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PRELIMINARY REPORT ON THE GEOLOGY AND OIL POSSIBILITIES OF THE KATALLA DISTRICT, ALASKA

By

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This report and accompanying illustrations are preliminary and have not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature

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INTRODUCTION

The Katalla district is on the Gulf of Alaska, 35 to 75 miles southeast of Cordova (fig. 1). The district, as defined in this report, extends from the valley of the Copper River eastward about 40 miles to the western margin of Bering Glacier, and from Kayak Island northward about 55 miles to the southern front of the Chugach Mountains (fig. 2). The district includes the western part of an arcuate lowland and front range belt--underlain mainly by sedimentary rocks of Tertiary age--which extends about 300 miles along the south coast of Alaska, between the Chugach and St. Elias Mountains and the sea (fig. 1). Oil seeps were discovered in the Katalla district, and also in the Yakataga district to the east, about 1896. Subsequent drilling in the vicinity of the largest seeps in the Katalla district led to the discovery in 1902 of the Katalla oil field. During the 32-year period from 1902 to 1933 this field produced about 154,000 barrels of high-gravity paraffin-base oil, the only commercial production of oil in Alaska to the present time.

The purpose of this report is to summarize the present status of information on the geology of the Katalla district as related to oil possibilities. The report is based mainly on geologic investigations undertaken in the Katalla district in 1944 and 1945 as part of the program of War-mineral investigations of the Geological Survey. In 1944 a Geological Survey party consisting of Darwin L. Rossman, Charles A. Hickcox, and the writer spent about 4 months, from June 6 to September 28, mapping the geology of the oil field and adjacent area (the Katalla area) and making a detailed stratigraphic study of the rocks exposed there (Miller et al., 1945). The preliminary geologic map resulting from the 1944 investigation constitutes figure 4 of this report. In 1945 a Geological Survey party spent about 5 months, from April 30 to October 2, in mapping the geology of Gandil Mountain, Nichawak Mountain, and Mount Campbell (the Nichawak area, fig. 5) in approximately the same detail as the Katalla area, and also in making less detailed geologic studies of other parts of the Katalla district. Richard M. Vosburgh assisted the writer in this work from April 30 to August 16, 1945.

GEOGRAPHY

The Katalla district lies on the south flank of the Chugach Mountains. The district comprises a northward-trending high ridge (Ragged Mountain); groups of generally lower and less rugged mountains or hills that are in part separated from each other and from the Chugach Mountains to the north by alluvial lowlands, ice, or water; and islands lying off the coast (fig. 2). Several parts of the Katalla district that are more or less distinct geologic and topographic units but lack a single inclusive geographic name are referred to repeatedly in this report. For convenience of reference, these parts of the district are called "areas," and are named after prominent geographic features, as follows:

Mirror Slough area--Low hills in the vicinity of Mirror Slough, bounded on the west by the alluvial lowland of the Copper River, on the north and east by Ragged Mountain, and on the south by the sea;

Katalla area--Isolated group of hills bounded on the west by the valley of the Katalla River, on the north and east by Bering Lake and the Bering River, and on the south by the sea;

Martin Lakes area--Hills in the vicinity of the Martin Lakes, bounded on the west by Ragged Mountain, on the north by Lake Tokun and the valley of the Martin River, on the east by Tokun Creek, Dick Creek, and Bering Lake, and on the south by the headwaters of the Katalla River and Clear Creek;

Bering River area--Hills and mountains in the northeastern part of the district, bounded on the west by the Martin Lakes area, on the north by Martin River Glacier and ice fields at its head, on the east by Steller and Bering Glaciers, and on the south and southeast by Bering Lake and the Bering River;

Nichawak area--Nichawak Mountain, Gandil Mountain, and Mount Campbell, at the west margin of Bering Glacier.

About one-third of the land area shown on figure 2 consists of tidal flats and swampy alluvial lowlands, and nearly one-fourth of the area is covered by ice. The bedrock uplands rise abruptly from lowlands, ice, or the sea to maximum altitudes of about 3,300 feet in the western part of the district (Ragged Mountain) and about 5,000 feet in the northeastern part of the district.

Spruce and hemlock are the prevailing trees in the district. They grow on some of the better drained lowlands and on the higher slopes to an upper limit ranging from about 700 to 1,700 feet. A thick growth of willow, alder, salmonberry, and devil's club covers the better drained lowlands and the slopes where timber is lacking or is not dense, and extends a short distance above timber line. The tidal flats and poorly drained lowlands generally are covered with grass and small bushes.

The amount of precipitation in the district is large, probably 150 inches or more per year. May, June, and July usually are the months most suitable for field work, though a large proportion of rainy or cloudy days may be expected even in these months. The temperature rarely falls below 0° F. in winter or rises above 75° F. in summer. East and northeast winds usually are accompanied by rain and stormy weather, west and southwest winds by clear weather.

In 1944 and 1945 the only regularly scheduled transportation to the Katalla district was by a plane that carried mail, passengers, and freight monthly from Cordova. Planes or small boats can usually be chartered at Cordova, however. At low tide the sand beach bordering Katalla Bay east of the town of Katalla provides an excellent landing place for small planes. Planes equipped with pontoons can land in the sloughs along the coast, on the lower part of the Bering River, on Bering Lake, and on any of the larger lakes in the northern part of the district except the Berg Lakes. At high tide small fishing boats can go up Martin River Slough, Mirror Slough, up Katalla Slough as far as the refinery site (see fig. 4), up the Bering River to Bering Lake, and up Kwinlatah Slough to the foot of the Suckling Hills. Light skiffs or canoes can be lined up the Martin River, the lower part of the Katalla River, the lower part of Shepherd Creek, and up most of the rivers that drain from Bering Glacier. Large boats can anchor in Katalla Bay or Controller Bay and, when the weather is fair, passengers and freight can be carried to shore in small boats or scows. The waters adjacent to the Katalla district and local navigational aids and hazards are described in the United States Coast Pilot 1947, pp. 81-85.

Land travel in the Katalla district is difficult because of thick brush except on ridges above brush line, on trails, and on some of the river bars and lowlands. In 1944 and 1945 much of the road that formerly extended from Katalla to the mouth of the Bering River (fig. 4) and most of the trails in the district were grown over with brush and were difficult or impossible to follow. The part of the abandoned road between the refinery site and Redwood Creek (fig. 4), the road from the Nichawak River to Nichawak Mountain (fig. 2), and the trails from the oil field to Cave Point and Redwood Bay (fig. 4) were in fair condition.

In 1944 and 1945 most of the permanent residents in the Katalla district, totaling about 12, lived at the town of Katalla. At that time the only habitable buildings in the district were on Martin River Slough, at Katalla, at the oil field, near the mouth of the Bering River, on Shepherd Creek, on Big Martin Lake, at the southwest end of Nichawak Mountain, at the southwest end of Mount Campbell, on Wingham Island, and at the south end of the Suckling Hills. (See fig. 2.) Fishing and trapping are the principal occupations of the residents of the district.

Additional information on general geographic features and early history of exploration and development of the Katalla district is given in reports by Martin listed in the section following.

GEOLOGIC INVESTIGATIONS

EARLY INVESTIGATIONS

Systematic geologic investigation of the Katalla district (formerly called the Controller Bay district), particularly of the oil and coal resources, was begun in 1903 by G. C. Martin and was continued in 1904, 1905, 1906, and 1915 by Martin and other geologists of the Geological Survey. The results of these investigations have been published in two reports by Martin (1908, 1921). Of the many private investigations in the district, those by Taliaferro (1932) in 1920 and by a group of oil-company geologists (1938) in 1938 were the most comprehensive.

SCOPE AND METHODS OF RECENT INVESTIGATIONS

The 1944-1945 investigations of the Geological Survey, having the objective of obtaining geologic information useful in appraising the oil possibilities of the Katalla district, were concentrated in two areas--the Katalla and Nichawak areas--which include the oil field and a large proportion of the known oil seeps. More than two-thirds of the field time was devoted to geologic mapping and stratigraphic studies in these areas. Geologic features and note stations were plotted in the field on vertical aerial photographs having an average scale of about 1 inch to 1,800 feet, and were later transferred to base maps of slightly smaller scale. During the latter part of the 1945 season other parts of the Katalla district--the Suckling Hills, the Martin Lakes area, the Mirror Slough area, and parts of Wingham and Kayak Islands--were mapped in less detail on aerial photographs where these were available, on published topographic maps, or by means of pace and compass traverses. The Bering River area--as defined in this report, the part of the Katalla district in which coal-bearing rocks are exposed--was not examined on the ground during the recent investigations except for a few reconnaissance traverses at the western margin. The geology of this part of the district, as shown on figure 2 and described in the text, is based mainly on the report by Martin (1908). Interpretation of the geology of the part of the district adjacent to the Chugach Mountains, which was not examined on the ground during the recent investigation nor, so far as is known, in any previous investigations, is based on the writer's study of aerial photographs and on information obtained during several reconnaissance flights over the area.

The Mollusca, which constitute the bulk of the fossil collections made during the 1944 and 1945 seasons, were identified by H. E. Vokes of the Geological Survey and the Johns Hopkins University. Vokes also reexamined part of the collections of Mollusca made in the Katalla district earlier by Martin and his associates. R. W. Brown, C. W. Cooke, and J. A. Cushman, all of the Geological Survey, identified, respectively, the plants, the Echinoidea, and the Foraminifera. The fossil crabs were identified by H. B. Stenzel of the University of Texas.

The base maps accompanying this report were compiled from the following sources: (1) published topographic maps of the Controller Bay region (Martin, 1908, pl. 2) and the Chitina quadrangle (Moffit, 1914, pl. 1); (2) unpublished planimetric and topographic maps compiled from vertical photographs, using horizontal and vertical control obtained from the published maps and from barometer traverses; (3) sketch maps made by the writer from aerial and ground photographs or by means of compass-barometer traverses. The previously published preliminary map of the Katalla area, which constitutes figure 4 of this report, has a slightly distorted latitude-longitude grid resulting from inadvertent use of a distorted enlargement of the published Controller Bay map at one stage of the compilation. Some features of the planimetry along the Bering River in the vicinity of the mouth of the Nichawak River also are in error on this map. These errors do not materially effect the geologic interpretation and, to a large extent, are corrected on figure 2. Systematic vertical photography of all the Katalla district except the eastern margin was obtained in 1950; during the 1951 field season the Topographic Division of the Geological Survey plans to get horizontal and vertical field control adequate for photogrammetric compilation of standard mile to the inch topographic maps of this part of the district.

For no part of the Katalla district, in the opinion of the writer, have the geologic studies undertaken up to the present time been sufficiently detailed to warrant positive statements on the oil possibilities. Indeed, because of the complex structure, lack of knowledge of local factors affecting the accumulation of oil, and the fact that bedrock is concealed over much of the district by alluvium or dense vegetation, this probably cannot be accomplished by surface mapping alone. The writer believes, however, that the recent investigations in the Katalla district, aided by the background of information obtained in earlier investigations, have yielded much information of value in appraising the oil possibilities and guiding subsurface exploration, should any be undertaken.

