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GEOLOGY OF THE SOUTHEASTERN PART OF THE ROBINSON MOUNTAINS, YAKATAGA DISTRICT, ALASKA

By

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GEOLOGY OF THE SOUTHEASTERN PART OF THE ROBINSON MOUNTAINS, YAKATAGA DISTRICT, ALASKA

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INTRODUCTION

This report gives the results of geologic investigations in the Yakataga district on the south coast of Alaska, including detailed geologic mapping in the southeastern part of the Robinson Mountains, and reconnaissance study of the stratigraphy and structure of adjoining areas. The geologic map that accompanies this report covers an area of 630 square miles and includes the Bering Glacier (A-2), (A-3), and (A-4) quadrangles and the Icy Bay (D-2 and D-3) quadrangle of the Alaska inch-to-the-mile quadrangle map series. (See fig. 1.)

The Robinson Mountains, rising abruptly from the coastal plain to a maximum altitude of about 9,000 feet, are bordered on the west, north, and northeast by the Bering and Guyot Glaciers and connecting ice fields. (See index map B, fig. 1.) The mountains extend nearly across the central part of the Gulf of Alaska Tertiary province. This province, a distinctive topographic and geologic subdivision of the Pacific Mountain System bordering the Gulf of Alaska, is an arcuate lowland and foothills belt 300 miles long and 2 to 40 miles wide in which sedimentary rocks of Tertiary age are exposed or are inferred to underlie lowland areas covered by ice or unconsolidated deposits (Gryc and others, 1951, p. 159-162).

Interest in the placer gold deposits and in the possibilities for petroleum and coal led to the first systematic geologic investigation of the Robinson Mountains, a reconnaissance of the southern part made by A. G. Maddren in 1913 (Maddren, 1914; Martin, 1921, p. 34-42). N. L. Taliaferro (1932, p. 750-777) described and named the Poul Creek and Yakataga formations, based on his study of the coastal area between Cape Yakataga and Icy Bay in 1920. The fossils collected from these formations by Taliaferro were described by Clark (1932). A field party representing the Standard Oil Company of California, the Tide Water Associated Oil Company, and the Union Oil Company of California made a geologic investigation of the southern part of the Robinson Mountains in 1938. The unpublished report resulting from this work was made available to the United States Geological Survey for confidential review. The most comprehensive of several other geologic studies made more recently on behalf of oil companies, the results also not intended for publication, are the investigations by the General Petroleum Corporation of California in 1951 and by the Shell Oil Company in 1953, and the continuing investigations by the Phillips Petroleum Company, started in 1953 in connection with exploration of a large lease tract in the Robinson Mountains.

The field studies on which this report is based were undertaken by the Geological Survey between 1944 and 1953, the primary objective being to obtain basic geologic information to appraise the petroleum possibilities of the Yakataga district and to aid the search for accumulations of oil or gas. A coastal area in the Robinson Mountains where many oil seeps occur was one of several areas in Alaska selected for geologic investigation in 1944, in response to the then acute national situation in regard to oil. During the summer of 1944 E. M. Spieker, M. S. Walton, Jr., and C. E. Kirschner mapped an area of 210 square miles, including most of the Yakataga River-Yakataga Glacier drainage basin and the coastal area between the Yakataga Airport and Johnston Creek (Spieker and others, 1945; Reed, 1946, p. 1437-1438. The writer began reconnaissance geologic mapping of the western part of the Robinson Mountains during the field season of 1946. During the 1947 field season this work was extended, with the assistance of R. E. Johnson, to the south central and southeastern part of the Robinson Mountain. More detailed mapping was begun in the coastal area between the Duktoth River and Icy Bay during the latter part of the 1947 field season and early part of the 1948 field season (Miller, 1951). Detailed mapping in the newly compiled inch-to-the-mile topographic quadrangles covering the southeastern Robinson Mountains was continued by the writer during the 1951 and 1952 field seasons (Miller, 1953) and completed, with the assistance of George Plafker and D. L. Rossman, during one month of the 1953 field season. In the field work between 1944 and 1953 extensive use was made of the airplane to transport men, equipment, and supplies to the Yakataga Airport and other base camps; to drop supplies for many supplementary camps that could be reached only on foot; and for air observation and photography as direct aids to geologic mapping.

In the course of the field work between 1946 and 1953 the writer remapped the area previously mapped by Spieker, Walton and Kirschner. Their work, although greatly handicapped by lack of a base map and adequate aerial photography, nonetheless aided later restudy of the area in greater detail, and contributed much to the writer's understanding of the many geologic problems encountered there. H. E. Vokes, Ralph Stewart, and L. G. Hertlein independently identified portions of the collections of fossil mollusks made during the 1944-1953 investigation. F. S. MacNeil reviewed the molluscan faunas in all Geological Survey collections from the Poul Creek and Yakataga formations, and prepared the faunal list that accompanies this report. W. W. Rau identified the Foraminifera in several samples from the Poul Creek and Yakataga formations. The Civil Aeronautics Administration, through its station at the Yakataga Airport, provided living quarters and storage space for equipment and supplies, and maintained radio contact with Geological Survey field camps when needed. Mr. and Mrs. Ben Watson and Messrs. Jack Carson and Carl Killian, long-time residents of the Yakataga district, as well as the frequently changing personnel of the Yakataga C. A. A. station, aided the field work in many ways.

