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RECONNAISSANCE GEOLOGY OF THE MALASPINA DISTRICT, ALASKA

By

George Plafker, 1929- and Don John J. Miller, 1919-

1956

This report is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

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DEPARTMENT OF THE INTERIOR

INFORMATION SERVICE

EOLOGICAL SURVEY

or Release to PM's, JUNE 25, 1956

GEOLOGIC INFORMATION ON MALASPINA DISTRICT, ALASKA RELEASED

Geologic information that will aid in the search for oil in southern Alaska as released to open file by the Geological Survey today Secretary of the Interior red A. Seaton announced.

The Malaspina district is a part of the 300-mile-long Gulf of Alaska Tertiary province, an area in which many seeps of oil and gas are known and from which some high-grade oil has been produced. Oil and gas leases are now in effect for a large part of the district and extensive exploratory activity by private industry is scheduled to begin shortly. To the west in the adjoining Yakataga district private industry is currently drilling for oil.

For much of the area the geologic observations contained in this report are the first to be obtained since the late 19th century. The current studies were made during parts of three field seasons as a part of the Survey's program to investigate the petroleum possibilities of the Gulf of Alaska Tertiary province.

In addition to a short text, the report consists of a geologic map and 5 structure sections of the Malaspina district and adjoining areas at a scale of 1:125,000.

The bedrock in the mountainous part of the district is divided into three major groups: (1) a crystalline complex consisting of Mesozoic and perhaps older metamorphosed sedimentary rocks; (2) the Yakutat group consisting of slightly metamorphosed sedimentary rocks of Mesozoic age; and (3) sedimentary rocks of Tertiary age, in which oil seeps and potentially favorable structures were found. The sequence of sedimentary rocks of Tertiary age is inferred to underlie a large part of the coastal plain area of the Malaspina district, where the bedrock is concealed by the Malaspina Glacier and by unconsolidated deposits of Tertiary age.

Entitled "Reconnaissance geology of the Malaspina district, Alaska" by George Plafker and Don J. Miller, the report has been placed on open file at the following Geological Survey offices: Library, Room 1033, General Services Administration Bldg., Washington, D. C.; Brooks Memorial Mines Bldg., College, Alaska; Room 117, Federal Bldg., Juneau, Alaska; 210 E. F. Glover Bldg., Anchorage, Alaska; Library, 4 Homehood Place, Menlo Park, Calif.; 468 New Customhouse, and Library, Denver Federal Center, Denver, Colo.; 807 Post Office and Courthouse, Los Angeles, Calif.; 724 Appraisers Bldg., San Francisco, Calif.; 504 Federal Bldg., Salt Lake City, Utah; South 157 Howard St., Spokane, Wash.; Territorial Department of Mines, Territorial Bldg., Juneau, Alaska. Copies from which reproductions of text and illustrations can be made at private expense are available at 4 Homewood Place, Menlo Park, Calif.

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RECONNAISSANCE GEOLOGY OF THE MALASPINA DISTRICT, ALASKA

By

George Plafker and Don J. Miller

INTRODUCTION

This report presents the results of a reconnaissance geologic investigation of the Malaspina district, undertaken by the Geological Survey as part of a project to investigate the petroleum possibilities of the Gulf of Alaska Tertiary province. (See index map, pl. 1.) This province, a distinct physiographic and geologic subdivision of the Pacific Mountain System bordering the Gulf of Alaska, is a 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 alluvium (Gryc, Miller and Payne, 1951, p. 159-162). The Malaspina district, as here defined, has an area of about 1,675 square miles and extends about 50 miles along the north shore of the Gulf of Alaska, between Icy Bay and the Guyot Glacier on the west and Yakutat and Disenchantment Bays on the east. It extends inland about 30 miles to the southern front of the St. Elias Mountains.

The Malaspina district comprises a coastal plain of low relief flanked on the north by a belt of rugged foothills, the higher ridges and peaks of which rise to an average altitude of 4,000 to 6,000 feet. At the northern margin of the foothills belt the southern front of

the St. Elias Mountains rises abruptly, culminating in Mount St. Elias (18,008 feet) and several other peaks higher than 10,000 feet. The Malaspina Glacier, which covers most of the coastal plain, rises gradually from an average altitude of about 100 feet at the outer margin to altitudes ranging from 1,000 to 1,600 feet at the southern margin of the foothills belt. Most of the alluvial plain bordering the terminal moraine of the Malaspina Glacier lies below 100 feet altitude.

Although the climate along the coast is temperate, almost three-fourths of the district is covered by glaciers or permanent snow and ice fields. The fronts of the Guyot, Tyndall, Turner, and Haenke Glaciers are either wholly or in part tidal, and the Malaspina Glacier extends almost to the high-tide line at Sitkagi Bluffs midway between Icy Bay and Yakutat Bay. Weather records at Yakutat, about 20 miles southeast of the Malaspina district, indicate a mean annual temperature of about 40° F. and an average annual precipitation of about 132 inches. All the larger streams in the district issue directly from glaciers and consequently are swift, muddy, and subject to large seasonal variation in volume of flow. A dense growth of vegetation covers the ice-free lowlands, excepting swampy areas and narrow belts of active erosion and deposition along the beach and larger streams. The brush line extends up the lower slopes to an altitude ranging from approximately 2,500 feet near the coast to 2,000 feet or less inland.

The Malaspina district has no permanent residents and is without roads or trails. With respect to land travel the district is virtually cut off from adjacent parts of Alaska and Canada by the ice fields and

rugged mountains to the north and by the bays heading in tidal glaciers to the east and west. The sole habitations in the area are two cabins along the beach which are intermittently occupied by fishermen or trappe from Yakutat. The nearest settlement, the village of Yakutat on the east shore of Yakutat Bay, has scheduled steamship and airline service. Light planes can land on wheels at many places along the coast and on floats in small lakes at the southern margin of the Chaix and Samovar Hills. Helicopters or ski-equipped light planes can land at many places in the ice-bound foothills belt. Riou Bay and a smaller unnamed bay on the east shore of Icy Bay afford small to medium-size boats an anchorage that is sheltered both from the ocean swell and from ice floes from the head of the bay. The west shore of Yakutat Bay is generally unsuitable either for landing or for anchorage of larger boats because it is exposed to the ocean swell and lies in the path of ice floes coming out of Disenchantment Bay. Under favorable conditions, however, small boats can find shelter in the mouths of the larger streams that empty into Yakutat Bay. Travel on foot along the coast is made difficult and hazardous by the numerous swift glacial streams that must either be waded or crossed with a small portable boat. Travel on foot is generally feasible and reasonably safe over much of Malaspina Glacier and over portions of many other glaciers in the district, although the surface characteristics of these glaciers may vary from year to year or even in different seasons of the same year.

