

UNITED STATES DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY

GEOLOGIC MAP AND CROSS SECTIONS OF THE CORDOVA AND MIDDLETON ISLAND  
QUADRANGLES, SOUTHERN ALASKA

by

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



## Introduction

This geologic map of the Cordova and Middleton Island quadrangles is the westernmost of a series of geologic maps that will cover the portion of coastal southern Alaska from Prince William Sound to the vicinity of the Alsek River. The central map of the series will comprise the Bering Glacier and Icy Bay quadrangles (Plafker and Hudson, unpublished data) and the eastern map will include the Alaska portions of the Mt. Saint Elias, Yakutat, and western Skagway quadrangles (Plafker, unpublished data).

Field studies have been carried out intermittently in the Cordova and Middleton Island quadrangles from 1903 to 1981. Large-scale published geologic maps for the Ellamar district (Capps and Johnson, 1915), the southern Katalla district (Miller, 1961, 1975; Kachadoorian, 1960), the Sherman Glacier area (Plafker, 1968), the Hinchinbrook Island area (Winkler, 1973), Kayak and Wingham Islands (Plafker, 1974), and the Ragged Mountain area (Tysdal and others, 1976a) have been incorporated, with minor revisions, into this compilation. The remainder of the quadrangles has been mapped, chiefly since 1970, as an adjunct to regional studies of the Gulf of Alaska Tertiary province, and the major fault systems of southern Alaska under the direction of George Plafker and as part of the Chugach National Forest Wilderness study under the direction of Steven W. Nelson.

Megafossil identifications (Table 1) have been made by F. S. MacNeil and W. O. Addicott of the Geological Survey; by J. Wyatt Durham of the University of California, Berkeley; and by Leo Hertlein of the California Division of Mines and Geology. Siliceous microfossils have been studied by J. A. Barron of the U.S. Geological Survey, and H. V. Kaska of Chevron Overseas Petroleum, Inc., kindly identified the foraminifera.

We acknowledge with gratitude the contributions of Travis Hudson, R. G. Tysdal, and S. W. Nelson, who participated in much of the geologic mapping and made many valuable suggestions for the improvement of this report.



## GENERAL GEOLOGIC AND TECTONIC SUMMARY

The Cordova and Middleton Island quadrangles straddle the boundary between the rugged Chugach Mountains, part of the Pacific Border Ranges physiographic province on the north, and the more subdued ridges, plains, and islands of the Gulf of Alaska Coastal Province on the south (Wahrhaftig, 1965). The region is segmented into three distinctive fault-bounded terranes that become progressively younger and less severely deformed from north to south (Plafker, 1969, 1971).

The oldest terrane, in the northern part of the Cordova quadrangle, is underlain by the Upper Cretaceous Valdez Group and is considered to be part of the Chugach Terrane as defined by Berg and others (1972). The Valdez Group in the map area consists of accretionary wedges of volcanogenic flysch with subordinate tholeiitic basalt that was accreted against the continental margin between Maestrichtian and probably late Paleocene time as a result of relative northeastward underthrusting of Pacific oceanic crust (Plafker and others, 1977). The sequence is tightly folded, commonly with overturning towards the south, and is imbricated along numerous steep- to northward-dipping thrust faults.

A major change in plate motions early in the Tertiary resulted in northwestward movement of the Pacific oceanic crust relative to Alaska continental margin. Also about this time, counterclockwise oroclinal bending of western Alaska may have occurred along a main axis near Prince William Sound (Carey, 1958; Plafker, 1969). As a consequence of these relative plate movements, ensimatic deep-sea fan deposits and intercalated tholeiitic basalts of middle to late Paleocene and possible earliest Eocene age that comprise the Orca Group were accreted, principally along the western limb of the oroclinal bend where they form a belt from southeast of Hinchinbrook Island to northwest of Valdez Arm, that is more than 110 km wide. The combination of northwest-southeast compression during accretion and east-west compression due to virtually simultaneous oroclinal bending resulted in exceedingly complex deformation of the Orca Group. The Orca Group strata are tightly folded, commonly overturned in various directions, but mostly towards the south and southeast, and are cut by numerous faults. A zone of landward (northwestward) verging structures characterizes Hinchinbrook and Montague Islands, which corresponds to the "Montague belt" of Helwig and Emmet (1981). Prevailing northeast trends that predominate in the western limb of the orocline are represented in the map area mainly by the belt of Orca Group rocks that extends from Montague Island through Hinchinbrook Island and onto the mainland in the central part of the Cordova quadrangle where it is truncated obliquely along the Gravina fault. The east-west trends that characterize the eastern limb of the orocline are present only near the eastern edge of the map area between the Bagley and Chugach faults. The Ragged Mountains apparently are an extension of the Orca sequence between the Chugach and Martin faults that has been rotated more than 90° counterclockwise. Northern Wingham Island appears to be a continuation of this same anomalous north-south-trending belt but offset in a sinistral sense by a submarine fault. In the northwestern corner of the Cordova quadrangle strata of the Orca and Valdez Groups are bent through an angle

of about 90° with generally northeast trends east of Valdez Arm and northwest trends west of Valdez Arm.

Granitic plutons of early Eocene age were emplaced in both the Orca and Valdez terranes shortly following the major phase of early Tertiary accretion and deformation. Gravity data suggest that granitic rocks in the Cordova quadrangle probably have considerably wider distribution in the subsurface than is indicated by their outcrop pattern (Case and others, 1966).

Bedded rocks younger than the Orca Group in the map area were deposited in a complex continental margin basin on a basement made up largely, if not entirely, of the Orca Group and associated plutonic rocks. During middle to late Eocene time there was a general marine regression, seas were relatively warm, and climate was subtropical to paratropical. The Stillwater, Kulthieth (formerly Kushtaka), and Tokun Formations, which were deposited during this interval, consist of a thick, interfingering coal-bearing lagoon, barrier beach, and delta complexes.

Marine transgression occurred during Oligocene and possibly early Miocene time with deposition in neritic to bathyal environments. Predominantly shaly sediment, in part organic-rich and intercalated with water-laid alkalic basaltic tuff, breccia, and pillow lava, accumulated to form the Poul Creek (formerly Katalla) Formation and perhaps the lower part of the sandy and conglomeratic Redwood Formation.