STRATIGRAPHY

The bedrock exposed in the area of this report and in the adjacent part of the Robinson Mountains consists of an apparently conformable sequence of well-indurated sedimentary rocks having a composite thickness of at least 25,400 feet and ranging in age from early Tertiary to late Tertiary. The bedrock sequence is divided into three formations: the nonmarine and marine Kulthieth formation of early Tertiary age; the marine Poul Creek formation of middle Tertiary age; and the marine Yakataga formation of late Tertiary age. (See fig. 3.) The age assignment of these formations within the Tertiary period is necessarily tentative, in part because of the uncertainty of their correlation with the standard Tertiary sections of the Pacific Coast of North America, and in part because of the difference of opinion that exists in the classification of the Pacific Coast Tertiary with reference to the international time scale based on the standard Tertiary sections in Europe (Weaver and others, 1944, p. 570-574, pl. 1).

Kulthieth formation

The oldest rocks exposed in the Robinson Mountains consist of at least 9,300 feet of nonmarine and marine sandstone and siltstone with many intercalated thin beds of high-rank coal, previously designated by the informal term "lower Tertiary sequence" (Miller, 1951, p. 13-17). The name Kulthieth formation (pronounced Kŭl-tĭ-ēt), which is a new name for these strata, is described in the Oil and

and Gas Map for this area in preparation for publication by the Geological Survey. These strata are extensively exposed in the area drained by the Kulthieth, Kaliakh, and Duktoth Rivers in the western and northern part of the Robinson Mountains. The area in the vicinity of the small lake at the head of the northeasternmost branch of the Kulthieth River, where stratigraphic section no. 2 was measured (index map B, fig. 1), affords what is believed to be the most complete and least disturbed section of the Kulthieth formation and will be designated the type locality. The Kulthieth formation is overlain with apparent conformity by the Poul Creek formation. The base of the Kulthieth formation is not exposed in the Robinson Mountains. In the map area of this report only the upper part of the Kulthieth formation is exposed. This includes small areas at the head of the Yakataga Glacier and a narrow belt north of the Miller Creek fault between Boulder Creek and the Watson Glacier.

At the type locality the Kulthieth formation includes three dominantly sandy units: the upper 1,400 feet, and the units 1,900 to 3,200 feet and 3,600 to 5,400 feet below the top. These alternate with three dominantly or conspicuously silty units. Reconnaissance study of the adjacent area in the western Robinson Mountains has indicated that at least four of these units are mappable units (Miller, 1951, p. 14) which may, after more detailed mapping, warrant designation as members.

Sandstone showing wide variety in grain size, bedding, color, and composition predominates in the Kulthieth formation, constituting about 65 percent of the section measured at the type locality. Most of the sandstone is well indurated and poorly sorted, consisting of very fine grained to medium-grained angular to subrounded mineral grains and rock fragments in a matrix composed chiefly of silt-size grains. Only a small proportion of the sandstone consists chiefly of detrital fragments coarser than 0.5 mm. diameter; detrital fragments as large as pebble size are rare. The most abundant type is massive to cross-bedded arkosic sandstone that is gray to olive gray on fresh surfaces and weathers yellowish gray to brown. In outcrop, some sandstone of this type is moderately well sorted and appears to have sufficient porosity and permeability to serve as a reservoir rock for petroleum. Other common types of sandstone occurring in the sandy units of the formation are massive to thin-bedded, partly banded olive-green to olive-gray sandstone that contains a large proportion of dark ferromagnesian minerals; massive gray to yellowish-gray arkosic sandstone with conspicuous brownish-gray to olive-gray mottling; and thin-bedded gray micaceous sandstone.

In the silty units of the Kulthieth formation dark-gray to black carbonaceous or micaceous siltstone is interbedded with generally thin beds of massive gray to brown arkosic sandstone and thin-bedded very fine grained micaceous sandstone. These silty units are characterized by thin discontinuous beds and lenticular concretions of calcareous arkosic sandstone or sandy limestone which are gray or brown on fresh surfaces but weather bright yellowish orange. Authigenic quartz crystals ranging from a fraction of an inch to 2 inches in largest dimension occur abundantly in some of the arkosic sandstone beds, especially those in the silty units.

Beds of coal ranging in thickness from a fraction of an inch to about 6 feet occur throughout the formation but are most abundant in the silty units. The coal commonly is sheared or powdered even in the freshest exposures, although locally it is blocky. Based on analysis of one sample from the Robinson Mountains (Maddren, 1913, p. 148) and on comparison with coal of approximately the same age and similar physical characteristics in the Katalla district, most of the coal in the Kulthieth formation ranges in rank from low-volatile bituminous to semianthracite. Thin, highly sheared beds of coal having the conchoidal fracture and luster typical of anthracite are present in outcrops of the Kultheith formation adjacent to the Chugach-St. Elias fault north and northwest of the Robinson Mountains.