GEOLOGY

DESCRIPTION OF THE ROCKS

The rocks exposed in the Katalla district, so far as known, include pre-Tertiary bedded metamorphic rocks and associated intrusive rocks, a thick sequence of strongly folded Tertiary sedimentary and volcanic rocks, Tertiary or younger intrusive rocks, and Quaternary unconsolidated sediments. The general succession and tentative correlation of the rocks exposed in the district is shown on figure 3. The position and age of some of the rock units is uncertain. In the recent investigation no fossils were found in the pre-Tertiary metamorphic rocks where examined on Ragged Mountain and on Wingham Island, or in the sequence of early Tertiary (?) sedimentary rocks exposed in the Mirror Slough area and on the east flank of Ragged Mountain. A few fossils were found in the formations here assigned to the Eocene, and fairly extensive collections were made from the Katalla formation (Oligocene), and from the younger Tertiary rocks on Kayak Island and in the Suckling Hills. Part of the collections made by Martin and his associates from the Eocene and Oligocene rocks were reexamined. Many of the fossils are poorly preserved and are either undescribed species or long range species that have little value for correlation.

Recent investigations in the Yakataga district, adjoining the Katalla district on the east, have resulted in recognition of an apparently conformable sequence of at least 25,000 feet of marine and continental sediments ranging in age from Paleocene or Eocene to Miocene or Pliocene (Miller, 1951, pp. 9-43). The equivalence of parts of the Tertiary sequences exposed in the adjacent districts has been established with some confidence on either or both lithologic and paleontologic grounds (fig. 3). Hence knowledge of the Tertiary sequence in the Yakataga district is of value in interpreting the age and relative position of some of the stratigraphic units exposed in the Katalla district.

An attempt is made in this report to classify the Tertiary sedimentary rocks of the Katalla district in terms of the standard time divisions of the Tertiary period (fig. 3). This classification is based mainly on comparison by H. E. Vokes of marine invertebrate megafaunas from the Katalla district with faunas of the better known Tertiary sections of Washington and Oregon. (See Weaver, 1942, chart following p. 627; Durham, 1944, fig. 7.) It should be noted, however, that considerable difference of opinion exists as to correlation of the marine Tertiary of western North America with the European type sections on which the standard time classification is based (Weaver et al., 1944, pp. 570-572). This is true especially of the Oligocene epoch and the Oligocene-Miocene boundary.

In earlier published descriptions of the sedimentary rocks of the Katalla district the term shale has been used primarily as a size term, to denote the indurated clastic rocks consisting predominantly of clay and/or silt particles, whether massive or fissile. In this report the term shale is retained as it has been used previously in formal stratigraphic names (formation and member names) or in lithologic descriptions. Where it is desired to emphasize the lack of lamination or fissility that is characteristic of many of the fine-grained clastic rocks exposed in the Katalla district, the terms claystone (predominantly clay particles), siltstone (predominantly silt particles), or mudstone (mixture of clay, silt, and sand particles) (Twenhofel, 1937, pp. 91-98) are used parenthetically. The term argillite is used in this report for an argillaceous sediment hardened by recrystallization, but lacking the secondary cleavage of slate.

Pre-Tertiary bedded rocks and associated intrusive rocks

Pre-Tertiary rocks comprise the bedrock of Ragged Mountain, all of Wingham Island except the southeast end, and the part of the Chugach Mountains bordering the Katalla district on the north (fig. 2). The pre-Tertiary rocks include a thick sequence of slightly to moderately metamorphosed shaly and sandy sediments, limestone, and volcanic rocks. The bedded rocks are intruded by small bodies of granite and more mafic igneous rocks. The pre-Tertiary rocks were subjected not only to the late Tertiary or Quaternary diastrophism that affected the youngest exposed Tertiary rocks in the Katalla district, but also to an early Tertiary or older diastrophism that occurred before the oldest exposed

Tertiary rocks of the Katalla district were deposited. The pre-Tertiary rocks are complexly faulted and folded and are in fault contact with the Tertiary rocks on Wingham Island, along the Chugach-St. Elias fault in the northern part of the district, and probably along the east flank of Ragged Mountain. On the west flank and at the south end of Ragged Mountain, possibly also on the east flank of Ragged Mountain at the southwest margin of the Martin Lakes area, the pre-Tertiary rocks appear to be overlain nonconformably by early Tertiary (?) rocks.

The age of the sequence of bedded metamorphosed rocks exposed in the Katalla district has not been established on paleontologic grounds. Other lines of evidence--the degree of deformation and alteration, the structural relationship to the Tertiary rocks, and the lithologic similarity to better known and more accurately dated rocks in adjacent parts of Alaska--show that they are older than the oldest known Tertiary rocks exposed in the Katalla and Yakataga districts. The Valdez and Orca groups in Prince William Sound and the Chugach Mountains west of the Katalla district, and also the Yakutat group in the vicinity of Yakutat Bay, east of the Katalla district (fig. 1), are similar in lithology and degree of deformation and alteration to the metamorphosed rocks of the Katalla district, and have yielded a few fossils. These groups are now generally considered to be mainly, if not entirely, of Mesozoic age, possibly in part as young as Upper Cretaceous (Smith, 1939, pp. 27, 49-50). Martin (1908, pp. 26-27) reported the occurrence of poorly preserved specimens of Globigerina in metamorphic rocks of the Katalla district, but no location is given and the specimens containing these fossils apparently were not saved. The range of Globigerina is stated by Cushman (1940, p. 289) to be Cretaceous to Recent.

Tertiary rocks

Early Tertiary (?) rocks

Sedimentary rocks tentatively assigned to the early Tertiary are exposed in the Mirror Slough area and possibly also in a narrow belt in the southwestern part of the Martin Lakes area (fig. 2). The rocks consist principally of massive hard fine- to medium-grained light- to dark-gray sandstone, dark-gray to black argillite and siltstone, and massive cobble-boulder conglomerate. The total thickness of the sequence is not known. At least 3,000 feet of interbedded sandstone, siltstone, and argillite is exposed in a conformable section in the ridge north of Mirror Slough, and this apparently is overlain by at least several hundred feet of similar beds, and conglomerate.

On the west side of Ragged Mountain the early Tertiary (?) rocks are compressed into a series of eastward-trending folds. Near the contact with the pre-Tertiary rocks the folding and shearing becomes more intense and the degree of metamorphism approaches that of the pre-Tertiary rocks. For these reasons the exact location and character of the contact of the early Tertiary (?) rocks with the pre-Tertiary rocks is difficult to determine. It is believed that the early Tertiary rocks rest with angular unconformity on the pre-Tertiary rocks on the west side and possibly at the south end of Ragged Mountain. This may be a fault contact, however. On the east side of Ragged Mountain the pre-Tertiary rocks are in fault contact and possibly in part in depositional contact with a sequence of sandstone, shale, and argillite similar in lithologic character to the early Tertiary (?) strata of the Mirror Slough area and possibly equivalent to them. All the observed contacts of the early Tertiary (?) strata with younger rocks are fault contacts.

The rocks referred to above as early Tertiary (?) are so designated mainly because they are not as highly altered as the pre-Tertiary rocks and are only slightly more indurated than the lower part of the sequence that is known definitely to be Tertiary. Martin (1921, p. 18) collected some poorly preserved and undiagnostic plant remains from exposures of arkosic sandstone and argillite on Softuk Lagoon in the Mirror Slough area. Although a careful search was made, no other fossils were found in the early Tertiary (?) rocks during the recent investigation.

Representative specimens of the early Tertiary (?) sandstones, examined in thin section and under the binocular microscope, are seen to consist of sand grains imbedded in a matrix of silt- and clay-size grains. The sandstones, and most of the finer-grained shaly rocks as well, are hard and dense, and appear to have very low porosity and permeability. In spite of these seemingly unfavorable characteristics, a number of small oil seeps and some fairly large gas seeps issue from the early Tertiary (?) rocks of the Mirror Slough area in a belt extending from the wells near Mirror Slough to the north side of Lone Baldy (fig. 2). The question of the ultimate source of the oil and gas is considered on page 60.

Eocene and younger (?) rocks exposed principally in the Bering River area

The Tertiary sedimentary rocks that are exposed north of Bering Lake in the Katalla district were divided by Martin (1908, pp. 24-25, 30-41) into the Stillwater, Kushtaka, and Tokun formations, and were considered by him to be Oligocene or Miocene and probably younger than the Katalla formation. The recent study of the Martin Lakes area, the west border of the Bering River area, and the Yakataga district; and reexamination by H. E. Vokes of the fossil Mollusca collected in the Bering River area by Martin and his associates indicated the following: (1) The Kushtaka, Tokun, and Katalla formations, as defined by Martin, are in apparently conformable sequence, the Kushtaka formation and the lower part of the Tokun formation being Eocene, the upper part of the Tokun formation and the Katalla formation being Oligocene. Furthermore, the upper part of the Tokun formation, as mapped north of Bering Lake by Martin, is equivalent to the lower part of the Katalla formation as mapped south of Bering Lake by Martin. (See fig. 3.) (2) The Kushtaka formation may be the oldest Tertiary formation exposed in the Bering River area, the Stillwater formation, as defined by Martin, being equivalent in part to the Tokun formation and in part to the Katalla formation.

The geology and coal resources of the Bering River coal field (coincident with but slightly less extensive than the Bering River area of this report) are reviewed in a report by Barnes (1951).

Stillwater formation.--Martin (1908, p. 30) defined the Stillwater formation as follows:

> The Stillwater formation occupies the entire valley of Stillwater Creek and extends for some distance up the valleys of Trout and Clear Creeks, eastward to Canyon Creek, and westward probably throughout the entire area of Shockum Mountains. Other areas are on the northern and western shores of Berg Lakes, on the west shore of Kushtaka Lake, and in the mountain north of Bering Lake.
>
> The formation consists of shale and sandstone without characteristic beds so far as is known. No detailed sections have been measured, but the thickness apparently exceeds 1,000 feet. The base of the formation has not been recognized.

