was drilled to 2,265 feet in 1920, but no oil was obtained.

No. 15. Derrick erected in 1920 and drilling was probably started in the fall.

No. 16. Drilled in 1920 to a depth of 740 feet. Some oil is produced. Oil was obtained at 365 feet, 510 feet, and 740 feet. The greatest yield was at 740 feet.

No. 101. The so-called Rathbun well, on the west shore of Bering Lake, was drilled in 1905 and 1906 to a reported depth of about 1,700 feet. Drilling was frequently interrupted by accidents to the machinery. It is not known that any oil was obtained.

No. 102. East shore of Bering River. Begun in 1903. Abandoned without reaching bedrock at a depth of 580 feet because of difficulty in sinking casing through the mud.

No. 103. Chilkat Creek on Chilkat No. 10 claim. Drilled in 1904 to a depth of about 400 feet, and said to have been abandoned because of the loss of tools. No oil, gas, or water is to be seen in the casing, and it is said that no oil or gas was obtained.

No. 104. Edge of tidal flats 1 mile west of mouth of Bering River on Chilkat No. 11 claim. Drilled in 1904 to a depth of 600 or 700 feet. It is said that the well was abandoned because the tools were lost in it. Water now stands near the top of the casing. Gas bubbles through the water almost continuously, and it is said that globules of oil occasionally rise to the surface.

No. 105. Edge of tidal flats a short distance northwest of No. 104 on Chilkat No. 11 claim. Drilled in 1904 to a depth of about 800 feet. Oil now stands near the top of the casing. Small but continuous flow of gas. The amount of oil has not been estimated. The well has never been pumped, but it is reported that oil has been bailed from it for local use.

No. 106. Clarence Cunningham's well No. 1, on Strawberry Harbor. The derrick was built on piling about 1,000 feet offshore. Casing sunk deep into the mud in 1904 without reaching bedrock.

No. 107. Clarence Cunningham's well No. 2, on Strawberry Harbor. Drilled several hundred feet in 1904 without obtaining oil.

No. 108. Tributary of Redwood Creek on Redwood No. 11 claim. Drilled to a depth of about 1,000 feet in 1904. Oil now stands a few feet below the top of the casing. The quantity of oil is not known, as the well has never been pumped.

No. 109. This is well No. 10 of the Chilkat Oil Co. and is on Redwood No. 12 claim. Drilled in 1917 to a depth of 1,613 feet. Small quantities of oil were found at depths of 1,050, 1,230, and 1,613 feet, and of gas at 260, 290, 460, and 1,520 feet. The well was abandoned because of caving.

No. 110. Alaska Petroleum & Coal Co.'s well No. 1, between the head of Katalla Slough and Cave Point. Drilled in 1903 to 1,710 feet and abandoned because limit of outfit was reached. No flow of oil was found, but it is said that a little oil was brought up in the bailer from time to time.

No. 111. Alaska Petroleum & Coal Co.'s well No. 2, on Katalla River. Casing sunk to a depth of 280 feet in 1903 without reaching bedrock.

No. 112. Alaska Petroleum & Coal Co.'s well No. 3, near Katalla. Drilled in 1904 to a depth of about 1,500 feet.

No. 113. Alaska Petroleum & Coal Co.'s well No. 4, near Katalla. This well, which is very near the site of well No. 3, was drilled in 1905 and 1906 to a depth probably exceeding 1,500 feet.

No. 114. Alaska Petroleum & Coal Co.'s well No. 5, on the west line of Bangor No. 3 claim and the east line of Tuttle No. 3 claim, was drilled to a reported depth of 1,600 feet in 1907. It is said that no oil was found.

No. 115. Alaska Coal Oil Co.'s well No. 1, on the south line of the Alhambra No. 2 and the north line of the Crescent No. 2 claim on Mirror Slough. This well was begun in 1911 and had been drilled in 1917 to a depth of 1,040 feet. Oil and gas were encountered at 700 feet. In 1917 an attempt was being made to bail out and shut off the water. A small quantity of oil was brought up in the bailer and there was a strong flow of gas whenever the pressure of the water was reduced.

SEEPAGES.

OCCURRENCE.

Petroleum seepages and gas springs are numerous in many parts of the oil belt, and the flow of oil or gas at some of them is large. The seepages all occur (see Pl. IV) within a long, narrow belt extending from the edge of the Copper River Delta eastward to Bering Glacier, a distance of about 28 miles. This belt is very narrow, not more than 4 miles wide at any known point, and is in general parallel to the coast. The seepages at Yakataga (see pp. 37–38) are in a belt having the same general direction and lying practically in line with it. Several of the smaller groups of seepages, such as the group on Redwood Creek and at the head of Katalla Slough, and the groups on Burls Creek, on Chilkat Creek, and in the Nichawak region, have a distinct linear arrangement, each running about N. 15° E. These lines coincide with the directions of the valleys.

Several large oil seepages were seen by the writer on the banks of Mirror Slough near the mouth of Martin River. At some of these the petroleum reaches the surface through the clay and mud of the valley floor, and a large quantity has accumulated in the pools on the swampy surface and in the soil. The nearest outcrops of hard rocks are sandstones or graywackes, probably of Tertiary age and possibly belonging to the Katalla formation. At two localities, one near the derrick on Crescent No. 2 claim and one near Sinclair's cabin, about a mile east of the derrick, the seepages have been excavated and small but continuous flows of oil obtained from bedrock.

Seepages were also seen near the head of Mirror Slough, at the base of Ragged Mountain. The oil here reaches the surface through soil that is immediately underlain by either glacial drift or by talus or landslide débris. The underlying rock is probably slate or graywacke. Another seepage about a mile south of this point, in a canyon just north of Bald Mountain, was visited by the writer. The oil was here seen oozing in small quantities directly from the joints and bedding planes of the steeply dipping slate, chert, and graywacke.

Oil is reported to have been seen in large quantities on the surface of the water of the small ponds and the creek at the south end of the town of Katalla after the earthquake of 1899. The surface material consists largely of rock débris derived from Ragged Mountain, and is underlain by the soft shales of the Katalla formation.

Numerous and copious seepages are to be seen in the vicinity of the wells at the head of Katalla Slough. (See Pl. V, *A*.) The oil impregnates the soil at many points and has accumulated in large quantities on the surface. These accumulations are chiefly oil, not residues, such as those at the California brea deposits.

On the west slope of the valley of Redwood Creek, about 1½ miles northwest of the mouth of the creek, near a well (No. 108, Pl. IV), oil can be seen coming directly from soft, fissile, iron-stained shale. The shale has been broken into small angular fragments and recemented by ferruginous material. This recemented rock is common at or near seepages in these shales and is believed to be a fault breccia. Here, as at many other seepages, sulphur springs are associated with the oil. Another seepage was seen near the headwaters of Redwood Creek, where oil flows directly from the shale.

It is reported that oil may be seen at low tide in the beach sands on the north shore of Strawberry Harbor. The rocks in the vicinity are sandstone and shale, which probably belong much higher in the stratigraphic column than the soft shale found at the seepages already described.

Several seepages occur along the wagon road that leads from the head of Katalla Slough to the mouth of Bering River. Two of these are about a mile and a half west of Burls Creek, close to the road. The quantity of oil at one of these seepages is large. The nearest visible rock is steeply dipping conglomerate, which crops out a few feet away, but the oil can be seen only on the surface of the soil, its direct source not being visible. At the other seepage in this locality a tunnel that has been driven into the hillside reveals a small but continuous flow of oil from bedrock.

OIL SEEPAGE NEAR HEAD OF KATALLA SLOUGH.

On Barrett Creek above the wagon road, near the locality last mentioned, oil flows continuously from the bedding planes and joints of the rocks exposed in the bank of the creek.

In the upper part of the valley of Burls Creek there are many seepages at which the oil oozes directly from steeply dipping shales that here contain a large quantity of glauconite, which gives the rock a bright-green color. Thin sections show abundant casts of foraminifers and diatoms. Large calcareous concretions are abundant, and some of them have the form of septaria filled with calcite. Organic remains consisting chiefly of mollusks and crabs are seen in many of these concretions. The soft shale also is rich in organic material, some beds being so dark as to resemble impure coal. The writer saw no coal in these rocks, however, either at this locality or elsewhere. The rocks at this point seem to be very strongly impregnated with oil, and seepages are numerous, but large surface accumulations are rare. Broken shale recemented by ferruginous material was seen here, as on Redwood Creek.

Some seepages at which considerable oil has accumulated were seen along the edge of the tidal flat, close to the wagon road, halfway between Burls Creek and the mouth of Bering River. No outcrops were seen near these seepages, but fragments of shale indicate the presence of beds of that rock.

Several seepages have been reported from Chilkat Creek. The largest one seen by the writer is in the west bank of the creek 1½ miles above the forks of the wagon road. The oil reaches the surface through soft, brecciated shale whose beds have a steep westerly dip. The seepage is associated with a black sulphur spring.

Many seepages have been reported in the group of hills centering around Nichawak Mountain. Those seen by the writer were small, but the oil issued directly from the rock, which is shale resembling that at the seepages west of Bering River. Others are reported to occur on the banks of a small lake, the surface of which is said to be covered at times with oil. The most conspicuous seepages are on Kathleen, Yuclaw, and Yakogelty creeks. (See analysis, pp. 31–32.)

Seepages have been reported from many parts of the Controller Bay region, but some of them, especially those seen in the mud on the tidal flats, are believed to be only decaying organic material or films of iron oxide. Many of the sulphur springs may bear no relation to any accumulations of petroleum.

Inflammable gas comes to the surface of the water in large quantities at several places. The largest of the "gas springs" seen by the writer are in Mirror Slough and in Katalla River. The gas from the spring in Mirror Slough will furnish a large, continuous flame. It issues from the mud on the bottom of the slough. Its composition is not known. It may be ordinary swamp gas derived from the decay of organic material in the mud, but it is more probably a true natural gas derived from bedrock, for it issues forth in large quantity at a point close to oil seepages. Most of the productive oil wells and several of the nonproductive wells yield considerable natural gas. (See p. 15.)

SIGNIFICANCE.

A petroleum seepage or oil spring is a place at which there is natural escape of petroleum to the surface, either directly from the outcrop of the oil sand or through some joint or fault plane or crushed and porous zone that extends from the oil sand to the surface. As soon as the oil reaches the surface it either dries up or flows away. In the cool, moist climate of the Katalla district there is comparatively little opportunity for residues to accumulate. The oil is washed away rapidly, so that at most of the seepages no residues are seen, and the oil becomes completely dissipated a short distance from its point of escape. The presence of residues in this region therefore means either that large quantities of oil are escaping or that exceptional conditions prevent the oil from being washed away, or more probably both. At some places, as at the well-known seepages at the head of Katalla Slough, large quantities of absorbent material, such as peat, may have permitted the accumulation of residues. As the oil at the surface is rapidly washed away in this region the presence of fresh oil in the soil or on standing or running water generally indicates that its immediate source is close at hand. At most of the observed seepages either close inspection of the natural exposure or a small amount of excavation has revealed the oil issuing from bedrock. At no seepage, even where the quantity of oil was large, did the writer see the oil traveling very far, for it is soon so completely washed away as to be unobservable. It may be safely concluded that any large quantity of fresh oil in the soil or on standing or running water in this district has its immediate source within a few feet, if not within a few inches, horizontally, of the place where it is observed. Most of the immediate bedrock sources will probably be found within a short vertical distance of the point where the oil comes to the surface. The presence of a residue in this region indicates that oil is escaping in large quantity and that its immediate source is directly beneath the highest point on the surface of the residue. The ultimate source of the oil within the bedrock, however, can be determined less definitely.

The seepages at the head of Katalla Slough and on Redwood, Burls, and Chilkat creeks are all in the soft shales that compose the middle part of the Katalla formation. Those between Redwood and Burls creeks are associated with conglomerates of presumably higher position. The seepages in the Nichawak region that were seen by the writer are in shales which closely resemble the soft shales just referred to. The seepages on Mirror Slough and at the neighboring localities west of Katalla are in an area of highly folded sandstone or graywacke that may be the equivalent of part of the Katalla formation.

The position of the seepages with reference to the structural features is somewhat uncertain. The seepages west of Katalla are on steeply folded and slightly metamorphosed beds whose detailed structural features have not been determined. The group of seepages on Redwood Creek and Katalla Slough is apparently close to a fault.

The seepage on Burls and Redwood creeks are possibly near the axes of anticlines. The Redwood Creek anticline, if it exists, is probably broken near or west of its axis by a fault. The seepages between Burls and Redwood creeks are on monoclinal beds of conglomerate. The general structure in the Nichawak region has not been determined, but the beds near the seepages have a steep dip and are probably closely and complexly folded.

It seems, therefore, that, although small groups of seepages lie along local structural lines, the general occurrence of all the seepages in a long, narrow belt, running east and west, diagonal to the structure and to the belts of outcrop of the various kinds of rock, is unexplained. The existence and position of this belt of seepages must, however, be related to the stratigraphy and structure of either the surface rocks or of some rocks that do not crop out. Among the systems that are represented at other localities on the Pacific coast of Alaska but that have not been recognized in this district is the Jurassic, rocks of which on the west shore of Cook Inlet and on the Alaska Peninsula have yielded oil (see pp. 53, 66) that is of the same kind as that of Controller Bay and very different from most of the Tertiary oil of California and other oil fields on the Pacific coast. The inference naturally follows that the petroleum of Controller Bay might be derived from Mesozoic rocks that lie beneath Tertiary rocks.

