DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

TO ACCOMPANY MAP MF 1645-A

MINERAL RESOURCE POTENTIAL OF THE CHUGACH NATIONAL FOREST, ALASKA

SUMMARY REPORT

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U.S. Geological Survey

and

Uldis Jansons, Robert B. Hoekzema, Joseph M. Kurtak, and Steven A. Fechner
U.S. Bureau of Mines

Mine, prospect, or mineral-occurrence locality numbers on the map sheet and in the pamphlet refer to localities described in Jansons and others (1984).

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STUDY RELATED TO WILDERNESS

Under the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and related acts, the U.S. Geological Survey and the Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the Wilderness Preservation System and some of them are presently being studied. The act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. The act directs that the results of such surveys are to be made available to the public and be submitted to the President and the Congress. This report discusses the results of a mineral survey of the Chugach National Forest, Alaska, including the Nellie Juan-College Fiord Wilderness Study Area established by Public Law 96-487, December 2, 1980.

SUMMARY

Geologic, geophysical, and geochemical investigations along with surveys of known mines, prospects, and mineral occurrences have been conducted to evaluate the mineral resource potential of the Chugach National Forest, Alaska. The study area lies within the Kenai-Chugach Mountains physiographic province and is the second largest national forest in the United States.

The identified and potential resources include gold, copper, zinc, silver, lead, coal, oil, and possibly manganese, molybdenum, nickel, chromium, and antimony. Gold, copper, and oil have been the principal resources produced from the area.

Gold (along with alloyed silver) occurs in lode deposits of several associations and as gold placers derived from the lodes. Gold and silver were also produced as byproducts from the smelting of sulfide ores and concentrates. Early gold mining activity included production from both placer and lode deposits, primarily from the Kenai Peninsula, Port Wells, and Port Valdez areas. Current mining activity is restricted to small placer gold mines along active stream channels on the Kenai Peninsula. New areas of potential gold placer deposits have been identified in the west-central and northeastern parts of the national forest.

Iron, copper, and zinc massive sulfide deposits from the study area accounted for a significant portion of the copper produced from Alaska in the early 1900's. The largest producers mined ore deposits on Latouche Island and at Ellamar. These deposits are typified by small, high grade lenses and larger tonnages of lower grade materials. The study area has a high potential for copper resources.

Other metallic resources occur within the study area but carry a lower resource potential than those previously discussed. The Miners Lake area near Miners Bay has a low to moderate potential for lead and zinc resources in polymetallic vein type deposits. Molybdenum, nickel, chromium, antimony, and manganese occurrences are present, but the national forest is considered to have a low potential for these resources due to lack of favorable geologic conditions and small size and and low grade of the known occurrences.

The Bering River area has a high potential for coal resources. The coal occurs in seams that are locally thin, lack continuity, and are structurally complex. The coal rank ranges from subbituminous to anthracite.

Numerous oil and gas seeps onshore in the western part of the Gulf of Alaska Tertiary province led to the discovery and development of the Katalla oil field. Production and refining operations provided products for local use and lasted about 30 years. Continued exploration and drilling have taken place at various times up to the present. There is abundant surface evidence of petroleum, but the structures are locally complex, and suitable reservoir rocks seem to be absent. The potential for oil and gas onshore is low.

INTRODUCTION

Location and geographic setting

The Chugach National Forest, located in the Kenai-Chugach Mountains physiographic province of Alaska (Wahrhaftig, 1965), comprises parts of the Anchorage, Seward, Blying Sound, Valdez, Cordova, Middleton Island, Bering Glacier, and Icy Bay quadrangles (fig. 1). The western boundary of the national forest is 45 mi by road southeast of Anchorage, Alaska. The towns of Whittier and Cordova are located within the national forest.

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 along the coast of Alaska between Cook Inlet and Cape Spencer on the Alaskan panhandle to the southeast. Prince William Sound contains numerous islands,

[1]Presently with the Alaska Division of Geological and Geophysical Surveys.

the largest of which are 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 are found throughout the Chugach Mountains to the north and the Sargent Icefield to the southwest. Mount Marcus Baker, at 13,176 ft, is the highest point in the national forest.

The national forest boundaries are still (1984) in a state of flux. Under the provisions of the Alaska Native Claims Settlement Act of 1971, several native villages selected about 400,000 acres of forest land for withdrawal as private land. Land status as of December 1982 is indicated in figure 2.