The Stillwater formation was thought by Martin to underlie the Kushtaka formation, probably conformably. Several lines of evidence, however, suggest that parts of the Stillwater formation, as mapped by Martin, are equivalent to the Katalla and the Tokun formations and raise some doubt that any part of the formation is older than the Kushtaka formation. The evidence is as follows: (1) Strata on the west side of Dick Creek, assigned by Martin to the Stillwater, are known as a result of the recent field investigation of the Martin Lakes area to be equivalent to the basal shale member of the Katalla formation. (2) W. H. Dall, describing the fossil collections obtained from the Stillwater formation by Martin and his associates (Martin, 1908, p. 31), noted that some of the forms are the same as those found "in the rocks above the coal" (above the Kushtaka formation). H. E. Vokes, on reexamining the same collections, noted the presence of a Pitar? n. sp. that is similar to or possibly the same as a common form in the Basin Creek member of the Katalla formation; of a Nuculana sp. having affinity with N. cowlitzensis (Weaver and Palmer), an upper Eocene species; and of a Nuculana sp. having affinity with N. washingtonensis (Weaver), a middle Oligocene species. (3) Upper Eocene strata in the Yakataga district, correlated on lithologic and paleontologic grounds with the lower part of the Tokun formation as defined by Martin, are underlain with apparent conformity by not less than 7,400 feet of predominantly continental coal-bearing strata designated as units A and B of the lower Tertiary sequence (fig. 3). The younger of the two units, unit B, about 2,400 feet thick, is comparable in lithology to the Kushtaka formation as exposed in the southwestern part of the Bering River area and contains plant remains, identified by R. W. Brown as Daphnogene kanii Heer, that are found also in the Kushtaka formation. Unit A, which is at least 5,000 feet thick and is characterized by (1) numerous beds of anthracite coal, (2) a striped appearance resulting from alternation of light- and dark-colored beds, and (3) beds and concretions of calcareous arkose that weather yellow to yellowish orange, appears to extend from the Yakataga district behind the piedmont bulb of Bering Glacier into the Katalla district and to be continuous with the anthracite-bearing part of the Kushtaka formation as mapped by Martin in the northeastern part of the Bering River area. Although the coal-bearing sequence of pre-Tokun age in the Yakataga district seems thick enough to include the equivalent of the lowest beds of the Kushtaka formation in the Katalla district, it does not show a marine interval that might correspond to the marine Stillwater formation, assumed by Martin to underlie the Kushtaka formation.

The evidence cited above, although largely indirect, does give basis for questioning the validity of at least part of the Stillwater formation, as defined and mapped by Martin, and indicates the need for further study of the formation in the vicinity of the type locality on Stillwater Creek.

Kushtaka formation.--This formation, so far as known, is the only coal-bearing formation exposed in the Katalla district. It is exposed only in the Bering River area and was not studied in any detail during the recent investigations, although parts of the formation were examined on the ground or were seen from the air. The Kushtaka formation is described as follows by Martin (1908, p. 31):

> The Kushtaka formation overlies the Stillwater formation, probably conformably, although as the contacts are in many places faults, the exact relations are none too well known.
>
> It consists predominantly of coarse arkose, although some sandstone and much shale are present. It contains a large but unknown number of coal beds. Marine conditions are not known to be represented.
>
> The thickness exceeds 2,000 feet, the exact total not being known.

A generalized section of the coal-bearing strata (presumably all assigned to the Kushtaka formation) given by C. A. Fisher (cited by Barnes, 1951, p.   ) has a total thickness of about 3,500 feet.

The fossils found in the Kushtaka formation consist mainly of plant remains. These were considered by Knowlton (Martin, 1908, pp. 34-35) to be Miocene, and, according to P. S. Smith (1936, p. 26) they may be either Oligocene or Miocene. Inasmuch as the coal-bearing strata of the Katalla and Yakataga districts are overlain with apparent conformity by marine strata now considered to be of upper Eocene age, the Kushtaka formation can be assigned to the Eocene with some confidence. It seems likely also that the Kushtaka formation, as mapped by Martin, includes two distinct and non-equivalent lithologic units corresponding to units A and B of the lower Tertiary sequence in the

Yakataga district--an older unit, containing anthracite coal, exposed mainly in the northeastern part of the Bering River area; and a younger unit, containing bituminous coal, exposed mainly in the southwestern part of the Bering River area.

Tokun formation.--Martin (1908, pp. 35-36) described the Tokun formation as follows:

> The Tokun formation crops out on both shores of Lake Tokun and extends thence north and northeast to the edge of the flats bordering Martin River Glacier and to Lake Charlotte. It also covers large areas on the crests and northwest slopes of Carbon and Charlotte ridges, on the west slope of Kushtaka Ridge, on the ridge north of Mount Hamilton, and on the northwest slope of Cunningham Ridge.
>
> These beds overlie the Kushtaka formation conformably, the transition apparently representing a change from fresh-water to marine conditions. The formation is at least 2,500 feet thick, the lower 2,000 feet consisting chiefly of sandy shales * * *
>
> The shales * * * are overlain by a bed of sandstone several hundred (possibly 500) feet thick. This sandstone is well exposed on the hills northeast of Lake Tokun and west of Lake Charlotte. The beds overlying this sandstone contain some shale, but are not well exposed.

Recent study of the Tokun formation as defined and mapped by Martin in the vicinity of Lake Tokun has shown that the formation there comprises a massive sandstone and underlying shale that are the equivalent of the basal shale member and Split Creek sandstone member of the Katalla formation. This possible correlation was anticipated by Martin (1908, p. 37). Farther south in the Martin Lakes area the shaly interval that is equivalent to the basal shale member of the Katalla formation is underlain by sandstone and shale believed to be upper Eocene in age and equivalent to the lower part of the Tokun formation of Martin. If this three-fold division of the Tokun formation is found to hold in the remainder of the area in which the formation was mapped by Martin, the most logical and useful solution would be to accept the massive sandstone (the Split Creek sandstone member) as the basal member of the Katalla formation and to assign to the Tokun formation the predominantly shaly strata lying between the massive sandstones of the Kushtaka formation and the Split Creek member of the Katalla formation. Pending additional work in the Bering River area, which is needed to settle this question, the interbedded sandstone and shale in the Martin Lakes area is assigned to the Tokun formation (restricted); the overlying shale and massive sandstone in the Martin Lakes area, as well as the lowest shale member in the Katalla area, are assigned to the Katalla formation; and the Tokun formation is retained as defined and mapped by Martin for the Bering River area. (See fig. 3.)

The Tokun formation (restricted), as mapped in the Martin Lakes area, consists of at least 2,000 feet of gray to dark-gray shale (mudstone, siltstone, and claystone, in part), and gray to brownish-gray fine-grained banded sandstone. The interbedded shaly and sandy strata are overlain with apparent conformity by the basal shale member of the Katalla formation. The contact has been drawn at the top of the highest prominent sandstone. So far as is known the base of the Tokun formation (restricted) is not exposed in the Martin Lakes area. Regarding three collections of fossils made in 1945 from the Tokun formation (restricted) of the Martin Lakes area, Vokes stated:

> The material * * * is probably of upper Eocene age. This determination is based largely on somewhat incomplete specimens of a spisula * * * which exhibit the size, and, on the dorsal lateral areas of the valves, the incised

sculpturing that is characteristic in the West Coast section of Spisula bisculpturata Anderson and Hanna, a Tejon and Cowlitz species. The evidence of this species is strenghtened by the occurrence * * * of a Lucina that is very close to L. Washingtonensis Turner, a Cowlitz species.

This material seems to be correlative with that from G. C. Martin's collections from the Tokun formation of the Bering River area (U. S. National Mus. Locs. 4377, 4378, 4383, and 4396). Certain of the internal casts of gastropods, particularly in both Martin's and the present collections, clearly represent the same species. This would seem to confirm the Eocene age of the "Tokun" of the Bering River area, as suggested in the report submitted on March 14, 1945.

Katalla formation

The Katalla formation, as defined in this report, includes the entire bedrock sequence exposed in the Katalla area--essentially the original definition of Martin (1908, pp. 27-28, pl. 5)--and known equivalents exposed elsewhere in the Katalla district. The formation includes the massive sandstone and underlying shale exposed in the vicinity of Lake Tokun, which were previously mapped as part of the Tokun formation by Martin but are now known to be the equivalent of the basal sandstone and shale of the Katalla formation at the type locality. (See pp. 19-20, fig. 3.) The Katalla formation consists of a conformable sequence of at least 8,700 feet of marine shale (in large part claystone, siltstone, or mudstone), sandstone, conglomerate, pyroclastic rocks, and lava flows ranging in age from lower Oligocene to upper Oligocene or possibly Miocene. In the Martin Lakes area the formation is underlain with apparent conformity by the Tokun formation (restricted); so far as is known the top of the formation is not exposed anywhere in the Katalla district.

The Katalla formation is known to be exposed in the Katalla area (fig. 4); the Nichawak area (fig. 5); the Suckling Hills, the Martin Lakes area, in the area lying between the Katalla River and Ragged Mountain, and on Kayak Island (fig. 2). The lower part of the Katalla formation at the type locality very likely is equivalent to the upper part of the Tokun formation as mapped by Martin in the Bering Lakes area. (See pp. 19-20.) The Stillwater formation of the Bering River area may also be equivalent in part to the Katalla formation. (See pp. 16-17.) The Katalla formation was studied in greatest detail during the recent investigations in the Katalla area, where nearly the entire thickness is exposed. There it has been divided into seven members on the basis of lithologic character. The general character of the members is shown in a columnar section (fig. 4) which was compiled from a continuous section measured from Split Creek southward along the Redwood Creek-Burls Creek divide and the Redwood Creek-Puffy Creek divide to a point near the south end of the latter divide. The measured section includes all the Katalla formation exposed at the type locality, except a few hundred feet of shale at the base and possibly a few hundred feet of sandstone and shale at the top. In most respects it is representative of the thickness and lithologic character of the formation as exposed throughout the Katalla area. The only known exposures of the basal beds of the Katalla formation, as defined in this report, are in the Martin Lakes area. The Katalla formation, as mapped in the Suckling Hills and on Kayak Island, may include some beds that are stratigraphically higher than any exposed in the Katalla area.

Table 1 shows the probable relationship of the members of the Katalla formation, as recognized in this report, to the divisions recognized by earlier investigators.

Table I

Probable relationship of divisions proposed for Tertiary sedimentary rocks exposed in the Katalla area, Alaska

U. S. Geological Survey (Miller et al., 1945, p. 7, and present report)		N. L. Taliaferro (1932, p. 773)	G. C. Martin (1908, p. 37)	Oil-company geologists (1938)[1]
Oligocene Katalla formation		Oligocene	Oligocene (?) Katalla formation	Oligocene
Puffy member		Redwood formation: Puffy shale member	e. Conglomerate and conglomeratic sandstones interbedded with shale and sandstone	Redwood formation (older than Split Creek formation): Puffy shale with conglomerate lenses
		Redwood formation: Point Hey sandstone member		Puffy conglomerate
Point Hey member	Sandstone		f. Flaggy sandstone	Point Hey sandstone
	Interbedded shale and sandstone	Katalla formation: Burls Creek shale member	g. Soft shale with calcareous concretions and with bed of glauconitic sandstone near base	Point Hey shale
				Fault
Organic shale member				Burls Creek formation: Cannon-ball shale
Burls Creek shale member				
Basin Creek member				Basin Creek interbedded sandstone and shale
Split Creek sandstone member		Katalla formation: Split Creek shale and sandstone member	h. Sandstone	Split Creek formation: Split Creek sandstone
Unnamed shale member			i. Soft shale	Split Creek shale

[1] The relationship of the Redwood formation to the Split Creek and Burls Creek formations was incorrectly shown in the preliminary report on petroleum possibilities in the Katalla area (Miller et al., 1945, p. 7): Bryan, J. J., Union Oil Co. of California, letter dated January 7, 1946. The Redwood formation is considered by the oil-company geologists to be older than the Split Creek formation, but in this table is placed at the top to facilitate comparison with divisions proposed by other geologists.