To account for the occurrence of the oil, however, it is not sufficient to suppose merely that it is derived from buried Mesozoic oil-bearing rocks, for if these have the same structure as the Tertiary rocks at the surface the chief difficulties will still remain. Nor will it be sufficient to assume that the Mesozoic rocks underlie the Tertiary rocks unconformably, for then the Mesozoic rocks would have a structure at least as complex as that of the Tertiary rocks. If, however, there was, in late Tertiary or in post-Tertiary time, a zone of intense deformation that lay in the present geographic position of the Chugach

Mountains but did not extend into the coastal part of the region here described; if the Tertiary rocks that now crop out on the shore of Controller Bay then lay well to the north of their present position and were involved in this deformation; and if, in the final stage of the deformation, the Tertiary rocks rode southward in one or more great overthrusts and came to rest upon Mesozoic strata that were at a distance from the zone of intense deformation and were therefore not deformed, we should then have in the present Controller Bay region complexly folded rocks at the surface resting upon buried rocks of simpler structure and perhaps not folded at all. If these possible conditions really existed a fault parallel to the coast and to the mountains would account for the position and character of the shore and would permit oil to come up from its original source in the possibly nonfolded buried Mesozoic rocks to its present apparent source in the complexly folded Tertiary rocks at the surface. The structure of the underlying rocks and the position of the fault or faults would thus determine the position of the major east-west belt of seepage, and the structure of the more intricately folded rocks at the surface would determine the positions and the details of the minor northeast-southwest groups of seepages.

The possibility tentatively suggested above removes the difficulty of accounting for light-gravity oils in complexly folded and faulted rocks and explains the occurrence of the seepages in a narrow zone diagonal to the trend of the folds, parallel to the mountains along the general east-west shore line, and in line with the belt of seepages at Yakataga. This possibility should be borne in mind in further local geologic studies or in interpreting the position of apparent oil sands in wells or at seepages. It should be noted, however, that there is no reason to believe that any such possible Mesozoic oil-bearing strata are within reach of the drill. If present at all, they probably lie at great depths.

CHARACTER OF THE PETROLEUM.

The following statement concerning the character of the oil now being obtained from the productive wells has been furnished by Dr. A. M. Bateman:

> The gravity of the oil is from 41½° to 45° Baumé. The oil is high in gasoline and naphtha and has a paraffin base. Sulphur is absent. The recoverable content of gasoline and distillate is about 63 per cent.

The following analyses and tests of samples of oil from wells and seepages in the Katalla field have been published. The samples of seepage oil probably have not the same properties nor do they yield so large a proportion of the more volatile constituents as the "live" oil in the wells.

Test of petroleum from well No. 1, Katalla Slough.[a]

	Per cent.	Gravity at 15° C.	
		Specific.	° Baumé.
Distillation by Engler's method:			
Benzine (80°–150° C.)	21	0.7573	54.9
Burning oil (150°–300° C.)	51	.8204	40.6
Residuum (paraffin base)	28	.9096	23.9
Sulphur	Trace.	....	....
Gravity of crude oil	....	.828	39.1

[a] Sample collected by G. C. Martin from well No. 1 in 1903. Analysis and statement of properties by Penniman & Browne, of Baltimore. Published in U. S. Geol. Survey Bull. 250, p. 57, 1905.

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.

Test of petroleum from well No. 1, Katalla Slough.[19]

Specific gravity at 60° F., 0.7958=45.9° Baumé.
Cold test: Did not chill at 3° F. below zero.
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

Physical properties of crude petroleums.[a]

Locality.	Specific gravity.	Flashing point (Abel test).	Color.
		°F.	
Burls Creek	0.942	234	Dark reddish brown.
Katalla Meadow, 1	.929	240	Dark brown.
Katalla Meadow, 2	.901	156	
Katalla Meadow, 3	.874	156	
Katalla Meadow, 4	.869	152	
Katalla Meadow, 5	.961	266	
Bore hole at Katalla, 120 feet (1902)	.802	Below 60	Dark red.
Bore hole at Katalla, 355 feet (1902)	.790	Below 60	Do.
Yakogelty Creek	.937	246	Dark brown.

[a] Redwood, Boverton, Petroleum, 3d ed., vol. 1, p. 205, 1913.

Commercial products of crude Alaska petroleum.[a]

Specific gravity.	Petroleum spirit (benzine).	Kerosene.	Intermediate and lubricating oils with solid hydrocarbons.	Coke.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
0.869	....	19.0	78.6	1.7
.914	....	9.0	87.6	2.7
.800	24.8	53.9	16.7	1.2

[a] Redwood, Boverton, op. cit., p. 228.

[10] Oliphant, F. H., Petroleum: U. S. Geol. Survey Mineral Resources, 1902, p. 583, 1903.

The analyses given below were published by Stoess.[11]

The following analysis was made in Seattle from a sample of the crude oil taken from the well at Katalla:

Analysis of oil from Katalla well.

Specific gravity, 0.800.

Naphtha	34.2
Illuminating oil	34.4
Lubricating oils	16.5
Coke and residue	14.5

Another analysis [possibly the same as that published by Oliphant and quoted above], made in Los Angeles, Cal., gave:

[*Analysis of oil from a point near Katalla.*]

Specific gravity, 0.7957 (45.9° B.).
Cold test, not chilled at 3° below zero.

Naphtha	38.5
Illuminating oil	31.0
Lubricating oil	31.5
Coke and loss	9.0

Oil has a flash test of 70° to 80°. Oil is light green in color.

The results of the foregoing analyses and tests on oils from the Controller Bay region are brought together in the following table:

Summary of analyses and tests of petroleum of Controller Bay region.

Locality.	Color.	Gravity.		Flashing point.	Benzine.	Kerosene.	Lubricating oil.	Residue, coke, and loss.
		Specific.	Baumé (°).					
				°F.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Katalla Slough, well No. 1.		0.8280	39.1		21.0	51.0	28.0	
Do		.7958	45.9		38.5	31.0	21.5	9.0
Do	Light green	.7957	45.9	70-80	38.5	31.0	21.5	9.0
Do		.800			34.2	34.4	16.5	14.5
Do	Dark red	.802		(a)				
Do	do	.790		(a)				
Unknown		.869				19.0	78.6	1.7
Do		.914				9.0	87.6	2.7
Do		.800			24.8	53.9	16.7	1.2
Burls Creek	Dark reddish brown.	.942		234				
Katalla Meadow	Dark brown	.929		240				
Do		.901		156				
Do		.874		156				
Do		.869		152				
Do		.961		266				
Yakogelty Creek	Dark brown	.937		246				

a Below 60° F.

CONCLUSIONS.

Prospecting and drilling in the Controller Bay region will be expensive, owing to the geographic conditions, but these conditions may be permanently improved without great engineering difficulties or excessive cost.

[11] Stoess, P. C., The Kayak coal and oil fields of Alaska: Min. and Sci. Press, vol. 87, p. 65, 1903.

The geology is complex and difficult to interpret and does not show definitely the relation of the occurrence of the petroleum to the stratigraphy and structure. The local geology, so far as known, is not especially favorable to the occurrence of productive bodies of oil and indicates that if oil is found in quantity the productive areas will be very irregular in distribution and difficult to locate. However, if future developments confirm the theory that an overthrust along the coast (pp. 29-30) separates the complexly folded rocks at the surface from rocks of simpler structure below, the conditions may be much more regular and more favorable to the development of a good oil field than the surface conditions indicate.

The surface oil showings (seepages), though widespread and copious, do not furnish conclusive evidence of the occurrence of large bodies of oil but apparently give more promise than any of the other known geologic features of the region. The only safe conclusion they warrant is that the rocks near them contain some oil.

The net result of the drilling has been to show the existence of moderate quantities of oil in at least a part of the region, notably within the area of the patented claim, where most of the successful wells have been drilled. The wells outside the area of the patented claim are neither numerous enough nor deep enough to determine the outline of the pools and the area of productive territory or to show whether oil exists in sufficient quantity to pay for exploitation. They have demonstrated the difficulty and expense of drilling and the need of ample resources and careful management. The existence of oil in remunerative quantities in the greater part of the district has neither been proved nor disproved. The evidence afforded by the existing wells, like that afforded by the seepages, is sufficient to warrant further testing, if the tests are made intelligently and carefully by companies strong enough to exploit large areas on a scale that permits wholesale economies, and also strong enough to risk their capital on what must certainly be regarded as a speculation rather than an investment.

Operators and investors who may not be familiar with local conditions will do well to be governed by the following suggestions:

1. They should be certain that legal title can be obtained to a sufficient area to make it possible to sink many test wells under widely differing conditions and to permit a large enough probable production to pay for heavy initial expenditures and large permanent improvements.

2. They should have enough capital to be able (*a*) to purchase in quantity and at low rates; (*b*) to build good roads and other improvements and thus reduce cost of operating; (*c*) to carry a large stock of tools and supplies, in order to avoid costly delays in drilling

and to be able to drill deep; (*d*) to procure the best professional advice and good drillers; (*e*) to drill many test wells without hope of immediate profit; and (*f*) to afford to lose the investment.

3. The first wells should be located on the strike and at no great distance from producing wells, or down the dip from a good seepage and at such varying distances that the rocks outcropping at the seepage will be encountered at depths ranging from a few hundred feet to the limit (in depth) of drilling.

4. Subsequent wells should be determined in position by the location of existing wells and by the structure. With respect to productive wells, they should be along the strike and close to the wells; with respect to nonproductive wells they should be either not along the strike and at a short distance, or along the strike and at a considerable distance from the wells.

5. Drillers and tool dressers should be obtained from regions where there is difficulty in keeping the holes straight.

6. If oil is obtained, it will probably be down the dip, rather than up the dip from a seepage; in shallow wells near a seepage, in deeper wells farther from a seepage.

YAKATAGA OIL FIELD.

INTRODUCTION.

The Yakataga oil field is on the Pacific coast of Alaska about midway between Controller and Yakutat bays. Oil seepages were discovered at Yakataga in 1896 and oil claims have been staked and surveyed, but no wells have been drilled. The earlier accounts [12] of the geology and petroleum were based chiefly on observations made by F. H. Shepherd and J. L. McPherson, who in making surveys for some of the oil claimants also took notes on the geology, which they did not publish themselves but generously turned over to members of the Geological Survey.

A geologic and topographic reconnaissance survey of this region was made in 1913 by A. G. Maddren, who prepared a brief report [13]

[12] Eldridge, G. H., The coast from Lynn Canal to Prince William Sound in maps and descriptions of routes of exploration in Alaska in 1898 (U. S. Geol. Survey Special Pub., p. 104, 1899.

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

Martin, G. C., The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: U. S. Geol. Survey Bull. 250, pp. 26–27, 1905.

Martin, G. C., Geology and mineral resources of the Controller Bay region, Alaska: U. S. Geol. Survey Bull. 335, pp. 26, 63, 114, 115, and 118, 1908.

[13] Maddren, A. G., Mineral deposits of the Yakataga district: U. S. Geol. Survey Bull. 592, pp. 119–153, 1914.

on it that was published by the United States Geological Survey. Maddren's report is the basis of the description given below.

GEOLOGY.

The rocks of the Yakataga oil field include shales, sandstones, and conglomerates having an aggregate thickness of possibly 7,000 or 8,000 feet. Sandstones form the most massive and shales the thickest and most persistent beds in the section. The only limestones known are thin bands in some of the thicker beds of shale, several of which are somewhat calcareous throughout several hundred feet of strata, but even these contain numerous sandy and gravelly layers. In general, calcareous and sandy shales are more abundant in the lower part of the section, but conglomerates and sandstones also occur there. Thick beds of shale lie near the top of the section and thinner layers of shale are interbedded with many of the conglomerates. Some of the pebble beds have a shale matrix containing marine shells. These rocks are thrown into a series of folds, in part open, in part closely compressed, whose axes trend about N. 70° W. There are some faults. No igneous rocks have been found.

The oldest of these strata consist of calcareous shales and thin limestones with some interbedded sandstones and a few thin beds of conglomerate. They are exposed in a belt that runs along the anticlinal axis and the line of seepages which extends eastward parallel to the coast from a point near Yakataga Reef to Johnston Creek.

These beds are succeeded above by a great series of sandstones and shales and some beds of conglomerate, which together make up the lower part of the ridge separating the valley of White River from the coastal plain and also occur west of the valley of White River and near Icy Bay. Similar rocks are found in the second ridge from the coast, between White and Yakataga rivers.

About 1,000 to 1,500 feet of buff sandstone occurs in the upper part of the ridge that lies between the coast and White River, and similar rocks occur in the two ridges to the west.

This sandstone is succeeded by a great series, more than 2,000 feet thick, of buff sandstones and shales and some beds of conglomerate. These rocks form the ridge between White and Yakataga rivers and also occur in the next ridge to the north, where they are overlain by presumably older coal-bearing rocks brought up by a great fault. The highest known rocks of this section include massively bedded marine shale and sandstone, 2,000 to 4,000 feet thick, containing a great number of large and moderate-sized boulders of various kinds of crystalline rocks, which have apparently been dropped by icebergs. These boulders are scattered through several thousand feet

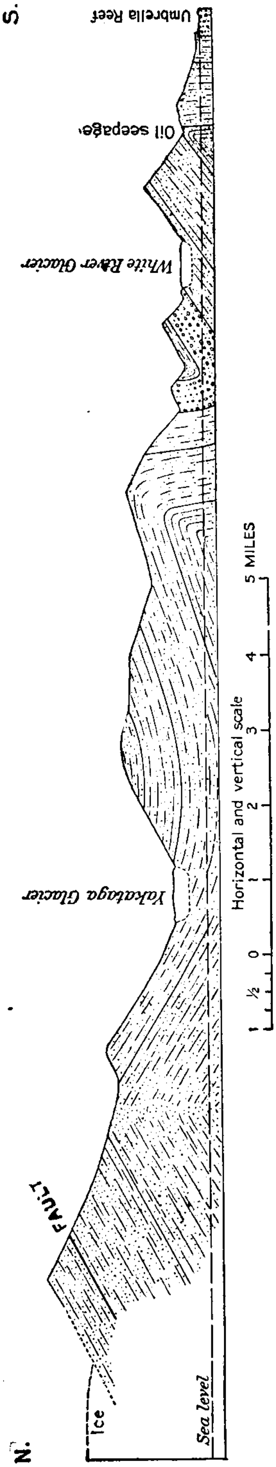

FIGURE 2.—Sketch showing structure in Yakataga field.

of silty sandstones and shales. This formation occurs at Umbrella Reef on the coast and in the ridge west of White River.

The precise ages of the strata described above have not been definitely determined. Many of the beds carry invertebrate fossils, but most of these are so much crushed as to be difficult to identify. Moreover, the conditions under which Maddren did his field work did not permit him to make and carry large collections. Maddren [14] has tentatively assigned the several strata to various horizons ranging from Oligocene to Pleistocene and has quoted lists of fossils determined by W. H. Dall, in which the known stratigraphic occurrence of each recognized species in other regions is cited. The writer believes that the evidence indicates that the sandstones and shales which make up the greater part of the section are probably all Miocene, and that the highest conglomerate is possibly Pliocene.