Marine invertebrate fossils have been collected from sandstone beds at several localities in the western part of the Robinson Mountains. The stratigraphic position of these fossiliferous beds within the Kultheith formation is not known with certainty, but they are believed to be in the upper part, probably not more than 2,000 feet and possibly not more than 1,000 feet below the top. According to H. E. Vokes, correlation with the late Eocene faunas of the Cowlitz formation of Washington and the Tejon formation of California is indicated by the following species in the Kulthieth formation:

Crassatella cf. *C. dalli* (Weaver)
Pitar cf. *P. californiana* (Conrad)
Gari cf. *G. columbiana* (Weaver and Palmer)
Ficopsis cowlitzensis (Weaver)
Perse cf. *P. sinuata* (Gabb)
Turritella uvasana Conrad subsp.

Crassatella, *Ficopsis*, *Turritella* and other genera of marine invertebrates found in the Kulthieth formation are generally regarded as indicating tropical to warm temperate water. This evidence of warm climate is corroborated by the widespread occurrence in Alaska of an early Tertiary flora containing many subtropical and temperate genera.

Poul Creek formation

Taliaferro (1932, p. 754-756) proposed the name Poul Creek formation for strata exposed along Poul Creek and elsewhere in the coastal area of the Robinson Mountains, consisting of "fully 3,000 feet of dark hard platy shales, in part calcareous and in part sandy, thinbedded sandstones, conglomerates, occasional thin limestones, and a few beds of glauconitic sandstone". He stated that the Poul Creek formation is conformably overlain by the Yakataga formation and that the base of the formation is not exposed in the coastal area.

In this report the Poul Creek formation is redefined to include approximately 6,100 feet of marine interbedded siltstone and sandstone that lies with apparent conformity on the Kulthieth formation. As thus defined the formation includes in its upper part most of the strata originally assigned to it at the type locality on Poul Creek (stratigraphic section no. 8, fig. 3) by Taliaferro. It also includes the lower part of the Yakataga Reef section, which Taliaferro assigned entirely to the Yakataga formation but excludes the beds he described as "glacio-fluvial conglomerates" ("conglomeratic" sandy mudstone of this report), here assigned to the overlying Yakataga formation. In the south-facing cliff at the head of the Yakataga Glacier (stratigraphic section no. 7, fig. 3) the entire formation is exposed in a continuous, homoclinal section which shows with striking clarity the predominantly silty, reddish-brown-weathering Poul Creek formation in contact with the predominantly sandy beds of the Kulthieth formation below and the gray-weathering interbedded sandstone and siltstone strata of the Yakataga formation above. The lower part of the Poul Creek formation is extensively exposed in the western and northern Robinson Mountains, including the northwestern part of the map area of this report. The upper part of the formation is exposed along the axes of the major anticlines in the southeastern Robinson Mountains.

Massive hard concretionary siltstone and silty very fine grained sandstone showing little evidence of stratification or sorting predominate in the Poul Creek formation. These rocks are gray, greenish gray, or olive gray on fresh surfaces, but weather reddish brown. Fresh angular grains of quartz and feldspar, and fragments of fine-grained rocks are the most abundant constituents. Gray impure limestone in the form of concretions or, less commonly, in thin discontinuous beds commonly is associated with the siltstone and silty sandstone. The smaller concretions range in shape from nearly spherical masses to flat lenses. The larger concretions, from 2 to 5 feet in largest dimension, are lenticular and are most common in the upper part of the formation. Over most of the area of outcrop a unit 200 to 700 feet thick at or near the top of the Poul Creek formation consists of siltstone that is less sandy and less resistant to erosion than adjacent beds of the Poul Creek and Yakataga formations. In the coastal area, especially between the White River and the Beare Glacier, this unit is marked by subsequent streams and by low saddles on the ridges between the major transverse streams.

Fine-grained to medium-grained sandstone is common only in the basal part of the Poul Creek formation through an interval ranging in thickness from 900 feet in the western Robinson Mountains to about 2,500 feet in the southeastern Robinson Mountains. The dominant types of sandstone in this interval are massive gray to olive-gray arkosic sandstone and thin-bedded gray micaceous sandstone like that in the upper part of the Kulthieth formation, massive to thin-bedded greenish-gray to olive-gray sandstone that weathers pale red or pink, and thin-bedded, finely banded and commonly ripple-marked gray sandstone that is rhythmically interbedded with dark siltstone. Sandstone beds in the middle and upper part of the formation commonly are light gray or light brown, and are in part tuffaceous. Most of the sandstone in the Poul Creek formation is poorly sorted, hard, and has low porosity and permeability. In the coastal area between Acme and Lawrence creeks, however, a few beds of light-colored sandstone in the interval 1,000 feet to 2,000 feet below the top of the formation are moderately well sorted and locally are friable. Many oil seeps in this area occur on or near outcrops of these sandstone beds.

Other rock types restricted to and characteristic of the Poul Creek formation are massive beds of dark-green to olive-black glauconitic sandstone, which occur in all but the upper 300 to 500 feet of the formation, and beds of dark-green water-laid tuff and volcanic breccia, which occur in the basal part. At most localities the base of the Poul Creek formation is marked by a 1- to 3-foot bed of dark-green sandstone consisting of fresh angular clastic fragments in a glauconitic or tuffaceous matrix. Water-laid tuff and volcanic breccia are best developed in the area between Boulder Creek and the Watson Glacier where, interbedded with limestone and green tuffaceous siltstone and sandstone, they form several units ranging in thickness from a few inches to about 200 feet.