It should be noted that the oil-company geologists considered their Redwood formation (Point Hey and Puffy members of the Katalla formation) to be older than and in fault contact with their Split Creek and Burls Creek formations (organic shale member and older members of the Katalla formation).

Unnamed shale member.--The entire thickness of the unnamed shale member (the basal member of the Katalla formation as defined in this report) is exposed in the Martin Lakes area. The upper part of the member is exposed in the Katalla area and probably also in the Nichawak area. As indicated on pages 19-20, further work in the Bering River area may demonstrate the desirability of placing the unnamed shale member in the Tokun formation.

In the Martin Lakes area and the Katalla area the unnamed shale member of the Katalla formation consists principally of dark-gray to black shale (in part siltstone or mudstone). Round calcareous concretions are fairly abundant in some parts of the member. Fine-grained calcareous sandstone, gray on fresh surfaces and light-brown on weathered surfaces, is interbedded with the shale and siltstone. The sandstone is most abundant near the top of the member, where beds a few inches to several feet thick regularly alternate with shale. In the middle and lower parts of the member the sandstone beds are thin and widely spaced. Thin beds of shaly glauconitic sandstone and glauconitic shale are present in the middle and lower parts of the member. The upper part of the unnamed member is resistant to erosion, forming steep cliffs.

In the Martin Lakes area the unnamed shale member is at least 1,500 feet thick and rests with apparent conformity on the more arenaceous beds assigned to the Tokun formation (restricted).

Over most of the Martin Lakes area and the Katalla area the upper contact of the unnamed member is sharply defined by an abrupt change from interbedded dark shale and fine-grained sandstone to massive medium-grained sandstone of the Split Creek sandstone member. Over most of the Nichawak area, however, the section that probably is equivalent to the upper part of the unnamed member and the Split Creek sandstone member consists of interbedded shale, siltstone, and sandstone, and no satisfactory means of differentiating the two members was found.

Fossils are not abundant in the unnamed shale member of the Katalla formation. Gastropods, pelecypods, echinoids, fish vertebrae, a scaphopod, and a starfish were found in the sandstone and shale beds of the member. The most abundant fossil is the crab Branchioplax washingtoniana Rathbun which occurs in calcareous concretions in the lower part of the member and also in the underlying Tokun formation (restricted) in the Martin Lakes area. This species has been reported from the upper Eocene and lower (?) Oligocene of Washington (Rathbun, 1926, p. 44). The presence of a gastropod identified as Turcicula columbiana Dall? suggests that the member is lower Oligocene in age.

Split Creek sandstone member.--This member of the Katalla formation is exposed in the Martin Lakes area, the Katalla area, and the Nichawak area. The rocks mapped as undifferentiated Katalla formation on Kayak Island and in the Suckling Hills may include beds that are equivalent in age to at least part of the Split Creek sandstone member. This sandstone, together with the underlying shale, was named the Split Creek sandstone and shale member by Taliaferro (1932, p. 772) from the exposures along Split Creek in the Katalla area.

The Split Creek member is typically exposed at the head of Split Creek, where it is of average thickness (1,000 feet) and is characteristic lithologically (see columnar section, fig. 4).

The member is composed principally of two types of sandstone: massive, thick-bedded, medium- to coarse-grained brownish-gray sandstone, and evenly banded fine- to medium-grained thin-bedded sandstone. The bands in the latter type consist of thin layers of dark minerals, principally biotite, and carbonized plant remains along bedding planes. Locally this type of sandstone is cross-bedded. The massive brownish-gray sandstone grades laterally into sandstone that is mottled with light-gray spots about one-eighth to one-half inch in diameter. This type of sandstone, called "spotted sandstone" in the field, is a reliable guide to the Split Creek member in the Katalla area and the Martin Lakes area, but is not prominent in the Nichawak area. Both types of sandstone are composed principally of fresh angular grains of quartz, feldspar, and biotite. The feldspar minerals, mainly orthoclase, albite, and oligoclase, constitute from 10 to 40 percent of the rock.

In the Katalla and Martin Lakes areas the Split Creek member contains only a few thin shale beds. In Nichawak Mountain, however, the part of the section that is assumed, on the basis of fossil content, to be equivalent to the Split Creek member consists of alternating beds of sandstone and shale (including siltstone) in nearly equal amounts. The equivalent part of the section in Gandil Mountain is poorly exposed but apparently contains a greater proportion of sandstone, including "spotted sandstone." In the eastern part of the Katalla area the member contains at least two beds of massive dark-green sandstone in which hornblende is a prominent mineral. Along the Bering River, a third of a mile north of Chilkat, 10 feet or more of fossiliferous conglomerate, apparently a lens, occurs about 400 feet below the top of the Split Creek member. A few pebbles were found in the sandstone at other places in the district.

The thickness of the Split Creek sandstone member ranges from 700 to 1,400 feet in the Katalla area and the Martin Lakes area. The section that is equivalent to the member in the Nichawak area probably is more than 750 feet thick. In the Katalla and Martin Lakes areas, and to a lesser extent in the Nichawak area, the member is much more resistant to erosion than the adjacent beds and therefore crops out principally in the ridges.

Fossils, principally pelecypods, gastropods, echinoids, and plant remains, are fairly abundant in the Split Creek member in the Katalla area, less abundant in the Martin Lakes and Nichawak areas. The fossils collected in the Katalla area indicate that the Split Creek member is probably uppermost lower Oligocene and lower middle Oligocene in age. The most abundant and characteristic forms in the Split Creek sandstone member are an echinoid Schizaster (Linthia) sp., two species of gastropods belonging to the genus Epitonium (Boreoscala), and the pelecypods Pitar n. sp. aff. P. dalli (Weaver), Spisula sp. aff. S. pittsburgensis Clark, and Acila shumardi (Dall).

An isolated pinnacle of coarse conglomerate at Chilkat in the Katalla area, included by Martin in the unit corresponding to the Split Creek sandstone member of this report, contains fossils that are unlike those from the Split Creek member or any other part of the Katalla formation in the Katalla area and apparently are Miocene in age. The pinnacle probably represents an exceptionally large boulder that was transported to its present position by a glacier or by floating ice. Fossil collections made from this outcrop by Martin (1908, p. 28) may have been partly responsible for the conflicting evidence on the age of the Katalla formation.

Basin Creek member.--This member was named by oil-company geologists (1938) for Basin Creek in the Katalla area, where it is well exposed. Beds that are equivalent to the Basin Creek member on the basis of the fossils contained in them, but that do not show the lithologic characteristics of the member at the type locality, are exposed in the Nichawak area, in the Suckling Hills, in the area lying between the Katalla River and Ragged Mountain, and probably on Kayak Island.

In the Katalla area the Basin Creek member of the Katalla formation consists of alternating beds of very fine grained massive gray sandstone and gray sandy shale (predominantly siltstone). The beds range in thickness from 1 to 50 feet and average about 10 feet for the sandstone and 25 feet for the shale. Stratification ordinarily is inconspicuous in both the shale and sandstone. The sandstone is composed of small, angular grains of quartz and feldspar in a fine-grained matrix. Some of the sandstone beds are glauconitic. The shale contains many round calcareous concretions from 1 to 6 inches in diameter. They are particularly common in beds near the middle of the member.

In the Nichawak area and in the Suckling Hills the section that is believed to be equivalent to the Basin Creek member consists principally of gray shale (siltstone and mudstone) but includes beds of tuff, volcanic breccia, and lava and a few thin beds of medium-grained sandstone. The section of interbedded sandstone, shale, and siltstone exposed on Kayak Island probably includes beds that are equivalent to at least part of the Basin Creek member.

In the Katalla area the thickness of the Basin Creek member ranges from about 550 feet to 1,000 feet. The average thickness is about 700 feet. The section that is equivalent to the Basin Creek member in the Nichawak area is at least 1,000 feet thick. The thickness cannot be accurately determined because the position of the Basin Creek-Burls Creek contact is not well defined.

The most abundant and characteristic fossil in the Basin Creek member is a crab identified as "Eumorphocorystes" naselensis Rathbun by H. B. Stenzel. This species is found only in the calcareous concretions and so far as known is restricted to the Basin Creek member. At some places in the Katalla and Nichawak areas more than half of the concretions that were broken open were found to contain well-preserved specimens of this crab. The crab Portunites alaskensis Rathbun, and the pelecypods Pitar n. sp., and Nemocardium weaveri Anderson and Martin also are common. The Basin Creek member contains some fossils, particularly Nemocardium weaveri, and "Eumorphocorystes" naselensis, that indicate correlation with the lower Oligocene part of the Keasey formation and with other lower Oligocene strata of Washington and Oregon. However, the Basin Creek member clearly overlies the Split Creek member. As the correlation of the Split Creek member with uppermost lower Oligocene and middle Oligocene beds in Washington and Oregon is based on a larger number of forms, the Basin Creek member is here assumed to be middle Oligocene in age.

Burls Creek shale member.--The name Burls Creek was used by Taliaferro (1932, pp. 772-774) to designate the entire sequence of shaly rocks that lies between his Split Creek and Point Hey sandstone members and is typically exposed in the valley of Burls Creek. In this report the name is restricted to the massive gray shale and associated glauconitic sandstone, tuff, and volcanic breccia that lies conformably between the Basin Creek and organic shale members in the Katalla area. Rocks that are equivalent in age and similar in lithologic character to the Burls Creek shale member at the type locality are also exposed in the Nichawak area, and probably in the Martin Lakes area, in the Suckling Hills, and on Kayak Island.

In the Katalla area gray massive partly sandy shale (mainly siltstone) forms the major part of the Burls Creek member. In stream beds the shale forms smooth light-gray surfaces; higher on the banks of the streams and on ridges, where frost action is more important, the shale breaks into fine, angular pieces that have dark-gray surfaces. Lens-shaped calcareous concretions averaging more than 2 feet across are abundant in the shale. Some are as much as 10 feet in diameter. Most of the concretions are oriented with the larger dimensions parallel to the bedding. Because of the lack of stratification, the attitude of small outcrops of the shale is difficult or impossible to determine unless concretions or contacts with beds of different lithologic characteristics are exposed.

The glauconitic sandstone beds in the Burls Creek shale member are dense, massive dark-green beds composed of angular to sub-rounded grains of glauconite in a fine-grained brownish-green matrix. The glauconitic sandstone beds, which may represent altered volcanic ash beds, are best developed in the Katalla area. Only a few thin beds were seen in the Martin Lakes and Nichawak areas and none were seen in the Suckling Hills or on Kayak Island.

In the western and central part of the Katalla area, in Nichawak Mountain, in the Suckling Hills, and on Kayak Island the Burls Creek shale member or equivalent sediments contain concordant beds and lenses of lava and water-laid tuff and volcanic breccia that clearly were deposited contemporaneously with the normal marine sediments. They also contain more irregular bodies of similar rocks that show some intrusive characteristics. These volcanic-appearing rock masses of doubtful origin are discussed in the section on intrusive rocks. At some places in Nichawak Mountain the total thickness of bedded volcanic material in the unit that is believed to be equivalent to the Burls Creek and Basin Creek members exceeds 1,000 feet.