Data base

Our reconnaissance-scale data include geologic mapping, aeromagnetic and gravity surveys, and stream-sediment, panned-concentrate, and rock geochemistry conducted by the U.S. Geological Survey (U.S.G.S.) and mine mapping and geochemical and mineralogical studies of mines, prospects, and mineral occurrences conducted by the Bureau of Mines (BOM) (Jansons and others, 1984). The regional mineral assessment reported here combines the results from investigations performed by both agencies.

Geologic setting

The geology of the national forest is dominated by two major lithologic units, the Valdez Group (Late Cretaceous) and the Orca Group (Paleocene and Eocene(?)) (Schrader, 1900). Both groups consist largely of graywacke, siltstone, and shale; the finer grained rocks commonly display a slaty fabric. The Orca Group has traditionally been considered to be somewhat less metamorphosed than the Valdez Group and to be further distinguished from it by the presence of mafic volcanic rocks and local beds of conglomerate. Subsequent mapping, however, has shown that both groups contain similar rock types (Moffit, 1954; Tysdal and Case, 1979; Winkler and Plafker, 1981) including local conglomerate and mafic igneous complexes that consist of sheeted dikes, thick pillow basalt flows, and minor gabbro and ultramafic rocks (Tysdal and others, 1977).

The contact between the Orca and Valdez Groups is designated as the Contact fault which includes the Bagley, Gravina, and Landlock fault segments in the Cordova quadrangle (Winkler and Plafker, 1981). In eastern Prince William Sound the location of the Contact fault is based on the change in structural trend in the two groups. Between the Copper River and Port Fidalgo the regional strike of the Orca Group is northeast. The Valdez Group in this area exhibits an east-west regional strike. In western Prince William Sound the regional strike of the two groups is parallel. This, coupled with the close lithologic similarities of the two groups, makes location of the contact problematic in western Prince William Sound.

Sedimentary rocks, in part younger than the Orca Group, crop out in the southeastern part of the project area. These represent sediment deposition in a continental margin basin in which marine regression and transgression took place during the middle Eocene and into the late Miocene (Plafker, 1971; Winkler and Plafker, 1981).

Plutonic rocks within the study area were emplaced during two main intrusive episodes and one minor intrusive episode. The earliest main plutonic event has been dated by potassium-argon methods as 50 to 53 m.y. (Plafker and Lanphere, 1974; Nelson and others, 1984). Plutons intruded during this event are generally medium-grained biotite granite and hornblende-biotite granite with lesser granodiorite and tonalite. These rocks are part of the Sanak-Baranof plutonic belt that is made up of plutons ranging from 43 to 60 m.y. in age (Hudson and others, 1979). Plutons ranging in age from 34 to 36 m.y. (and possibly to 38 m.y.) comprise the younger main plutonic suite (Lanphere, 1966). These plutons are found only in western Prince William Sound near the contact between the Valdez and Orca Groups. These younger plutons are generally medium grained, but show a wide range in composition because several plutons have early mafic phases. The mafic phases include pyroxene $\pm$ hornblende gabbro to diorite. The more felsic phases are generally biotite granodiorite. The Perry Island pluton however is unique; samples from near the center of the island are clinopyroxene- and hornblende-bearing granites. At the south end of Kayak Island, a dacitic plug forms the spectacular Cape St. Elias. This minor intrusion has been dated by potassium-argon techniques at 6 m.y. (Nelson and others, 1984) and represents the youngest igneous activity in the area.

MINERAL PROVINCES AND MINERAL DEPOSIT TYPES

Our studies question the common belief that the Valdez and Orca Groups represent two different metallic mineral provinces (Tysdal and Case, 1982). Although the Valdez Group is characterized by deposits that have been worked for gold and the Orca Group by deposits that have been worked for copper, this distinction is weakened by our observations that both types of deposits occur in each group, and that the deposit types instead are related to the presence of specific rock types or to the tectonic settings of both groups.