Marine invertebrate fossils, chiefly mollusks, have been collected throughout the Poul Creek formation. Ralph Stewart, on the basis of his study of fossil collections believed to be representative of all but the basal part, regards the fauna of the Poul Creek formation as of Upper Tertiary or Neogene age, probably lower Neogene, and possibly correlative with the faunas of the Ashiya "Group" of Japan and the type Blakeley formation of Washington. According to

H. E. Vokes the best-preserved fossils from the basal part of the formation, collected in the vicinity of Hanna Lake in the western Robinson Mountains, are of middle Oligocene age and indicate a correlation with either the Lincoln formation of Washington or the Pittsburg Bluff formation of Oregon. Vokes correlates the fauna of the remainder of the Poul Creek formation with faunas of the upper part of the Lincoln formation, the Blakeley formation, and the Twin Rivers formation of Washington. L. G. Hertlein, on the basis of his study of the Poul Creek fauna, including some collections from the basal beds, regards it as correlative with the fauna of the Blakeley formation and probably the upper part of the Lincoln formation.

F. S. MacNeil, at the request of the writer, made a preliminary study of all the Geological Survey collections of mollusks from the Poul Creek and Yakataga formations, including the collections previously identified by W. H. Dall (Maddren, 1914, p. 127-130) and the collections identified by Vokes, Stewart, and Hertlein. Based on this study MacNeil has furnished the following tentative statement on the age of the Poul Creek and Yakataga molluscan faunas:

"While the forms represented seem to correspond to the species of the standard west coast section in a general way, there are discrepancies in both the part of the section in which certain types (not necessarily identical species) are found, and in the sequence. It is to be expected, probably, that some species occupying narrow intervals in the section to the south may be found elsewhere in higher or lower beds. One important difference is the apparently coincident range of _Echinophoria_ _rex_ and _Echinophoria_ _apta_, assuming, of course, that _E._ _rex_ is even represented. _Turritella_ _porterensis_, which was identified by at least some of the other paleontologists who examined this material, is not present in the collections from the very lowest part of the Poul Creek formation, the only part of the section containing some other species supposed to be restricted to the _T._ _porterensis_ zone.

"Making allowances for both such inconsistencies as are mentioned above, and the general disagreement among west coast paleontologists regarding the location of the Oligocene-Miocene boundary, I would hazard an opinion on the age of the beds in the Yakataga district about as follows:

1. The Poul Creek formation is late Oligocene and early Miocene in age. The lower part of it is certainly as old as late Oligocene and may be as old as middle Oligocene.

2. The Yakatage formation is middle and late Miocene and possibly early Pliocene in age."

Significant elements of the Poul Creek and Yakataga molluscan faunas, as selected by MacNeil, are listed in table 1.

Foraminifera have been found in some siltstone beds and glauconitic sandstone beds of the Poul Creek formation but are not abundant, are poorly preserved, and are difficult to extract from the hard matrix. W. W. Rau identified the species listed below from three samples of siltstone cored in the upper part of the Phillips Petroleum Company and Kerr-McGee Oil Industries, Inc. Sullivan No. 1 well. The stratigraphic positions of these samples are not known precisely but they are probably from the middle part:

Cyclammina? sp.
Gaudryina alazanensis Cushman
Robulus sp.
Guttulina sp.
Bulimina sp.
Pseudoglandulina sp.
Gyroidina orbicularis planata Cushman
Eponides mansfieldi oregonensis Cushman, Stewart and Stewart
Cassidulina cf. C. crassipunctata Cushman and Hobson
Anomalina cf. A. californica Cushman and Hobson
Cibicides elmaensis Rau

Of this fauna, Rau commented:

"In western Washington this combination of species is restricted to the upper part of the Lincoln formation as defined by Snavely and others (rept. in preparation) and the Blakeley formation. The known foraminiferal assemblages from these Washington strata are best referred to Kleinpell's Zemorrian stage of "Oligo-Miocene" age (Beck and others in Weaver and others, 1944, pl. 1)."

The molluscan fauna of the Poul Creek formation includes genera that are believed to be indicative of warm temperate or subtropical water (Aturia, Ancilla, Crassatellites, Macrocallista, Pitar and others) and also of moderately deep water (Solemya). Some elements of the fauna, such as Mya and Solena, which are found mainly in sandstone beds, are indicative of shallow water. Faunal evidence that the sediments of the Poul Creek formation were deposited mainly in moderately deep water is corroborated by the predominance of massive, unsorted or poorly sorted silty rocks.

Yakataga formation

The marine sedimentary rocks of varied lithology lying conformably on the Poul Creek formation in the coastal area of the Robinson Mountains were named the Yakataga formation by Taliaferro (1932, p. 756-762). He did not designate a specific type locality, although he stated that the formation is well exposed at Yakataga Reef and on both flanks of the "Yakataga" anticline (the Sullivan anticline of this report). Taliaferro's concept of the Yakataga formation as including all the younger Tertiary marine strata above the Poul Creek formation is followed in this report, but the position of the contact between the two formations and the criteria for placing this contact are redefined..

