GEOLOGIC MAP OF THE CHUGACH NATIONAL FOREST, ALASKA

By

Steven W. Nelson, J. A. Dumoulin, and Marti L. Miller

STUDIES RELATED TO WILDERNESS

The Wilderness Act (Public Law 88-577, September 3, 1964) and related acts require the U.S. Geological Survey and the U.S. Bureau of Mines to survey certain areas on Federal lands to determine their mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a geological survey of the Chugach National Forest, Alaska, including the Nellie Juan and College Fiord Wilderness Study Area established by Public Law 96-487, December 2, 1980.

INTRODUCTION

LOCATION

The Chugach National Forest, located in the Kenai-Chugach Mountains physiographic province of Alaska, comprises parts of the Anchorage, Cordova, Blying Sound, Bering Glacier, Middleton Island, Valdez, Seward and Icy Bay quadrangles (fig. 1). The western boundary of the national forest is 45 mi by road southeast of Anchorage, Alaska. Whittier and Cordova are the only towns located within the forest boundary.

SIZE AND GEOGRAPHIC SETTING

The Chugach National Forest is the second largest National Forest in the United States and is about 9,000 mi^2 in area. This area encompasses scenic Prince William Sound, the largest embayment on the coast of Alaska between Cape Spencer on the Alaskan panhandle to the southeast and Cook Inlet. Prince William Sound contains numerous islands, the largest being Montague, Hinchinbrook, Knight, and Hawkins Islands. The shoreline is characterized by numerous fiords, one of which contains Columbia Glacier, one of the largest tidewater glaciers in North America. Numerous other glaciers originate in the high Chugach Mountains to the north and in the Sargent Icefield to the southwest. Mount Marcus Baker, at 13,250 ft, is the highest point in the national forest.

The national forest boundaries are still in a state of flux. Under the Alaska Native Claims Settlement Act of 1971 several native villages have selected about 400,000 acres of national forest land for withdrawal as private land.

GENERAL GEOLOGY

The geology of the Chugach National Forest is dominated by two major units, the Valdez Group (Schrader, 1900) and the Orca Group (Schrader, 1900). Both groups consist largely of graywacke, siltstone, and shale, with the finer grained rocks commonly displaying a slaty fabric. As summarized by Moffit (1954), the Orca Group was thought to be somewhat less metamorphosed than the Valdez Group (based on the dominance of slate in the latter unit) and it was furthermore distinguished from the Valdez Group by the presence of mafic volcanic rocks and local beds of conglomerate. Tysdal and Case (1979) and Winkler and Plafker (1981) described the metamorphism in the Orca Group as ranging from zeolite and prehnite-pumpellyite facies to low greenschist facies and in the Valdez Group as ranging from zeolite and low greenschist facies to amphibolite facies (east of the Copper River). Miller and others (1984) describe amphibolite (or hornblende-hornfels) facies being present in both groups east of the Copper River. This supports our observations that both groups contain remarkably similar rock types, so that in some areas of the national forest the two groups are difficult to distinguish. Previous workers also suggested that the type of mineral deposit present distinguishes the two groups (Tysdal and Case, 1982) - the Valdez Group typically containing gold deposits and the Orca Group mainly containing copper deposits. However, we find that both types of deposits occur in each group. Deposit association appears to be related to specific host-rock types or geologic conditions found in both groups.

Known massive sulfide copper deposits in the study area are associated with mafic volcanism, and these deposits are found in, or are spatially related to, these types of rocks in both the Valdez and Orca Groups. The one known exception is the Ready Bullion prospect near Lynx Creek on the Kenai Peninsula, where there are no known volcanic rocks.

The copper deposits can be divided into volcanic-hosted and sediment-hosted deposits. Volcanic-hosted deposits commonly occur in shear zones (some as massive sulfide lenses) primarily in the mafic complexes on Knight Island, Glacier Island, in the Ellamar district (Orca Group) on Resurrection Peninsula, and in the northern part of the Cordova quadrangle (Valdez Group). Copper sulfide minerals are also found as disseminated grains in pillow basalt (Knight Island); in small lenses and stringers in greenschist (Cordova quadrangle); in quartz veins radiating from the distal(?) end of a basalt flow (Hinchinbrook Island); as the matrix in volcanic breccia and as sulfide breccia (Knight Island); and as stockwork veins cutting volcanic rocks on Knight Island.

Sediment-hosted copper deposits historically formed the largest producing mines in the area. These mines, located on Latouche Island, at Ellamar (Orca Group), and at Solomon Gulch (Valdez Group) near Valdez, contained sulfide ore localized in sedimentary rocks near mafic volcanic rocks.

Gold in the Valdez Group is found predominantly in three settings: (1) in quartz veins that are dated at 53 Ma and cut flysch (Mitchell and others, 1981); (2) in quartz veins that cut both flysch and 34 million year-old plutons (Tysdal and Case, 1982); and, (3) as placers derived from both of the above. Minor gold occurrences exist in the Orca Group in three situations: (1) as deposits in quartz veins that cut flysch near the 50 million year-old McKinley Peak pluton east of Cordova; (2) in quartz veins cutting greenstone on Culross Island; and (3) as possible placer deposits. Preliminary data suggest that a particular late-metamorphic (temperature) condition must be met for gold-bearing quartz veins to develop in this area (Mitchell and others, 1981; Pickthorn, 1982). These conditions apparently have been satisfied near granitic plutons of both Eocene and Oligocene age and in regionally metamorphosed rocks of lowest greenschist facies.

The Orca Group, structurally, is characterized by a predominantly northeast-trending regional strike. In contrast, the Valdez Group is characterized by a northwest regional trend in the eastern part of the study area that has been rotated 90° to a northeast trend in the western part of the area. This oroclinal bending may have occurred along a northwest-trending axis in Prince William Sound (Carey, 1958; Plafker, 1969). The combination of northwest-southeast compression during accretion of the Orca Group and almost concurrent east-west compression due to the oroclinal bending of the Valdez Group resulted in complex deformation of the Orca Group in the eastern part of Prince William Sound (Winkler and Plafker, 1981). This deformation has resulted in numerous faults.

Many of the major faults in the area lack any significant evidence of strike-slip displacement, although the lack of marker units may obscure this relation. The few places where faults have apparently truncated rock units suggests high-angle reverse or thrust fault relations. This interpretation is best observed in such places as: (1) along the Martin fault that juxtaposes Eocene granitic rocks against Orca Group volcanic and sedimentary rocks; (2) along the Gravina fault that has truncated the north end of the Sheep Bay pluton; and (3) along the unnamed thrust fault west of Day Harbor that places sedimentary rocks of the Valdez Group over the mafic complex that forms the Resurrection Peninsula.

For the purposes of this map, we use the terms Valdez and Orca Groups as defined and mapped by Tysdal and Case (1979) and Winkler and Plafker (1981). This was done for convenience pending completion of detailed comparative studies of sandstone petrography and metamorphic mineral distribution in the two groups. Preliminary observations made during these studies indicate that modification of the stratigraphic nomenclature for the Valdez and Orca Groups is warranted, because in many places these rock units are indistinguishable with respect to the parameters presently used to define them.

ACKNOWLEDGMENTS

We gratefully acknowledge the logistical support for this project provided by Captain A. C. Frothingham and his crew of the Research Vessel Don J. Miller II. Without their cheerful and helpful attitude the long periods of inclement weather would have been unbearable.

Also, a significant aspect of the project was the excellent existing geologic foundation and background provided by the following colleagues: Jim Case, Travis Hudson, George Plafker, Russ Tysdal, and Gary Winkler. We have relied heavily on their previous work in order to focus on other geologic problems in the area.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

The surficial deposits have previously been mapped in detail in five areas: near Katalla (Kachadoorian, 1960), on Kayak and Wingham Islands (Plafker, 1974), near Sherman Glacier (Plafker, 1968), on Hinchinbrook Island (Winkler, 1973), and in the Seward and Blying Sound quadrangles (Tysdal and Case, 1979). For the purposes of this map surfical deposits have been combined into one unit.

Qu SURFICIAL DEPOSITS, UNDIVIDED (HOLOCENE)—Predominantly alluvium deposited by nonglacial streams and outwash deposited by glacial meltwater. Consists of sand and gravel; terminal, lateral, and ground moraine composed of unsorted deposits of boulders, cobbles, gravel, and sand left by the retreat of alpine, valley, and regional glaciers; and talus and landslide deposits consisting of coarse angular rock debris derived from adjacent bedrock. Also includes less extensive deposits consisting mostly of sand that may be locally abundant and form such features as beaches, spits, offshore bars in coastal areas, and dunes on the Copper River delta

SEDIMENTARY, VOLCANIC, AND METAMORPHIC ROCKS

Ty YAKATAGA FORMATION[1] (MIOCENE)—Named by Taliaferro (1932) for sandstone, shale, and conglomerate that occur conformably above the Poul Creek Formation in the coastal area near Cape Yakataga (53 mi east of the Cordova quadrangle). The name Yakataga Formation has been extended (see Plafker and Addicott, 1976) to include strata throughout the onshore Gulf of Alaska Tertiary province and Middleton Island (Plafker, 1967) (not mapped in this report) and to include rocks on Kayak and Wingham Islands (Plafker, 1974). The Yakataga Formation on Kayak and Wingham Islands is of early and middle Miocene age only (Plafker and Addicott, 1976; Rau and others, 1977); elsewhere the Yakataga Formation ranges from Miocene to Holocene in age.

On western Kayak Island, the 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 is 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).

The unit consists of diverse marine and glaciomarine clastic rocks more than 5,475 ft thick on Kayak and Wingham Islands, with at least an additional 3,934 ft 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 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 about 12 percent on Middleton Island.

Fossil marine invertebrates are abundant and associated with all the lithologic types of the formation. 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 taxa with high latitude species is attributable to the initiation of middle 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 lower part of the formation is of middle Miocene age. Foraminifers collected about (3,500 ft above the base on Kayak and Wingham Islands are typical of the lower or middle Miocene Saucesian 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 Chron of early Pleistocene age, although almost all mollusks and foraminifers collected from outcrops there are identical to living species (Plafker and Addicott, 1976).