The earliest observations on the bedrock geology of the Malaspina district were made by expeditions attempting to climb Mount St. Elias (Libbey, 1886; Broke, 1890; Russell, 1891, 1893; Filippi, 1900). Early

investigations of the geology of the bedrock exposed in the region adjoining the Malaspina district include a brief visit to the Yakutat Bay area in 1899 by geologists of the Harriman expedition (Emerson, 1904; Ulrich, 1904), and mapping by United States Geological Survey parties in 1905 and 1906 in the Yakutat Bay area (Tarr and Butl 1909) and in 1913 on the west shore of Icy Bay and adjacent parts of the Yakataga district (Maddren, 1914). Expeditions of the Artic Institute of North America in 1949 and 1951 obtained information on bedrock exposed in an area adjoining the Malaspina district on the north (Odell, 1950; Sharp and Rigsby, 1956).
and on the bedrock floor of the Malaspina Glacier (Allen and Smith, 1953).

Geologic mapping and stratigraphic studies under the current Geological Survey project of petroleum investigations in the Gulf of Alaska Tertiary province were carried out intermittently from 1944 to 1953 in the Yakataga district, and in 1947 in the western part of the Malaspina district (Miller, 1951; in preparation). Field work in the Malaspina district was resumed by the writers and D. L. Rossman from July 22 to July 28, 1953. During this period Plafker and Rossman mapped a part of the Samovar Hills, an area in the vicinity of the Pinnacle Glacier, and an area on the west side of Yakutat Bay in the vicinity of Esker Stream, working from camps shown on the map. Miller, using a light plane equipped with wheels and retractable skis, simultaneously carried out an aerial and photographic reconnaissance of the entire district and made spot observations on the ground at a few localities. Results of the 1954 field investigation relating

particularly to the petroleum possibilities of the Malaspina district have been summarized by Gates (1954, p. 1259; 1955, p. 1120-1121), and a preliminary report on the geology of the area was released to open files (Plafker and Miller, 1954). During the 1954 field season, Plafker spent an additional 6 days mapping the south-central part of the Samovar Hills and 2 days in reconnaissance flights over the entire district.

Much of the geology shown on the map accompanying this report is based on observations made during several flights in a small plane, on study of ground and aerial oblique photographs including many photographs in color, and on study of vertical aerial photographs of the entire district. Localities at which ground observations were made are indicated by a distinctive strike and dip symbol. (See map explanation.) H. E. Vokes, Ralph Stewart, L. G. Hertlein, and C. E. Merriam independently studied portions of the collections of fossil mollusks made during the 1947-1954 investigations. F. S. MacNeil reviewed the molluscan fauna in all Geological Survey collections from the Yakataga formation in the Yakataga and Malaspina Districts. H. R. Bergquist and Ruth Todd examined microfossils collected in 1953. R. W. Brown examined fossil plant material collected in 1953 and re-examined fossil plant material collected in 1905 from Tertiary rocks exposed near the west shore of Yakutat Bay.

DESCRIPTION OF THE ROCKS

The bedded rocks exposed in and adjacent to the Malaspina district are tentatively divided by the writers into four major sequences that are separated by unconformities and differ considerably

in age, lithology, degree of deformation, and topographic expression. These sequences are, from oldest to youngest: (1) a crystalline complex consisting of Cretaceous and older metamorphosed sedimentary and volcanic rocks and associated intrusive igneous rocks; (2) the Yakutat group of slightly metamorphosed sedimentary rocks of Cretaceous age, probably at least in part Upper Cretaceous; (3) indurated continental and marine sedimentary rocks in large part or entirely of Tertiary age; and (4) unconsolidated continental and marine deposits of Quaternary age. The sequence of Tertiary and probable Tertiary age is further subdivided into a siltstone unit of early Tertiary(?) age, the Kulthieth formation of Paleocene(?) and Eocene age, and the Yakataga formation of Miocene and Pliocene(?) age.

Bodies of granitic rocks intrude the crystalline complex, and small diabase dikes intrude both the crystalline complex and the Yakutat group. These igneous rocks are not differentiated on the map. No igneous rocks were observed to cut the Tertiary sedimentary rocks.

Inasmuch as indications of petroleum in the Malaspina district and elsewhere in the Gulf of Alaska Tertiary province appear to be associated with the Tertiary rocks, the pre-Tertiary and Quaternary sequences were given less attention in the field and are described in less detail in this report.

Cretaceous and older crystalline complex

The bedded metamorphic rocks and intrusive igneous rocks assigned to this group are exposed in the part of the St. Elias Mountains that makes up the northern part of the Malaspina district, and the area

immediately east of the Malaspina district along the northeast shore of Russell Fiord, and in several small areas between Disenchantment Bay and Russell Fiord. According to Russell (1891, p. 173-174) the upper several thousand feet of the mountain range in the vicinity of Mount St. Elias consists of a bedded schist, which he named the St. Elias schist. Specimens of amphibolite and diorite were collected in place on the northeast flank of Mount St. Elias at altitudes of 13,000 to 16,500 feet (Russell, 1893, p. 49; Filippi, 1900, p. 234-236). A large mass of light-colored igneous rock, which appears to intrude darker-colored bedded rock, is exposed high on the south face of Mount St. Elias. The most common type of igneous rock in the morainal debris on Libbey Glacier is a light-gray, medium-grained hornblende diorite, believed to have come from this intrusive body. Medial moraines on the Haydon and Marvine Glaciers, which drain the southwest, west, and northwest flanks of Mount Cook, were found by Russell (1891, p. 168) to be composed of gabbro and serpentine. According to Tarr and Butler (1909, pl. 37, p. 146-152) the bedrock exposed in the Yakutat Bay area, northeast of the major fault along Russell Fiord includes clay slate and phyllite, gneiss, schist, gneissoid conglomerate, and granite. Southwest of the fault, between Disenchantment Bay and Russell Fiord, Tarr and Butler mapped several small areas of greenstone and marble that appear to lie unconformably beneath rocks of the Yakutat group. Odell (1950) found the region along the northern border of Upper Seward Glacier to be underlain by metamorphic rocks, dominantly gneiss, schist and marble, which are intruded by igneous rocks of granodioritic to dioritic composition. Mount St. Elias and Mount

