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THE INISKIN-CHINITNA PENINSULA AND THE SNUG HARBOR DISTRICT, ALASKA

BY

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THE INISKIN-CHINITNA PENINSULA, ALASKA

By Fred H. Moffit

INTRODUCTION

The area described in this paper (see fig. 1) is on the west side of Cook Inlet between Iniskin and Chinitna Bays. It is a peninsula

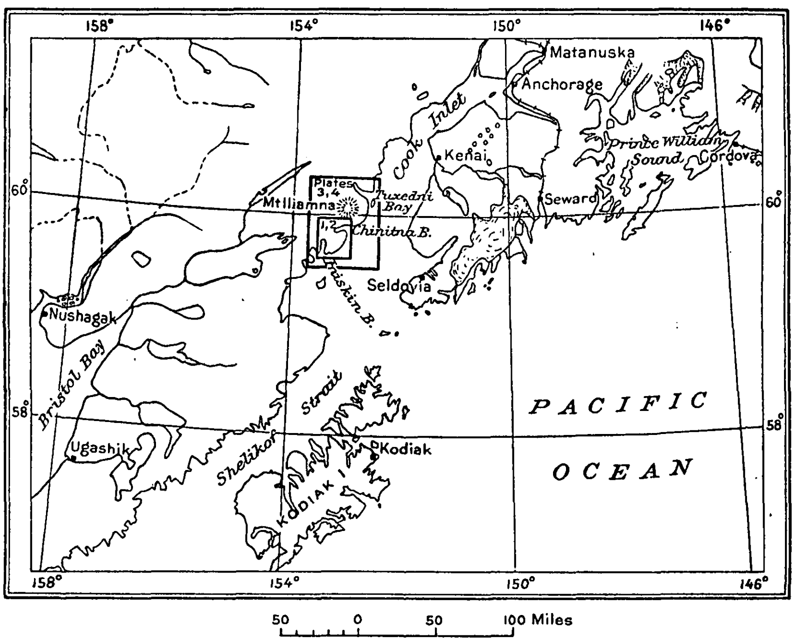


Figure 1.—Index map of the Cook Inlet region showing the Iniskin-Chinitna Peninsula and the area represented on Plates 1, 2, 3, and 4

that has an area of about 130 square miles and is separated from the mainland mountains on the west by a narrow valley which extends from the Right Arm of Iniskin Bay northeastward to the head of Chinitna Bay. For convenience this area may be called the Iniskin-Chinitna Peninsula. Oil Bay, on the south side of the peninsula, is near the intersection of parallel 59° 40′ north latitude with meridian 153° 20′ west longitude. Seldovia, on the southwest end of Kenai Peninsula, is directly across Cook Inlet from Chinitna Bay and is the nearest white settlement and the nearest post office except that at Iliamna, a native village on Iliamna Lake.

The west coast of Cook Inlet has never had more than a scanty white population. It does not abound in fur-bearing animals, has not attracted many prospectors for the metals, and, until recently has had no canneries. The vicinity of Oil Bay, however, at one time received considerable attention because of the petroleum seepages found there and was the scene of drilling for a number of years. Shortly before the Alaskan oil lands were withdrawn from entry in 1910, the oil properties were abandoned, and no further attention was paid to them until the new leasing law was passed in 1920. This law renewed interest in the district, so that much of the ground was restaked, and it accordingly became necessary, in order to carry out the provisions of the law, to collect information regarding the areal geology and structure of the area likely to be prospected for oil. This report, which is based on topographic and geologic surveys made in 1921, includes the information thus collected.

Although this paper deals particularly with the geology of the Iniskin Peninsula, it also contains an account of the field work in the vicinity of Snug Harbor in 1920. A separate section (pp. 57–70) describes the areal geology of the Snug Harbor district, but the conclusions relating to the possibilities of obtaining oil or other minerals in that district are stated together with those regarding the Iniskin-Chinitna Peninsula on pages 54–56.

PREVIOUS WORK

Oil Bay was visited by Martin [1] in 1903, when the work of drilling for oil was in progress. This visit yielded the first report on the possibilities of obtaining oil in the district, based on field investigation by the United States Geological Survey. In the following year Stanton and Martin [2] studied the geology of the west coast of Cook Inlet and the Alaska Peninsula from Tuxedni Bay to Cold Bay and in the course of the summer visited Chinitna, Iniskin, and Oil Bays, where they carefully measured and studied in detail sections of the Mesozoic sedimentary rocks. These sections, with others measured on the Alaska Peninsula, form the basis of much that has since been published on the Mesozoic stratigraphy of this part of Alaska. In 1909 Martin and Katz [3] mapped the Iliamna region and

[1] 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. 37–49, 1905.

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

[3] 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.

published as part of their report a discussion of the sections between Tuxedni and Iniskin Bays made by Stanton and Martin in 1904. From that time no further geologic mapping was done in this vicinity till 1920, when McKinley and Moffit[4] made a topographic and geologic reconnaissance in the vicinity of Snug Harbor, 25 miles north of Chinitna Bay.

PRESENT INVESTIGATION

The investigation whose results are here presented was made in 1921. It was undertaken with the object of mapping topographically and geologically the part of the west coast of Cook Inlet that has the greatest present interest to prospectors for petroleum and was restricted to the peninsula between Iniskin and Chinitna Bays, except that the contiguous mainland and the north shore of Chinitna Bay were included in order to round out the map and join the work with that done in previous surveys. It was intended to publish a detailed map on a scale of 1:62,500 (pl. 1), and this intention was carried out for the topographic map but not for the geologic map. Owing to a strike of marine engineers only a part of the field force, without horses, was able to leave Seattle and reach the area to be mapped at the beginning of the field season. The remaining members of the party with the horses did not arrive till July. For this reason more progress was made with the topographic than with the geologic mapping.

The field force consisted of two parties, one topographic and one geologic. C. P. McKinley had charge of topographic mapping. He was assisted by Gerald Fitzgerald, topographic assistant, T. E. Johnson, Ellison Morris, A. H. Armstrong, and Ray Russell. The writer was in charge of the geologic mapping and was assisted by Arthur A. Baker, geologic aid, C. C. Tousley, Volney L. Gray, and C. P. Dyer.

McKinley with his party and two of the geologic party, including Baker, landed at the cannery in Snug Harbor June 2 and were taken by the cannery tender to Camp Point in Chinitna Bay the next day. The writer, with the rest of the men and 11 horses, arrived in Snug Harbor July 2 and in Chinitna Bay July 5. Field work ended for both parties August 29, for it was necessary to return to Snug Harbor in order to take the last boat of the season to Seattle. The length of the field season was thus 87 days. Fine weather favored the work during June and the first week of July, but during the remainder of July and August the rainy and clear days were about

[4] Moffit, F. H., Geology of the vicinity of Tuxedni Bay, Cook Inlet, Alaska: U. S. Geol. Survey Bull. 722, pp. 141–147, 1921.

equal in number. This distribution of rain and fair weather probably represents the average year and contrasts sharply with the unusually wet summer of 1920.

GEOGRAPHY

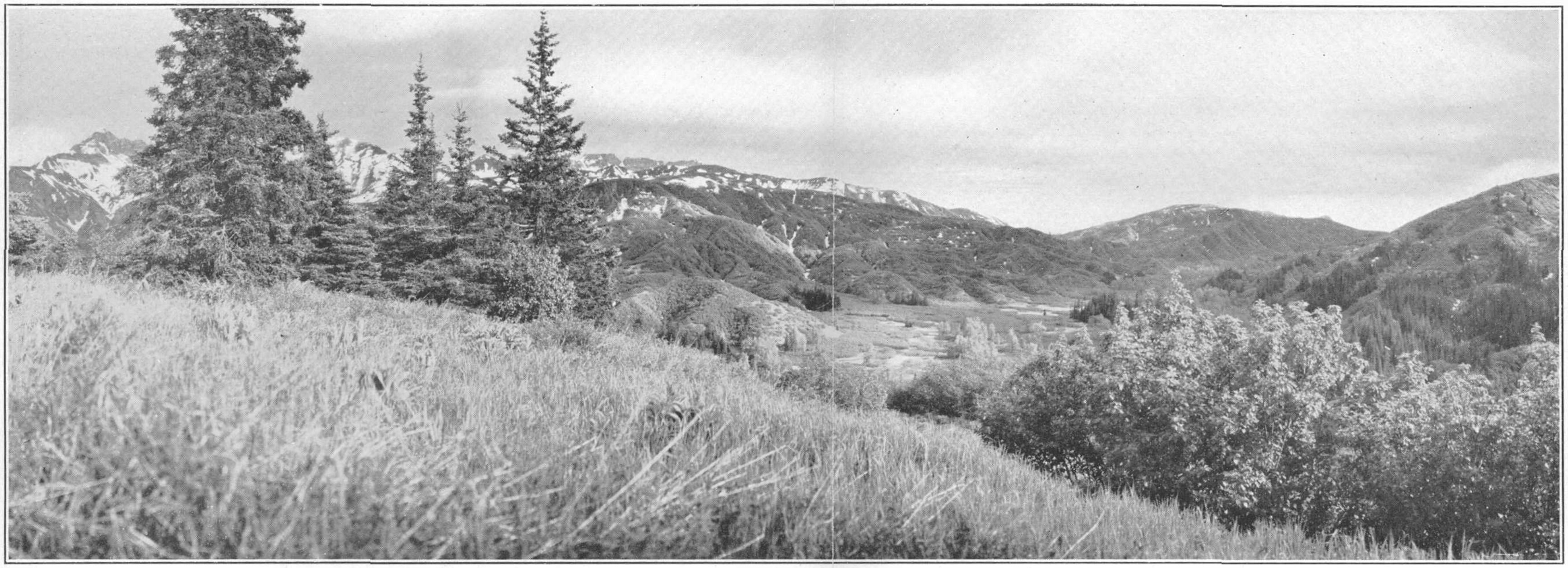
THE COAST LINE

The peninsula between Iniskin and Chinitna Bays has roughly the form of a sector equivalent to somewhat more than a quarter circle, with its convex side turned to the southeast. (See pl. 1.) Iniskin Bay on the west and Chinitna Bay on the north are the radii of the sector, and the curving coast of Cook Inlet is the arc of the circle included between the radii. The greatest dimension of the area is the chord of the arc, which runs from southwest to northeast and is 19½ miles long. The part of the peninsula described in this report is limited on the landward or west side by a valley, about 6 miles long, extending from the Right Arm of Iniskin Bay to the head of Chinitna Bay. The maximum width of the area is thus about 10.5 miles.

The curving coast line is interrupted by indentations at Oil Bay on the south side of the peninsula and again at Dry Bay a few miles east of Oil Bay. The indentation at Dry Bay, however, is so slight as hardly to merit the designation bay.

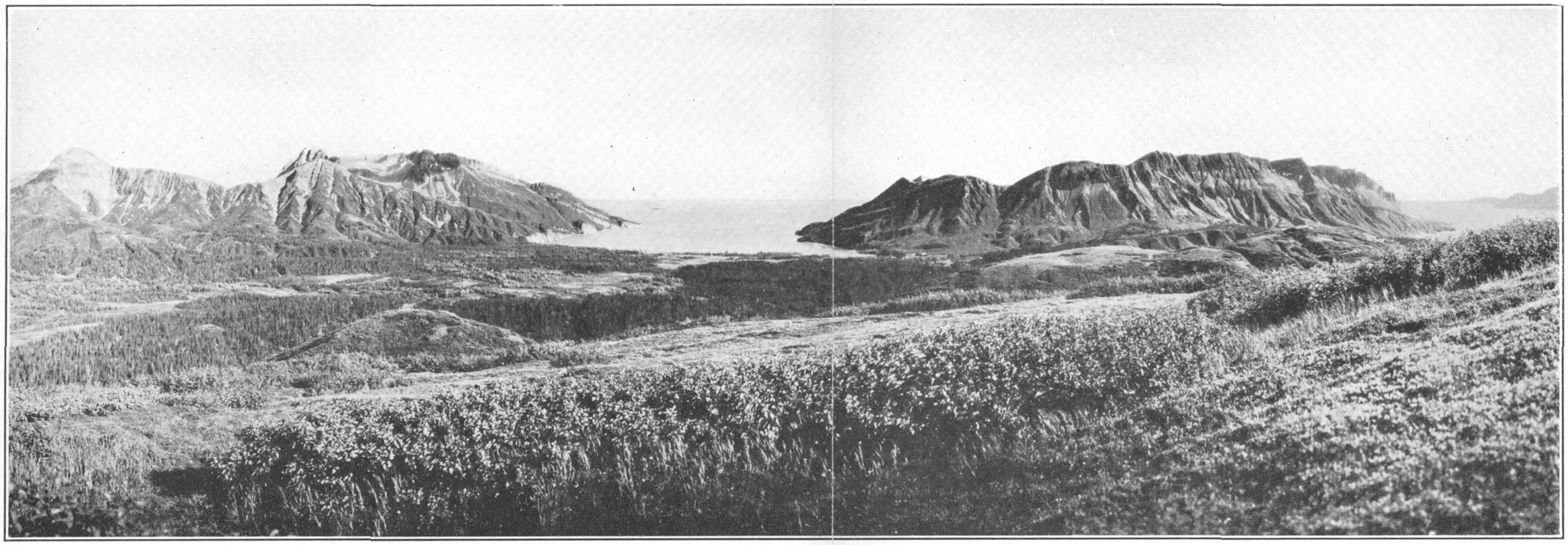
RELIEF

The Iniskin-Chinitna Peninsula is an outlier of the mountain range that extends along the west side of Cook Inlet and down the Alaska Peninsula. Its prominent topographic features are a curving line of mountains that border Cook Inlet and determine the coast line and a lower ridge that extends northeastward from the east side of Iniskin Bay to Chinitna Bay. Both of these topographic features are clearly determined by the geologic structure of the sedimentary beds of which they are formed. The coast mountains in general are higher than the interior mountains. Their altitude decreases from 3,130 feet above sea level at Mount Chinitna, near Chinitna Bay, to 2,410 feet in Mount Pomeroy, between Iniskin and Oil Bays. This ridge shows a steeper and more rugged face (pls. 5, *B*, and 6, *A*) on the landward side than on the side toward Cook Inlet, for the seaward slope is a dip slope that is controlled by the light-colored massive sandstones of the Naknek formation. The scarp of the sandstone and the underlying beds protected by it makes the steep inner slope of the ridge. This coast wall is broken through by Bowser Creek and Oil Bay (pl. 5, *B*), by Brown Creek at Dry Bay (pl. 6, *A*), and by Bow Creek 3 miles northeast of Dry Bay.



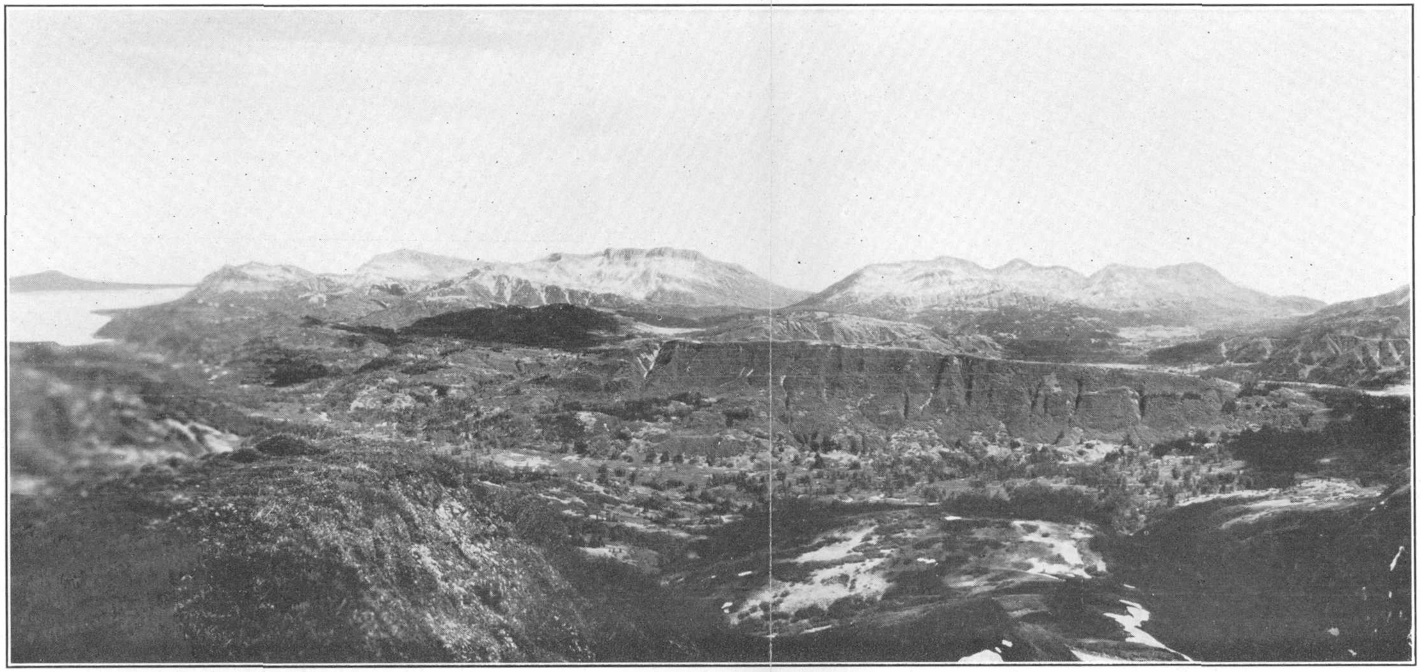
A. VIEW TO THE SOUTH IN PARK CREEK VALLEY

Shows the vegetation and character of the topography where shale and soft sandstone predominate



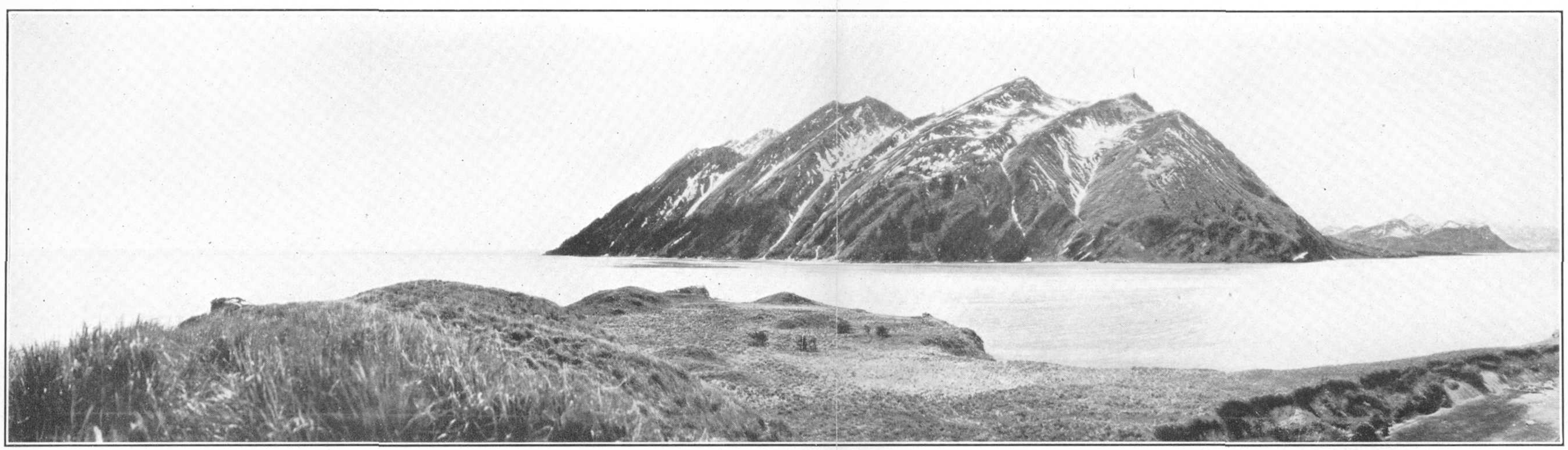
B. OIL BAY (IN CENTER) AND INISKIN BAY

Shows the precipitous landward face of the coast mountains



A. VIEW TOWARD THE EAST ACROSS FITZ CREEK VALLEY

Coast mountains in the distance, Bow Creek valley in far center, and Brown Creek valley on the right



B. STEEPLY DIPPING BEDS OF CHINITNA SHALE AND NAKNEK FORMATION ON THE SOUTH SIDE OF THE ENTRANCE TO CHINITNA BAY

The ridge on the west side of the peninsula is straight and not so high as that along Cook Inlet. Its highest point is 2,442 feet above sea level, and its summits are smoother and more rounded. Between the two ridges, in the central and northern part of the peninsula, stand lower smooth-topped hills (pls. 5, *A*, and 6, *A*), which occupy only a small portion of the whole area.

The principal valleys are the straight, narrow valley leading from Right Arm to Chinitna Bay, the similar valleys of Fitz and Bowser Creeks, parallel to the first, and the transverse valleys of Brown and Bow Creeks. A shorter transverse valley connects the Bowser Creek Valley with Right Arm.

DRAINAGE

Bowser, Brown, and Fitz Creeks are the principal streams of the district. They head near together in almost the exact center of the peninsula and with their branches drain most of it. Bowser and Fitz Creeks flow in opposite directions, the first into Oil Bay and the second into Chinitna Bay, but are in almost direct alignment and occupy valleys whose positions coincide with an anticlinal fold in the Tuxedni sandstone. Another smaller stream, Bow Creek, whose valley is parallel to that of Brown Creek, drains a considerable area east of Brown Creek. None of these creeks are glacial streams, but they are fed during spring and early summer by melting snows on the mountains and at that time carry much more water than later in the summer. Bowser and Fitz Creeks and the two smaller parallel creeks on the west that flow into Right Arm and Chinitna Bay occupy valleys whose direction and position are dependent on the principal lines of geologic structure in the district. The transverse valley between Bowser Creek and Right Arm, the valley of Brown Creek, and the parallel valley of Bow Creek are apparently determined by a system of jointing and faulting that has the same direction as the valleys.