The Robinson Mountains, where studied, consist of a series of folds whose axes trend about N. 70° W. A closely compressed anticline is marked by the minor valleys along which the petroleum seepages are found. This anticline pitches west, and its nose is at Yakataga Reef. Its northern limb includes the rocks west of the valley of White River, beyond which there is a syncline. The anticlinal fold is marked by the broad ridge south of the valley of Yakataga River, and the valley itself occupies a synclinal trough. The next highland mass to the north is anticlinal. A great fault lies along the west limb of this anticline, by which the supposed Eocene coal-bearing rocks are thrust over other sediments, probably Pliocene. These structural features are believed to dominate the area, though it may contain other unrecognized faults. (See fig. 2.)

[14] Maddren, A. G., Mineral deposits of the Yakataga district: U. S. Geol. Survey Bull. 592, pp. 127, 130–131, 1914.

PETROLEUM.[15]

All the best-known petroleum seepages of the Yakataga district are near the base of the seaward slopes of the coastal ridge of Robinson Mountains. (See Pl. VI.) These seepages are distributed along a line extending from a point near Yakataga Reef to Johnston Creek, a distance of about 18 miles. They are from half a mile to 2 miles from the beach. About a dozen seepages are distributed at irregular intervals along this line, but the easternmost, on Johnston Creek about 1½ miles above its mouth, is the only one of considerable volume. Most of these seepages are little more than meager indications of oil in the form of sulphurous coatings or exudations along joint cracks of the rocks, or iridescent films over moist rock surfaces and on any small pools of water that may be collected near by. Thick oily residue has accumulated in notable quantity only at the seepage on Johnston Creek. Here the discharge of rather fresh petroleum is free enough to furnish considerable quantities to the swift-flowing, turbulent stream, so that appreciable quantities of oil are carried down its course to the ocean. A scum of oily residue also occurs on the cobble bars of Johnston Creek from its mouth up to the seepage. Probably a barrel or more of petroleum a day escapes from this seepage. The odor of petroleum was also noted at the mouths of Munday, Poul, Lawrence, and Crooked creeks, small streams that flow across the narrow coastal plain west of Johnston Creek. (See Pl. VI.) The seepages on these streams are from 1 to 2 miles above their mouths and are not so indicative of the free escape of oil as the one on Johnston Creek.

Prospectors report the occurrence of petroleum seepages in the second ridge of the Robinson Mountains from the coast. Prospectors also report a strong petroleum seepage east of Icy Bay and not far from Yahtsee River. This locality may mark an eastern extension of the Yakataga oil field.

The westernmost of the main line of seepages lies near the base of the mountain slope, where it joins the coastal plain, whereas those to the east lie in valleys separated by minor ridges from the seaboard. This line of seepages in part marks a series of depressions, extending east and west, occupied by the headwaters of streams flowing southward. The chain of depressions between the foothill belt and the main mountain front appears to lie along the axis of a symmetrical anticline, whose south limb is sharply flexed into a nearly vertical position and the dip of whose north limb is 15° to 45° N. All the seepages of petroleum reach the surface along the axial zone of this anticlinal flexure, which strikes about N. 70° W. The rocks, which are sandstones and shales, are provisionally assigned to the Oligocene.

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[15] The discussion under this heading is reprinted from Maddren's report essentially without change.

The development of the depressions between the foothill belt of vertical strata and the main mountain front at right angles to the north and south trunk gorge valleys across that belt is primarily caused by the more rapid erosion and removal of material that has occurred along the zone of the anticlinal axis. Here the sharp flexuring of the strata has shattered the rocks, and thus exposed them to the more rapid disintegration and consequent removal by the streams.

The strata at the base of the exposed portion of the section in the vicinity of Johnston Creek seepage are chiefly made up of sandstones that are favorable for either storage or migration of petroleum. These sandstones are overlain by close-textured shales, which may have served as the retentive cover. The liberal escape of fresh oil at this locality might be used as an argument for considering this horizon—the lowest rocks exposed in the coastal mountain ridge—to be at or near the ultimate oil-bearing horizon. This can not, however, be demonstrated without drilling, and there are some strong arguments against this hypothesis which will not here be presented.

Several seepages occur at or near the base of the seaward slopes of the coastal mountain west of the lower White River valley and extend nearly to Yakataga Reef. Here all the outcropping strata belong to the moderately northward-dipping limb of the anticlinal fold, the south limb being covered by the coastal-plain deposits or the ocean. The geologic structure of Yakataga Reef indicates distinctly the plunging nose of the anticline marked by the seepage.

The crest of this anticline appears to have a decided inclination to the west, but the dip is not so marked as that of its terminal nose at Yakataga Reef. This westward inclination amounts to a fall of at least 2,000 or 3,000 feet in the distance of about 18 miles along the seepage belt.

As the ultimate source of the petroleum at Johnston Creek seepage may be near if not at the outcrop from which the free flow of fresh oil comes (about 100 feet above sea level), it may be supposed that the oil-bearing bed becomes progressively deeper westward along the anticlinal axis. If this is so, it must be heavily covered by a greater thickness of strata in this direction. This may account for the more scanty escape of oil at the seepages in the western part of the belt. These views are based on the assumption that there is only one oil-bearing stratum developed along the anticline—the one marked by the free-flowing Johnston Creek seepage. All this is mere assumption, for there may be oil-bearing beds at several horizons in the section. There are in the exposed section several extensively developed porous sandstone and conglomerate members with impervious capping of fine-textured shale that should afford storage for petroleum. Some of these, where under deep cover toward the western part of the anticline, may contain oil. Only intelligently directed drilling will determine these matters.

The evidence in hand indicates that the search for oil here should not be nearly so involved with structural complexities as in the Katalla oil field, in the Controller Bay district. In the Katalla field folding and faulting are so intricate that the drilling thus far done has not proved very satisfactory. The essential structural features in the Yakataga seepage belt do not seem to be any more complex than those in some of the productive fields of California. If anything, the structure governing the occurrence of petroleum in the Yakataga district is probably more simple than that of some of the well-known California fields. If this is true, possibly only a small amount of intelligent drilling will be necessary to test the commercial value of the Yakataga belt. The inaccessibility of the field and the local difficulties of transportation will be strong deterrents to development. The discussion of transportation is reserved for a later section of this report.

There are no complete tests of the petroleum from the Yakataga district, and, in the absence of any drilling, such as have been made are necessarily tests of samples taken from seepages in which there has been a loss of the volatile compounds. There is every reason to believe that the Yakataga petroleum is of the same high grade as that of the Katalla field. The Katalla petroleum is a refining oil of the same general nature as the Pennsylvania petroleum. Like that oil, it has a high percentage of volatile compounds, a paraffin base, and almost no sulphur. The following table summarizes the available information about the composition of the oil from this field:

Summary of analyses and tests of Yakataga petroleum.[a]

Locality.	Color.	Specific gravity.	Flashing point.
Johnston Creek	Dark brown	0.964	200
Do	do	.879	178
Poul Creek	do	.970	250
Do	do	.881	67
Do	do	.914	156
Crooked Creek	do	.921	172
Oil Creek	do	.855	108
Morrison Creek [b]	do	.991	270
Argyll Creek, Icy Bay [b]	do	.962	310

[a] Redwood, Boverton, Petroleum, 2d ed., vol. 1, p. 198, 1906.
[b] The exact localities of seepages where these samples were taken are not known, but they are believed to be in the Yakataga field.

In 1897, soon after the occurrence of petroleum in Yakataga became known, a continuous tract of land about 1½ miles wide and 20 miles long was located and surveyed along the belt of seepages. This tract included all the known seepages in the coastal ridge of Robinson Mountains and covered the anticlinal axis from Johnston

Creek on the east to its westward-plunging nose at Yakataga Reef. The original locations aggregated some 50 square miles, or about 32,000 acres. Since then, however, the locators have relinquished much of this land in order to concentrate their assessment work on claims covering chiefly the actual seepages.

HARBORS AND TRANSPORTATION.

The Pacific coast between Controller and Yakutat bays, a distance of about 175 miles, is open to the full sweep of the ocean, with no shelter for even a light-draft launch except at Icy Bay. (See p. 41.) The glaciers that bound the district on the east, north, and west make it almost inaccessible by land. There is only one route of approach to it by land, and this presents serious difficulties. It follows the shore for about 50 miles from Cape Suckling, at the east side of Controller Bay, about 30 miles from Katalla. For 30 miles east of Cape Suckling this route passes along the front of Bering Glacier and crosses half a dozen swift glacial streams. All these streams are dangerous because of quicksands. Several are so large that they must be crossed by rafts or boats. The others may be forded at low water, but even under the most favorable conditions fording is hazardous. Two swift glacial rivers that flow between Bering Glacier and Yakataga Reef must be crossed by boats or rafts. All supplies for the journey must be carried, and it is also best to take a canoe. This route is seldom traveled, and only under guidance of those familiar with its dangers. Several men have lost their lives in attempting this trip.

All landings on this part of the coast must be made through the surf in small open boats. The only place for landing with even approximate safety is at Yakataga Reef, a low, rocky point that juts about half a mile into the ocean and affords a slight protection in calm weather, the only time when it is possible to make a safe landing. Southeasterly winds throw breakers against the east side of the reef, southwesterly winds against its west side, and the only time it is not awash is during a low tide when there is no ocean surge.

During the summer of 1903, when beach placer mining was at its height, steamers called at Yakataga Reef, weather permitting, about once a month. Since 1903 steamers have seldom called at Yakataga Reef, for it is not a good roadstead and the sea is rarely favorable for landing. Moreover, the trade is now small. Most supplies are brought from Katalla in launches that are navigated by men who closely observe the weather and who are generally able to foretell the conditions at Yakataga Reef a day or two in advance. At favorable times quick trips are made, generally at night, so that the work of landing the freight may be begun by daylight. This work is usually done in a few hours, when the launches return to Controller Bay without delay. By this irregular means the district is served with supplies and mail. The weather may be unfavorable for a landing at Yakataga Reef for fully a month.

Until recently Icy Bay was occupied by Guyot Glacier. Since 1904 the ice has retreated and a considerable embayment has been formed, which might be used as a harbor for Yakataga district if it were free from icebergs and if its western shore is deep enough for anchoring lighters near land or for the construction of a pier.

Mr. Maddren's survey of Icy Bay (see accompanying map, Pl. VI) was very hasty and was made without a boat and therefore without soundings. The bay, though its entrance is 7 miles wide, affords considerable shelter. The surf is broken by a bar off Icy Cape, at the southwestern entrance. The drift ice from Guyot Glacier and the shoals on the west side of the bay are adverse to its commercial utilization. The following statement is based on Mr. Maddren's observations in 1913. Later observers report that there is fairly deep water close to the western shore which is clear of ice much of the time and that there is good anchorage off the eastern shore.

The large quantity of drift ice would make it difficult, at least in summer, for boats to land cargoes on the west shore, where they would be available for transportation to the Yakataga district. Cargoes landed on the east side of the bay would not be available because that side is completely surrounded by impassable barriers of glacial ice.

Comparatively small icebergs become stranded on the west side of Icy Bay, which, though not sounded, therefore appears to be rather shallow for at least half a mile from shore, and smaller masses of ice are generally so closely packed along this shore for a width of a quarter of a mile that even small boats would find it difficult to land. It is questionable whether piers that would withstand the ice could be built out to deep water from the west shore. Even if such piers could resist the ice they would obstruct its movement, so that ice would accumulate about the piers. Perhaps two piers might be built to form a small inclosed basin.

Icy Bay is therefore not now available as a landing place for the Yakataga district, and it seems doubtful whether the commercial interests to be served will justify the expenditures necessary to make it available. A further recession of Guyot Glacier might bring about favorable changes. The glacier might then no longer discharge bergs. On the other hand, the glacier may advance and the bay may again be closed, so that any improvements would be destroyed.

If Icy Bay is utilized as a harbor a wagon road or railroad must be built from its western shore to the placer and petroleum deposits. Possibly a tramway, for which there is an abundance of timber, would be cheaper than a wagon road. Aside from the bridging of several glacial streams, whose channels are shifting, such an undertaking would not be difficult.

COOK INLET.

INTRODUCTION.

The supposed oil fields of Cook Inlet are on the west shore. Most of the reported seepages are in an area of Middle Jurassic rocks in the peninsula between Iniskin and Chinitna bays. (See Pl. VIII.) Jurassic beds have been noted in other areas along the west shore of Cook Inlet (see Pl. VII), and oil seepages have been reported from several of them, notably on Douglas River south of Kamishak Bay.

This district lies near the regular steamship route to ports on Cook Inlet. There are no regular ports of call within this district at present, but steamers will call at Tuxedni (Snug Harbor) and Iniskin bays whenever there is sufficient business. The steamers do not go to the head of Cook Inlet during the winter on account of ice. Iniskin Bay is said to be open throughout the year, but Tuxedni Bay is reported[16] to be blocked with ice from December to March. Chinitna Bay is a possible harbor for craft of light draft, and landings can be made at Oil and Dry bays in good weather.

A wagon road runs from the lower landing on Iniskin Bay to the head of Oil Bay, and trails extend from Oil Bay to Dry Bay, to the head of the eastern arm of Iniskin Bay, and to a point 2 miles above the lower landing on Iniskin Bay. Two trails also run from Dry Bay to Chinitna Bay, and a trail runs from the head of Iniskin Bay to the head of Chinitna Bay.

The lowlands north of Iniskin Bay are covered with dense vegetation, 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. The trees are not large, but many of them are straight and sound. The local supply of timber is probably ample for fuel and for construction during pioneer drilling. South of Iniskin Bay there are no trees except a few small scattered cottonwoods.

The writer made geologic reconnaissance surveys of the oil fields in 1903 and 1904, the reports[17] on which were subsequently expanded into a more detailed description.[18] These reports are the basis of the description here given.

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[16] U. S. Coast Pilot, Alaska, pt. 2, p. 101, 1916.