vancouver, which is approximately 15 miles northeast of Mt. Cook, consist mainly of batholithic intrusions of these igneous rocks, according to Odell. Along the eastern margin of the Upper Seward Glacier, Sharp and Rigsby (1956) mapped and subdivided a sequence of metasedimentary and meta-igneous rocks representative of the amphibolite facies of regional metamorphism which is unconformably overlain by a slightly metamorphosed sequence of calcareous graywacke, sandy limestone, calcareous quartzite and conglomerate. The entire sequence is cut by small bodies of quartz diorite and by lamprophyre dikes.

Aerial reconnaissance flights in 1953 and 1954, supplemented by study of aerial photographs, indicate that much if not all of the portion of the St. Elias Mountains that borders the Malaspina district on the north consists of metamorphic and igneous rocks of the general types described in the preceding paragraph. Rocks of the crystalline complex were examined on the ground only at the southwestern flank of Mt. Owen where they consist of slate and greenstone cut by granitic intrusions.

In the Samovar Hills a small triangular area along upper Hubbs Creek is underlain predominantly by mafic volcanic and shallow intrusive rocks interbedded with slate. These rocks are on the uplifted northeast side of the Hubbs Creek fault, a major northwest-trending high-angle thrust fault which is well exposed along upper Hubbs Creek. The rocks are dark brown, black, and drab olive green in color. They consist of hydrothermally altered diabase, amygdaloidal

basalt, glassy flows or tuffs, and reworked tuff and agglomerate interbedded with minor thin beds of black slate. In general the bedded pyroclastic rocks and slate trend roughly north and are nearly vertical. The crystalline complex is inferred to be unconformably overlain by rocks of the Yakutat group along the east margin of the outcrop area; both units are unconformably overlain by the Yakataga formation along the north margin of the outcrop area. Although the age of this isolated complex of rocks in the Samovar Hills is not established, it is considered as possibly equivalent to the greenstone described from Russell Fiord (Tarr and Butler, 1909, p. 150-152 and 174) and is tentatively assigned to the crystalline complex.

No fossils were found in rocks of the crystalline complex in the Malaspina district. Aucellas collected by R. P. Sharp from limy graywacke and limy quartzite beds along Upper Seward Glacier are of Early Cretaceous age (Imlay and Reeside, 1954, p. 229). Granitic rocks intrude the strata of Early Cretaceous age and underlying crystalline metamorphic rocks in the Upper Seward Glacier area (Sharp and Rigsby, 1956) but are not known to cut the Yakutat group or Tertiary sequence anywhere in the Malaspina district or Yakutat Bay area. These granitic rocks may belong to the same epoch of intrusion as similar granites of the Coast Range batholith in southeastern Alaska that were emplaced in Late Jurassic to Early Cretaceous time (Buddington and Chapin, 1929, p. 252-253; Payne, 1955).

Yakutat group

The slightly metamorphosed sedimentary rocks of the Yakutat group were originally named the Yakutat system by Russell (1891, p. 167-170). They are exposed in the Malaspina district in a large area extending from the west side of Disenchantment Bay to the eastern part of the Samovar Hills, and in a narrow belt extending along the southern base of the St. Elias Mountains from the Seward Glacier to the Tyndall Glacier. The Yakutat group also forms a major part of the coastal mountains from Disenchantment Bay southeast nearly to Dry Bay (Blackwelder, 1907; Tarr and Butler, 1909, pl.37). Equivalent rocks may extend along the southern flank of the Chugach Mountains west of the Malaspina district (Miller, 1951, p. 6-7).

As exposed in the Malaspina district the Yakutat group consists largely of dense, hard poorly sorted gray to brown impure sandstone (graywacke) interbedded with gray to black argillite and slate. Thin units of pebble or cobble conglomerate occur locally. From the Samovar Hills eastward in the Malaspina district the Yakutat group is characterized by thick units of brown-weathering graywacke, alternating with thinner discontinuous units of thin-bedded black argillite and light-colored graywacke. In the vicinity of Haydon Peak in the western part of the Malaspina district the graywacke is darker gray and is more thinly and uniformly interbedded with dark argillite or slate.

East of the Malaspina district, in the area between Disenchantment Bay and Russell Fiord, the basal member of the Yakutat group,

according to Tarr and Butler (1909, p. 153-154), is a black conglomeratic argillite which rests with apparent unconformity on greenstone and marble assigned to the crystalline basement complex. Neither this type of rock nor the blue flint-bearing limestone that Tarr and Butler (1909, p. 154) observed in the same area were seen in the Yakutat group in the Malaspina district during the present investigation. No diabase dikes such as those found to cut the rocks of the Yakutat group on the shores of Disenchantment Bay (Tarr and Butler, 1909, p. 157) were seen in the Yakutat group farther west in the Malaspina district.

The sedimentary sequence assigned to the Yakutat group is probably thousands of feet thick. An exact estimate of the thickness is not possible because of the lack of recognizable key beds, and because of duplication and interruption of the sequence by complex folding and faulting.