These streams occupy rather wide, open valleys without canyons and with only minor exposures of bedrock. Their smaller tributaries, on the other hand, are cutting narrow V-shaped valleys in the soft shales and in many places have developed falls and cascades on the hard conglomerate and sandstone beds interstratified with the shales.

ROUTES AND TRAILS

Travel to Chinitna and Iniskin Bays is more or less inconvenient and at times is difficult, for no boats call at ports on the west side of Cook Inlet except during the summer, when the cannery on Chisik Island in Tuxedni Bay is in operation. The nearest regular stopping place for Alaska steamers is at Seldovia, near the mouth of Kachemak Bay, on the east side of Cook Inlet. This town is almost 65 miles from Iniskin Bay and is the nearest post office. The cannery on Chisik Island is about 60 miles by sea from Iniskin Bay and 26 miles from Chinitna Bay. It has no post office, and there are no accommodations for travelers except such as are furnished through the courtesy of the cannery people.

Iniskin Bay has deep water and furnishes shelter for large boats. The anchorage, however, is nearer the west shore than the east shore and freight under present conditions must be discharged by lighter. This bay was formerly used at times by boats seeking shelter from storms while discharging freight in Iliamna Bay, but has not been entered by the larger boats in recent years. Chinitna Bay is shallow in its upper sheltered part and is not used by large boats.

The district under consideration is without trails. When drilling was in progress at Oil and Dry Bays a wagon road was built between Iniskin and Oil Bays for transporting supplies and equipment to the wells. There was also a trail from Oil Bay to Right Arm and another to Dry Bay. These trails have not been used in recent years and are now grown up with alders and willows, so that in most places they are difficult to find. Where they ran through the timber and were blazed, or where they were graded or had bridges built over the gulches, they can be followed, but for the most part they furnish slight assistance, and in many places there is no advantage in trying to use them.

The wagon road followed a creek from Iniskin Bay to the summit of the ridge between Iniskin and Oil Bays. This part of the road has been entirely washed out, but the remainder, from the summit of the ridge to the cabin on Oil Bay, could be put in usable condition without great expense. A trail from Right Arm to Chinitna Bay was originally used by the natives and doubtless was known to them long before white men came to this country. Evidently it was never used much by white men, for almost no traces of it are left. It is said that there was once a trail from Oil Bay or Dry Bay to Chinitna Bay. Traces of such a trail were found on Fitz Creek, but it is doubtful if this trail was ever used much.

None of these old trails except the wagon road from Oil Bay to Iniskin Bay and part of the trail to Right Arm in the valley between Right Arm and Bowser Creek were of particular assistance to the surveying parties in 1921. In most places the parties found it quicker and better to wade the streams and to cut trail only where that work was unavoidable. This plan was open to the objection that in early summer and after heavy rains the streams were high and difficult, if not dangerous, to follow. In the later part of August, however, the larger streams were so low that they offered no difficulty whatever, except where driftwood had lodged or where they were overgrown by brush. All the streams are remarkably free from quicksand. In fact, soft ground, difficult for horses to travel, was much less common throughout the district than had been expected, for in most places the sand and fine material derived from the weathering of the sedimentary formations was packed firmly.

TIMBER AND VEGETATION

An open stand of spruce and cottonwood timber covers the valley floors and the lower hill slopes of the interior of the peninsula, but is absent from the mountain slopes that face Cook Inlet. (See pl. 7.) In addition to spruce and cottonwood there is a growth of alder and willow, either of which may be found in the lower lands or on the hill slopes above timber line. As a rule the heaviest growth of willow is on the valley bottoms near the streams or wet ground, for the willow requires much water. The densest growth of alder, on the other hand, is near timber line on the hill slopes. This vegetation, however, is not considered timber.

Spruce and cottonwood are not uniformly distributed over the area in which they grow and are commonly more or less separated from each other. The timbered areas are interspersed with parks overgrown by willow and alder or with tall grass, giving a most pleasing aspect to the landscape. (Pl. 5, *A*.) Cottonwood thrives along the stream courses, where it reaches a large size and forms extensive groves, yet many lone trees are scattered along gulches above the valley bottoms. Seemingly the cottonwood is also able either to establish itself earlier or to maintain itself better in many exposed, wind-swept places than the spruce.

Spruce timber is present in all the larger valleys but is larger and better in the valleys of Bowser and Brown Creeks than elsewhere. In the vicinity of Oil Bay (pls. 5, *B*, and 8, *B*) there are many fine, straight spruces suitable for almost any use for which timber is likely to be needed in this vicinity. Timber line in no place reaches an altitude of 1,000 feet and in only a few places is as high as 750 feet. Good timber grows also on the north shore of Chinitna Bay in a place convenient for transportation, and for several years this area has furnished piling for fish traps and the cannery pier in Snug Harbor.

Grass of the variety commonly called "redtop" by Alaskan prospectors grows luxuriantly on the better-drained land throughout the district and furnishes abundant feed for stock. It covers the "parks" (pl. 9, *B*) where it is not crowded out by the willow or prevented from growing by wet ground and extends up the hill slopes (pl. 5, *A*) to the limit of alders, making it difficult to climb the hills in the later part of summer and especially in the fall after the seed has formed and the stalks are bent to the ground. Stalks of grass 7 feet tall are not uncommon after the seed panicles have formed. Native grass was cut and cured at Oil Bay for the horses during the years when the drillers were at work there.

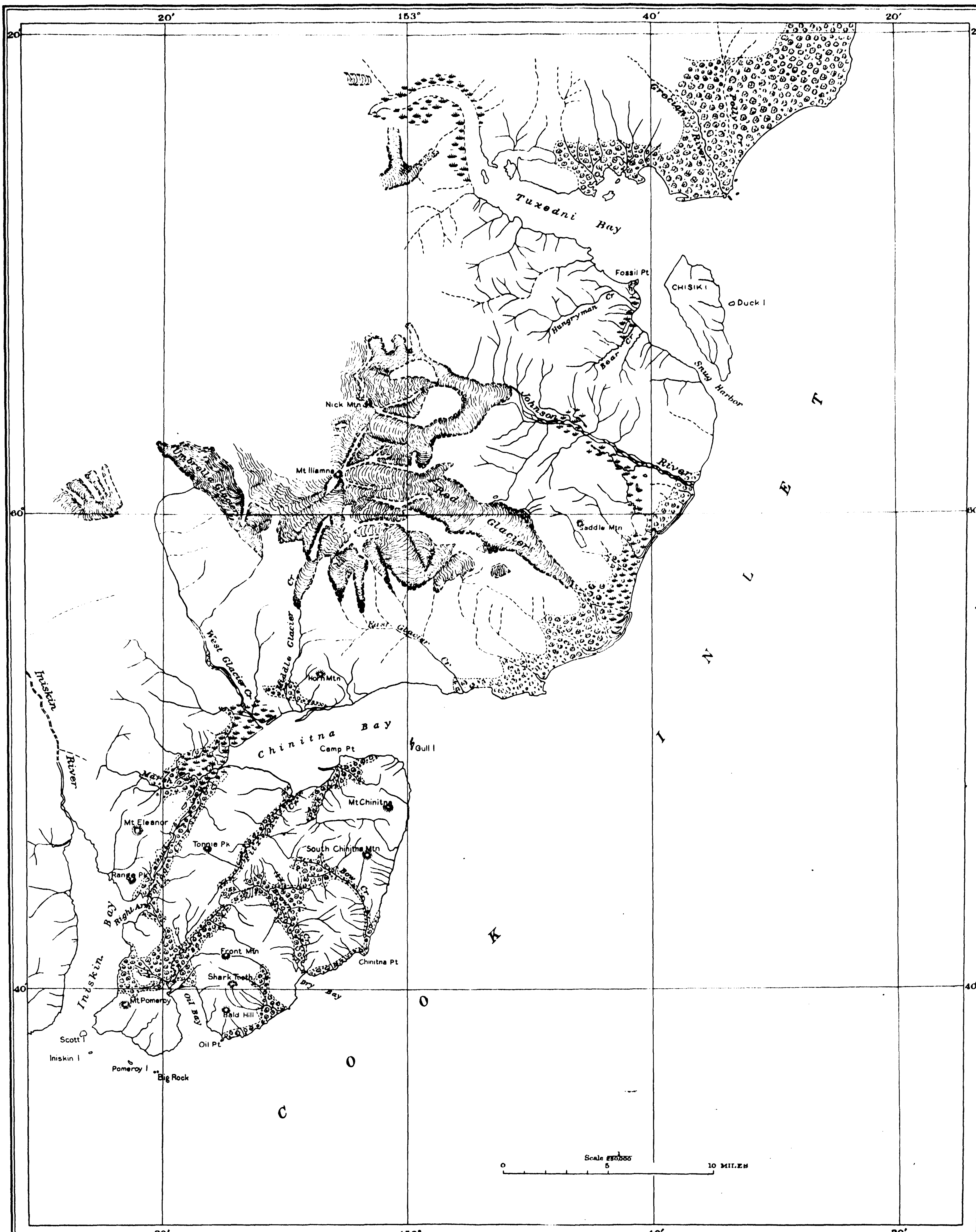
This district is not as abundantly supplied with wild fruit as some parts of the interior of Alaska. Salmonberries, blueberries, and currants were found and furnished a welcome addition to the table. Blueberries are more plentiful than either salmonberries or currants. They are chiefly of the high-bush variety and grow best in the shaded timber areas in contrast with the low-bush berries, which grow in the open on the hill slopes above timber.

GAME

The west coast of Cook Inlet in the vicinity of Chinitna and Iniskin Bays furnishes only a small variety of animals and birds to interest the prospector and hunter. Brown and black bears are the principal larger animals. They are numerous and are present in all parts of the district mapped, so that careful precaution must be taken against the loss of food supplies that have to be left unguarded. They are seen more frequently in the spring and early part of the summer than at other times, for they come out to feed when the vegetation first starts and are less protected from view by the grass and the leaves of the underbrush. The marshy flats at the head of Chinitna Bay are favorite feeding grounds for them in spring, so that it is not unusual to see several at one time in the evening. After the salmon begin to ascend the streams in July and early August the bears get much of their food by fishing on the riffles where the fish are running or by collecting the dead or dying fish along the banks. Their trails are found along all the fish streams, and the track of a big bear who crosses a grass patch on the hillside may be seen for weeks.

The wolverine is the only other large animal in this district likely to molest a cache. He is universally despised and dreaded because of his thieving habits, and until recently was counted as of no value as a fur-bearing animal. There are no moose, caribou, or mountain sheep in the district, and fur-bearing animals are not numerous, so that trapping has not been particularly profitable. Expectation of the removal of restrictions on taking beaver, however, induced several trappers to come into the district and prepare to set out trap lines. A few hair seal are taken for their oil, which has an outside market as well as a small local use.

Ducks are plentiful in the fall, and a few ptarmigan and grouse were seen by members of the surveying parties in 1921. The number



SKETCH MAP SHOWING DISTRIBUTION OF TIMBER BETWEEN INISKIN AND TUXEDNI BAYS of ptarmigan and grouse varies greatly from year to year, so that no single year gives a correct idea of their abundance or scarcity.

Salmon begin to run up the streams to their spawning places in July or the early part of August in accordance with variations in the season or the spawning instinct. They are much less numerous than in many streams of the Alaska Peninsula and are reported to be less plentiful now than formerly, when the canneries were fewer. They are followed in their course upstream by great numbers of Dolly Varden trout, which feed on the salmon eggs and pay little attention to other food. A salmon has an unappetizing appearance after the upstream journey is begun, and the trout is much preferred for table use.

DESCRIPTIVE GEOLOGY

STRATIGRAPHY

FORMATIONS IN THE AREA

The rocks of the peninsula between Iniskin and Chinitna Bays are almost exclusively marine sedimentary deposits, but are composed of clastic material derived in large part from older igneous rocks, among which granitic rocks were abundant. (See pl. 2.) The sedimentary rocks are cut here and there by dark-colored dikes or are intruded by light-colored sills, and are separated by a great fault from the volcanic rocks (Lower Jurassic?) of the mountains between the heads of the two bays. In the order of their ages, from the oldest to the youngest, they are the Tuxedni sandstone (Middle Jurassic) and Chinitna shale and Naknek formation, of Upper Jurassic age.

The Tuxedni sandstone is composed of sandstone, arkose, conglomerate, and sandy shale and reaches a thickness of possibly 7,000 feet. In the lower part of the formation the sandstone and other coarser-grained beds predominate over shale, but in the upper part shale predominates greatly over sandstone. The shale commonly is more or less sandy, except at the top of the formation, where it is argillaceous instead of arenaceous and grades into the overlying Chinitna shale.

Next above the Tuxedni sandstone is the Chinitna shale, a fairly homogeneous formation of gray, black, and reddish shales containing subordinate sandstone and calcareous beds. This formation is approximately 2,300 feet thick.

The Chisik conglomerate, here treated as the basal member of the Naknek formation, overlies the Chinitna shale. In its largest and most typical exposure in this area it is 290 feet thick and includes boulders and cobbles of igneous rock, especially granite. It is, however, of variable thickness and character and throughout most of the district either is represented by beds of grit and arkose or is absent altogether.

The part of the Naknek formation above the Chisik conglomerate member includes at least 4,500 feet of shale and sandstone, which are the youngest rocks in the district. Immediately above the Chisik member lies about 1,500 to 1,645 feet of shale and subordinate sandstone. This shale is overlain by 3,000 feet of beds of white or light-colored sandstone, which are the conspicuous cliff-forming rocks (pl. 8, *A*, *B*) of the mountains bordering Cook Inlet in this peninsula.

These formations succeed one another without structural unconformity, so far as is known. Locally they are abundantly fossiliferous, so that their age is well determined.

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

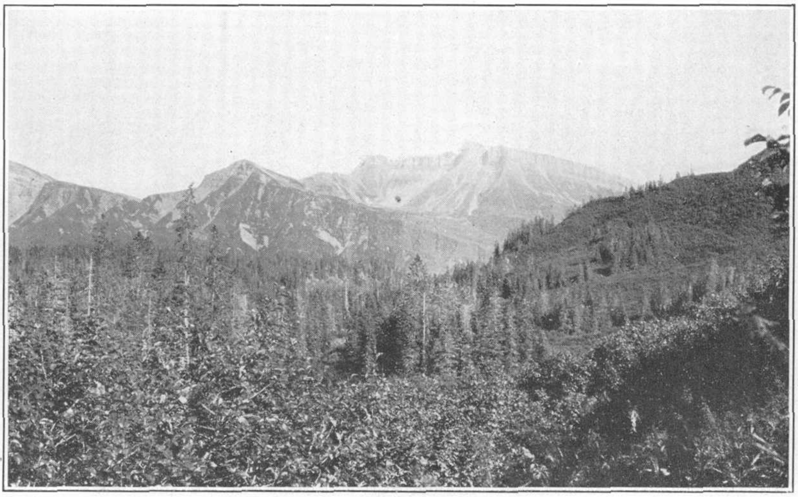
Deposits of gravel lie along the streams and on the coast, but bench gravels and glacial deposits are uncommon. Erratic boulders of rock different from the bedrock of the peninsula, however, bear evidence that the glaciers brought in and left morainal material, but apparently the glacial deposits were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

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

Rocks of the west side of Cook Inlet

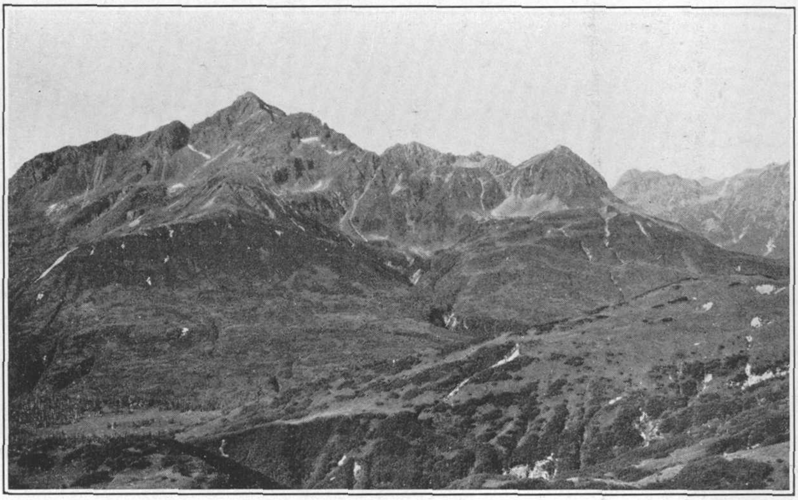
Age	Formation		Lithologic character	Thickness (feet)
Quaternary.			Stream and coastal gravel and sand. Glacial deposits: Sand, gravel, and erratic boulders.	
Upper Jurassic.	Naknek formation.		Massive light-colored sandstone, arkose, and tuff.	3,000
			Gray shale with sandstone beds.	1,645
		Chisik conglomerate member.	Coarse, massive conglomerate with boulders, possibly represented in many places by grit and arkose.	0–290
	Chinitna shale.		Fairly homogeneous argillaceous gray, black, and reddish shales with subordinate calcareous and arenaceous beds.	2,300
Middle Jurassic.	Tuxedni sandstone.		Arenaceous gray shale with subordinate sandstone beds. Sandstone beds, shale, arkosic sandstone, and conglomerate.	7,000
Lower Jurassic (?)			Volcanic rocks (porphyry, tuff, and basaltic and andesitic lavas). May possibly be late Triassic.	(?) 1,000

A. VIEW OF OIL BAY, SHOWING THE WHITE NAKNEK BEDS OVERLYING THE CHINITNA SHALE ON THE EAST SHORE



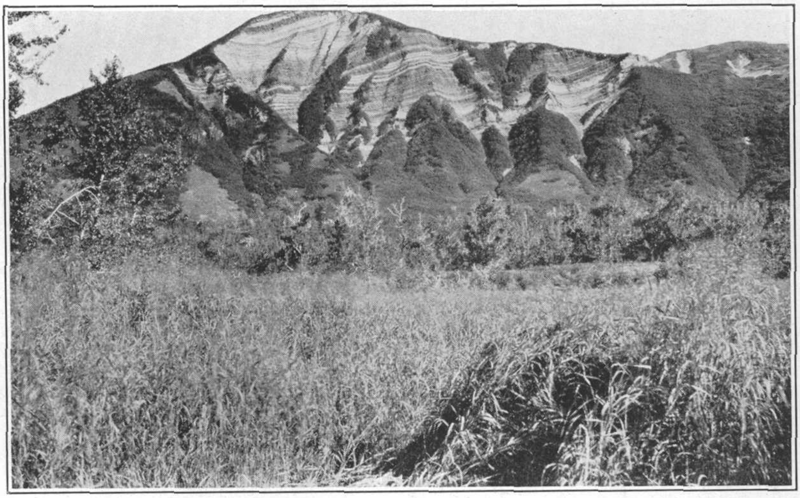
B. MOUNTAINS ON THE EAST SIDE OF OIL BAY FROM A POINT NEAR THE SUMMIT OF THE ROAD TO INISKIN BAY