A dacite body (unit Td) dated at 6.2 ± 0.3 Ma that

[1]Unit descriptions somewhat modified from Winkler and Plafker (1981, p. 9-12).

intruded the upper part of the already deformed Yakataga Formation indicates that such deformation occurred prior to 6.2 ± 0.3 Ma (table 1)

Tr REDWOOD FORMATION[1] (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 as much as 492 ft thick, which conformably overlies the Poul Creek Formation (strata formerly assigned to the Katalla Formation), and the upper Puffy Member as much as 4,000 ft thick, whose top is not exposed. The sandstone member consists of about two-thirds thick-bedded sandstone and one-third silty sandstone and siltstone. The 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 its deposition below wave base in cold water at depths ranging 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 redeposited in the marine environment. The sparse and poorly preserved molluscan fauna from the formation suggests either 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 upper part of the formation may be as young as 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. Unit age is considered late Oligocene(?) and Miocene

POUL CREEK FORMATION[1] (MIOCENE, OLIGOCENE, AND EOCENE)—Originally named the Katalla Formation (Martin, 1905) and redefined in the central Katalla district by Miller (1975). As so 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. Therefore, the name Poul Creek Formation is extended into the map area and applied to these equivalent strata, thereby abandoning the name Katalla Formation. (The older name Katalla Formation is here abandoned in favor of the younger name Poul Creek Formation inspite of the rules of priority owing to the more widespread extent of the Poul Creek Formation in the adjacent Yakataga district.) In this area, the Poul Creek Formation is divided into:

Tps Sedimentary rocks, undivided[1]—Concretionary, pyritic, and glauconitic reddish-weathering, dark-gray to greenish-gray siltstone, claystone, and sandstone with subordinate dark-brown, laminated organic-rich shale, silty shale, and gray calcareous sandstone; also includes thin interbeds of basaltic tuff locally. In the Don Miller Hills consists of, in ascending order, the Split Creek Sandstone Member, Basin Creek Member, and Burls Creek Shale Member with aggregate maximum thickness of approximately 5,246 ft (Miller, 1975). On Kayak and Wingham islands the formation, which is 4,787 ft thick, is undivided, and the Split Creek Sandstone Member is not present (Plafker, 1974). Deposited in a cool neritic to bathyal marine environment, mostly below wave base. Occurrence of shales as much as 800 ft thick that have high organic-carbon contents (as much as 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 (unit Tpv) indicate episodic submarine mafic volcanism in the basin (Plafker, 1974).

Mollusks from the unit 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, foraminifers from the same localities indicate slightly younger ages, ranging from late late Eocene through early Miocene (Refugian, Zemorrian, and Saucesian Stages) (Rau and others, 1977)

Tpv Volcanic rocks, undivided[1]—Basaltic pyroclastic and flow rocks including minor pillowed flows; locally interbedded with marine sedimentary rocks, including tuffaceous or glauconitic strata, probably genetically related to mafic dikes, sills, and plugs of the mafic plugs unit (Tm)

Tt TOKUN FORMATION[1] (OLIGOCENE AND EOCENE)—Named by Martin (1908) for transgressive marine sequence approximately 3,508 ft thick that 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 (strata formerly assigned to the Kushtaka Formation). Contact with the 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.

Unit 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 calareous siltstone and silty limestone occur within the darker siltstone. Spheroidal calcareous concretions as much as 3 ft in maximum dimension are distributed randomly or along 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 gray 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.

Unit's 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 they 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 molluscan 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[1] (EOCENE)—Coal-bearing sedimentary rocks exposed in the Bering River area that were originally named the Kushtaka Formation by Martin (1905, 1908). These rocks are equivalent to coal-bearing rocks assigned to the Kulthieth Formation in the adjacent Bering Glacier, Yakutat, and Mount Saint Elias quadrangles to the east; therefore, the name Kulthieth Formation is extended into the map area and applied to these equivalent rocks, thereby abandoning the name Kushtaka Formation. (The older name Kushtaka Formation is here abandoned in favor of the younger name Kulthieth Formation in spite of the rules of priority owing to the more widespread extent of the Kulthieth Formation in the adjacent Malaspina and Yakataga districts.)

Unit consists of at least 4,918 ft of interbedded, massive to thin-bedded coal-bearing, arkosic sandstone, dark-gray to black carbonaceous siltstone and shale, and minor coal. Sandstone and shale ratios in measured sections of the Kulthieth Formation average about 1:1 (Martin, 1908). The sandstone varies from massive intervals as much as 492 ft thick to thin bedded and shaly. Bituminous to semianthracite coal in beds as much as 10 ft thick is a conspicuous, but minor part of the sequence. Commonly intensely deformed into imbricated stacks of fault-bounded chevron folds (Sanders, 1975, 1976) with shearing and structural thinning and thickening of coal beds.

Unit mostly nonmarine and has minor tongues of transitional marine strata lithologically similar to the underlying Stillwater Formation and overlying Tokun Formation. Represents major pro-gradational cycle into an otherwise marine lower Tertiary sequence.

Eocene age of unit in map area 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, p. 6). Fossil plant collections from the Kulthieth indicate a wider range, from lower Ravenian (late middle to early middle Eocene) to lower Kummerian (late Eocene) (Wolfe, 1977; Turner and others, in press)

Ts STILLWATER FORMATION[1] (EOCENE)—Named by Martin (1908) for a sequence that crops out in the southeastern part of the Cordova quadrangle just east of Ragged Mountain and in the drainage of the northern tributaries of Bering River. Lithology and microfauna of the Ragged Mountain exposures, which may constitute part of the lower part of the formation, indicate marine deposition in neritic to upper bathyal depths (Tysdal and others, 1976a). Unit's lithology and megafauna in exposures north of the Bering River, which may constitute part of the upper part of the formation, indicate regressive shallow marine deposition. In this area the Stillwater intertongues with, and grades upward into, the shallow marine and nonmarine Kulthieth Formation (Miller, 1951; MacNeil and others, 1961). The Stillwater Formation is complexly deformed and is characterized by tight folds and shearing in incompetent strata; hence, its thickness can be only crudely estimated to be at least 4,918 ft (Plafker, 1971).

The 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 varigated 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 and others (1977), the foraminifers indicate a range from possibly the Paleocene and lower Eocene Bulitian Stage to the middle Eocene Ulatisian Stage. The mollusks indicate a younger age, late middle or early late Eocene (F. S. MacNeil in Wolf, 1977 p. 4). 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 40 mi to the east in the Bering Glacier quadrangle (Miller, 1961; MacNeil and others, 1961)

ORCA GROUP (EOCENE? AND PALEOCENE)—Named by Schrader (1900) for a widespread, thick, and complexly deformed sequence of flysch and mafic volcanic rocks in fault contact with the southern margin of the Valdez Group. The Contact fault system forms the landward boundary of the belt (Plafker and others, 1977). The Orca Group is considered to be an accretionary sequence and part of a geologic belt that extends through Prince William Sound to the Kodiak Islands to the west and that probably underlies much of the contiguous continental shelf (Plafker, 1969, 1971; Tysdal and Case, 1979).

Rocks originally assigned to the Orca Group consist of those on most of the islands in Prince William Sound and those on the adjacent mainland in the Cordova quadrangle (Schrader, 1900; Grant and Higgins, 1910). In the Seward and Blying Sound quadrangles, rocks eastward of a line from the west end of Glacier Island through Knight Island Passage and Bainbridge Passages were considered to be part of the Orca Group; those to the west of the line were considered part of the Valdez Group (Grant and Higgins, 1910; Moffit, 1954). Winkler and Plafker (1975) and Plafker and others (1977) placed the Contact fault in western Prince William Sound 10 mi west of this line along what is now mapped as the Johnstone Bay fault, whereas Tysdal and Case (1979) placed the Contact fault an additional 6-10 mi further west, because they were not able to distinguish a stratigraphic break across the Johnstone Bay fault. In western Prince William Sound the regional strike in the two groups is parallel and the close lithologic similarities of the two groups makes placement of the boundary difficult. In eastern Prince William Sound the placement of the boundary is easier. Between the Copper River and Port Fidalgo the northeast-trending regional strike of the Orca Group is truncated along the Gravina fault (part of the Contact fault system), while the Valdez Group in this area exhibits an east-west structural trend (Condon, 1965).

Sedimentary rocks of the Orca Group make up a monotonous sequence of thin- to thick-bedded sandstone, siltstone, and mudstone showing abundant sedimentary structures indicative of deposition from turbidity currents. Typical structures include graded bedding, crossbedding, ripple marks, and flute, groove, and load casts. Sandstone is more abundant than the finer grained rocks. Pebbly sandstone and conglomerate are widespread but the total amount is minor.

Tholeiitic basalt is the characteristic volcanic rock type in the Orca Group. The basalt occurs as massive flows interlayered with pillowed flows in several areas. On Knight Island these volcanic rocks may be as much as 5,000 ft thick and were probably derived from feeder dikes composing the sheeted-dike unit seen on Knight Island and, to a lesser extent, on Glacier Island. In the Ragged Mountain area, volcanic flows are less abundant, and volcaniclastic sedimentary rocks, tuff, and breccia are more common.

Detailed studies by Winkler (1976) on Hinchinbrook Island and in the vicinity of Cordova suggest that the Orca Group flysch in these areas was deposited primarily in the middle lobate parts of a complex system of westward-sloping submarine fans. To the north, in the vicinity of Long Bay and Miners Lake, extensive chaotic deposits (probably due to mass slumping) and thick lenses of matrix-supported conglomerate interbedded with subordinate massive sandstone and thinly bedded sandstone and mudstone suggest deposition in the inner fan area (Mutti and Ricci-Lucchi, 1978).

Mafic volcanic rocks of the Orca Group contain interbedded sedimentary rocks, usually siltstone, shale, or argillite. Mafic dikes and sills occasionally intrude the various mixed volcanic and sedimentary rock units. Larger areas of volcanic rocks commonly are fault bounded, at least in part.

Sparse paleontologic and radiometric data indicate a Paleocene and early Eocene(?) age for the Orca Group. Foraminifers from eastern Prince William Sound suggest a middle or late Paleocene age (Winkler, 1976); crabs from near Galena Bay are of probable late Paleocene age (Addicott and Plafker, 1971); silicoflagellates from Ragged Mountain are late Paleocene or early Eocene (Tysdal and others, 1976b). Fossil identifications and ages are listed in table 2. The Orca Group has been intruded by both Eocene (50.5 to 53.5 Ma) and Oligocene (34.2 to 36.6 Ma) granitic plutons (table 1) (Plafker and Lanphere, 1974; Tysdal and Case, 1979).

