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RECONNAISSANCE GEOLOGY OF THE MALASPINA DISTRICT, ALASKA

By

George Plafker and Don J. Miller

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Note: 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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INTRODUCTION

This report presents in preliminary form the results of a reconnaissance geologic investigation of the Malaspina district, undertaken by the United States Geological Survey as part of a project to investigate the petroleum possibilities of the Gulf of Alaska Tertiary province. (See index map.) 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). The Malaspina district, with an area of about 1,600 square miles, as here defined extends about 50 miles along the north shore of the Gulf of Alaska, between Icy Bay and 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 300 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, about two-thirds of the district is covered by glaciers or permanent snow and ice fields. The fronts of the Guyot, Tyndall, Turner, Haenke and Hubbard 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, and 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 is uninhabitated 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 nearest settlement, the village of Yakutat on the east shore of Yakutat Bay, has scheduled steamship and airline service. Light planes equipped with wheels or floats can land at many places along the coast and 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 an anchorage for small to medium-size boats 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 because it is exposed to the ocean swell and lies in the path of ice floes coming out of Disenchantment 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 feasible and reasonably safe over much of Malaspina Glacier and over portions of many other glaciers in the district.

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; Russel, 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, Ulrich, 1904), and mapping by United States Geological Survey parties in 1905 and 1906 in the Yakutat Bay area (Tarr and Butler, 1909) and in 1913 on the west shore of Icy Bay and adjacent parts of the Yakataga district (Maddren, 1914). Expeditions of the Arctic 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) 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, 1953b). 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. Further field work is planned in the Malaspina district during the 1954 season. Results of the 1953 field investigation relating particularly to the petroleum possibilities of the Malaspina district have been summarized by Gates (1954).

The interpretation of the geology of much of the bedrock areas of the Malaspina district, as 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 which cover the entire district. The approximate extent of the areas in which ground observations were made is indicated by a distinctive strike and dip symbol. (See map explanation.) The geology shown on the map in the area east of Yakutat Bay and Disenchantment Bay is from the published report by Tarr and Butler (1909); the geology shown in the area west of Icy Bay is from the open-file map by Miller (1953b). Small collections of mollusks obtained in the Chaix Hills in 1947 were examined by H. E. Vokes and R. S. Stewart. Preliminary identification of mollusks collected in 1953 was made by L. G. Hertlein, of microfossils collected in 1953 by H. F. Bergquist. R. W. Brown reexamined 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 groups that are separated by unconformities and differ considerably in age, lithology, degree of deformation, and topographic expression. These groups are, from oldest to youngest: a crystalline complex consisting of Mesozoic and older(?) metamorphosed sedimentary and volcanic rocks and associated intrusive igneous rocks; the Yakutat group of slightly metamorphosed sedimentary rocks of Mesozoic age, probably at least in part Upper Cretaceous; indurated continental and marine sedimentary rocks of Tertiary age; unconsolidated continental and marine sediments of Quaternary age. The Tertiary group is further subdivided into a basal siltstone unit of Paleocene or Eocene age, a coal-bearing sandstone unit of Eocene age, and the Yakataga formation of Miocene and Pliocene age. Undifferentiated sedimentary rocks exposed in the northwestern part of the Malaspina district in the vicinity of the Tyndall Glacier, which may be entirely or in part equivalent to either the Yakutat group or the two lower units of the Tertiary group, or intermediate in age, are described and shown on the map as a separate unit.

Bodies of granitic rocks intrude the crystalline complex. 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 groups were given less attention in the field and are described in less detail in this report.

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 borders the Malaspina district on the north, in the Yakutat Bay area northeast of Russell Fiord, and in several small areas between Disenchantment Bay and Russell Fiord. According to Russell (1891, pp 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 but evidently did not examine in place. 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, believed to have come from this intrusive body, is a light-gray, medium-grained hornblende diorite (Miller, 1951, p 7). 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, pp. 234-236). 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. The bedrock exposed in the Yakutat Bay area, northeast of the major fault along Russell Fiord, according to Tarr and Butler (1909, pl. 37, pp. 146-152) includes clay slate and phyllite, gneiss, schist, gneissoid conglomerate, and granite. Southwest of this 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 bordering upper Seward Glacier to be underlain by metasedimentary rocks, dominantly gneiss, schist and marble, intruded by igneous rocks of granodioritic to dioritic composition. Mount St. Elias and Mount Vancouver consist mainly of batholithic intrusions of these igneous rocks, according to Odell.