Shows the cliff-forming Naknek beds and the character of the vegetation



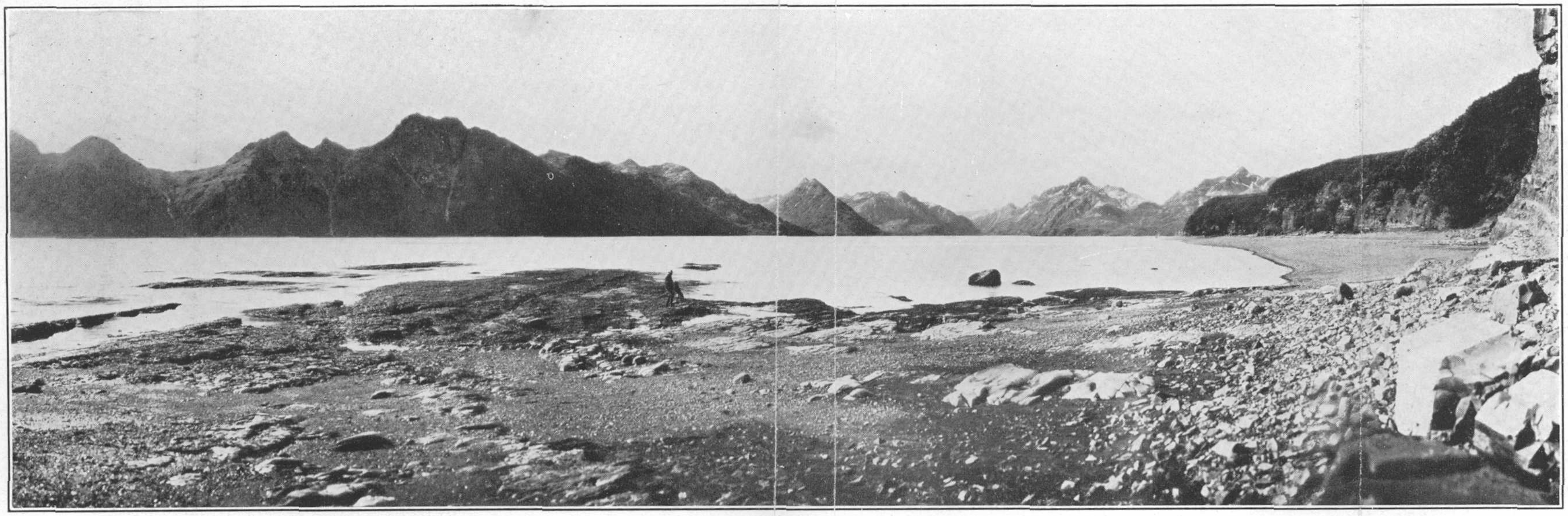
A. MOUNT ELEANOR

Shows typical topography in the area of volcanic rocks east of Portage Creek



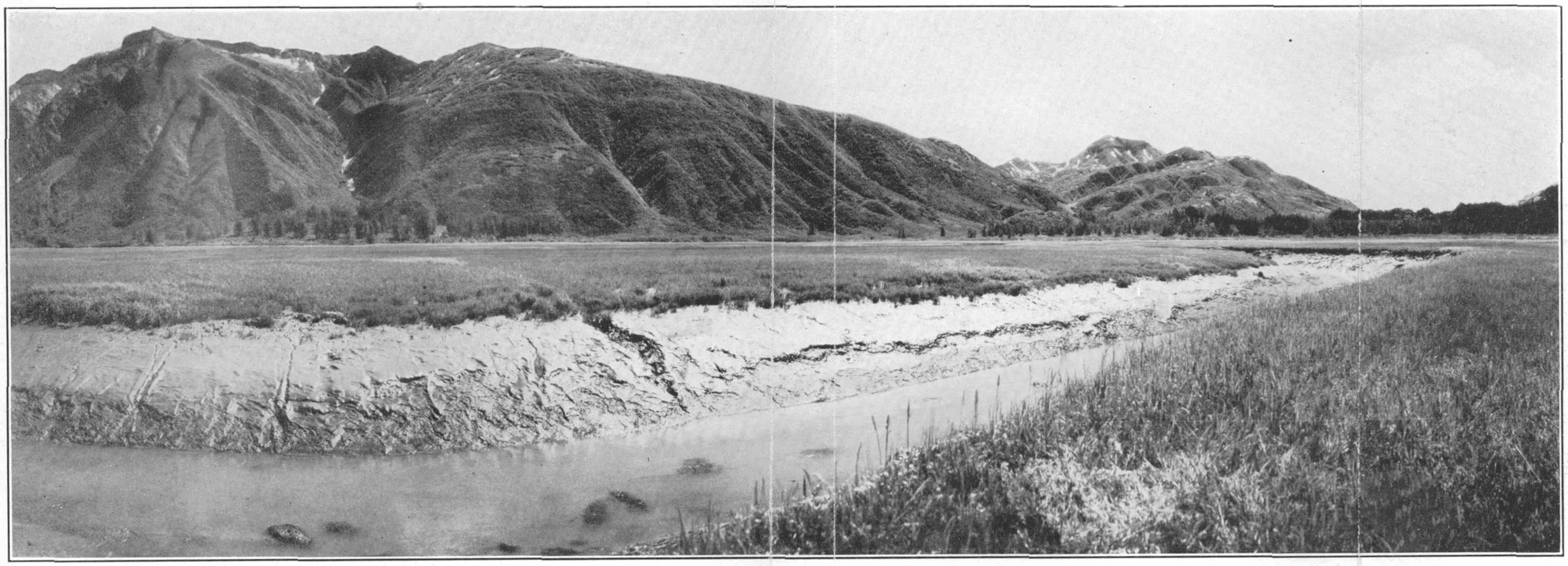
B. WESTWARD-DIPPING BEDS IN THE LOWER PART OF THE TUXEDNI SANDSTONE HALF A MILE EAST OF RIGHT ARM

Redtop grass in the foreground



A. VIEW UP INISKIN BAY FROM A POINT NEAR THE END OF THE WAGON ROAD TO OIL BAY

Shows flat-lying beds of Tuxedni sandstone on the right and typical topography of volcanic rocks in center and left background



B. VIEW TO THE SOUTH AND EAST ACROSS THE MUD FLATS AT THE HEAD OF CHINITNA BAY

Shows channel followed by stream and tide and alder-covered slopes on mountains of Tuxedni sandstone

The geologic map (pl. 2) shows the areal distribution of the formations given in the table and also the principal structural features, together with structure sections. Because of the short field season and the purpose for which the map was largely intended, emphasis was laid on working out the geologic structure of the possible oil-bearing beds rather than on mapping the boundaries of the formations, and for that reason most of the boundaries are not shown with an accuracy comparable to that of the topographic base map. North of Brown Creek as far as Mount Chinitna the boundary lines between the Tuxedni, Chinitna, and Naknek formations are shown only approximately and are so marked, but the line between the shale and the overlying light-colored sandstone of the Naknek formation is placed with more accuracy except near Dry Bay.

Most of the office work in correlating stratigraphic sections from different parts of the area, in constructing the structure sections and preparing the maps, and in studying thin sections under the microscope for use in this report was done by Mr. Baker.

LOWER JURASSIC (?) ROCKS

Mount Eleanor (pl. 9) and the adjacent mountains west of Portage Creek between the heads of Iniskin and Chinitna Bays are on the border of a belt of volcanic rocks that extends for many miles along the eastern side of the Chigmit Mountains and flanks the central granite mass. These volcanic rocks are older than the granite and were intruded by it. They are more resistant to weathering than the Jurassic sedimentary beds along the coast, and this fact, together with their manner of breaking into angular blocks along joint planes, has given the area occupied by them a characteristic topography (pls. 9, *A*, and 10, *A*) that is usually recognized with ease. However, as these rocks are not a possible source of petroleum, they were not examined in detail and will not be described at length.

The volcanic rocks were studied by Martin and Katz[5] and were described in their report. They form a thick series of volcanic beds that include both flows and tuffs and are characterized especially by amygdaloidal basalt and volcanic agglomerate. Martin found "fine-grained green and gray felsitic rocks and tuffs, in part cherty, invaded by large dikes of quartz-feldspar porphyries" on the north shore of Iliamna Bay. Basalt, gabbro, and tuff are present on the west side and head of Iniskin Bay and olivine basalt, tuff, and andesite on the head of Chinitna Bay. These rocks form a complex assemblage whose relations can be learned only by detailed study. They are separated from the Jurassic sediments of the west shore

[5] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 50–59, 1912.

of Cook Inlet by a profound fault or zone of faulting many miles in length.

Martin found that the volcanic rocks on the south shore of Cottonwood Bay, at the head of Iliamna Bay, rest apparently in conformable stratigraphic succession on the Kamishak chert (Upper Triassic), a relation which would indicate that they belong either high in the Triassic or low in the Jurassic. Their relation to the Kamishak chert and their lithologic resemblance to rocks in Seldovia Bay which have the same relations and which are tentatively referred by Stanton to the Lower Jurassic led Martin to assign the volcanic rocks of Iliamna Bay tentatively to the Lower Jurassic. The volcanic flows and tuffs of Iniskin and Chinitna Bays are part of the same belt of rocks as those at Cottonwood Bay and are accordingly regarded as of the same age. Other localities where similar rocks of possibly the same age have been found are given in the correlation table opposite page 22.

MIDDLE JURASSIC ROCKS

TUXEDNI SANDSTONE

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

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

	Feet
Shale of unknown thickness.	
Coarse gray sandstone	75
Shale	1,000
Coarse conglomerate.	
Shale	300
Gray sandstone.	
Shale	1,000
Conglomerate, coarse	20
Thin shale band.	
Heavy sandstone bed.	
Dark shale	1,200
Fine-grained gray sandstone with small beds of shale and sandy shale	1,500
Conglomerate	30
Sandy beds, including sandstone, sandy shale, and conglomerate } Dark shale, sandy shale, and thin sandstone }	1,800
	6,925+

This formation is exposed along nearly the whole south shore of Chinitna Bay and the east shore of Iniskin Bay and occupies approximately the northwestern half of the peninsula, including the valleys of Bowser, Fitz, and Park Creeks and the upper valleys of Brown and Bow Creeks. In general the topography of the area shows smooth slopes with rounded hilltops and broad valleys. The part of the peninsula west of Fitz and Bowser Creeks is believed to be occupied chiefly by the lower part of the Tuxedni sediments, in which hard beds of sandstone and conglomerate are numerous and through differential weathering have formed many waterfalls on small streams that drain the ridges.

A more detailed section on the east shore of Iniskin Bay, which includes only a small part of the whole Tuxedni formation, was measured by Martin[6] and Stanton and is given to show the variability of the beds. Such variability is more characteristic of the lower part of the formation than of the upper part.

Section of Tuxedni sandstone on east shore of Iniskin Bay, Alaska

	Feet
Zone C	
Sandy shale with many *Belemnites* and other fossils	50
Concealed	20
Soft shale	20
Dark-drab shale with scattered fossils	33
Hard calcareous shale full of fossils, principally *Inoceramus*, *Pleuromya*, and other pelecypods	2
Black sandstone	1
Dark shale	5
Black sandstone	1
Dark shale and many fossils	12
Reddish limestone	½
Dark shale with many fossils	14
Dark shale with scattered fossils	62
Dark soft sandstone with streaks of conglomerate	10
Concealed.	
Zone B	
Shale with several fossil bands containing *Trigonia doroschini* and other fossils	50
Concealed.	
Zone A	
Shale with several abundantly fossiliferous beds each 10 to 25 inches thick; *Trigonia doroschini*, *T. devexa*, and other fossils	30
Concealed.	
Shale	12
Coarse conglomerate	20
Unconformity (?).	

[6] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region Alaska: U. S. Geol. Survey Bull. 485, p. 61, 1912.

An unconformity at the base of this section was thought to have been observed by Martin, but a further study of the rocks about Right Arm indicates that the Tuxedni sandstone and the volcanic rocks on the west are in contact along a great fault rather than a plane of sedimentation. The exact position of this small section within the general section is not known, although it appears to be in the lower part, where alternations and variations of beds such as appear here are especially common.

Thickness and structure.—Study of the Tuxedni sandstone during the summer of 1921 shows that the formation is much thicker than earlier work in Cook Inlet seemed to indicate. No single section is known where the thickness of all the beds can be measured consecutively. The evidence of the thickness is therefore obtained from a number of incomplete sections in different localities and is subject to errors arising from the possibility of incorrect correlation of beds in these sections and also to possible duplication of beds arising through faulting or folding. Furthermore, the base of the Tuxedni sandstone has never been unmistakably recognized in this district, although the top, which was determined solely on paleontologic evidence, was seen in a few places. The combined sections from all the localities indicate a minimum thickness of 7,000 feet, more or less, for the formation. This total is large and represents a thickness much greater than the sandstone is known to attain elsewhere in Cook Inlet, so that some doubt is felt as to its correctness, although it is comparable with the thickness of the overlying Upper Jurassic rocks in the Alaska Peninsula. The structure of the Tuxedni sandstone is shown on the map (pl. 2) and is of particular significance to those interested in the problem of finding petroleum in the district, for the known seepages and the holes that were drilled and produced oil or gas are within the area of this formation.

The valley of Portage Creek, which extends northeastward from Right Arm of Iniskin Bay to Chinitna Bay, marks the course of a great fault and the axis of a closely compressed anticlinal fold which meet each other at a slight angle. All the rocks on the west side of the valley, except a small area on Right Arm, belong in the belt of volcanic rocks that borders the main mountain range.

The great fault that brought the Tuxedni sandstone into contact with the volcanic rocks appears to lie on the west side of the anticlinal axis at Right Arm but crosses to the east side in the valley farther north, for it cuts off the west limb of the anticline. The valleys of Bowser and Fitz Creeks mark the position of a second anticlinal fold, parallel to the fold previously described and somewhat less compressed, which extends from the vicinity of the head of Oil Bay to Chinitna Bay. This fold is compound and divides into two minor anticlines in the Fitz Creek Valley. East of Bowser and Fitz Creeks the Tuxedni sandstone dips toward the coast and passes beneath the Chinitna shale in a monocline which is interrupted in places by small local folds.

The western anticline is hidden on the south by the waters of Right Arm and Iniskin Bay, so that nothing is known of it there. but the anticline of Bowser and Fitz Creeks, together with the synclinal trough between it and the Right Arm anticline, flattens out toward the south and pitches or dips beneath the younger rocks of the mountains between Iniskin and Oil Bays. The relation of the Tuxedni sandstone to the Chinitna shale between Iniskin and Oil Bays is not simple, however, for faulting disturbs the normal relation, as is known from the exposures on Iniskin Bay and the absence of the higher beds of the Tuxedni sandstone. Unfortunately, the low hills formed of the shale between Oil and Iniskin Bays are so thickly covered with timber and particularly with alders that only scanty information about the faulting was obtained, in spite of the realization that such information may be important in considering the accumulation of oil.

Age and correlation.—The Tuxedni sandstone is the most highly fossiliferous formation in the district and contains abundant fossils at many horizons. Numerous collections were accordingly made to assist in determining the position of the boundaries of the formation and to supplement the collections of earlier workers, yet the number of species found could undoubtedly have been increased if more time had been available. On the evidence of the fossils collected in former years the Tuxedni sandstone was determined to be of Middle Jurassic age. This determination is further corroborated by the collections of marine invertebrate fossils made in 1921. which were submitted to T. W. Stanton for identification and are listed below as described by him.

10979. F 2. South shore of Chinitna Bay. Most easterly exposure of Tuxedni on west side of Fitz Creek heading against Bowser Creek:

Pecten sp. Smooth form.

Fossil not distinctive.

10980. F 3. South shore of Chinitna Bay, 800 feet west of locality F 2:

Stepheoceras carlottense (Whiteaves)?

Probably from the Tuxedni sandstone.

10981. F 4. East side of Fitz Creek, 3 miles south of south shore of Chinitna Bay:

Sphaeroceras oblatum (Whiteaves)?

Phylloceras sp.

Tuxedni sandstone.

10983. F 5. Head of Bowser Creek, south side of valley at about elevation 800 feet.

Inoceramus ambiguus Eichwald.

Pleuromya sp.

Tuxedni sandstone.

10984. F 6. Head of Bowser Creek, near F 5:
Inoceramus ambiguus Eichwald.
Tuxedni sandstone.

10985. F 7 a and b. Tributary to Bowser Creek, from south next below head of stream; 3,800 feet from place where tributary enters Bowser Creek valley:
Trigonia devexa Eichwald.
Pleuromya sp.; short, broad form.
Tuxedni sandstone.

10987. F 9. A little less than 50 feet south of and stratigraphically below F 8:
Inoceramus ambiguus Eichwald.
Tuxedni sandstone.

10993. F 15. Northwest side of Right Arm of Iniskin Bay at head of arm:
Trigonia doroschini Eichwald.
Tuxedni sandstone.

10998. AB F 6. Southwest shore of Chinitna Bay:
Eumicrotis? sp.
Inoceramus sp.
Pleuromya sp.
Tuxedni fauna.

10999. AB F 7. On cliffs on south shore of Chinitna Bay toward head of bay:
Inoceramus ambiguus Eichwald.
Tuxedni sandstone.

11000. AB F 8. At elevation 250 feet up creek which drains from topographic station Sharp into head of Chinitna Bay:
Eumicrotis? sp.
Tuxedni fauna.

11014a. AB F 5. Southwest shore of Chinitna Bay in Tuxedni sandstone:
Ostrea sp.
Eumicrotis? sp.
Dentalium? sp.
Fossils not distinctive.

11019a. AB F 26. South shore of Chinitna Bay about 700 feet north of point where Tuxedni emerges from under alluvium:
Inoceramus sp.
Fossils not distinctive.

11020a. AB F 27. 300 feet north of 11019:
Inoceramus sp.
Fossils not distinctive.

11021. AB F 28. 100 feet south of 11019:
Pleuromya sp.
Ammonite fragment.
Tuxedni sandstone.

11022. AB F 29. Fitz Creek, about 3 miles from Chinitna Bay:
Sphaeroceras cepoides (Whiteaves)?
Fragment of undetermined ammonite.
Tuxedni sandstone.

11023–11029. AB F 30–36. Same locality as AB F 29:
Pinna sp.
Stepheoceras? sp. Three species.
Tuxedni sandstone.

11030a. AB F 37. Short distance up tributary to Fitz Creek which drains divide northeast of Tonnie Peak:

Amberleya? sp.
Belemnites sp.
Fossils not distinctive.

11031. AB F 38. About 1,000 feet up same tributary on which AB F 37 was collected:

Eumicrotis? sp.
Tuxedni sandstone.

11032. AB F 39. Tuxedni sandstone. About 1,500 feet up tributary on which AB F 37 was collected.

Eumicrotis? sp.
Venerid and other forms.
Probably Tuxedni sandstone.

11033. AB F 40. Tuxedni sandstone. At topographic station Round:

Eumicrotis? sp.
Pleuromya sp.
Probably Tuxedni sandstone.

11034. AB F 42. Tuxedni sandstone about 7,200 feet up small creek branching off to south from Fitz Creek about 1⅔ miles from Chinitna Bay:

Stepheoceras? sp.
Haploceras? sp.
Tuxedni sandstone.

11035. AB F 44. About 9,000 feet up creek on which AB F 42 was collected:

Ostrea? sp.
Stepheoceras? sp. (Same as in AB F 42.)
Sphaeroceras sp.
Harpoceras sp.
Phylloceras sp.
Tuxedni sandstone.

11036. AB F 43. About 8,000 feet up same creek as 11035:

Trigonia sp.
Inoceramus porrectus Eichwald?
Stepheoceras? sp.
Harpoceras sp.
Sphaeroceras sp.
Sphaeroceras? sp.
Tuxedni sandstone.

11037a. AB F 45. B 600, about 3,000 feet up creek that drains into Bowser Creek from the south:

Anomia sp.
Amberleya? sp.
Fossils not distinctive.

11038. AB F 46. About 1,000 feet up creek from AB F 45:

Pecten sp.
Inoceramus ambiguus Eichwald.
Grammatodon sp.
Isocardia? sp.
Pleuromya sp.
Thracia sp.
Amberleya? sp.
Sphaeroceras? sp.
Belemnites sp.
Tuxedni sandstone.

11039. AB F 47. 2,000 feet farther up creek than AB F 46:
Terebratula sp.
Rhynchonella sp.
Camptonectes sp.
Pecten sp. Smooth form.
Pteria sp. Large, strongly sculptured.
Pteria? sp.
Trigonia sp.
Astarte sp. Two or more species.
Phylloceras sp.
Tuxedni sandstone.

11040. AB F 49. 1,120 feet from AB F 47 on first right fork of left fork:
Pecten sp. Small ribbed form.
Pecten sp. Smooth form.
Inoceramus ambiguus Eichwald.
Grammatodon sp.
Pleuromya sp.
Undetermined gastropod.
Belemnites sp.
Tuxedni sandstone.

11041. AB F 50. Over hill from locality AB F 49, to next creek to west at elevation 800 feet:
Inoceramus sp.
Grammatodon sp.
Astarte sp.
Cadoceras doroschini (Eichwald).
Cadoceras stenoloboide Pompeckj.
Sphaeroceras? sp.
Belemnites sp.
The pelecypods in this lot suggest the Tuxedni fauna, but the ammonites certainly came from the Chinitna shale.

11042. AB F 51. On tributary to Bowser Creek from south, about 1,900 feet up creek from trail crossing.
Pecten sp.
Lima sp.
Pteria? sp.
Eumicrotis? sp.
Grammatodon sp.
Grammatodon? sp.
Cerithium sp.
Sphaeroceras sp.
Belemnites sp.
Tuxedni sandstone.

11043a. AB F 52. On same tributary mentioned under AB F 51, about 2,300 feet up creek from trail crossing:
Phylloceras sp.
Fossil not distinctive.

11044a. AB F 53. 3,300 feet up creek from trail crossing at elevation 300 feet; up east fork at 2,500 feet:
Trigonia sp. Fragmentary imprint.
Fossil not distinctive.

11045. AB F 54. 3,900 feet up creek described under AB F 51 and up east fork at 2,500 feet, at elevation 350 feet:

Astarte sp.

Probably Tuxedni sandstone.

11046. AB F 55. 4,400 feet up same creek mentioned under AB F 51:

Inoceramus ambiguus Eichwald.

Tuxedni sandstone.

11047. AB F 56. 4,800 feet up same creek mentioned under AB F 51:

Terebratula sp.
Pecten sp.
Lima sp.
Inoceramus ambiguus Eichwald.
Pinna sp.
Grammatodon sp.
Pleuromya sp.
Natica sp.
Macrocephalites sp.
Phylloceras sp.
Oppelia? sp.
Belemnites sp.

Tuxedni sandstone.

11048. AB F 57. At the forks, 6,540 feet up same creek mentioned under AB F 51:

Phylloceras sp.
Oppelia? sp.

Probably Tuxedni sandstone.

11051. AB F 62. 5,400 feet up south fork of creek mentioned under AB F 51:

Camptonectes sp.
Inoceramus ambiguus Eichwald.
Macrocephalites? sp.
Belemnites sp.

Tuxedni sandstone.

11053. AB F 64. Chinitna shale. A short distance above assumed Tuxedni-Chinitna contact along creek mentioned under AB F 51:

Thracia? sp.
Oppelia? sp.

The ammonite suggests the Tuxedni fauna rather than Chinitna.

11057. AB F 70. Southward along east shore of Iniskin Bay about 250 feet from end of trail at lower cabin:

Trigonia sp.

Tuxedni sandstone.