The present sedimentary and tectonic regime results from movement of the Pacific Plate northwestward relative to the Alaskan continental margin since the early Miocene together with a general marine regression and climatic cooling. During this time, the Chugach and other coastal mountains were uplifted to elevations that fostered development of extensive alpine and piedmont glaciers. From about the middle Miocene to the present, an enormous thickness of clastic sediment comprising the Yakataga Formation and part or all of the Redwood Formation, and including much glacially-derived material, was deposited in a predominantly shelf environment. Emplacement of the dacitic plug at Cape Saint Elias on Kayak Island after deposition and folding of the early Miocene Yakataga Formation attests to continuing minor magmatic activity. Structures in the Neogene sequence tend to parallel the trends of the older structures. Folds involving Oligocene and Miocene strata are typically of small amplitude, tightly compressed, and asymmetric or overturned, having axial planes inclined towards the west or north. The notably divergent northerly trends in the area east of Ragged Mountain may reflect local deformation of the younger rocks against the more competent high of Orca Group rocks during relative eastward thrusting along the Ragged Mountain fault (Tysdal and others, 1976b).

### Faults

Important faults in the Cordova and Middleton Island quadrangles fall into the following general categories: (1) the Contact fault system which separates the Cretaceous Valdez Group from the lower Tertiary Orca Group, (2) a system of faults including the Chugach,

Ragged Mountain, and Wingham Island faults which juxtapose the Orca Group against younger Tertiary rocks, and (3) faults which affect only rocks younger than the Orca Group.

The Contact fault system (Plafker and others, 1977) is a major early Tertiary plate boundary which extends from the vicinity of Mt. Saint Elias to Kodiak Island. In the Cordova quadrangle it consists of northward-dipping reverse faults, the Bagley, Gravina, and Landlock segments, which separate multiply-deformed flysch, greenstone, and derivative metamorphic rocks of the Valdez Group on the north from strongly deformed flysch and tholeiites of the Orca Group on the south. Accretion of the Orca Group south of the Contact fault system was accompanied by intense folding and faulting in both upper and lower plate rocks, resulting in parallel structures in both groups adjacent to parts of the fault system. Successive accretionary wedges within the Orca Group may be bounded by major splays from the system that diverge westward. The Martin fault (Tysdal and others, 1976a) diverges from the Bagley fault in the Bering Glacier quadrangle and juxtaposes Eocene granitoid rocks and sedimentary rocks of the Orca Group on the north with volcanic rocks of the Orca on the south. The Rude River fault, which is largely concealed, must bifurcate from the Bagley fault near the head of Childs Glacier and extend westward along the Rude River, for dissimilar sedimentary rocks of the Orca occur on opposite sides of the apparent trace and structural trends in the southern block are truncated abruptly across the apparent trace. Major northeast-trending faults within the Orca Group including the Etches, Cordova, and Eyak faults and the Scott Glacier lineament also may represent faults that bound accretionary wedges.

The Bagley, Gravina, and Landlock segments of the Contact fault system have different characteristics that may reflect some post-Orca oroclinal bending of a fault that initially was more linear. The Bagley segment (Plafker and Lanphere, 1974a) is remarkably linear and probably is nearly vertical. Minor structures indicate that the youngest sense of movement was predominantly dextral strike-slip, although original movement presumably was thrust or oblique thrust. In the vicinity of Miles Glacier where the Bagley fault has been intruded by an unfoliated pluton with K-Ar ages of 50.6 and 50.9 m.y. (Locs. #3 and 4, Table 2), it cannot have undergone significant displacement since early Eocene time. The eastern portion of the Gravina segment is more sinuous, with dips as shallow as 30°; however, its western portion from the Cordova Glacier to Port Fidalgo is very steep to vertical. The pluton north of Sheep Bay, with K-Ar ages of 50.5 to 53.2 m.y. (Loc. #1, Table 2), is cut by the Gravina fault, indicating some post-early Eocene movement. The trace of the Landlock segment (Winkler and Plafker, 1975) is more variable and has an average dip to the north of 45°. The relatively shallow dip of the Landlock segment is anomalous and may explain why this part of the fault system apparently was short-circuited within the Valdez Group rocks of the upper plate by the younger, steeply-dipping Jack Bay fault. The Jack Bay fault extends northwestward into the Valdez quadrangle to rejoin the Contact fault system west of Valdez Arm where the trace of the Contact fault system again becomes more nearly linear (Winkler and others, 1981).

The Orca Group is bounded on the south and east by the Chugach, Ragged Mountain, and Wingham faults, along which rocks younger than the Orca Group were thrust relatively beneath and against the upper plate of older, more competent rocks. The Chugach fault is not exposed in the Cordova quadrangle, but extends eastward across the Bering Glacier quadrangle for more than 165 km (G. Plafker and T. Hudson, unpublished data). Where it is best exposed, the Chugach fault is a thrust with northward dips as low as 35° (Miller, 1971). The Ragged Mountain fault, which probably is part of the same fundamental boundary, has an even shallower dip, apparently about 8° to the west (Tysdal and others, 1976b). Late Holocene movement on the Ragged Mountain fault has been westward-directed gravity sliding of at least 180 m of the upper plate, in a direction opposite to the (relative) eastward tectonic transport of the Ragged Mountain block during the Neogene of at least 6.4 km (Tysdal and others, 1976b).

The Wingham fault may be an offset continuation of the Ragged Mountain fault on the continental shelf. It is a thrust that dips very steeply westward at the surface, but must become more shallow at depth (Plafker, 1974). Net displacement on the Wingham fault is upwards of several kilometers, inasmuch as it juxtaposes prehnite-pumpellyite metavolcanic and metasedimentary rocks of the Orca Group against the unmetamorphosed Poul Creek Formation.

The Cenozoic sequence of post-Orca age in the Katalla district and on Kayak, Wingham, and Middleton Island does not include major unconformities and appears to have been deformed essentially as a unit beginning during post-middle Miocene time. This deformation continues to the present, as indicated by the topographic relief, intense seismicity, recent faulting, and regional warping that characterize the Gulf of Alaska region (Plafker, 1969).

On Kayak and Wingham Island, post-Orca strata are imbricated along at least five up-to-the-northwest reverse faults (Plafker, 1974). The sense of displacement and the prevailing steep dips suggest the interpretation that the faults and axial planes of folds with original shallower dips were rotated into their present steep attitudes in response to strong northwest-southeast directed compression. Net displacement on the faults is not known, but may be as much as 4,500 m on the more important faults, such as the Kayak fault. The presence of the inferred Tenthathom fault off the southeast coast of Kayak Island is suggested by a submarine topographic break and by a pronounced steepening of seismic reflectors in marine geophysical records in the offshore as Kayak Island is approached (Plafker and others, 1975).