The thickness of the Burls Creek shale member and the amount of glauconitic sandstone and volcanic material in it ranges widely. In the Katalla area, east of the fault along Chilkat Creek, the Burls

Creek member, and possibly the organic shale member, are represented by several hundred feet of massive gray shale. Glauconitic sandstone was not found in this part of the area south of latitude 60° 12' N. From the Chilkat Creek fault to the head of the west fork of Burls Creek the member consists of 100 to 200 feet of shale between two beds of glauconitic sandstone that have a total thickness of about 60 feet. A third glauconitic sandstone is present near the middle of the member at some places. The shale thickens westward in the Katalla area to a maximum of perhaps 1,000 feet. The glauconitic sandstone beds thicken westward along the east fork of Burls Creek to about longitude 144° 14' W., thin to a foot or less on the Redwood Creek-Burls Creek divide, thicken again to a maximum of about 40 feet at a few places between Redwood Creek and the Katalla River, and thin again or are absent in the Clear Creek-Katalla River ridge. Bedded volcanic material was found in the Burls Creek shale member along the west fork of Burls Creek and in the valley of Redwood Creek in the Katalla area.

The shale section at the southwest end of Nichawak Mountain includes beds that are equivalent to the Burls Creek shale member. The thickness cannot be determined accurately because the contact with the beds that are equivalent to the Basin Creek member is not sharply defined. Several hundred feet of gray concretion-bearing shale, believed to be the equivalent of the upper part of the Burls Creek member, is exposed in Mount Campbell. No glauconitic beds or volcanic material were found in it.

Pelecypods are the most common fossils in the Burls Creek member. Gastropods, foraminifers, fish vertebrae, and plant remains also were found in it. None of the fossils found is sufficiently abundant to be considered characteristic of the member and none is useful for determining the age of the member, other than that it probably is Oligocene.

Organic shale member.--This member, so named because of its high content of organic material, has been recognized in the Katalla and Nichawak areas. The member is best developed in the Katalla area and was found to be the most useful key bed for geologic mapping there, since it has a distinctive lithologic character and is easily recognized even as float. The member consists of black shale (mainly claystone or siltstone) that is strongly contorted and sheared at most places. Where relatively undisturbed the shale is massive and compact; where sheared it breaks into small irregular pieces that have shiny, slickensided surfaces and resemble coal. The shale contains numerous lens-shaped and some round, dark-gray calcareous concretions ranging in diameter from a few inches to 2 feet. Over most of the Katalla area the organic shale rests on the glauconitic sandstone at the top of the Burls Creek shale member. At the top of the member the black shale grades into the dark-gray shale near the base of the Point Hey member, usually within a thickness of a few feet, but at some places, for example on the divide between Redwood and Burls Creeks, through a thickness of 100 feet or more. Both the upper and lower contacts are gradational in the Nichawak area. The apparent thickness of the organic shale member ranges from 50 to 400 feet in the Katalla area and also in the Nichawak area. The shale is incompetent and no doubt has been considerably thickened at some places. Nevertheless, the figures given above are believed to represent approximately the range in true thickness.

In the central part of the Katalla area, especially on the west fork of Burls Creek, the organic shale member contains several bodies of green to brown rocks that may be in part water-laid volcanic material or lava, but that also show some intrusive characteristics. These are discussed in the section on intrusive rocks.

Taliaferro (1932, pp. 772-774, 779) called attention to the petroliferous character of the so-called organic shale which he included in his Burls Creek shale member of the Katalla formation, and to the probable role of the shale as a source of oil. Some specimens of the shale emit a strong petroleum odor when struck with a hammer. A sample of partly weathered organic shale collected in 1944 from an outcrop near the main forks of Burls Creek contains 5.1 percent total organic matter and 0.8 gallon of oil per ton of shale._/ The unweathered

_/ Analysis by W. W. Brannock, U. S. Geological Survey

shale probably contains more oil and possibly a higher percentage of other types of organic material.

A few foraminifers and poorly preserved scaphopods were collected from the organic shale member. According to J. A. Cushman, a mixture of two distinct types of foraminifers is represented. One type may be Oligocene; the other is fairly definitely Eocene and presumably represents redeposition of Eocene material.

Point Hey member.--This member, so named because it is well exposed in the vicinity of Point Hey in the Katalla area, lies conformably between the organic shale member and the conglomerate at the base of the Puffy member. The Point Hey member also is exposed in the Nichawak area and beds that are equivalent to it may crop out in the Suckling Hills and on Kayak Island.

In the Katalla area, west of longitude 144° 19' W., the Point Hey member includes two distinct lithologic divisions, a lower division consisting mostly of shale but including some sandstone and an upper division of thick sandstone beds and thin shale beds. The columnar section on figure 4 shows the thickness and lithologic character of the divisions on the Redwood Creek-Burls Creek divide. The lower shaly division thickens westward and, unless the section is repeated by structures not detected in the field, is more than 2,000 feet thick south of the oil field. The shale is light- to dark-gray, sandy, and in most outcrops shows a well-developed lamination. It contains numerous thin beds of dense, fine-grained, noncalcareous sandstone, some of which show closely spaced bands. The sandstone division is similar to the Split Creek sandstone member in lithologic character but does not contain the "spotted sandstone" beds and contains more shale and more thin-bedded sandstone. The sandstone beds contain a higher percentage of feldspar than most of the Split Creek sandstone. East of longitude 144° 19' W. the member consists of at least several hundred feet of gray to nearly black partly sandy shale with beds of fine- to medium-grained sandstone as much as 100 feet thick. The sandstone beds are more numerous near the top of the exposed section. The member is about 850 feet thick near longitude 144° 19' W.

At least 1,000 feet of gray shale with thin beds of sandstone, representing the lower division of the Point Hey member, and 400 feet of gray and brownish-gray fine- to medium-grained sandstone, representing the lower part of the upper division of the Point Hey member, are exposed in the isolated hill at the south end of Nichawak Mountain. If the structure of the rocks in Mount Campbell is correctly interpreted, the Point Hey member is represented there by at least 1,600 feet of gray shale and shaly siltstone containing a few thin beds of sandstone, overlain by 500 feet or more of alternating thick beds of sandstone and shale. So far as is known neither the top nor the bottom of the member is exposed on Mount Campbell.

The Point Hey member has yielded a few fossils, including pelecypods, gastropods, plant remains, and echinoids. Some of the pelecypods, particularly _Lucina hannabali_ (Clark), indicate that the member is upper Oligocene.

Puffy member and younger (?) rocks.--Taliaferro (1932, pp. 775-776) used the name "Puffy" to designate the sequence of fine-grained sediments, conglomerate, and sandstone exposed along Puffy Creek in the Katalla area, but apparently did not include the massive conglomerate at the base of the sequence. As defined in this report, the Puffy member extends from the base of the lowest bed of conglomerate through the highest exposed Tertiary beds in the Katalla area. As shown in the columnar section on figure 4, the member is more than 3,700 feet thick and consists of dark-gray massive shale (largely mudstone or siltstone); many beds of medium- to coarse-grained sandstone; and several thick beds and lenses of conglomerate.

Rocks that are similar lithologically to the Puffy member as exposed in the Katalla area, and that possibly are equivalent to it, are exposed in the Suckling Hills and on Kayak Island. The section in the Suckling Hills, which has a total exposed thickness of several thousand feet, has yielded one fairly extensive fossil collection, including pelecypods and gastropods that are said by H. E. Vokes to be upper Oligocene or younger. The section on Kayak Island, which has an exposed thickness of at least 1,000 feet, contains pelecypods and gastropods that, according to Vokes, have a general Miocene or Pliocene aspect. Only a few poorly preserved pelecypods, a gastropod, and some plant remains, none of which is diagnostic, were found in the Puffy member in the Katalla area.

The conglomerate is composed of well-rounded and -sorted pebbles and cobbles in a matrix of either coarse sandstone or dark-gray mudstone. The rounded fragments, which range in diameter from less than 1 inch to 12 inches or more, are composed principally of igneous and metamorphic rocks. The rock called shale-matrix conglomerate by Taliaferro ranges in character from true conglomerate, in which the pebbles and cobbles are closely packed, to pebble- or cobble-bearing mudstone in which the rounded fragments are widely spaced and are scattered erratically through mudstone. The conglomerate beds near the base of the Puffy member in the Katalla area and those exposed on Kayak Island seem to be persistent, but the higher conglomerate beds in the Katalla area and those exposed in the Suckling Hills grade laterally into beds of different lithologic character.

Undifferentiated Tertiary rocks

The rocks mapped as undifferentiated Tertiary on Wingham Island (see fig. 2) include several hundred feet of alternating beds of pink-weathering sandstone, shale, and siltstone that are exposed on the bay at the south end of Wingham Island and on the east shore north of Kayak, and 500 feet or more of alternating beds of mudstone-matrix conglomerate, mudstone, and sandstone that are exposed only in the point south of Kayak. Several specimens of a small crab and several small pelecypods were collected from the sandstone and shale exposed in the bay at the south end of the island. According to H. E. Vokes, the pelecypods are probably not diagnostic, but nevertheless are suggestive of Eocene forms. The sequence containing the mudstone-matrix conglomerate is similar to that exposed on the adjacent shore of Kayak Island, except that it is not fossiliferous.

The rocks mapped as undifferentiated Tertiary in the northeastern part of the Bering River area (fig. 2) adjacent to the area mapped by Martin, probably are largely of the Kushtaka formation, but may include some younger rocks.

Quaternary unconsolidated sediments

The Quaternary sediments unconformably overlie the Tertiary and older rocks in the Katalla district. They are unconsolidated and include marine silt, clay, sand, and gravel; stream and lake deposits of mud, sand, and gravel; glacial moraines; and residual products of weathering. The Quaternary sediments are not differentiated on the maps in this report, except in the Nichawak area (fig. 5) where the thin covering of moraine representing a recent retreat of Bering Glacier is differentiated. The Quaternary sediments are of interest from the point of view of oil possibilities only because they conceal the potentially petroliferous Tertiary rocks over large parts of the Katalla district. According to Martin (1908, p. 52), the thickness of the Quaternary deposits exceeds 280 feet at a well drilled in Katalla Valley, and 580 feet at a well drilled on the east shore of the Bering River.

Tertiary and younger(?) intrusive rocks

The Tertiary rocks of the Katalla district are intruded by relatively small bodies of igneous rocks including dacite, diorite, diabase, and basalt. According to Martin (1908, pp. 41-42) small dikes and sills, mainly basalt but including some diabase, are abundant in the part of the Bering River area lying north and northeast of Stillwater Creek. Martin also noted a diabase dike, about 20 feet wide and several hundred feet in length, on the crest of the ridge between the Katalla River and Clear Creek. The high peak and a nearby spire at the south end of Kayak Island consist of a white igneous rock which Martin (1908, p. 42) identified as dacite from beach pebbles collected near the north end of the island. The approximate extent of this igneous body as interpreted from aerial photographs is shown on figure 2. During the recent investigations small dikes and sills mainly of basalt were observed in shaly rocks of approximately the lower half of the Katalla formation in the Katalla area, and in shaly rocks of the middle part of the Katalla formation on Nichawak

Mountain, on Kayak Island, and in the Suckling Hills. Two small bedrock hills in the alluvial flats about half a mile southwest of Gandil Mountain (fig. 5) were found to be diorite. Intrusive igneous rocks appear to be lacking or scarce in Early Tertiary(?) rocks of the Mirror Slough area, and in Tertiary rocks of the Martin Lakes area, of the part of the Bering River area that lies south and west of Stillwater Creek (Martin, 1908, p. 41), and of Gandil Mountain and Mount Campbell.

