GEOLOGY OF THE VICINITY OF TUXEDNI BAY, COOK INLET.

By FRED H. MOFFIT.

INTRODUCTION.

Location and area.—The district considered in these notes includes Chisik Island and an area of about 225 square miles of mainland, approximately square in outline, extending from the south shore of Tuxedni Harbor[1] and Tuxedni Bay southward toward Chinitna Bay, as far as Red Glacier, but it does not include the head of Tuxedni Bay, which was not visited by the field party in 1920. Interest in this area lies chiefly in the relation of its rocks to the oil-bearing sediments of Oil and Iniskin bays, to the south, and the possibility of oil production within it.

Tuxedni Bay was visited by Martin and Stanton in 1904, and a detailed description of the rocks is contained in the account of the Iliamna region[2] published *in* 1912. A further report dealing especially with the ail possibilities of the district has recently been prepared by Martin.[3] The work of 1920 had as its objects the making of a topographic map of the coast of Cook Inlet from Tuxedni Bay to Iliamna Bay and a study of the geology with reference to the possibilities of producing oil. These objects, however, owing to various difficulties, were accomplished only in part.

Outline of geography.—The area outlined above extends from the shore of Cook Inlet westward to Mount Iliamna and the high mountains on the north-northeast. It is a rugged country that consists principally of the flanking mountains of the main range and includes little flat land except the valley of Johnson River. The maximum relief is 10,017 feet (Iliamna Peak), but the average elevation, exclusive of Mount Iliamna and the ridge north of it, is under 4,000 feet. The flanking mountains trend parallel to the west shore of Cook Inlet and conform with the trend of the major geologic structure. These mountains consist chiefly of sandstones and soft shales dipping from 10° to 25° or possibly 30° ESE. Their gentle eastern slopes are dip slopes, and their abrupt western slopes are scarp faces. Erosion has dissected them deeply, and they are profoundly glaciated.

[1] Commonly known as Snug Harbor, but called Tuxedni Harbor by decision of United States Geographic Board.

[2] 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.

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

The chief stream within the area is Johnson River, which heads in a large glacier on the side of Mount Iliamna and flows eastward into Cook Inlet. The level valley bottom on each side of the river is crossed by small sluggish streams and dotted with numerous beaver ponds. Most of the valley bottom is impassable for pack horses because of marshy ground, so that considerable time and labor may be required in crossing the valley. In times of high water during the warm summer days Johnson River is difficult to ford with horses because of swift water and quicksands.

Up to an elevation of about 2,000 feet the area is covered by a dense growth of alders, which make travel with horses absolutely impossible until a trail has been cut. Through the alders, both on the hill slopes and in the valley bottom, are scattered cottonwoods in groves and as individual trees. Spruce, except a few scattered trees on Chisik Island and at Fossil Point, does not grow on the shores of Tuxedni Harbor, but it occupies much of the narrow coastal plain extending southward from the mouth of Johnson River to Chinitna Bay, and in the vicinity of Chinitna Bay it furnishes pilings for fish traps and for the wharf at the cannery in Tuxedni Harbor.

DESCRIPTIVE GEOLOGY.