[17] Martin, G. C., The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: U. S. Geol. Survey Bull. 250, pp. 37–40, 1905.

Martin, G. C., Notes on the petroleum fields of Alaska: U. S. Geol. Survey Bull. 259, pp. 133–134, 1905.

[18] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 26–27, 59–74, 95–100, 126–130, 1912.

GEOLOGY.

GENERAL FEATURES.

The known seepages and the supposed oil-bearing Jurassic rocks from which they issue lie in a belt of foothills and lowlands between the shore of Cook Inlet and the high mountains. The rocks of this belt include unmetamorphosed Mesozoic sedimentary and volcanic strata and, farther east, one or two small remnants of a former fringe of Tertiary beds. The structure is dominantly simple, the Jurassic and Tertiary rocks being but gently flexed and having a general eastward dip, the Triassic rocks alone being complexly folded. The Jurassic strata are believed to be the source of whatever petroleum is present and to be the surface strata in any possible oil fields. The following section shows the general character and thickness of the strata:

General section of Jurassic rocks on west coast of Cook Inlet.

	Feet.
Upper Jurassic:	
Naknek formation (sandstone, arkose, shale, and conglomerate, interbedded with some tuff and lava)	5,000
Chisik conglomerate (tuffaceous conglomerate with shale and sandstone lenses)	300
Chinitna shale (shale with many calcareous concretions and with some limestone and sandstone)	2,400+
Middle Jurassic:	
Tuxedni sandstone (sandstone with some shale, limestone, and conglomerate)	1,500
Lower Jurassic(?):	
Porphyries and tuffs (basaltic and andesitic lavas and tuffs)	1,000?

The rocks of this section overlie or are faulted against Upper Triassic strata that crop out west of them and are overlain unconformably at one or two localities by Tertiary beds; Cretaceous rocks are not present on Cook Inlet.

The Tuxedni sandstone, which rests unconformably upon lavas and tuffs of probable Lower Jurassic age, consists predominantly of sandy beds but contains many thin strata of shale and limestone and at least one bed of coarse conglomerate. Its thickness at the type locality on Tuxedni Bay is at least 1,500 feet, and may be 2,000 feet or more. It contains abundant fossils, a large and highly characteristic marine molluscan fauna ranging through the formation and terrestrial plants having been found in the marine deposits at several horizons.

The Tuxedni sandstone is overlain, probably conformably, by a formation of Upper Jurassic age, which has been named the Chinitna shale. This formation, which has a thickness of at least 1,300 feet and may reach 2,400 feet, consists of a conformable and fairly uniform succession of fine-grained marine sediments, mostly shale. The Chinitna shale has previously been referred to the Middle Jurassic.

The Chisik conglomerate is a massive plate of coarse conglomerate, consisting of granitic and other crystalline boulders embedded in a tuffaceous matrix. The formation appears to be local rather than continuous in its distribution and to be variable in thickness. The maximum observed thickness is between 300 and 400 feet. This formation rests, without observed unconformity, upon the Chinitna shale and is overlain by the Upper Jurassic rocks of the Naknek formation.

The Naknek formation of the west coast of Cook Inlet consists of sandstone, shale, arkose, conglomerate, andesitic tuff, and probably some andesitic lava. The thickness exceeds 5,000 feet. This formation rests, with apparent conformity, upon the Chisik conglomerate, or, in the absence of the latter, upon the nonfossiliferous shales referred tentatively to the upper part of the Chinitna shale. The original top of the Naknek formation has not been observed on Cook Inlet, the Cretaceous being absent, and the next younger beds being Tertiary and overlying the Naknek formation unconformably.

The dominant structural features of the area occupied by Jurassic rocks on the west shore of Cook Inlet include a fault or zone of faulting, which separates the crystalline rocks of the mountains from the sedimentary rocks of the foothills, and a monoclinal ridge composed of Middle and Upper Jurassic sedimentary rocks which marks the shore from Tuxedni Bay to Iniskin Bay. West of this monoclinal ridge in the peninsula between Chinitna and Iniskin bays the Middle Jurassic rocks are thrown into a series of open folds. A broad, low anticline occupies a lowland area that lies immediately west of the coastal monoclinal ridge. The crest of this fold undulates somewhat and is believed to be cut by one or more faults. The details of the minor folds and of the faults have not been worked out. In the area west of this anticline the rocks are involved in several folds, which become sharper and more irregular as they approach the fault on the border of the mountains. The folds just described were not recognized north of Chinitna Bay and are probably cut off by the fault that marks the eastern boundary of the crystalline rocks of the mountains. In the area north of Chinitna Bay the Jurassic rocks apparently dip uniformly eastward, and this area is regarded as the northward extension of the coastal monocline. The folds described above do not appear on the shore south of Iniskin Bay, where the Jurassic rocks are in general horizontal.

LOCAL DETAILS.

The stratigraphy of the Jurassic rocks in the area between Tuxedni and Iniskin bays has been described in detail by Martin and Katz.[19] The following description gives the available details concerning the structure of that area, as well as some details of the stratigraphy and structure of the coast south of Iniskin Bay.

TUXEDNI BAY.

The rocks exposed on Tuxedni Bay consist of granites at its head, a belt of volcanic rocks farther east, and a belt of Jurassic sedimentary rocks (Tuxedni, Chinitna, Chisik, and Naknek formations) on the lower part of the bay and on Chisik Island.

The volcanic rocks include several types, the interrelations of which are not known. They may include successive flows, flows with intrusive masses cutting them, or either or both kinds of rock brought into their present structural arrangement by folding or faulting, or both. The nature of the contact of the volcanic rocks with the western edge of the sedimentary rocks east of them is not known. One of three possible relations exists: The Tuxedni sandstone, which is the lowest and westernmost of these sedimentary formations, may rest conformably or unconformably upon the volcanic rocks, the two may be separated by a fault, or the easternmost member of the volcanic rocks may locally be a dike younger than the Tuxedni sandstone. The fault relationship is believed to be the most probable. (See p. 46.)

The several sedimentary formations belong in normal, conformable, stratigraphic sequence one above the other in the order of their areal distribution from west to east. In harmony with this sequence there is a general easterly dip on the lower part of the bay. This dip continues without interruption, except possibly between Chisik Island and the point on the mainland west of it, from the westernmost sedimentary outcrop on the western arm of the bay to and somewhat beyond the northern and southern extremities of Chisik Island. There is a western dip on the northern part of the eastern shore of Chisik Island, so the island is, in part at least, synclinal in structure. Numerous small faults and probably several larger ones were observed on the south shore of the bay.

COAST BETWEEN TUXEDNI AND CHINITNA BAYS.

The shore of Cook Inlet from Tuxedni Bay to Chinitna Bay is mostly a low, sandy beach, behind which is a marshy flat. Except at the mouth of Tuxedni Bay, the hills are a mile or two back from

[19] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 59–74, 77–78, 1912.

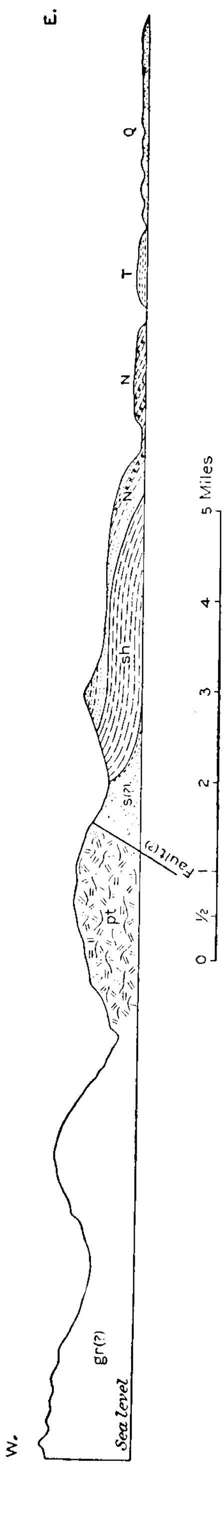

FIGURE 3.—Sketch showing structure on north shore of Chinitna Bay. gr, Granitic rocks (?); pt, porphyries and tuffs; s, Tuxedni sandstone (?); sh, Chinitna shale; N, Naknek formation; T, Tertiary beds; Q, Quaternary deposits.

the shore. The easternmost of these hills form a monoclinal ridge parallel to the shore. They consist of the rocks of the Naknek formation, having a dip of 10°–30° E.

CHINITNA BAY.

The upper end of Chinitna Bay is at or near the western edge of the presumably Lower Jurassic porphyries and tuffs. These rocks form all the outcrops on the western half of the north shore of the bay. The eastern half has magnificent exposures of the Chinitna and Naknek formations. At the entrance on the north shore is a lone outcrop of Tertiary rocks which is separated from the nearest Jurassic rocks west of it by an interval of sand beach and marsh. The southern shore has outcrops of Tuxedni sandstone near the head of the bay, and of Chinitna shale and Naknek formation near the entrance. Marshy land intervenes between them.

The structural relations of the porphyries and tuffs to the sedimentary rocks east of them could not be directly determined. The fact that westernmost outcrops of sedimentary beds are of the Chinitna shale on the north shore but of the Tuxedni sandstone on the south shore, and that in each case the concealed interval is not large, suggests that this contact is a fault. The concealed interval on the north shore of the bay may contain a narrow belt of the Tuxedni sandstone and is so indicated on the geologic map (Pl. VIII) and on the structure section in figure 3. The presence of a fault is also indicated by the fact that the contact of the Tuxedni sandstone with the porphyries and tuffs has here transgressed eastward in comparison with its position on Iniskin Bay, so that there is on the north shore of Chinitna Bay only one fold between the eastern border of the porphyries and tuffs and the coastal monocline, whereas on Iniskin Bay (see p. 48) there are several folds in this interval.

The exposures of the Naknek formation at the mouth of the bay are part of the eastward-dipping monoclinal belt which extends parallel to the coast northward to Tuxedni Bay. The dip of the beds of the Naknek formation just within the bay is from 20° to 25° but flattens going westward until, at a point about 3 miles inside the bay, the Chinitna shale exposed on the north shore is almost horizontal. Observations made at a distance from the outcrops suggested that the dip turns westward just before the contact with the volcanic rocks is reached.

Exposures on the south shore of the bay are lacking between the cliffs at the entrance to the bay and those near its head. Eastward dip was observed at both these points, but conditions farther south indicate that several folds may be present in this concealed interval.

The Tertiary rocks on the north shore of Chinitna Bay near the entrance are horizontal. It may be that the general structure has flattened at this point, and that the underlying Jurassic rocks also are horizontal, or the latter may continue dipping eastward beneath the Tertiary rocks which lie unconformably upon them in the attitude of deposition.

The structural facts observed on Chinitna Bay are presented graphically in figure 3.

COAST BETWEEN CHINITNA AND INISKIN BAYS.

The shore of Cook Inlet from Chinitna Bay to Iniskin Bay consists of rocky cliffs giving clean but not very thick sections of the massive rocks of the Naknek formation. A range of hills parallel to the coast and monoclinal in structure lies close to the shore and contains the Naknek formation on its crest and east side and the Chinitna shale on its western slope. The dip here, as in the continuation of this ridge north of Chinitna Bay, already described, is uniformly eastward. The ridge is broken through by drowned valleys at Dry

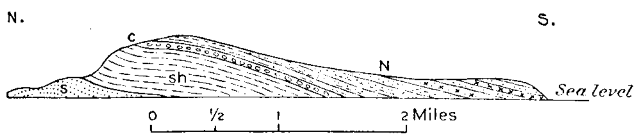

FIGURE 4.—Structure section on east shore of Oil Bay. s, Tuxedni sandstone; sh, Chinitna shale; c, conglomerate; N, Naknek formation.

and Oil bays. At Oil Bay magnificent exposures of the rocks of the Naknek, Chisik (?), and Chinitna formations reveal the monoclinal structure of the range, as shown in figure 4. The strike parallels the shore throughout the length of this belt, and the dip varies from 20° to 45°. The steepest observed dip is about a mile south of Chinitna Bay. The dip flattens eastward from the monoclinal ridge, and on the end of the low point at the entrance to Oil Bay and on the islands between there and Iniskin Bay it is almost horizontal.

INISKIN BAY.

The rocks exposed on Iniskin Bay consist of the presumably Lower Jurassic porphyries and tuffs with intrusive masses on the west and north shores, and of sedimentary Jurassic beds on the east shore. The latter lie in parallel belts consisting successively from north to south of the Tuxedni, Chinitna, Chisik, and Naknek formations. The structural relation of the sedimentary to the older igneous rocks is in part due to faulting, as is shown in figure 5, although at one locality the Tuxedni sandstone was observed to overlie porphyries and tuffs unconformably.

The sedimentary formations are flexed into open folds and are cut by faults. The dips are low and gently undulatory for the greater part of the length of the shore. Several folds are present, of which the most prominent is the monocline, exposed on the lower part of

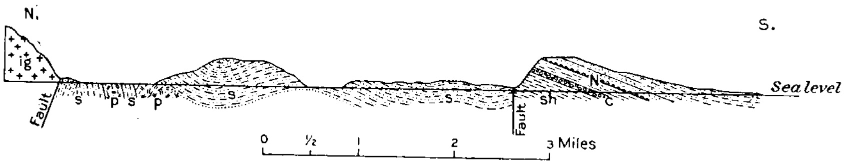

FIGURE 5.—Generalized structure section on east shore of Iniskin Bay. ig, Igneous rocks; s, Tuxedni sandstone; p, porphyry; sh, Chinitna shale; N, Naknek formation; c, Chisik conglomerate.

the bay. This is the southern end of the monoclinal block which has been described above as extending down the coast from Tuxedni Bay. The section in figure 5 is believed to represent the structural details exposed on the east shore of the bay.

URSUS COVE.