The Yakataga formation includes a minimum of 10,000 feet, possibly 15,000 feet or more of sedimentary rocks, chiefly siltstone, sandstone, and an unsorted rock containing much coarse ice-transported debris, provisionally named "conglomeratic" sandy mudstone (Miller, 1953, p. 26). Interbedded sandstone and siltstone predominate in the lower part of the formation through an interval ranging in thickness from about 5,500 feet in the western Robinson Mountains to about 3,500 feet near Icy Bay in the southeastern Robinson Mountains. "Conglomeratic" sandy mudstone equals or exceeds the proportion of sandstone and siltstone in the upper part of the formation, which includes the youngest beds of Tertiary age exposed in the Yakataga district and in the Malaspina district to the east (Plafker and Miller, 1954). At most localities where it has been observed the contact between the Yakataga and Poul Creek formations is gradational through a stratigraphic interval of 50 to 200 feet in which typical gray-weathering siltstone and fine-grained sandstone of the Yakataga formation is interbedded with typical reddish-brown weathering silty rocks of the Poul Creek formation. At some localities a prominent sandstone is present at the base, but the thick sandstone which Taliaferro (1932, p. 757) cited as marking the base of the Yakataga formation in the vicinity of Twomile Creek and farther east is well down in the Poul Creek formation as defined in this report.

The Yakataga formation underlies most of the southeastern part of the Robinson Mountains, southeast of the Miller Creek fault. It is exposed also in the Guyot Hills, in a belt extending from Duktoth Mountain west to the Bering Glacier, and in the upper part of Mount Leeper and the high ridge extending south to the Yakataga Glacier. Representative sections of a major part of the formation are afforded by continuous exposures on the south face of Kulthieth Mountain (stratigraphic section no. 3, fig. 3) and the ridge extending north to the Hope Creek fault, and by continuous exposures in cliffs extending from the White River Glacier eastward along the southern margin of the Guyot Glacier to the head of Icy Bay. The striking contrast in color between the weathered outcrops of the Yakataga and Poul Creek formations is best seen in exposures of the contact in the vicinity of Poul Creek (stratigraphic section no. 8, fig. 3), in the east-facing scarp of Duktoth Mountain (stratigraphic section no. 4, fig. 3), and in the cliff at the head of the Yakataga Glacier (stratigraphic section no. 7, fig. 3). This contact is well exposed also in Yakataga Reef (stratigraphic section no. 6, fig. 3).

The sandstone in the Yakataga formation is predominantly of two types: (1) thin-bedded, partly banded very fine grained sandstone in units commonly ranging in thickness from a fraction of an inch to a few feet, and (2) slabby to massive fine- to coarse-grained sandstone in units ranging in thickness from a few feet to several hundred feet. Both types commonly are light gray, greenish gray, or brown. Quartz, feldspar, and fragments of igneous, metamorphic and sedimentary rocks are the principal constituents. Most of the sandstone in the lower part of the formation is hard and poorly sorted. The degree of induration decreases upward in the formation, and some of the slabby to massive sandstone in the upper part is moderately well sorted. Conglomerate consisting of generally well-rounded pebbles or cobbles in a matrix of sandstone or sandy mudstone forms massive but commonly lenticular units ranging in thickness from a few inches to as much as 250 feet.

The siltstone is platy to massive, in part slightly calcareous, and is medium gray to dark gray on both fresh and weathered surfaces. It forms some thick units, but more commonly occurs interbedded with sandstone in units ranging in thickness from a fraction of an inch to several feet. Dark-gray impure limestone in thin, discontinuous beds and elongate lenses is associated with the siltstone.

The rock called "conglomeratic" sandy mudstone in this report consists of gray to greenish-gray or olive-gray sandy mudstone containing scattered rock and mineral fragments ranging in size from granules to huge boulders. This rock, which forms massive beds of relatively uniform thickness and large lateral extent, is a marine tillite (Miller, 1953, p. 22-35). The gravel fragments and at least a part of the finer sediments were transported to the site of deposition by floating ice; glacial striae are preserved on many gravel fragments. The "conglomeratic" sandy mudstone resembles typical tillite of terrestrial origin in that it consists of fresh rock and mineral fragments of clay to boulder size deposited with little or no sorting, but differs in that it contains fossil remains of marine invertebrates and is interbedded with normal marine sedimentary rocks.

Local folding during Yakataga time is recorded by minor unconformities at two or more horizons within the Yakataga formation as exposed in the southern part of the Guyot Hills (structure section D-D', fig. 2). The intensity of folding increased eastward, for in the Karr Hills, about 3 miles east of the Guyot Hills, gently dipping upper Yakataga beds rest with marked angular contact on lower Yakataga beds that dip 30°-90° (Plafker and Miller, 1954). No evidence of an unconformity was seen in exposures of the Yakataga formation in the Robinson Mountains south and west of the Guyot

Hills, other than local discordance or truncation of beds, which is common in the upper part of the formation and is attributed to submarine slumping or erosion.

