OUTLINE OF THE GEOLOGY AND MINERAL RESOURCES OF THE ILIAMNA AND CLARK LAKES REGION.

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INTRODUCTION.

LOCATION.

The region described in this report covers an area of about 4,900 square miles, situated in southwestern Alaska, west of the southern half of Cook Inlet and north of the Alaska Peninsula. It comprises the greeter part of the drainage basin of Kvichak River, which is the outlet of Iliamna and Clark lakes, and of the streams flowing into Cook Inlet from the west, south of and including Tuxedni Bay. It lies between the parallels of 59° and 60" 30' north latitude and the meridians of 152° 30' and 157° west longitude.

GEOGRAPHIC FEATURES.

Most of the northeastern part of this region lies within the Chigmit Mountains and consists of high, rugged mountain masses with narrow intervening valleys. The general elevation of these mountains is from 4,000 to 6,000 feet, although many peaks near the north end of Clark Lake are 7,000 feet high, and the highest peak of the whole district is Mount Iliamna, between 9,000 and 10,000 feet.

At Iliamna Bay the mountains extend eastward to the waters of Cook Inlet. Both north and south of this point a belt of foothills and lowlands from 2 to 10 miles in width reaches from the edge of the high mountains to the shore of the inlet. Much of the coast is deeply embayed, Tuxedni Bay, Iniskin Bay, and Iliamna Bay extending into the high mountains, while the other bays have their heads in the foothill belt. Iliamna and Bear bays head at well-known low passes through the mountains, and there are reported to be passable routes through the mountains from Tuxedni Bay and the southwest arm of Kamishak Bay.

The western part of the region lies in the valleys of the lower ends of Iliamna and Clark lakes and consists of broad gravel-covered flats with numerous isolated hills and groups of hills distributed irregularly through them. At the west end of Iliamna Lake the'

valley opens out into the wide coastal plain of Bering Sea. A broad, low pass at the head of Chulitna River leads into the Mulchatna Valley, which is a region of flats and low rounded hills.

Iliamna Lake lies in the south-central part of the region. It is about 80 miles long and in general from 8 to 20 miles wide. It is about 50 feet above tide and drains through Kvichak River into Bristol Bay. Lake Clark, in the northern part of the region, is about 52 miles long and from 1 to 4 miles wide. It is about 220 feet above tide and is tributary to Iliamna Lake through Sixmile Lake and Newhalen River. Kontrashibuna Lake, tributary to Lake Clark from the east through the river of the same name,[a] is at an elevation of about 560 feet above tide. Upper and Lower Tazimina lakes, which are about 650 feet above tide, drain through Tazimina River into Sixmile Lake. Meadow and Moose lakes lie at an elevation of about 600 feet above tide, on the headwaters of Copper River, which flows into Iliamna Lake at the head of Intricate Bay. Kakonak Lake, about 260 feet above tide, drains through Kakonak River into Iliamna Lake at the head of Kakonak Bay. Hundreds of smaller lakes are distributed over the whole western part of the region.

The largest stream of this region is Kvichak River, which flows from Iliamna Lake into Bristol Bay. Its length from the outlet of the lake to Koggiung is about 62 miles. In the upper half of its course it has a current of 3 to 6 miles an hour. The lower half of its course is tidal, the water being of considerable depth even at low tide. The river is navigated by cannery steamers for about 22 miles above Koggiung, and by launches and Columbia River boats (when favored by strong west winds) for its entire length.

Newhalen River, the second stream of the area in size, has about half the volume of the Kvichak and is about 23 miles in length. For the upper 11 miles of its course it can be navigated by canoes and poling boats. Rapids and reported falls make even canoe navigation impossible for the lower 12 miles. These rapids are avoided by a 5-mile portage.

CLIMATE AND VEGETATION.

This region has abundant precipitation, though not as much as the ocean coast. The early summer months are frequently favored with long intervals of clear weather. Similar conditions are said to exist also during part of the winter. It was noticed during the summer of 1909 that cloudiness and precipitation were much greater in the high mountains at the upper ends of Iliamna and Clark lakes and in the Aleutian Range than in the broad valleys of the lower ends of the lakes. In the summers of 1903 and 1904 cloudiness and rain

[a] Generally called Tanalian River.

were far less at the head of Kamishak Bay than on the mountainous parts of the coast both north and south of that point.

This region is also believed to have a colder winter and a warmer summer temperature than the open coast, in this respect also being intermediate between the coast and the interior.

Iliamna Lake is usually frozen from late in December till late in May. The snow usually leaves the low ground between April 1 and May 1, remaining in the pass between Iliamna Bay and Iliamna village till June. Some snow may be expected in September, but the ground is not permanently covered at low altitudes till several months later. Winter temperatures range from 40° to —30° F.

Spruce forests extend throughout the lowland areas north of Iniskin Bay, in the valley of Lake Clark, and along the shores of Iliamna Lake east of longitude 155° W. The south shore of Iliamna Lake between longitude 115° W. and the outlet of the lake and most of the Kvichak Valley has only small scattered areas of spruce. Birch is practically coextensive with the spruce, except possibly on Cook Inlet. The north shore of Iliamna Lake between Newhalen and Kvichak rivers has no trees except cottonwoods. The same condition exists on the west coast of Cook Inlet south of Iniskin Bay and over the greater part of the Alaska Peninsula.

Throughout the region the higher lands, above an elevation of 800 to 1,200 feet, are bare of all vegetation, except moss, grass, and small bushes.

The spruce forests mentioned above contain good timber only locally. They are everywhere interspersed with open grassy meadows, bare ridges and hilltops, treeless swamps, and patches of alders and willows. Much of the spruce is, moreover, very small and is worthless, save for firewood. None of the forest is commercially timber land. The best of it would supply good lumber for barely more than the slight present local needs. The supply of material suitable for mine timber is, however, probably adequate to any local demands that are likely to arise.

A rank growth of grass is present in all parts of the region, especially where the timber has been burned. Abundant horse feed can be found throughout the greater part of the region from about June 1 to October 1.

Large areas of "reindeer moss" are present throughout most of the region, the low hills south of Iliamna Lake having an especial abundance of it.

SETTLEMENTS AND TRANSPORTATION ROUTES.