Thickness of the Orca Group is estimated as many thousands of feet (possibly 19,000 to 32,000 ft) (Winkler and Plafker, 1981). During the accretion of the Orca Group, the rocks underwent regional changes resulting in advanced diagenesis to low greenschist-facies metamorphic assemblages. These changes are indicated by recrystallization of matrix material for the lower grade conditions and by the presence of secondary prehnite, pumpellyte, and actinolite for the higher conditions. Locally, near the Tertiary plutons the Orca Group has been thermally metamorphosed to the albite-epidote hornfels facies as indicated by metamorphic biotite, andalusite, sillimanite, cordierite, and hornblende. In this area, the Orca Group is divided into:

Toc CONGLOMERATE—Ranges from matrix-supported pebbly mudstone and sandstone to massive clast-supported pebble, cobble, and boulder conglomerate. The generally well-rounded clasts consist of various lithologies that have locally predominant types as follows: near Valdez Arm, greenstone, sandstone, argillite, and limestone; near Sheep Bay, felsic porphyry and tuff, granite, and sandstone; west of Ragged Mountain, felsic tuff and porphyry; on Evans and Latouche Islands, white quartz, felsic porphyry, and argillite; and at Miners Bay, sandstone and siltstone. The conglomerates usually occur as lenses 300-700 ft thick within flyschoid rocks. The thickest lens is found near Miners Bay and measures about 3,000 ft in thickness. The conglomerates probably represent different stratigraphic horizons: the conglomerate north of Galena Bay rests depositionally on pillow basalts and contains Paleocene crab fossils (Addicott and Plafker, 1971), but the conglomerate west of Ragged Mountain is apparently stratigraphically above upper Paleocene or lower Eocene volcaniclastic rocks. Winkler and Tysdal (1977) have interpreted the clast-supported conglomerates of the Orca Group as deposits in feeder and distributory channels that supplied a fan complex; they suggest that matrix-supported conglomerates and pebbly mudstones may have been formed by sub-marine landslides on unstable slopes

Tos SEDIMENTARY ROCKS, UNDIVIDED—Sedimentary rocks of the Orca Group make up a sequence of thin- to thick-bedded sandstone, siltstone, and mudstone. Abundant sedimentary structures, such as graded bedding, crossbedding, and ripple marks, along with flute, groove, and load casts, indicate deposition from turbidity currents. Sandstone is more abundant than finer-grained rocks. Massive sandstone is prominent in a belt that extends from Johnstone Bay on the south through Nassau Fiord to the Unakwik Inlet area on the north (Tysdal and Case, 1979). Minor amounts of hemipelagic mudstone that contain scattered planktonic foraminifers occur throughout the Orca Group. Limestone lenses or concretions are found locally, and these, along with the earlier mentioned conglomerates, are characteristic of sedimentary rocks belonging to the Orca Group (Moffit, 1954).

Thin-section petrography indicates that most of the sandstones are feldspathic to feldspatholithic (classification of Decker, 1975). Point counts of 20 medium-grained sandstone samples yield a modal composition of 31 percent quartz, with a range of 22 to 58 percent (including chert and polycrystalline quartz); a range of 18-48 percent feldspar; and 28 percent lithic grains, with a range of 15-40 percent. The Orca Group samples fall largely within the magmatic arc-derived provenance field of Dickinson and Suczek (1979). When analyzed in terms of geographic distribution, preliminary results indicate that Orca Group sandstone compositions in the western part of the study area (17 of the 20 samples analyzed) show a systematic decrease in lithic grains and increase in quartz and feldspar from west to east. Modal compositions of the lithic clasts vary, becoming generally poorer in volcanic clasts and richer in sedimentary and metamorphic clasts to the east, and suggest progressive erosion of a magmatic arc that includes exposure of the plutonic roots (Dickinson and Suezek, 1979).

The shoreline surrounding Orca Bay was

designated as the type area of the Orca Group (Moffit, 1954). During this study three stratigraphic sections were measured in the Cordova quadrangle. Two are in shoreline exposures along the south fork of Simpson Bay, a part of Orca Bay. The third is from a shoreline exposure at the west end of the peninsula separating Port Gravina and Port Fidalgo. One Simpson Bay section (T. 14 S., R. 3 W., sec. 19) consists of 115 ft of sandstone (67 percent), siltstone, and argillite (33 percent). The thickest sandstone bed is 6 ft thick and has a distinctly channeled form; other beds are less than 2 ft thick and seem to represent complete or base-absent Bouma sequences. Parallel and cross laminations are locally well-developed, and beds occur primarily in fining- and thinning-upward sequences. The other Simpson Bay section, located 0.5 mi north of the first (township, range, and section as given above), consists of 135 ft of conglomerate (20 percent), sandstone (66 percent), and siltstone and argillite (14 percent). The conglomerate occurs in lenses 3 to 9 ft thick that are typically inverse to normally graded; associated fine- to medium-grained sandstone constitutes 2- to 6-ft thick beds. Fine-grained sandstone, siltstone, and argillite occur in 0.5- to 10-in. interbeds that show few sedimentary structures. The third section (Porcupine Point, T. 13 S., R. 8 W., sec. 19) consists of 250 ft of sandstone (84.5 percent), siltstone and argillite (15 percent), and limey argillite (0.5 percent). Sandstone beds show water-escape (dish) structures, basal load casts, and abundant locally derived mudstone rip-up clasts; beds average 6 to 9 ft in thickness, but occasionally reach 35 ft thickness in the upper third of the section. Interbedded finer grained sediments form 2- to 15-in. packages with well-developed cross, parallel, and convolute laminations. Typically, these beds represent complete Bouma sequences and occur in thinning- and fining-upward sequences. These measured sections support Winkler's (1976) and Winkler and Tysdal's (1977) contention that the bulk of the Orca Group was deposited as the middle part of a deep sea fan that had local inner fan deposits representing feeder and distributary channels within the complex. The northern Simpson Bay section and the upper part of the Porcupine Point section may represent such channel deposits, while the predominance of thinning- and fining-upward sequences elsewhere in the sections suggest a mid-fan depositional environment (Mutti and Ricci-Lucchi, 1978).

The degree of regional metamorphism exhibited by these rocks ranges from less than zeolite facies (probably better classified as diagenitic alteration) to lower greenschist facies. Rocks of lower metamorphic grade are generally found seaward of the higher grade rocks. Outboard graywackes with minimum grade show the development of matrix material and clay rims on detrital grains. However, metamorphism of most of the outboard graywackes have reached zeolite to prehnite-pumpellyite facies with mineral assemblages that include phyllosilicates. This gradation from diagenetic and low-grade metamorphic changes is probably due to increasing depth of burial (Galloway, 1974). The more inboard graywackes exhibit lower greenschist-facies assemblages, including white mica ± chlorite ± epidote.

Near Tertiary plutons the sedimentary rocks have been converted to hornfels that have thermal-metamorphic mineral assemblages. In the Seward and Blying Sound quadrangles, Tysdal and Case (1979) reported a biotite + quartz + feldspar assemblage in graywackes near the plutons. In the Cordova quadrangle, just south of Miles Glacier, Orca Group metamorphic rocks contain biotite ± muscovite ± andalusite ± cordierite ± garnet mineral assemblages.

The Orca Group flysch is complexly deformed, particularly in the vicinity of major faults. Thick homoclinal sequences are common, but isoclinal folds are well developed in some places. On Montague Island, folds have south-dipping axial surfaces, whereas other folds to the northwest have north-dipping axial surfaces. Rocks found near major thrust faults show cataclastic deformation that is expressed by a semischistose fabric in graywackes

Top PILLOW BASALT—Pillow basalt of the Orca Group in Prince William Sound has been previously described by several workers, most extensively by Capps (1915) and Richter (1965). Pillow basalt, associated broken pillow breccia, and massive flows make up large parts of Glacier, Lone, Knight, and Elrington Islands, Copper Mountain, and Ragged Mountain. This unit may be more than 5,000 ft thick on Knight Island where it is part of a larger mafic igneous complex (Tysdal and others, 1977). Pillow diameters average 3 ft; however, elongated pillows as much as 12 ft long, as well as multilobed and bifurcated pillows, are common.

Pillow breccia and massive flows are subordinate in quantity to pillow basalt. Minor intercalated sedimentary rocks are predominantly siliceous mudstone and argillite. Interpillow material consists of silicious mudstone, sandstone, or carbonate rocks. Pillow basalts are porphyritic and have phenocrysts of plagioclase and clinopyroxene; olivine is present but not abundant. Altered brown-colored volcanic glass makes up much of the matrix, especially in the outer parts of pillows. Vesicles are usually filled with calcite and (or) chlorite. This unit is gradational into sheeted dikes on Glacier and Knight Islands and into mixed sedimentary and volcanic rocks elsewhere

Tops PILLOW BASALT AND SEDIMENTARY ROCKS—Pillow basalt, massive basalt flows, minor volcanic breccia interbedded with sandstone, siltstone, and shale. Distinguished from the interbedded sedimentary and mafic volcanics rocks unit on the basis of the predominance of pillow basalt in the section. Probably gradational with the pillow basalt unit. Two measured sections on Ellamar Mountain show significant differences in the percent of interbedded volcanic and sedimentary rocks that reflect rapid lensing out of units, probably due to the presence of an irregular paleosurface. One section contains 92 percent volcanic rocks and 8 percent sedimentary rocks, and the other section (about 1,200 ft laterally distant) contains 75 percent volcanic rocks and 25 percent sedimentary rocks. The petrography of these volcanic rocks is similar to those of the pillow basalt unit

Tosv INTERBEDDED SEDIMENTARY AND MAFIC VOLCANIC ROCKS—Unit consists of locally variable amounts of volcanic and sedimentary rocks. In some cases unit is marginal to thicker sequences composed of pillowed and massive basalt flows. The lithologies are quite variable throughout the study area. In Ragged Mountains volcaniclastic and tuffaceous sedimentary rocks are abundant, and pillow basalt is rare. On Eyak Ridge above the city of Cordova, an 1,120-ft-thick measured section (T. 15 S., R. 3 W., sec 1 and T. 15 S., R. 2 W., sec. 6) contains 75 percent sedimentary rocks and 25 percent volcanic rocks. The sedimentary rocks consist of 35 percent fine- to medium-grained sandstone, 38 percent siltstone and argillite, and 2 percent breccia composed of mudstone and (or) greenstone clasts in a sandstone matrix. The coarser grained sandstone occurs mostly in distinctly channel-shaped beds, which have maximum thicknesses of 3-12 ft and lateral extents ranging from 50-160 ft. The finer-grained sandstone, siltstone, and argillite beds are from 1-15 in. thick and often display well-developed parallel and cross laminations. These beds seem to represent complete or base-absent Bouma sequences in thinning- and fining-upward cycles, possibly deposited in a mid-fan environment. The volcanic rocks from this section consist of 13 percent pillowed basalt flows (individually ranging from 35-90 ft thick) and 12 percent massive basalt flows or sills (individually ranging from 3-60 ft thick). In contrast, a 6,230-ft-thick measured section from Hinchinbrook Island (T. 17 S., R. 7 W., sec. 34) consists of 22 percent broken pillow breccia, 20 percent massive basalt flows, 30 percent pillow basalt flows, and 26 percent sedimentary rocks. The sedimentary rocks from this section are predominantly dark-gray shale and variously colored mudstone (gray, green, and red) and have subordinate limestone and fine-grained sandstone. On Knight Island this unit consists of massive basalt flows and sills(?) intercalated with shale and argillite.