The marine molluscan fauna of the Yakataga formation, although moderately abundant and varied, includes few identifiable species that permit even approximate correlation with faunas of the Pacific Coast standard section. Study of the collections made during the recent field investigations has resulted in considerable diversity of opinion as to the age of the Yakataga formation. It is regarded by Ralph Stewart as of Upper Tertiary or Neogene age, referrable to the Upper Neogene or possibly the lower part of the Upper Neogene; by L. G. Hertlein as in part of Miocene age and in part of Pliocene age; and by H. E. Vokes as probably in part of Miocene age and possibly in part of latest Oligocene age. MacNeil regards the Yakataga formation as middle and late Miocene and possibly early Pliocene in age (page 14).

Although many species range through the upper part of the Poul Creek formation and lower part of the Yakataga formation, there is a marked change in the molluscan fauna approximately at the contact between the formations. (See table 1.) The fauna of the Yakataga formation, taken as a whole, indicates colder and shallower water than the fauna of the Poul Creek formation. Some common and diagnostic genera of the Poul Creek formation, such as *Echinophoria*, *Ancistrolepis*, *Psephaea* (*Miopleiona*), and *Aturia* range up to or near the contact but are not found in the Yakataga formation.

Other forms, such as large pectinids and several species of large neptuneids, first appear at or near the base of the Yakataga formation. The incorrect conclusion of Clark (1932, p. 799) that the molluscan fauna of the two formations is identical and represents a single zone was due in part to incorrect stratigraphic assignment of some collections studied by him, and in part to lack of representative collections from either the lower part of the Poul Creek formation or the upper part of the Yakataga formation.

Deposition of the sediments of the Yakataga formation at least in part at relatively shallow depth is indicated by thin-bedded and ripple-marked sandstone, by lenticular beds of conglomerate made up of well-rounded pebbles and cobbles, and by the presence of fossil shells of Mya, Mytilus and other genera now found living in shallow water. A climate sufficiently cold to result in active glaciation of the adjacent land area is indicated by the massive marine tillites, which first appear near the base and make up much of the upper part of the formation. Lack of sorting of the massive "conglomeratic" sandy mudstone may indicate deposition below the lower limit of effective wave or current action, or it may indicate that wave or current action was prevented either by land or ice barriers, or by floating shelf ice or bergs.

Quaternary deposits

The Tertiary bedrock sequence of the Robinson Mountains is overlain with marked angular unconformity by essentially horizontal unconsolidated deposits formed in both marine and terrestrial environments and attaining greatest thickness and areal extent on the coastal plain. Chief among these deposits are: well-sorted sand and gravel formed on the present and former beaches; interstratified sand and mud containing much organic debris, formed in tidal lagoons or bays; mud interstratified with poorly to moderately well sorted sand and gravel, formed along the channels of the larger streams, on fans at the mouths of the smaller streams, and on outwash plains at the margins of glaciers; and till formed at the margins of glaciers, in part in the sea. These deposits are not differentiated on the map.

STRUCTURE

In latest Tertiary time or in Quaternary time the belt of older metamorphic and igneous rocks forming the Chugach-St. Elias Mountain chain was uplifted and thrust southward along the Chugach-St. Elias fault and other faults of an arcuate, northward-dipping system, and the bordering belt of younger sedimentary rocks in the Gulf of Alaska Tertiary province was folded, faulted, and uplifted. (See index maps A, B, fig. 1.) In the Robinson Mountains the Tertiary rocks are moderately to intensely compressed in eastward-trending folds and are displaced along northward-dipping thrust faults that are subparallel to the Chugach-St. Elias fault but of smaller magnitude. The principal faults of this system that have been recognized in the Robinson Mountains are the Kosakuts, Hope Creek, and Miller Creek faults.

The Miller Creek fault divides the map area of this report into two belts of contrasting structure and stratigraphy, best illustrated by the structure section B-B' (fig. 2). The belt lying southeast of this fault is characterized by narrow, tightly compressed asymmetrical anticlines alternating with broad synclines. The rocks exposed belong chiefly to the Yakataga formation; only the upper part of the Poul Creek formation is exposed in narrow bands along the axial parts of the major anticlines. The belt lying northwest of the Miller Creek fault is characterized by smaller, less tightly compressed but more closely spaced anticlines and synclines of nearly equal amplitude. In this belt the exposed rocks belong chiefly to the Poul Creek formation, and the upper part of the Kulthieth formation is exposed in narrow bands just northwest of the Miller Creek fault.

The major folds and faults in the map area are shown on figure 1 and figure 2, and are described below.

The Leeper syncline, a southwestward-plunging asymmetrical fold, is exposed for a distance of 7 miles in the northwestern corner of the map area. It is inferred to extend at least 8 miles farther northeastward up the valley of the Leeper Glacier and to be continuous with the prominent syncline exposed in the west face of Mount Leeper, north of the mapped area. Beds of the Yakataga formation on the north flank of this syncline form the upper part of Mount Leeper (altitude about 9,000 feet), the highest peak in the Gulf of Alaska Tertiary province.