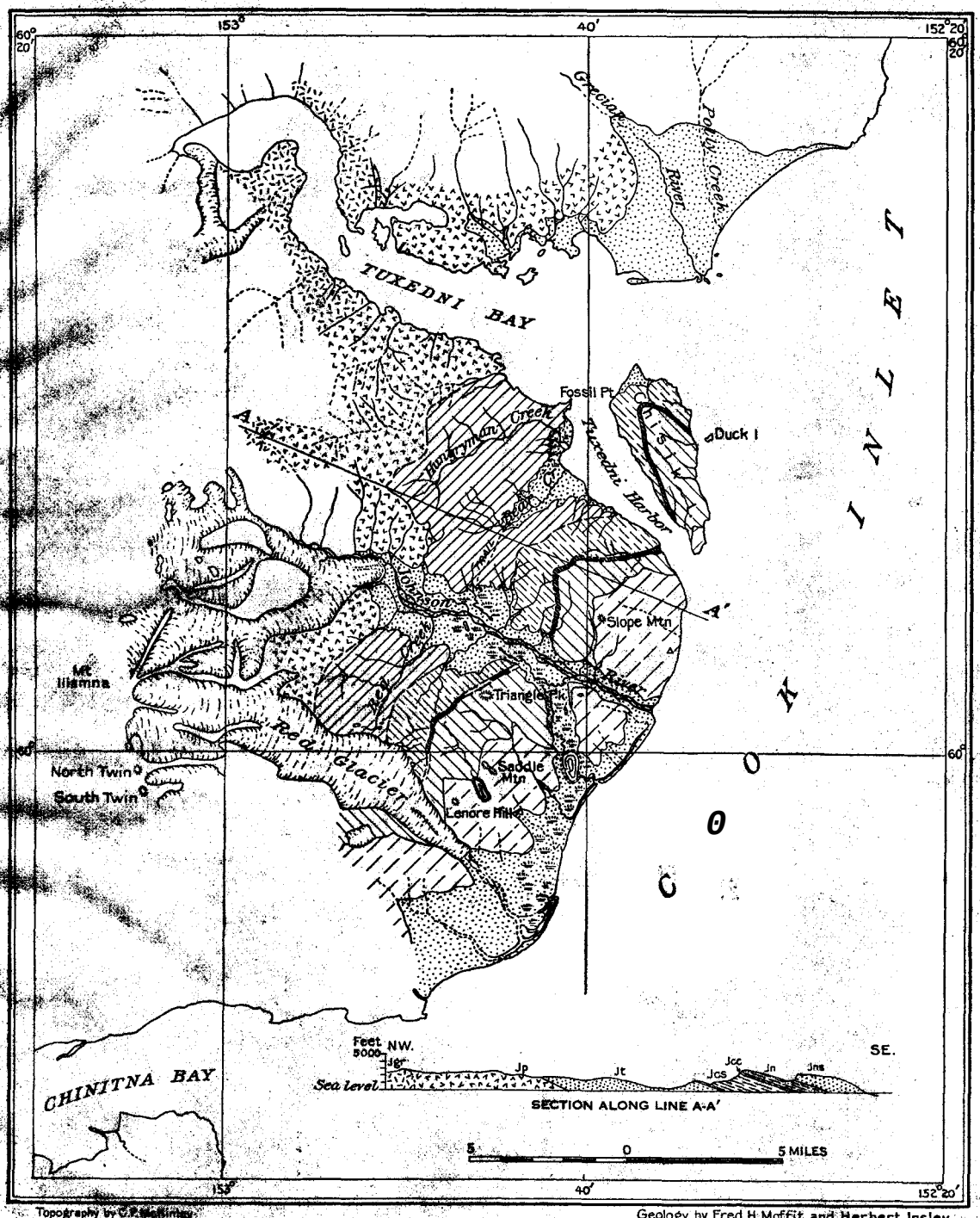
GENERAL SECTION.

The distribution of the geologic formations in the vicinity of Tuxedni Harbor and Tuxedni Bay is represented on the map (Pl. II) and in the following table, which is based largely on the work of Martin:

	Feet.
Quaternary: Sands, gravel, morainal, and other unconsolidated deposits.	
Upper Jurassic:	
Naknek formation; shale, sandstone, arkose, andesitic tuff, and conglomerate	5,000
Chisik conglomerate; 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 with 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 with 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 are those given by Martin, but it is probable, as he points out, that the Tuxedni sandstone is much thicker than is indicated in the table.