In the western part of the Katalla district, the structural style of the post-Orca sequence is less regular, with many trends that are transverse to regional structures (Miller, 1975). This structural discordance may reflect a combination of rejuvenated early Tertiary structures and local deformation of younger rocks against more competent highs of older Tertiary rocks (Plafker, 1971). Displacement on the Clear Creek fault, which is roughly parallel to and about 2 km east of the Ragged Mountain fault, is more than 1.6 km with the west side relatively upthrown (Tysdal and others, 1976a). However, displacement

on other subparallel faults, such as the Chilkat fault, is considerably less. Many faults, such as the Redwood fault, either reverse their sense of displacement along their traces, or are transformed into tight folds in the Cenozoic sequence.

### Mineral Resources

Mineral resources in the Cordova and Middleton Island quadrangles include deposits of copper, gold, petroleum, and coal; copper has been produced from the defunct Ellamar Mine near Ellamar in the northeastern corner of the Cordova quadrangle, and oil has been produced from a small abandoned field at Katalla.

Rocks of the Orca Group are hosts to numerous, mainly stratabound, iron-copper-zinc sulfide deposits in the Ellamar district of Prince William Sound (Capps and Johnson, 1915; Winkler and others, 1977). Generally the sulfide minerals are conformable and are concentrated in nonvolcanogenic shale and siltstone intercalated with basalt; in a few places pillow breccia or aquagene tuff is mineralized. Apparently areas fringing local centers of mafic submarine volcanism were favorable sites for syngenic formation of sulfide minerals. In many places, the sulfide minerals have been remobilized along cross-cutting faults, probably during regional deformation and metamorphism. However, the deposits lack alteration haloes, and the brecciated and crystalloblastic character of the sulfide minerals indicate that they must have predated the deformation.

In the McKinley Lake district 32 km southeast of Cordova, sedimentary rocks of the Orca Group host quartz veins that bear gold, pyrite, and arsenopyrite (Chapin, 1913). The principal mineralized veins form networks approximately parallel to bedding in the enclosing rocks and generally occur at contacts between sandstone and shale where the sandstone has been brecciated extensively. Transverse quartz veins also have minor gold values, even where no free gold is visible. The U.S. Bureau of Mines (1973) reports a lode gold prospect at the northern end of Wingham Island. No other lode gold occurrences are known in sedimentary rocks of the Orca Group in the quadrangles, although quartz veins and similar lithologies prevail through most of its extent.

Metavolcanic rocks of the Valdez Group are hosts to stratabound Fe-Cu-Zn sulfide mineral deposits in adjacent parts of the Valdez quadrangle to the north, such as Solomon and Sulphide Gulches (Johnson, 1919; Moffit and Fellows, 1950); widely disseminated sulfide mineralization in such rocks occurs in many places. Low-grade disseminated sulfide mineralization in Valdez Group metavolcanic rocks in the Cordova quadrangle also is widespread; oxidation of the sulfide minerals, especially pyrite, probably is responsible for the tendency of such rocks to weather a rusty brown color. Quartz veins bearing gold and some silver are localized in slate, argillite, and graywacke of the Valdez Group in the Port Valdez area north of the Cordova quadrangle. Quartz stringers and veins, generally less than 1 m thick, are widely dispersed in the Cordova quadrangle within metasedimentary rocks of the Valdez Group and associated Tertiary plutons, but their mineral potential has not been systematically evaluated.

Concentrations of heavy minerals, including gold, were found in sands sampled from offshore beach bars of the Copper River delta (Reimnitz and Plafker, 1976). Although the gold concentrations were only 0.25 ppm in the best samples, the presence of large volumes of such sands in the Copper River barrier beaches may warrant additional evaluation.

Oil and gas seeps were discovered east of Katalla about 1896, and active exploration for petroleum began shortly thereafter (Martin, 1921). Numerous oil seeps were discovered along Chilkat Creek, east of the Nichawak River, and west of Ragged Mountain; several gas seeps occur along the south edge of Bering Lake. Locations of these seeps and the Katalla oil field are shown by Miller (1961, 1975) and Tysdal and others (1976a). The most probable sources for the hydrocarbons are carbonaceous shaly horizons in the upper part of the Poul Creek Formation (former Katalla Formation of Miller [1975]). They have been designated as the organic shale unit in the middle of the Burs Creek Shale Member on the mainland (Miller, 1975), and similar organic-rich strata occur in the upper part of the Poul Creek Formation on Kayak Island (Plafker, 1974). Analyses of eight organic shales from Kayak Island indicate total organic carbon contents ranging from 1.88 to 7.57 percent and averaging 4.2 percent. In the period 1902 through 1933, the Katalla field produced about 154,000 barrels of paraffin-base crude oil from fracture porosity in the Poul Creek Formation at shallow depths (Miller, 1975). More recently, three unsuccessful wells were drilled in the map area--two in the Katalla district and one near Middleton Island (Plafker and others, 1975; Rau and others, 1977). The Richfield Oil Corporation Bering River 1 well at Bering Lake penetrated 6,175 feet of Tokun Formation and possible Kulthieth Formation; the Bering River 2 well at Bering River was drilled to 6,019 feet in the Poul Creek Formation and possible Tokun Formation. The Tenneco Middleton Island State 1 well, which penetrated 12,002 feet of strata correlative with the Yakataga, Poul Creek, and Tokun Formations, bottomed in strata of middle or early Eocene age. These wells proved to be unsuccessful due to a general lack of permeable reservoir rocks and, in the case of the Katalla wells, to structural complexity at depth. Available data suggest that the Tertiary sequence within the map area, both onshore and offshore, is relatively unfavorable for accumulation of petroleum in commercial quantities due to the prevailing structural complexity and general absence of suitable reservoirs in close proximity to potential source rocks.

Coal in the Kulthieth Formation in the vicinity of Bering Lake has long been of interest as a potential fuel because it ranges from low-volatile bituminous to anthracite in rank and includes some coking quality coal (Barnes, 1951, 1967). The coal occurs in numerous beds that show marked changes in thickness within short distances with measured thicknesses ranging from a few inches to 60 feet. The coal is strongly crushed and sheared and the thicker beds have pod-like shapes due to extreme structural deformation. Because of complex structure no meaningful estimate of the coal resource is possible. The complex structure of the coal-bearing strata, lack of a deep water port, and the environmental problems involved in development of a coal mining operation make it unlikely that coal will be mined in the Bering Lake area.

## DESCRIPTION OF MAP UNITS

### Unconsolidated Deposits

The diverse unconsolidated deposits in the quadrangles have been mapped in detail in four areas: near Katalla (Kachadoorian, 1960), on Kayak and Wingham Island (Plafker, 1974), near Sherman Glacier (Plafker, 1968), and on Hinchinbrook Island (Winkler, 1973). In other parts of the quadrangles, unconsolidated deposits have been examined only briefly; their distribution on the geologic map is based largely on interpretation of high-altitude aerial photographs and includes only the thicker, more extensive deposits.