The largest settlement and the chief trading point for this entire region is Iliamna village, situated on Iliamna River, 4 miles above its mouth and 12 miles from Iliamna Bay. This village has a United

States commissioner, a government school, and three stores. A government reindeer station has been located at the head of Kakonak Bay since the spring of 1905. The other villages, which are inhabited permanently only by natives, include Kakonak, on the south shore of Iliamna Lake, 12 miles west of the head of Kakonak Bay; Newhalen, near the mouth of Newhalen River; Nondalton, on the west shore of Sixmile Lake, and Kaskanak, on Kvichak River, about 10 miles below Iliamna Lake. There are several cabins belonging to prospectors and traders at Iliamna and Cottonwood bays, but these are occupied only when a steamer is expected or when freight is being moved from the coast. Numerous prospectors' camps and cabins are scattered throughout the district.

There are two well-traveled routes into this region—one from the east by way of Iliamna Bay and the other from the west by way of Koggiung. The steamers from Seattle to Prince William Sound and Cook Inlet, and also the local steamers from Valdez westward and from Seldovia arid Port Graham to the upper Cook Inlet ports, will land at Iliamna Bay whenever weather permits and sufficient business warrants it. Iliamna Bay is about one day's sail from Seward or six to twelve days from Seattle. A boat usually calls about once a month from May to October, inclusive, and occasionally during the winter.

A good horse trail leads from the head of Iliamna Bay to Iliamna village, a distance of about 12 miles. This trail crosses a 900-foot summit 3 miles west of Iliamna Bay. Another trail leads from the head of Cottonwood Bay to Iliamna village, a distance of about 20 miles, crossing three summits at elevations of about 1,700, 1,500, and 1,975 feet, at distances of 4, 5½, and 15 miles from Cottonwood Bay, descending to 1,400 and 600 feet between the summits. A good wagon road has been built for the first 2 miles and from the fifth to the fourteenth mile, or as far as the Dutton copper prospects. These trails can generally be used by horses from June 1 to November 1. Dogs are used during the rest of the year.

From Iliamna village all parts of Iliamna Lake and Kvichak River can be reached in boats, there being several large sailboats and a gasoline launch at the village. Horses can also be taken from Iliamna village throughout the greater part of the region, except in the high mountains. The shores of Clark Lake are impassable for horses east of longitude 154° W.

Bristol Bay is visited by cannery vessels about May 1 and by a passenger steamer from Valdez once a month in June, July, August, and September. Part of the supplies for the stores at Iliamna village are brought in by this route, which has the advantage of being all water and avoiding the portage from Iliamna Bay to the village.

Iliamna Lake can also be reached by a portage from the head of Kamishak Bay to the head of Kakonak Bay. This route is said to be an easy one, the pass being low. It is, however, not much used except by natives, because of the difficulty of having supplies landed on this uncharted part of the coast.

Many of the supplies for Lake Clark and the Mulchatna country west of it are taken in from Iliamna village by dogs in the winter. Summer transportation to Lake Clark may be accomplished either with horses or by boats to a point on the shore of Iliamna Lake 4 miles east of Newhalen River, thence by a 5-mile portage to Newhalen River above the lower rapids, and thence by boat up to Newhalen. Native packers are usually available at this portage.

The Mulchatna country can be reached from Lake Clark by boats up Chulitna River to a short portage at the head of Swan River or up Chulitna and Koksetna rivers to a point near the headwaters of the higher eastern tributaries of the Mulchatna. Horses could also be used in this district.

Prospecting has been carried on in a small way over the greater part of this region and in the adjacent Mulchatna region since 1898. The most active operations were from 1903 to 1906 and will be described at length under the heading "Mineral resources."

GEOLOGY.

GENERAL FEATURES.

The region here described covers the south end and parts of the east and west sides of the Chigmit Mountains, the north end of the Aleutian Range, an intermediate region lying between these two ranges, and parts of the Cook Inlet and Bristol Bay regions on the east' and west sides. It consequently includes parts of several geographic and geologic subprovinces, the general features of which will be briefly reviewed. The geologic subprovinces which this area includes, or into which it extends, are the Cook lnlet basin on the east, the Chigmit Mountains west of it, the Alaska Peninsula in the southern part, the Bering Sea coastal plain in the western part, and the Iliamna Basin in a central position between the last three. (See Pl. V.)

DESCRIPTION OF THE ROCKS.

GENERAL SEQUENCE.

Tho rocks of this region include a great variety of sedimentary, metamorphic, intrusive, and volcanic types. At no locality is there a geologic section showing the complete stratigraphic sequence. The complex structure and the general absence of fossils throughout all

but the eastern part of the area make correlation and the establishment of a complete geologic section rather difficult and subject to doubt. The following table shows what is now believed to be the probable geologic sequence:

General section of rocks in the Iliamna and Clark lakes region.

Age.	Lithologic character.	Areal distribution.
Quaternary.	Beach and flood-plain deposits, terrace gravels, and glacial till.	Entire region.
Tertiary.	Basaltic flows and tuffs with some interbedded sandstone.	Iliamna Lake.
	Shale, sandstone, and conglomerate.	Cook Inlet.
Upper Jurassic.	Shale sandstone, conglomerate, arkose, and tuff, with interbedded andesitic flows.	Cook Inlet.
Middle Jurassic.	Sandstone, shale, and conglomerate.	Cook Inlet.
Middle or Lower Jurassic.	Granite, quartz diorite, etc.	Chigmit Mountains.
Lower Jurassic or older.	Rhyolitic and andesitic porphyries and tuffs.	Cook Inlet, Iliamna Lake, Clark Lake, east of Clark Lake.
Upper Triassic.	Chert, shale, and limestone.	Cook Inlet.
Triassic or older.	Tuffaceous greenstones.	Iliamna Bay, Pile Bay, Kakhonak Bay, Clark Lake.
	Limestone.	Iliamna Lake, Iliamna Bay, south of Iliamna village (?).
Late Paleozoic.	Slate and chert,	Iliamna Bay, Clark Lake, east of Clark Lake.
Paleozoic.	Limestone and calcareous schist.	Clark Lake, south of Ilismna village (1).
	Gneiss, mica schist, and quartzite, with some crystalline marble.	West of Iliamna Bay, south of Iliamna village, Clark Lake.

METAMORPHIC ROCKS.

GNEISS, SCHIST, AND QUARTZITE.

The oldest rocks of this region are metamorphosed sediments now appearing as gneisses, mica schists, quartzites, and crystalline limestone. These rocks occupy two districts, one being in the mountains between Iliamna and Pile bays and the other in the valley of Lake Clark from Kontrashibuna Lake northward to the mountains west of Tlikakila River.