Fossils have been found in the Yakutat group only in the vicinity of Yakutat Bay. Supposed worm tubes Terebellina palachei Ulrich, now considered by some paleontologists to be the arenaceous tests of foraminifera, have been found at many localities (Tarr and Butler, 1909, p. 157-158). This form occurs in lithologically similar rocks elsewhere about the Gulf of Alaska at or near localities that have yielded other fossils of definite Late Cretaceous age (Imlay and Reeside, 1954, p. 227-229). An echinoid indicating an age certainly later than Triassic and possibly as young as Tertiary was found on the moraine of the Atrevida Glacier, which lies entirely within the area

of outcrop of the Yakutat group (Tarr and Butler, 1909, p. 158). On the basis of the scanty fossil evidence, the similarity in lithology and degree of metamorphism to rocks of known Cretaceous age elsewhere about the Gulf of Alaska, and the unconformable relationship with the overlying Tertiary rocks, the Yakutat group may be assigned with some assurance to the Cretaceous. The similarity to rocks of known Late Cretaceous age, and general absence of granitic intrusive rocks of Late Jurassic to Early Cretaceous age in the Yakutat group suggests that the group is probably largely or entirely of Late Cretaceous age.

Early Tertiary(?) siltstone sequence

A predominantly silty sedimentary rock sequence crops out in a belt extending from the Libbey Glacier westward along the northern margin of the Guyot Glacier into the Yakataga district. Rocks of similar general appearance that are tentatively assigned to this sequence are exposed at the confluence of the Newton Glacier with the Agassiz Glacier. The siltstone sequence was examined on the ground in the Malaspina district at only one point along the eastern margin of the Tyndall Glacier. There it consists dominantly of dark-gray partly slaty siltstone interbedded with many thin beds of fine-grained banded sandstone and lesser amounts of olive-gray to dark-gray partly carbonaceous sandstone, pebble conglomerate with a dark silty matrix, green basaltic(?) tuff, and light-gray tuffaceous sandstone. On the west side of the Tyndall Glacier the predominantly silty part of the sequence apparently is overlain and underlain by more sandy units in which the dark siltstone and light-gray sandstone

occur in approximately equal proportions. The predominantly massive black siltstone at the confluence of Newton and Agassiz Glaciers is tentatively assigned to this unit.

The total thickness of the siltstone sequence exposed in the western part of the Malaspina district is estimated to be at least 3,000 feet. Along the southwest flank of Haydon Peak, between the Libbey and Tyndall Glaciers, the siltstone sequence is in contact with rocks assigned to the Yakutat group. From air observation and study of aerial photographs the contact appears to be an angular unconformity, locally offset along numerous minor faults. West of the Libbey Glacier the siltstone sequence is in fault contact with Tertiary rocks along the southern margin of its outcrop belt, and west of the Tyndall Glacier it is in fault contact with the crystalline complex to the north. At the confluence of Agassiz and Newton Glaciers the rocks tentatively assigned to the siltstone sequence occur stratigraphically below the coal-bearing Kulthieth formation and above rocks of the Yakutat group. General structural relationships in this area, as determined from air photographs, suggest that the siltstone sequence lies unconformably on the Yakutat group and is in depositional contact with the overlying Kulthieth formation. From the available evidence it is not possible to determine whether or not this contact with the Kulthieth formation is conformable.

No fossils were found in this sequence in the Malaspina district. Strata probably equivalent to the siltstone sequence are exposed along the northern margin of the Guyot Glacier, 20 miles west of the Malaspina

district. These strata have yielded a poorly preserved Turritella which, according to L. G. Hertlein, resembles a form described from the Cowlitz formation of late Eocene age in western Washington.

On the basis of structural, stratigraphic, and lithologic evidence the siltstone sequence is considered to be intermediate in age between the Yakutat group of Late(?) Cretaceous age and the Paleocene(?) and Eocene Kulthieth formation. The apparent structural conformity with the overlying Kulthieth formation, and the presence of a fossil of early Tertiary age in probably equivalent strata to the west, suggest that the siltstone sequence is most likely of early Tertiary age. The evidence now available, however, does not preclude the possibility that rocks of latest Cretaceous age may be included in this sequence.

Kulthieth formation

A coal-bearing sandstone sequence having a distinctive banded or striped appearance and over-all yellowish-orange color on weathered surfaces crops out as a discontinuous belt from the western margin of the Malaspina district to the Marvine Glacier, and as smaller isolated areas in the Samovar Hills and near Yakutat Bay. This sequence is similar to a unit of coal-bearing strata in the Yakataga district named the Kulthieth formation by Miller (in preparation). The name Kulthieth formation is here extended to the equivalent coal-bearing strata in the Malaspina district.

In the Samovar Hills the Kulthieth formation consists of arkosic sandstone and siltstone intercalated with black coal, bone, and carbonaceous shale. The sandstone is typically yellowish-gray to pinkish-gray, massive, cross-bedded, and is moderately well sorted and indurated. It is composed predominantly of approximately equal amounts of angular to sub-rounded very fine- to medium-grained quartz, relatively fresh feldspar, and rock fragments, mainly chert, generally with less than 10 percent interstitial silt, kaolinite clay, and calcite. West of Mussell Creek the proportion of massive sandstones in the sequence increases notably. The sandstone beds contain many hard concretions and irregular fine-grained zones consisting of as much as 50 percent ankerite and small nodules of siderite. These minerals weather readily to iron oxide which imparts the distinctive yellowish-orange cast to the sandstones of the Kulthieth formation. The siltstone is typically soft, thin-bedded, gray when fresh and pale brown to brown on weathered surfaces. It consists largely of kaolinite clay and quartz with minor amounts of feldspar and finely divided mica. Locally the siltstone is interlaminated with, or grades into, very fine-grained sandstone. The siltstone occasionally shows poorly preserved imprints of plant fragments along the bedding planes. More than 60 percent of the lower half of the coal-bearing section between Hubbs and Marvitz Creeks is composed of siltstone. Intercalated with the sandstone and siltstone are zones of bituminous coal in persistent beds that individually range from 1 to 8 feet in thickness and average about 3 feet in thickness. Closely associated with the coal are brown and black platy bone and black

carbonaceous shale in beds as much as 50 feet thick. The coal is massive, has a high luster and a hackly or blocky fracture. It is generally clean but may contain thin shale partings or fragments of silicified wood.