In the central part of the Katalla area, in Nichawak Mountain, and in the Suckling Hills the shaly rocks of the middle part of the Katalla formation (Basin Creek, Burls Creek shale and organic shale members, or their equivalents) contain sills, dikes, and irregularly-shaped bodies that show intrusive relationship to the enclosing sediments but appear to consist wholly or in part of sediments, pyroclastic rocks, or bedded flows. Typical of these is an irregular-shaped body in the organic shale member, on the west fork of Burls Creek about a mile above the junction with the east fork (fig. 4). In the field this was mapped as an intrusive igneous body, although the large proportion of fragments of sediments in it, the lack of alteration of the country rock at the contacts, and other non-igneous features were noted. Later study of thin sections showed that some parts of the supposed intrusive body consist of angular fragments of sedimentary and igneous rocks imbedded in a matrix of calcite or of the country rock (the organic shale member). In other parts of the body, however, the matrix appears to consist of a basaltic glass. Another body of this type, mapped as part of the enclosing sediments, forms the south peak of Nichawak Mountain. This body, which is roughly lenticular in plan, was called a volcanic plug by Taliaferro (1932, pp. 779-780 and fig. 14). During the 1945 investigation, however, it was noted that the body consists, at least in part, of beds of tuff and volcanic breccia that are roughly concordant with the enclosing sediments. The enclosing sediments, mainly shales, show none of the contact effects that would be expected around an intrusive igneous body of this size.

The intrusive-like bodies described above, as well as smaller dikes, sills and other irregular bodies showing the same features, are believed to consist at least in part of lenticular lava flows or pyroclastic material that was deposited as the enclosing sediments were being formed. During folding some of the larger of these masses acted as competent "knots" around which the enclosing shaly sediments flowed. At some places these bodies were fractured and were injected into the enclosing sediments along fractures in a manner analogous to the formation of sandstone dikes. Fluid igneous material may have later invaded some of the bodies, such as the one on the west fork of Burls Creek.

True sandstone dikes were found in shales of the Katalla formation in the eastern part of the Katalla area.

The Tertiary and younger(?) intrusive bodies appear to have caused little alteration of the enclosing sediments, even within a few feet of the contacts. Hence, their effect on the oil possibilities probably is negligible.

STRUCTURE OF THE TERTIARY ROCKS

The Tertiary rocks of the Katalla district are intensely folded and are cut by many faults. The folds and major thrust faults (except in the Mirror Slough area) are the result of uplift combined with compressive forces that were, in general, normal to either the Chugach Mountain front or the east face of Ragged Mountain. In the northern and northeastern part of the Katalla district the fold axes and major thrust faults trend northeastward, approximately parallel to the Chugach Mountain front. The intensity of folding and magnitude of displacement along the major thrust faults here, as in the Yakataga district to the east, appears to increase northward, culminating in the Chugach-St. Elias fault which borders the belt of Tertiary rocks on the north. In the western part of the Martin Lakes area and farther south in the vicinity of Clear Creek and Katalla, the fold axes and major faults trend northward, parallel to the Ragged Mountain fault along the east face of Ragged Mountain.

The Chugach-St. Elias fault, along which the arcuate block of pre-Tertiary rocks forming the Chugach and St. Elias Mountains was uplifted and thrust southward against the bordering belt of Tertiary strata, is one of the major structural features of Southern Alaska (Miller, 1951, pp. 46-47). It has been traced with some certainty for a distance of 170 miles, by ground and aerial reconnaissance and study of aerial photographs, from the Katalla district on the west to Yakutat Bay on the east (fig. 1). The regional geologic and topographic trends suggest that the same fault may continue southwestward beyond the Katalla district under the delta of the Copper River and the Gulf of Alaska, possibly as far as Kodiak Island, and southeastward beyond Yakutat Bay under the alluvial plain at the front of the St. Elias Mountains. From the Katalla district to Yakutat Bay the trace of the fault at the bedrock surface, evidently a zone of weakness due to shattering of the rocks, is largely concealed beneath glaciers, the fault plane being exposed only where it crosses some of the more rugged spurs. The fault was examined on the ground at two localities in the Yakataga district where it was found to dip to the north at an angle of about 60°. In the Katalla district the trace of the fault lies for the most part under Martin River Glacier and the alluvial flood plain of the Martin River. On the basis of study of aerial photographs, as well as distant views from the air and from points of vantage on the ground, the fault is interpreted as crossing two bedrock spurs of the Chugach Mountains north of the Martin River (fig. 2).*

The Ragged Mountain fault, the surface trace of which lies along the base of the east face of Ragged Mountain, and also a fault exposed at the south end of Wingham Island (fig. 2), are similar to the Chugach-St. Elias fault in that they place pre-Tertiary metamorphic rocks in contact with Tertiary sediments.

The Ragged Mountain fault has not been observed in outcrop, but the approximate location of the fault trace at the surface is indicated by the abrupt rise of Ragged Mountain to the west, and by the presence of stream valleys and small sag lakes along the base of the mountain. Recent minor movement along the fault is indicated by the presence of linear scars in talus cones along the east face of Ragged Mountain.

*Field work during the 1951 season indicates this interpretation is incorrect. The rocks on both spurs appear to be of pre-Tertiary age. The Chugach-St. Elias fault is presumed to lie under the ice and alluvium of the Martin River Basin.

These scars are plainly evident on aerial photographs. By analogy with the Chugach-St. Elias fault and the fault on Wingham Island, the Ragged Mountain fault is assumed to be a thrust fault, dipping to the west at a large angle. Beyond the observation that the trace of the fault at the surface appears to migrate to the east as the altitude increases, the writer has no direct evidence to indicate the direction or amount of dip of the fault plane. Because of the regional structural pattern, and the evidence in the Tertiary rocks of pressure from the west, it is unlikely that the Ragged Mountain fault is a normal fault dipping to the east, however.

A fault contact of pre-Tertiary metamorphic and igneous rocks with Tertiary sediments is fairly well exposed at the south end of Wingham Island. Although the exact location and altitude of the fault plane is not readily determined, because of sheared and altered condition of the rocks along the fault, it appears to dip to the west at an angle of 70°-80°. This fault may represent the southward continuation of the Ragged Mountain fault, but if so, its trace under Controller Bay is a sinuous one.

The Ragged Mountain fault and the fault exposed on Wingham Island may have significance in the broader structural pattern of the Gulf of Alaska region, for they lie approximately along the axis (extended northeastward) of the main part of the Aleutian Trench (Murray, 1945, pl. 3).

The orogeny that resulted in uplift of the Chugach and Ragged Mountains and in folding and faulting of the Tertiary rocks is believed to have taken place in either late Tertiary or early Quaternary time.

The youngest Tertiary rocks involved in the folding and faulting in the Katalla district (exposed on Kayak Island and in the Suckling Hills) are at least as young as late Oligocene and possibly are Miocene. In the Yakataga district and farther southeast beds at least as young as upper Miocene, and possibly as young as Pliocene or even Pleistocene, are involved in the orogeny (Miller, 1951, pp. 16-19). Intensely folded Tertiary strata at the south end of Wingham Island are overlain unconformably by only slightly warped beds of marine silt and clay, which presumably post-date the major orogeny. These unconsolidated beds were thought by Martin (1908, p. 46) to be Quaternary. Foraminifera collected from these beds during the recent investigation are either Pliocene or Pleistocene forms, according to J. A. Cushman.

Mirror Slough area

The general trend of the folds in the presumed Tertiary rocks in the Mirror Slough area is N. 60°-90° E. (See fig. 2.) Between Cape Martin and the east end of Softuk Bar in the sea cliffs are exposed a series of closely alternating tight anticlines and synclines whose axes trend N. 80°-90° E. The numerous reversals of dip along the beach here are not shown on figure 2 because of the scale limitations. North of the east end of Softuk Bar the folds are evidently broader and are asymmetrical or overturned to the south. The nature of the contact of the early Tertiary(?) rocks with the pre-Tertiary rocks is discussed on pages 13 and 14.

Katalla area

In general the structure of the Katalla area is that of a broad southward-plunging syncline complicated by many northward- and some eastward-trending folds, and by northward- and eastward-trending faults. (See fig. 4.) Most of the folds are tightly compressed and plunge steeply southward. In describing the structure of the Tertiary rocks in the Katalla area it is convenient to divide the area into five structural units, each of which has a characteristic structural pattern, as follows: (1) Unit lying east of the northward-trending fault along Chilkat Creek; (2 and 3) Two units lying between the Chilkat Creek and Redwood Creek faults, but separated by the northeastward- and northwestward-trending anticlines along Split Creek; (4 and 5) Two units west of the Redwood Creek fault but separated by the westward-trending fault zone in the vicinity of the oil field.

The unit that includes the ridge east of Chilkat Creek is believed to have moved northward as well as downward along the Chilkat Creek fault relative to the rest of the Katalla area. That the horizontal component of movement was the larger is suggested by the abrupt change in the lithologic character of beds on opposite sides of the fault, south of latitude 60° 13' N. East of the Chilkat Creek fault and south of latitude 60° 15' N., the structure consists of nearly isoclinal folds, the axes of which trend at a small angle to the trend of the ridge and plunge southward. (See structure section H-H', fig. 4.) North of latitude 60° 15' N. the folds are broad and the axes are nearly horizontal or plunge at a low angle to the north. (See structure section G-G', fig. 4.)

The unit in the central part of the Katalla area, bounded on the east by the Chilkat Creek fault, on the west by the Redwood Creek fault, and on the northwest by the anticline at the head of Split Creek, is a complex syncline that plunges southward at angles of about 45° southwest of Burls Creek and 30° north of the east and west forks of Burls Creek. (See structure sections F-F', G-G', and H-H', fig. 4.) North of the east and west forks of Burls Creek at least 12 smaller anticlines and synclines are superimposed on the major synclinal structure. The rocks are cut by at least three major faults that trend parallel to the axes of the folds; along each of these faults the west, or hanging-wall side, probably moved up relative to the east side. Because distinctive and persistent beds are lacking south of the main forks of Burls Creek, the structure could not be worked out in as much detail there as was possible north of Burls Creek. As shown on the map (fig. 4), the rocks south of the main forks of Burls Creek are strongly folded parallel to the axis of the major syncline. Southwest of Burls Creek eastward-trending folds also are present.

The broad, basin-like structure in the vicinity of Basin Creek is separated from the rest of the Katalla area by an anticline that extends from the upper valley of Split Creek to Bering Lake (section F-F', fig. 4).