The rocks of the district west of Iliamna Bay include hornblende and biotite gneiss of moderately fine to coarse grain, coarse crystalline marble, quartzite, and mica and chlorite schists. The marble is known to occupy two small areas within the area of the gneiss, 2 miles west of Iliamna and Cottonwood bays, on the trails to Iliamna village. These may be lenses, but are believed to be small detached areas of a larger mass, having undetermined structural and stratigraphic relationships to the neighboring gneiss.

The metamorphic rocks of Lake Clark consist of quartzite, mica schist, calcareous schist, and crystalline limestone. These are believed to be separable into an older series of quartzite and mica schist and a younger series of calcareous schists and limestones. The quartzite and schist occupy the mountain west of the lower half of Kontrashibuna Lake, being bounded on the east by limestone and on the west and south by much younger volcanic rocks. Another area of schist is on the northwest side of Lake Clark from 3 to 5 miles south of the mouth of Tlikakila River. This is believed to be continuous with the other area. This area apparently has limestone on each side of it, the probable relation being anticlinal structure and limestone overlying the schist.

The schist and quartzite of Lake Clark are, in the absence of evidence to the contrary, considered equivalent to the somewhat similar metamorphic rocks west of Iliamna Bay.

LIMESTONE AND CALCAREOUS SCHIST.

The limestone and calcareous schist which apparently overlie the mica schist and quartzite on Lake Clark have already been mentioned. These rocks have an apparent thickness of many hundred feet, but the complexity of folding is such that the actual thickness can not be determined. They are predominantly calcareous throughout, and pure limestone beds contribute to a large proportion of the thickness. Their separation from the presumably underlying siliceous rocks is made wholly on the basis of their calcareous character, neither unconformity nor difference in degree of metamorphism having been detected.

Another area of limestone, possibly much younger than that just described, appears on the north shore of Iliamna Lake about 3 miles west of Chekok River. This limestone differs from that on Lake Clark in not being associated with schists and in being much less metamorphosed, This is a fine-grained blue limestone with a considerable amount of bituminous matter. It has been much shattered and crushed, the fractures being healed by the deposition of fine-grained white calcite. Otherwise it has not been much altered, there having been little recrystallization of the noncrushed fragments except along

the lodes and no observed development of secondary silicates. The areally associated rocks are masses of fine-grained basic igneous rocks on both the east and the west sides and unconformably overlying tuffaceous beds on the south.

The limestone of this locality is of especial interest and importance, because it has yielded most of the fossils which have been found in this area. This fauna consists chiefly of corals and indicates that the limestone is Triassic.

Another area of limestone extends from a locality near the northwest side of Meadow Lake northward to the valley of Iliamna River. This limestone is bordered on the east by schists and on the west by altered basic igneous rocks. Several masses of schist occur within the limestone, but whether they are interbedded or were brought in by structural disturbances is not known. The latter origin is believed to be the more probable. This limestone is somewhat more altered than that on the north shore of Iliamna Lake, but decidedly less so than that on Lake Clark. In its relation to the schist it resembles the latter, although there is here a strong suggestion of greater alteration of the schist than of the limestone and presumably of an important time break between their dates of deposition.

On the south shore of Iliamna Bay, about halfway between the mouth of the bay and Cottonwood Bay, is a large mass of limestone, which is so complexly folded that no idea of its thickness may be obtained. It is white and blue, fine grained, much shattered, the fractures being healed with calcite, and very slightly altered, save by this crushing and healing. In all this it resembles the limestone on Iliamna Lake, as it does also in the presence of a coral fauna. The fauna is, however, meager and can not be definitely correlated with that from Iliamna Lake, although the suggestion of identity from the combined lithologic similarity, degree of alteration, and presence of roughly similar corals is strong. The associated rocks are amygdaloidal basaltic tuffs of indeterminate relationship on the west side and younger granitic intrusive rocks on the east.

SLATE AND CHERT.

A belt of black slate, with a few thin beds of limestone and quartzite and possibly some schist or phyllite along the western margin, lies along the face of the mountains west of Cottonwood Bay. These beds are many hundred and possibly several thousand feet thick. Gneiss and schist border the slate on its west side and greenstone on its east side. The gneiss is overthrust or overfolded upon the slate, which in turn bears the same structural relationship to the greenstone.

Slates with much associated chert and altered igneous rocks, and with several thin beds of limestone, were seen on either side of Lake

Clark just above the mouth of Tlikakila River. These rocks differ from the slates of Cottonwood Bay in being less altered and in the presence of associated cherts and igneous rocks. A granite mass which is intrusive into the slate, lies east of it, while on the west also is granite upon which the slate is overthrust.

Cherts and slates were also seen at three localities within the area between Kontrashibuna Lake and Iliamna Lake. At each of these localities the rock consists of very fine grained black slates, argillites, or graywackes, and banded white, gray, and dark-colored cherts or very fine grained quartzitic rocks. The cleavage in the slates is only imperfectly developed. These rocks are all minutely crumpled and no evidence could be obtained as to their thickness and age. The adjacent rocks are all volcanic, and from their slight degree of alteration are evidently much younger than the slates, which they are believed to overlie uncomformably, burying them except in the areas noted above and probably in other small undetected areas.

GREENSTONE.

Altered volcanic rocks here grouped under the name greenstone occur at several places within this region. Considerable diversity of character exists among them, but they possess in common a number of features—the presence of original basic igneous material; such a degree of alteration that the original character of that material can not in general be determined; original banding or secondary schiitosity, or both; and superficial similarity in color, texture, and general physical appearance.

A belt of these rocks extends across the heads of Iliamna and Cottonwood bays. The original material was here probably a fine-grained basic volcanic rock including considerable tuff and chert. It now contains much secondary epidote and near the head of Iliamna Bay exhibits considerable schistosity, probably due to local shearing. These rocks are in contact with a belt of slates west of them which are evidently older, being more altered, but which are overthrust or overfolded upon them. The rock adjacent to the greenstone on the east is younger intrusive granite.

A large area of greenstone occupies the mountain between the mouth of Iliamna River and Meadow Lake. The original rock was in part diabase and diorite, although tuffaceous beds were recognized on the shore of Iliamna Lake and pyroxenite occurs near the crest of the mountain. The entire mass is now much altered through the development of secondary minerals but without notable schistosity. These rocks lie immediately west of a belt of limestone, evidently being younger than the limestone, though it is not known whether the contact represents uncomformity or intrusion. Granite is intrusive into the greenstone on the shore of Iliamna Lake.