In the Samovar Hills the Kulthieth formation is divided into an upper and a lower unit separated by an unconformity. The lower unit (Tkl), consisting of at least 2,000 feet of tightly folded coal-bearing strata, is overlain unconformably by an additional 2,700 feet of gently dipping strata of similar lithology (Tku). The base of the formation is not exposed. East of Marvitz Creek gently dipping upper Kulthieth strata overlap the Yakutat group with pronounced unconformity; the contact is marked by a thick zone of well-indurated, dark reddish-brown and white conglomerate composed largely of chert pebbles and cobbles in a light-gray or light-brown silicieous matrix. The Kulthieth formation is in angular depositional contact with the overlying Yakataga formation.

Air observations and ground observations at several localities indicate that the Kulthieth formation in the belt which extends from the western margin of the Malaspina district to Marvine Glacier is similar to the formation as described above. In this belt it was not possible to locate or map the intraformational unconformity found in the Samovar Hills. More than 10,000 feet of strata assigned to the Kulthieth formation are exposed in the ridge between the Tyndall and Libbey Glaciers, but here the sequence is partly repeated by tight drag folds and possibly also by thrust faults. The base of the

formation may be exposed along the north margin of Agassiz Glacier where, from aerial observation and photographs, the coal-bearing strata appear to be in depositional contact with dark argillaceous beds tentatively assigned to the siltstone sequence. Except in the Agassiz Glacier area, this belt of Kulthieth formation exposures is bounded by fault contacts.

Near the head of Esker Stream, 2 to 3 miles west of Disenchantment Bay, coal-bearing strata are exposed in two small areas (Tarr and Butler, 1909, pl. 37, p. 160-163). The westernmost of the two areas was re-examined in 1953. These strata are similar to the Kulthieth formation as exposed in the Samovar Hills and elsewhere in the Malaspina and Yakataga districts in all respects except degree of induration. The sandstone crumbles readily in the hand, the argillaceous beds are clay or soft shale, and the coal, in beds 18 inches or less in thickness, is black and crumbly with a blocky fracture, and appears to be lower in rank than coal in the Samovar Hills.

Although the Kulthieth is designated as Paleocene(?) and Eocene in age, this formation in the Malaspina district is in the authors' opinion of Eocene age, probably largely if not entirely of late Eocene age. Marine mollusks were found in the formation at two localities in the Samovar Hills, lot D333(T) from the lower unit, and lot D332(T) from strata that probably are in the upper unit. The collection from the lower unit contains a gastropod identified by C. E. Merriam as

Turritella uvasana sargeanti Anderson and Hanna, a late Eocene (Tejon) form. Both collections contain an oyster which L. G. Hertlein compared with *Ostrea iridaensis fettkei* Weaver, a form originally described from the Cowlitz formation of late Eocene age in western Washington. Fragmentary plant remains and pieces of wood collected from the Kulthieth formation at several localities in the Malaspina district during the present investigation were examined by R. W. Brown and found not to be diagnostic as to age. Plant fossils collected by Tarr and Butler (1909, p. 162-163) from the outcrops near Disenchantment Bay, according to Brown, definitely indicate an early Tertiary age. A sample collected at this locality in 1953 contained a foraminifer which, although not specifically identifiable and not diagnostic as to age, indicates a marine environment of deposition for a part of the unit. The flora and fauna indicate a warm climate and a predominantly continental environment of deposition, alternating with shallow marine or brackish water conditions.

Yakataga formation

Marine sandstone, conglomerate, and other clastic sedimentary rocks exposed in the Pinnacle Hills were first named the Pinnacle system by Russell (1891, p. 170-173). He later stated that equivalent strata are exposed in the Samovar and Chaix Hills, possibly also in the Robinson Mountains of the Yakataga district (Russell, 1893, p.26). Taliaferro (1932, p. 756-759) proposed the name Yakataga formation for the upper part of the Tertiary sequence ex-

posed in the Yakataga district, which overlies with apparent conformity the Poul Creek formation, now considered to be of Oligocene and Miocene age. Equivalent strata in the Guyot Hills to the west of the map area and in the Karr and Chaix Hills were described and mapped as part of the Yakataga formation by Miller (1951, p. 21-27) and this name is here extended to include the strata originally called the Pinnacle system in the Samovar and Pinnacle Hills.

The Yakataga formation includes a large variety of marine sedimentary rocks, of which the types listed below are the most abundant and most characteristic in both the Malaspina and Yakataga districts:

Gray partly calcareous massive to platy siltstone containing lenses and thin discontinuous beds of dark-gray limestone. Characteristically gray-weathering, but weathers reddish brown locally in Malaspina district.

Gray to brown fine- to coarse-grained sandstone, mostly massive to slabby and well indurated, but locally thin-bedded or poorly indurated.

Gray to greenish-gray moderately hard sandy mudstone containing scattered angular to rounded rock fragments of gravel size (marine tillite or "conglomeratic" sandy mudstone).

Pebble or cobble conglomerate with a matrix of sandstone or sandy mudstone. Weathers reddish brown locally in Malaspina district.

Claystone, siltstone, and fine-grained sandstone in rhythmically alternating thin beds.

The origin of the "conglomeratic" sandy mudstone, as a marine glacial deposit, as well as the distinctive name for the rock is discussed by Miller (1953, p.26).

In the western and central part of the Yakataga district the Yakataga formation is an apparently conformable sequence totaling at least 10,000 and possibly as much as 15,000 feet. Here the lower 2,000 to 5,500 feet of the formation is dominantly interbedded sandstone and siltstone, whereas the upper part of the formation is characterized by thick units of the "conglomeratic" sandy mudstone. In the Malaspina district and eastern part of the Yakataga district evidence was found to indicate folding, faulting, and uplift during the time of deposition of the Yakataga formation and progressive increase in the magnitude of uplift towards the east. In the Guyot Hills west of the area of this report and in the Karr Hills gently dipping strata of the upper Yakataga formation (Tyu) overlap truncated steeply dipping strata of the lower part of the formation (Tyl). In the Chaix Hills only gently dipping Yakataga strata, apparently of the upper part of the formation, are exposed. In the western part of the Samovar Hills gently dipping strata, presumably of late Yakataga age, rest with angular contact on the more intensely folded Kulthieth formation. At this locality it is inferred that several thousand feet of strata which are represented farther west in the Yakataga district, including the lower part of the Yakataga formation, the entire Poul Creek formation, and the upper part of the Kulthieth formation, have been removed by erosion. The unconformity is even more pronounced in the eastern part of the Samovar Hills and in the vicinity of Pinnacle Glacier, for at these

localities the upper part of the Yakataga formation rests on the Yakutat group.