Aerial reconnaissance flights in 1953, 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. The rocks exposed in this area were not examined on the ground during the present investigation.

In the Samovar Hills a small body of highly sheared, serpentinized basic and ultrabasic igneous rocks occurs in fault contact with Tertiary rocks and in either depositional or intrusive contact with rocks of the Yakutat group. Fragments of metasedimentary rocks similar to those of the Yakutat group are scattered through the mass of igneous rock. Although the age and contact relationships of this body of igneous rock to the Yakutat group is not clear, it is tentatively considered to be a part of the crystalline complex in which fragments of the overlying Yakutat group have been intermixed through shearing and possibly plastic flow in a fault zone.

No fossils have been found in bedded rocks of the crystalline complex in the region adjoining the Malaspina district. This group lies approximately along the strike of similar metamorphic rocks of the Lituya and Chichagof districts in southeastern Alaska, which were formerly thought to be of Paleozoic age but are now thought to be more probably of early Mesozoic age (Kennedy and Walton, 1946; Payne, 1953). Intrusive granitic rocks of the crystalline complex probably are to be correlated with similar granitic rocks of the Coast Range batholith of southeastern Alaska, which were emplaced in mid-Jurassic to early Cretaceous time (Buddington and Chapin, 1929; Payne, 1953, sheet 2).

Yakutat group

The slightly metamorphosed sedimentary rocks of the Yakutat group, originally named the Yakutat system by Russell (1891, pp. 167-170), are exposed in the Malaspina district in a large area extending from the west side of Disenchantment Bay to the Hitchcock Hills, in the eastern part of the Samovar Hills, and in a narrow, discontinuous belt along the northern margin of the district between the Seward and Tyndall Glaciers. 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, pp. 6-7).

As exposed in the Malaspina district the Yakutat group consists largely of dense, hard, poorly sorted gray to brown 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 massive argillite. 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 units of 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, pp. 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 which Tarr and Butler 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, p. 157) were seen in the Yakutat group farther west in the Malaspina district.

The sedimentary sequence assigned to the Yakutat group probably totals many thousands of feet. A more 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. A supposed worm tube *Terebellina palachei*, now considered by some paleontologists to be the arenaceous test of a foraminifer, has been found at many localities (Tarr and Butler, 1909, pp. 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). 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, similarity in lithology and degree of metamorphism to rocks of known Cretaceous age elsewhere about the Gulf of Alaska, and unconformable relationship with the overlying Tertiary group, the Yakutat group may be assigned with some assurance to the Cretaceous. It is probably at least in part Late Cretaceous.

Undifferentiated sedimentary rocks

A sedimentary rock sequence of uncertain age and stratigraphic relationship crops out in a narrow belt extending from the Libbey Glacier westward along the northern margin of the Guyot Glacier into the Yakataga district. This sequence was examined on the ground in the Malaspina district at only one locality along the eastern margin of the Tyndall Glacier. There it consists dominantly of dark-gray, partly slaty siltstone containing many thin beds of fine-grained banded sandstone. Interbedded with the sandy siltstone are 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 both overlain and underlain by more sandy units in which the dark silty sediments and light-gray sandy sediments occur in approximately equal proportions.

The total thickness of the undifferentiated sedimentary rocks exposed in the western part of the Malaspina district is estimated to be not less than 3,000 feet. Along the southwest flank of Haydon Peak, between the Libbey and Tyndall Glaciers, the undifferentiated sedimentary sequence is in angular contact with rocks assigned to the Yakutat group. From air observation and study of aerial photographs it has not been possible to determine whether this is a depositional contact or a fault contact. The undifferentiated sedimentary sequence appears to be in fault contact with the Tertiary rocks along the southern margin of its outcrop belt, and in fault contact with rocks of the crystalline complex to the north in the area west of the Tyndall Glacier.