These rocks are typically metamorphosed to zeolite or prehnite-pumpellyite facies and on Knight Island they have been converted to a hard hornfels by the abundant sills(?). Foraminifers in these rocks from near Cordova and from Hinchinbrook Island are indicative of a Paleocene to possibly late middle Eocene age

Tots TUFFACEOUS SEDIMENTARY ROCKS—Tuffaceous sedimentary rocks, volcaniclastic sandstone, and minor chert. Locally, these rocks contain abundant radiolarians and diatoms of probable Tertiary age (table 2). South of the Martin fault, this unit also includes minor pillow basalt and abundant volcanic breccia. The rocks are altered to a bright orange-weathering gossan and are intruded by numerous porphyritic dikes for a distance of 10 mi along the south side of the Martin fault

Tov VOLCANIC ROCKS, UNDIVIDED—Mostly tabular or lenticular bodies of mafic volcanic rocks altered to greenstone and not examined in detail. As mapped, may include pillowed or massive flows, broken pillow breccia, tuff, and dikes

Tod SHEETED DIKES—Mafic sheeted-dike complexes in the Orca Group occur on Knight and Glacier Islands. The dikes are basaltic in composition and display diabasic, equigranular, and porphyritic textures. Phenocrysts of plagioclase and clinopyroxene are common. Facings of chilled margins and other field observations indicate that the dikes were intruded into, between, and across preexisting dikes. Individual dikes usually trend north-south and are vertical.

Small irregular pods, veins, and dikes of plagiogranite were observed in the dike complex north of Bay of Isles on Knight Island. Also on Knight Island, numerous major and minor shear zones consist of chlorite schist, tuffaceous rocks, and sheared pillow basalt and are commonly cut by unsheared mafic dikes. Also found within the larger shear zones are small to large (as much as 650 by 1,300 ft) outcrops of ultramafic rocks. On the east side of the dike complex a xenolith of an unusual white rock forms a linear but discontinuous outcrop belt 2 mi long. Thin-section examination shows that the white rock consists of both metasedimentary and metaigneous rocks. The presence of these diverse lithologies and the presence of mafic dikes cutting the shear zones indicate that the dike complex was undergoing significant deformation coincident with magmatic activity and that the present outcrops may represent the upper part of the dike system. This unit is metamorphosed to greenschist facies locally on Knight Island

Togb GABBRO—Several small intrusive bodies of gabbro occur on Knight Island. The largest body crops out east of Drier Bay, where it intrudes sheeted dikes. Other gabbro bodies that have been reported (Richter, 1965; Tysdal and Case, 1979) are too small to show at the scale of this map. Most of these are elongate parallel to the trend of the sheeted dikes. At the north end of Latouche Island a 100-ft-wide exposure of gabbro can be seen intruding slate and sandstone

Tou ULTRAMAFIC ROCKS—Richter (1965) reported xenoliths of peridotite and gabbro in massive rocks (sheeted dikes) of the east and southeast shores of Drier Bay on Knight Island. These xenoliths were not observed during subsequent mapping (Tysdal and Case, 1979, and this study); however, three previously undescribed peridotite bodies were discovered during the summer of 1982. Two of these peridotite bodies occur within or near major shear zones in the sheeted-dikes unit; only the larger (650 by 1,300 ft) body is shown in the Port Audry shear zone. The third body occurs as a xenolith in sheeted dikes. The ultramafic rocks weather orange brown in color and form subdued rubble outcrops. Minor plagioclase-bearing amphibolite is spatially associated with the peridotite from the Port Audry shear zone

VALDEZ GROUP (UPPER CRETACEOUS)—The name Valdez Group was originally used by Schrader (1900) for a sedimentary sequence several thousand feet thick. Presently the group is interpreted as the outboard part of a belt of Cretaceous accretionary rocks 1,060 mi long and as much as to 60 mi wide that extends along the Alaska coastal margin from Chatham Strait in southeastern Alaska to Kodiak and Shumagain Islands in southwestern Alaska (Plafker and others, 1977; Plafker and Campbell, 1979). The northern limit of the Valdez Group in the Anchorage and Valdez quadrangles is considered to be the Border Ranges fault system in the Anchorage and Valdez quadrangles (MacKevett and Plafker, 1974; Plafker and others, 1977) and the Eagle River fault system in the Anchorage and Seward quadrangles (Clark, 1972; Tysdal and Case, 1979). The entire sequence is folded and deformed and metamorphosed to grades ranging from zeolite to lower greenschist and to the amphibolite facies. Paragneiss with a probable Valdez Group protolith is exposed along Wernicke River in an area of abundant small granitic stocks and dikes that probably represent the upper cupolas of a more extensive granitic pluton.

The Valdez Group within the map area constitutes most of the rocks north of the Contact fault and is composed chiefly of interbedded sandstone, siltstone, and minor mudstone and pebble conglomerate. Mafic volcanic rocks consist of greenstone, metapillow basalt and mixed metasedimentary rocks, greenstone, and tuffaceous units. These rocks crop out in a large area in the northern Cordova quadrangle and contrast in degree of metamorphism with the mafic complex comprising the Resurrection Peninsula. The mafic complex of the Resurrection Peninsula is strikingly similar to the mafic complex within the Orca Group found on Knight Island. Both complexes consist of well-developed pillow basalt and sheeted-dike units with lesser amounts of gabbro, plagiogranite, and ultramafic rocks. On the Kenai Peninsula, interpretation of sedimentary and volcanic lithofacies by Budnik (1974) suggested the following depositional environments: (1) a deep ocean basin; (2) an abyssal plain; (3) the floor of a trench; (4) submarine fans at the base of a continental slope; and (5) the lower continental slope. The Valdez Group is considered to be of Late Cretaceous age (Tysdal and Plafker, 1978). Age diagnostic fossils have been found, in place, in the Girdwood area of the Anchorage quadrangle and near the outlet of Kenai Lake at the Seward quadrangle (table 2). Fossils identified to species level are Inoceramus kursiroensis and Inoceramya concentrica, which indicate a Maastrichtian (Late Cretaceous) age (Jones and Clark, 1973). In this area the Valdez Group is divided into:

Kvs SEDIMENTARY ROCKS, UNDIVIDED—Thick sequences of deformed and metamorphosed flysch consisting of metasandstone, metasiltstone, argillite, slate, and phyllite, with rare beds of conglomerate and pebbly argillite. Layers are generally a few inches to a few feet thick, but massive sandstone as much as several tens of feet thick is locally present. In many places primary internal sedimentary structures, consisting of graded bedding, cross laminations, and convolute bedding, are preserved, especially in the areas to the south of Harriman Fiord and to the east of the Copper River. However, in most places, original bedding is transposed by regional shearing. This shearing could be related to the accretionary and (or) oroclinal bending deformational events.

Two sections were measured in this unit. One in the Valdez quadrangle on the west shore of Valdez Narrows (T. 9 S., R. 8 W., sec. 29) at the entrance to Port Valdez, which is the type area of the Valdez Group (Moffit, 1954). This section totals 120 ft in thickness and consists of sandstone (83.4 percent), siltstone and argillite (13.2 percent), and diabase (3.4 percent). The sandstone forms sequences as much as 9 ft thick; finer grained rocks occur in layers 0.5–15 in. thick. Parallel lamination is common in some horizons, and load casts and cross beds are common locally. No evidence of isoclinal folding was found. The finer grained rocks display a locally developed cleavage, and some pinch and swell features observed in individual layers may have been tectonically produced. Minor metamorphic biotite was identified in thin section. Postdepositional textures range from essentially no penetrative fabric to slightly semischistose fabric. The diabase occurs as a flow or a dike at least 6 ft thick intercalated with sandstone.

The other measured section is in the Cordova quadrangle about 1.5 mi east of Mount Denson (T. 11 S., R. 6 W., sec. 20). It contains 77 percent sandstone and 23 percent siltstone and argillite and totals 285 ft in thickness. Sandstone occurs in beds as much as 15 ft thick, but interbedded finer grained sediments typically constitute layers only a few inches thick. Beds locally contain primary parallel laminations, cross beds, and convolute laminations. Isoclinal folds were noted at several horizons within the section. All sedimentary rocks studied contain metamorphic biotite. The sandstones display a moderately developed semischistose texture that has abundant randomly oriented interstitial biotite and less abundant weakly aligned biotite. One of the two siltstone thin sections studied shows no penetrative fabric at all: biotite laths are randomly oriented, and delicate sedimentary structures, such as burrows and bioturbated horizons, are preserved. The other siltstone sample, taken 130 ft below the first, is more penetratively deformed and displays a well-developed parallel alignment of the biotite.

The variable distribution of semischistose fabric seen in the two measured sections is common within the Valdez Group. The presence of semischistose fabric is probably a function of local deformation. In general, relatively incompetent fine-grained units display more penetrative shearing than coarser grained units.