- Qo UNDIFFERENTIATED SURFICIAL DEPOSITS (Holocene)--Predominantly alluvium deposited by nonglacial streams and outwash deposited by glacial meltwater. Locally includes miscellaneous deposits that formed on marine terraces and in swamps. Mostly well sorted stratified gravel and sand. Terrace deposits, however, are less well sorted. Swamp deposits generally consist of peat, muck, and silt. Thickness not well known, but the sediment load of coastal rivers in the Cordova quadrangle is very high and sedimentation rates seaward of their mouths are as rapid as 64 m/1,000 years (Molnia, 1979). Nearshore deposits on the Copper River delta are up to 180 m thick (Reimnitz, 1966) and accumulations nearly as thick may underlie parts of the Bering Glacier foreland and Controller Bay.
- Qb BEACHES, SPITS, AND OFFSHORE BARS (Holocene)--Constructional shoreline deposits of well sorted gravel and sand formed as (1) offshore bars on the submerged parts of the Bering and Copper River deltas; (2) spits extending westward or northwestward from headlands; and (3) beach complexes consisting of successive flights of ridges and runnels extending landward from the present shoreline. At least six successive episodes of shoreline progradation are preserved in beach complexes at the eastern end of Hinchinbrook Island (Winkler, 1973) and nine elevated beach ridges occur near Katalla which appear to be related to tectonic emergence (Plafker, 1969). Due to progradation, spits in the vicinity of Katalla Bay are now as much as 4.5 km inland (Kachadoorian, 1960).
- Q1 LAGOONAL DEPOSITS (Holocene)--Fine-grained, organic-rich silt, mud, and peat deposited in calm water landward of beaches or spits.
- Qd DUNES (Holocene)--Well sorted, fine-grained sand and silt aligned in longitudinal ridges up to 82 m high on the Copper River delta. Dunes are nourished by sustained, unidirectional, high-velocity winds that blow down the Copper River canyon, especially during the spring and fall (Swift and others, 1978).

- Qs SUPRAGLACIAL MORaine (Holocene)--Unweathered, poorly sorted, generally coarse rock debris on the surfaces of alpine and valley glaciers, conspicuous as stripes of medial and lateral moraines, and especially abundant on the lower reaches of many glaciers.
- Qm TERMINAL, LATERAL, AND GROUND MORaine (Holocene)--Unsorted deposits of boulders, cobbles, gravel, and sand left by the retreat of alpine, valley, and regional glaciers; alpine moraines generally are small, and are weathered but unvegetated; lateral and terminal moraines left by valley glaciers are both unvegetated and vegetated, in some places sustaining dense brush and forest, but retain their morainal morphology; moraines on seaward islands in Prince William Sound are relicts of older regional glaciation and consist of till with well developed soil profiles. Terminal moraines of Kushtaka and Martin River Glacier are at least 1,000 years old (Kachadoorian, 1960). Older glacial deposits occur locally at low elevations in Prince William Sound, have well-developed soil profiles, and are characterized by foliated metamorphic and coarse-grained plutonic rocks. These rocks were deposited by regional glaciers and must have been transported from sources a minimum of 40 to 50 km to the north, and perhaps considerably more distant.
- Qt TALUS (Holocene)--Coarse, angular rock debris derived from adjacent bedrock; only extensive deposits are shown; relatively older talus is inactive and has been stabilized by vegetation; relatively younger talus is active and is unvegetated.
- Qls LANDSLIDES (Holocene)--Unsorted angular rock debris derived by failure of bedrock slopes that in many places have been oversteepened by glaciers but have been left unsupported by retreat of the ice; relatively older landslides are hummocky and vegetated; relatively younger, unweathered landslides commonly have spread over glaciers or snowfields; many but not all of the latter were triggered by the 1964 earthquake (Post, 1967).

#### SEDIMENTARY, VOLCANIC, AND METAMORPHIC ROCKS

- Ty YAKATAGA FORMATION (Oligocene(?)-Pleistocene)--Named by Talliaferro (1932) for sandstone, shale, and conglomerate, including "shale-matrix" conglomerate, in the coastal area near Cape Yakataga 85 km east of the Cordova quadrangle, which occur conformably above Poul Creek Formation. Name extended to include similar strata throughout the onshore Gulf of Alaska Tertiary province and Middleton Island (Plafker, 1967) and to include rocks on Kayak and Wingham Islands (Plafker, 1974).

On western Kayak Island base of formation is abrupt and perhaps disconformable above the Poul Creek Formation; on the eastern side of the island, the contact is gradational. Contact placed at the lowest occurrence of "floating" sand grains or coarse angular clasts believed to record the initiation of ice-rafting of sediment from tidewater glaciers formed in response to pronounced uplift along the Gulf of Alaska margin (Plafker, 1974).

Consists of diverse marine and glaciomarine clastic rocks more than 1,670 m thick on Kayak and Wingham Islands, with at least an additional 1,200 m on Middleton Island. Much of the continental shelf between those two areas is also underlain by the Yakataga (Plafker and others, 1975). Interbedded gray to dark-gray and greenish-gray siltstone, mudstone, and sandstone predominate in the lower part of the formation. Till-like diamictite is interbedded with siltstone and sandstone in all but the lowest part of the formation, and is the dominant rock type in the upper part of the formation, particularly on Middleton Island (Miller, 1953; Plafker and Addicott, 1976). Conglomerate is a minor lithology throughout the formation, and scattered clasts--presumably dropstones--are present in all lithologies. Sandstone and conglomerate combined constitute about 10 percent of the section on Kayak Island and 12 percent on Middleton Island.

Fossil marine invertebrates are abundant and associated with all lithologic types. Bivalves commonly are found articulated and in growth position. Microfossils locally are very abundant in siltstone laminae. A two-fold drop in molluscan species diversity across the basal Yakataga contact, and the replacement of taxa of temperate water aspect by cold water, high latitude species is attributable to the initiation of mid-Miocene glaciation along the basin margin to the north (Plafker and Addicott, 1976). Molluscan faunas range in age from early Miocene to early Pleistocene. Early Miocene assemblages are known only from Kayak Island; elsewhere in the Gulf of Alaska Tertiary province, the basal part of the formation is of middle Miocene age. Foraminifera collected about 1,000 m above the base on Kayak and Wingham Islands are typical of the lower or middle Miocene Saucian or Relizian Stages of Washington (Rau and others, 1977). Exposures of the upper part of the formation on Middleton Island apparently were deposited entirely during the Matuyama reversed polarity epoch of early Pleistocene age, although almost all mollusks and foraminifers collected from outcrops there are identical to living species (Plafker and Addicott, 1976).