Most copper deposits in the study area appear to be related to mafic volcanism and the sulfide deposits generally are found in, or spatially related to, mafic volcanic rocks in both the Valdez and Orca Groups (Wiltse, 1973; Wiltse and McGlasson, 1973; Winkler and others, 1977; Winkler and others, 1981). Gold is most abundant in the Valdez Group and is found in this unit in three occurrence types: (1) in quartz veins (yielding an average potassium-argon age date of 53 m.y.) that cut flysch (Mitchell and others, 1981) in the Hope-Sunrise and Port Valdez districts, (2) in quartz veins in sedimentary host rocks peripheral to early Tertiary stocks at Girdwood, and in quartz veins in and peripheral to middle Tertiary plutons in the Port Wells district (Tysdal and Case, 1982), and (3) as local placer deposits derived from the above. Gold is less abundant in the Orca Group and is restricted to deposits in quartz veins cutting flysch, as at Bligh Island, Blue Fiord, Jackpot Bay, and near the early Tertiary McKinley Lake pluton, and cutting metasedimentary rocks and greenstone on Culross Island. Gold also has been detected in stream-sediment geochemical samples south of the Sargent Icefield. Favorable conditions for gold deposition appear to have been met locally near granitic plutons of both Eocene and Oligocene age, and more regionally, where the rocks have been subjected to lowest greenschist facies metamorphic conditions.

Base-metal sulfide deposits

Recent studies applying modern concepts of mineralization suggest that the base-metal sulfide deposits in the area owe their formation to submarine volcanogenic processes (Wiltse, 1973; Wiltse and McGlasson, 1973; Winkler and others, 1977; Winkler and others, 1981). These deposits can be classified into volcanic-hosted and sediment-hosted deposits.

Volcanic-hosted iron, copper, and zinc sulfide deposits

Areas of copper deposits and regions that have potential for copper resources (fig. 3 and map sheet) have a close spatial relation of mineralization to the distribution of mafic volcanic rocks. Volcanic-hosted sulfide deposits commonly occur in shear zones (some as massive sulfide lenses) primarily in the mafic complexes on Knight Island, Glacier Island, the Ellamar district, in the northern Cordova quadrangle, and to a lesser extent, on the Resurrection Peninsula. Johnson (1918) felt that some of the shear zones probably developed early in the magmatic history of the volcanic rocks. We have observed undeformed mafic dikes in the Port Audrey shear zone on Knight Island. The Port Audrey shear zone is confined to the sheeted dike unit and the presence of mafic dikes cutting the sheared rocks suggests that mafic igneous activity continued after shearing in this area.

Sulfides also are found in a number of other occurrences: as disseminated grains in both massive and pillow basalt (Knight Island), in small lenses and stringers in greenschist (near Wortmanns Glacier, immediately north of the national forest boundary), in quartz veins radiating from the distal(?) end of a basalt flow (Hinchinbrook Island), as matrix in volcanic breccia and as sulfide breccia (Knight Island), and as stockwork veins cutting volcanic rocks (Knight Island) (Richter, 1965; Hartley, 1977; Tysdal, 1978; R. A. Koski, written commun., 1982).

The deposits of Knight Island have undergone extensive study. The geologic units exposed on Knight Island (the minor ultramafic and gabbroic rocks, extensive sheeted dike unit, and thick pillow lavas) are considered to be of the upper, constructional part of an ocean crust or ophiolite-like sequence and emphasize the volcanogenic association of the sulfide deposits. These deposits on Knight Island occur in pillow lavas, pillow breccia, tuff/hyaloclastite, and shear zones in sheeted dikes. Many of the sulfide deposits show postdepositional shearing and recrystallization (McGlasson, 1976; Winkler and others, 1977; R. A. Koski, written commun., 1982).

Observations from the Rua Cove deposit that support the volcanogenic hypothesis are: (1) the gross aspect or configuration of the deposit, that is, stratiform (if not stratabound) massive sulfide overlying a stockwork (or feeder) system; (2) bedding features in the massive sulfide body; (3) the occurrence of massive sulfide in volcanic rocks that are part of an ophiolite sequence; (4) the occurrence of massive sulfide fragments in the volcanic breccia; (5) the altered and mineralized nature of volcanic breccia and tuff; and (6) the relatively unaltered appearance and paucity of sulfides in fine-grained, crosscutting intrusive bodies (R. A. Koski, written commun., 1982).