The ridge west of Redwood Creek, between the oil field and Split Creek, is essentially a northward-trending anticline and adjecent syncline cut into four blocks by three eastward-trending cross faults and bounded on the east by a northward-trending fault (along Redwood Creek) on which these blocks were thrust eastward. The amount of displacement along the northward-trending thrust fault increases to the south. The structure is further complicated by an anticline parallel to the fault along Mitcher Creek, and by overturning of some of the northward-trending folds in the two southernmost fault blocks. Additional study and re-evaluation of the 1944 field data following publication of the preliminary report on the Katalla area indicates that in the vicinity of Split Creek the trace of the northward-trending fault along Redwood Creek probably lies farther west than shown on the preliminary map of the Katalla area (fig. 4, this report). The location shown on figure 2 is believed to be more nearly correct.

The unit south of the oil field is a broad syncline that plunges to the south at an angle of about 50°. It is separated from the more complex unit to the north by at least one and probably two eastward-trending faults in the vicinity of the oil field.

The narrow belt of Tertiary rocks adjoining the Katalla area on the west, between the Katalla River and Ragged Mountain, appears to include several tightly compressed anticlines and synclines whose axes strike about N. 15° E. and are nearly horizontal. These folds are terminated or overridden by the Ragged Mountain fault on the west. The lack of similarity in the structure of the Tertiary rocks exposed on opposite sides of the valley of the Katalla River suggests that they are separated by a major north-trending fault concealed beneath the alluvium of the Katalla River valley and the valley of lower Split Creek.

Martin Lakes area

The Martin Lakes area (fig. 2) includes two structural units of dissimilar structural pattern. In the structural unit that lies west of a line from the east side of Big Martin Lake to a point on the west shore of Bering Lake at latitude 60° 17' N., the rocks are compressed into folds whose axes trend about north, parallel to the trend of the faults near the base of Ragged Mountain. In the unit that lies northeast of the line mentioned above the predominant trend of the fold axes is east-northeast, or nearly parallel to the trend of the fault at the base of the Chugach Mountains in the northern part of the district. In this unit the regional dip is northward so that successively younger beds are exposed to the north. The folds in the relatively incompetent beds of the Tokun formation (restricted) and the unnamed shale member of the Katalla formation are closely spaced and generally are asymmetrical, the steeper flanks of the anticlines being on the north or west. In the more competent Split Creek sandstone member the folds are broader.

It is believed that the Martin Lakes area is separated from the Bering River area by a major fault along the valley of Dick Creek. The evidence for the fault is largely stratigraphic. The fault plane was not found where the rocks were examined in detail in the valley of Dick Creek. It was noted, however, that the trend of the structures and the lithologic character of the beds changes abruptly on opposite sides of the assumed trace of the fault in the valley of Dick Creek. The location of this fault north of Dick Creek is not known, as this area was not examined during the recent investigations. In terms of the regional trends and structural pattern, as shown on aerial photographs and on the geologic map of the Controller Bay district (Martin, 1908, pl. 5), the fault may be expected to continue northeastward toward Lake Charlotte.

Bering River area

According to Martin (1908, pp. 42-43, pl. 5) the axes of the folds in the Bering River area trend northeastward. Some of the folds are overturned to the southeast and the rocks are cut by a number of northwestward-dipping thrust faults, indicating that the force causing the folding and faulting came from the northwest.

Nichawak area

The rocks in Gandil Mountain are compressed into several relatively broad folds whose axes strike about N. 30° E. and plunge to the southwest at a low angle. The folds are cut by a major thrust fault that strikes about N. 20° E. and dips about 70° NW. (See map and structure section A-A', fig. 5.)

The rocks in Nichawak Mountain are more tightly compressed and more extensively faulted (map and structure section B-B', fig. 5). The average trend of the axes of the folds is about N. 25° E. In the southwest part of the mountain the plunge of the fold axes is to the southwest; in the central and northeastern part of the mountain the fold axes are nearly horizontal or, at a few places, plunge to the northeast. The isolated hill at the southwest end of Nichawak Mountain consists of a broad syncline and narrower anticline whose axes plunge to the southwest at an angle of about 40°. The folds in Nichawak

Mountain are cut by many steep faults that trend nearly at right angles to the trend of the fold axes, and by at least one steep thrust fault that cuts the axes of the folds at an angle of about 45°.

The structure of Mount Campbell is puzzling. Most of the mountain consists of shale or siltstone without distinctive or persistent beds. Bedding is difficult to determine in many outcrops, and sedimentary features that would aid in determining whether the beds are overturned or upright are generally lacking. The attitude of the beds changes abruptly from one outcrop to another. If the organic shale member, the Burls Creek shale member, and the Point Hey member are correctly identified and the major structure is therefore an overturned anticline, as suggested on the map and structure section C-C', figure 5, it is, so far as known, the only major structure in the Katalla district that is overturned to the northwest. Another possible interpretation is that the shale mapped as Burls Creek is really the lower part of the Point Hey member and that the structure is a southeastward-dipping monocline with only minor folding and faulting. However, the interpretation of the structure and stratigraphy shown on figure 5 is favored for the following reasons*: (1) The shale overlying the organic shale on the northwest side of Mount Campbell is light gray and contains large lenticular calcareous concretions, features that are characteristic of the Burls Creek member elsewhere in the Katalla district but not of the lower part of the Point Hey member; (2) on the northwest flank of the main peak of Mount Campbell the beds appear to flatten and arch over as on the crest of an overturned anticline and a zone in which many

*Field work during the 1951 season has yielded further evidence which supports the interpretation that the structure is a southeastward -- dipping homocline. This interpretation is favored in preference to that of the overturned anticline.

low dips to the southwest were measured extends northeastward and southwestward from this locality; (3) a persistent zone of shale containing one or more beds of brown partly sandy siltstone extends along the main ridge of Mount Campbell and apparently is exposed also in the steep slope south of the main peak and farther southeast.

Suckling Hills

Although the time spent in the examination of the Suckling Hills was too short to map the structure in any detail, particularly in view of the fact that an adequate base map was not available, the rocks appear to be compressed into a major anticline and syncline with steep, at some places isoclinal, flanks (fig. 2). The axes of the folds trend about N. 70° E. near Cape Suckling, but swing in a broad arc to about N. 10° W. near the north end of the area. In the central part of the hills the folds are offset by one or more faults trending about N. to N. 20° W.

Kayak and Wingham Islands

The Tertiary rocks on Kayak and Wingham Islands are compressed into closely spaced isoclinal or nearly isoclinal folds whose axes trend N. 10°-35° E. (fig. 2). In addition to the major thrust fault described on page 44, some minor cross faults were seen on Wingham Island. Strike faults of considerable displacement probably are present on Kayak Island.

OIL POSSIBILITIES

HISTORY OF EXPLORATION AND DEVELOPMENT

Thomas White, a prospector, is reported to have discovered the oil seeps at the head of the Katalla Slough in the Katalla area (fig. 4) in 1896 and to have staked the first oil claims there (Prosser, 1911, p. 746).

The first well was drilled near the discovery seeps in 1901, but was abandoned at a depth of 270 feet because of the loss of the drilling tools. The first successful well (no. 1 on fig. 4) was completed in 1902. From 1901 to the present time at least 44 wells were drilled or started in the district, 3 in the Mirror Slough area, 2 near the mouth of the Katalla River, and one on the west shore of Bering Lake (fig. 2); at least 37_/ in the Katalla area (fig. 4); and one in the Nichawak area (fig. 5). Of these, 11 wells were not finished because of accidents to the drilling equipment or because they failed to reach bedrock; 11 yielded little or no oil; 4 are reported to have yielded promising shows, though oil was not produced from them; and 18 wells (all on the patented claim at the head of Katalla Slough) produced oil. The depths of the productive wells range from 366 to 1,810 feet. The deepest well, no. 24 in the Katalla area, extends about 2,260 feet below sea level. The history of the field and descriptions of the wells are given in more detail in a report by Martin (1921, pp. 13-15),

_/ Wells A, B, and C, whose locations nearly coincide with the locations of wells 19, 18, and 16, respectively, are not shown on figure 4.

covering the development to the end of 1919, and in the annual reports of the Geological Survey on the mineral resources of Alaska for the years 1920 to 1942, inclusive. The numbers used in this report to designate the wells correspond to the numbers used in the earlier reports of the Geological Survey.

The following statement concerning the character of the oil produced from the wells is by A. M. Bateman (Martin, 1921, p. 30):

> The gravity of the oil is from $41\frac{1}{2}$ to 45° Baumé. The oil is high in gasoline and naphtha and has a paraffin base. Sulfur is absent. The recoverable content of gasoline and distillate is about 63 percent.

Most of the productive wells and some of the non-productive wells yielded considerable natural gas.

The total production of the Katalla field is about 154,000 barrels of oil. Most of the crude oil was treated at the refinery near the head of Katalla Slough, and the products were used locally, principally at Cordova. Production ended in December 1933 when part of the refinery was destroyed by fire. The patented claim on which the productive wells are located was reported to be controlled by the Standard Oil Company of California in 1945.

In 1945 all the Katalla district was open to leasing under the federal oil and gas mineral-leasing laws except for two patented claims in the Mirror Slough area, the Katalla townsite, two patented claims covering the Katalla oil field, and five oil and gas leases covering a large part of the Katalla area. Early in 1951 applications for oil and gas leases covering large tracts of land in the Katalla and

Yakataga districts were reported_/ to be on file.

_/ The Cordova Times, Jan. 25, 1951, page 1.

OIL AND GAS SEEPS

At least 75 oil seeps and 11 gas seeps have been observed at one time or another in the Katalla district. The maps accompanying this report show the locations of all oil and gas seeps observed during the recent investigations in the Mirror Slough area (fig. 2), the Katalla area (figs. 2, 4), and the Nichawak area (figs. 2, 5). The maps of the Mirror Slough and Nichawak areas (figs. 2 and 5) show also the seeps reported earlier by Martin (1921, pp. 25-28, pl. 4) but not seen during the recent investigations. The map by Martin shows 17 additional oil seeps in the Katalla area which were not observed during the recent investigations and are not shown on figures 2 and 4 of this report. A group of seeps within a small area (roughly the area occupied by the symbol on the maps) is counted as a single seep. Gas issues intermittently or continuously with oil at many seeps, but gas seeps, as defined in this report, include only those seeps emitting a substantial volume of inflammable gas but no oil. In addition to the wells of the Katalla field, several other wells drilled in the vicinity of seeps are reported to have yielded showings of oil and gas. One well drilled some distance from the nearest known oil seeps (no. 101, on the west shore of Bering Lake) still yields some gas.

Oil seeps have been reported from time to time to occur in parts of the Katalla district other than the Mirror Slough, Katalla, and Nichawak areas. So far as is known to the writer, none of these reported occurrences has been verified.