11061. AB F 77. Northward along east shore of Iniskin Bay 5,400 feet from end of trail at lower cabin:

Pecten sp.
Pteria sp.
Astarte? sp.
Trigonia sp.
Arctica sp.
Quenstedtia? sp.
Pleuromya sp.
Thracia? sp.
Anatina? sp.

Tuxedni sandstone.

11062. AB F 78. Northward along east shore of Iniskin Bay 6,500 feet from end of trail at lower cabin:

Pecten sp.
Arctica? sp. Large form.
Quenstedtia? sp.
Tuxedni sandstone.

11063a. AB F 80. 3,500 feet up tributary of Fitz Creek from north about 1⅔ miles from Chinitna Bay:

Rhynchonella sp.
Fossil not distinctive.

The fossils noted above as not distinctive are included in the list because they were collected from beds that are shown by the field evidence to belong to the Tuxedni sandstone. The collection from locality 11041 was made at the contact of the Tuxedni sandstone and the Chinitna shale before the position of the boundary was determined and probably contains fossils from both formations, as is suggested by Stanton in his description. The collection from locality 11053, near the contact, may also contain fossils from both formations.

A list of Tuxedni fossils collected on Iniskin Bay by Stanton and Martin is given for comparison and because it contains a few forms not found in the list already given.[7] Zones A, B, and C refer to the zones mentioned in the section on page 13.

East shore of Iniskin Bay, zones A and B (2919):

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

East shore of Iniskin Bay, near lower cabin, zone C (2920):

Stephanoceras sp.
Belemnites sp. a.
Belemnites sp. b. Abundant.
Belemnites sp. c.
Grammatodon? sp. a.
Grammatodon? sp. b.
Inoceramus eximius Eichwald. Abundant. The forms described by Eichwald as I. eximius, I. ambiguus, and I. porrectus may all belong to one species.
Pecten sp. Small form same as in lot 2919.
Pecten sp. Large individual that may be adult of species last named.
Ostrea sp. Same as in lot 2919.

Collections of fossil plants were made at several localities, but satisfactory specimens were found less frequently than in the type locality of the Tuxedni sandstone in Tuxedni Bay, although twigs

[7] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, p. 62, 1912.

and pieces of logs are common. Most of the material is fragmentary and not sufficient for close determinations but is nevertheless useful for comparison and includes some interesting species. The determinations as made by F. H. Knowlton are given in the following list:

7519. South shore of Chinitna Bay: A single fragment of the tip of a leaf, probably *Phoenicopsis speciosa* Heer.

7520. A single fragment of a cycad leaf, probably Zamites or *Pterophyllum*, but impossible to tell.

7521. About 1 mile from divide between Fitz Creek, Brown Creek, and Bowser Creek: Fragments of *Sagenopteris* and *Nilsonia*, but too fragmentary for certain identification.

7522. About 8,300 feet up creek from locality 7521: A single small fragment, possibly of *Phoenicopsis*, but impossible to say more.

7523. About 2½ miles from divide described in locality 7521: Probably *Phoenicopsis*, but too fragmentary to be certain.

7524. About 7,200 feet up creek described under locality 7523: Fragments of *Sagenopteris* sp.

7526. Sandstone on east shore of west arm of Right Arm of Iniskin Bay.

7527. Bowser Creek: A coniferous stem, but too fragmentary to determine.

7528. Right Arm of Iniskin Bay.

Nos. 7526 and 7528 comprise about 30 specimens and all belong to the same species. This is extremely interesting material. It is a fern with extraordinary stout rachis bearing numerous, separated, linear, entire pinnules, with a very thick midrib and fine forked nerves at right angles to the midrib. A few pinnules are in fruit. I have not been able to identify this fern, and it is probably new. It belongs to the family Marattiaceae and probably to *Marattiopsis* or *Danaeopsis*.

The other lots are so fragmentary that it would be unwise to venture a very positive opinion as to their age, though there is nothing incompatible with their belonging to the Jurassic. As they all come from the Tuxedni sandstone there can be no doubt of the Jurassic age.

The type locality of the Tuxedni sandstone is on the south shore of Tuxedni Bay, about 25 miles north of Chinitna Bay. (See p. 62.) Excellent exposures are available for study at that place and form a continuous outcrop for about 3 miles along the shore from Fossil Point to the volcanic rocks toward the head of the bay. This section was visited by Dall,[8] who collected fossils there in 1895, and was carefully measured by Stanton and Martin[9] in 1904 as shown on pages 62–63. In 1905, when Stanton and Martin's paper was published, the Tuxedni sandstone was regarded as the lower part of the "Enochkin formation,"[10] which included also the Chinitna shale

[8] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, pp. 869–870, 1896.

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

[10] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, p. 38, 1905.

but was given a distinctive name, "because of the dissimilarity of the lithologic character and faunas of the two parts."[11]

The Tuxedni sandstone of the Iniskin-Chinitna Peninsula is part of a belt of Middle Jurassic marine sediments exposed along Cook Inlet from Tuxedni Bay to Iniskin Bay. Its characteristic fauna has been found in Matanuska Valley[12] and in the Tordrillo formation[13] around the headwaters of Skwentna River.

The fauna was collected also by Moffit[14] and Chapin from a small area of tuffaceous slate associated with conglomerate near the mouth of Chitina River, in the Copper River basin. Capps[15] collected fossils from bedded rocks, including shale, sandstone, and conglomerate, on Wide Bay, on the Alaska Peninsula, opposite the south end of Kodiak Island, which Stanton regards as of Middle Jurassic age but somewhat older than the fauna of the Tuxedni sandstone in Cook Inlet, although the fauna from Wide Bay includes the lowest part of the Tuxedni fauna of Cook Inlet.

In 1921, when Capps visited the area, not more than about 500 feet of Middle Jurassic beds were recognized. More recent work by W. R. Smith,[16] however, has shown that the Tuxedni beds in this locality are at least 1,200 feet thick and that the upper 600 feet probably is equivalent to the lower beds exposed at Tuxedni Bay. Furthermore, a new locality southwest of Alinchak Bay was discovered, where about 1,300 feet of beds, chiefly sandstone, referred to the Tuxedni sandstone, is exposed.

A section of bedded rocks on the shore of Kamishak Bay in the vicinity of Amakdedori is described by Mather[17] as belonging to the Tuxedni sandstone. The rocks exposed in the cliffs at the mouth of Amakdedori Creek include about 500 feet of fossiliferous sediments, comprising dark carbonaceous shale, sandstone, grit, and volcanic tuff, and are both overlain and underlain by dense basic lava flows. This section is therefore somewhat different from the others just described.

Aside from these three localities the Tuxedni sandstone has not been identified elsewhere on the Alaska Peninsula, although Upper Jurassic sediments are well developed.

The Jurassic sedimentary formations of Alaska, so far as they are known, are shown in the following correlation table:

[11] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, p. 59, footnote 4, 1912.

[12] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 18–19, 1907.

[13] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 90, 1911.

[14] Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, pp. 25–27, 1914.

[15] Capps, S. R., The Cold Bay district, Alaska: U. S. Geol. Survey Bull. 739, p. 91, 1922.

[16] Personal communication.

[17] Mather, K. F., Mineral resources of the Kamishak Bay region: U. S. Geol. Survey Bull. 773, p. 165, 1925.

Jurassic sedimentary rocks of Alaska

Age	West Coast of Cook Inlet	Alaska Peninsula [a]	Kenai Peninsula [b]	Upper Matanuska and Nelchina Valleys [c]	Mount McKinley region [d]	Broad Pass region [e]	Nabesna-White River region [f]	Lower Chitina Valley [g]	Southeastern Alaska [h]	Cape Lisburne district [i]	Canning River district [j]
Upper Jurassic	Naknek formation: Light-colored arkosic sandstone, 3,000 feet; underlain by gray shale and thin sandstones, 1,645 feet; and, at base, Chisik conglomerate member, 0–290 feet. Conformity. Chinitna shale: Gray, black, and reddish argillaceous shales with sandstone beds; thin calcareous shale beds; concretions, 2,300 feet.	Naknek formation, conglomerate and arkosic sandstone from 1,000 to 3,000 feet thick, overlain by sandy shale; 5,000+ feet. Shelikof formation: Black shale, 700 to 1,000 feet thick, with some limestone lenses at top, overlying a thick series of sandstone, with minor amounts of conglomerate and sandy to calcareous shale; carries the Chinitna fauna; 5,000–7,000 feet.		Unconformity. Naknek formation: Shale and sandstone of great but unknown thickness, underlain by conglomerate, with lenses of sandstone and shale, which is possibly equivalent to the Chisik conglomerate; 450+ feet. Unconformity. Chinitna formation: Concretionary sandy shale and arkose.			Banded slate or shale, graywacke, and conglomerate, with which are associated sandstone and limestone in minor amount. Contains *Aucella* sp. related to *A. bronni* Rouiller.	Sandstone, sandy shale, limestone, and conglomerate. Locally contains *Aucella pallasi* Keyserling. May eventually prove to be Cretaceous. Isolated areas with a possible thickness of 2,500 feet.	(?) Interbedded conglomerate, graywacke, and black slate.	Corwin formation (Jura-Cretaceous): Thin-bedded shale, sandstone, conglomerate, and coal beds; contains numerous fossil plants; 15,000+ feet.	
	Conformity.	Unconformity.						Unconformity.			
Middle Jurassic	Tuxedni sandstone: Arenaceous shale with thin sandstone beds. Sandstone, arkosic sandstone, conglomerate: 7,000± feet.	Kialagvik formation: Sandstone and sandy shale at Wide Bay. (Middle? Jurassic) [1,200+ feet.]		Tuxedni sandstone: Sandstone, sandy shale, and arkose.	Tordrillo formation: Conglomerate, grit, sandstone, and slate, with some tuff; 2,000± feet. Invertebrate fossils. Tuxedni fauna.	(?) Closely folded dark-blue and black slates interbedded with graywacke and conglomerate. Some impure limestone.		Water-laid tuff and massive conglomerate; contains the fauna of the Tuxedni sandstone; 500+ feet.			
				Unconformity ?	Unconformity						
Lower Jurassic (?)	Porphyry, tuff, and basaltic and andesitic lavas; 1,000 (?) feet. May possibly be late Triassic.	Calcareous sandstone and sandy shale, with limestone, at Cold and Alinchak Bays; 2,300± feet.	Tuff and agglomerate with interbedded marine fossiliferous strata; 1,000–3,000 feet.	Volcanic rocks, consisting of andesite, rhyolites, dacite, breccia, and tuffaceous sediments; 1,200+ feet.	Skwentna group: Andesitic dacite, trachite, and basaltic lava and tuff, with some slate, chert, and limestone. Age determination uncertain.						Kingak shale: Thin-bedded friable black shale, with concretions and sandstone; 4,000 feet. Conformity.

[a] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, p. 91, 1922. The thickness given for the Kialagvik formation is a revised estimate by W. R. Smith, personal communication.
[b] 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. 63–67, 1915.
[c] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 21, 29–38, 1918. Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, p. 16, 1907.
[d] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 52, 1911.
[e] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 32–40, 1915.
[f] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, p. 28, 1910.
[g] Rohn, Oscar, A reconnaissance of the Chitina River and Skolai Mountains, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 424 and 428, 1900. Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska: U. S. Geol. Survey Special Pub., pp. 48–50 1901. Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 31–43, 1911. Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, pp. 25–27, 1914. Moffit, F. H., and Mertie, J. B., jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, pp. 44–51, 1923.
[h] Chapin, Theodore, The structure and stratigraphy of Gravina and Revillagigedo Islands, Alaska: U. S. Geol. Survey Prof. Paper 120, pp. 97–98, 1918.
[i] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: U. S. Geol. Survey Bull. 278, pp. 27–30, 1906.
[j] Leffingwell, E. deK., The Canning River region, Alaska: U. S. Geol. Survey Prof. Paper 109, p. 119, 1919.

INTRUSIVE ROCKS IN THE TUXEDNI SANDSTONE

Intrusive rocks in the Tuxedni sandstone are uncommon; and the only ones that were observed are confined to the vicinity of Iniskin Bay. They include sills of quartz diorite and basaltic dikes.

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

Several dikes that cut Tuxedni beds are exposed on the east shore of Iniskin Bay. They are not conspicuous, for the color of the weathered dikes is much like that of the including shale. The dikes are composed of dense fine-grained black basalt and are less than 10 feet in thickness. At one locality a small dike, 10 inches thick, is amygdaloidal, the vesicles having been filled with a white secondary mineral resembling heulandite. The microscope shows phenocrysts of feldspar, augite, and olivine in a groundmass of feldspar and augite.

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

UPPER JURASSIC ROCKS

The Upper Jurassic beds include, in ascending order, the Chinitna shale and the Naknek formation, the latter including the Chisik conglomerate member at its base. These formations succeed each other and the Tuxedni sandstone without structural unconformity and form a belt of high mountains, averaging less than 4 miles in width, along the coast of Cook Inlet from Chinitna Bay to Iniskin Bay. About half the area of sedimentary formations mapped on Plate 2 is occupied by Upper Jurassic rocks.

CHINITNA SHALE

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

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

The type section of the Chinitna shale on the north side of Chinitna Bay, as measured by Stanton,[18] is as follows:

Section of Chinitna shale on north shore of Chinitna Bay

	Feet
Indurated dark argillaceous shales with conspicuous thin bands and elongated lenses of yellowish impure limestone	500
At this point a change in the strike of the beds and in the direction of the coast carries the cliffs some distance from the shore. The section is continued on a small creek that enters the bay about half a mile west of the end of the sea cliffs. Along this creek the exposures are not so continuous nor so conspicuous as those in the sea cliffs, but they are sufficient to show the relation of the beds to the general section.	
Dark shales which in places carry more indurated bands of argillaceous sandstone	425
Dark shales and beds of argillaceous sandstone, forming many cascades; *Cadoceras* found near the middle	650
Indurated bands of argillaceous sandstone; abundant specimens of *Cadoceras* and *Belemnites*	10
Dark shales and argillaceous sandstones	115

[18] Stanton, T. W., and Martin, G. C., Mesozoic section of Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, p. 400, 1905.

	Feet
Similar beds not well exposed	200
Dark shales which in weathering form brownish slopes with bands of small concretions containing *Cadoceras doroschini* and other fossils	75
Dark clay shales, weathering brownish, with concretions containing *Cadoceras* and other fossils near middle	110
	2, 085

The sections on the east shore of Iniskin Bay and Oil Bay are also given as measured by Stanton and Martin, for although they were revisited they were not remeasured. The section on the shore of Iniskin Bay begins at the fault contact of the Tuxedni sandstone and Chinitna shale, about 1,000 feet south of the trail to Oil Bay, and extends southwestward 7,000 feet to the outcrop of the Chisik conglomerate, including 1,308 feet of beds as shown in the first section below. The base of the shale is therefore not represented in the measured section.

Section of Chinitna shale on east shore of Iniskin Bay

	Feet
Dark-drab shale containing numerous bands of limestone concretions filled with well-preserved specimens of *Cadoceras, Belemnites,* and other fossils, and also a few sticks of fossilized wood	146
Shale as above, partly concealed by talus at "Mushroom Rocks"; thickness computed	77
Dark shales, as above, containing same concretions and wood	196
Limestone	1
Shales, as above	363
Shales, partly concealed by talus; thickness computed	300
Shales, as above, containing *Cadoceras doroschini* and a few other fossils	200
Concealed	25
	1, 308

The section on Oil Bay is as follows:

Section of upper part of Chinitna shale on east of Oil Bay

	Feet
Dark shale with concretions	690
Hard dark sandstone	½–¾
Dark-drab shale with numerous concretions	530
Calcareous shale with *Cadoceras schmidti* Pompeckj, *Cadoceras* sp. cf. *C. stenoloboide* Pompeckj, and *Phylloceras*	1
Dark shale with *Cadoceras doroschini* and other fossils	60
Soft green sandstone	½
Dark-drab shale	12
	1, 294

This section also begins at a point somewhere above the base of the shale, for the top of the Tuxedni sandstone is not exposed at this locality.

Thickness and structure.—The thickness of the Chinitna shale in its type locality as measured by Stanton (see p. 24) is 2,085 feet, and that of the partial sections on Iniskin and Oil Bays is 1,308 and 1,294 feet, respectively. The base of the shale is not included in sections on Iniskin and Oil Bays, yet the thickness represented by them is nearer the thickness of some other sections between Iniskin and Chinitna Bays than that of the type section. A section at the head of Bowser Creek gives 1,400 feet as the thickness of the Chinitna shale. So far as is known this thickness is not made questionable by folding and faulting, although faults might be difficult to detect. Such a thickness would contrast strongly with that of the type section. Especially does it contrast with the Shelikof formation on the Alaska Peninsula, which reaches a maximum thickness of 7,000 feet and carries the Chinitna fauna, although it has not been correlated with the Chinitna shale.

The Chinitna shale nearly everywhere has a seaward dip, although at one locality a small fold with reverse dips was seen. In general, then, the formation has a monoclinal structure, with dips that range from 15° to a maximum of 35° (pl. 6, *B*) and strikes that approximate the trend of the coast line.

Age and correlation.—The Chinitna shale was at first included by Martin in the "Enochkin formation" and regarded as of Middle Jurassic age. Later studies, however, led to its separation from the "Enochkin formation" and assignment to the Upper Jurassic.

This formation is less fossiliferous than the Tuxedni sandstone but yields numerous fossils at some horizons in its lower part, especially certain ammonites, among which several species of *Cadoceras* are prominent. These forms were regarded as diagnostic in mapping the formation boundary. A list of marine invertebrate fossils from the Iniskin-Chinitna Peninsula, identified by T. W. Stanton, follows:

10978. F 1. South side entrance to Chinitna Bay; 700 feet west of point 2½ miles east of Camp Point:

Cadoceras stenoloboide Pompeckj?

Chinitna shale.

10982. F 4a. Head of Bowser Creek, south side of valley at elevation of about 1,000 feet above sea:

Cadoceras doroschini (Eichwald).

Cadoceras? sp. Globose form with very narrow umbilicus.

Chinitna shale.

10986. F 8. Tributary to Bowser Creek from south, next below head branch of stream; three-fourths mile below forks of stream at locality 507:

Cadoceras sp.

Chinitna shale.

10989. F 11. East shore of Iniskin Bay, south of trail to Oil Bay:
Trigonia sp.
Cadoceras doroschini Eichwald.
Chinitna shale.

10990. East shore of Iniskin Bay, 1 mile south of trail to Oil Bay:
Cadoceras stenoloboide Pompeckj.
Chinitna shale.

10991. East shore of Iniskin Bay, 1 mile south of trail to Oil Bay. Float:
Harpoceras? sp.
Cosmoceras? sp.
Probably Chinitna shale.

10992. F 14. East shore of Iniskin Bay, 1 mile south of Trail to Oil Bay:
Kepplerites? sp. Very closely related and possibly identical with Ammonites loganianus Whiteaves.
Chinitna shale.

10994. AB F 1. South shore of Chinitna Bay, in upper member of Chinitna shale:
Lucina? sp.
Fossil not distinctive.

10996. AB F 3. South shore of Chinitna Bay, in upper member of Chinitna shale:
Inoceramus sp.
Pleuromya sp.
Fossils not distinctive.

10997. AB F 4. South shore of Chinitna Bay, in top member of Chinitna shale:
Phylloceras sp.
Claw of a crustacean.
Fossils not distinctive.

11003. AB F 10. South shore of Chinitna Bay, in top member of Chinitna shale:
Cadoceras doroschini (Eichwald)?
Chinitna shale.

11004. AB F 12. South shore of Chinitna Bay, in talus probably from beds near top of Chinitna shale:
Pecten sp. Smooth form.
Fossils not distinctive.

11007. AB F 15. South shore of Chinitna Bay, in talus, probably from beds near top of Chinitna shale:
Rhynchonella sp.
Astarte sp.
Tellina? sp.
Fossils not distinctive.

11008. AB F 16. South shore of Chinitna Bay in upper part of Chinitna shale:
Grammatodon sp.
Fossils not distinctive.

11010. AB F 18. South shore of Chinitna Bay, in upper middle part of Chinitna shale:
Fragmentary imprint of an undetermined gastropod with possibly incrusting bryozoans.

11011. AB F 19. South shore of Chinitna Bay, in upper part of Chinitna shale:
Phylloceras? sp.
Fossil not distinctive.

11012. AB F 20. South shore of Chinitna Bay, from upper part of Chinitna shale:

Grammatodon sp.
Leda? sp.
Small venerid?
Thracia sp.
Burrows of a pelecypod?
Fossils not distinctive.

11049. AB F 58. On tributary to Bowser Creek from south, 8,080 feet up creek from trail crossing:

Cadoceras doroschini (Eichwald).
Macrocephalites sp.
Chinitna shale.

11050. AB F 59 and 60. 8,400 feet up creek leading to peak east of C Y peak:

Cadoceras doroschini (Eichwald).
Phylloceras sp.
Chinitna shale.

11052. AB F 63. About 9,000 feet up creek:

Cadoceras doroschini (Eichwald).
Chinitna shale.

11052a. AB F 68. East shore of Oil Bay at northeast corner:

Cadoceras stenoloboide (Pompeckj)?
Chinitna shale.

11053. AB F 64. A short distance above assumed Tuxedni-Chinitna contact along above-mentioned creek:

Thracia? sp.
Oppelia? sp.
Chinitna shale. The ammonite suggests the Tuxedni fauna rather than the Chinitna.

11054. AB F 65. About 600 feet down west shore of Oil Bay from Bowser Creek:

Pecten sp.
Pteria sp.
Grammatodon sp.
Amberleya sp.
Belemnites sp.
Fossils not distinctive.