A small area of schistose amphibolite of indeterminate origin lies along the contact between granite and rhyolites near the mouth of Pile Bay. It is much more altered than any of the greenstones above described, being essentially a schist.

Somewhat similar green schist (probably chloritic schist) occhrs on the south shore of Kakonak Bay near its head. The neighboring rocks are much younger altered volcanic rocks, which are believed to be unconformable above it and here locally cut through by erosion.

Schistose greenstone was also seen on the west shore of Lake Clark opposite the mouth of Currant Creek.

UNALTERED MESOZOIC ROCKS.

The shore of ,Cook Inlet from Tuxedni Bay to the head of Kamishak Bay, except at the heads of some of the deeper bays, is occupied by a thick series of unaltered Mesozoic sediments. These beds form a section with which the rocks of the Iliamna Lake region must be compared and in terms of which the age references must be in large part expressed. It is consequently important to describe this section somewhat in detail, although it lies largely outside the proper geographic limits of this paper.

UPPER TRIASSIC CHERTS.

The lowest known member of the unaltered Mesozoic sediments exposed on the west shore of Cook Inlet comprises a series of black, green, and dark-red chert with subordinate amounts of shale and limestone. These rocks are well exposed on Bear Cove and Bear Bay At the former place the thickness probably exceeds 2,000 feet, although the beds are so disturbed that no accurate measurement has been made. The shales and limestones at these localities carry *Pseudomonotis subcircularis* and *Halobia superba,* which show the age of the rocks to be Upper Triassic.

These beds extend northward in an apparently continuous belt from Bear Bay to the south shore of Cottonwood Bay, near its head. At this locality several hundred feet of chert is exposed in the cliffs just east of the low pass leading southward to Bear Cove.

In the lower part of the section at Bear Cove there are large amounts of fine-grained green igneous rock, intimately but obscurely associated with the chert. It is somewhat doubtful whether this rock is intrusive or interbedded. It is somewhat altered, especially in the developme'nt of epidote, and resembles in a way the greenstone at the head of Cottonwood Bay.

LOWER JURASSIC (?) PORPHYRIES AND TUFFS.

Overlying the chert on the south shore of Cottonwood Bay is a thick series of volcanic beds which includes both flows and tuffs. Amygdaloidal basalt and volcanic agglomerates are among the more

characteristic rocks of this series. Similar rocks were seen on the north shore of Iliamna Bay, where they include fine-grained green and gray felsitic rocks and tuffs, in part cherty, invaded by large dikes of quartz-feldspar porphyry; and also on the south shore of Bear Cove where quartz porphyry tuff, andesite, and andesitic and rhyolitic agglomerates are present. The belt also extends northward from Iliamna Bay, being exposed on the west and north shores of Iniskin Bay, where basalt, gabbro, and tuff are present; near the head of Chinitna Bay, where it includes olivine basalt and tuff; and on the upper arm of Tuxedni Bay, where quartz porphyry, augite andesite tuff, and quartz porphyry tuff were seen.

These rocks accord fairly well in their relation with the Upper Triassic chert, as also in general lithologic character with the Lower Jurassic tuffs, which are exposed on Seldovia Bay and Port Graham. These beds were referred by Stanton to the Lower Jurassic on the basis of the fauna obtained at Seldovia.

No Lower Jurassic faunas have been found west of Cook Inlet, but the volcanic beds on the west shore of Cook Inlet, described above, and also those near Iliamna and Clark lakes, to be described later, may possibly be correlated with the Lower Jurassic rocks of Seldovia on the evidence of similar lithology and sequence.

The shore of Iliamna Lake from a point near the mouth of Pile Bay, 15 miles below the head of the lake, to a point 27 miles below the head of the lake, is composed of quartz latite and quartz latite tuff. The same rocks occur near the head of Kakonak Bay and along the south shore from 4 miles west to 7 miles west of Kakonak village and from 25 miles east to 19 miles east of the outlet of the lake. These rocks show considerable difference in lithologic character from the volcanic rocks already described as occurring on Iliamna Bay and elsewhere on the west coast of Cook Inlet. They appear, however, to correspond with those rocks in general relation to the neighboring rocks, although definite evidence of their age and relations is almost lacking. The same statements apply concerning their relation to the rocks described below.

Large areas around Lower Tazimina Lake and thence northward to Lake Clark are underlain by a group of rocks of porphyritic texture, ranging in composition from acidic rhyolites through quartz porphyries, trachytes, and mica andesites to intermediate hornblende andesites. Associated with these are tuffs, some composed of angular fragments of porphyry embedded in either a felsite or a porphyry base, or again in a fine fragmental base, and others composed chiefly of fine feldspar crystals and fragments in a finely comminuted base. The relation of these rocks to one another seems to be that of a succession of products of volcanic eruption. The various types, in so far as any structures are discernible, seem to lie in successive or

alternating belts. This is particularly well shown on and near the mountain 8 miles north of the mouth of Chekok River, where a similar order of succession is encountered on the southeast and north sides. About 5 miles south of Tanalian Point there are porphyries distinctly interbedded with tuffs, the whole formation there having a minimum observed thickness of 2,000 feet, with a uniform strike of N. 65° W. (magnetic) and a dip of 25° NE. All these rocks are indurated but are internally undeformed and are altered only by weathering processes.

Pine-grained granular rocks occupy an area extending northward from the head of Lower Tazimina Lake for about 4 miles. These rocks are of very fine grain, of light color, locally with porphyritic texture, and in many places miarolitic. They show considerable variation in appearance and the distribution of the different types of rock suggests a series of thick flows in approximately horizontal position. These rocks should probably be considered part of the porphyry and tuff formation, rather than be grouped with the neighboring granites. They have about the same range in composition as the porphyries and tuffs and, though granitic, they are generally also fine-grained porphyritic and miarolitic in texture, indicating crystallization under slight pressures, perhaps of thick flows at the surface. They seem to have the same bedded-flow distribution as the porphyries and tuffs, which they adjoin directly on the north and west.

MIDDLE JURASSIC BEDS.