Tr REDWOOD FORMATION (Oligocene(?) and Miocene)--Named by Taliaferro (1932) for marine siltstone, sandstone, and conglomerate that crops out on the southern slopes of the Don Miller Hills in the central Katalla district. Formation redefined by Miller (1975) to include a lower sandstone member up to 150 m thick, which overlies the Poul Creek Formation (formerly Katalla Formation) conformably, and an upper Puffy Member up to 1,220 m thick whose top is not exposed. Sandstone member consists of about two-thirds thick-bedded sandstone and one-third silty sandstone and siltstone. Puffy Member is more diverse and consists of about 50 percent siltstone, mudstone, and claystone, 30 percent conglomeratic mudstone and conglomerate, and about 20 percent sandstone (Miller, 1975). The characteristic conglomeratic beds show complete gradation from coarse, clast-supported conglomerate to matrix-supported conglomeratic mudstone and sandstone, in

which coarse clasts are suspended in the matrix. The siltstone, mudstone, and claystone are similar in appearance to parts of the underlying Poul Creek Formation, but they contain few or no concretions, no glauconitic or volcanic beds, and are sandier and more resistant to erosion.

The fauna and the lithology of the Redwood Formation indicate deposition below wave base in cold water at depths from neritic to probably bathyal. The well rounded character of clasts in the conglomerate indicates that the coarser clastic material was thoroughly abraded before being resedimented in the marine environment. The sparse and poorly preserved molluscan fauna from the formation suggests a correlation with the upper Galavinian ("Lincoln") and Matlockian ("Blakeley") Stages of the Pacific Northwest, or a range in age from late Eocene through Oligocene (Addicott and others, 1978). Foraminiferal control is extremely sparse, but suggests that the upperpart of the formation may be as young as late Miocene (Rau and others, 1977). Thus, the Redwood Formation in the Don Miller Hills apparently correlates with the upper part of the Poul Creek Formation and the lower part of the Yakataga Formation exposed on Kayak and Wingham Islands.

POUL CREEK FORMATION (Oligocene)--Originally named Katalla Formation (Martin, 1905) and redefined in central Katalla district by Miller (1975). As redefined, the Katalla Formation is equivalent in age and lithology to the Poul Creek Formation in the Bering Glacier quadrangle to the east and in offshore wells. Name Poul Creek Formation is herein extended to include correlative strata in the map area and the name Katalla Formation is formally dropped.

Tp SEDIMENTARY ROCKS, UNDIVIDED--Concretionary, pyritic, and glauconitic reddish-weathering, dark-gray to greenish-gray siltstone, claystone, and sandstone; subordinate dark-brown, laminated organic-rich shale, silty shale, and gray calcareous sandstone; includes thin interbeds of basaltic tuff locally. In the Don Miller Hills includes, in ascending order, the Split Creek Sandstone Member, Basin Creek Member, and Burls Creek Shale Member with aggregate maximum thickness of approximately 1,600 m (Miller, 1975). On Kayak and Wingham Islands the formation, which is 1,460 m thick, is undivided and the Split Creek Sandstone Member is not present (Plafker, 1974). Deposited in cool neritic to bathyal marine environment, mostly below wave base. Occurrence of shales as much as 244 m thick with high organic carbon contents (to 7.57 percent), extractable petroleum (0.8 gallons per ton), abundant glauconite, and common pyrite are suggestive of deposition in part under conditions of restricted bottom circulation. Intercalated basaltic fragmental rocks and less common pillow basalt (map unit Tpv) indicate episodic submarine mafic volcanism in the basin (Plafker, 1974).

Mollusks indicate a range in age from late Eocene (Galvinian or "Keasey") through much of the Oligocene (Matlockian or

"Blakeley") (Addicott and others, 1978). In general, foraminifera from the same localities indicate slightly younger ages, ranging from late late Eocene through early Miocene (Refugian, Zemorrian, and Saucelian Stages) (Rau and others, 1977).

Tpv VOLCANIC ROCKS, UNDIVIDED--Basaltic pyroclastic and flow rocks, including minor pillowed flows; interbedded with marine sedimentary rocks locally, including tuffaceous or glauconitic strata; probably genetically related to mafic dikes, sills, and plugs of unit Tm.

Tt TOKUN FORMATION (Eocene and Oligocene)--Named by Martin (1908) for transgressive marine sequence approximately 1,070 m thick which is widespread in the Katalla district (Miller, 1961, 1975) and also occurs on Kayak and Wingham Islands (Plafker, 1974). Base exposed only north of Bering Lake, where it is gradational with the underlying coal-bearing Kulthieth Formation (formerly Kushtaka Formation). Contact with overlying Poul Creek Formation in exposures south of Bering Lake is abrupt, but apparently is conformable. In the vicinity of Nichawak River, the contact is gradational.

Consists predominantly of concretionary siltstone with a lesser and variable amount of interbedded sandstone, chiefly in the lower part of the formation. Thick sandstone beds exposed near Point Hey and on Kayak and Wingham Islands presumably correlate with lower part of the formation to the north but were closer to the sediment source. The siltstone generally is medium- to dark-gray and nearly massive; in places, thin beds and lenses of lighter gray, brown-weathering calcareous siltstone and silty limestone occur within the darker siltstone. Spheroidal calcareous concretions up to 1 m in maximum dimension are distributed randomly or along bedding surfaces in the siltstone. In the vicinity of Bering Lake, thin beds of glauconitic sandstone occur near the top of the formation. Interbedded sandstone in the Tokun, which generally is lighter grey than the siltstone, is micaceous, feldspathic, and brown-weathering. Intertidal outcrops of coarse- to fine-grained, brown-weathering, feldspathic sandstone on Wessels Reef may correlate with the Tokun Formation on the basis of lithologic similarities.

Lithology and megafauna indicate general deposition under quiet bottom conditions seaward of the surf zone in tropical to warm temperate water (Miller, 1975). Crabs predominate in fossil collections from the Tokun and are especially abundant in the upper part of the formation where they characteristically occur intact in concretions. Sparse mollusks occur mainly in thin beds or lenses of calcareous sandstone in the lower part of the formation. The molluskan fauna indicates a correlation with the middle and upper Eocene "Tejon" and "Keasey" Stages of the Pacific Coast standard section (Addicott and others, 1978).