The rocks exposed on Ursus Cove consist of the Lower Jurassic igneous rocks on the south shore, the Kamishak chert (Upper Triassic), with its associated igneous rocks and with possibly some older

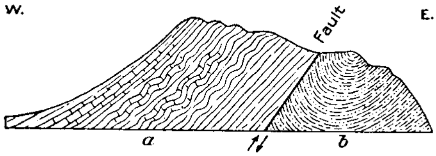

FIGURE 6.—Sketch showing Kamishak chert overthrust upon Naknek formation at mouth of Ursus Cove. *a*, Triassic cherts and limestone; *b*, Naknek shales and sandstones.

limestone, on the greater part of the north shore, and the shale and sandstone of the Naknek formation on the north shore at the entrance. The structural relations of the various igneous rocks to each other and to the Kamishak chert are not known. The Kamishak chert is strongly folded and appears to lie in a syncline. In its deformation some minor faulting is known to have occurred, and the weaker beds are in places severely contorted. A beautifully exposed fault (see fig. 6) at the north entrance to the cove shows the Kamishak chert overthrust upon the Naknek formation, which is locally folded into an overturned syncline with its axial plane dipping west. This fold either dies out northward or is more probably cut off by the eastward transgression of the fault, for where the latter cuts the shore about 2 miles north of Ursus Cove the Naknek formation is almost horizontal.

COAST BETWEEN URSUS COVE AND BRUIN BAY.

The fault seen at the north entrance to Ursus Cove cuts the shore of Cook Inlet again just south of Ursus Cove and separates the igneous rocks exposed on the south shore of the cove from the Naknek formation, which forms the shore of Cook Inlet almost as far south as Bruin Bay, a distance of about 8 miles. The Naknek formation is practically horizontal where it is exposed on the foreland south of Ursus Cove. The outcrops on a small indentation of the coast known as Rocky Bay consists of about 75 feet of dark-gray shaly sandstone and sandy shale that resemble some of the beds in the upper part of the section on Oil Bay and contain *Aucella* and other fossils (No. 3090). Along the coast between Rocky Bay and the fault contact with the Triassic rocks just north of Bruin Bay there are strata, possibly 800 feet thick, which overlie those seen at Rocky Bay.

BRUIN BAY.

The rocks on Bruin Bay include the Triassic rocks of the Kamishak chert, the Jurassic rocks of the Naknek formation, and some granitic intrusives. The rocks of the Kamishak chert are closely crumpled and cut by numerous small faults. The broader structure of these rocks could not be determined. By the southern continuation of the fault seen at Ursus Cove they are overthrust upon the Naknek formation, which here lies horizontal or is flexed into very gentle wavy folds whose dips do not exceed a few degrees. The granitic rocks are intrusive into the Kamishak chert, having been intruded after the chert was folded. The exposures on the cape at the south entrance to Bruin Bay and in the cliffs for about 5 miles south of this point consist of nearly horizontal beds of dark-gray sandstone and sandy shale belonging in the Naknek formation and having a thickness of at least 500 feet. Neither the top nor the bottom of the formation is exposed, the contact with the adjacent Triassic rocks being a fault. *Aucella* and other fossils (No. 9032) were collected near the entrance to Bruin Bay.

COAST OF KAMISHAK BAY SOUTH OF BRUIN BAY.

The shale and sandstone of the Naknek formation in the cliffs at the entrance to Bruin Bay continue southward in an unbroken series of cliffs for about 5 miles to a place where the great overthrust fault, which has been traced southward, cuts the cliffs and brings up a series of massive or poorly bedded rocks that may be Triassic sediments, but that, as seen from the water, look more like fine-grained homogeneous crystalline rocks. These rocks extend southward to the south end of the cliffs. The shore for 5 or 6 miles south of the end of the cliffs is low and sandy, with no rock outcrops.

At the head of Kamishak Bay horizontal beds of sandstone, shale, and conglomerate of undetermined age appear on the west shore and horizontal beds of the Naknek formation on the east shore. The relations of the two series of rocks were not determined.

The Naknek formation is exposed almost continuously in the cliffs on the south shore of Kamishak Bay for about 10 miles west of the mouth of Douglas River. The exposures are of nearly horizontal buff and gray sandstone, and some beds carry numerous fossils, of which *Aucella* is most abundant. A very striking but apparently not important unconformity was observed near the mouth of Douglas River. The character and relations of the beds at this unconformity are shown in the following section, which was measured by T. W. Stanton:

Section of part of Naknek formation on south shore of Kamishak Bay near mouth of Douglas River.

	Feet.
Gray sandstone with many fossils (No. 3096) in lower part	50
Unconformity.	
Brownish-yellow cross-bedded sandstone, mostly very friable and barren of fossils. Lignitized wood, *Tancredia*, etc. (No. 3097), near top and *Modiola*, etc. (No. 3098), 25 feet above base	100
Gray sandstone, with some masses weathered yellowish brown. *Aucella*, etc. (No. 3099), 70 feet above base and *Tancredia*, etc. (No. 3100), 50 feet above base	75

The total thickness of the Naknek formation along this part of the coast was not determined. The top and bottom of the formation and its contacts with other formations were not observed. The rocks are in most places nearly horizontal and undulate gently, so that only a slight thickness is exposed at the base of the cliffs. Similar horizontal rocks appear to extend inland up to an altitude of 800 or 1,000 feet, there forming the hilltops. The structural relations of these beds to the granites and other rocks south of them in the mountains and east of them on the coast are not known.

PETROLEUM.

SEEPAGES.

The surface indications of petroleum in this region consist of seepages or oil springs and so-called "gas springs." In the seepages the petroleum may be seen oozing from the cracks in the rocks or from the soil. The known seepages are all in the lowlands on the coast of Cook Inlet, most of them between Chinitna and Iniskin bays, where many claims have been staked as petroleum land and several wells have been drilled. The geology and the indications of petroleum in this district have been already described in several reports, from which the facts presented below are taken.

A copious seepage was seen on the east shore of Iniskin Bay, about 1,000 feet below the lower cabin, between high and low tide. The flow is more or less intermittent, and is often so strong that the oil collects in large blotches on the pool or even covers its entire surface. At one point in this seepage the oil was seen issuing from a crevice in the shale of the upper part of the Tuxedni sandstone.

A number of large seepages are reported to be near the cabin at Oil Bay. From the bottom of one of these the petroleum rose almost continually, 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, as was done for the test recorded on page 54.

About 2 miles west of the beach at Dry Bay is a so-called "gas spring," in which gas of unknown composition rises 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.

All these seepages and gas springs are on the outcrop of the Tuxedni sandstone. Their structural position is a short distance northwest of the monocline described above (pp. 44–48) as extending parallel to the coast. A broad, flat-topped anticline is believed to lie northwest of this monocline, although there is evidence (fig. 5, p. 48) that the structure may be further complicated by the presence of a fault, which marks the northwest edge of the belt of monoclinal dip. The seepages are at or very close to the line on which the dip changes from nearly horizontal to steeply inclined. If the fault extends throughout this belt the seepages are probably on or near it and are intimately related to it genetically.

Seepages are also reported from the shores of Kamishak Bay, especially on the south shore at Douglas River. The rocks in this region, as far as seen by the writer, are the shales, sandstones, and conglomerates of the Naknek formation. They are horizontal or have very gentle dips over large areas.

WELLS.

Indications of petroleum are said to have been discovered in this region about 1853. The first samples were taken out in 1882 by a Russian, named Paveloff. Claims were staked in 1892 by Edelman, near the heads of the creeks entering Oil and Dry bays, but these claims were abandoned. Pomeroy and Giffin staked claims at Oil Bay in 1896, organized the Alaska Petroleum Co. in 1897, and began work in 1898. The first well drilled at Oil Bay is said to have been put down in 1898, but any work done at that date was doubtless merely preparatory drilling. Drilling was also reported [20] at Oil Bay in 1900, but Oliphant [21] says that the well at Oil Bay was started during the summer of 1902, although unsuccessful attempts had been made to land machinery in 1899 [22] and to begin drilling in 1901.[23] When the writer was at Oil Bay in August, 1903, the first well was completed and preparations for drilling the second well were underway.

The first well at Oil Bay is said to have been drilled to a depth of more than 1,000 feet. No log of this well or any other authentic information containing it can be obtained, as the property has changed management several times. According to report gas was encountered all the way below 190 feet, and considerable oil was found at a depth of either 500 or 700 feet. The flow of oil is reported to have been 50 barrels a day, but it may be doubted whether any such quantity was obtained. On drilling deeper salt water under strong pressure was encountered, which shut off the flow of oil. In 1903 the well was said to be more than 1,000 feet deep and afforded a continuous flow of gas, which at times became very strong. Attempts were made to shut off the flow of water and either to recover the lost oil or to drill deeper, but without success.

During the summer of 1904 a second well was drilled at Oil Bay about a quarter of a mile west of the first well. The log of this well, according to Mr. August Bowser, who was in charge of the drilling, was as follows:

Record of well No. 2 at Oil Bay.

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

[20] Report of the Governor of the District of Alaska [for 1900], pp. 59–60, 1900.
[21] Oliphant, F. H., Petroleum: U. S. Geol. Survey Mineral Resources, 1903, p. 691, 1904.
[22] Oliphant, F. H., Petroleum, in Mineral Resources of the U. S. for 1899: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 6 (continued), p. 167, 1901.
[23] Oliphant, F. H., Petroleum: U. S. Geol. Survey Mineral Resources, 1901, p. 208, 1902 (not in bound volume).

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

During the summer of 1904 a third well was drilled about 250 feet south of the second. The general sequence of strata is reported to be the same as in the second well, the shale continuing to the bottom of the hole. The well was cased to a depth of 630 feet. Oil and gas were reported at a depth of 770 feet, where there were three oil sands, each 6 to 8 inches thick and 4 or 5 feet apart. The output of the well is said to have been about 10 barrels a day. Caving rock was encountered at 830 feet. Work was stopped at a depth of 900 feet at the end of the season. Considerable gas is said to have been encountered, and the pressure at some depths was reported to be strong enough to blow the water up in the derrick to a height of 20 feet.[24]

No information is available concerning operations at Oil Bay in 1905 and 1906. No drilling has been done since 1906, and in 1909 the oil camps were abandoned.

The Alaska Oil Co. was organized in 1901 and began operations at Dry Bay in 1902. The first well at Dry Bay was drilled in the summer of 1902 to a depth of 320 feet without encountering oil. A Star rig was used. The well had a diameter of 8 inches to a depth of 212 feet and of 6 inches to a depth of 320 feet, where the tools were lost and the well abandoned. A second well was started in August, 1903, 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. No drilling has been done at Dry Bay since 1903.

CHARACTER OF THE PETROLEUM.

A sample of petroleum from the seepage at Oil Bay was collected by the writer by skimming the oil from the surface of the 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 lubrication at the neighboring wells has been 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, so that the analyses do not represent the composition of the live oil from wells in this region. Such live oil would have a lower specific

[24] Information in this paragraph was furnished by Mr. August Bowser.

gravity, a higher percentage of the more volatile constituents, and a 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 paraffin base and would doubtless be a refining oil.

This sample was submitted to Penniman & Browne, of Baltimore, who return the following report on their tests:

Tests of sample of seepage petroleum from Oil Bay.

	Per cent.	Gravity (°Baumé).
Distillation by Engler's method:		
Burning oil (distillation up to 300° C., under atmospheric pressure)	13.2	29.5
Lubricating oils (spindle oils) (120 mm. pressure, up to 300° C.)	39.2	22.6
Lubricating oils (120 mm. pressure, 300°-350° C.)	19.6	17.9
Paraffin oils (by destructive distillation under atmospheric pressure)	22.4	20.4
Coke and loss	5.6	
	100.0	
Sulphur	0.098	
Specific gravity of crude oil at 60° F., 0.9557, or 16.5° Baumé.		
Initial boiling point, 230° C.		

The lubricating oils were distilled under diminishing pressure, according to refinery practice, until signs of decomposition set in. The residue obtained was unsuitable for making cylinder stock and was therefore distilled for paraffin oils. These paraffin oils contain a considerable quantity of solid paraffin—how much it was not practicable to determine with the small quantity of oil tested.

The iodine absorption of the oils and distillates was determined by Hanus's method (solution standing 4 hours) and is here tabulated:

Iodine absorption of oils and distillates from Oil Bay.

	Per cent of iodine.
Burning oil	17.8
Lubricating oil	26.2
Heavy lubricating oil	35.8

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

Iodine absorption of commercial oils.

	Per cent of iodine.
Light distilled lubricating oil (spindle oil)	32.0
Dark lubricating oil (engine oil)	45.4

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 oil has a paraffin base, and the products of distillation are "sweet." We are informed that this sample is a "seepage oil." If a sufficient yield can be obtained by drilling, an oil suitable for refining may be expected, containing a very much larger quantity of the more desirable lighter products.

CONCLUSIONS.

The seepages on the west coast of Cook Inlet, especially those between Chinitna and Iniskin bays, indicate that the Jurassic rocks may contain considerable petroleum.

The results of the drilling are not especially encouraging, but it is said that some oil was found in the wells. (See pp. 52–53.) The wells that have been drilled are too few, too shallow, and were drilled in too small an area to give a final test of the possibilities of the field.

The stratigraphy and structure of certain parts of the district are not unfavorable to the occurrence of oil. The coarse and porous sandstones that contain an abundance of organic remains, especially those in the lower part of the Tuxedni sandstone, may be regarded as possible oil sands and as the probable source of the petroleum and gas that are escaping at the seepages. The areas in which the structure is most favorable for the accumulation of oil include the crest of the easternmost anticline, which extends from Iniskin Bay to Chinitna Bay. Some faulting, however, has occurred on and near the crest of this anticline. The effect of this faulting on the accumulation of oil is not known. No statement can be made concerning possibly favorable localities for drilling in the area west of the crest of the main anticline, except that further investigations may reveal them. In general, however, this western area does not appear to be so favorable as the main anticline, but special localities where the conditions are favorable may be found. The monoclinal belt along the coast, including its northern extension from Chinitna Bay to Tuxedni Bay, and any possible extension into the unsurveyed region north of Tuxedni Bay, must also now be regarded as less favorable for the occurrence of oil. This conclusion is based on the steep dips and on the fact that in most of this area the possible oil sands in the Tuxedni sandstone lie too deep to be reached by the drill. It is possible, however, that favorable areas of gentler dip or higher oil-bearing horizons, perhaps in the Naknek formation, may be found.