The lowest known member of the Middle Jurassic of southwestern Alaska consists of at least 1,100 feet of sandstone and shale with a few thin beds of conglomerate and limestone. These beds are well exposed on the south shore of Tuxedni and Chinitna bays and on the east shore of Iniskin Bay. Their abundant and characteristic fauna is regarded by Stanton as indicating that they include at least part of the Lower Oolite or Middle Jurassic. At Iniskin Bay they rest unconformably upon beds of greenish basalt. Beds of somewhat similar lithologic character and with the same fauna have been found in the upper end of the Matanuska Valley and in the Alaska Range.

These beds are overlain conformably by a higher but lithologically and faunally distinct member of the Middle Jurassic, consisting of 1,300 to 2,400 feet of shale with subordinate amounts of sandstone and limestone. These beds are typically exposed on the north shore of Chinitna Bay, and are also known in a continuous belt extending from that place parallel to the shore of Cook Inlet northward to Tuxedni Bay and southward to Iniskin Bay. Detailed sections at Chisik Island, Oil Bay, and Iniskin Bay on Cook Inlet and at Cold

Bay on the Alaska Peninsula have been described. The rocks are also known to occur in the upper Matanuska Valley. These beds carry a characteristic marine fauna, marked by the presence of various species of *Cadoceras* and by other associated forms. It is regarded by Stanton as the equivalent of the Callovian, which belongs at the base of the Upper or at the top of the Middle Jurassic. These two members of the Middle Jurassic have previously been grouped as the Enochkin formation.

UPPER JURASSIC BEDS.

The Middle Jurassic shales just described are overlain on Chisik Island and on the east shore of Iniskin Bay by a varying thickness (probably 100 to 300 feet) of predominantly coarse conglomerate consisting of pebbles of granite (more rarely other crystalline rocks) in an andesitic tuffaceous matrix. This bed is probably of very local development, not having been definitely recognized elsewhere in this region, except possibly on the east shore of Oil Bay. Its age is determined within approximate limits by the presence of Middle Jurassic faunas below it and of Upper Jurassic faunas above. In lithologic character (presence of andesitic tuffs) it is more nearly related to the rocks bearing the latter than to those bearing the former fauna, and hence it may be most reasonably interpreted as the basal conglomerate of the Upper Jurassic. A conglomerate of similar lithology, at about the same stratigraphic position, occurs in the upper Matanuska Valley.

The beds which overlie the conglomerate just described, or in its absence rest upon the uppermost shales of the Middle Jurassic, consist of about 5,000 feet of shale, sandstone, arkose, andesitic tuff, and conglomerate. Some andesitic flows are also probably present. These rocks are the equivalent of the Naknek formation of Spurr, the type locality of which is on the shores of Naknek Lake, Alaska Peninsula, where the beds on which the original description was based consist largely of granitic arkose and conglomerate. These beds extend from Naknek Lake over a broad area in the vicinity of Katmai, Cold Bay, and Becharof Lake, and also occupy the shore of Cook Inlet from Tuxedni Bay to Iniskin Bay and much of the shore from a point near the mouth of Iliamna Bay to the south shore of Kamishak Bay. They carry a marine fauna characterized by the presence of Aucella *pallasi* and *Cardioceras*, on the basis of which they have been correlated with beds in the Matanuska and Copper River valleys and on the west end of the Alaska Peninsula, and which show their relation with rocks carrying Upper Jurassic faunas in California, in the Black Hills, in Russia, and throughout the European boreal region.

GRANITIC ROCKS.

Granitic rocks of considerable diversity of character, including granites of various kinds and quartz diorite, occupy the greater part of the area of the Chigmit Mountains from the head of Bear Bay northward beyond the head of Lake Clark and Tuxedni Bay. The rocks probably constitute one large, continuous area, with many smaller ones along its margins. Several of these were seen on Lake Clark. The margin of another mass was observed on the northern flank of Mount Douglas. This is probably the north end of a large mass in the Aleutian Range, which is in all probability widely detached areally from the Chigmit Mountain mass, although it is doubtless closely related in lithologic character and period of intrusion.

The granitic rocks are known to cut all the rocks described above, except the Upper and Middle Jurassic rocks of the coast of Cook Inlet. This relation, together with the presence in the Upper Jurassic and probably also Middle Jurassic conglomerates of pebbles of granitic rocks similar to these, points strongly to the late Lower Jurassic or early Middle Jurassic as the date of intrusion.

TERTIARY ROCKS.

SEDIMENTARY BEDS.

Shale, sandstone, and conglomerate of Tertiary age were observed in one small area on the north slope of Chinitna Bay and covering larger areas in the vicinity of Cape Douglas. The character of the exposures did not permit an estimate of the thickness of the beds in either district. Fragmentary fossil leaves were found, but neither they nor the character and sequence of the rocks are sufficient to warrant detailed correlation with the Tertiary (Kenai) beds so well exposed on the east coast of Cook Inlet. The recognized species all occur in the Kenai flora, and there is no doubt of the general equivalence.

BASALTIC FLOWS AND TUFFS.

Most of the shores of Iliamna Lake below the large islands at the mouth of Pile Bay, except those covered by sand and gravel, are made of basaltic rocks, including effusive sheets, tuffs, and probably some intrusive dikes and sills. A few thin beds of sandstone and shale were observed. These rocks cap all the high hills northeast of Intricate Bay, descending westward and reaching the lake shore just north of the end of the peninsula north of Intricate Bay. The basaltic rocks of this part of the area have a gentle westward dip, but are otherwise not folded. The islands of Intricate and Kakonak bays and the peninsula between them are likewise composed of basalt and basaltic tuffs, the basalt being prominently exposed in flat mesa caps where horizontal and in monoclinal strike ridges where steeply

inclined. At most of the exposures the basalt shows the typical vertical columnar jointing characteristic of such sheets. Basaltic sheets also cap the high hills between Kakonak Bay and Kakonak Lake, many of the lower ridges being of conglomerate or conglomeratic tuff. The latter rock is also to be seen on some of the shores of Kakonak Bay. These basic volcanic rocks, with some interbedded conglomerate, form the greater part of the south shore of Iliamna Lake from Kakonak Bay to a point about 25 miles east of the outlet of the lake. A few small outcrops protrude through the sands and gravels at scattered localities from this place to the mouth of Newhalen River, from which to the cape at the west side of Chekok Bay the shores and islands are composed entirely of these rocks, except on the low beaches. Similar basalts and tuffs cap the high hills west of Newhalen River and Sixmile Lake. Basaltic masses, probably dikes or sills, occur at scattered points along the west shore of Lake Clark as far north as the head of Chulitna Bay.