11060. AB F 76. Just below contact of Chinitna with Chisik beds on east shore of Iniskin Bay, 8,200 feet down shore from trail to Oil Bay, about 750 feet below Toadstool Islands:

Pleuromya sp.
Thracia sp.
Cadoceras grewingki Pompeckj?
Chinitna shale.

The following lists show the invertebrate and plant fossils collected by Stanton and Martin on Chinitna, Iniskin, and Oil Bays and include a number of species not mentioned in the foregoing list. The plant forms were identified by F. H. Knowlton.

3018. Chinitna Bay. Upper part of *Cadoceras* zone:

Cadoceras sp.; compressed ribbed form.
Cadoceras doroschini Eichwald?
Belemnites.

3019. Chinitna Bay. Several hundred feet lower than 3018:
Cadoceras doroschini Eichwald.
Cadoceras sp.; less convex form.
Cadoceras ? ?; smooth close-coiled form; umbilicus nearly closed

3020. Chinitna Bay. Lower than 3019:
Cadoceras doroschini Eichwald ?
Oxynoticeras ?; smooth sharp centered form.
Belemnites; very large phragmacone.

3021. Chinitna Bay at west end of cliffs north of camp:
Pleuromya.
Goniomya.
Avicula.
Undetermined gastropods; very small.

3028. Enochkin Bay. One-fourth of a mile below lower cabin, *Cadoceras* zone:
Cadoceras doroschini (Eichwald).
Cadoceras sp.
Cadoceras sp.
Cadoceras ?
Sphaeroceras.
Phylloceras.
Oxynoticeras ?
Cerithium.
Grammatodon.
Avicula.
Pecten and other forms.

3029. Enochkin Bay 1 mile below lower cabin. *Cadoceras* zone
Cadoceras doroschini (Eichwald).
Cadoceras sp.
Cadoceras sp.
Sphaeroceras.
Phylloceras.
Oxynoticeras?
Belemnites.
Grammatodon.
Pecten.
Thracia.
Goniomya.
Pholadomya.
Astarte.
Modiola?

3030. Enochkin Bay 1¼ miles below lower cabin:
Cadoceras doroschini (Eichwald)?
Cadoceras sp.
Belemnites; very large phragmacone.

3041. Oil Bay above *Cadoceras* zone. Near large waterfall:
Cardioceras sp.; not in place.
Phylloceras sp.
Pecten.
Turbo.

3042. Oil Bay. Lower 50 feet of section. *Cadoceras* zone.
Cadoceras doroschini Eichwald.
Cadoceras sp.
Belemnites.
Pleuromya, two species.
Pecten and other forms.

No. 2921. East shore of Iniskin Bay:
- Cadoceras doroschini (Eichwald). Abundant.
- Cadoceras wosnessenskii (Grewingk).
- Cadoceras schmidti Pompeckj.
- Cadoceras catostoma Pompeckj?
- Cadoceras sp.
- Macrocephalites? sp.
- Phylloceras subobtusiforme Pompeckj?
- Stephanoceras sp. Form figured by Eichwald as Amm. astierianus D'Orbigny aff.
- Belemnites sp. a. One specimen.
- Goniomya sp. One small specimen.
- Lima sp.
- Pecten sp. Small smooth form.
- Pleuromya? sp. One specimen.
- Serpula? sp. Small discoidal form abundant in one rock fragment.
- Several undetermined bivalves represented by imperfect material.

No. 2941. East shore of Oil Bay, 72½ feet above base of section:
- Cadoceras schmidti Pompeckj.
- Cadoceras sp. cf. C. stenoloboide Pompeckj.
- Phylloceras sp.

No. 929. Iniskin Bay, east shore, half a mile below lower cabin:
- Cladophlebis denticulata (Brongniart) Nathorst.
- Ctenis grandifolia Fontaine.
- Hausmannia sp.? Mere fragment.
- Dictyophyllum cf. D. obtusilobum.

No. 929a. Iniskin Bay, east shore, 1 mile below cabin:
- Fossil wood, not studied.

The type section of the Chinitna shale is the section measured by Stanton on the north shore of Chinitna Bay. (See p. 24.) The shale, like the overlying Upper Jurassic beds, extends northward to Chisik Island in Tuxedni Bay (see p. 66) but is not known to be present farther north on the west shore of Cook Inlet.

Paige and Knopf[19] found a series of concretionary sandy shale and sandstone beds, together with some conglomerate at the head of Little Nelchina River, north of the headwaters of Matanuska River, from which they collected the *Cadoceras* fauna, at that time regarded as indicative of the upper third of the "Enochkin formation" but now included in the Chinitna shale.

The greatest known thickness of sediments containing the Chinitna fauna is on the Alaska Peninsula near Wide Bay. This section was studied by Capps,[20] and the beds were given the name Shelikof formation. The section includes a thick series of sandstone, together with some conglomerate, sandy shale, and calcareous shale, all overlain by black shale containing limestone lenses near its top. These

[19] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 20–23, 1907.

[20] Capps, S. R., The Cold Bay oil district, Alaska: U. S. Geol. Survey Bull. 739, p. 97, 1922.

sediments, prevailingly sandstone, reach a maximum thickness of 7,000 feet and have a wide distribution.

NAKNEK FORMATION

Character and subdivisions.—The Naknek formation, like the Tuxedni sandstone, includes a heterogeneous mixture of shale, sandstone, arkose, andesitic tuff, and conglomerate, and in the region between Chinitna Bay and Oil Bay it may be separated into a lower and an upper part with distinctive lithology and decidedly conspicuous differences as expressed in topography and the landscape. These two divisions continue westward from Oil Bay to Iniskin Bay, but about midway between these two bays a coarse massive conglomerate 290 feet thick, which is here mapped as Chisik conglomerate member, occurs beneath the lower division and extends westward to Iniskin Bay. As the Chisik appears to be equivalent to the basal arkosic beds of the Naknek formation of the vicinity of Chinitna and Oil Bays, it is here treated as a member of the Naknek.

In the area between Chinitna and Iniskin Bays the lower part of the formation, or the beds mapped as "shale and arkosic sandstone" and ranging from about 1,500 to 1,645 feet in thickness, consists predominantly of gray shales that have dark arkosic beds and fine conglomerate or grit at the base and thin sandstones and sandy beds scattered through them. The sediments overlying these beds are white or light-gray sandstones that contain an abundance of igneous material—in part tuff, in part clastic material derived largely from granite or granitelike rocks, and in part intrusive sills. This upper part includes all the remainder of the formation exposed in the district.

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

On the geologic map (pl. 2) the Chisik conglomerate is represented as a narrow band extending only part way between Iniskin and Oil Bays, for the beds immediately overlying the Chinitna shale on both sides of Oil Bay are made up of grit or fine conglomerate and arkosic sandstone and bear no lithologic resemblance to the beds occupying this position on Iniskin Bay. In all other places from Oil Bay to Chinitna Bay where the base of the Naknek formation was examined the beds overlying the Chinitna consist of coarse arkose and fine grit. The Chisik conglomerate of Iniskin Bay therefore appears to be probably a local phase of the basal part of the Naknek, and it is so treated in this report. It is mapped separately because of its distinct lithologic character and its conspicuous outcrops, although a somewhat similar conglomerate of less thickness within the Tuxedni sandstone was not separately mapped. Blocks of the conglomerate have fallen from the cliffs on the east shore of Iniskin Bay and have been worn by the sea waves into the peculiar shapes that have given them the name Mushroom Rocks, a name also applied to certain small islands near the entrance to the bay.

The type locality of the Chisik conglomerate is on Chisik Island in Tuxedni Bay (see p. 67), where the beds resemble lithologically the conglomerate of Iniskin Bay and probably have a slightly greater thickness. The extent of the conglomerate at Tuxedni Bay is also somewhat greater than at Iniskin Bay, although at Tuxedni Bay also it seems to be of local development.

Paige and Knopf[21] report a similar conglomerate at about the same stratigraphic position in the upper Matanuska Valley.

Chapin[22] described a similar conglomerate at the base of his Upper Jurassic section on Nelchina River and correlated it with the Chisik conglomerate. At that time the Chinitna shale was still considered to be the highest of the Middle Jurassic sediments.

In the Cold Bay district, on the Alaska Peninsula, Capps[23] found a massive bouldery conglomerate at the base of the Naknek formation, overlying rocks with the Chinitna shale fauna and ranging in thickness from 70 to 1,000 feet and possibly much more. This conglomerate was originally included in the typical Naknek formation of Spurr and is mapped as Naknek by Capps. Thus the base of the sedimentary formations carrying the Naknek fauna appears to be characterized in the regions of Cook Inlet and the Alaska Peninsula by clastic beds containing much material of igneous origin, in part volcanic, which are nearly everywhere coarser than the immediately underlying beds, and in many places are exceedingly coarse and massive. Furthermore, these beds are not known to lie near a structural unconformity, such as might be expected in view of their wide distribution and the coarseness of the material composing them.

Lithology.—The upper and lower parts of the Naknek formation are so distinct in lithologic character, and especially in their appearance in the landscape as seen in the field, that it has seemed desirable

[21] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 21–23, 1907.

[22] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 35–36, 1919.

[23] Capps, S. R., The Cold Bay oil district: U. S. Geol. Survey Bull. 739, p. 101, 1922.

to distinguish them separately on the geologic map. The separation is made on the basis of lithologic character and not on the evidence of fossils. These rocks are confined to a curving belt ranging from 2 to 4 miles in width, which extends along the whole seaward side of the peninsula from Iniskin Bay to Chinitna Bay.

The basal arkosic beds are made up of material from a land mass where granite or granite rocks supplied an abundance of rock waste for the formation of new sediments and are believed to be the time equivalent of the Chisik conglomerate of Iniskin Bay, for no conglomerate comparable to the Chisik conglomerate of Iniskin Bay was seen elsewhere in the district. The thickness of these coarse-grained basal beds is 147 feet on the east shore of Oil Bay and is approximately the same in other places where the beds were examined. Sandy shale with beds of sandstone succeeds the basal beds and together with them makes up the lower part of the Naknek formation below the light-colored cliff-forming beds. This part of the Naknek reaches a thickness of 1,645 feet in the section measured by Martin at Oil Bay. (See p. 36.)

The remaining upper part of the Naknek formation is conspicuous (pls. 5, *B*, 6, *A*, and 8, *A*) wherever it crops out because of its light color and because it resists erosion better than the underlying beds. It forms the dip slope on the seaward face of the mountains along the coast. Its scarp makes the white cliffs along most of the crest of the mountains, as seen from the landward side. This part of the Naknek formation reaches a thickness of possibly 3,000 feet. The beds are prevailingly hard and massive but in large exposures show distinctly the bedding lines. They include hard arkosic sandstone, andesitic tuff, coarse and fine sandstone, shale, and conglomerate. Thin sills of quartz diorite are intruded into the sedimentary beds and are distinguished from them only on close examination.

The strike of beds of the Naknek formation ranges from about N. 30° E. on Chinitna Bay to nearly east on Iniskin Bay. The dips are everywhere toward the sea and decrease between Chinitna and Iniskin Bays from an average of about 35° on Chinitna Bay (pl. 4, *B*) to about 15° on the Iniskin shore. Local variations of dip are found, as at Mount Chinitna, where the beds are tilted to an angle of nearly 45°, but no such high dips were seen in the Naknek formation farther south.

A better idea of the complexity of the Naknek formation may be had from a study of the detailed sections measured by Martin [24] on

[24] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 69–72, 1912.

the north shore of Chinitna Bay, on the east side of Oil Bay, and on Iniskin Bay. These sections are as follows:

Section of Naknek formation on the north shore of Chinitna Bay, Alaska

	Feet
Coarse conglomerate with granite pebbles 6 inches or less in diameter and smaller pebbles of various lithologic character, in a tuffaceous or arkosic matrix	10
Shaly arkose or sandstone	2
Conglomerate	2½
Arkosic sandstone or andesitic tuff	1½
Conglomerate	½
Massive tuffaceous rock with numerous inclusions	9
Tuffaceous rock with much shale	3
Andesitic flow or tuff	12
Shale	2
Concealed	10
Andesitic flow or tuff	15
Concealed	5
Contorted shale with large *Belemnites* at base	23
Sandstone	½
Shale	½
Andesitic flow or tuff	4½
Contorted shale with concretions	3
Arkose with granite pebbles at top	7
Sandy shale	2
Sandy shale with fossil band at top (*Aucella*-bearing bed)	3
Dark shale	15
Conglomerate with shaly matrix	5
Sandstone	½
Conglomerate	3
Dark shale	4
Conglomerate with much shaly matrix	13
Agglomerate	9
Dark shale	20
Coarse conglomerate	2
Pinkish sandstone with bands of pebbles	2½
Conglomerate	5
Sandstone	¼
Shale	½
Andesitic flow or tuff	2½
Agglomerate	2
Andesitic flow or tuff	7
Sandstone with bands of shale	8
Dark shale	25
Concealed (for 1,350 feet at 20° dip)	462
Andesitic flow or tuff	18
Concealed (for 100 feet at 20° dip)	34
Andesitic flow or tuff	10
Concealed (for 50 feet at 20° dip)	17
Andesitic flow or tuff	5
Concealed (for 130 feet at 20° dip)	44

	Feet
Andesitic flow or tuff	32
Agglomerate	3
Arkose with shaly bands	19
Andesitic flow or tuff with agglomerate at base	55
Andesitic flow or tuff	30
Shale	6
Andesitic flow or tuff	79
Concealed (for 430 feet at 25° dip)	182
Agglomerate	63
Andesitic flow or tuff	185
Shale	1
Andesitic flow or tuff	158
Agglomerate	2
Andesitic tuff with abundant pebbles	60
Shale	4
Concealed (for 60 feet at 24° dip)	24
Sandy shale	68
Sandstone and shale	30
Andesitic flow or tuff	25
Concealed (across cove for 800 feet at 25° dip)	338
Coarse gray sandstone mostly heavy bedded	66
Alternating bands of sandstone and shale	7
Coarse gray sandstone	12
Concealed	10
Coarse gray sandstone	25
Shaly sandstone	4
Coarse gray sandstone	26
Coarse gray sandstone with bands of fine conglomerate	5
Coarse gray sandstone with thinner shaly bands	27
Coarse gray sandstone with bands of fine conglomerate	162
Fault; displacement probably small.	
Coarse gray sandstone with bands of fine conglomerate	50
Dark shaly sandstone	25
Alternating bands of shaly sandstone and fine conglomerate	10
Coarse gray sandstone with bands of fine conglomerate	12
Dark shale	2
Coarse gray sandstone with fine conglomerate	21
Dark shale with *Belemnites*	40
Coarse gray sandstone	25
Dark shales with thinner bands of coarse gray sandstone	100
Massive coarse gray sandstone	60
Coarse gray sandstone alternating with more shaly layers	125
Covered, except two or three small outcrops of shaly sandstone	425
Dark shale with *Belemnites*	160
Cross-bedded coarse sandstone	30
Dark shales and shaly sandstones with *Aucella* and other fossils	290
Alternating bands of coarse gray and argillaceous fossiliferous sandstones	100
Coarse gray sandstone	20

	Feet
Thin-bedded argillaceous sandstone in irregularly alternating lighter and darker bands	338
Coarse gray sandstone	30
Banded argillaceous sandstone with *Belemnites*	300
Coarse gray sandstone with *Belemnites*	40
Banded argillaceous sandstone	56
Coarse gray sandstone and fine conglomerate	35
Banded argillaceous sandstone with several fossiliferous beds, and a few thin bands of fine conglomerate	156
Somewhat massive dark-gray argillaceous sandstone with a few thin yellowish bands	150
	5, 139

Concerning this section Martin says that the great thickness may possibly be due to repetition of beds by faulting but that no repetitions were detected. The exposures of the Naknek formation between Chinitna and Dry Bays confirm the measurement on the north shore of Chinitna Bay and indicate that it is not necessarily too great.

Section of Naknek formation on east shore of Oil Bay

	Feet
1. Arkose, andesite, sandstone, conglomerate, and shale	2, 000±
2. Sandy shale with *Aucella* near base	600
3. Shale with fossils	380
4. Coarse sandstone	3
5. Shale with *Cardioceras*, *Astarte*, and other fossils	165
6. Concealed	40
7. Sandstone and sandy shale with *Lytoceras*, *Phylloceras*, and plant impressions	310
8. Conglomerate with an abundance of small pebbles one-twelfth to one-twenty-fifth inch in length, and with numerous poorly preserved impressions of plants	7
9. Sandy shale and sandstone	85
10. Conglomerate with pebbles as above	3
11. Shale	1
12. Fine conglomerate of same pebbles as above	7
13. Fine conglomerate of same pebbles as above, but interbedded with shale	14
14. Olive shale with an abundance of small pebbles, and with indeterminate fragments of a crustacean 5 feet above the base	30

The beds numbered 8 to 14 are probably the local representatives of the Chisik conglomerate member. This part of the section includes the beds that Martin considered to be the local representative of the Chisik conglomerate. Beds of this kind are present on the south shore of Chinitna Bay and elsewhere on the peninsula and are regarded as marking the base of the Naknek formation. As already pointed out (p. 33), because of their lithologic differences they were not designated on the geologic map (pl. 2) as Chisik conglomerate, although they are considered to be the time equivalent of it.

Section of lower part of Naknek formation on east shore of Iniskin Bay, Alaska

	Feet
Sandstone, arkose, shale, andesite flows, and conglomerate	270+
Dark sandy shale with *Aucella* in upper part	583

Martin makes the following statement concerning the beds of volcanic material associated with the other beds of the Naknek formation:

The beds described as andesite or as andesitic tuff in the above sections are composed of fragmental material. The microscope reveals fragments and crystals of plagioclase (some of which were determined to be basic), hornblende, biotite, and quartz and also some bits of fine-grained igneous rocks. All of these are predominantly angular in outline, but a few are rounded. The matrix in some specimens is distinctly fragmental; in others it is so fine and iron stained as to be obscure but is probably also fragmental and composed of the same materials as the other specimens. In one specimen, slightly coarser than the rest, the larger grains are well rounded. The clastic, angular, character of the grains of the rocks and their composition leaves no doubt that they are tuffs derived from andesitic lavas. The fragments of rock are too fine grained and too much weathered to be determined but seem to be basic.

Intruded igneous rocks.—In addition to the bedded rocks, made up in part at least of the fragmental volcanic material just mentioned, the Naknek formation is intruded by light-colored granite sills and basaltic dikes. Lack of time prevented a thorough examination of the upper part of the formation, so that other igneous rocks than those mentioned may be present without having been noted.

Several sills were seen near the base of the upper part of the Naknek formation on the east side of Oil Bay. Two sills of quartz diorite, one 10 inches thick and the other 2 feet thick, are intruded between beds of sandstone just below the base of the white beds. The rock is light gray and fine grained but still sufficiently coarse for biotite, hornblende, quartz, and feldspar to be distinguishable with the unaided eye. So far as observed the sills are structurally conformable with the sandstone beds and resemble the arkosic sandstones that are associated with them and that occur also in the lower part of the Naknek, so that only by close examination is their presence detected.

Thin sections under the microscope show labradorite feldspar, biotite, hornblende, quartz, apatite, magnetite, and chlorite. The groundmass consists essentially of feldspar and hornblende.

A second sill is present a short distance stratigraphically below the sill just described. It also is composed of light-gray quartz diorite which is rather coarse grained and shows feldspar, quartz, and

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pyroxene. The sill is intruded as a thin sheet into beds of sandstone and sandy shale and is structurally conformable with them. Thin sections under the microscope show andesine, augite, hornblende, quartz, abundant magnetite, a small quantity of apatite, secondary chlorite, and iron stains. Phenocrysts of feldspar (andesine), augite, hornblende, and quartz appear in a granular groundmass. The rock shows little alteration, although some chlorite has developed from the hornblende and augite, and iron stains are present.

Martin reports that two basaltic dikes cut the Naknek formation on the shore of Cook Inlet between Dry and Oil Bays. No other dikes of this kind were noted in the Naknek formation.

Age and correlation.—Fossils are less numerous in the sedimentary beds of the Naknek formation than in the underlying Chinitna shale and the Tuxedni sandstone. The basal Chisik conglomerate member has furnished no fossils, but fossils are abundant at certain horizons in the Naknek and yield conclusive evidence that the formation is of Upper Jurassic age. More than 20 species as identified by T. W. Stanton are contained in the following list:

10988. F 10. West side of Oil Bay, about half a mile from head:
Arctica? sp.
Cardioceras martini Reeside.
Lower part of Naknek formation.

10995a. AB F 2. South shore of Chinitna Bay in the lower part of the Naknek formation about 200 feet above assumed base:
Thracia? sp.
Several small undetermined pelecypods and gastropods.
Phylloceras sp.
Presumably Naknek, but fossils not distinctive.

11001a. AB F 9. South Shore of Chinitna Bay, in talus, probably from lower part of Naknek formation:
Goniomya sp.
Phylloceras? sp. Young shell.
Fossils not distinctive.

11002. AB F 11. South shore of Chinitna Bay, in talus, probably from lower part of Naknek formation:
Cardioceras martini Reeside.
Cardioceras lillooetense Reeside.
Lower part of Naknek formation.

11006a. AB F 14. South shore of Chinitna Bay, in talus, probably from lower part of Naknek formation:
Arctica? sp.
Pleuromya sp.
Goniomya sp.
Fossils not distinctive.

11013. AB F 21. South shore of Chinitna Bay:
Fragmentary plants.
Cardioceras distans (Whitfield).
Lower part of Naknek formation.