Some of the areas occupied by the Naknek formation on Kamishak Bay, especially those in the vicinity of Douglas River, would seem to be more promising prospective oil fields, at least as far as structure is concerned, than the district north of Iniskin Bay, where the wells were drilled. It should be noted, however, that in the known areas of gentle dip along the coast the supposed oil-bearing beds in the Tuxedni sandstone lie so deep that they are beyond the reach of the drill. This part of the coast is, moreover, a very difficult place to land machinery, for the bays are all shallow and filled with rocks, and numerous uncharted reefs extend out many miles from shore.

ALASKA PENINSULA.

INTRODUCTION.

Seepages of petroleum on Alaska Peninsula, especially in the vicinity of Cold and Portage bays and Becharof Lake, have been known for many years. The seepages described as "near Katmai" (see bibliography, pp. 76, 79) are believed to be the seepages between Cold Bay and Becharof Lake. Four wells were drilled near Cold Bay in 1903 and 1904, but no oil has been produced there in commercial quantities, and the camps have been abandoned for many years.

Seepages have also been reported to occur on Aniakchuk River, on the peninsula between Kujulik and Hook bays, on the north end of Chignik Bay, and on the shore of Shelikof Strait about 20 miles southeast of Cape Douglas.

Cold Bay is on the east side of Alaska Peninsula near the west end of Shelikof Strait, nearly opposite the southwest end of Kodiak Island. The bay is roughly triangular, is about 10 miles long and 7 miles wide at its mouth, and includes a large area of deep water. The harbor at Cold Bay is open throughout the year, but it is subject to violent winds and the known anchorages are not very secure. The harbor has not been surveyed, and it is possible that a survey might disclose more satisfactory anchorages and landing places. It is also possible that a survey of some of the neighboring bays might find good harbors.

The surrounding country is an upland that stands in general about 750 feet above tidewater and is surmounted by gently rounded or flat-topped hills. 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 there are high mountains. Among these mountains is the volcano Peulik, a peak about 5,000 feet high, which is on the west shore of Becharof Lake about 35 miles west of Cold Bay.

In this district there is no timber that can be used either for fuel or for construction. When the wells were being drilled in 1903 and 1904 derrick timbers and blacksmith coal were imported and the petroleum residue from a local deposit (see p. 64) was burned under the boilers. The only trees are a few small cottonwoods, willows, and alders, which grow along the banks of the streams. The flat lowlands on the shores of Cold Bay are covered with deep grass, but the hillsides and uplands bear no vegetation except moss, scattered tufts of grass, and small growths of brush.

The account of the geology and petroleum given below is based on reconnaissance surveys made in 1903 and 1904. The more important results of those surveys have already been published,[25] but some details concerning the stratigraphy and structure are here presented for the first time.

GEOLOGY.

GENERAL FEATURES.

The rocks of the Cold Bay district (see Pl. IX) include Upper Triassic shale, limestone, chert, and igneous rocks; Lower Jurassic (?) shale and sandstone; Middle Jurassic (?) sandstone, shale, and conglomerate; Upper Jurassic arkose, conglomerate, sandstone, and shale; and post-Jurassic (chiefly Recent and Tertiary?) volcanic rocks which occur in a belt along the axis of the peninsula. This belt includes several volcanoes, some active and some dormant, among which are Mount Peulik, near Becharof Lake, on the border of the Cold Bay district, and Mount Katmai, a little farther east. Granite and other coarse crystalline rocks are reported from the interior of the Alaska Peninsula and may underlie the Cold Bay district. Cretaceous and Tertiary rocks occur in other parts of the Alaska Peninsula but have not been found near Cold Bay. The main structural features are broad, open folds, whose axes parallel the coast, trending about northeast. The dips of the strata do not generally exceed 15°. Some faults have also been noted.

A number of oil seepages occur in this field, some of which are strong. At one of these seepages there is a considerable flow of gas. The known seepages are on the outcrops of the Upper (and Middle ?) Jurassic rocks, and the oil-bearing beds are believed to be the general equivalent of those of Cook Inlet.

TRIASSIC ROCKS.

Triassic rocks are exposed in Alaska Peninsula, as far as known, only between Cold and Alinchak bays. They form the northeast shore of Cold Bay for at least half a mile inside Cape Kekurnoi and probably extend continuously northeastward along the shore of Shelikof Strait to Alinchak Bay, where they outcrop for at least a quarter of a mile along the southwest shore of the bay and on some of the islands in its mouth.

The exposures at Cape Kekurnoi consist of crumpled limestone and calcareous shale cut by dikes and sills of basalt. Within the bay

[25] Martin, G. C., The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: U. S. Geol. Survey Bull. 250, pp. 50–59, 1905; Notes on the petroleum fields of Alaska: U. S. Geol. Survey Bull. 259, pp. 134–139, 1905.
Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Bull. Geol. Soc. America, vol. 16, pp. 393–397, 401–402, 1905.
Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 30–35, 120–124, 1911.

the dip becomes uniformly westward at angles of about 20°, the cliffs exposing a thickness of about 700 feet of limestones and shales similar to those at the cape. Fossils consisting exclusively of *Pseudomonotis subcircularis* (Gabb) are distributed through the upper half of the strata and were collected at several localities (3107) from a quarter to half a mile northwest of the cape. Similar calcareous beds about 100 feet above the highest noted occurrence of *Pseudomonotis* yielded a small collection (No. 3108) of ammonites. A gradual change in the lithologic character of the beds, the rocks becoming less calcareous, begins a short distance northwest of and stratigraphically above this locality. The beginning of this change is regarded as marking the top of the undoubted Triassic rocks. The overlying beds may also belong partly or wholly in the Triassic, but as there are reasons for believing that they may be at least in part Jurassic, and as there is no evidence of a break within them, they will be discussed with the Jurassic rocks on page 59.

The rocks exposed on Alinchak Bay, named in order of age, are basic igneous rocks, contorted cherts, and shales and limestones that contain *Pseudomonotis* (No. 3129). The beds that yield *Pseudomonotis* crop out for about 500 feet along the shore. They differ in dip from place to place, but they are nearly everywhere steeply inclined and at some places reach an angle of 45°. The next exposures are a quarter of a mile farther up the shore and consist of Jurassic or possibly Triassic rocks. (See p. 60.)

The known fauna of the Upper Triassic rocks of Alaska Peninsula consists practically of a single species, *Pseudomonotis subcircularis* (Gabb), which may be the same as *Pseudomonotis ochotica* (Keyserling) of the Triassic rocks of Europe and Asia. This species is characteristic of at least part of the McCarthy shale of the Chitina Valley and has been recognized at many other localities in Alaska. It indicates a horizon corresponding to the uppermost Triassic of California and to the Noric of Europe.

This species has been found on the Alaska Peninsula only in limestone and shale, which are underlain, on Alinchak Bay, by contorted cherts in which no fossils have thus far been found. The stratigraphic conditions are possibly similar to those on the west coast of Cook Inlet, where this same species is abundant in the uppermost shaly and calcareous members of the beds that have been referred to the Kamishak chert, but not in the more massive chert beds below.

JURASSIC ROCKS.

The Jurassic rocks of Alaska Peninsula include the direct southwestward extension of the Jurassic rocks on Cook Inlet and constitute a section which, when fully known, will probably be found to rival if not excel the section of Cook Inlet in thickness and completeness. Most of the formations and faunal zones at Cook Inlet are now known on Alaska Peninsula, which contains also some Lower or Middle Jurassic strata that are but little known and that are apparently absent on Cook Inlet. The contact of the Jurassic with the Cretaceous rocks is also exposed on the Alaska Peninsula but not on Cook Inlet. The general section of the Jurassic rocks on Alaska Peninsula is as follows:

General section of Jurassic rocks on Alaska Peninsula.

	Feet.
Upper Jurassic:	
Naknek formation (arkose, conglomerate, sandstone, and shale)	3,000–5,000
Upper and Middle Jurassic:	
Sandstones, shales, and conglomerates carrying the fauna of the Chinitna shale	3,800–4,300
Beds of unknown character at Dry Bay and near Becharof Lake with the fauna of the Middle Jurassic Tuxedni sandstone.	
Lower or Middle Jurassic:	
Beds of unknown character at Kialagvik Bay with a Lower Oolite or Upper Lias fauna.	
Lower Jurassic or Upper Triassic:	
Shales and sandstones at Cold and Alinchak bays	2,000?

The Triassic rocks on the northeast shore of Cold Bay (see pp. 57–58) appear to grade upward, with no abrupt change, into less calcareous beds, which do not contain the characteristic Upper Triassic fauna. The change begins about half a mile northwest of Cape Kekurnoi, which is at the eastern entrance to Cold Bay, and the first several hundred feet of strata overlying the known Triassic beds is barren of fossils. Beds of fissile somewhat calcareous sandstone containing ammonites, pelecypods, and plants (No. 3109) (see p. 58) were seen a mile northwest of the cape at a horizon about 700 feet above the highest observed occurrence of Triassic fossils. The general aspect of the ammonites from this locality, according to Stanton, is Jurassic rather than Triassic, but the fossils are unlike any previously known from Alaska. A little farther northwest along the shore, 200 or 300 feet higher, a few more ammonites were collected (No. 3110) and a few specimens of *Rhynchonella* were obtained from a boulder (not in place) on the beach. These ammonites, according to Stanton, include two or three genera of Jurassic aspect and are probably Lower Oolite or older. Another small collection of ammonites and pelecypods (No. 3111) was obtained a short distance south of a large waterfall about 1½ miles northwest of Cape Kekurnoi, about 1,800 feet stratigraphically above the highest beds containing *Pseudomonotis*. There is a sharp change from sandstone to shale at this place and the dip abruptly changes from 18° to 28°. These changes possibly indicate a fault. The next rocks exposed on the shore northwest of this locality are soft brownish shales several hundred feet thick, above which is a heavy bed of coarse conglomerate. The overlying rocks are apparently Upper Jurassic and will be described on page 61.

These Lower Jurassic (?) rocks probably extend northeastward through the hills to Alinchak Bay, where a collection of ammonites (No. 3130) similar to those of lot No. 3109 has been obtained. The beds that yielded this collection crop out about a quarter of a mile up the shore beyond the Upper Triassic beds containing *Pseudomonotis* (see p. 58) and were not studied in detail. The interval between them and the Triassic exposures is concealed and the beds that overlie them were not observed.

The beds described above include about 2,000 feet of shales and sandstones, which constitute an unnamed formation of problematic age. They apparently overlie the Upper Triassic *Pseudomonotis*-bearing beds conformably, and are either overlain by or are separated by a fault from strata that carry the Upper Jurassic fauna of the Chinitna shale. It is possible that they may, at least in part, represent the highest Triassic, which elsewhere in Alaska was either not deposited or was removed by subsequent erosion. It is also possible that they may include the offshore representatives of the Lower Jurassic volcanic beds of Cook Inlet. Several horizons that are known in Europe between the Rhaetic and the Oolite may here be represented.

Of the few fossils that have been obtained from these beds, neither the marine mollusks nor the plants are sufficiently characteristic for the determination of the exact horizon.

An undescribed Jurassic formation, which has not been observed in the immediate vicinity of Cold Bay but which may outcrop there, and which almost certainly underlies the Middle (?) and Upper Jurassic rocks of the Cold Bay district, occurs on Kialagvig or Wide Bay, where two collections[26] of fossils have been made, although, unfortunately, no description of the rocks containing them is available. The fossils indicate that the rocks at this locality belong in the lowest part of the Middle Jurassic or near the top of the Lower Jurassic series. They certainly belong beneath any of the beds known in the oil fields at Cold Bay or on Cook Inlet, and they are

[26] White, C. A., On invertebrate fossils from the Pacific coast: U. S. Geol. Survey Bull. 51, pp. 64–70, 1889. Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, p. 871, 1896.

possibly younger than the Lower Jurassic (?) rocks exposed on Cold and Alinchak bays.

The presence of the Tuxedni formation on the Alaska Peninsula is indicated by fossils collected on the west shore of Dry Bay and near Becharof Lake. The localities at which these fossils were obtained have not been visited by a geologist, so the occurrence can not be described, nor can even the presence of the formation be positively affirmed.

The oldest rocks of undoubted Jurassic age on Cold Bay are some sandstones, shales, and conglomerates that carry the *Cadoceras* fauna (Upper Jurassic) of the Chinitna shale. The cliffs on the northeast shore of Cold Bay contain a thick section of strata carrying the fauna of the Chinitna shale, but neither the bottom nor the top of these beds has been clearly recognized, for the contacts with the adjacent formations are probably faults. The contact of this formation with the underlying Lower Jurassic (?) shales and sandstones (see p. 60) is about 1½ miles northwest of Cape Kekurnoi. Here the Lower Jurassic (?) rocks are either overlain by or faulted against soft brownish shales, several hundred feet thick, which are overlain by a heavy bed of coarse conglomerate. Above this conglomerate are sandstones interbedded with thinner strata of shale and conglomerate that form the cliffs for about 2 miles and have an estimated thickness of probably 1,000 to 1,200 feet. The fossils contained in lot No. 3106 were obtained from a fine conglomerate near the top of these beds. The overlying rocks are massive sandstones, possibly 1,400 feet thick, overlain by 200 feet of dark shales. Near the top of these shales is a thin band with abundant fossils, as in No. 3105. Above these shales are coarse gray sandstones apparently containing no fossils except *Belemnites* and probably 1,200 or 1,500 feet thick. These beds are separated by a fault from the known Upper Jurassic rock northwest of them.

The following section was measured by T. W. Stanton in the cliffs on the southwest shore of Cold Bay. The base of the section is at Cape Aklek and its top is at Lathrop's store. Neither the base nor the top of the formation is exposed.

Section of part of Chinitna formation on southwestern shore of Cold Bay.

	Feet.
Shaly sandstone with some beds of shale and with *Belemnites*	800±
Coarse gray sandstone with thinner beds of more shaly sandstone and some bands of conglomerate. *Cadoceras*, *Phylloceras*, and *Belemnites* found sparingly from base to above the middle	1,000
Dark shaly sandstone, with some beds of shale and thinner bands and local lenses of conglomerate. *Belemnites* abundant in conglomerate about 100 feet above the base	400

The following section, which was measured by the writer about 10 miles southwest of Cold Bay, shows the character of the upper beds of this formation and the contact with the overlying rocks:

Section of part of Chinitna formation on hillside east of Rex Creek, 1 mile above head of Dry Bay.