The Dahlgren anticlinorium is a complex major upwarp which forms Leeper Ridge, lying between the predominantly synclinal valleys of the Leeper Glacier on the north and the Yakataga Glacier and Yakataga River on the south. As shown in the structure sections A-A' and B-B' (fig. 2), beds of the Poul Creek formation in this ridge are warped in a broad arch and are further compressed into many subsidiary asymmetrical folds of small amplitude in proportion to their length. The axial planes of the subsidiary folds dip northward, in keeping with the regional structural pattern. The approximate location of the axis of the Leeper anticlinorium is shown on index map B (fig. 1). The axis trends at a small angle across the axes of the subsidiary folds, plunges southwestward, and is cut off by the Miller Creek fault near the head of Miller Creek. Many northward-dipping high-angle strike thrust faults are present on the crest and south flank of the anticlinorium. Only the largest of these faults are shown on the map.

The Miller Creek fault, on the southeast flank of the Leeper anticlinorium, has been traced in outcrop for a distance of 8 miles between Boulder Creek and the Yakataga Glacier. Discordant structure and stratigraphy in the bordering valley walls indicate that the fault continues northeastward beneath the Yakataga Glacier to and beyond the northern boundary of the map area. The fault is best exposed at the head of Miller Creek, where the upper part of the Kulthieth formation in the hanging wall is in contact with the lower part of the Yakataga formation along a fault plane dipping about 70° N. At this locality the fault has a stratigraphic displacement of about 8,400 feet and an indicated net slip of about 9,000 feet. At Boulder Creek the trace of the Miller Creek fault swings southwestward, and the regional strike of the beds in the hanging wall block likewise changes from nearly west to southwest.

The Yaga syncline is a northeastward-plunging, broad fold exposed in the vicinity of the Yaga Glacier. The northern flank, which has an average trend of about N. 20° E., is complicated by minor warping and by faulting in the vicinity of the Yaga Glacier and farther north. The Yaga syncline extends westward beneath the lower part of the Yakataga Glacier, and may be continuous with a syncline mapped in the Yakataga formation in the vicinity of Porcupine Creek. It is inferred to continue northeastward beneath the Guyot Glacier at least as far as the line of structure section C-C' (fig. 1).

The Yakataga anticline is strikingly exposed for a distance of 11 miles in Yakataga Ridge. Nearly vertical beds of the Yakataga formation on the south limb of the fold form the crest of the ridge. Opposing dips in several nunataks show that the Yakataga anticline extends eastward under the Guyot Glacier and is continuous with the anticline exposed in the southern part of the Guyot Hills and in the Karr Hills, east of the mapped area. In Yakataga Ridge the anticline is tightly compressed and the more gently-dipping north flank is displaced upward along a fault which, at the surface, is nearly vertical and lies in or just south of the axial plane. The net displacement along this fault may be as much as 4,000 feet at the west end of Yakataga Ridge, but decreases gradually to the east end of the ridge where the fault apparently dies out. In the Guyot Hills the Yakataga anticline is less tightly compressed, and the north flank is complicated by subsidiary folds. Here, and in the Karr Hills, angular unconformities on the crest and flanks, as well as thickening of beds away from the flanks, show that uplift of this fold was initiated during the time of deposition of the Yakataga formation.

An anticline exposed near the mouth of Porcupine Creek is similar in profile to the Yakataga anticline and may represent its extension west of the foot of the Yakataga Glacier. If this correlation is made it is necessary to infer that the Yakataga anticline is offset by a fault trending northward through the low saddle east of Porcupine Creek, as shown on figure 1.

The White River syncline, which is the major downwarp in the southeastern Robinson Mountains, has been traced for a distance of 35 miles, from the Yakataga River valley on the west to the southern part of the Karr Hills on the east. The syncline is well exposed in the vicinity of the White River Glacier. Its width, measured between the crests of the adjacent anticlines, ranges from 5 miles near the foot of the Yakataga Glacier to more than 16 miles near Icy Bay. From a point approximately on the line of structure section C-C' the axis of the White River syncline plunges westward at an angle of 3°; east of this point the axis plunges eastward at approximately the same angle.

A supposed anticlinal structure in the coastal area between Cape Yakataga and Icy Bay has been the focus of interest in the oil possibilities of the Yakataga district from the time of the earliest leasing activity, because it is the site of nearly all the known oil seeps in the Yakataga district and because it is the most readily accessible part of the district. Most geologists who have studied the coastal area have recognized a major anticlinal structure complicated by a longitudinal fault, but their interpretations have differed considerably in such details as the location of the axis of the fold, the significance of the discordantly trending strata exposed in Yakataga Reef, and correlation of beds in the north and south flanks of the fold.

The structure in the coastal area between Acme Creek on the west and Munday Creek on the east is here interpreted as a large asymmetrical anticline with a nearly vertical or slightly overturned south flank, the Sullivan anticline. The north flank of this anticline is displaced upward 4,000 to 6,000 feet along the Sullivan fault which, at the surface, dips steeply to the north and lies in or nearly in the axial plane of the fold. The axis of the anticline is not shown on the large-scale map (fig. 1) because it either coincides with the trace of the Sullivan fault or is concealed by the fault. The Sullivan anticline and Sullivan fault in this area are remarkably similar to the smaller Yakataga anticline and associated fault as exposed in Yakataga Ridge.