The oil in active seeps is light green and is similar in composition to the oil from the wells but of higher specific gravity due to loss of the more volatile constituents. In 1944 and 1945 samples of gas were collected from a seep on Mirror Slough, fram a seep near the south shore of Bering Lake, and from the well on the west shore of Bering Lake, in an effort to determine whether the gas is associated with petroleum or with coal. Analyses of these samples are given in table 2. Petroleum gas characteristically contains a substantial percentage of the longer chain hydrocarbons (ethane, propane, etc.) whereas coal gas and marsh gas characteristically consist almost wholly of methane. Some petroleum gases, however, are "dry," i. e., consist largely of methane. Hence none of the samples, excepting possibly number 184 from Mirror Slough, can be regarded conclusively as being a petroleum gas. The scarcity or lack of ethane or longer chain hydrocarbons in samples 40 and 153 is suggestive of coal gas. The large amount of nitrogen and oxygen in sample 40 probably indicates contamination by air.

Martin (1921, pp. 25-30) noted that the known oil seepages in the Katalla district lie in a narrow belt which roughly parallels the trend of the coast and the Chugach Mountains, and, to some extent, cuts across the structural trends of the exposed Tertiary rocks.

Table 2

Analyses of natural gas from the Katalla district, Alaska[1]

Component	Mole percent		
Sample number	40[2]	153[3]	184[4]
Methane	72.01	96.57	93.96
Ethane	0.00	-----	1.60
Propane	0.01	-----	-----
Nitrogen	21.72	2.26	1.74
Oxygen	4.82	0.33	0.25
Argon	0.32	0.06	0.04
Carbon dioxide	1.12	0.07	2.41
Total	100.00	99.99	100.00

1 Consolidated Mass Spectrometer analyses by the U. S. Bureau of Standards, March 1 and November 16, 1945.

2 Gas seep in Bering Lake near south shore, 0.73 miles east of the mouth of Rope Creek.

3 Well no. 101, west shore of Bering Lake 1.1 miles west of mouth of Dick Creek.

4 Gas seep in Mirror Slough approximately 1 mile northeast of well no. 115.

Because of this apparent discordance, the high gravity of the oil, and the known occurrence of similar oil in Mesozoic rocks of the Cook Inlet-Alaska Peninsula area, Martin suggested that the oil in the Katalla district may have originated in relatively undisturbed Mesozoic strata over which the complexly deformed Tertiary rocks rode southward in one or more great overthrusts. This hypothesis seems unlikely in the light of present knowledge of the regional structural and stratigraphic relations of the belt of Tertiary rocks in which occur most of the oil seeps at Katalla and all the oil seeps at Yakataga. The bedded metamorphic rocks exposed in the Chugach Mountains, Ragged Mountain, and elsewhere about the northern part of the Gulf of Alaska are now thought to be largely, if not entirely, Mesozoic, possibly in part as young as Upper Cretaceous (Smith, 1939, pp. 27, 49-50). The dominant fault pattern in the belt of Tertiary rocks, as exemplified by the Chugach-St. Elias fault, is one of relatively high-angle reverse faulting rather than low-angle overthrusting. Furthermore, in the part of the Katalla district lying east of Ragged Mountain, and also in the Yakataga district, the distribution of oil seeps appears to be related to stratigraphic and structural features of the Tertiary rocks. The distribution of the few oil seeps west of Ragged Mountain in the Mirror Slough area, it must be admitted, is more favorable to a pre-Tertiary source as postulated by Martin.

The distribution, with respect to stratigraphic and structural features, of the known oil seeps east of Ragged Mountain in the Katalla district suggests that the petroliferous rocks giving rise to the oil are located mainly in the shaly middle part of the Katalla formation (the Basin Creek, Burls Creek shale, and organic shale members and the lower shaly division of the Point Hey member), and possibly in part in the Puffy member. The evidence for this conclusion follows: (1) About 91 percent of the known oil seeps (excluding those in the Mirror Slough area) are located on outcrops of the shaly middle part of the Katalla formation; about 7 percent are on outcrops of the lower part of the Puffy member. Only one oil seep appears to be issuing from rocks older than the Basin Creek member. This seep, near an outcrop of the Split Creek sandstone member on the west bank of the Bering River at Chilkat (fig. 4), is in a location where downfaulting of the Split Creek sandstone member against younger beds under Bering River is a possibility. No oil seeps are known to occur on Gandil Mountain, where the exposed rocks are mainly equivalent to the Split Creek sandstone member or older beds of the Katalla formation, nor in the Martin Lakes and Bering River areas, where pre-Katalla formations and the lower part of the Katalla formation (Split Creek sandstone and unnamed shale members) are extensively exposed. (2) The organic shale member is rich in organic material, has an oily odor at many places, and at least at one locality yields oil on distillation. (See p. 34.) (3) The producing zones of all the wells in the Katalla field, as well as all other wells (excepting those in the Mirror Slough area) that yielded showings of oil, are in shaly rocks of the middle part of the Katalla formation. (4) Most of the oil seeps in the Yakataga district issue from the Poul Creek formation, which consists mainly of siltstone and is equivalent, at least in part, to the shaly middle part of the Katalla formation. A few seeps issue from slightly younger beds of the lower part of the Yakataga formation. No seeps have been found in beds known definitely to be older than the Poul Creek formation, that is, in beds equivalent to the Split Creek sandstone and older rocks in the Katalla district.

The known oil seeps west of Ragged Mountain, in the Mirror Slough area, are in a belt that trends southeastward at an angle to the regional strike of both the Early Tertiary(?) rocks and the pre-Tertiary metamorphic rocks. Most of these oil seeps, comprising about 10 percent of the total known seeps in the Katalla district, issue from early Tertiary rocks. A few oil seeps at the southeastern end of the belt issue along fractures in the pre-Tertiary metamorphic rocks. At least one of the wells drilled near the northwest end of the belt of seeps yielded showings of oil (Martin, 1921, p. 25). These seeps possibly can be explained by overthrusting of the more highly altered pre-Tertiary and early Tertiary(?) rocks of the Mirror Slough-Ragged Mountain area over petroliferous younger Tertiary rocks. This hypothesis is supported by the occurrence of the oil in rocks of seemingly unfavorable lithology, and also by the fact that the trend of the belt of oil seeps cuts across the regional strike of both the pre-Tertiary and early Tertiary(?) rocks. On the other hand, it is not impossible that the oil is indigenous to the younger group of rocks exposed in the Mirror Slough area.

ACCUMULATIONS OF OIL

The coarse clastic Tertiary sediments of the Katalla district, so far as they are known in outcrop, are characteristically poorly sorted, consisting of particles of sand and gravel size imbedded in a matrix of silt- and clay-size grains. Field observations and laboratory study of the exposed Tertiary sandstones and conglomerates indicate low porosity and permeability. One sample of sandstone or tuff from each of the following members of the Katalla formation--the unnamed shale, the Split Creek sandstone, the Basin Creek, the Burls Creek shale, the Point Hey, and the Puffy--were submitted to the Navy Oil Unit of the Geological Survey for permeability tests. All the samples were reported_/ to have a permeability of less than 10 millidarcys (the minimum value that could be determined). The porosity of the samples was not determined. These samples were selected, on the basis of field observations and by comparing--under the binocular microscope--the rate of absorption of water, as being representative of some of the most favorable potential reservoir beds observed during the 1944-1945 field work. Beds having more favorable reservoir characteristics may be exposed or present in the subsurface section, however.

Many of the sandstone and conglomerate units are known to show lateral variations in thickness, grain size, and sorting, but the stratigraphic information obtained to date is not adequate to predict whether or not such variations offer possibilities for oil traps.

_/ Payne, T. G., personal communication.

The wells in the Katalla field are believed to have produced from fractured but otherwise relatively impermeable shaly rocks of the middle part of the Katalla formation, in a zone of complex folding and faulting (Miller et al., 1945, p. 16). The chances are good for finding similar zones of shattered rocks elsewhere on the Katalla district, but whether or not oil has accumulated in them in substantial amount is less certain. Substantial production has been obtained from fracture zones in fine-grained, relatively impervious rocks in several major oil fields of the United States (Lalicher, 1949, p. 103).

The known anticlines in the Tertiary rock of the Katalla district, for the most part, are of small amplitude, are tightly compressed, and appear to have little or no closure. Anticlines with fairly broad flanks and with nearly horizontal axes or even small closure, occur at some places, for example in the northern part of the Katalla area and in Gandil and Nichawak Mountains. Most of these broader folds involve a part of the sedimentary sequence (beds of Split Creek age and older) not known to include petroliferous rocks or suitable reservoir beds. In view of the apparent scarcity or lack of porous and permeable beds, the anticlines that are most tightly folded and most intensely faulted, hence in which the rocks are most fractured, may afford the best possibilities for anticlinal production of oil.

SUMMARY OF OIL POSSIBILITIES

The distribution of oil seeps in relation to structural and stratigraphic features in the Katalla district points to the presence of petroliferous rocks in the shaly middle part of the Katalla formation and possibly in the upper part of the Katalla formation and in pre-Katalla early Tertiary(?) rocks of the Mirror Slough area. Except possibly in the Mirror Slough area, where both the age of the rocks and the ultimate source of the oil are in doubt, oil seeps are not known to occur in pre-Katalla sediments in the Katalla district. The wells in the Katalla field are believed to have produced from fractured rocks of the shaly middle part of the Katalla formation, in a fault zone. Comparable zones of fractured rocks along faults or folds elsewhere in the Katalla district appear to offer the best possibilities for accumulations of oil in quantity equal to or larger than the Katalla oil field. Most of the known anticlines are of small amplitude, are tightly compressed, and lack structural closure. Beds with favorable reservoir characteristics appear to be scarce or lacking.

Most of the wells in the Katalla district, including the discovery well of the Katalla oil field, were drilled on oil seeps or near producing wells. They have little significance as a test of the oil possibilities of the Katalla district, except that they proved the presence of a small accumulation of oil in an area of 60 acres in the Katalla oil field. Selection of drilling sites in the Katalla district should be preceded by detailed geologic mapping of the general vicinity of the proposed sites, supplemented by core drilling if necessary, in order to determine as accurately as possible the nature of the structure and the location and character of potential traps for oil at depth. Because of (1) the general scarcity of diagnostic fossils, either macroscopic or microscopic; and (2) the lack, in parts of the section, of diagnostic key beds of distinctive lithology, careful study of well cuttings and cores will be necessary in order to correlate subsurface sections. Location of accumulations of oil at depth in the Katalla district, except in the vicinity of the successful wells of the Katalla field, is likely to be difficult because of the complexity of the structure and lack of information on local factors affecting the accumulation of oil. Any plan for exploring the oil possibilities of the Katalla district should take into account the possibility that many test wells may be required to prove the presence or absence of significant accumulations.

Over much of the southern part of the Katalla district the bedrock is covered by ice, alluvium, or water. Much of this area is doubtless underlain by Tertiary rocks, very likely in part equivalent to the petroliferous rocks exposed in the Katalla and Nichawak areas. Except for the clues provided by adjacent areas in which the bedrock is exposed, the oil possibilities of this substantial part of the Katalla district can be evaluated only by geophysical prospecting or by drilling through the cover of ice, alluvium and water to bedrock.

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