The undifferentiated sedimentary sequence is in general less metamorphosed and less deformed than the Yakutat group rocks, but more indurated and more deformed than rocks of known early Tertiary age. It includes rock types similar to those occurring in both the Yakutat group and the siltstone and coal-bearing sandstone units of the Tertiary group, but in gross appearance differs appreciably from both groups. No fossils were found in the undifferentiated sedimentary rocks in the Malaspina district. Probably equivalent strata exposed along the northern margin of the Guyot Glacier, 20 miles west of the Malaspina district, 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.

From the information now available it is not possible to determine whether the undifferentiated sedimentary sequence is equivalent to the Yakutat group, is equivalent to the siltstone and coal-bearing sandstone units of the Tertiary group, or is intermediate in age and stratigraphic position.

Siltstone unit

As exposed in the Samovar Hills, the siltstone unit is dominantly hard, massive, brown-weathering gray siltstone, with a minor amount of fine-grained sandstone in thin beds. Approximately 2,500 feet of the upper part of the siltstone unit is exposed north of Oily Lake between Marvitz Creek and Hubbs Creek. The contact between the siltstone unit and the overlying coal-bearing sandstone unit was not examined on the ground, but the two units appear to be structurally conformable and may be in conformable depositional contact. The base of the siltstone unit was not seen in the Samovar Hills.

Foraminifera and fish scales were found in one sample of hard siltstone collected near the top of the siltstone unit on Marvitz Creek. According to H. R. Bergquist the Foraminifera are not specifically determinable, but the genera present indicate either Cretaceous or Tertiary age. On the basis of stratigraphic position, degree of induration, and degree of deformation, the siltstone unit is considered to be early Tertiary, probably Eocene. The fauna and lithology indicate that the unit was deposited in a marine environment.

Coal-bearing sandstone unit

In the Samovar Hills the siltstone unit is overlain by conspicuously banded, massive, fine- to medium-grained yellowish-brown to gray sandstone, interbedded with dark-gray siltstone and numerous beds of bituminous or subbituminous coal. The sandstone is typically cross-bedded, moderately sorted to well sorted, well indurated, and is made up of subangular to rounded grains of quartz, feldspar, mafic minerals, and rock fragments, in a fine-grained matrix. The sandstone beds contain many calcareous concretions and irregular zones which weather yellowish orange. Between Marvitz Creek and Hubbs Creek the total thickness of the coal-bearing sandstone unit lying between the underlying siltstone unit and the unconformable contact with the overlying Yakataga formation is about 5,000 feet. Coal beds as much as 6½ feet thick occur in this area. West of Marvitz Creek in the Samovar Hills the angular contact with the overlying Yakataga formation is more pronounced, and higher beds of the coal-bearing sandstone unit are exposed beneath the unconformity.

The coal-bearing sandstone unit occurs in a narrow belt extending from the western margin of the Malaspina district eastward to the vicinity of the Marvine Glacier. In this belt, based on air observation and ground observation at several localities, the lithology is similar to that described above. More than 10,000 feet of strata assigned to the coal-bearing sandstone unit are exposed in an apparently homoclinal sequence in the ridge between the Tyndall and Libbey Glaciers, but part of this section may be repeated by faults and folds not detected from the air or from study of photographs.

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, pp. 160-163). The western of these two areas was reexamined in 1953. These strata are similar to the coal-bearing sandstone unit 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 up to 1 foot thick, is a crumbly lignite. At the eastern of these two areas of outcrop Tarr and Butler measured a section totaling about 370 feet.

The coal-bearing sandstone unit is of early Tertiary age, probably largely, if not entirely of Eocene age. Fragmentary plant remains and pieces of wood collected from the coal-bearing sandstone unit 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, pp. 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. On the basis of similarity in lithology, especially in the presence of yellowish-orange-weathering calcareous concretions and in the banded or striped appearance due to the regular alternation of dark-colored siltstone and coal with contrasting beds of light-colored sandstone, the coal-bearing sandstone unit of the Malaspina district is correlated with the lower Tertiary sequence of the Yakataga district (Miller, 1951, pp. 13-17).