Tk

**KULTHIETH FORMATION (Eocene and Oligocene(?))**--Originally named Kushtaka Formation by Martin (1905, 1908) for coal-bearing rocks exposed in the Bering River area. Correlates with coal-bearing rocks of the Kulthieth Formation in adjacent Bering Glacier, Yakutat, and Mount Saint Elias quadrangles to east. Name Kulthieth Formation herein extended to include coal-bearing rocks of the map area and use of Kushtaka Formation is formally discontinued.

Includes at least 1,500 m of interbedded massive to thin-bedded coal-bearing arkosic sandstone, dark-gray to black carbonaceous siltstone and shale, with minor coal. Sandstone:shale ratios in measured sections of the Kulthieth Formation average about 1:1 (Martin, 1908). The sandstone varies from massive intervals as much as 150 m thick to thin-bedded and shaly. Bituminous to semi-anthracite coal in beds to 3 m thick is a conspicuous, but minor part of the sequence. Commonly intensely deformed into imbricated stacks of fault-bounded chevron folds (Saunders, 1975) with shearing and structural thinning and thickening of coal beds.

Mostly nonmarine, with minor tongues of transitional marine strata lithologically similar to the underlying Stillwater Formation (Tsu) and overlying Tokun Formation (Tt). Represents major progradational cycle into an otherwise marine lower Tertiary sequence.

Age based on widespread fossil plant collections, on a single collection of mollusks from near the top of the formation on Kushtaka Ridge, and on stratigraphic relations with the underlying Stillwater and overlying Tokun Formations. The mollusks indicate a late Eocene (Tejon) age (F. S. MacNeil in Wolfe, 1977). Fossil plant collections from the Kulthieth indicate a wider range, from lower Ravenian (late middle Eocene) or older, to lower Kummerian (early Oligocene in floral geochronology, latest Eocene in marine molluscan geochronology) (Wolfe, 1977).

Tsu

**STILLWATER FORMATION (Eocene)**--Named by Martin (1908) for sequence that crops out in the southeastern part of the Cordova quadrangle just east of Ragged Mountain and in the drainages of the northern tributaries of Bering River. Lithology and microfauna of the Ragged Mountain exposures, which may constitute a lower part of the formation, indicate marine deposition in neritic to upper bathyal depths (Tysdal and others, 1976a). Lithology and megafauna of exposures north of the Bering River, which may constitute a higher part of the formation, indicate regressive shallow marine deposition. In this area the Stillwater intertongues with and grades upward into shallow marine and nonmarine rocks of the Kulthieth Formation (Miller, 1951; MacNeil and others, 1961). The Stillwater Formation is complexly deformed and is characterized by right folds and shearing in incompetent strata; hence its thickness can be estimated only crudely to be at least 1,500 m (Plafker, 1971).

Dominant lithology is dense, hard, dark-gray siltstone. Where the siltstone is carbonaceous, it has a "coaly" appearance; where it is calcareous, the siltstone may be variegated in shades of reddish brown to pale green and usually contains foraminifers.

Foraminifers have been collected from the formation on the east side of Ragged Mountain (Tysdal and others, 1976a) and mollusks have been collected from outcrops in the Shockum Mountains north of the Bering River (Wolfe, 1977). According to W. W. Rau, the foraminifera indicate a range from possibly the Paleocene and early Eocene Bulititan Stage to the middle Eocene Ulatisian Stage. The mollusks indicate a younger age, late middle or early late Eocene (F. S. MacNeil *in* Wolfe, 1977). At present the age of the Stillwater cannot be defined more closely than Eocene. Dominantly marine strata of the Stillwater Formation in the map area may be coeval with the nonmarine lower part of the Kulthieth Formation 65 km to the east in the Bering Glacier quadrangle (Miller, 1961; MacNeil and others, 1961).

ORCA GROUP (Paleocene and Eocene(?))--Named by Schrader (1900) for a widespread, very thick, and complexly deformed accretionary sequence of flysch and tholeiitic basalt in fault contact with the southern margin of the Valdez Group. Sequence in the Cordova quadrangle is part of an extensive belt that extends through western Prince William Sound to the Kodiak Islands and probably underlies much of the contiguous continental shelf (Plafker, 1969, 1971; Tysdal and Case, 1979). To the east, the sequence extends into the Bering Glacier quadrangle as a fault bounded belt less than 10 km wide for some 85 km (Plafker and Hudson, unpublished data). Flysch deposited dominantly in the middle lobate parts of a complex system of westward-sloping submarine fans (Winkler, 1976). The tholeiitic basalt intrudes and is interlayered with flysch, which may indicate that it was formed along sea-floor faults near the continental margin (Plafker and MacNeil, 1966; Tysdal and others, 1977). Thickness estimated as many thousands of meters (possibly on the order of 6,000 to 10,000 m). Mostly metamorphosed to the zeolite or prehnite-pumpellyite facies; in some areas adjacent to the Contact fault system, the rocks may be metamorphosed to the chlorite zone of the greenschist facies.

Sparse paleontologic and radiometric data indicate a Paleocene and early Eocene(?) age for the Orca Group in the Cordova quadrangle. Identifications and ages of microfossils and megafossils from eight localities in the Orca are listed in table 1. Foraminifera from eastern Prince William Sound are suggestive of a middle or late Paleocene age (H. V. Kaska *in* Winkler, 1976); megafossils from near Galena Bay are most likely to be of late Paleocene age (Addicott and Plafker, 1971); and silicoflagellates from Ragged Mountain are late Paleocene or early Eocene (Tysdal and others, 1976a). Deformation began prior to complete dewatering of the sedimentary rocks (Winkler, 1976), and soon was followed by intrusion of late early Eocene granodiorite, granite, and tonalite plutons, ranging in age from 50.5 to 53.5 m.y. old (Plafker and Lanphere, 1974b, table 2).

Prominant aeromagnetic anomalies are associated with all the exposed volcanic (Tov) or interbedded volcanic and sedimentary (Tovs) rocks except for thick volcanic sequence at Ellamar and the area of Tovs between Port Fidalgo and Port Gravina (U.S. Geological Survey, 1979). Anomalies associated with these units range from about plus 200 to 663 milligals. Magnetic data show that the units with volcanic rocks are considerably more extensive and continuous beneath Hawkins Island and Orca Inlet than is indicated by surface geology. This volcanic belt and associated magnetic anomalies are abruptly terminated on the north by the Rude River fault. Large positive magnetic anomalies similar in major characteristics to those onshore are present in the southern part of the Cordova quadrangle to the seaward limit of the aeromagnetic survey (about 35 km offshore) and are present on marine magnetic data obtained over the continental shelf (Schwab and Bruns, 1979). These anomalies, which are outlined on the geologic map, suggest that volcanic units within the Orca Group extend offshore and that they probably underlie much of the offshore between Ragged Mountain and Wingham Island, and the area extending along the northwest side of Kayak Island southwestward to the edge of the continental shelf. Absence of a positive anomaly in the Ellamar area and between Port Fidalgo and Port Gravina may be related to widespread alteration of volcanic rocks that occurred during metamorphism.