11015. AB F 22. South shore of Chinitna Bay:
Cardioceras alaskense Reeside.
Cardioceras hyatti Reeside.
Lower part of Naknek formation.
11016. AB F 23. South shore of Chinitna Bay:
Pecten? sp.
Pteria sp.
Grammatodon sp.
Thracia? sp.
Pleuromya sp.
Cardioceras hyatti Reeside.
Lower part of Naknek formation.
11017. AB F 24. South shore of Chinitna Bay:
Pecten? sp.
Pteria sp.
Inoceramus sp.
Astarte sp.
Pleuromya sp.
Corbula? sp.
Phylloceras, two species.
Cardioceras martini Reeside.
Cardioceras aff. C. distans (Whitfield).
Cardioceras lillooetense Reeside.
Lower part of Naknek formation.
11018. AB F 25. South shore of Chinitna Bay:
Pteria sp.
Phylloceras sp. Large shell.
Lower part of Naknek formation.
11050a. AB F 61. From talus below contact of Chinitna and Naknek formations; 8,400 feet up creek leading to peak east of C Y peak:
Cardioceras n. sp.
Lower part of Naknek formation.
11055. AB F 66 and 67. Near contact of Chinitna shale and Chisik conglomerate member at second point down Oil Bay from gravel pit near Bowser Creek:
Plant fragments.
Pinna sp.
Arctica? sp.
Pleuromya sp.
Thracia sp.
Phylloceras sp.
Cardioceras martini Reeside.
Lower part of Naknek formation.
11056. AB F 69. Naknek formation. East coast of Oil Bay N. 61° E. of Mount Pomeroy:
Phylloceras sp.
Cardioceras aff. C. distans (Whitfield).
Lower part of Naknek formation.

These collections, as well as those of Stanton and Martin from the vicinity of Chinitna and Iniskin Bays given below, were made from beds in the lower part of the Naknek formation below the massive cliff-forming beds. No fossils were collected from the upper member of the formation on this peninsula. All the forms of *Car-*

dioceras in the list are therefore from the lower part of the Naknek, where, although not abundant, they are common enough to be of great assistance in drawing the formation boundary. Two other species, *Aucella pallasi* and *Aucella bronni*, or forms closely related to them, are characteristic of the Naknek formation but do not appear in the list just given, possibly because less time was given to collecting from the upper beds of the Naknek formation than from the formations below the Naknek.

One collection of fossil plants, made from beds on Iniskin Bay, assigned to the Naknek formation in the field, was determined by Knowlton as follows:

7525. Naknek formation. About 6,060 feet south along east shore of Iniskin Bay from end of trail at lower cabin:

A small fragment of *Nilsonia* like *N. orientalis* Heer, but too small to be certain.

The collections of invertebrate fossils from the Naknek formation, made by Stanton and Martin during their investigations, contain some additional forms and are therefore given:

3022. North shore of Chinitna Bay, one-fourth mile west of mouth of East Glacier Creek:

Belemnites.
Aucella cf. A. erringtoni.
Avicula.
Pecten and other forms.

3023. Chinitna Bay, 25 feet above base of No. 34 of section:

Phylloceras.
Belemnites.
Pleuromya.
Cyprina?
Astarte.
Pecten.
Pinna.
Eumicrotes?

3024. Chinitna Bay, 30 feet above base of No. 34 of section:

Phylloceras.
Pleuromya.
Corbula?
Avicula.
Undetermined gastropods, very small.

3025. Chinitna Bay, No. 26 of section:

Pecten.
Avicula.
Arca and other forms.

3026. Chinitna Bay, No. 25 of section:

Phylloceras.
Belemnites.
Aucella.

3048. Chinitna Bay near head of small creek above *Cadoceras* zone:

Astarte, large sp.

3031. Enochkin Bay, on east shore of Iniskin Bay; first cove on east shore near entrance to bay:
 Aucella cf. A. erringtoni.
 Belemnites.
3043. East shore of Oil Bay; 15 feet above base of No. 11 of section:
 Lytoceras, fragments of large species.
 Belemnites.
 Pleuromya.
 Goniomya.
3044. Oil Bay, 170 feet above base of No. 11; not in place:
 Cardioceras sp.; fine sculpture, cf. C. altemus, C. cordiforme, C. dubium Hyatt, and C. whitneyi Smith.
 Thracia sp.; short form.
3045. Oil Bay, 80 feet above base of No. 13 of section:
 Cardioceras sp.; coarse sculpture.
 Phylloceras.
 Avicula.
 Astarte.
3046. Oil Bay, 150 feet above base of No. 13 of section:
 Cordioceras; coarse sculpture: same as 9342.
 Pleuromya.
3047. Oil Bay, 700 feet above base of No. 13 of section:
 Lytoceras: not collected.
 Pleuromya.
 Aucella.

The type locality of the Naknek formation is the vicinity of Naknek Lake on the Alaska Peninsula. The beds were first described by Spurr,[25] who says of them:

> The Naknek series consists of a great thickness of granite arkoses and conglomerates, which generally contain pebbles of granite. All these sedimentary rocks are evidently derived from the destruction of a land mass which consisted largely of hornblende-biotite granite. There are probably some volcanic flows interstratified with the arkoses and conglomerates, although it is not absolutely proved that those examined may not be intrusive.

These rocks throughout the series contain abundant fossils and in all but one of Spurr's localities yielded a species of *Aucella.*

Beds belonging to the Naknek formation extend northeast of Naknek Lake and are widely distributed in the valleys of Savanoski and Kamishak Rivers, where they were studied by Mather.[26]

In the Cold Bay district the Naknek formation consists of conglomerate, arkosic sandstone, and sandy shale as described by Capps.[27] This section includes a basal conglomerate which ranges in thickness from 70 to 1,000 feet and which is believed to be the equivalent of the Chisik conglomerate member. The whole succession of Naknek beds is more than 5,000 feet thick.

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[25] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 170, 1900.

[26] Mather, K. F., Mineral resources of the Kamishak Bay region: U. S. Geol. Survey Bull. 773, pp. 169–171, 1925.

[27] Capps, S. R., The Cold Bay district, Alaska: U. S. Geol. Survey Bull. 739, p. 101, 1922.

Upper Jurassic rocks that carry the fauna of the Naknek formation occur in Matanuska and Nelchina Valleys, in Chitina Valley, between Nabesna and White Rivers on the east side of the Wrangell Mountains, on the Arctic coast, and in southeastern Alaska. The *Cardioceras* fauna in the lower part of the Naknek formation of the Iniskin-Chinitna Peninsula, however, is known from only two of the districts where Upper Jurassic faunas have been collected—that is, from the Cold Bay district and the Upper Matanuska and Nelchina Valleys. The localities and lithologic character of the Upper Jurassic formations are given in the correlation table opposite page 22.

QUATERNARY DEPOSITS

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

Coastal gravel and sand form a narrow band, limited by high tide, along the outer shores of the peninsula but are somewhat better developed within the bays, where they are protected from the strong currents of the inlet. The marshy flats on the south side and around the head of Chinitna Bay (pl. 10, *B*) are in part built up of marine shore gravel intermingled with gravel and sand contributed directly by streams and with accumulations of vegetable matter. The flats around Camp Point are of this nature, as are probably also the lowlands at the heads of Oil and Dry Bays. Without doubt the sea at no distant geologic time extended much farther into valleys like that of Bowser Creek, possibly cutting off the mountains between Oil and Iniskin Bays from the rest of the peninsula and leaving marine deposits on the valley floors on its retreat. Deposits of this kind, however, would be subject to more or less redistribution by streams and possibly by glaciers and may no longer remain. No gravel of marine origin was recognized except along the shore line.

The deposits of stream and bench gravel are here considered together because the only bench gravel seen is but a few feet above the level of the near-by streams and was quite evidently laid down by the streams. Deposits of gravel and sand are less common in this area than in much of interior Alaska and are restricted to the flood plains of the streams and to the adjacent valley floors. The deposits are mostly of local origin but contain erratic boulders, which were doubtless brought to their present resting places by ice moving from the high mountains west of this area. Owing to the rapid weathering of the shale that occupies a large part of the peninsula within the bounding zone of the sandstone at the top of the Naknek formation, the stream and bench gravel contains much argillaceous material and packs down so as to make compact deposits that furnish firm footing for horses, except where they are poorly drained, like the grass-covered flats at the head of Chinitna Bay. Quicksands were not found in any of the streams traversed during the summer. So far as known, the stream gravel nowhere contains gold or other valuable minerals. The readiness with which the shale and sandstone disintegrate and the ease with which the resulting loose material is carried away by the streams are probably the principal reasons for the lack of conspicuous gravel deposits in the district.

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

STRUCTURE

The structure of the sedimentary beds of the peninsula has been indicated in the descriptions of the different formations, but a summary of the features will be given in order to present this part of the geology in a more convenient form.

Almost 14,000 feet of Middle and Upper Jurassic sediments were deposited to form the total thickness of beds represented in the stratigraphic section. Presumably all these beds were laid down in a practically horizontal position, but their original attitude was altered by forces that produced in them a succession of folds which are more closely compressed on the landward side of the peninsula than on the side toward Cook Inlet. Two principal anticlinal folds resulted from the deformation and trend about N. 30° E., parallel to the trend of Cook Inlet. These folds are shown on Plate 2. The axis of the smaller fold lies along the east side of the Portage Creek Valley but is cut off midway between Right Arm and Chinitna Bay by a great fault, which extends for many miles along the west coast of the inlet and separates the Tuxedni sandstone of this district from the Lower Jurassic (?) volcanic rocks north of Iniskin Bay and west of Portage Creek. The axis of the main anticline of the peninsula extends from a point between Oil and Iniskin Bays along the west side of the Bowser Creek Valley and through the Fitz Creek Valley, but before reaching Chinitna Bay, it divides into two minor anticlinal folds, as shown on the geologic map. Chinitna Bay interrupts the sedimentary beds north of the peninsula and conceals their structure, but the beds appear again on the north shore of the bay near its mouth in such a way as to suggest that within the area of the bay the folds pitch gently northeastward. Between Oil and Iniskin

Bays the main anticline is less compressed than in the Fitz Creek Valley and flattens out into a broad, flat arch. This flattening of the anticline is well shown along the east shore of Iniskin Bay northward from the wagon road, for although the exposures are continuous for several miles only a slight thickness of the Tuxedni sandstone is exposed. The structure in this vicinity, however, is complicated by an eastward-trending fault, transverse to the axis of the anticline, whose exact location is known only where it appears on the shore of Iniskin Bay and whose displacement is of such magnitude that beds believed to belong below the middle of the Tuxedni sandstone, as shown by their lithology and the stratigraphic section a few miles to the north, are brought into contact with the Chinitna shale, thus cutting out possibly 3,000 feet or more of upper Tuxedni sandsone.beds. The synclinal axis between the two principal anticlines is remarkably straight and in the vicinity of Right Arm is less than half a mile from the Portage Creek anticline.

East of Bowser and Fitz Creeks the Tuxedni sandstone and the overlying Chinitna shale and Naknek formation, including the Chisik conglomerate member, dip away from the peninsula toward Cook Inlet. The strike of the beds changes from east-northeast at the mouth of Chinitna Bay to nearly east at Iniskin Bay, and the dip diminishes from a maximum of 45° north of Mount Chinitna to about 15° at the entrance to Iniskin Bay. Minor folds are probably present on the east limb of the main anticline in the area between Bowser and Park Creeks. This area was not examined carefully, for time was lacking, but one small fold was seen in the lower part of the Chinitna shale on the larger headwater branch of Bowser Creek, and the presence of other minor folds is suspected. The fold mentioned is a small anticline crossed by the creek and exposed along the west bank to its full extent within a distance of not over 300 feet. The folding was accompanied by faulting, which caused much disturbance in the shale and concretionary sandy shale of the locality. No evidence of the fold was recognized on the adjacent streams in the direction of the strike.

Reference has been made to the fault between the Tuxedni sandstone and the volcanic rocks west of Portage Creek and to the eastward-trending fault between Oil and Iniskin Bays. The fault between the Tuxedni sandstone and the Lower Jurassic (?) volcanic rocks extends through the valley of Portage Creek and throughout most of its length is concealed by vegetation and unconsolidated material on the valley floor, so that direct observation is rarely possible. In some places it is evidently formed by a succession of parallel, vertical faults. Locally it has produced great disturbance of the beds, as is particularly well shown in the small hill projecting into Iniskin Bay south of the entrance to Right Arm, where the sandstone beds are broken into blocks and shaken up so as to destroy all evidence of the original structure.

The exact trend of the fault between Oil and Iniskin Bays is not known. Possibly it swings to the northeast and connects with the fault indicated on the map as extending parallel to Bowser Creek on the east side of the valley. This fault was not observed in the field, but its presence is inferred from evidence furnished by the stratigraphic sections, for there appears to be too little room below the Chinitna shale in this vicinity to provide space for all the upper beds of the Tuxedni sandstone. This fault may be of much greater extent than is indicated on the map.

Many small faults were observed during the field work. Some of them suggest considerable disturbance of the adjacent rocks and are shown on the map where the data are available, but undoubtedly many others were not detected.

The beds traversed by some of the faults are conspicuously jointed. Two prominent vertical faults that strike N. 20° W. on the west shore of Oil Bay are accompanied by closely spaced parallel joints. Similar jointing is seen on the east shore also, and in exposures of Tuxedni sandstone along Bowser Creek 1½ miles north of Oil Bay it is conspicuous because of the unusual regularity of the spacing and the presence of horizontal joints, which together with the vertical joints give the outcrop the appearance of masonry. The position and form of Oil Bay are doubtless directly due to this combination of faults and joint planes, for the close fracturing of the rocks would make them particularly susceptible to attack by the sea and to the action of streams and the weather. A similar cause is suggested for the formation of Dry Bay and lower Brown Creek Valley.

GEOLOGIC HISTORY

The earliest events in the geologic history of the area between Iniskin and Chinitna Bays that may be learned from the rocks exposed there go back no further than Middle or Lower Jurassic time and are revealed by the volcanic rocks that compose the mountains west of Portage Creek. These mountains form the eastern front of the Chigmit Range and lie in a belt of volcanic beds, including both tuffs and flows, which extends for many miles along the west side of Cook Inlet. Amygdaloidal basalt and volcanic agglomerate are among the more characteristic rocks of this series.[28]

On the west and north shores of Iniskin Bay basalt, gabbro, and tuff are present, and at the head of Chinitna Bay olivine basalt and tuff are included among the volcanic rocks. According to Martin

[28] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, p. 51, 1912.

and Katz the volcanic rocks overlie the Kamishak chert (Upper Triassic) of Kamishak Bay and in the absence of positive evidence for their age were assigned to the Lower Jurassic. The volcanic rocks of Kamishak Bay overlie conformably the thin-bedded chert, black calcareous shale, and impure limestone which compose the Kamishak chert and indicate that the period of marine sedimentation represented by that formation was succeeded by a period of great volcanic activity, which is represented by a wide distribution of volcanic rocks in southern and southwestern Alaska, but which was not known beyond the Alaska Range.

In Middle Jurassic time the sedimentary beds of the Tuxedni sandstone were laid down. The conglomerates and arkoses of the lower part of the Tuxedni sandstone indicate that they were derived from a near-by land mass toward the west. This land mass was probably a region of high relief, where the streams vigorously attacked the granitic rocks of which it must have been in considerable part composed, for the coarse-grained material of the arkose and the pebbles and boulders of the conglomerate in the Tuxedni sandstone consist largely of coarse-grained granitic rocks, although they include also volcanic rocks.

The coarse-grained sediments of the lower Tuxedni beds are succeeded by shale and finer sandstone and a few small limestone beds, which were laid down in quieter waters, probably with less vigorous action of the streams on land or else at greater distance from the shore. Deposition seemingly continued without interruption from Middle Jurassic time into Upper Jurassic time, when the Chinitna shales were formed. The more homogeneous character of these shales suggests quiet waters in which the fine mud accumulated with only subordinate admixtures of sand but with more calcareous material than is found in the Middle Jurassic beds.

The Chisik conglomerate member of the Naknek appears to have been laid upon the Chinitna shale without a structural break in the continuity of beds, but in itself it expresses a variety of conditions of sedimentation that differed widely within short distances. The coarse gravel and boulders of the Chisik conglomerate on Iniskin Bay and at the type locality on Chisik Island indicate deposition near shore. On the shores of Oil Bay and thence northeastward to Chinitna Bay no such conglomerate is present, but in its place—that is, between the Chinitna shale and the shale and sandstone beds at the base of the Naknek formation—there are beds of grit and arkose which seemingly are contemporaneous with the conglomerate. These beds grade into the overlying finer-grained sandstone and shale beds of the Naknek formation.

A change in the kind of material brought to the Upper Jurassic sea was marked by the beginning of the deposition of the massive light-colored sandstone beds that make up the highest part of the Naknek formation in this district. These beds are composed of a considerable amount of tuffaceous material, which indicates that volcanic activity was again resumed after an apparent lapse that continued from the Lower Jurassic well into Upper Jurassic time.

The formation of the light-colored sandstone in the upper part of the Naknek formation completed the Jurassic sedimentation in this peninsula. No evidence of younger consolidated sediments was found, although Tertiary beds are exposed on the north shore of Chinitna Bay at the mouth of East Glacier Creek.

The next great event in the geologic history of the area was the uplift and folding of the Jurassic sedimentary beds, which were raised above the sea and became subject to the processes of weathering. Evidence collected in other parts of Alaska indicates that this uplift began some time after the end of the Jurassic period and continued well into the Cretaceous.

The folding and uplift were not necessarily continuous processes and may not have proceeded simultaneously, but together they mark the beginning of the development of the present topographic form of the area. Erosion of the rising land began the formation of valleys and uplands as they are at present distributed, but was not the sole agent in their formation, for the normal processes of stream erosion and weathering were modified by the advance of glacial ice from the mainland. This ice was of sufficient depth to spill over the ridge between Portage and Fitz Creeks, as is shown by erratic boulders, and probably flowed from Right Arm to Oil Bay, for the highest point of the depression between these bodies of water is only 100 feet above present sea level. Possibly the ice occupied the Brown Creek Valley also, although the form of that valley does not suggest extensive glaciation. The soft, rapidly weathering shales through which Brown Creek flows are, however, not well adapted for preserving the topographic forms carved by the ice.

In its major features the area probably does not now present an appearance greatly different from its appearance when the ice receded, although the evidence of many localities on the coast of Alaska indicates that changes of sea level may have occurred since that time and that these changes were of sufficient amount to have brought the sea well into the lower valleys of the streams at Oil Bay, Dry Bay, and similar places. Glacial streams have contributed and are now contributing great quantities of silt and gravel to the heads of Iniskin and Chinitna Bays, where the material is exposed in wide grass-covered lowlands above high tide or in mud flats at low tide.

MINERAL RESOURCES

PETROLEUM

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

SEEPAGES

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

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

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

A strong flow of gas, bubbling up through water, about 2 miles north of Dry Bay led to drilling at that locality.

Oil claims have been staked recently on the shores of Chinitna Bay, where oil seepages are also reported. Although the south shore of Chinitna Bay was examined rather carefully, no seepages were found there by the surveying parties in 1921. Oil springs might easily be missed, however, unless their location was fairly well known, for the vegetation by midsummer is so rank as to hide them. The known seepages, with the exception of the gas spring at Dry Bay, are within the area of the Tuxedni sandstone, and their presence probably depends on the fact that the rocks where they occur are faulted or conspicuously jointed, thus giving an opportunity for oil and gas to escape to the surface.

EXPLORATION AND DRILLING

Oil Bay and its vicinity was visited by Martin[29] in 1903 and again in 1904, during the time when drilling operations were in progress. Martin's reports on his investigations made at that time are the best available source of information on the development of the district and the character of the oil seepages and are used freely in this report.

Martin states that indications of petroleum were discovered in the Iniskin Bay region in 1853 and that the first samples of petroleum were taken by a Russian named Paveloff in 1882. A man named Edelman staked claims near the heads of Bowser and Brown Creeks in 1892, but these claims were not drilled and apparently no work of any kind was done on them. Pomeroy & Griffen staked claims near the head of Oil Bay in 1896, organized the Alaska Petroleum Co. in 1897, and began preliminary work on the ground in 1898. Drilling is reported to have been in progress in 1900, although Oliphant[30] says that the well at Oil Bay was started in 1902, after unsuccessful attempts had been made in 1899 to land machinery and in 1901 to begin drilling. Work on the first well, half a mile from the bay, near Bowser Creek (pl. 2) was ended in 1903.

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

A second hole was drilled in 1904 near the base of a hill three-tenths of a mile northwest of the first well and nearly 400 feet

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

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

north of the road to Iniskin Bay. When this well had reached a depth of 450 feet it was abandoned because of caving shale. The log of the well, as furnished by Mr. August Bowser, who had charge of the drilling, is as follows:

Record of well No. 2 at Oil Bay

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

A third well was started in the same year almost directly south of the second well and about 150 feet from the road. It was sunk to a depth of 900 feet but was cased for only 630 feet. Caving ground was encountered at 830 feet. At 770 feet three oil sands 6 to 8 inches thick and 4 or 5 feet apart were passed through. According to Mr. Bowser the well produced about 10 barrels of oil a day and had a gas pressure sufficient to blow water into the derrick to a height of 20 feet.

Water now flows from the pipe in this well but in less amount than from the first well. A little gas and oil also came up the pipe with the water, but the quantity is less than that in the natural seepage at the foot of the hill a short distance to the east.