	Feet.
Shale and sandstone (overlain by 600 feet of arkose, sandstone, and shale belonging to Naknek formation)	500
Sandstone	90
Argillaceous shale	400
Sandstone, shale, and conglomerate	300

All the rest of the Upper Jurassic rocks now known in Alaska Peninsula have been grouped in the Naknek formation, which is composed of beds of arkose, conglomerate, sandstone, and shale aggregating several thousand feet in thickness and carrying a marine fauna characterized by species of *Aucella* related to *Aucella pallasi* and *Aucella bronni*. The Naknek formation has been recognized at many places on the Alaska Peninsula from the shores of Cook Inlet to Herendeen Bay. It covers large areas, probably being the most extensive of the surface formations, and may be areally continuous throughout the greater part of the length of the peninsula.

The Naknek formation of Cold Bay and vicinity has been described very briefly in a previous report.[27] It consists of arkose, conglomerate, sandstone, and shale, and rests, without observed unconformity, upon the Chinitna formation, as is shown in the following section:

Section of lower part of Naknek formation on east side of Rex Creek about 1 mile above head of Dry Bay.

	Feet.
Arkose, sandstone, and shale	600
Chinitna formation (shale and sandstone, as in section above).	

The thickness of the Naknek formation in the Cold Bay district has not been measured but is probably between 3,000 and 5,000 feet. No overlying formation has been seen.

The best exposures are in the high cliffs along the southwest shore for about 2 miles below the head of Cold Bay. The southern half of these cliffs, according to unpublished notes by T. W. Stanton, is composed mainly of conglomerate, the lower beds being rather coarse, interbedded with coarse sandstone and with some shaly beds. One of the shaly beds near the base of the exposure is several feet thick and contains a few small, indeterminate pelecypods. The beds

[27] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 52–53, 1905.

in this part of the cliff are nearly horizontal and have a thickness of approximately 400 feet. About the middle of the cliff there is a fault, north of which the beds have a much steeper northwesterly dip and contain no conglomerate but a great thickness of shaly and thin-bedded sandstones overlain by more massive sandstone, above which are several hundred feet of dark sandy shales. The total thickness between the fault and the head of the bay is probably 1,500 feet. The fossils contained in lot No. 3102 came from the lower part of these beds.

The Naknek formation is exposed over a large area between the head of Cold Bay and the southeast shore of Becharof Lake. Several collections of characteristic Upper Jurassic fossils were obtained on creeks tributary to Becharof Lake. A large proportion of the rock exposed in this area is conglomerate.

STRUCTURE.

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 a point near the mouth of Oil Creek northeastward into Cold Bay. The north 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 dip is rather 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 the dip is northwestward or the beds are horizontal. On Dry Bay the dip is southeastward. The dips seldom exceed 15°, except toward the mouth of the bay, and are low and regular over wide areas.

The beds in the region between Becharof Lake and the Becharof-Cold Bay divide have a uniform westward and northwestward dip. This dip is reversed again 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 the mass of coarse crystalline rocks. There is also a great anticline parallel to the southern coast that has its axis near the ends of the forelands.

PETROLEUM.

SEEPAGES.

Several seepages occur at the north end of the anticline near the oil wells (see Pl. X), and at all of those seen by the writer the flow of petroleum is large and constant. One of them furnished lubricating oil for use at the wells, and another produced a considerable flow of gas. Other seepages, not seen by the writer, are reported from different places along the crest of this fold, near the head of Dry Bay, and elsewhere between that point and Kanata. Larger seepages are said to occur on the west shore of the south arm of Becharof Lake.

RESIDUE.

Some of the seepages of petroleum on the hillsides near the oil derricks 5 miles inland from Cold Bay are continuous; others are intermittent. The petroleum runs down the hillsides into the water-courses and collects at the bottom in peat bogs. Losing enough of its volatile constituents by evaporation to become immobile, it remains there, impregnating the peat and forming over its surface a thick coating of black paraffin wax.

These deposits have already proved most useful in the development of the region, for the peat, impregnated with the paraffin wax, is a fuel of great value, replacing even the coal from the mines of Puget Sound, which was imported for use under the boilers used in drilling. The deposit that furnished this fuel in 1903 and 1904 covers about 3 acres. In some places the material has been dug to a depth of about 3 feet without reaching bottom. Another deposit, which has an area of 3 acres and a thickness of at least 10 feet, has also been discovered in the vicinity, and many more will doubtless be found.

Chemical and calorimetric tests of the 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.

Moisture	per cent	None.
Volatile matter	do	85.40
Fixed carbon	do	7.76
Ash	do	6.84
		100.00
Sulphur	do	.36
Soluble in gasoline	do	68.20
Heating value	calories	8,193

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

WELLS.

Drilling in the vicinity of Cold Bay was begun in the summer of 1903 and was continued in 1904. Two companies drilled two wells each. Three wells were begun in the summer of 1903. They are about 5 miles from the landing on the western shore of Cold Bay, at an elevation of about 750 feet above sea level, and are about 9 miles in an air line from Becharof Lake. (See Pl. XI.)

One of the wells drilled by J. H. Costello at an elevation of 780 feet near the headwaters of Oil Creek during the summer of 1903 was abandoned in the autumn, because of a crooked hole, at a depth of 728 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, in September, 1904, but it was reported that the well was only spudded in and reached a depth of 15 feet.

Log of Costello's well No. 1, at Cold Bay.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sandstone	76	76	Soft argillaceous sandstone	15	430
Hard sand with crevices	39	115	Soft blue sandstone with oil	5	435
Sand with hard streaks	85	200	Small showing of oil	45	480
Oil sand, not hard	40	240	Sandstone with streaks of clay	20	500
Sandstone with hard streaks	60	300	Sandstone	120	620
Oil sand, soft	8	308	Show of oil	30	650
Sandstone with hard streaks	82	390	Sandstone	50	700
Oil sand	25	415			

Another well, also begun in 1903, was drilled by the Pacific Oil & Commercial Co., at an elevation of 580 feet, on the divide between Trail, Dry, and Becharof creeks, to a depth of 1,421 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 in the summer of 1904 because of the strong, continual flow of fresh water. It seems safe to assume that this well is near a fault. This assumption may explain the presence of large quantities of fresh water at all depths and the absence of the more volatile and fluid constituents in the oil. In 1904 the machinery from this well was moved to a new location about 2¼ miles to the southeast, on Trail Creek, and here a well was drilled to a depth of 1,524 feet, where the tools were lost in October of that year.

Log of Pacific Oil & Commercial Co.'s well No. 1, at Cold Bay (elevation, 580 feet).

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Soil	15	15	Sandstone; showings of oil at 522 to 525, 606 to 619, 625 to 630, and 706 to 719 feet, and an increased pressure of gas at 645 feet	228	750
Gravel	15	30	"Oil sand"; oil at 752 to 755 feet	5	755
Blue clay	5	35	Shale; showing of oil at 783 to 785 and at 799 feet and increased gas at 785 feet	45	800
Sandstone	103	138	Sandstone	37	837
Shale	14	152	"Slate"	82	919
Sandstone with showing of oil	19	171	Sandstone and showing of oil	21	940
"Slate"	4	175	"Slate"	7	947
Sandstone (gas pressure at 204 feet)	62	237	Sandstone and showing of oil	3	950
"Slate and shale"	8	245	"Slate"	6	956
Sandstone	62	307	Sandstone and showing of oil	7	963
Sandstone and shale	4	311	"Slate"	132	1,095
"Slate"	5	316	Sandstone and showing of oil	7	1,102
Sandstone	46	362	"Slate and shale"	9	1,111
"Slate"	3	365	Sandstone	12	1,123
Sandstone	9	374	"Slate"	7	1,130
Limestone	12	386	"Slate and shale"	51	1,181
"Slate"	4	390	Sandstone	21	1,202
Limestone	8	398	"Slate and shale"; showing of oil at 1,202 to 1,203 feet	8	1,210
"Slate"	5	403	Sandstone; showing of oil at 1,314 to 1,321, 1,326 to 1,335, 1,342 to 1,349, and 1,419 to 1,421 feet	211	1,421
Limestone	28	431			
Sandstone (showing of oil at 435 and 445 feet)	31	462			
Limestone	10	472			
Sandstone	14	486			
"Slate"	4	490			
Sandstone	22	512			
"Slate"	10	522			

Log of Pacific Oil & Commercial Co.'s well No. 2, at Cold Bay (elevation, 175 feet at Trail Creek).

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Soil and gravel	10	10	Sandstone	20	508
Sandstone	153	163	Sandstone and shale	17	525
Shale	12	175	Sandstone; showing of oil at 857 to 867 feet, steady increase of gas at 950 to 959 feet	434	959
Sandstone; showing of oil at 262 to 265 feet	98	273	Sandstone and shale	34	993
Limestone and shale	17	290	Sandstone; showing of oil at 1,008 to 1,013 feet, increase of gas at 1,061 feet, and gas and showing of oil at 1,150 feet	549	1,542
Sandstone	22	312			
Sandstone and shale	15	327			
Sandstone	153	480			
Shale	8	488			

The tools were lost in October, 1904.

CHARACTER OF THE PETROLEUM.

A sample of oil from the large seepage at the head of Oil Creek was collected by the writer in 1904. This sample was obtained by skimming the petroleum from the surface of the pools of water, where it was continually rising from the bottom. An effort was made to obtain as much of the fresher oil as possible. Vegetable and earth impurities were removed by straining through coarse cloth. Water could not be entirely removed. Oil for lubrication 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, so that the analyses would not correctly represent the composition of live oil from wells in this region. Such live oil would have a lower specific gravity, a higher percentage of the more volatile constituents, and a 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 paraffin base. It might not be as good as the Controller Bay petroleum but would nevertheless be a refining oil. The sample was submitted to Penniman & Browne, of Baltimore, who returned the following report of their tests:

Report of tests of oil from Cold Bay.

Specific gravity at 60° F	0.9547 (16.6° B.)
Distillation by Engler's method:	
Initial boiling point ° C	225
Burning oil (distillation up to 300° C., under atmospheric pressure) per cent	13.3 (29.6° B.)
Lubricating oils (spindle oils) (120 mm. pressure up to 300° C.) per cent	28.3 (23.8° B.)
Lubricating oils (120 mm. pressure, 300° C.–350° C.) per cent	18.3 (18° B.)
Paraffin oils (by destructive distillation under atmospheric pressure) per cent	32.0 (20.4° B.)
Coke and loss do	8.1
Total sulphur do	0.116

The lubricating oils were distilled under diminishing pressure, according to refinery practice, until signs of decomposition set in. The residue was unsuitable for making cylinder stock, and was therefore distilled for paraffin oils. These paraffin oils contain a considerable quantity of solid paraffin, how much it was not practicable to determine with the small quantity of oil furnished.

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

Iodine absorption of oils and distillates.

	Per cent.
Burning oil	17.2
Lubricating oil	27.2
Heavy lubricating oil	35.2

For comparison, samples of similar oils were obtained from the Standard Oil Co. and their iodine numbers determined as follows:

Light distillated lubricating oil (spindle oil)	32 per cent iodine.
Dark lubricating oil (engine oil)	45.4 per cent 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 quantity can be had by drilling, an oil suitable for refining, containing a very much larger quantity of the more desirable lighter products, may be obtained.

CONCLUSIONS.

The seepages near Cold Bay indicate that some of the Jurassic rocks there may contain considerable petroleum. The reported seepages between Cold and Portage bays and near Becharof Lake apparently indicate a considerable extension of the possible oil-bearing belt. The character of the Jurassic rocks at Cold Bay, which contain numerous thick, porous beds and an abundance of organic matter, indicates that strata from which oil can be generated and in which it can be stored extend through a considerable thickness of rocks and over a wide area. The structure in parts of the district where the dips are low and uniform appears to be favorable to the presence of petroleum. The dips in a large part of the region do not exceed 10° or 15°, but in some areas the dip is steeper and several faults have been noted. The few shallow wells that were drilled at Cold Bay afforded no conclusive test of the district. Drilling has been restricted to a very small area which probably does not include the more promising part of the district. Certain areas, notably the reported anticlines and zones of seepages between Cold and Portage bays and near the west arm of Becharof Lake, may be worthy of further tests with the drill, but the wells should be located according to competent geologic advice.

Probably other areas on Alaska Peninsula may be at least as promising as the Cold Bay area. In fact, the entire area of Jurassic sedimentary rocks in the peninsula may be worthy of preliminary prospecting, and probably the most promising localities for drilling have not yet been found.

ARCTIC COAST.

Indications of petroleum have been reported from several localities on the Arctic coast and elsewhere in northern Alaska. Petroleum may be found at many places in the Arctic coastal plain, but even if an oil pool were discovered in this northern field the difficulties of transportation would prohibit commercial development except by enormous expenditures. The only available harbors are shallow lagoons that are locked in ice for at least 10 months of the year.

An occurrence of petroleum residue on Smith Bay, about 50 miles east of Point Barrow, has been described by Leffingwell[28] as follows:

At Cape Simpson, on the west side of Smith Bay, there are two conspicuous mounds. The writer has been informed by natives that the northern mound contained a petroleum residue, but, according to information furnished by Stefánsson, this residue is contained in a pool a few hundred yards from the mound. A sample was secured from a keg of the material collected by natives in the employ of Mr. C. D. Brower, of Barrow. It resembles axle grease. An analysis by David T. Day is given below. The deposit is near the seashore, and the natives say that a considerable amount could easily be dug out with spades.

Composition of petroleum residue from Cape Simpson, Alaska.

Water and soluble matter	22
Alcoholic extract (resins and some oil)	8
Naphtha extract:	
Light oil	12
Heavy oil	16
Benzol extract (asphaltic material)	11
Clay and vegetable fiber	29
	98

Another possible occurrence of petroleum is reported on the coast about 300 miles farther east, or about 35 miles west of the Alaska-Yukon boundary, where, according to Leffingwell,[29] "natives report another petroleum mound between Humphrey Point and Aichillik River, near the coast."

It has been stated by Brooks[30] that an oil seepage was discovered in 1914 near Wainwright Inlet, about 130 miles west of Smith Bay, but later information indicates that the discovery was farther east, possibly at the Smith Bay locality.