Other deposits on Knight Island possibly have overall somewhat higher copper grades, but much lower tonnages, as compared to the Rua Cove deposit. These deposits occur along continuous shear zones (the majority in the sheeted dike unit) and may represent widely spaced volcanic vents of limited scope. The presence of metasandstone and tuffaceous sedimentary rocks in the shear zones in the sheeted dike unit suggests that the deposits are near the upper part of the sheeted dike unit, possibly concentrated along the original fractures in which the mafic dikes were emplaced.

Sediment-hosted iron, copper, and zinc sulfide deposits

Iron and copper sulfide deposits occurring as massive lenses in sedimentary rocks formed the largest producing mines in the area. The mines, located on Latouche Island, at Ellamar, and at Solomon Gulch near Valdez, contained ore localized in sedimentary rocks near volcanic rocks. These deposits tend to contain proportionately more chalcopyrite, pyrite, sphalerite, and galena than do the volcanic-hosted deposits. Byproduct gold and silver was recovered from these deposits.

The mines at Latouche and at Ellamar are now largely inaccessible due to flooding or cave-ins, but it is clear from the literature that the main ore bodies are hosted in sedimentary rocks. Volcanic rocks are not reported from the mine at Ellamar (Capps and Johnson, 1915; Moffit and Fellows, 1950). At the Beatson mine on Latouche Island, Bateman (1924) reported an underground lamprophyre dike but no surface exposures of volcanic rocks.

The sulfide deposit at the Ellamar mine occurs in what Capps and Johnson (1915) called the lower "slates and graywackes". Our stratigraphic studies in the area support their interpretation: the massive sulfides occur in sedimentary rocks that are stratigraphically below the thick volcanic pile north and east of Ellamar.

We tested the stratigraphic relation of mineralization in the Knight Island area by concentrating our field observations along the contact between the volcanic and sedimentary rocks at the south end of the island. The sedimentary rocks in this area are north of, but along the strike of, the rocks on Latouche Island and may represent the same stratigraphic horizon (Zelinski and others, 1977). Geologic mapping by Tysdal and Case (1979) and an analysis of minor folds in Bay of Isles on Knight Island led Tysdal and Case (1982) to conclude that Knight Island forms the core of a south-plunging anticline and that the rocks on the islands to the south are stratigraphically younger and higher in the sequence. Latouche Island would then be on the eastern limb of the anticline, which leads to their interpretation that sedimentary rocks flanking the volcanic rocks would be favorable areas to prospect for sediment-hosted sulfide deposits. However, our field observations of the geometry of the contact at the south end of Knight Island suggest that the sedimentary rocks lie structurally below the volcanic rocks. Projecting this relation south to Latouche Island, it can be argued that sedimentary rocks lying structurally or stratigraphically below thick sequences of mafic volcanic rocks are favorable for hosting sulfide mineralization.

Our interpretation is further supported by the lack of any significant sulfide mineralization observed stratigraphically above volcanic rocks, although it needs to be tested in other areas such as the Midas mine, at Solomon Gulch, south of Port Valdez. Stratigraphic relations determined for the Resurrection Peninsula, Knight Island, Ellamar, and Ragged Mountain all show that the sedimentary rocks overlying the volcanic rocks there lack any significant sulfide mineralization.

Gold deposits

Gold deposits occur in many parts of the national forest as veins emplaced along shear zones, faults, and fractures, largely, but not entirely restricted to low-grade metamorphosed sedimentary rocks of the Valdez Group (Mitchell, 1979). Placer deposits derived from veins occur in the Girdwood, Hope-Sunrise, and Moose Pass areas.

Mitchell (1979) defined two main types of vein occurrences: those related to intrusive rocks and those distant from plutonic rocks. The first type includes veins in sedimentary host rocks near intrusive stocks of Eocene and Oligocene age, such as in the Port Wells area (34 m.y.) and at McKinley Lake (51 m.y.) (Winkler and Plafker, 1981), and veins in the vicinity of smaller intrusions of Eocene age (54 m.y.) (Nelson and others, 1984), such as in the Girdwood area (Park, 1933). At these occurrences, some of the mineralized veins cut the granitic rocks as well as the intruded sedimentary rocks.