Yakataga formation

Marine sandstone, conglomerate and other clastic sedimentary rocks exposed in the Pinnacle Hills were first named the Pinnacle system by Russell (1891, pp. 170-173). He 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) proposed the name Yakataga formation for the upper part of the Tertiary sequence exposed in the Yakataga district. Equivalent strata in the Guyot, Karr, and Chaix Hills were described and mapped as part of the Yakataga formation by Miller (1951, pp. 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 ("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 and terminology of the "conglomeratic" sandy mudstone, a marine glacial deposit, is discussed by Miller (1951, pp. 22-23, 26; 1953a).

In the western and central part of the Yakataga district the Yakataga formation comprises 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 that folding, faulting, and uplift occurred within the time of deposition of the Yakataga formation. The magnitude of uplift increased to the east. In the Guyot and Karr Hills gently dipping strata of the upper part of the Yakataga formation overlap truncated, steeply dipping strata of the lower part of the formation. 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 Yakataga strata, presumably of the upper part of the Yakataga formation, rest with angular contact on more intensely folded Eocene? beds of the coal-bearing sandstone unit. 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 lower Tertiary sequence, 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 rocks of the Yakutat group.

The Yakataga formation in the Yakataga district has yielded a fairly abundant marine fauna, largely mollusks, which has not so far, however, 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, together with collections from the equivalent part of the Yakataga formation in the Yakataga district are probably Miocene, according to H. E. Vokes, Pliocene according to R. S. Stewart. Collections obtained from the Yakataga formation at several localities in the Samovar Hills and Pinnacle Hills in 1953 contain few well-preserved diagnostic forms but are regarded by L. G. Hertlein as definitely late Tertiary, and more likely Pliocene than Miocene.

Unconsolidated 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 from view 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 rocks exposed in and adjacent to the Malaspina district record three major periods of orogeny which are represented by the unconformities shown on the map explanation, and one lesser period of orogeny which is represented by the unconformity in 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 typically 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 lithology and the prevalence of brecciation and shearing associated with minor folding and faulting. The southeast face of Haydon Peak exposes a complex asymmetrical anticline involving beds of the Yakutat group through a vertical distance of several thousand feet. (See structure section A-A'.) 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 undifferentiated sedimentary sequence exposed in the vicinity of the Tyndall Glacier is intensely folded. The fold axes trend about N. 60° W. Many of the folds in these strata 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 north-dipping thrust faults.

Folding, faulting, and uplift occurred during Yakataga time in what is now the foothills belt of the Malaspina district. During this orogeny 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. Later the crest of the anticline was truncated by erosion and overlaped by flat-lying strata of the upper part of the Yakataga formation. The magnitude of the uplift increased to the eastward in the Malaspina district to the extent that an area including what is now the Hitchcock Hills and the eastern part of the Samovar Hills was striped of Tertiary sedimentary rocks to the Yakutat group, which formed a structural high during the deposition of the upper part of the Yakataga formation. In the area north of Oily Lake in the Samovar Hills uplift of the structurally high area to the east during the Yakataga orogeny took place along a northwest-trending fault that dips northeast at an angle of 75°. Along this fault beds of the Yakutat group on the northeast are in contact with early Tertiary strata on the southwest. Uplift of the structurally high area of the Hitchcock and Samovar Hills at this time may have occurred also along an east-trending fault which is inferred to separate the Yakutat group from the small exposures of early Tertiary coal-bearing strata at the head of Esker Stream, near the west shore of Disenchantment Bay.