Basalts, probably to he correlated with those already described, cap a group of high hills north of Chekok Bay and the low hill on the east side of Lake Clark, about 7 miles northeast of Tanalian Point.

These basaltic rocks are considered much younger than the rhyolitic and andesitic lavas and tuffs already described. They are mostly unconformable upon the more acidic volcanic rocks, though in part intrusive into them. The sandstones that are probably at the base of the basaltic rocks have yielded a few fossil plank, which have been referred to the Tertiary.

Small porphyry dikes, which cut all the other rocks, were seen on the shores of Iliamna Bay. They are younger than the granite and possibly belong to the Tertiary period of intrusion.

QUATERNARY DEPOSITS.

The Quaternary deposits of this region include the flood-plain and delta deposits on the present streams; beach and lagoon deposits on the shores of Cook Inlet and of the lakes; terrace deposits, which are best developed around the lower ends of Iliamna and Clark lakes; a rather small amount of glacial till; and the lava and ash of the active volcanoes.

MINERAL RESOURCES AND MINING DEVELOPMENT.

INTRODUCTION

During the last decade prospectors have located in this region lode claims of copper, silver, and gold, placer-gold claims, and petroleum claims. On some of these development work has been begun. One group of copper claims has been entered for patent. On many of the

claims, however, not even bona fide "assessment work" has been done. In justice to the prospectors it should be said that the district's remoteness from usual lines of travel in Alaska, the earlier scarcity of supplies, and the unreliable transportation service have held back the development. Only brief descriptions of the claims visited in 1909 by the Survey party and of those about which reliable reports were obtained will be attempted here. Each claim or group of claims discussed is taken up in the order of geographic occurrence westward and northward from Iliamna Bay.

LODES.

DESCRIPTION OF CLAIMS.

Several lode claims have been staked on or near the shores of Iliamna Bay. One of these is on Diamond Point, near the entrance to Cottonwood Bay. The country rock is granite, locally intruded by small dikes of porphyry, with the contact of a large mass of greenstone several hundred feet away. The supposed ore body consists of a shattered and much weathered zone 4 to 12 feet wide on Iliamna Bay and apparently 100 feet or more wide on Cottonwood Bay, in which the granite is thoroughly crushed and impregnated with narrow veins and stringers of pyrite. No other sulphides were recognized and no authentic information could be procured concerning assay values, although it was rumored that $2 a ton in gold had been obtained.

Other claims have been staked on the south shore of Iliamna Bay near its mouth. These claims were not examined, but the shore of the bay here is formed of limestone and igneous rocks, some of which were seen to be locally fractured and impregnated with pyrite.

The Keyes prospects are on the Copper King group of claims, located by the late Charles M. Keyes in 1905. At the time they were visited by the Survey party snow covered much of the property, but two prospect holes were found on the Black Prince claim, about 1⅓ miles west of the head of Iliamna Bay and one-third mile south of the main trail to Iliamna village, at an elevation of 1,000 to 1,500 feet, near the contact of hornblende granite and greenstone. The surface exposures consisted of irregular, nonpersistent masses of garnet rock and crystalline limestone, the latter having a maximum observed thickness of about 20 feet. The garnet rock is cut by smaller veins of quartz and epidote. The ore body exposed in one of the prospect openings is magnetite impregnated with chalcopyrite. The other prospect opening was filled with snow.

The Dutton prospects are about 9⅜ miles west-northwest from the head of Cottonwood Bay, and 6 miles southwest of Iliamna village. A good 14-mile trail on easy grade, about three-fourths of which has

been made into a wagon road, has been built from Cottonwood Bay to the prospects as a part of the development work on the property. The prospects are also reached by a steeper 6-mile trail from Iliamna village. The region is one of bold relief, and the neighboring mountain peaks rise abruptly from elevations near sea level to about 4,000 feet. The prospects lie along the flank of one of the higher peaks and extend from a point in a col on the Iliamna village trail, at an elevation of 1,900 feet, about 2½ miles southwestward to an elevation of approximately 1,200 feet.'

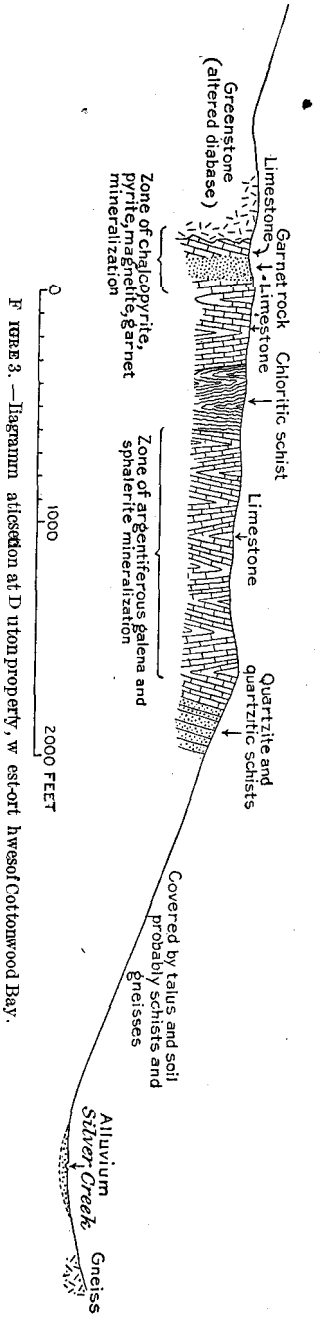

FIGURE 3.—Diagrammatic section at Dutton property, west of Cottonwood Bay.

The property was located in 1902 by George W. Dutton, Silas J. Goodro, and Pierce Thomas. It is controlled by the Dutton Mining Company, which conducted active development work during 1904 and 1905 and more or less desultory work since then. The property has been developed by the construction of 11 miles of wagon road and 3 miles of trail from Cottonwood Bay, two houses, two barns, and a blacksmith shop. Three short adits and a shallow shaft with 46 feet of drift, all of which were blocked at the time of the visit by the Survey party, and numerous surface cuts comprise the actual mining work. A considerable amount of mining machinery and building materials and equipment for a smelter lie scattered along the road all the way from Cottonwood Ray to the prospect. The claims have been surveyed and entered for patent, which, it is reported, the owners expected to procure in the winter of 1909–10.