Toc CONGLOMERATE--Massive, clast-supported, well rounded pebble, cobble, and boulder conglomerate, with clast compositions varying from place to place: near Valdez Arm, greenstone, sandstone, argillite, and limestone clasts predominate; near Sheep Bay, felsic porphyry and tuff, granitoid, and sandstone clasts predominate; and west of Ragged Mountain, felsic tuff and sandstone clasts predominate. The massive conglomerate probably represents inner fan deposits that mark the entry points of major feeder channels onto the Orca submarine fan complex (Winkler and Tysdal, 1977).

Tos SEDIMENTARY ROCKS, UNDIVIDED--Very thick, complexly deformed, monotonous sequences of thin- to thick-bedded turbidites: sandstone, siltstone, and mudstone; metamorphosed to the zeolite or prehnite-pumpellyite facies. Sandstone is feldspathic to lithofeldspathic. Abundant primary sedimentary features indicate deposition from sediment gravity flows, chiefly turbidity currents (Winkler, 1976). A widespread, yet minor amount of the mudstone is hemipelagic with scattered planktonic foraminifers. Lenticular, matrix-supported pebbly mudstone and sandstone also are widespread and apparently mark distributary channels which fed mid-fan depositional lobes (Winkler and Tysdal, 1977).

Abundant quartzofeldspathic detritus (especially the consistent presence of k-feldspar) in sedimentary rocks of the Orca Group indicates derivation from a dissected magmatic arc. A possible source is the plutonic and high-grade metamorphic complex of the Coast Mountains of British Columbia and southeastern Alaska, which, according to Hollister (1979), was exposed by erosion

of 10 to 20 km during the early Tertiary. Presumably the resulting sediment initially was deposited along the continental margin as a submarine fan complex, but subsequently was displaced northwestward by dextral transform faulting along the margin of the North American plate.

Tov VOLCANIC ROCKS, UNDIVIDED--Thick and thin tabular bodies of altered tholeiitic basalt, consisting chiefly of pillowed, massive, or crudely columnar flows, but including pillow breccia, aquagene tuff, and diabase or gabbro sills; pillows have chilled margins that are palagonitic and amygdaloidal. Minor mudstone and siltstone interbedded with the basalt is included locally. Commonly with red, green, or grey chert in interstices between pillows, rarely with interpillow clots of pink limestone. Radial cooling cracks in pillows commonly are mud-filled, especially near Ellamar (Capps and Johnson, 1915). Metamorphosed to zeolite or prehnite-pumpellyite facies.

Tovs INTERBEDDED SEDIMENTARY AND VOLCANIC ROCKS--Variable proportions of interbedded tholeiitic basalt and turbidites; the basalt consists of pillowed and massive flows, pillow breccia, and tuff; the turbidites in most places are mudstone and siltstone, but in a few places nonvolcanogenic sandstone is interbedded; on Hinchinbrook Island, bioclastic limestone is interbedded in several places, and on Ragged Mountain tuffaceous sandstone is common in this unit; metamorphosed to the zeolite or prehnite-pumpellyite facies.

VALDEZ GROUP (Late Cretaceous)--Named by Schrader (1900) for thick sequence of complexly deformed, interbedded flyschoid metasedimentary and tholeiitic metavolcanic rocks that comprise an accretionary wedge several thousand meters thick. The Valdez Group is part of a belt of Cretaceous marine rocks 1,700 km long and up to 100 km wide that extends along the Gulf of Alaska margin from Chatham Strait to the Kodiak and Shumagin Islands (Plafker, 1969; Plafker and others, 1977; Plafker and Campbell, 1979). Consists dominantly of turbidites with facies associations that represent complexly intertonguing continental slope, submarine fan, and fan-fringe environments. In part, the turbidites may have been confined to a trench, as suggested by Moore (1973) for correlative rocks on Kodiak and Shumagin Islands. Approximately 20 percent of Valdez terrane underlain by interbedded basaltic metatuff and, less commonly, metabasalt. More extensive areas of metavolcanic rocks have associated prominent positive aeromagnetic anomalies of up to +400 gammas with local amplitudes in excess of 200 gammas (U.S. Geological Survey, 1979).

Regionally metamorphosed to grades ranging from the zeolite to the lower greenschist facies west of Copper River. In poorly known areas near the Gravina River and the Cordova, Woodworth, and Schwan Glaciers, Valdez rocks are locally schistose, and are transitional into amphibolite-grade rocks characterized by coarse biotite, epidote, and muscovite, and by porphyroblastic andalusite, garnet, and staurolite. These areas are not differentiated on

the geologic map. East of Copper River Valdez Group rocks are mainly epidote- amphibolite- and amphibolite-facies schist (unit Mvm) that is crudely concentric to a core zone of amphibolite-facies schist, gneiss, and migmatite (unit Mvg). The gneissose rocks in the Cordova quadrangle are the western termination of a regional high-grade metamorphic belt that extends eastward across the Bering Glacier quadrangle to the Canadian border. These rocks represent deeply buried parts of the accretionary prism and their development is believed to be spatially and genetically related to emplacement of lower Eocene anatectic granodiorite and granite plutons (Hudson and others, 1979). Gneiss from the central part of the metamorphic belt in the Bering Glacier quadrangle has been dated by K-Ar as 47-52 m.y. old, approximately the same age as the anatectic plutons (Hudson and others, 1979). A K-Ar age of 47.6 m.y. from amphibolite near the southern margin of the belt (loc. 6, table 2) agrees well with previously published dates. Typical granoblastic textures and the superimposition of progressive metamorphism across regional structural trends indicate that much of the amphibolite facies metamorphism of the Valdez Group occurred after it was deformed against and accreted to the continental margin.

The age of the Valdez Group is considered to be Late Cretaceous (Tysdal and Plafker, 1978). Although no age-diagnostic fossils have been collected from the Valdez Group in the Cordova quadrangle, the group is coextensive with rocks in the Valdez quadrangle, the Anchorage quadrangle, and the Kenai Peninsula that have yielded Late Cretaceous (Maestrichtian) fossils (Jones and Clark, 1973).