Another possible indication of petroleum has been found on Colville River, which Stoney[31] described as "a substance called wood by the natives; it was hard, brittle, light brown in color, very light in weight, and burned readily, giving out quantities of gas."

According to Dall,[32] who may have seen either the specimen brought out by Stoney or Stoney's lost original report, the material was possibly ozokerite and was described as

A brown material resembling powerfully compressed peat, recalling pitch in hardness and weight but not brilliant nor disposed to melt with heat but making a clean cut like "plug" tobacco when whittled with a knife. This material was

[28] Leffingwell, E. deK., The Canning River region, northern Alaska: U. S. Geol. Survey Prof. Paper 109, pp. 178–179, 1919.

[29] Op. cit., p. 178.

[30] Brooks, A. H., The Alaskan mining industry in 1915: U. S. Geol. Survey Bull. 642, p. 52, 1916.

[31] Stoney, G. M., Naval explorations in Alaska, 1900, p. 69.

[32] Dall, W. H., Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 818–819, 1896.

sufficiently inflammable to ignite and burn with a steady flame on applying a match to a corner of it, so that in their cold and weary journey it formed a most welcome substitute for wood or other fuel for the camp fire.

Reference to Dall's description of this material was made by Redwood,[33] who said that "from the description there is little doubt that the substance is desiccated petroleum."

The possible occurrence of similar material in the Noatak Valley is suggested in the following statement:[34]

Near the mouth of the Noatak, not far from the camp of August 25, a prospector reported finding a recent deposit of material that he has used as fuel. Specimens from this place show a dark-brown, compact material that burns readily in the flame of a match and gives out considerable smoke and oil but leaves practically no ash. David White, who examined the material, reports that the specimen is composed entirely of large fern spores and resembles the so-called "bogheads." This deposit was not seen in place and no facts as to its extent or relations were learned. If there is enough of it, the deposit should have considerable value as a local fuel.

The possible presence of an oil seepage near Cape Beaufort is indicated by Woolfe's statement:[35] "I have noticed on the shelving banks of a small stream that runs through the coal lands an oil exudation resembling crude petroleum."

The occurrences cited above suggest that there may be petroleum at many places in the Arctic coastal plain, and that possibly there may be a more or less continuous oil-bearing belt extending across northern Alaska. The Arctic coastal plain is composed of nearly horizontal unconsolidated or poorly consolidated Tertiary and Quaternary sediments, which rest in places upon gently folded Cretaceous and Jurassic rocks. The geology of parts of the province has been described by Collier,[36] Schrader,[37] and Leffingwell.[38]

POSSIBILITIES OF PETROLEUM IN OTHER PARTS OF ALASKA.

Petroleum may be discovered in other parts of Alaska, especially in the unsurveyed areas, but the chances of finding it in any of the better-known districts besides those described in this report are very small. In much of Alaska there is practically no hope of discovering oil.

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[33] Redwood, Boverton, A treatise on petroleum, 3d ed., p. 184, London, 1913.

[34] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, p. 153, 1913.

[35] Woolfe, H. D., The seventh or Arctic district: Report on population and resources of Alaska at the Eleventh Census, p. 133, 1893.

[36] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: U. S. Geol. Survey Bull. 278, 54 pp., 1906.

[37] Schrader, F. C., A reconnaissance in northern Alaska, across the Rocky Mountains, along Koyukuk, John, Anaktuvuk, and Colville rivers and the Arctic coast to Cape Lisburne, in 1901: U. S. Geol Survey Prof. Paper 20, 139 pp., 1904.

[38] Leffingwell, E. deK., The Canning River region, northern Alaska: U. S. Geol. Survey Prof. Paper 109, 251 pp., 1919.

The regions that can be definitely excluded from the list of possible oil fields include all the areas of igneous and mineralized rocks in southeastern Alaska; the areas of intrusive, volcanic, and mineralized rocks in the Copper River valley; the areas of metamorphic and igneous rocks of Prince William Sound, Kenai Peninsula, and Kodiak Island; the areas of igneous and mineralized rocks in the Talkeetna Mountains and Susitna Valley; the areas of schists, granites, and other igneous, metamorphic, and mineralized rocks in the Yukon-Tanana region and other parts of the Yukon Valley; and all of Seward Peninsula.

For many years there have been frequent reports of the discovery of oil seepages and gas springs on Prince William Sound and Kenai Peninsula, especially in the vicinity of Cordova and Seward. Most, if not all, of these supposed seepages are in swampy areas and may be caused by decaying organic material in the mud. The geology of all parts of Prince William Sound and of the mountainous parts of Kenai Peninsula is very unfavorable to the occurrence of petroleum or natural gas.

At Seward some interest has been aroused over the discovery of inflammable gas issuing from the mud and water at several localities in the swamps along the railroad. The rocks near these localities, as described by Grant,[38a] are slates that have been metamorphosed and folded to a degree which makes it impossible for accumulations of oil or gas to be retained in them. Although it is reported that a considerable volume of inflammable gas issues from the mud, the writer does not believe that it is other than ordinary swamp gas. The reasons for this belief are (1) that the gas has been seen only in swampy areas where there is an adequate probable source in decaying vegetable detritus, (2) that no accompanying oil has been reported, (3) that no gas has been seen at or near exposures of bedrock, and (4) that the neighboring rocks are so metamorphosed and folded that they can not be considered as a probable source of oil or gas.

Unverified reports of oil seepages on the east shore of Cook Inlet are probably based on the occurrence of gas and scum given off from decaying organic matter in the mud or on iron-stained or sulphurous waters derived from beds of lignite. It is possible but not probable that the gently dipping and poorly consolidated lignite-bearing Tertiary strata on the east shore of Cook Inlet[39] may contain petroleum. If they do, the petroleum may have been derived from underlying Jurassic rocks, and its distribution is probably restricted, irregular, and without any relation to the beds that are exposed at the surface.

[38a] Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, pp. 211–212, 217, 1915.

[39] Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, pp. 67–107, 1915.

Oil claims have been staked near the head of Cook Inlet, near Wasilla and Anchorage, but no indications of oil have been found at these localities, so far as known. The surface exposures in the vicinity of Wasilla and Anchorage consist of Quaternary silts and gravels, which are believed to be underlain either by Tertiary lignite-bearing strata like those of the east shore of Cook Inlet or by slaty rocks like those of the Kenai Mountains. It is possible that swamp gas derived from decaying vegetable material in the mud may have misled someone into believing that there were indications of oil at these localities.

It has been reported that there are seepages at the mouth of Little Susitna River and near Tyonek. The known exposures in the vicinity of the mouth of Little Susitna River are Quaternary silts and gravels. Tertiary lignite-bearing beds are exposed near Tyonek,[39a] but no oil seepages have been seen by any of the six or more Survey geologists who have visited the locality.

At Yakutat and Lituya bays there are Tertiary rocks that may mark an eastern extension of the Tertiary rocks of the Controller Bay and Yakataga districts. The supposed presence of petroleum at Yakutat [40] has caused some excitement, but it is unlikely that seepages were found. Most of the coast between the Yakataga district and Lituya Bay is heavily covered with glacial and alluvial deposits. Oil-bearing rocks may possibly occur beneath these unconsolidated deposits or may protrude through them at isolated localities, but there is no reason to believe that oil will be found at any special localities or that expenditures in search of oil would be justified.

Several oil claims have been staked near Cape Spencer. It is said that several years ago some Indians who worked at the cannery at Dundas Bay brought in a sample of petroleum but refused to tell where it was found. A white man is also said to have reported finding oil in this region. In 1920 several members of the crew of the U. S. S. *Henshaw* found what they believed to be petroleum. They were hunting and found black peat and what they believed to be an oil skim on the surface of a pool. No detailed information concerning the rocks at Cape Spencer is at hand. The only available geologic map [40a] shows this locality included in "Paleozoic limestones, schists, phyllites, and greenstone lavas and tuffs." This map represents a belt of "Tertiary sandstone, conglomerates, and rhyolitic lavas and tuffs" trending toward Cape Spencer, and the supposed seepages may lie in this belt.

[39a] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 95, 187, 1911.

[40] Tarr, R. S., The Yakutat Bay region, Alaska: U. S. Geol. Survey Prof. Paper 64, pp. 169–170, 1909.

[40a] Knopf, Adolph, The Sitka mining district, Alaska: U. S. Geol. Survey Bull. 504, pl. 1, 1912.

A large number of oil claims have been staked near Killisnoo, on Admiralty Island. It is not known that seepages have been discovered at this locality. The rocks near Killisnoo include Tertiary coal-bearing rocks and Carboniferous limestones and schists.[40b]

It has been reported that there are oil seepages near Nushagak, in the Mulchatna region, and on the east shore of Andronica Island, one of the Shumagin Islands, but these reports have not been confirmed.

The discovery of oil seepages has also been reported in different parts of the Yukon basin, notably in the Tanana Valley. These supposed seepages, so far as investigated, have all proved to be films of iron oxide, which, especially in combination with marsh gas, simulate seepages of petroleum. Those that have been examined occur in alluvial deposits. Some gas has been encountered in placer mining, where shafts have been sunk below the level of permanent ground frost. As prospectors have been frequently misled by such occurrences into the belief that they had found petroleum seepages, the following note by David White describing simple tests is quoted:

> Among the most important surface indications of the presence of oil and gas deposits are films of oil on water, oil seeps or springs, gas emanations, asphaltic deposits, lenticular accumulations of rock salt or sulphur, and rocks saturated with oil and emitting the odor of petroleum. However, most of these indications should be examined critically with respect to genuineness as well as natural source, especially under certain conditions, and they may require the scrutiny of a specialist in geology or petroleum chemistry. In most of the supposed petroleum seepages the oil-like substance is in reality iron oxide, which commonly forms an iridescent film on the surface of water, especially in marshy places. It can be readily recognized by the fact that it will not burn, and when stirred with a stick breaks into flakes and does not cover the water evenly like an oil film. It also lacks the odor of petroleum; and if a little is put on a piece of muslin and pressed with a hot flatiron, the familiar iron stain is formed. Another simple test for determining the nature of the film is to absorb some of the substance in a blanket or burlap and after allowing it to dry to set fire to it. If the substance is petroleum, it will burn with a long, vigorous flame and will give forth the odor of petroleum.

It was reported in the summer of 1920 that a petroleum seepage had been discovered in the vicinity of Healy Creek, near the southern margin of the Nenana coal field. The rocks in the valley of Healy Creek, according to Capps,[40c] include loosely consolidated sands, clays, and gravels, with beds of lignite underlain by schists and igneous rocks. No petroleum seepages or geologic structure favorable to the occurrence of petroleum were described by Capps or were seen by the writer[40d] in the neighboring part of the Nenana coal field, which was examined in detail in 1916.

[40b] Wright, C. W., A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 267, pl. 33, 1906.

[40c] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pl. 2, 1912.

[40d] Martin, G. C., The Nenana coal field, Alaska: U. S. Geol. Survey Bull. 664, 54 pp., 1919.

There are said to be oil seepages at the locality known as the Palisades or the Bone Yard, on the south bank of the Yukon about 35 miles below Tanana. The strata exposed in the river bank at this locality, according to Collier,[40e] include poorly bedded and unconsolidated silt and gravel containing bones of the mammoth and other mammals, fresh-water and land shells, and vegetable remains which form thick beds "containing wood in all stages of change, from pliable sticks to brittle brown lignite." The lignite from this locality, according to Collier, "is of inferior quality, scarcely changed from wood or peat. Where examined by the writer this peat is mixed with red sand." The supposed indications of petroleum at this locality may be only gases or liquids given off in the surficial decay of the vegetable and animal remains.

Petroleum seepages and "oil shales" have been reported from the upper Yukon Valley, but these reports also have not been confirmed. Some of the less-disturbed areas of Carboniferous and Triassic rocks in the upper part of the Yukon Valley[41] may possibly contain petroleum, but the search for petroleum in this region can not be encouraged until true seepages are found.

The broad areas of Mesozoic rocks in the Kuskokwim[42] and lower Yukon[43] regions may possibly contain areas in which the geologic conditions are favorable to the occurrence of petroleum, but no such areas are now known, and there is no special reason to suspect their existence. The same is true of the areas of Carboniferous and Cretaceous rocks in the Koyukuk,[44] Kubuk,[45] and Noatak valleys. It has been reported[46] that there are indications of petroleum near Nulato, but this report has never been confirmed.

An attempt was made in 1906, according to S. H. Cathcart,[47] to obtain oil at Cape Nome. It is reported that gas was encountered at a depth of 122 feet which blew a 1,200-pound stem 75 feet up the hole. A second hole, 176 feet deep, drilled in 1906, is said to have shown a trace of oil. No further drilling was done until the sum-

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[40e] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, pp. 43–44, 1903.

[41] Prindle, L. M., The Fortymile quadrangle, Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 375, 52 pp., 1909. A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, 82 pp., 1913.

Blackwelder, Eliot, A geologic reconnaissance in the northern part of the Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. — (in preparation).

[42] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, 162 pp., 1917.

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

[44] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, 88 pp., 1916.

[45] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, 160 pp., 1913.

[46] Oliphant, F. H., Petroleum: U. S. Geol. Survey Mineral Resources, 1902, p. 584, 1903.

[47] Cathcart, S. H., Mining in northwestern Alaska: U. S. Geol. Survey Bull. 712, pp. 196–197, 1920.

mer of 1918, when two wells were drilled with a star drill. The first well was abandoned at 210 feet owing to the loss of a bailer; the second reached a depth of about 150 feet at the end of the season. The hopes of the operators are based upon the supposed gas and oil indications encountered in 1906; upon oil-like films of unknown composition which occur on the lagoons in the neighborhood; and upon a beach foam which is brought in by the on-shore winds and which they suspect to be paraffin. The hard rocks at this locality are granite and schist. Rocks of this kind do not contain oil or gas, and it is believed that any gas which may have been encountered was derived from the alluvial deposits. Petroleum has also been reported near Port Clarence,[48] but it very doubtful whether this report has any substantial basis.

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[48] Redwood, Boverton, Petroleum, 3d ed., p. 184, London, 1913.

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