In the area between the faults along Hubbs Creek and Marvitz Creek in the Samovar Hills the early Tertiary siltstone and coal-bearing sandstone units form a north-dipping homocline. West of the fault along Marvitz Creek the Tertiary strata are complexly folded and faulted. The structure of the narrow belt of early Tertiary coal-bearing strata north and northwest of the Samovar Hills is dominantly homoclinal, although aerial photographs show many overturned folds of small amplitude in this belt east of the Libbey Glacier. The coal-bearing strata at the head of Esker Stream strike east or northeast and dip 45°-75° N.

Beginning in late Pliocene or early Pleistocene time the Chugach-St. Elias Mountain chain was uplifted and thrust seaward along a system of north-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 to by the abruptness and great height of the south-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 third 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 along the fault of Yakataga age north of Oily Lake. 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 north-dipping thrust faults that place the crystalline complex on the north in contact with the Yakutat group, the undifferentiated sedimentary sequence, and the lower part of the Tertiary group to the south. A fault which was traced from the eastern margin of upper Agassiz Glacier along the south face 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 Mount 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 believed to be represented by a fault that extends through the saddle between Mount St. Elias and Haydon Peak, continuing westward as the previously recognized Chugach-St. Elias fault of the Katalla and Yakataga districts (Miller, 1951, p. 28, map). An alternative possibility is that the Chugach-St. Elias fault continues eastward along the southern boundary of outcrops of the Yakutat group in the vicinity of Haydon Peak.

The fault shown on the map between rocks assigned to the Yakutat group and the lower part of the Tertiary group between the Libbey and Agassiz Glaciers is well exposed on two spurs southeast of Mount St. Elias. The fault plane dips about 30° north, and at one locality is marked by a thick gouge zone. Continuation of this fault along the contact between the undifferentiated sedimentary sequence and the Tertiary group west of Libbey Glacier is inferred from the topography and from the contrasting lithology and structural pattern of the two groups of rocks.

The southernmost of the major thrust faults recognized in the western and central part of the Malaspina district foothills belt forms the northern boundary of the outcrop belt of the Yakataga formation. This fault was seen on the ground in the Chaix Hills, where the fault plane dips north at an angle of 35°. The stratigraphic throw on the fault at this locality, based on the stratigraphic sequences exposed to the west in the Yakataga district, is not less than 18,000 feet.

PETROLEUM POSSIBILITIES

Oil and gas seepages and other indications of petroleum occur in Tertiary sedimentary rocks in the Katalla, Yakataga, and Lituya districts of the Gulf of Alaska Tertiary province (Gryc, Miller and Payne, 1951; Gryc and Miller, 1953). The Katalla field has produced a small amount of high-gravity oil. Reported occurrences of 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, pp. 169-170) have not been substantiated. During the 1953 investigation of the Malaspina district large seepages of oil were found on Marvitz Creek and Hubbs Creek in the Samovar Hills. Both groups of seepages are situated along fault zones near the contact between the siltstone and coal-bearing sandstone units. A sample collected from one of the active seepages on Hubbs Creek is a brownish-green, intermediate-base oil with a gravity of 29.5 A.P.I. and a sulfur content of 0.13 percent (analysis by K. P. Moore, U. S. Geological Survey).

With regard to petroleum possibilities, the Malaspina district may be divided into four distinct areas on the bases of (1) what is known about bedrock geology; (2) 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, extending from Disenchantment Bay to the eastern part of the Samovar Hills, is 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 difficulty accessible.

Tertiary sedimentary rocks which are favorable for petroleum are exposed in the western foothills, from the western part of the Samovar Hills to the Karr Hills. The Karr Hills, where a large anticline is exposed, and the Samovar Hills, where oil seepages occur in association with faults and an unconformity, are completely surrounded by ice. Only the southwest margin of the Chaix Hills in the western foothills can be regarded as readily accessible.

The bedrock beneath the coastal plain belt of the Malaspina district is concealed by a probably thick mantle of ice and unconsolidated sediments. Potentially favorable Tertiary sedimentary rocks like those exposed west of Icy Bay and in the adjoining foothills belt may be expected to underlie at least a substantial 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 on map) indicate a bedrock floor of sedimentary rocks with a north-dipping homoclinal structure, according to the interpretation of Allen and Smith (1953). 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 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.

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