The excellent exposures of geologic formations on the coast of Chisik Island and Tuxedni Bay were studied in detail by Martin and Stanton, and the carefully measured sections made by them are given



Topography by C. P. Mathews
Surveyed in 1920

Geology by Fred H. Moffit and Herbert Insley
Surveyed in 1920

EXPLANATION

SEDIMENTARY ROCKS

- Stream and coastal-plain gravel, sand, and silt and glacial deposits — QUATERNARY
- Light-colored sandstone *(Conspicuous outcrops)* — Naknek formation — UPPER JURASSIC
- Chiefly shale with some sandstone, arkose, tuff, and conglomerate — Naknek formation — UPPER JURASSIC
- Chisik conglomerate — UPPER JURASSIC
- Chinitna shale — UPPER JURASSIC
- Tuxedni sandstone *(Sandstone, conglomerate, and limestone)* — MIDDLE JURASSIC

IGNEOUS ROCKS

- Granitic rocks — MIDDLE OR LOWER JURASSIC
- Porphyry and tuff — LOWER JURASSIC(?)
- Magnetite
- Formation boundaries *(Full line, fairly well determined; dashed line, approximate)*

GEOLOGIC MAP OF TUXEDNI BAY AND VICINITY.

in the account by Martin." Additional collections of fossils were obtained from these formations in 1920, yet little can be added to the descriptions of the rocks themselves, although they were carefully studied in order that the geologists might familiarize themselves with the sections.

The axis of the main range of mountains, which extends north and south from Mount Iliamna, is made up of granite or of granitic rocks. This granite in the vicinity of Tuxedni Bay is bordered on the east by a belt of volcanic rocks averaging about 5 miles in width and making up many of the high mountains of the district. The volcanic rocks and the granite which intrudes them are not oil bearing and will not here be described in greater detail, although they may contain deposits of metallic minerals. The volcanic rocks in turn are succeeded on the east by a great thickness, approximately 9,000 feet, of sedimentary beds, which form the principal subject of this report. They are the rocks assigned to the Middle and Upper Jurassic epochs in the table and consist chiefly of shales and sandstones but include many beds of conglomerate. It is believed that the contact of these sedimentary beds with the volcanic rocks on the west is a fault contact. The beds have a fairly uniform easterly dip averaging about 20° but diminishing from the west toward the east. They are described briefly below.

MIDDLE JURASSIC ROCKS.

TUXEDNI SANDSTONE.

The type locality of the Tuxedni sandstone is on the south shore of Tuxedni Bay, where it is exposed in practically continuous outcrops for about 2½ miles. This section, however, does not include an unknown thickness of beds overlying the beds exposed on the shore of the bay. The rocks of this formation extend southwestward from Tuxedni Bay in a narrow belt that reaches into the Alaska Peninsula, but they are not known to be present on the north side of the bay, although they probably continue in that direction and may sometime be found there.

The formation is made up of marine sediments comprising alternating beds of sandstone and sandy shale which range in thickness from 1 foot to 100 feet. Although the top of the formation was not determined in 1920 it is known that more than 1,000 feet of sediments, chiefly shale, lie above the beds exposed on the shore of the bay, as is shown in the ridge between Tuxedni Harbor and Johnson River. It appears, therefore, that the minimum thickness of 1,128 feet given by Martin must be increased, possibly to 3,000 feet. A notable feature of the sandstone members that crop out on the shore of Tuxedni Bay is that in considerable part they were formed of material result-

[4] Martin, G. C., op. cit.

ing from the rapid weathering of igneous rocks, which were probably granite or related granitic rocks, for the sandstones contain an abundance of angular feldspar and ferromagnesian minerals.

The Tuxedni sandstone is the lowest known formation of the Middle Jurassic series in southwestern Alaska. It contains an abundant invertebrate fauna and has yielded good collections of plants.

The Tuxedni sandstone, like the beds overlying it, dips away from the high mountain axis toward Cook Inlet. The strike is about N. 30° E., parallel to the coast line of the inlet. The dip is slightly undulating and ranges from 15° to 25° E. The sedimentary beds of the Tuxedni Bay district flatten out toward the inlet. In a few places small open folds were seen, but otherwise the nearly uniform easterly slope of the beds appears to be uninterrupted.

UPPER JURASSIC ROCKS.

CHINITNA SHALE.