A fourth hole was started on the low hill half a mile north of the cabin at the first hole. The derrick is still standing. No information concerning this hole is at hand. The pipe was plugged, and no evidence of oil, gas, or water was seen when the place was visited in 1921. No drilling was done at Oil Bay after 1906, and in 1909 the claims were abandoned.

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

CHARACTER OF THE OIL

The character of the oil from the principal seepage at Oil Bay is described by Martin,[31] and as the opportunities for collecting sam-

[31] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 53–54, 1921.

ples were better at the time of his visit than they were in 1921, no attempt was made to duplicate his work. The following statement is quoted from his description:

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 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 millimeter pressure, up to 300° C.)	39.2	22.6
Lubricating oils (120-millimeter pressure, 300° 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.

OCCURRENCE OF PETROLEUM

The oil seepages and drill holes showing oil are within the area of the Tuxedni sandstone. So far as is known none of the seepages, except the gas spring at Dry Bay, are within areas of the Chinitna shale or the Naknek formation. It is therefore believed that the source of the oil is within the Tuxedni sandstone or possibly at some lower horizon. Two of the drill holes at Oil Bay are reported to have penetrated oil-bearing sands at depths of 500 and 770 feet and to have shown a considerable quantity of oil. These figures indicate the minimum depth below the top of the Tuxedni sandstone at which the oil-bearing beds can lie, but the evidence from this source is made highly inconclusive by the probable existence of an eastward-trending fault of considerable vertical displacement between the drill holes and the mountains on the south. This fault is exposed on the shore of Iniskin Bay, and if it extended eastward to Bowser Creek it would increase rather than decrease the estimate just given. It appears probable, although it is not definitely proved, that many hundred feet of the sandy shale that forms the upper part of the Tuxedni sandstone is missing between Oil and Iniskin Bays and that the oil seepages and the oil from the drill holes may well come from a horizon as low as the middle of the Tuxedni if not lower.

The oil seepages in the Cold Bay district, on the Alaska Peninsula, issue from two formations. In the vicinity of Cold Bay they come from the Shelikof formation,[32] which contains beds equivalent in time to at least part of the Chinitna shale, for they carry the *Cadoceras* fauna. The seepages on the Pearl Creek dome, west of the south end of Becharof Lake, come from beds of the Naknek formation, which caps the dome. The oil, however, may originate in the Shelikof formation, below the Naknek, and thus come from practically the same horizon as that in the seepages near Cold Bay.

[32] Capps, S. R., The Cold Bay district, Alaska: U. S. Geol. Survey Bull. 739, p. 110, 1922.

The relation of the oil seepages and wells to the geologic structure of the formation in which they occur must be considered in predicting the location of a possible oil pool. The seepage on Iniskin Bay is near a fault, and the principal seepage at Oil Bay is in a zone of jointing and faulting. The position of the east and west shores of Oil Bay was determined by a system of vertical faults and closely spaced joints, which in general strike N. 20° W. A glance at the geologic map (pl. 2) shows clearly that the seepage and drill holes at Oil Bay are in line with the west shore of the bay and that unless the fracturing does not extend that far north the position of the seepage may readily have been controlled by the same causes that controlled the form and location of Oil Bay.

The accumulation of oil, however, would be determined by other conditions than these, and in this locality it might be expected to depend primarily on the structure of the beds and the presence of rocks of proper character to contain and to retain the oil. In addition the quantity of oil in a given reservoir would also depend, in part, on the extent of the gathering ground or drainage area.

The rocks of a narrow curving belt along the coast of Cook Inlet dip seaward in a monocline that carries them from view beneath the water. This structure includes the rocks above the Tuxedni sandstone as well as that formation and is so pronounced that it suggested the name Tilted Hills for the mountains of the belt. The Tuxedni sandstone of the interior and the northwest side of the peninsula has been thrown into a succession of folds whose axes run about N. 30° E. The position of these folds is indicated on Plate 2, where it is shown that one of the two principal anticlines follows the valleys of Bowser and Fitz Creeks. This anticline divides into two minor anticlines in the north end of the Fitz Creek Valley and flattens out toward the south end near Oil Bay, apparently losing its identity beneath the southward-dipping beds of Mount Pomeroy. Possibly there are minor folds on the east flank of this anticline between Park Creek and the head of Brown Creek, but lack of time prevented a careful examination of this area.

The other anticline, which extends through the Portage Creek Valley, is a closely compressed fold and is cut off on the north by a fault that crosses its axis at an acute angle. It would seem that the anticline of the Fitz and Bowser Creek Valleys and the seaward-dipping beds along Cook Inlet furnish structural conditions that would favor the accumulation of oil, because the anticline and its broad eastern limb provide both a reservoir and a drainage area. The storage of oil in the anticline would necessarily depend further on the presence of beds capable of holding oil and on a capping of beds that would prevent its escape.

One possibly unfavorable feature of the Bowser-Fitz Creek anticline should be pointed out. Fitz Creek has cut its valley deep into the Tuxedni sandstone, so that the rocks exposed near Chinitna Bay, as indicated by the sections, are somewhat lower in the formation than the beds at Oil Bay. The lowest beds exposed on Fitz Creek may thus lie below the oil-bearing beds and possibly no oil will be found in them. Whether or not this is true can not be determined till more is known about the source of the oil.

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

Oil might be found in other structural features than the two folds already mentioned. One such feature would consist of a lenticular bed of porous sandstone, capable of holding oil, inclosed in a bed of shale tight enough to prevent the escape of the oil. Such beds may be present in the upper shaly part of the Tuxedni sandstone, but their occurrence at a particular locality could not ordinarily be predicted from surface indications and could be determined only by the drill.

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

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

CONDITIONS IN THE VICINITY OF TUXEDNI BAY (SNUG HARBOR)

The probability of obtaining oil from the sedimentary beds between Chinitna and Tuxedni Bays appears to be less than from the same formations south of Chinitna Bay. Although the Jurassic beds in the vicinity of Iniskin Bay and Oil Bay are known to carry a certain quantity of petroleum, as is shown by oil seeps and drilling, the structure of these beds in the vicinity of Tuxedni Bay is not especially favorable for the accumulation of oil, for, so far as observation has shown, the structural features commonly considered as favorable or necessary for the retention of oil within an oil reservoir are not well developed here. On the other hand, the sedimentary beds themselves are seemingly as favorable for the development of the oil as the corresponding beds farther south. The petroleum of Iniskin and Oil Bays is believed to be derived from the lower part of the Tuxedni sandstone or possibly from some lower sediments and is stored in the porous beds of that formation. If the lower beds of the Tuxedni sandstone in the vicinity of upper Tuxedni Bay have ever contained oil it seems likely that much of the oil has escaped to the surface and been lost during the long time that these upturned beds have been exposed to erosion, yet they may possibly still contain oil stored either in lenticular beds of sand surrounded by impervious shale or in beds of sand that are sealed by being faulted against impervious shale.

If the deeply buried part of the formation in the area nearer the inlet is oil bearing, it is unfavorable for drilling because of the great thickness of overlying beds that must be penetrated in order to reach the oil. The depth of the drill hole would be not only the thickness of the beds but an added depth due to the tilt of the beds, which, however, in beds of low dip is not great. The maximum depth to the top of the Tuxedni sandstone near the entrance to Tuxedni Harbor is at least 5,000 feet. Drilling in this vicinity would therefore seem unadvisable unless much more favorable structural conditions should be discovered than are now known.

IRON

A deposit of magnetite was found near the shore of the north side of Tuxedni Bay near its head. This deposit was not examined by the writer but was described to him by the owner, Mr. Roy A. Trachsel, of Anchorage. Apparently it cuts the volcanic rocks at a point not far distant from the contact of the granitic intrusive that is exposed about the upper end of Tuxedni Bay. A considerable body of the iron oxide is in view at this place and is not far distant from the deep channel extending northwestward from Snug Harbor toward the head of the bay. The accessibility of the deposit will be of importance if the development of the property is undertaken.

The following analyses of ore from this locality were furnished by Mr. Trachsel:

Analyses and assay of iron ore from Snug Harbor

Analysis by Kansas City Testing Laboratory, Kansas City, Mo., October 14, 1920:		
Loss on ignition		0.11
Silica (SiO_2)		4.34
Alumina (Al_2O_3)		1.20
Iron (Fe_3O_4)		88.89
Lime (CaO)		1.55
Magnesia (MgO)		1.12
Sulphur (S)		.59
Manganese (Mn)		2.06
Phosphorus (P)		.05
Total iron as metal (Fe)		64.27
Analysis by Abbot A. Hanks, San Francisco, Calif., February, 1921:		
Silica		2.80
Iron		67.82
Phosphorus		.064
Sulphur		.11
Assay by Bogardus Testing Laboratories, Seattle, Wash., July 25, 1916:		
Gold	ounce per ton	0.01
Silver		Trace
Copper	per cent	.40

OTHER MINERALS

The gravel deposits of the Snug Harbor district (p. 69) have not given promise of containing valuable gold placers or deposits of other valuable minerals. This district, furthermore, has not furnished lode deposits of commercial value up to this time. The possibility exists, however, that future prospecting may reveal such lodes, as one metalliferous deposit of some promise has just been described.

THE SNUG HARBOR DISTRICT, ALASKA

By Fred H. Moffit

INTRODUCTION

The name Snug Harbor is used here to designate the district on the west side of Cook Inlet extending southward from the north side of Tuxedni Bay to Chinitna Bay. Snug Harbor is the local term for the waterway between Chisik Island and the mainland on the west and is the usual destination given for freight consigned to the cannery on the south end of Chisik Island. A topographic map of the Snug Harbor district as far south as Red Glacier was made by C. P. McKinley in 1920. At the same time a geologic map of the area was made by Herbert Insley and the writer. In 1921 this work was continued southward so as to cover the north shore of Chinitna Bay and join with the detailed topographic and geologic maps of the Iniskin-Chinitna Peninsula, surveyed in that year, which are described in the first part of this report.

The Snug Harbor district includes the northward extension of the geologic formations exposed on the Iniskin-Chinitna Peninsula and has received attention as a possible source of petroleum. A description of its geology is accordingly included in the present report, together with topographic and geologic maps (pls. 3 and 4) of the whole area between Tuxedni and Iniskin Bays on a scale of 1:250,000. The topographic and geologic surveys of the Snug Harbor district in 1920 were made during unusually adverse weather, in addition to which much time and labor had to be given to the problem of transportation in an unsettled country poorly adapted to travel with pack animals. In consequence the extent of the surveys was much less than had been anticipated. Although the areal and structural geology of the district is here treated separately from that of the Iniskin-Chinitna district, where the work was done in a more detailed way, it seems advisable to consider the petroleum resources in connection with those of the southern area. The conclusions regarding petroleum will therefore be found in the earlier part of this report. (See pp. 54–55.)

Location and area.—The district here described includes Chisik Island and a part of the mainland between Tuxedni and Chinitna

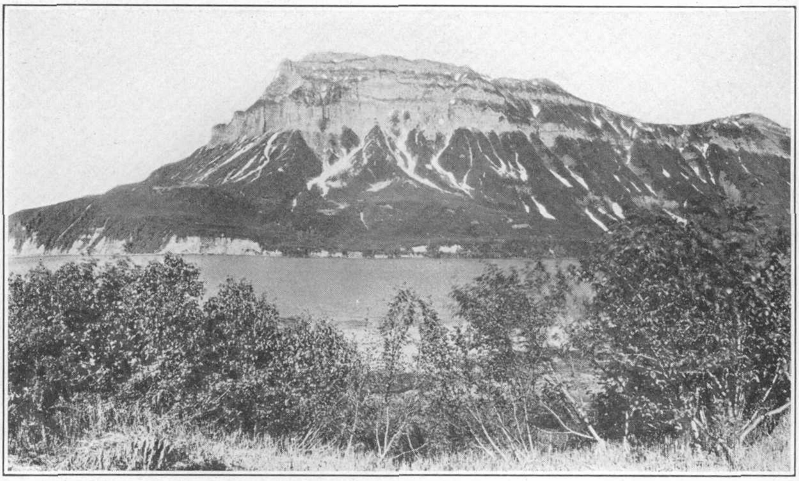
Bays, which comprises the eastern foothills of Mount Iliamna. The areal geology of approximately 300 square miles of mountainous country is represented on Plate 4. This area is somewhat less than the area represented by the topographic map (pl. 3).

Outline of geography.—The shore of Cook Inlet from the head of Tuxedni Bay to the head of Chinitna Bay forms a rude semicircle with Mount Iliamna (10,086 feet) near its center. From this high peak the streams radiate to the sea and the intervening ridges slope to its shore. The upper reaches of Iliamna are snow covered (pl. 11, *B*) and supply ice to the numerous glaciers, which give rise to the larger streams. When viewed from the sea, the foothills surrounding Iliamna appear less rugged than when seen in the opposite direction, for the seaward slopes are dip slopes, conforming to the bedding of the underlying rocks, and the steep scarps, which are due to erosion and faulting, are not in view. Chisik Island exhibits this characteristic well, for its highest point is on the northwest end (pl. 11, *A*), its northwest face is abrupt, and its surface slopes gradually with the beds to the southeast. These striking features of abrupt slopes on the landward side of the mountains and more gentle slopes on the seaward side are also characteristic of the mountains bordering Cook Inlet between Iniskin and Chinitna Bays.

All the principal streams between Tuxedni and Chinitna Bays are glacial streams and on warm summer days carry a large volume of water, but the glaciers that supply the water extend so far down the slopes of Mount Iliamna, whose summit is only about 17 miles from the coast at the most distant point, that none of the streams are long. Johnson River and West Glacier Creek are the longest and carry the largest volume of water. Their waters are heavily charged with silt, and their grades are so small that much of their load is dropped before it reaches the sea. Johnson River especially has thus built up for itself a wide, flat valley floor, which is poorly drained and in most places is difficult to cross with horses or even on foot because of the soft ground. The shore of Cook Inlet from Iliamna Point to East Glacier Creek is a broad swampy flat, crossed by meandering streams and bordered by sand bars, which doubtless have been built up in large part of the fine material deposited by the glacial waters descending from Mount Iliamna.

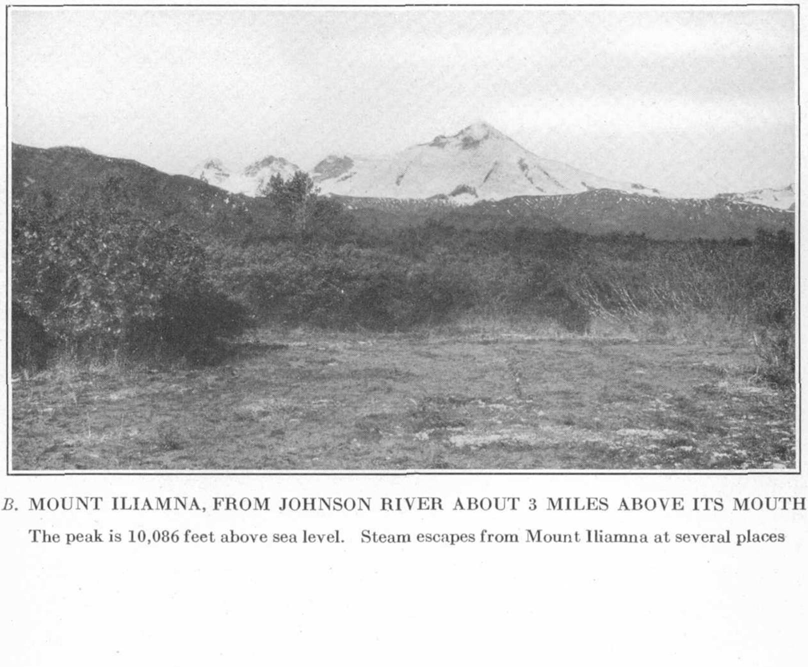
This district is without trails. All travel alongshore is by boat, and apparently there has been no incentive sufficiently strong to draw anyone away from the coast. Swampy ground and thick alders make travel inland difficult, except in winter, so that even the natives rarely go away from the shore.

Spruce timber does not grow in the vicinity of Snug Harbor, except in a few small areas like that at Fossil Point and on Chisik



A. NORTH END OF CHISIK ISLAND, FROM FOSSIL POINT

The island is here 2,600 feet high. Shows the upper part of the Chinitna shale, the Chisik conglomerate, and the lower part of the Naknek formation



B. MOUNT ILIAMNA, FROM JOHNSON RIVER ABOUT 3 MILES ABOVE ITS MOUTH

The peak is 10,086 feet above sea level. Steam escapes from Mount Iliamna at several places

Island, but it grows along the coast from Johnson River to Chinitna Bay. Cottonwood, on the other hand, is widely distributed and grows to large size. Trees 3 and 4 feet thick may be seen on Bear Creek, and fine groves are numerous. Practically all the country up to an altitude of about 2,000 feet is covered with a luxuriant growth of alders, through which are scattered here and there small parks of fine grass. The grass in summer, as in most of the Cook Inlet region, grows rank and furnishes abundant forage for stock.

A cannery on Snug Harbor, at the south end of Chisik Island, is the only settlement in this part of Cook Inlet. A wharf facilitates the loading and unloading of freight, but there is no business aside from that of the cannery, and there are no accommodations for travelers except those furnished through the courtesy of the cannery officials. The cannery is closed in winter, and only the caretaker remains. Even the timbers are removed from the wharf, for the ice drifting back and forth through Snug Harbor carries away the piling and makes it necessary to renew the wharf each spring.

DESCRIPTIVE GEOLOGY

STRATIGRAPHY

CHARACTER OF THE ROCKS

The geologic investigations made by Martin and Stanton in Tuxedni Bay in 1904 are described in a report on the Iliamna region [1] published in 1912. A further report dealing particularly with the possible presence of oil in the district was prepared by Martin,[2] and still more recently a brief statement of the results of the surveys conducted in 1920 was made by the writer.[3]

The geology of the Snug Harbor district differs little, except in details, from that of the Iniskin-Chinitna Peninsula. The same formations are present, and the same general type of structure, though slightly simpler in some respects, is seen. Only a small area of Tertiary rocks and an area of granite are present in addition to the formations of the southern district. The areal distribution of the geologic formations between Tuxedni and Chinitna Bays is represented on Plate 4. This map also shows their distribution in the Iniskin-Chinitna Peninsula but on a smaller scale than that of Plate 2. The character and thickness of these formations in the vicinity of Tuxedni Bay are set forth in the following table, which is based in part on the work of Martin and Stanton:

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[1] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 59–64, 1912.

[2] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 42–55, 1921.

[3] Moffit, F. H., Geology of the vicinity of Tuxedni Bay, Cook Inlet: U. S. Geol. Survey Bull. 722, pp. 141–147, 1921.

Geologic formations in the vicinity of Tuxedni Bay, Alaska

Quaternary: Sand, gravel, morainal, and other unconsolidated deposits.	
Upper Jurassic:	
Naknek formation:	Feet
Shale, sandstone, arkose, andesitic tuff, and conglomerate	5,000
Chisik conglomerate member; coarse conglomerate, of variable thickness, consisting predominantly of well-rounded granite pebbles in an andesitic tuffaceous matrix	290
Chinitna shale: Fairly homogeneous marine sedimentary formation, consisting of soft shale and subordinate amounts of sandstone and limestone	1,300–2,400
Middle Jurassic: Tuxedni sandstone; marine sedimentary formation consisting predominantly of sandstone but including a large proportion of shale and subordinate conglomerate and limestone	1,100
Middle or Lower Jurassic: Granite, granodiorite, and quartz diorite.	
Lower Jurassic (?): Lava flows cut by later intrusives.	

The thicknesses shown in the table are those given by Martin, except that the thickness of the Tuxedni sandstone is increased, which he suggested might be necessary, as the result of the later investigation in this vicinity.

Martin and Stanton studied in detail and measured with much care the excellent sections of Mesozoic rocks exposed on the shores of Tuxedni Bay and Chisik Island and on Chinitna Bay. They also made extensive collections of fossils, which were the basis for separating the beds into the formations given in the table. Insley and the writer reexamined these sections in order to familiarize themselves with the character of the beds, but did not remeasure them. They were able, however, to make a considerable addition to the number of species of fossils from the locality.

The areal distribution of the formations given in the table is in general as follows: The axis of the main range of mountains extending north and south from Mount Iliamna is made up of granite or of granitic rocks, chiefly amygdaloidal basalt and volcanic agglomerate, which intruded an older complex of volcanic rocks. These igneous rocks are bordered on the east by a succession of Jurassic marine sediments, from which they are separated by a fault of great displacement and length. The sediments, which include five distinct formations structurally conformable to one another, dip moderately and at a fairly uniform angle toward Cook Inlet. They thus form a series of long, narrow belts parallel to the main mountain range, with the oldest formation lying adjacent to the volcanic rocks and the youngest disappearing beneath the waters of Cook Inlet on the east. Two of the formations, however, are developed only locally, and consequently are not shown in places on the geologic map. Approximately 9,000 feet of these Middle and Upper Jurassic sediments, consisting chiefly of sandstone and shale but including many beds of conglomerate, are known to be present in the vicinity of Tuxedni Bay. They extend southward and form the Iniskin-Chinitna Peninsula, but are not known on Cook Inlet north of Tuxedni Bay, although it seems probable that some of them may be present there.

LOWER JURASSIC (?) ROCKS

Lava flows, tuff, and associated intrusive rocks are exposed about the upper part of Tuxedni Bay. These rocks form the high mountains north of Mount Illiamna and the adjacent inland foothills and are separated from the shores of Cook Inlet by the younger sedimentary beds described below, except where arms of the inlet, such as Tuxedni and Chinitna Bays, reach back to them.