The Yakataga formation in the Yakataga district has yielded a fairly abundant marine fauna, largely mollusks, which, however, has not so far permitted precise correlation with the standard Tertiary section. This is in part due to differences of opinion among paleontologists as to correlation of the standard West Coast Tertiary section with the type Tertiary sections in Europe. It seems probable that the Yakataga formation includes strata of both Miocene and Pliocene age, although only the Pliocene may be represented east of the Chaix Hills in the Malaspina district. Mollusks collected at several localities in the Chaix Hills (lots 17882, 17805, 17817), together with collections from the equivalent part of the Yakataga formation in the Yakataga district, are probably Miocene according to H. E. Vokes; "Upper Neogene" (Pliocene) according to R. S. Stewart. Collections obtained from the Yakataga formation at several localities in the Samovar Hills and Pinnacle Hills in 1953 (lots D258(T) through D263(T), contain few well-preserved diagnostic forms but are regarded by L. G. Hertlein as definitely late Tertiary, and more likely Pliocene than Miocene. F. S. MacNeil, on the basis of his preliminary study of the Geological Survey collections from the Malaspina and Yakataga districts, believes the Yakataga formation to be middle and late Miocene and possibly early Pliocene in age; this formation is designated in this report as Miocene and Pliocene(?) in age. The sediments of the Yakataga formation were deposited at least in part at relatively shallow depth, as 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 sheels 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 presence of numerous beds of the massive marine tillite that characterizes the Yakataga formation in the Malaspina district.

Quaternary deposits

The Tertiary and older rocks of the Malaspina district are overlain with marked angular unconformity by essentially flat-lying unconsolidated deposits of gravel, sand, and mud (including till), which were laid down largely, if not entirely, in Recent time by glaciers, streams, and the sea. These deposits are characteristic of and largely confined to the coastal plain. No attempt is made in this report to differentiate between the various types of unconsolidated deposits, or to show small thin deposits found inland along some of the streams, around lakes, and around margins of some glaciers.

The unconsolidated deposits and the large ice sheet on the coastal plain are of interest with respect to the petroleum possibilities of the Malaspina district in that they conceal the bedrock over a large area. Recent seismic and gravity investigations have provided some information on the thickness of the Malaspina Glacier and of the unconsolidated deposits at one locality near its margin (Allen and Smith, 1953). Seismic measurements along a line 10 miles in length on the surface of the Malaspina Glacier (see map) indicate ice thicknesses ranging from 1,130 to 2,050 feet above a bedrock

floor which is at minus 700 feet altitude at the lowest point along the profile. Seismic measurements at one locality near Point Manby suggest that the unconsolidated deposits there are at least 500 feet thick.

STRUCTURE

The bedded rocks exposed in and adjacent to the Malaspina district record three major periods of orogeny, which are represented by unconformities between the crystalline complex and the Yakutat group, between the Yakutat group and the sequence of Tertiary or probable Tertiary age, and between rocks of Tertiary and older age and the Quaternary deposits. Two periods of relatively minor, local folding, faulting and uplift are represented by an unconformity within the Kulthieth formation and a similar unconformity within the Yakataga formation.

The earliest major period of orogeny, tentatively placed in the time interval from Middle Jurassic to Early Cretaceous, resulted in folding and dynamic metamorphism of the bedded rocks of the crystalline complex, and was accompanied by or closely followed by emplacement of granitic batholiths. The bedded metamorphic rocks show pronounced foliation, jointing, and cleavage. The strike of bedding planes in the metamorphic rocks in general parallels the trend of the St. Elias mountain front, ranging from about N. 30° W. along Russell Fiord to about due west near Mount Huxley. There are notably divergent trends along the Seward Glacier.

The second major period of orogeny, in Late Cretaceous or early Tertiary time, resulted in intense folding, brecciation, and faulting

of the Yakutat group but probably had little effect on the more competent rocks of the older crystalline complex. The strike of bedding planes and trend of fold axes in the Yakutat group is generally northwestward, but there are many local variations. The average trend is about N. 40° W. from Russell Fiord to the Hitchcock Hills, about N. 15° W. in the Samovar Hills, and about due west in the vicinity of Haydon Peak. The folds are characteristically tightly compressed and apparently of small amplitude and lateral extent. Drag folds and minor thrust faults are common. Thrust faults of large displacement may be present, but are not easily recognized because of the uniform rock type and the prevalence of brecciation and shearing associated with minor folding and faulting. On the southeast face of Haydon Peak a complex asymmetrical anticline involving beds of the Yakutat group is clearly exposed through a vertical distance of several thousand feet. (See structure section B-B'.) On the south flank the beds are vertical or overturned; on the north flank the beds in general dip at a low angle to the north but show intricate drag folding and thrust faulting.

The early Tertiary(?) siltstone sequence exposed in the vicinity of the Tyndall Glacier is intensely folded. The fold axes trend about N. 60° W. west of Libbey Glacier, and about N. 30° E. along the Agassiz Glacier. Many of the folds are tightly compressed and overturned to the south, with axial plane dips of 25° to 60° N. At many places the strata, unable to yield further by folding, have been displaced along northward-dipping thrust faults. The initial folding of this unit is presumed to have been during Kulthieth time.

Relatively minor folding, faulting, and uplift occurred during Kulthieth time in what is now the Samovar Hills area of the Malaspina district. During this disturbance the lower part of the Kulthieth formation was compressed into asymmetrical overturned folds with eastward-trending axes and northward-dipping limbs. Concurrently, the area east of Marvitz Creek was uplifted along an unnamed fault which is inferred to trend northwestward along the course of Marvitz Creek, bringing the Yakutat group on the east in contact with the folded lower Kulthieth beds on the west. Following a period of erosion, sediments of the upper part of the Kulthieth formation were deposited on both the folded lower Kulthieth beds and the Yakutat group. (See structure sections C-C', D-D'.) The intensity of the Kulthieth disturbance appears to have diminished to the west as no evidence of it was recognized in the type section in the Yakataga district.