The metamorphic grade of the Valdez Group is generally low greenschist-facies, but ranges from zeolite to amphibolite facies. This range, as well as specific facies assemblages, are similar to those of the Orca Group and in both cases may represent metamorphism associated with accretion. Upper greenschist-facies assemblages (with biotite) are found mainly in local occurrences near major faults. The highest grade assemblages, although regionally extensive, suggest a late thermal aspect to the metamorphism. This is demonstrated in two areas in particular: north of Port Fidalgo and east of the Copper River. In both places, primary sedimentary structures are well preserved in sedimentary rocks that have abundant metamorphic biotite and locally well-developed porphyroblasts of andalusite ± cordierite ± garnet. In these graywackes, biotite usually parallels, but sometimes grows across, any penetrative fabric as porphyroblastic grains. The parallel biotite growth is considered to be mimetic (of an earlier formed fabric) rather than entirely syntectonic (Hudson and Plafker, 1982).

A schist unit has previously been differentiated in three places within the Valdez Group: in a 44-mi-long belt west of the Placer River fault (Budnik, 1974; Tysdal and Case, 1979); on the Resurrection Peninsula (Tysdal and Case, 1979); and adjacent to the paragneiss unit (Kvg) near the Wernicke Glacier (Winkler and Plafker, 1981). Based on field and thin-section observations from all three areas, we feel that the schist distinction should be dropped. The schistose rocks of these areas are texturally semischistose and are interlayered with rocks that have no penetrative fabric. In addition, semischistose rocks are common throughout the entire area mapped as the Valdez Group, especially near faults and in areas dominated by fine-grained sedimentary rocks. In areas where thicker sandstone beds are more common, the thinner, finer grained interbeds usually have a semischistose texture even though all rock types may contain metamorphic biotite.

Valdez Group sandstones range from lithic to feldspatholithic (classification of Decker, 1975) in composition. Twelve medium-grained sandstones from the western half of the study area yield a modal composition of 19.3 percent quartz (including chert and polycrystalline quartz), with a range of 8 to 30 percent; 36.3 percent feldspar, with a range of 18 to 54 percent; and 44.4 percent lithic grains, with a range of 24 to 72 percent. The Valdez Group samples plot within the magmatic arc-derived provenance field of Dickinson and Suczek (1979) as did the Orca Group samples. Preliminary results indicate that Valdez Group sandstones cannot be petrographically separated from Orca Group sandstones on the basis of texture and composition alone. Rather, the Valdez sandstones fit the trend previously described for the Orca Group sandstones, with samples becoming less lithic-rich and more feldspar- and quartz-rich from west to east. For example, Valdez sandstones from west of the Placer River fault tend to be particularly rich in volcanic lithic grains, while Valdez Group sandstones from east of the Placer River fault (richer in quartz, feldspar, and sedimentary and metamorphic lithic grains) have Q-F-L modes intermediate between those from the western part of the Valdez and sandstone samples from the western part of the Orca. Two samples of medium-grained sandstone intercalated with the mafic volcanic rocks of the Resurrection Peninsula have a modal composition of 34 percent quartz, 49.5 percent feldspar, and 16.5 percent lithic grains. These values are quite unlike those of other Valdez Group sandstones analyzed; they suggest that the sandstones of the Resurrection Peninsula may have had a different provenance than other sandstones currently assigned to the Valdez Group (Zuffa and others, 1980)

Kvg PARAGNEISS—Predominantly metasedimentary rocks with well-developed gneissic foliation consisting of alternating quartz and feldspar-rich layers with biotite-rich layers. The paragneiss is brown weathering, medium grained, and banded on a 2- to 4-mm scale. However, thicker biotite-rich layers are also found. Quartz segregations parallel to the banding are common but not laterally continuous. Locally some layers in the paragneiss contain 1-in.-long porphyroblasts of andalusite.

This unit contains up to 10 percent orthogneiss. The orthogneiss is cream colored or light gray, coarse grained, contains less biotite than the paragneiss, and locally grades into normal-textured granitic rocks containing abundant inclusions of country rock. The contact with the paragneiss is usually sharp and conformable but is locally crosscutting. The orthogneiss is probably an injection feature of the biotite granite plutons in this area

Kvp PILLOW BASALT—Pillow basalt and lesser massive basalt and broken pillow breccia make up most of the western flank of the mafic complex on the Resurrection Peninsula. These pillow basalts form a west-dipping sequence and contain minor amounts of interbedded siliceous siltstone. This unit is remarkably similar to the pillow basalt unit of the Orca Group exposed on Knight Island. Discrete pillows average 2 ft in diameter and are metamorphosed to the lowest greenschist facies

Kvgr GREENSTONE—This unit consists of massive greenstone, metamorphosed pillow basalt, and mafic dikes exposed near the heads of Woodworth and Schwan Glaciers. Elsewhere in the Cordova and Valdez quadrangles, the unit includes lenticular bodies of chorite schist that may have originally been mafic tuffs or flows. These rocks are typically metamorphosed to greenschist and low amphibolite facies. The higher grade facies is distinguished by the presence of dark-green hornblende

Kvd SHEETED DIKES—Mafic sheeted dikes forming the topographically rugged crest of the Resurrection Peninsula are similar to the sheeted dikes unit of the Orca Group on Knight Island. Most dikes are 3 to 6 ft thick, vertical, and generally have a parallel north-south orientation. Locally crosscutting dikes intrude preexisting dikes at low angles. Aphanitic, porphyritic, and diabasic textures are common even across one outcrop. Weathering color varies from buff to dark gray to dark green and along with the textural variations suggest slightly differing compositions and (or) cooling rates. The sheeted dikes grade westward into pillow basalt and eastward into gabbro

Kvgb GABBRO—Two north-south-trending plutons of medium- to coarse-grained gabbro occur east of the sheeted dikes unit on the Resurrection Peninsula. Several features are displayed in shoreline exposures of the westernmost pluton that were not observed in the easternmost pluton. Well-developed, west-dipping magmatic mineral layering was observed in shoreline outcrops between Driftwood Bay and Talus Bay. Hornblende plagiogranite in a 65-ft-wide stockwork zone from the western pluton has intruded the gabbro in Killer Bay. Other small dikes and pods of plagiogranite intrude the gabbro along the west shore of Day Harbor. These features may be present in the easternmost pluton as well, but were not observed due to limited exposures. Mafic dikes intrude the western gabbro pluton and increase in abundance from east to west

Kvu ULTRAMAFIC ROCKS—Serpentinized peridotite and dunite occur at three localities underlain by the Valdez Group: two of these are on the Resurrection Peninsula and the third is near the head of Port Fidalgo. On the Resurrection Peninsula small (16 ft across) sparse inclusions of altered dunite are found in the gabbro unit. Blocks of serpentinite and serpentinized peridotite crop out within the interbedded volcanic and sedimentary rocks unit on the ridge above Talus Bay and along the west shore of the adjacent bay to the north. Their strongly sheared margins suggest that these rocks have been tectonically emplaced. The third outcrop of ultramafic rocks is northeast of the head of Port Fidalgo and forms a rounded hill approximately 700 ft in diameter at the toe of a glacier. The margins of the hill are covered by moraine. This outcrop consists of both banded and massive dark- to light-green serpentinized dunite and peridotite. A lower exposure of talc-carbonate rock 300 ft high appears to be squeezed into the Valdez Group flysch on the north valley wall and is probably a marginal phase of the serpentinized rocks (Wyllie, 1979)

Kvvs INTERBEDDED VOLCANIC AND SEDIMENTARY ROCKS—This unit is composed of approximately equal amounts of interbedded volcanic rocks, consisting of volcanic breccia, tuff, tuffaceous sediment, and minor pillow basalt, and sedimentary rocks, consisting of sandstone, siltstone, shale, and chert. The two exposures of this unit differ in character. In the Cordova quadrangle the unit tends to weather orange and includes more sedimentary rocks (including marble) than on the Resurrection Peninsula. Near the head of Port Fidalgo this unit has been metamorphosed to amphibote-bearing greenschist with a K-Ar age of 47.6 $\pm$ 1.4 Ma (table 1)

Km MCHUGH COMPLEX (LOWER CRETACEOUS)—The McHugh Complex is only exposed along the extreme western boundary of the study area and was not examined during the course of this study. The following description is taken from Clark (1981, p. 3-4). "The McHugh Complex is a heterogeneous, chaotic assemblage that includes metamorphosed clastic and volcanic rocks of diverse ages. The clastic rocks, which are the most abundant, comprise thick, fault-bounded sequences of weakly metamorphosed graywacke, arkose, siltstone, and conglomeratic sandstone. Bedding is rarely seen and commonly discontinuous. The clastic sequence was deposited in a high-energy environment. The poor sorting and rounding of the sediments and their diverse compositions indicate derivation from a continental terrane, rapid deposition, and little reworking of the sediments. The volcanic portion of the McHugh Complex is composed of greenstones, mostly of basaltic composition, that are associated with radiolarian metacherts, siltite, and argillite * * *. The volcanic rocks of the McHugh Complex are thought to represent oceanic crust upon which radiolarian ooze, silt, and mud were deposited at a mid-ocean rise or on the abyssal ocean floor. The clastic sediments are thought to have been deposited in an ocean trench. The lack of continuity of the units, the contrasting environments of deposition, and the style of deformation lead to the conclusion that this heterogeneous assemblage of rocks is a melange in which rocks from two differing areas have been brought together as tectonically mixed blocks * * *. The McHugh Complex includes blocks of rocks that range in age from late Paleozoic through Cretaceous. The age of the McHugh is considered to be the time of emplacement of the blocks, which can be no older than the youngest rocks included in the melange (Early Cretaceous). Poorly preserved fossils from marble in the McHugh Complex include fusilinids of late Paleozoic, possibly Pennsylvanian, age and an assemblage of foraminifera and calcareous algae of Permian age. A granitic clast * * * from a conglomeratic metasandstone was dated, using the potassium argon (K-Ar) method on hornblende, at 146 ± 7 m.y. Early Cretaceous (Valanginian) radiolarians have been collected from bedded chert and from the correlative Uyak Complex of Kodiak Island (Connelly, 1978), limiting the age of emplacement to post-Valanginian."

INTRUSIVE ROCKS

The intrusive rocks of the Chugach National Forest consist of those associated with two main intrusive events, one Eocene and the other Oligocene, and those composing three minor intrusive units of various ages.