The head of Tuxedni Bay is surrounded by granitic rocks of a considerable variety, including granite, granodiorite, and quartz diorite, which are part of the backbone of the Chigmit Mountains and extend north and south from this vicinity. Both shores of Tuxedni Bay east of the area of granitic rocks are occupied by darker volcanic rocks, which apparently are older than the granitic rocks and are intruded by them. These rocks, as determined by Martin,[4] include quartz porphyry, augite andesite tuff, and quartz porphyry tuff. Farther south on Chinitna Bay olivine basalt and tuff are present. The volcanic rocks, including the lava flows and tuff, apparently form a belt, about 4 or 5 miles in width, extending southward for many miles along the east side of the granitic rocks previously mentioned. The prominence of the granitic rocks of the high mountains is the result of differential erosion. Although the volcanic rocks consist largely of tuff and material in which bedding might be expected, their structure was not studied, and the degree of folding which they have undergone is not known. Presumably they show the effects of pressure much more than the sedimentary beds on the east, from which they are separated by a fault of great longitudinal extent and large displacement.

The age of the volcanic and intrusive rocks is not accurately determined but was tentatively regarded by Martin[5] as Lower

[4] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, p. 51, 1922.
[5] Martin, G. C., op. cit., p. 51.

Jurassic(?). Mather[6] found no evidence in the Kamishak Bay region to disprove Martin's tentative assignment of Lower Jurassic age to the volcanic rocks. He showed unmistakably that the granitic rocks are intruded into the volcanic rocks but could find no evidence to prove that sills of granodiorite in the Tuxedni sandstone are offshoots from the main granite batholith, although he regards that conclusion as reasonable. With regard to the age of the granitic rocks he says:

> In all probability the granitic rocks in this and adjacent portions of the Alaska Peninsula are the result of several intrusions, closely associated in time but distributed at intervals throughout the Lower and Middle Jurassic epochs.

MIDDLE JURASSIC ROCKS

TUXEDNI SANDSTONE

The Tuxedni sandstone exposed on Tuxedni Bay may be divided into two parts, which differ from each other lithologically but are characterized by the same fossils. The lower part consists dominantly of sandstone and other coarse-grained fragmental rocks, including grit and conglomerate. This part of the formation also contains sandy shale and a little limestone. It is typically exposed in a practically continuous outcrop on the shore of Tuxedni Bay from Fossil Point westward to the boundary of the volcanic rocks. The character of the fragments that compose the lower part of the Tuxedni formation indicates that these coarser-grained beds were formed from material such as angular grains of feldspar and ferromagnesian minerals derived from a land mass made up in large part of granitic rocks, which was being worn down mechanically more rapidly than chemical distintegration could destroy the débris, and that the conditions of sedimentation varied rapidly. A section of the Tuxedni sandstone, which includes the lower part from Fossil Point westward, was measured carefully by Martin and Stanton in 1904 and is reproduced here to show the variety of beds included and the changing conditions of sedimentation.

Section of part of the Tuxedni sandstone on south shore of Tuxedni Bay

	Feet
Shaly sandstone with scattered fossils, *Inoceramus, Trigonia, Sphaeroceras, Phylloceras,* and others	55
Black sandstone with small white angular grains	8
Hard gray sandstone	1
Black sandstone with *Inoceramus ambiguus, Stephanoceras* cf. *S. humphriesianum, Sphaeroceras oblatum?* and other fossils	3
Dark shale	8

[6] Mather, K. F., Mineral resources of the Kamishak Bay region: U. S. Geol. Survey Bull. 773, pp. 164–165, 1925.

	Feet
Soft coarse black sandstone with white grains	39
Fine-grained gray shale with *Sphaeroceras oblatum*, *Belemnites*, and other fossils	18
Fine-grained gray shale	35
Bands of sandstone and shale	3½–6
Dark soft shaly rock with coarse grains	10
Dark limestone with abundant fossils, *Sphaeroceras cepoides*, *Pleuromya*, and others	2–4
Dark shale	3
Dark conglomerate rock (arkose)	7½
Dark shale with conglomerate bands	26
Sandstone	1
Gray shale	15
Sandstone	2
Shale with scattered fossils	12½
Sandstone and shale with *Stephanoceras carlottense*, *S. richardsoni*, *Sphaeroceras cepoides*, *Lytoceras*, *Phylloceras*, and many other fossils	3–3½
Shale with concretionary bands	10
Concealed by a fault	100±
Gray shale with numerous sandstone and concretionary bands and a few fossils, including *Stephanoceras* cf. *S. humphriesianum*	100
Gray shale containing sandstone and concretionary bands	150
Gray sandstone with *Inoceramus ambiguus* and a few other bivalves	120
Limestone conglomerate with clavellate and undulate Trigonias and other fossils	1
Gray sandstone	3½
Dark-gray fossiliferous sandstone	1
Gray sandstone with many small fossils	11
Fossiliferous conglomerate with *Belemnites*	2
Shaly sandstone with *Inoceramus lucifer* and *Lima* cf. *L. gigantea*	52
Sandy shale with a few thin indurated fossiliferous sandstone bands	35
Indurated ledges of argillaceous sandstone 1 to 4 feet thick, alternating with somewhat thicker beds of clay (fossiliferous)	25
Shale with abundant ammonites, *Stephanoceras*, *Harpoceras*, and others	20
Indurated bands of sandstone in ledges 1 to 1½ feet thick, alternating with thicker beds of shale	14
More or less sandy shale, weathering yellowish	100
Sandstone with clay partings with abundant *Lima* cf. *L. gigantea*	36
Softer sandstone and shale to base of exposure, partly covered by talus composed of shale	100
	1,128

The upper part of the Tuxedni sandstone consists dominantly of gray and brownish shale and is indistinguishable lithologically from the overlying Chinitna shale. It contains many sandy beds, especially in its lower part. This part of the formation was not recognized in the field as belonging to the Tuxedni sandstone, and it is separated from the Chinitna shale on the evidence of fossils that were determined after the field work was ended. The boundary line between the two formations as represented on the map may therefore be subject to some alteration.

The Tuxedni sandstone is exposed on Tuxedni Bay and on the upper part of Johnson River but has not been recognized on the north shore of Chinitna Bay. Only a part of the formation, if any, can be present there. The Chinitna shale apparently lies adjacent to the volcanic rocks in this vicinity, as is shown on the geologic map, which indicates that the Tuxedni formation has been cut out by the great fault previously mentioned.

The thickness of the Tuxedni sandstone on Tuxedni Bay is known only approximately. Martin and Stanton found a thickness of 1,128 feet for that part of the formation which they measured. To this measurement must be added a considerable thickness of shale that forms the upper part of the formation, which is not exposed in the locality studied by them. More than 1,000 feet of sedimentary rock, chiefly shale, on Bear Creek is known to lie above the beds measured by Martin and Stanton, and the total thickness of beds belonging to the formation in the vicinity of Tuxedni Bay is probably not less than 3,000 feet. How much of the original formation has been cut out by the great fault on the west can not be determined from the evidence at hand.

The beds of the Tuxedni sandstone on Tuxedni Bay strike N. 30° E., parallel in a general way to the coast line of Cook Inlet. The dip undulates slightly, ranging from 15° to 25° E., and is highest on the west side of the belt of sediments. A few open folds were seen, but except for them the easterly dip of the beds seems to be notably uniform and practically uninterrupted.

The age of the Tuxedni sandstone is well established. Certain parts of the formation are highly fossiliferous and have furnished large collections which give proof that the sediments were deposited in late Middle Jurassic time. Fossil Point, which has long been known for the abundance of its fossils, furnished some of the earliest collections of fossils made in Alaska. The large collections of Tuxedni fossils from Iniskin Bay made by Martin and Stanton in 1904 was extended by Insley and the writer in 1920, and the combined list of forms is here given:

Aporrhais? sp.
Arca? sp.
Astarte sp.
Astarte? sp.
Belemnites sp.
Cyprina? sp.
Eumicrotis sp.
Grammatodon sp.

Haploceras? sp.
Inoceramus ambiguus Eichwald.
Inoceramus eximius.
Inoceramus lucifer.
Inoceramus porrectus.
Lima sp.
Lima cf. L. gigantea.
Lytoceras carlottensis.
Ostrea sp.
Pecten sp.
Pecten sp.; smooth form.
Perisphinctes sp.
Phylloceras sp.
Pinna sp.
Pleuromya sp.
Pleuromya sp. a.
Pleuromya sp. b.
Pleuromya sp. c.
Pleuromya, three species.
Praeconia? sp.
Protocardia sp.
Protocardia? sp.
Pteria sp.
Rhynchonella sp.
Sphaeroceras sp. cf. S. oblatum (Whiteaves).
Sphaeroceras sp. cf. S. cepoides (Whiteaves).
Sphaeroceras sp.
Sphaeriola? sp.
Stephanoceras carlottensis.
Stephanoceras cf. S. humphriesianum.
Stephanoceras loganium.
Stephanoceras richardsoni (Whiteaves.
Stephanoceras sp.
Trigonia sp. cf. T. dawsoni Whiteaves.
Trigonia, two species belonging to the Clavellatae and Undulatae.
Turritella? sp.

All these forms except three species were found in the vicinity of Fossil Point. A single collection of ten species from a small stream 5 miles south of Fossil Point yielded three forms, *Aporrhais?* sp., *Phylloceras* sp., and *Turritella?* sp., which were not collected at Fossil Point. This collection is undoubtedly from a higher horizon in the Tuxedni sandstone than those of Fossil Point.

The following list shows the plants collected in the vicinity of Tuxedni Bay. The determinations were made by F. H. Knowlton, and the numbers are the specimen numbers of the National Museum.

7465. Just southeast of the end of Fossil Point, Tuxedni Bay:
Sagenopteris sp.? Fragment.
Stems and other fragments.
7466. Just west of extreme end of Fossil Point, Tuxedni Bay:
Sagenopteris göppertiana Zigno.
Fieldenia? sp.
7467. Fossil Point, Tuxedni Bay:
Pterophyllum rajmahalense Morris.
Sagenopteris göppertiana Zigno.
Stems.
7467. Two hundred yards south of Fossil Point, Tuxedni Bay:
Fragments of Sagenopteris, presumably S. göppertiana.
7458. Two hundred yards south of Fossil Point, Tuxedni Bay:
Sagenopteris göppertiana?
7469. Two hundred yards south of Fossil Point, Tuxedni Bay:
Sagenopteris sp.?
7470. Five miles south of Fossil Point, on Tuxedni Bay:
Sagenopteris göppertiana Zigno.
Macrotaeniopteris californica Fontaine.
Nilsonia orientalis Heer.
Cladophlebis sp.
Pagiophyllum? sp.
Fieldenia nordenskioldi Nathorst?

In commenting on these collections Knowlton says:

> This material, although mostly pretty fragmentary, contains a number of interesting things. It belongs in the upper part of the Jurassic. * * * There is a specimen of *Sagenopteris* in the lot that is the most interesting specimen of this genus I have seen. It is a very large, mature leaf and has much of the surface between the veins covered with raised pores that appear to represent the fruit. The systematic position of *Sagenopteris* has long been in doubt, some placing it among the ferns and others in the Hydropteridiae near *Marsilea*. This specimen may help to settle the question.

UPPER JURASSIC ROCKS

CHINITNA SHALE

The Chinitna shale is a dark argillaceous shale of gray, black, or reddish color, which includes subordinate beds of sandstone and limestone and shows numerous lines of limy concretions, especially in its lower part. It rests conformably on the upper shaly portion of the Tuxedni sandstone, from which it is distinguished by its fossils rather than by differences in lithology, although the shale of the Tuxedni formation is in part sandy. Chinitna Bay is the type locality for this formation. The shale is well exposed on both sides of the bay and extends in a narrow belt northeastward to Chisik Island, probably an unbroken belt between 1 and 2 miles wide, although the presence of the shale between East Glacier Creek and Red Glacier was not determined.

A section of the Chinitna shale on the north shore of Chinitna Bay, measured by Martin and Stanton, is given on page 24. This section shows a thickness of beds amounting to 2,085 feet, but possibly not all the formation is included, for the west boundary of the formation on Chinitna Bay is believed to be a fault contact, and part of the beds may be lacking in the section. In general the Chinitna shale has the same strike as the Tuxedni sandstone beneath it—about N. 30° E.—but a slightly lower dip. Folds were not seen in the Chinitna shale in the vicinity of Tuxedni Bay, but everywhere the low easterly dip is maintained.

The Chinitna shale occupies the base of the Upper Jurassic section of Cook Inlet. At one time it was regarded as forming the uppermost part of the Middle Jurassic, but further study of the fossils led to the separation of the two formations as has been indicated. Fossils are abundant in the limy concretions of the lower part of the shale but are much less common in the upper part. They were not collected from the Chinitna shale of Tuxedni Bay in 1920. The shale of the type locality on Chinitna Bay is characterized by an abundance of large cephalopods, among which several species of *Cadoceras* are most numerous. The fossils collected from the shale of Chinitna Bay are given in the list on pages 28–30.

NAKNEK FORMATION

The Naknek formation, like the Tuxedni sandstone, is of heterogeneous composition and includes interbedded shale, sandstone, arkose, andesitic tuff, and conglomerate. These rocks, however, fall into two main divisions, of which the lower consists dominantly of shale but includes tuff and arkose and the upper of sandstone. The total thickness of the formation in this district is more than 5,000 feet.

A coarse massive conglomerate is present beneath the shale member of the Naknek formation in the vicinity of Snug Harbor, and because of its development on Chisik Island it has been named the Chisik conglomerate. This conglomerate is a deposit of variable character and is not developed in parts of the area. It lies above the Chinitna shale and is now regarded as the basal member of the Naknek formation. It includes several hundred feet of coarse conglomerate in which are beds of finer conglomerate and of sandstone. In some places, as on the beach near the cannery in Snug Harbor, it contains cobbles and boulders of granite and other granitic rocks inclosed in a matrix of finer waterworn material and angular fragments, which according to Martin is an andesitic tuff. It is well displayed on Chisik Island, its type locality, where it forms a conspicuous cliff along the west and north sides, and it occurs in somewhat poorer development on the south shore of Tuxedni Bay opposite the island. It is present also in the mountains south of Johnson River but was not seen on the shores of Chinitna Bay. Beds of grit and coarse sandstone at the base of the Naknek formation in places where the Chisik conglomerate is not developed are believed to be the time equivalent of the conglomerate. The Chisik conglomerate is structurally conformable with both the underlying and the overlying formations and has shared with them the moderate folding to which they were subjected. No fossils have been found in it, but as it lies between beds which are known to be of Upper Jurassic age it also is assigned to the Upper Jurassic.

The upper part of the Naknek formation in this district is a massive light-colored sandstone which forms a strong contrast with the dark underlying shale and which is prominent topographically because it is resistant to weathering. It is conspicuous both because of its color and because of the cliffs that mark its western boundary.

The Naknek formation is exposed in a belt averaging 4 or 5 miles in width along the coast of Cook Inlet from Chisik Island to Chinitna Bay and as noted elsewhere continues southward along the east side of the Iniskin-Chinitna Peninsula and into the Alaska Peninsula. Throughout the distance from Chisik Island to Iniskin Bay it dips eastward beneath the waters of Cook Inlet. In this area the resistant light-colored sandstone has determined the position of the eastern slope of the mountains but is less conspicuous there than on the west side of the mountains, where its precipitous scarp is more easily seen.

The most complete section of the Naknek formation that has been measured is exposed on the north shore of Chinitna Bay. It was studied there by Martin and Stanton in 1904 and furnishes the evidence for the thickness already given. This section is given on page 34.

The strike of the Naknek formation between Tuxedni and Chinitna Bays is about N. 30° E., parallel to the axis of Cook Inlet, and the dip ranges from 10° to possibly 20° E.; in general it is lower than that of the underlying sedimentary beds. No minor folds were seen in the district examined.

Fossils are less numerous in the Naknek formation than in the Tuxedni sandstone but are locally abundant. A list of fossils collected from the Naknek formation on Chinitna Bay is given on page 40.

TERTIARY ROCKS

Tertiary sedimentary beds occur in the Snug Harbor district, so far as known to the writer, only at a single exposure in the cliffs on the north shore of Chinitna Bay near its mouth. The beds are horizontal, but their relation to the near-by beds of the Naknek formation and their areal extent are not known, further than that the area occupied by them must be small. These beds were examined by Martin,[7] from whom the following description is quoted:

Lithologic character.—The following section shows the stratigraphic sequence at this point.

Section of Tertiary rocks at mouth of Chinitna Bay, north shore

	Feet
Conglomerate with interbedded shale and sandstone	15
Dark shale	20

The shale at the base of the exposure contains several fossil tree trunks from 1 to 2 feet in diameter, at least two standing upright. Numerous small sticks lie in the bedding of the shale. The tree trunks are silicified and show the structure of the wood very distinctly (992a).

The contact of the conglomerate and shale is very irregular. The conglomerate also contains much fossil wood, partly lignitized and partly silicified (922b).

Above the lower bed of conglomerate comes a few feet of sandstone with shaly bands and lenses in which a few fossil leaves were collected (922c).

Obsidian was also found at this locality, apparently being interbedded with the Tertiary rocks. A thin section shows slightly devitrified glass containing rare quartz and feldspar phenocrysts.

Flora and age.—The fossils collected at Chinitna Bay have been identified by F. H. Knowlton as follows:

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

Nos. 922a, b. Chinitna Bay:
  Coniferous fossil wood, not studied.
No. 922c. Chinitna Bay, near entrance on north side:
  Ginkgo adiantoides (Unger) Heer.
  Taxites olriki Heer.
  Populus sp.?
  Corylus macquarrii (Forbes) Heer.
Age: Arctic Miocene [Eocene].

These beds are presumably the general equivalent of the Kenai formation of the east shore of Cook Inlet. They differ from those beds in degree of induration and in the presence of associated volcanic material, and probably bear a closer stratigraphic relation to the Alaska Peninsula type of beds carrying the Kenai flora. These latter beds occur just outside of the region here under discussion, being well developed in the vicinity of Cape Douglas.

QUATERNARY DEPOSITS

The Quaternary deposits of Tuxedni Bay and the area adjacent on the south include glaciofluvial and beach deposits made up of re-sorted glacial débris, stream gravel, and the gravel and sand deposited by the sea.

Typical glacial deposits are not well developed except in the vicinity of the existing glaciers. The deposits of stream and beach gravel, however, contain an abundance of foreign material, which was undoubtedly brought in by the ice and was contributed directly to them or was derived from the destruction of previous glacial deposits. The area is profoundly glaciated and must have supplied an immense quantity of débris to the moving ice. Part of this débris was carried to the sea, but another part was left on the land and was thus subjected to re-sorting and redistribution by streams.

The valleys of Bear Creek and Johnson River furnish the best examples of these re-sorted deposits, but the gravel of glacial origin is so thoroughly intermingled with gravel of stream origin that no distinction between them is possible. The valley floors of both these streams are little elevated above the sea and are marshy. In a few places the streams have cut shallow channels into the gravel deposits, but in many places nothing but mud and silt is visible.

Johnson River in part of its course has cut through the surface deposits and reveals a bed of fairly coarse gravel tightly cemented with iron oxide, forming a hard conglomerate. This bed is conspicuous because of its bright color and contains a large proportion of fragments of vesicular lava, from which the cementing material and consequently the color was derived.

The source of the lava was not visited, but it is believed to have come either from some comparatively recent flow from Mount Iliamna or else from the volcanic rocks underlying the Tuxedni sandstone. So far as is known the stream gravel does not carry gold, but it is difficult to prospect and little attention has been given to it.

The beach deposits form a narrow border along the shore for the most part, but on the north side of Tuxedni Bay and north of Chinitna Bay they widen to a narrow coastal plain, which in one place has a breadth of over 2 miles.

STRUCTURE

The structure of the sedimentary beds in the vicinity of Tuxedni Bay has been indicated in the descriptions already given and is shown on the section on Plate 4. These beds from the Tuxedni sandstone to the Naknek formation have a moderate easterly dip toward the shore of Cook Inlet and strike parallel to the shore, about N. 30° E. A slight flattening of beds near the coast line is noticed, for the average dip there is between 10° and 15°, as compared with 20° or more at the upper end of Tuxedni Bay. The rarity of local variations in dip is notable. Folds and even short undulations in the beds are uncommon, although the dense covering of alders on all the lower hill slopes obscures the structure in many places and possibly conceals folds that are present.

The degree of folding, however, increases toward Chinitna Bay and becomes pronounced between Iniskin and Chinitna Bays, as is shown in the description of the Iniskin-Chinitna Peninsula (pp. 43–45).

Faults of small displacement were observed at different places, but no great faults were seen within the area occupied by the sedimentary rocks. It is probable, however, that the contact of the Tuxedni sandstone with the underlying volcanic rocks is a fault contact. Martin, from his study of the relations between the volcanic rocks, the Tuxedni sandstone, and the Chinitna shale on Chinitna Bay, reached the conclusion that the sedimentary beds are most probably separated from the volcanic rocks by a fault of considerable vertical and longitudinal extent, although he suggested other possible explanations of the relations existing there. The more recent investigations in Cook Inlet have shown that this fault exists and is one of the notable features of the structural geology of the district.

HISTORICAL AND ECONOMIC GEOLOGY

The geologic history of Tuxedni Bay and its vicinity is the same as that of the Iniskin-Chinitna Peninsula, a few miles to the south. This subject is treated in the earlier part of this report (pp. 45–47).

Some conclusions and suggestions relating to the possibilities of producing petroleum in the Snug Harbor district and a description of a deposit of magnetite near the head of Tuxedni Bay are given on pages 55–56.

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