Mvs

METASEDIMENTARY ROCKS, UNDIVIDED--Thick, drab, rhythmically alternating sequences of multiply deformed metamorphosed turbidites: metasandstone, metasilstone, argillite, slate, and phyllite, with rare beds of pebbly argillite. Generally the beds are a few centimeters to a few meters thick, but locally massive metasandstone up to several tens of meters thick is present. In many places, primary internal sedimentary structures, including graded bedding, current ripple cross-lamination, and convolute bedding, have been retained; in a few places external sole markings have been preserved; variably metamorphosed regionally to grades ranging from zeolite to lower greenschist facies, although near the Cordova, Woodworth, and Schwan Glaciers the rocks are transitional with the amphibolite facies. Provenance for the metasedimentary rocks must have been predominantly a supracrustal volcanic terrane (Mitchell, 1980), which also is true for the correlative Kodiak and Shumagin Formations (Zuffe and others, 1980). Inasmuch as the Valdez Group may have been deposited far to the south and have been transported tectonically northward to be accreted to the Alaska continental margin (Grommé and Hillhouse, 1981), the identity of that source terrane is unknown.

- Mvv METAVOLCANIC ROCKS, UNDIVIDED--Tholeiitic metabasalt and basaltic metatuff with pillow structures and probable pillow breccia preserved locally; a lenticular marble bed 3-4 m thick overlies upper surface of a pillow flow and breccia sequence near head of Port Fidalgo. Metabasalt tends to form rugged, nearly massive exposures whereas semischistose metatuff forms more subdued outcrops; metavolcanic rocks exhibit variable metamorphic grades, as in the metasedimentary rocks of unit Mvs.
- Mvvs INTERBEDDED METAVOLCANIC AND METASEDIMENTARY ROCKS--Approximately equal proportions of interbedded metavolcanic and metasedimentary rocks; the metavolcanic rocks are chiefly semischistose metatuff and breccia; the metasedimentary rocks chiefly are slate and phyllite, although metasilstone and metasandstone are interbedded in many places; same variation in metamorphic grades as for unit Mvs.
- Mvm SCHIST--Chiefly homogenous pelitic schist with minor amphibolite; spotted schist with porphyroblasts of andalusite, garnet, and staurolite occurs in several places; the schist is transitional into gneissose rocks to the east and into greenschist facies rocks of the Valdez Group to the west.
- Mvg GNEISS--Biotite-quartz-feldspar schist, gneiss, and migmatite; commonly granoblastic texture; transitional into schistose rocks to the north, south, and west. The schistose and gneissose rocks of units Mvm and Mvg extend eastward into adjacent quadrangles; their regional setting and tectonic significance are described in Hudson and others (1979).

#### INTRUSIVE ROCKS

- Td DACITE OF CAPE SAINT ELIAS (Pliocene(?))--A prominent, very pale gray dacite plug complex forms the landmarks of Cape Saint Elias and Pinnacle Rock at the seaward end of Kayak Island (Plafker, 1974). The dacite is very dense and hard, and is conspicuously jointed. It has a microgranitic and porphyritic texture, and consists of about 35 percent plagioclase, 35 percent quartz, 25 percent orthoclase, and 5 percent relict brown hornblende and biotite. Has sharp, nearly vertical contacts with adjacent dark-gray argillaceous rocks of the Yakataga and upper Poul Creek Formations, which have been hornfelsed for at least 100 m around the intrusion. Intrudes the upper part of the Yakataga Formation and must be at least as young as Miocene, more likely Pliocene because it has been emplaced after the enclosing strata were deformed.
- Tm MAFIC DIKES, SILLS, AND PLUGS (Oligocene(?))--Strongly altered intrusions of diabase, alkalic basalt, olivine basalt, and lamprophyre; coarse-grained west of the Nichawak Hills; dense, fine-grained or glassy, and vesicular or amygdaloidal elsewhere. Plagioclase, clinopyroxene, olivine, and opaque minerals are the main constituents, but most of the ferromagnesian minerals are strongly altered. One dike near Lemusurier Point on the northeast

end of Kayak Island contains abundant rounded clasts of altered, coarse-grained gabbroic and peridotitic rocks and felsic granitic rocks (Plafker, 1974). The mafic rocks intrude the Tokun Formation and both the lower and upper parts of the Poul Creek Formation, and probably are feeders for the mafic pyroclastic and flow rocks (map unit Tpv) that are interbedded with sedimentary rocks of the Poul Creek. Chemical analyses of flows, dikes, and breccias indicate that the mafic rocks are enriched in alkalic and volatile elements and are depleted in silica; they have affinities with the alkali-olivine basalt and lamprophyre compositional families.

On the mainland, diabasic intrusions consisting of 45 percent euhedral plagioclase intergrown with 30 percent anhedral augite and enstatite, about 20 percent chlorite, and 5 percent opaque minerals crop out in isolated small hills rising above the alluvium just west of the Nichawak Hills (Miller, 1975). Nepheline syenite, consisting of 50 percent feldspathoids, 25 percent barkevikite, 10 percent titaniferous augite, with minor microperthite, apatite, and titaniferous magnetite occurs at one isolated locality east of Ragged Mountain and about 4.5 km south of Martin Lake. These intrusions probably are related to small dikes, sills, and plugs of mafic igneous rocks too small to delineate on the geologic map that mostly are associated with bedded extrusive rocks in the Basin Creek and Burls Creek Shale Members of the Katalla Formation of Miller (1975).

Lithologic associations of these rocks on Kayak Island and the mainland strongly suggests that they are of Oligocene age, probably early and middle Oligocene age. Nowhere have they been observed to intrude rocks younger than the upper part of the Poul Creek Formation. One whole-rock K-Ar analysis of a basaltic dike rock from Kayak Island indicates a mid-Oligocene age of 31.2 m.y. (loc. 7, table 2).

Tg GRANITOID ROCKS (Eocene)--Biotite granodiorite, granite, and minor tonalite; generally medium-grained, hypidiomorphic, and equigranular; foliated in many places, especially near contacts with country rocks. Larger plutons tend to be elongate and conformable to regional structural trends with generally sharp and locally discordant contacts. Thermal aureoles are well developed locally, but migmatitic and gradational contact zones are widespread, especially for the plutons east of the Copper River.

Six K-Ar ages ranging from 50.5 to 53.5 m.y. have been measured on samples from the plutons at five locations (table 2). The dated plutons are epizonal and are not deformed or metamorphosed. Measured ages are probably close to the time of emplacement of the plutons in the early Eocene and are comparable to ages of similar plutonic rocks along the Gulf of Alaska continental margin (Sanak-Baranof plutonic belt of Hudson and others, 1979).

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