The claims lie along the northwest side of a limestone belt. On the northwest are greenstones (probably altered diorites and more basic rocks), and on the east are quartzitic slates and gneisses. (See fig. 3.) The mineralized zone, averaging 200 feet in width and locally 300 feet, is partly in the greenstone, but chiefly in the limestone, and contains chalcopyrite, pyrite, garnet, magnetite, calcite, quartz, and amphibole, and lesser amounts of other minerals. There are local developments, in considerable bandlike

masses paralleling the strike of the limestone and the mineralized zone, of nearly pure garnet rock and magnetite rock and of garnet-magnetite rock. Iron oxides and copper carbonate are the only secondary minerals noted. They are unimportant, and rarely constitute more than a thin film. Glaciation has almost entirely removed whatever gossan there may once have been.

The average values in the ores, as reported by those in charge of the Dutton properties in 1909, are 4 to 6 per cent of copper and 2 ounces of silver and $1.50 in gold to the ton. Lead values are unusual, though it is said that at one opening 6 per cent of lead with 9 per cent of copper was found on the east side of the ore zone. It is asserted that one drift at a depth of about 27 feet developed 46 feet of ore containing 13½ per cent of copper.

There is no timber on the claims. Logs may be brought by an easy trail from the forested region 6 or 8 miles to the southwest. The prospects are situated about 9 miles from the outlet of several small lakes lying about 500 feet above and draining into Iliamna Lake. It is possible that a hydro-electric power installation here would assist, during the summer months at least, the working of these claims.

Adjoining the Dutton properties on the east are the claims of W. E. and E. Duryea. These are on the limestone, and hence the group of prospects is locally spoken of collectively as the "lime belt." The discovery and first locations were made in 1905. The development work consists of a house, trails, a number of shallow pits or shafts, and two adits about 300 feet in combined length. One of these adits was opened on a gulch about 500 feet below a surface prospect, in the expectation of cutting the vein. It had not, at the time of the visit, been driven far enough. The other, begun a short distance below a vein shown in a shallow surface opening, has reached what is regarded as the foot wall of the lode. Further development during 1909 was hindered by lack of powder and other supplies.

The limestone has been cut nearly at right angles to its strike by many small, nearly vertical, dikes, of which 27 were seen which had widths of 3 feet or less. Several larger dikes and irregular masses were also observed, most of which are parallel to the strike of the limestone. In a number of places on the bare limestone surface small chunks and nodules of black manganiferous iron oxide have been found, and wherever these localities have been explored by test pits argentiferous galena-sphalerite lodes have been found along fissures in the limestone. Near the eastern margin of the limestone there seems to be indicated, by patches of manganiferous gossan and by test pits, a more or less persistent mineralization through a distance of 5,000 feet on a fissured zone in the limestone, striking about 20° east of north (magnetic) and standing approximately vertical. A cliff in the tributary gulch of Silver Creek crosses this zone

and exposes, through a height of 50 feet or more, much oxidized ledge matter. The width of this mineralized zone on the Silver Bell claim is estimated by the owners at 75 feet. The distribution of other showings on the surface and in test pits would seem to indicate that there has been mineralization along various fractures or fracture zones.

Values as reported by the owners for selected samples are as follows: On the Silver Bell claim, gold $20, silver 195 ounces, lead 35 per cent, and zinc 15 to 20 per cent; on the Ida G. claim, gold 3 ounces, silver 196 ounces; on the War Eagle claim, silver 80 ounces, lead 50 per cent. The black manganiferous gossan carries from 2 to 5 or 6 ounces of silver to the ton.

Other silver lode claims have been staked for a distance of 1½ miles southwest from the Duryea prospects, but no work has been done on them.

The Durand prospect, on Success No. 1 and No. 2 claims, is about a mile from the shore of Pile Bay and 23 miles below the mouth of Iliamna River, at an elevation of about 1,000 feet. It is about 3 miles northwest of the Dutton prospect. The ore body is a 10-foot quartz vein, striking N. 80° E. (magnetic) and dipping 45° NE., in schistose greenstone. The vein contains rather uniformly disseminated masses of chalcopyrite and pyrite. The hanging wall is impregnated with pyrite for 4 feet from the vein. The development work comprises a cabin, about a mile of trail, and two shallow prospect pits.

About 2 miles north of the shore of Knutson Bay, on Iliamna Lake, is the Knutson prospect, which was not visited by the Survey party. It is reported to be a quartz vein in granite, bearing copper minerals and gold and silver. The only development work reported is a cabin on Iliamna Lake, a trail to the claim, and a shallow pit.

The Millet copper prospect, on the north shore of Iliamna Lake, is about 25 miles west of Iliamna village and 15 miles east of Newhalen River. The ledge runs N. 35° W. to N. 40° W. (magnetic) up a low knoll from a point near the head of a small bight. In 1906 O. B. Millet staked four claims along this ledge. The development work includes a house, a blacksmith shop, a trail along the lode, seven open crosscuts from 22 to 42 feet long and averaging 4 or 5 feet in depth, and a shaft 16 feet deep. The prospect is on a dense bluish-white crystalline limestone and parallels the contact of a dark fine-grained trap or altered basaltic rock. This contact is not exposed, and therefore its nature is not known. Near the lake shore there is a thin capping of tuffs and porphyritic flows covering both basalt and limestone. The surface indication which led to the discovery is a weathered and deeply iron-stained limestone with limonite, both very slightly copper stained. The ledge has been traced for 3,500 feet, is 22 to 42 feet wide, and consists of dark-blue crystalline limestone,

much shattered and broken, at intervals of 1 to 8 or 10 feet by shear zones having a trend N. 35° to 45° W. (magnetic), and dipping from 75° NE. to vertical. The walls are shattered crystalline limestone, whitish to gray-blue, healed by white calcite seams. The mineralization is in stringers a fraction of an inch to 10 feet in thickness, some of which are of pyrite and chalcopyrite and others of calcite and quartz, with black oxidized iron and copper minerals. The surface of the ore stringers shows limonite and black oxidized iron, copper minerals, and copper carbonates. Complete oxidation is limited to the surface and cracks or fracture zones in the sulphide bodies, where it extends downward 2 or 3, rarely 7 or 8, feet. Mr. Millet reports that a picked sample assays gold $2 to the ton and copper 10 per cent. An estimate, somewhat unreliable because of the black weathering products which mask both country rock and ore in the old faces of the cut, makes the entire sulphide content of the ledge at least 5 per cent. Not much large timber is available on the claims, but large spruce is abundant about 15 miles farther east on the lake.