A second period of relatively minor folding, faulting, and uplift took place during Yakataga time in what is now the foothills belt of the Malaspina district. During this disturbance the Tertiary sedimentary sequence up to and including the lower part of the Yakataga formation in the area of the Karr Hills was compressed into a large asymmetrical anticline which represents the eastward extension of the Yakataga anticline, one of the dominant structural features in the Yakataga district. Later the crest of the anticline was truncated by erosion and overlapped by gently dipping strata of the upper part of the Yakataga formation. (See structure section A-A'.) Deposition of the upper sediments of the Yakataga on a structurally high area is indicated by thinning of the strata on the crest of the anticline.

The magnitude of the uplift increased to the east in the Malaspina district. The area including what is now the Hitchcock Hills and the eastern part of the Samovar Hills was stripped of Tertiary sedimentary rocks during late Yakataga time, exposing rocks of the Yakutat group on a strucutral high. North of Oily Lake in the Samovar Hills, uplift of the structurally high area to the east during the Yakataga disturbance took place along the northwest-trending Hubbs Creek fault that dips northeastward at an angle of 75°. Along this fault, the crystalline complex on the northeast is in contact with early Tertiary strata of the Kulthieth formation on the southwest. Uplift of the structurally high area of the Hitchcock and Samovar Hills at this time may have been initiated along an unnamed eastward-trending fault which is inferred to separate the Yakutat group from the small exposures of early Tertiary coal-bearing strata of the Kulthieth formation at the head of Esker Stream, near the west shore of Disenchantment Bay.

The third major orogeny in the district began in late Pliocene or early Pleistocene time when the Chugach-St. Elias Mountain chain was uplifted and thrust seaward along a system of northward-dipping faults, and the bordering belt of Tertiary sediments was folded, faulted, and uplifted. That uplift and faulting associated with this orogeny have continued intermittently to the present is attested by the abruptness and great height of the southward-facing front of the Chugach and St. Elias Mountains, by the frequent occurrence of earthquakes in the region, and by the abrupt elevation of the shores of Disenchantment Bay as much as 47 feet during the Yakutat Bay earthquakes of September 1899 (Tarr and Martin, 1912). This major period of orogeny, together

with the erosion that accompanied and followed it, is largely responsible for the present distribution of rock units and major topographic features of the Gulf of Alaska Tertiary province.

Faulting predominated over folding in the Malaspina district during the late Cenozoic orogeny. The strata of the upper part of the Yakataga formation from the Chaix Hills eastward to the Pinnacle Hills area form a homocline with dips ranging from 2° to 40° N. Local reversals of dip in this area appear to represent drag along faults. The apparent reversal of dip at the south end of the Karr Hills is believed to represent the eastward continuation of the White River syncline, a major fold of the late Cenozoic orogeny in the Yakataga district.

Renewed uplift of the structurally high area of the Hitchcock and Samovar Hills is indicated by the northward and westward tilt of the flanking belt of upper Yakataga strata, and by minor displacement and folding of upper Yakataga strata resulting from renewed displacement of the Hubbs Creek fault. Displacement is thought to have occurred along the inferred fault at the head of Esker Stream, as well as along other faults in the Yakutat Bay area, during the 1899 earthquakes (Tarr and Martin, 1912).

The foothills belt of the Malaspina district is bounded on the north by one or possibly two major northward-dipping thrust faults that brought the crystalline complex on the north into contact with the Yakutat group, the early Tertiary (?) siltstone sequence, and the lower part of the Tertiary group to the south. The eastward extension of the Chugach-St. Elias fault, which was traced from the eastern margin of upper Agassiz Glacier along the south flank of the

St. Elias Mountains to Disenchantment Bay, is believed to be the "boundary fault" mapped in the Russell Fiord area by Tarr and Butler (1909, pl. 37, p. 150). This fault is well exposed on the southeast flank of M unt Cook, where the dip of the fault plane is estimated to be 45° N. West of the Agassiz Glacier the same fault relationship, if not the same fault, is represented by a fault that extends through the saddle between Mount St. Elias and Haydon Peak and continues westward as the previously recognized Chugach-St. Elias fault of the Katalla and Yakataga districts (Miller, 1951, p. 28, map).

The fault between the early Tertiary(?) siltstone sequence and the Kulthieth formation west of Libbey Glacier is named the Coal Glacier fault for Coal Glacier along which it is exposed in two places. In this area the fault dips 30°-40° N. East of the Libbey Glacier the fault separates the Yakutat group and Kulthieth formation and is well exposed on two spurs southeast of Mount St. Elias, where it dips about 30° N.; on one spur it is marked by a thick gouge zone.

The southernmost of the major thrust faults recognized in the Malaspina district foothills belt, the Chaix Hills fault, forms the northern boundary of the Yakataga formation from the Karr Hills eastward to the Pinnacle Hills. This fault is named for the Chaix Hills where it was seen on the ground. In this locality the fault plane dips northward at an angle of 35° and the stratigraphic throw, based on the stratigraphic sequence exposed to the west in the Yakataga district, is not less than 18,000 feet.

PETROLEUM POSSIBILITIES

Oil and gas seeps and other indications of petroleum are present in Tertiary sedimentary rocks in the Katalla, Yakataga, and Lituya

districts of the Gulf of Alaska Tertiary province (Gryc, Miller and Payne, 1951, p. 159-162; Gryc and Miller, 1953, p. 1483). The Katalla field has produced a small amount of high-gravity oil. Reported indications of oil on the coastal plain in the western part of the Malaspina district (Miller, 1951, p. 42) and in the vicinity of Yakutat Bay (Tarr and Butler, 1909, p. 169-170) have not been substantiated. During the 1953 and 1954 investigations of the Malaspina district large oil seeps were found in the Samovar Hills. The seeps issue from fracture zones in the Yakutat group and from sandstone beds and fault zones in the lower unit of the Kulthieth formation. A sample collected from one of the active seeps on Hubbs Creek is a brownish-green intermediate-base oil with a gravity of 29.5 A.P.I. and a sulfur content of 1.13 percent (analysis by K. P. Moore, U. S. Geological Survey).