The Chinitna shale is a marine sedimentary formation occupying the base of the Upper Jurassic section on Cook Inlet. Its type locality is Chinitna Bay, where it is well exposed on both the north and south shores, but it extends in a narrow belt a mile or more wide along the east side of the Tuxedni sandstone, appearing on the south shore of Tuxedni Harbor and on the west side of Chisik Island. It consists chiefly of dark argillaceous shale but contains subordinate beds of sandstone and limestone. Its thickness, as measured by Martin, is nearly 2,400 feet. So far as is now known the Chinitna shale rests conformably on the underlying Tuxedni sandstone and differs from it, as pointed out by Martin, in that its shales are argillaceous rather than arenaceous. In general it has the same strike as the Tuxedni sandstone, about N. 30° E., but it has a lower average dip and in the vicinity of Tuxedni Harbor was not found to be folded except for the eastward tilting of the beds.

CHISIK CONGLOMERATE.

The Chisik conglomerate forms a conspicuous cliff on the north and west side of Chisik Island and is well developed also on the south side of Tuxedni Harbor. It includes several hundred feet of coarse conglomerate in which are included beds of finer conglomerate and of sandstone. Boulders and cobbles of granite and other granitic rocks are abundant in the conglomerate outcrops of Chisik Island. The matrix containing the pebbles and cobbles, according to Martin, is an andesitic tuff. The Chisik conglomerate is variable in composition and in thickness. Seemingly it is much less well developed south of Tuxedni Harbor, although it appears in the mountain south of Johnson River

Fossils have not been found in the conglomerate, but it lies between formations of Upper Jurassic age, and it is therefore assigned to the Upper Jurassic.

NAKNEK FORMATION.

The Naknek formation is of heterogeneous composition and includes more than 5,000 feet of interbedded shale, sandstone, arkose, andesitic tuff, and conglomerate. It forms a belt averaging 4 or 5 miles in width along the coast of Cook Inlet from Chisik Island to Iniskin Bay and continues beyond that into the Alaska Peninsula. The shale, tuff, and arkose are best developed in the lower part of the formation. The upper part consists largely of massive light-colored sandstones which form the mountain slopes toward the coast but are more conspicuous because of the prominent westward-facing cliffs made by their scarps. These cliffs, owing to their light color and steep faces, are very noticeable topographic features when seen from the landward side but are less prominent when seen from the inlet.

The most complete section of the Naknek formation that has yet been measured is exposed on the north shore of Chinitna Bay, where it was studied by Martin and Stanton in 1904.

Fossils are not numerous throughout the Naknek formation but are locally abundant and fill thick beds. From their evidence the Upper Jurassic age of the formation is determined.

The strike of the Naknek formation is parallel to the shore of the inlet in the vicinity of Tuxedni Harbor and in the small area under consideration shows little deviation. The dip ranges from 10° to possibly 20° E. and in general is lower than that of the underlying sedimentary beds. No reversed dips or minor folds were observed in this formation.

QUATERNARY DEPOSITS.

The Quaternary deposits of Tuxedni Bay and the area adjacent on the south include glaciofluvial and beach deposits made up of resorted glacial debris, stream gravels, and the gravels and sand deposited by the sea.

Typical glacial deposits are not well developed except in the vicinity of the existing glaciers. The stream and beach gravels, 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 debris to the moving ice. Part of this debris 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 resorted deposits, but the gravels of glacial origin

are so thoroughly intermingled with gravels of stream origin that no distinction between them is possible.

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 gravels are not gold bearing, but they are difficult to prospect and little attention has been given to them.

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 the map (Pl. II). 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, or 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 it should be said that the dense covering of alders on all the lower hill slopes obscures the structure in many places and possibly conceals folds that are present.

Faults of small displacement were observed at different places, but no great faults were been within the area of the sediments. It is probable, however, that the contact of the Tuxedni sandstone with the underlying volcanic rocks is a fault contact. Martin,[5] from his study of the relations between the volcanic rocks, the Tuxedni sandstone, and the Chinitna shale in 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 suggests other possible explanations of the relations existing there.

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

[5] Martin, G. C., op. cit. p. 97.

by oil seeps and drilling, the structure of these beds in the vicinity of Tuxedni Bay is not considered to be 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 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 been oil bearing, 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 sand beds surrounded by impervious shale or in sand beds 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 from the standpoint of the driller 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.