The Aukney claim (staked, according to the location notice, by S. A. Aukney October 16, 1908) is situated on the south shore of Iliamna Lake, 23 miles from the outlet of the lake. The rocks as exposed in the lake cliffs consist of tuffaceous and cherty beds striking northeast, parallel to the shore, and dipping from vertical to 75° SE. They contain much fine disseminated pyrite, which where oxidized give them a bright-yellow stain. No sulphides other than pyrite could be recognized visually and nothing is known as to what precious metals they may contain. The only work done on the claim is a little blasting on the face of the cliff.

The Hardenberg prospect lies on Kasna Creek at an elevation of 2,200 to 2,300 feet, about 1½ miles from the south shore of Kontrashibuna Lake. It is about 10 miles from Tanalian Point, on Lake Clark, whence it is reached by trail and boat. The claims were staked in 1906 by Charles Brooks and C. von Hardenberg. No development work has been done except the building of a house and a cache on the lake and a trail from them to the prospect. The ledge is in a limestone and approximately parallel to its strike—about north (magnetic). The contacts of the mineralized body with the limestone are masked. by slide and soil. Within a zone about 75 feet wide are various bands, some of specular hematite with a little quartz and chalcopyrite; others of micaceous specular hematite, chalcopyrite, quartz, and calcite in a hard gray gangue composed in part of an amphibole; and still other small irregular stringers of chalcopyrite, pyrite, and quartz—all in a much shattered dense limestone. There is very little oxidized material, probably because the region has been thoroughly scoured by glaciation. In the absence of exploratory tunnels, shafts, etc., and because of the masking talus gnd soil it is difficult to make out the relations of the mineralized bands or to

estimate their proportions. There appear to be two hematite bands, 7 to 10 feet thick, and three or four zones of similar width which contain chalcopyrite with other minerals. Perhaps the total chalcopyrite aggregates 8 per cent of the mass and may be locally segregated in bodies large and rich enough to constitute ore.

This prospect is about 40 miles from Iliamna Bay and now is accessible only by a roundabout route through Iliamna and Clark lakes. Its development, therefore, is sure to be retarded. A timber supply more than sufficient for development purposes exists immediately below the prospect. Water rights and a power site have been staked by some of the men interested in the property at the falls of Kontrashibuna River, the outlet of Kontrashibuna Lake, 8 miles from the prospect. There is a fall of 60 feet here and a large flow during the summer months, so that sufficient power might be developed to assist materially in the working of the claims. There is another fall on the river entering the head of Kontrashibuna Lake.

It is reported that on the north side of Kontrashibuna Lake another copper prospect has been staked.

SUMMARY.

To speak broadly, it may be said that three classes of ore occurrence have been found in this region—deposits in limestones at or near the contact of igneous rocks; quartz veins in granites and greenstones, some of which are associated with porphyry dikes; and pyritized fracture zones in various rocks, some of which are healed by quartz.

The most promising of the present locations are on deposits of the first-named class. Although generalization regarding ore occurrence in the region is hardly warranted by what is known of the few prospects so far located, yet it is perhaps indicated that the limestone belts, especially along their contacts with igneous rocks, will be the more fruitful fields for prospecting. The larger of the known copper deposits are restricted to the limestones, which have not been found to have a very wide distribution, but they have not been prospected throughout their known extent. The silver-bearing lead and zinc lode south of Iliamna village, another promising prospect, is also in the limestone. It seems probable, from such meager data as are at hand, that the mineralization of the limestones is genetically related to the intrusion of igneous rocks, probably diorites, now altered to greenstones.

The Iliamna region offers to the prospector the advantages of accessibility, good exposures, a fair timber supply, and water power. Transportation within the region is no more seriously handicapped than in many other parts of Alaska. There appears to have been less prospecting than might be expected, for the region offers certain facilities and attractions for that pursuit. Though not along any

of the usual lines of travel in Alaska, the district is easily accessible and supplies are readily obtainable. The region lies in the border land of the forests and the tundras and is without the thick mantle of plant growth of either province in areas of their more characteristic development. Consequently travel is comparatively easy and rock exposures are good and abundant. There is sufficient timber in the valleys for building, mining, and fuel during the prospecting and early stages of development. Water powers, especially in the Newhalen, Kontrashibuna, Tazimina, Copper, and Kakonak river basins, invite development and application to mining. Except for the localities directly on the shores of Cook Inlet or Iliamna Lake, transportation of supplies and mining products would encounter the difficulties of a mountainous country. However, the experience with the Iliamna and Dutton trails indicates that conditions are favorable for the maintenance of wagon roads. A preliminary survey of a railroad from Iliamna Bay to the Kuskokwim has been made across this region. Such a railroad would serve as a trunk line from which the several prospects could be reached by wagon road or branch railroads without excessive grades. Transportation at present is effected chiefly by small boats on Iliamna and Clark lakes. Supplies are brought from Iliamna Bay to the village by packing on horses or natives or by sledding in the winter. Some are brought from Bristol Bay by gasoline launches. Between Iliamna and Clark lakes there is a 5-mile portage, which is accomplished by native packers.

If this region reaches the productive stage of development, fuel will have to be brought in.

PLACER DEPOSITS.

There has been some desultory effort to prospect placers on the streams tributary to Lake Clark from the north. From Caribou Creek, a northeasterly tributary of Chulitna River, fine gold but no pay is reported. On the headwaters of Kijik River the alluvium of Kellet Creek and Ingersol, Lincoln, and Franklin gulches is reported to be auriferous. On Portage Creek, entering Lake Clark about 35 miles above the outlet and heading against the streams just mentioned, one man, now dead, is said to have done considerable work. He took out about $40, all coarse gold. The alluvium was found to be about 12 feet deep and composed chiefly of large glacial bowlders.

PETROLEUM.

The lowlands on the coast of Cook Inlet, especially between Chinitna and Iniskin bays, have been extensively staked as petroleum land and several wells have been drilled. The geology and indications of petroleum in this district have been already described.[a] No drilling has been done since 1906 and the oil camps are now abandoned.

a Martin, G. C., Bull. U. S. Geol. Survey No. 250, 1905, pp. 37-49.