Td DACITE OF CAPE SAINT ELIAS (MIOCENE)—This minor unit was described by Winkler and Plafker (1981, p. 18) as follows: "A prominant, 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. The dacite has sharp, nearly vertical contacts with adjacent dark-gray argillaceous rocks of the Yakataga and upper Poul Creek Formations * * *". A zone of hornfels at least 300 ft wide borders the body (Winkler and Plafker, 1981). A whole rock (K-Ar) age determination of 6.2 ± 0.3 Ma was obtained from the dacite (table 1)

Tg GRANITE AND GRANODIORITE (OLIGOCENE)—The latest main-phase intrusive event in western Prince William Sound is described by Grant and Higgins (1910), Moffit (1954), and Tysdal and Case (1979). Surface exposures of the plutons range from less than 1 mi^2 (near Billings Glacier) to greater than 50 mi^2 (Esther Granite). Both the Orca and Valdez Groups are intruded by these roughly circular plutons; contacts are sharp and crosscut deformed bedding. The marginal zones of the plutons are rich in rounded inclusions of country rock. Thermal aureoles extend outward from the pluton contacts up to 0.5 mi into the country rock.

The central parts of the plutons are dominantly light-gray, medium- to coarse-grained granite with color index ranging from 3 to 8. The plutons grade outward to fine- to medium-grained, more mafic mineral-rich (color indices of 10 to 20) margins of granitic, granodioritic, and sometimes tonalitic compositions. Hypidiomorphic-granular texture is most common, but equigranular as well as porphyritic varieties also exist. Primary biotite is the most abundant mafic mineral and is sometimes accompanied by hornblende. Towards the pluton margins, however, hornblende commonly dominates over biotite. Two of the plutons (on Culross Island and near Eshamy Lagoon) have biotite plus minor amounts of late muscovite. The granite on Perry Island is unique in that it bears primary magnetite, hornblende, and primary(?) clinopyroxene. Optically determined plagioclase compositions range from oligoclase to andesine for all rocks of this unit.

Potassium-argon radiometric ages for these plutons range from 34.2 ± 1.7 to 36.2 ± 1.0 Ma (table 1; Lanphere, 1966)

Tgd GABBRO AND DIORITE (OLIGOCENE)—This unit consists of mafic rocks belonging to one of the main intrusive events. These rocks are dominantly medium- to coarse-grained gabbro (labradorite-bearing) and subordinate diorite (andesite-bearing) with finer grained borders of quartz gabbro and quartz diorite. The color index varies from a range of 30 to 70 in the gabbro and diorite to a range of 20 to 40 in the quartz diorite. Texture and mineralogy are also variable. Most of the rocks are subophitic, some are hypidiomorphic- to allotriomorphic-granular, and a few are porphyritic. The dominant mafic assemblage is clinopyroxene ± orthopyroxene. Grant and Higgins (1910) reported an assemblage of clinopyroxene + olivine from Esther Island. Assemblages of primary + subsequent hornblende and hornblende ± biotite are also found, mainly in the dioritic and quartz dioritic rocks. Where present, clinopyroxene commonly shows alteration to hornblende or actinolite + chlorite.

Rocks of this unit are considered to be an early mafic phase associated with the granitic plutons of the granite and granodiorite unit (Tg), as was suggested by Grant and Higgins (1910) and Tysdal and Case (1979). The mafic phase is exposed in the plutons near Passage Canal, near Eshamy Lagoon, and on Esther Island and is subordinate in outcrop to the granitic phase. The granite intrudes the mafic phases, and granitic veins and dikes are most numerous near the mafic rock-granite boundaries. However, the boundaries themselves are gradational from granite through granodiorite, diorite, quartz diorite, quartz gabbro, to gabbro over a distance of 0.2-1 mi. The contact has been drawn at the granodiorite-quartz gabbro (or quartz diorite) boundary where the color index increases noticeably.

A radiometric age (36.6 ± 1.01 Ma) for this unit (table 1), indicates a chronologic relation to the granite and granodiorite unit (Tg)

Tmb MINERS BAY PLUTON (OLIGOCENE)—The pluton at Miners Bay is unique among the plutons that belong to the younger of the two main intrusive events. Here, a slightly older mafic phase (similar to the gabbro and diorite unit) is intruded by a felsic phase (similar to the granite and granodiorite unit, Tg), but the mafic rocks are more abundant than the felsic rocks. Additionally, the Miners Bay mafic rocks carry disseminated pyrrhotite, pentlandite, and chalcopyrite that are lacking in the mafic rocks of the gabbro and diorite unit (Tgd).

The Miners Bay pluton is roughly wedge shaped and is bounded on the south by the Contact fault. The mafic part of this unit was previously mapped and briefly described by Grant and Higgins (1910). The mafic rocks intrude Valdez Group sedimentary rocks and are themselves intruded by a granite phase that is exposed in a narrow zone on the north side of the pluton.

The mafic phase varies in grain size, texture, and composition, but consists mainly of medium-grained subophitic clinopyroxene ± orthopyroxene gabbro (labradorite-bearing) with a color index of 35 to 45. A major part of the body, however, is fine- to medium-grained diabasic to hypidiomorphic-granular clinopyroxene + hornblende diorite (andesine-bearing) containing pods of medium-coarse grained gabbro. As with the gabbro and diorite unit, quartz gabbro and quartz diorite compositions are found, primarily near the pluton borders, and they carry clinopyroxene + hornblende ± late biotite. The color index of the quartz-bearing mafic rocks ranges from 25 to 35. The slightly younger felsic phase consists of medium-grained biotite granite with a range in color index from 3 to 10.

Two whole-rock radiometric ages were obtained from the Miners Bay pluton, but they are considered minimum ages because of alteration. Biotite in the felsic phase yielded an age of 32.2 ± 1.6 Ma, while hornblende in the mafic phase yielded an age of 38.4 ± 1.9 Ma (table 1)

Tm MAFIC PLUGS (OLIGOCENE?)—This minor unit is part of Winkler and Plafker's (1981) "Mafic dikes, sills, and plugs" unit. As described here the unit only includes mafic plugs in the eastern Cordova quadrangle west of Nichawak Mountain mainly in the Blying Sound quadrangle. These irregularly shaped intrusive plugs are shown schematically as two small bodies; in reality, there are numerous intrusions that are too small to delineate on the geologic map. Miller (1975) and Winkler and Plafker (1981) described the mafic plugs as coarse grained and diabasic with 45 percent euhedral plagioclase intergrown with 30 percent anhedral augite and enstatite. The remainder of the rock is composed of 5 percent opaque minerals and 20 percent secondary chlorite. According to Winkler and Plafker (1981, p. 19), the mafic rocks are " * * * probably early and middle Oligocene age. Nowhere have they been observed to intrude rocks younger than the upper part of the Poul Creek Formation."

Tgg GRANITE AND GRANODIORITE (EOCENE)—The older of the two main intrusive events is represented by plutons exposed in the central and eastern parts of the study area, which intrude both the Orca and Valdez Groups. Surface exposures of these plutons range from less than 0.3 mi^2 (Ragged Mountain, for example) to greater than 55 mi^2 (Sheep Bay pluton). Faults truncate a few of the bodies, but elsewhere the plutons are surrounded by contact-metamorphic aureoles. East of the Copper River the intruded sedimentary rocks show local injection migmatite and hornblende-hornfels and amphibolite-facies metamorphic minerals.

Plutons of this unit are generally medium- and medium- to coarse-grained hypidiomorphic-granular biotite granite with border phases of biotite ± hornblende granite to granodiorite and tonalite. However, hornblende accompanies biotite as a significant mafic mineral phase in the elongate body west of Columbia Glacier, in the Sheep Bay pluton, in the pluton south of the Rude River, and in the plutons west of the Copper River. The mafic mineral content varies with composition such that the color index of the granite ranges from 5 to 10; the granodiorite color index ranges from 10 to 20; and the tonalite color index ranges from 15 to 35.

Several plutons within this unit have various distinguishing characteristics. (1) The group of three stocks west of Columbia Glacier are slightly more alkali feldspar-rich compared with the rest of the plutons in this unit. (2) Although many of the plutons have country rock inclusions near their borders, the Sheep Bay pluton contains large (up to 300 ft across) inclusions in its interior parts. Moreover, the granitic rocks near these inclusions are mildly to moderately foliated as expressed by mafic mineral alignment. (3) The pluton just south of the Rude River is unique in having a significant part composed of mafic rocks. Here, an older mafic phase of clinopyroxene (altered to hornblende + actinolite) gabbro (labradorite-bearing) is intruded by biotite>clinopyroxene and biotite>hornblende granodiorite (andesine-bearing). Perhaps the high mafic content of the early phase is due to assimilation of mafic volcanic country rock.

Six potassium-argon ages ranging from 50.5 to 53.5 Ma (table 1) have been obtained from rocks within the granite and granodiorite unit (Tgg). However, several of the plutons that have been correlated with this unit remain undated; notably, the three exposures west of Columbia Glacier. Of these three plutons, the Eocene(?) Cedar Bay Granite was correlated with the Sheep Bay pluton by Tysdal and Case (1979) on the basis of similar major-oxide chemistry. We have correlated the remaining two plutons that are west of Columbia Glacier with the Cedar Bay Granite on the basis of close spatial relationship. Winkler and Plafker (1981) have correlated rocks of this unit to the Sanak-Baranof plutonic belt of Hudson and others (1979)

xxxx Tfd FELSIC DIKES (EOCENE? AND PALEOCENE?)—Leucocratic dikes, sills, and small stocks that are not obviously connected to large intrusive bodies are found throughout the Valdez Group flysch and locally in Orca Group flysch. The dikes and sills range from 1 to 10 ft wide and can generally be traced for 300 ft or more along strike. A few of the more continuous dikes and sills of this unit are shown schematically on the map.

The leucocratic dikes were first described by Grant and Higgins (1910), commented upon by Moffit (1954), and further described by Winkler and others (1981). They are usually prophyritic with fine- to medium-grained phenocrysts of plagioclase and occasional hornblende. The groundmass is usually a very fine-grained, sometimes felted mat of felsic minerals. Extensive secondary sericite and calcite often replace the felsic minerals; the scarce mafic minerals are almost completely altered to chlorite. Winkler and others (1981) have interpreted the dikes, sills, and small stocks as hypabyssal intrusive bodies. We found that dacitic compositions dominate but more rhyolitic compositions can also be found. The dikes usually have a very thin (less than 0.5-in. scale) chilled rind, but the intruded country rock rarely shows any thermal metamorphism.