Although no exposures of the Sullivan fault have been found between Twomile Creek and Johnston Creek, its trace at the surface can be mapped within narrow limits by its topographic expression and on stratigraphic evidence. The zone of fractured and easily eroded rocks of the Poul Creek formation adjacent to the fault in this area is marked by the development of subsequent stream valleys and by low saddles on the ridges between the major transverse streams. The fault plane dips about 60° N. between Oil Creek and Hamilton Creek, and about 80° N. between Lawrence Creek and Poul Creek, based on approximate locations of the trace of the fault. The gradual change in strike of beds on the north flank of the Sullivan anticline near the west end of Brower Ridge, from about due east at the head of Acme Creek to about N. 15° E. in Yakataga Reef, is believed to be related to a similar change in strike, also a decrease in dip of the Sullivan fault west of Acme Creek. This interpretation is supported by outcrop data for a distance of 1 mile west of Acme Creek, and by the possibly analogous situation along the Miller Creek fault at the mouth of Boulder Creek.

A marked change occurs in the structural pattern of the rocks exposed along the trend of the Sullivan anticline and fault east of Munday Creek. Between Johnston Creek and Munday Creek the strike of the Sullivan fault and also of beds on the south flank of the Sullivan anticline swings abruptly southward. At least four anticlines are exposed between the Beare Glacier and Munday Creek, but all apparently are minor folds. The Sullivan anticline is inferred to continue east of Munday Creek (index map B, fig. 1), but as a complex of en echelon minor folds and northward-dipping thrust faults rather than a simple anticline. East of Johnston Creek the south flank of the inferred major fold is concealed in part by unconsolidated deposits of the coastal plain, and in part by predominantly north-dipping beds overthrust from the north flank. This interpretation, which is illustrated graphically in structure section C-C' (fig. 2), is admittedly speculative, but it is believed to be consistent with the outcrop data and with the regional structural pattern. Revision of this interpretation may be required when the results of current drilling in this area are known.

PETROLEUM POSSIBILITIES

Some of the oil seeps in the coastal area of the Robinson Mountains are reported to have been discovered in 1896 by prospectors looking for gold. By 1897 a continuous tract extending 20 miles along the coast was located and surveyed for oil exploration (Martin, 1921, p. 39-40). During the years 1926-1927 the General Petroleum Corporation of California drilled the first test well in the Robinson Mountains, near a large oil seep on Johnston Creek. This well was abandoned at a depth of 2,005 feet as a dry hole with shows of gas and oil. Interest in the petroleum possibilities was again revived briefly during the late thirties, when new applications for oil and gas leases and prospecting permits were filed, and geologic mapping was undertaken jointly by the Standard Oil Company of California, and the Tide Water Associated Oil Company, and the Union Oil Company of California.

In 1953 the Phillips Petroleum Company and Kerr-McGee Oil Industries, Inc. began exploration of a lease tract covering more than a million acres in the Yakataga and Katalla districts of the Gulf of Alaska Tertiary province, under a development contract with the Department of the Interior. Exploration was begun in the coastal area of the Robinson Mountains in July 1953, when equipment and supplies were landed on the northwest shore of Icy Bay. The first well, the Sullivan Strat No. 1, drilled in April and May 1954 near the head of Big River, was completed as a dry hole at a depth of 4,837 feet. The Sullivan No. 1, started near the head of the west fork of the Little River in June 1954, was reported to be drilling below a depth of 7,390 feet at the end of the year.

The many seeps of high-gravity oil in the coastal area of the Robinson Mountains, which first attracted attention to the petroleum possibilities of the area, undoubtedly have been the most important factor in keeping alive this interest. All of the known oil and gas seeps are in the southeastern part of the Robinson Mountains and are shown on the large-scale map (fig. 1). All of the known large gas seeps and all but one of the known active oil seeps are near the coast and lie in a narrow belt extending along the axis of the Sullivan anticline from Johnston Creek to a point near the west end of Brower Ridge. One oil seep occurs on the north side of the Yakataga River valley near the mouth of Porcupine Creek.

Indications of petroleum other than active oil seeps were found elsewhere in the Robinson Mountains. Beds of sandstone or coarse siltstone having a petroliferous odor, some yielding a small amount of oil when treated with carbon tetrachloride, were found in outcrops of the Yakataga formation near the mouth of the Kulthieth River in the western Robinson Mountains, at several localities between Boulder Creek and Miller Creek, on the north side of Brower Ridge, and on Crystal Creek about 1 mile southeast of the Beare Glacier. At one locality on the north branch of the White River, near the axis of the White River syncline, oil is entrapped in calcite veinlets that fill fractures in sandstone of the Yakataga formation.

About 75 percent of the known oil seeps and all of the large gas seeps in the Robinson Mountains are located on outcrops of the Poul Creek formation. The remaining known oil seeps and other indications of petroleum are associated with the Yakataga formation, mostly with the lower part of the formation. Other than a few small gas seeps noted near exposures of coal beds, no indications of petroleum are known to occur in outcrops of the Kulthieth formation in the Robinson Mountains. In the Samovar Hills area of the Malaspina district, however, large oil seeps occur in outcrops of coal-bearing strata correlated with the Kulthieth formation (Plafker and Miller, 1954, p. 13).

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