No likely source beds for the oil in these seeps are exposed in the Samovar Hills. However, argillaceous strata of the lower Tertiary(?) siltstone sequence may underlie the Kulthieth formation west of Hubbs Creek. This basal Tertiary unit may be petroliferous, although it has not been examined in detail on the ground.

With regard to petroleum possibilities, the Malaspina district may be divided into four distinct areas on the basis of what is known about the bedrock geology and accessibility for the heavy equipment required for exploration. These areas are: the eastern foothills, the western foothills, the Malaspina Glacier, and the part of the coastal plain that borders the Malaspina Glacier.

The eastern foothills area, extending from Disenchantment Bay to the southeastern part of the Samovar Hills, is predominantly underlain by slightly metamorphosed and complexly deformed sedimentary rocks of the Yakutat group, which are unfavorable for petroleum. Except for the part adjoining Disenchantment Bay, the eastern foothills are relatively inaccessible.

Tertiary sedimentary rocks which are potentially favorable for petroleum are exposed in the Pinnacle Hills and in the western foothills area, extending from the northeast end of the Samovar Hills to the Karr Hills. The Karr Hills, where the Yakataga anticline is exposed; the Samovar Hills, where oil seeps occur in association with tight folds, faults, and an unconformity; and the Pinnacle Hills are all completely surrounded by ice. Only the southwest margin of the Chaix Hills in the western foothills area can be regarded as readily accessible.

The bedrock beneath the coastal-plain belt of the Malaspina district is concealed by a generally thick mantle of ice and unconsolidated sediments. Potentially favorable oil and gas-bearing Tertiary sedimentary rocks, like those exposed in the adjoining foothills belt and west of Icy Bay, may be expected to underlie at least a part of the coastal plain. Geologic guidance for locating the areas most favorable for testing is obtainable only by drilling or by geophysical methods. Seismic investigations near the southeastern margin of Malaspina Glacier (see profile line on map) indicate a bedrock floor of sedimentary rocks with a northward-dipping homoclinal structure, according to the interpretation of Allen and Smith (1953, p. 758).

Geologic structures that are potentially favorable for the entrapment of oil, such as the folds and unconformities in the Karr and Samovar Hills, may also be present in the Tertiary sequence beneath the coastal plain. On the other hand, the presence of a basement high associated with the Yakataga orogeny in the eastern foothills area of the Malaspina district presents the possibility that pre-Tertiary rocks unfavorable for petroleum may underlie a part of the coastal plain.

The coastal plain around the margin of the Malaspina Glacier, or at least the part bordering Icy Bay and Yakutat Bay, is relatively accessible. The feasibility of carrying out petroleum exploration with heavy equipment on a glacier such as the Malaspina has not yet been tested, so far as is known to the writers.

COAL RESOURCES

In the Malaspina district numerous coal beds occur throughout the Kulthieth formation of Paleocene(?) and Eocene age. Coal beds were examined on the ground in the Samovar Hills and along Esker Stream near Yakutat Bay.

The coal in the Samovar Hills is black and has a high luster and rectangular to hackly fracture. A distinct lamination is generally visible, and locally the coal contains thin shale partings and fragments of silicified wood. The upper Kulthieth unit, between Hubbs and Marvitz Creeks, contains 13 relatively clean and persistent coal beds ranging individually from 1 to 8 feet in thickness and averaging 3 feet in a measured stratigraphic interval of 2,700 feet.

Eleven of the coal beds are in the upper 1,000 feet of the section. An unknown number of coal beds having approximately the same frequency of occurrence, composition, and range of thickness are in the lower unit of the Kulthieth formation between Marvitz and Mussell Creeks. Few coal beds are present in the upper Kulthieth unit west of Mussell Creek. Analysis of one channel sample of typical coal from an outcrop along the west side of upper Marvitz Creek (table 1) indicates a high-volatile C bituminous coal with low ash and sulfur content.

Table 1.--Analysis of coal from Kulthieth formation, Samovar Hills (Lab. No. E-54267)

	As received	Moisture free	Moisture and ash free
Moisture	9.0	---	---
Volatile matter	41.8	45.9	47.0
Fixed carbon	47.0	51.7	53.0
Ash	2.2	2.4	---
Sulfur	.4	.4	.5
B.T.U.	12,490	13,730	14,060

(Analyst, Roy F. Abernethy, U. S. B. M.)

The presence of numerous coal beds, one of which was 6 to 8 feet thick, in the Kulthieth formation along Coal Glacier is mentioned by Broke (1891, p. 86; 90-91). The rank of this coal is not known; it was said by Broke to burn fairly well in camp fires. During the present study no coal was seen on the ground in the remainder of the belt of outcrop of Kulthieth formation strata between Tyndall and Marvine Glaciers. Black bands seen in the Kulthieth formation from the air and in photographs may represent coal beds, dark shale, or both.

The coal from outcrops of the Kulthieth formation along Esker Stream near Yakutat Bay is black and crumbly with a blocky fracture. This coal has not been analyzed, but appears to be lower in rank than coal from the Samovar Hills. The presence of sulfur is indicated by pyrite along some of the fractures. The exposed coal-bearing strata in this area total 505 feet in thickness and contain 9 coal seams 6 to 18 inches thick (Tarr and Butler, 1909, p. 160-161). Prior to 1891 claims were filed on the areas of coal outcrop, and exploratory shafts were sunk (Russell, 1891, p. 169), but the properties were soon abandoned.

With the exception of the coal near Yakutat Bay, the known areas in which the Kulthieth formation has been found are almost entirely surrounded by glaciers and are virtually inaccessible to heavy equipment. The coal along Esker Creek is of low rank and crops out only as thin seams. Shipment by boat from the harborless west coast of Yakutat Bay would be a difficult and hazardous undertaking. This coast is exposed to a vigorous surf and the water is shallow and generally choked with ice floes. The fact that this coal has long been known but never utilized even locally in Yakutat indicates that it is of doubtful commercial value.

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