Another set of leucocratic dikes of slightly different character intrude Orca Group flysch between Unakwik Inlet and Columbia Glacier. These dikes generally contain quartz and plagioclase phenocrysts in an alkali feldspar-rich fine-grained groundmass. Another characteristic that distinguishes this set of dikes is the occurrence of minor fluorite, sphalerite, galena, and chalcopyrite in some of the dikes. These felsic dikes may be related to the Cedar Bay Granite, which also shows minor zinc mineralization.

Five potassium-argon radiometric ages ranging from 43.6 ± 1.8 to 54.8 ± 2.7 Ma (table 1) were obtained from leucocratic dikes that cut Valdez Group flysch. In the Chugach Wilderness Study Area the youngest rocks intruded by felsic dikes belong to the Paleocene and Eocene(?) Orca Group. Winkler and others (1981) state that these leucocratic dikes are younger than the most recent metamorphism that affected the Valdez Group

REFERENCES CITED

Addicott, W. O., and Plafker, George, 1971, Paleocene mollusks from the Gulf of Alaska Tertiary province - A significant new occurrence on the North Pacific rim, in Geological Survey research 1971: U.S. Geological Survey Professional Paper 750-B, p. B48-B52.

Addicott, W. O., Winkler, G. R., and Plafker, George, 1978, Preliminary megafossil biostratigraphy and correlation of stratigraphic sections in the Gulf of Alaska Tertiary Province: U.S. Geological Survey Open-File Report 78-491, 2 sheets.

Budnik, R. T., 1974, The geologic history of the Valdez Group, Kenai Peninsula, Alaska: Los Angeles, California, University of California, Ph.D. thesis, 139 p.

Capps, S. R., 1915, Some ellipsoidal lavas in Prince William Sound, Alaska: Journal of Geology, v. 23, no. 1, p. 45-51.

Carey, S. W., 1958, The tectonic approach to continental drift—a symposium: Hobart, Australia, University of Tasmania, Geology Department, p. 177-355.

Clark, S. H. B., 1972, Reconnaissance bedrock geologic map of the Chugach Mountains near Anchorage, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-350, 1 sheet, scale 1:250,000.

_____ 1981, Guide to the bedrock geology along the Seward highway north of Turnagain Arm: Alaska Geological Society, no. 1, 36 p.

Condon, William, H., 1965, Map of eastern Prince William Sound area, Alaska showing fracture traces inferred from aerial photographs: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-453, scale 1:250,000.

Connelly, William, 1978, Uyak Complex, Kodiak Islands, Alaska—A Cretaceous subduction complex: Geological Society of America Bulletin, v. 89, p. 755-769.

Decker, John, 1975, Geology of the Mt. Galen area, Mt. McKinley National Park, Alaska: Fairbanks, Alaska, University of Alaska, M.S. thesis, 77 p.

Dickinson, W. R., and Suczek, C. A., 1979, Plate tectonics and sandstone compositions: American Association of Petroleum Geologists Bulletin, v. 63, p. 2164-2182.

Galloway, William E., 1974, Deposition and diagenetic alteration of sandstone in northeast Pacific arc-related basins: implications for graywacke genesis: Geological Society of America Bulletin, v. 85, p. 379-390.

Grant, U. S., and Higgins, D. F., 1910, Preliminary report on the mineral resources of the southern part of Kenai Peninsula: U.S. Geological Survey Bulletin, 442, p. 166-178.

Hudson, Travis, and Plafker, George, 1982, Paleogene metamorphism of an accretionary flysch terrane, eastern Gulf of Alaska: Geological Society of America Bulletin, v. 93, p. 1280-1290.

Hudson, Travis, Plafker, George, and Peterman, Z. E., 1979, Paleogene anatexis along the Gulf of Alaska margin: Geology v. 7, p. 573-577.

Jones, D. L., and Clark, S. H. B., 1973, Upper Cretaceous (Maestrichtian) fossils from the Kenai-Chugach Mountains, Kodiak and Shumagin Islands, southern Alaska: U.S. Geological Survey Journal Research, v. 1, no. 2, p. 125-136.

Kachadoorian, Reuben, 1960, Engineering geology of the Katalla area, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-308, 1 sheet, scale 1:63,360.

Lanphere, M. A., 1966, Potassium-argon ages of Tertiary plutons in the Prince William Sound region, Alaska, in Geological Survey research 1966: U.S. Geological Survey Professional Paper 550-D, p. D195-D198.

MacKevett, E. M., Jr., and Plafker, George, 1974, The Border Ranges fault in south-central Alaska: U.S. Geological Survey Journal of Research, v. 2, no. 3, p. 323-329.

MacNeil, F. S., Wolfe, J. A., Miller, D. J., and Hopkins, D. M., 1961, Correlation of Tertiary formations of Alaska: American Association of Petroleum Geologists Bulletin, v. 45, p. 1801-1809.

Martin, G. C., 1905, Notes on the petroleum fields of Alaska: U.S. Geological Survey Bulletin 259, p. 128-139.

_____ 1908, Geology and mineral resources of the Controller Bay region, Alaska: U.S. Geological Survey Bulletin 335, 141 p.

Miller, D. J., 1951, Preliminary report on the geology and oil possibilities of the Katalla district, Alaska: U.S. Geological Survey Open-File Report (51-20), 66 p.

___ 1953, Late Cenozoic marine glacial sediments and marine terraces of Middleton Island, Alaska: Journal of Geology, v. 61, n. 1. p. 17-40.

_____ 1961, Geology of the Katalla district, Gulf of Alaska Tertiary province, Alaska: U.S. Geological Survey Open-File Report (61-99), 2 sheets, scale 1:96,000.

____ 1975, Geologic map and sections of the central part of the Katalla district, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-722, 2 sheets, scale 1:40,000.

Miller, Marti L., Dumoulin, J. A., Nelson, Steven W., 1984, A transect of metamorphic rocks along the Copper River, Cordova and Valdez quadrangles, in Reed, Katherine and Bartsch-Winkler, Susan, eds., The United States Geological Survey in Alaska: Accomplishment during 1982: U.S. Geological Survey Circular 939, p. 52-57.

Mitchell, P. A., Silberman, M. L., and O'Kneil, J. R., 1981, Genesis of gold vein mineralization in an Upper Cretaceous turbidite sequence, Hope-Sunrise district, southern Alaska: U.S. Geol. Survey Open-File Report 81-103, 18 p.

Moffit, F. H., 1954, Geology of the Prince William Sound region, Alaska: U.S. Geological Survey Bulletin 989-E, p. 225-310.

Mutti, E., and Ricci-Lucchi, F., 1978, Turbidites of the northern Apennines: introduction to facies analysis: translated by Tor H. Nilsen, U.S. Geological Survey, from Le torbiditi dell' Appennino settentrionale: introduzione all' analisi di facies, Memorie della Societa' Geologica, 1972, p. 161-199; American Geological Institute, v. 20, no. 2, p. 125-166.

Pickthorn, W. J., 1982, Stable isotope and fluid inclusion study of the Port Valdez gold district, southern Alaska: Los Angeles, California, University of California, M.S. thesis, 66 p.

Plafker, George, 1967, Geologic map of the Gulf of Alaska Tertiary Province, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-484, 1 sheet, scale 1:500,000.

_____ 1968, Source areas of the Shattered Peak and Pyramid Peak landslides at Sherman Glacier, in The great Alaska earthquake of 1964 (Hydrology Volume): National Academy of Sciences, Publication 1603, p. 374-382.

_____ 1969, Tectonics of the March 27, 1964, Alaska Earthquake: U.S. Geological Survey Professional Paper 543-I, p. I1-I74.

_____ 1971, Possible future petroleum resources of Pacific-margin Tertiary basin, Alaska, in Future petroleum provinces of North America: American Association of Petroleum Geologists, Memoir 15, p. 120-135.

_____ 1974, Geologic map of Kayak and Wingham Islands, Alaska: U.S. Geological Survey Open-File Report 74-82, 1 sheet, scale 1:31,680.

Plafker, George, and Addicott, W. O., 1976, Glaciomarine deposits of Miocene through Holocene age in the Yakataga Formation along the Gulf of Alaska margin, Alaska: U.S. Geological Survey Open-File Report 76-84, 36 p. Superseded by article of same title in Miller, T. P., ed., Recent and ancient sedimentary environments in Alaska, Anchorage, Alaska Geological Society Symposium Proceedings, 1976, p. Q1-Q23.

Plafker, George, Burns, T. R., and Page, R. A., 1975, Interim report on petroleum resource potential and geologic hazards in the Outer Continental Shelf of the Gulf of Alaska Tertiary Province: U.S. Geological Survey Open-File Report 75-592, 74 p.

Plafker, George, and Campbell, R. B., 1979, The Border Ranges fault in the Saint Elias Mountains, in Johnson, K. M., and Williams, J. L., eds., The United States Geological Survey in Alaska: Accomplishments during 1978: U.S. Geological Survey Circular 804-B, p. 102-104.

Plafker, George, Jones, D. L., and Pessagno, E. A., Jr., 1977, A Cretaceous accretionary flysch and melange terrane along the Gulf of Alaska margin, in Blean, K. M., ed., United States Geological Survey in Alaska: Accomplishments during 1976: U.S. Geological Survey Circular 751-B, p. B41-B43.

Plafker, George, and Lanphere, M. A., 1974, Radiometrically dated plutons cutting the Orca Group, in Carter, Claire, ed., United States Geological Survey Alaska Program, 1974: U.S. Geological Survey Circular 700, p. 53.

Plafker, George, and MacNeil, F. S., 1966, Stratigraphic significance of Tertiary fossils from the Orca Group in the Prince William Sound region Alaska, in Geological Survey Research 1966: U.S. Geological Survey Professional Paper 550-B, p. B62-B68.

Rau, W. W., Plafker, George, and Winkler, G. R., 1977, Preliminary foraminiferal biostratigraphy and correlation of selected stratigraphic sections and wells in the Gulf of Alaska Tertiary Province: U.S. Geological Survey Open-File Report 77-747, 54 p.

Richter, D. H., 1965, Geology and mineral deposits of central Knight Island, Prince William Sound, Alaska: Alaska Division of Mines and Minerals Geological Report 16, 37 p.

Sanders, R. B., 1975, Bering Glacier coal field structure, in Yount, M. E., ed., United States Geological Survey Alaska Program, 1975: U.S. Geological Survey Circular 722, p. 49.

_____ 1976, Summary of the geology and coal resources of the Bering River Coal Field, in Cobb, E. H., ed., The United States Geological Survey in Alaska: Accomplishments during 1975: U.S. Geological Survey Circular 733, p. 54.

Schrader, F. C., 1900, A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898: U.S. Geological Survey 20th Anniversary Report, pt. 7, p. 341-423.

Taliaferro, N. L., 1932, Geology of the Yakataga, Katalla, and Nichawak districts, Alaska: Geological Society of America Bulletin, v. 43, p. 749-782.

Turner, D. L., Frizzell, V. A., Triplehorn, D. M., and Naeser, C. W., in press, Radiometric dating of ash partings in coal of the Eocene Puget Sound Group, Washington: Implications for paleobotanical stages: Geology.

Tysdal, R. G., and Case, J. E., 1979, Geologic map of the Seward and Blying Sound quadrangles, Alaska: U.S. Geological Survey Miscellaneous Investigation Series Map I-1150, scale 1:250,000.

_____ 1982, Metalliferous mineral resources potential of the Seward and Blying Sound quadrangles, southern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-880-H, scale 1:250,000.

Tysdal, R. G., Case, J. E., Winkler, G. R., and Clark, S. H. B., 1977, Sheeted dikes, gabbro, and pillow basalt in flysch of coastal southern Alaska: Geology, v. 5, no. 6, p. 377-383.

Tysdal, R. G., Hudson, Travis, and Plafker, George, 1976a, Surface features and recent movement along the Ragged Mountain Fault, south-central Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-782, 1 Sheet, scale 1:24,000

_____ 1976b, Geologic map of the Cordova B-2 quadrangle and northern part of the Cordova A-2 quadrangle, south-central Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-783, 1 sheet, scale 1:63,360.

Tysdal, R. G., and Plafker, George, 1978, Age and continuity of the Valdez Group, southern Alaska, in Sohl, N. F., and Wright W. B., compilers, Changes in stratigraphic nomenclature by the U.S. Geological Survey, 1977: U.S. Geological Bulletin 1457-A, p. A120-A124.

Winkler, G. R., 1973, Geologic map of the Cordova A-7, A-8, B-6, B-7, and B-8 quadrangles, Hinchinbrook Island, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-531, 1 sheet, scale 1:63,360.

___ 1976, Deep-sea fan deposition of the lower Tertiary Orca Group, eastern Prince William Sound, Alaska: U.S. Geological Survey Open-File Report 76-83, 20 p.

Winkler, G. R., and Plafker, George, 1975, The Landlock fault: part of a major early Tertiary plate boundary in southern Alaska, in Yount, M. E., ed., United States Geological Survey Alaska Program, 1975: U.S. Geological Survey Circular 722, p. 49.

___ 1981, Geologic map and cross sections of the Cordova and Middleton Island quadrangles, southern Alaska: U.S. Geological Survey Open-File Report 81-1164, 24 p.

Winkler, G. R., Silberman, M. L., Grantz, A., Miller, R. J., and MacKevett, E. M., Jr., 1981, Geologic map and summary geochronology of the Valdez quadrangle, southern Alaska: U.S. Geological Survey Open-File Report 80-892-A, scale 1:250,000.

Winkler, G. R., and Tysdal, R. G., 1977, Conglomerate in flysch of the Orca Group, Prince William Sound, southern Alaska, in Blean, K. M., ed., The United States Geological Survey in Alaska: Accomplishments during 1976: U.S. Geological Survey Circular 751-B, p. B43-B44.

Wolfe, J. A., 1977, Paleogene floras from the Gulf of Alaska Region: U.S. Geological Survey Professional Paper 997, 108 p.

Wyllie, P. J., ed., (1979), Utramafic and related Rocks: New York, John Wiley and Sons, Inc., 464 p.

Zuffa, Gian G., Nilsen, Tor H., Winkler, Gary R., 1980, Rock-fragment petrography of the Upper Cretaceous Chugach Terrane, southern Alaska: U.S. Geological Survey Open-File Report, 80-713, 28 p.

Table 1.--Potassium-argon age data for rocks from the Chugach National Forest

Map No.	Field No.	Unit	Mineral	Age (Ma)	Quad	Reference (analysts)
1	81 AMH 65A	Tfd	Whole rock	43.6±1.6	Anchorage	This study (Teledyne Isotopes)
2	81 AMH 69A	Tmb (granite)	Biotite	32.2±1.6	-do-	This study (L. Gray)
	81 AMS 82	Tmb (quartz diorite)	Hornblende	38.4±1.9	-do-	
3	PW-2	Tk	Biotite	35.5±0.9	Seward	Lanphere (1966) (H. Whitehead, L. Schlocker, M. Lanphere)
4	PW-1	Tgd	-do-	36.6±1.0	-do-	Do.
5	80 AMS 60A	Tg	Whole rock	34.2±1.7	-do-	This study (Teledyne Isotopes)
6	80 AMS 34	Tfd	Muscovite	54.5±1.6	Anchorage	Do.
	80 KMS 32I	Tfd	Whole rock	54.8±2.7	-do-	
7	PW-9	Tg	Biotite	36.1±0.9	Seward	Lanphere (1966) (H. Whitehead, L. Schlocker, M. Lanphere)
8	PW-8	Tg	-do-	36.2±1.0	-do-	Do.
			Hornblende	34.4±1.2		
9	81BS116C	Tfd	Whole rock	52.5±1.6	-do-	This study (P. Klock, L. Gray, M. Silberman)
10	81 KMS 25	Kvs [1]	-do-	51.5±1.5	-do-	This study (S. Neil, L. Gray, M. Silberman)
11	79 PW008	Tfd	Muscovite	51.6±1.6	Valdez	Winkler and others (1981) (P. Klock, B. Lai, C. Conner, M. Silberman)
12	71 APr 23A	Kvs [2]	Whole rock	47.6±1.4	Cordova	Winkler and Plafker (1981) (Geochron Lab, University of Alaska, Fairbanks)
13	71 APr 22C	Tgg	Hornblende	50.5±1.5	-do-	Winkler and Plafker (1981) (L. Schlocker, J. Von Essen, M. Lanphere, A. Atkinson)
			Biotite	53.2±1.6		
14	67 APr 1	Tgg	Phlogopite	51.6±2	-do-	Do.
15	71 APr 20C	Tgg	Biotite	50.9±1.5	-do-	Do.
16	71 APr 20B	Tgg	Hornblende	50.6±1.5	-do-	Do.
17	80 AMS 148A	Tgg	Biotite	52.7±1.6	-do-	This study (D. Vivit, L. Gray, M. Silberman)
			Hornblende	51.3±2.9		
18	71 APr 25C	Tgg	-do-	53.5±1.6	-do-	Winkler and Plafker (1981) (L. Schlocker, J. Von Essen, M. Lanphere, A. Atkinson)
19	72 APr 76A1	Tpv	Whole rock	31.2±1.3	Middleton Is.	Winkler and Plafker (1981) (Krueger Enterprises, Inc.)
20	80 AMR 159A	Td	-do-	6.2±0.3	-do-	This study (Teledyne Isotopes)

[1] Biotite semischist
[2] Amphibolite

Table 2.--Fossil localities in the Valdez and Orca Groups

Map Locality	Sample No.	Fossil Identification	Age	Unit	Quadrangle	Identified by	References/remarks
A	31-AP-63V	Pelecypod: Inoceramus kusiroensis	Late Cretaceous (Maestrichtian)	Kvs	Anchorage	---	Jones and Clark (1973)
B	7454	Pelecypod: Inoceramus kusiroensis	Late Cretaceous (Maestrichtian)	Kvs	-do-	---	Do.
C	7453	Pelecypod: Inoceramus kusiroensis	Late Cretaceous (Maestrichtian)	Kvs	-do-	---	Do.
D	8601	Pelecypod: Inoceramus ulrichi Inoceramus kusiroensis	Late Cretaceous (Maestrichtian)	Kvs	-do-	D. L. Jones	Plafker and MacNeil (1966)
E	8603	Pelecypod: Inoceramya concentrica	Late Cretaceous (Maestrichtian)	Kvs	Seward	T. W. Stanton	Tysdal and Case (1979) (float)
F	M6009	Pelecypod: Inoceramus kusiroensis	Late Cretaceous (Maestrichtian)	Kvs	-do-	D. L. Jones	Budnik (1974)
G	76ATZ 547A	Foraminifers: Globigerina or Subbotina	Probably Tertiary	Tosv	-do-	R. L. Poore	Tysdal and Case (1979)
H	64APr 150B	Pollen: Alnus (Alder)	Tertiary	Tos	Blying Sound	W. R. Evitt	Plafker and MacNeil (1966)
I	64APr 138A	Pollen: Alnus (Alder)	Tertiary or Cretaceous(?)	Tos	-do-	-do-	Do.
J	M2603	Crab: Branchioplax washingtoniana Pelecypod: Acila decisa	Paleocene(?) to late Eocene	Tos	Cordova	F. S. MacNeil	Addicott and Plafker (1971)
K	71W60	Foraminifers: Globogerina sp. G. senni Globorotalia sp.	Paleocene to early Eocene	Tos	-do-	H. V. Kaska	Winkler and Plafker (1981)
L	71W58 71W57 72W36	Foraminifers: Globogerina sp. G. senni Globogerina sp. (hispid) Globorotalia sp.	Late Paleocene to early Eocene	Tos	-do-	-do-	Do.
M	72P155	Foraminifers: Globigerina sp. (?) Globorotalia sp.	Paleocene	Tosv	-do-	-do-	Do.
N	71W149	Foraminifers: Globigerina sp. cf. G. senni Globorotalia	Paleocene to early Eocene	Tos	-do-	-do-	Do.
O	------	Foraminifers: Globigerina cf. G. senni Globorotalia sp. ?Eoconuloides parvulus Globigerina sp. (high-spired) Globigerina sp. (hispid)	Paleocene to late middle Eocene	Tosv	-do-	-do-	Do.
P	M2882	Echinoids: Holaster sp. ?Hypsopygaster sp. Nucleopygus	Late Cretaceous to Eocene	Tos	-do-	J. W. Durham L. G. Hertlein	Plafker (1968)
Q	D4612	Diatoms: Arachnoodiscus cf. A. ehrenbergii Trinacria cf. T. pileolus . Silico-flagellates: ?Corbisema geometrica ?Corbisema hastata ?Corbisema triacontha Dictyocha aspera Navoculopsis constricta	Late Paleocene to Eocene	Tots	-do-	J. A. Barron	Tysdal and others (1976b)