The second type of vein occurs in regionally metamorphosed sedimentary rocks distant from plutonic rocks, such as in the Port Valdez, Hope-Sunrise, and Moose Pass districts (Johnson, 1915; Tuck, 1933). Felsic dikes, some of which contain gold- and sulfide-bearing quartz veins, occur at Hope-Sunrise and Moose Pass, but no plutonic rocks have been recognized. In the Port Valdez, Hope-Sunrise, and Moose Pass districts, the veins are localized in fissures, shears, and faults that crosscut regional axial-plane cleavage, which itself contains a barren, early generation of quartz veins. The mineralized structures probably originated as steep, conjugate joints that opened during regional uplift.

The mineralogy of the vein-gold deposits is relatively simple. The veins contain quartz $\pm$ carbonate minerals, broken rock fragments, and small amounts of sulfides, including pyrite, galena, chalcopyrite, arsenopyrite, sphalerite, pyrrhotite, molybdenite, and stibnite. Only gold, the principal precious metal, and subordinate alloyed silver are of economic interest (Moffit, 1954). The gold deposits are small; samples from them commonly contain 3 to 5 oz per ton, but may exceed 15 oz per ton (Mitchell, 1979).

Consistency of structural orientation of the mineralized vein sets and characteristic stable isotope signatures of quartz in the mineralized veins appear to be useful guides in prospecting for similar types of deposits in areas that have not previously been examined in detail. Stable isotope and fluid inclusion studies of the deposits document the formation of the gold-bearing quartz veins from meteoric waters that were heated during circulation through a hot, but gradually cooling, wedge of metamorphosed, accreted sedimentary rocks. Mitchell (1979) strongly emphasizes the importance of a large (greater than 50 percent) lithic volcanic component in the sandstones that are interbedded with argillite, siltstone, and slate that host mineralized veins. Evidently, the metals and sulfur were dissolved from the mafic volcanic component of the sedimentary rocks and deposited in the open structures that developed as the rocks were uplifted (Mitchell and others, 1981; Pickthorn, 1982).

GEOCHEMICAL STUDIES

A regional geochemical survey was conducted to help identify areas of mineral resource potential. Suites of anomalous elements were used to define geochemically favorable areas for the occurrence of various mineral resources within the Chugach National Forest. Analytical data are compiled in Goldfarb and others (1984).

Areas of lode or placer gold deposits were characterized by anomalously high silver, gold, ± arsenic values in the heavy-mineral concentrate samples (R. J. Goldfarb, unpub. data, 1983). Sulfide minerals, consisting of various combinations of chalcopyrite, arsenopyrite, pyrite, pyrrhotite, galena, and sphalerite, are reported from many of the gold workings. However, there is a poor correlation between gold occurrences and base-metal values in the geochemical data. This may be due to the fact that these sulfides also are widely disseminated throughout the flysch of the Valdez Group (Goldfarb and Tripp, 1983). Anomalous base-metal values in concentrate samples were therefore only of limited use in helping to identify areas of favorable gold potential. Silver concentrations above the 0.5 ppm lower limit of analytical determination in stream-sediment and moraine samples are associated with favorable gold terranes.

The geochemical data indicate that areas favorable for gold are widespread within regions underlain by the Valdez Group. Much of the Kenai Peninsula (areas 2, 3, fig. 3 and map sheet), a zone northeast from Portage to Miners Bay (parts of areas 5, 9, 16A), and the area north of the crest of the Chugach Mountains in the Cordova quadrangle (area 19B) constitute most of the gold province (Tysdal and Case, 1982). Boron, a common pathfinder for gold-quartz veins, is present in anomalously high concentrations in sediments throughout the area south of Kenai Lake (area 3E). Areas 2, 5A, 9, and 16 all lack chalcopyrite in gold-bearing concentrates, while areas 3, 5B, 5C, and 19B all show a strong gold-chalcopyrite association. The Girdwood-Crow Pass region (area 1B), although having had a significant placer gold production, lacks widespread anomolous gold and silver values, possibly reflecting a more limited areal extent of gold occurrences relative to other areas underlain by the Valdez Group.

Antimony in heavy-mineral concentrate samples is associated with the favorable gold terrane throughout the northern Kenai Peninsula (area 2) and between Coghill Lake and Unakwik Inlet (within area 9). Relatively high gold, silver, and arsenic concentrations in the southern part of area 5C are associated with anomalous antimony values in samples from Bear Valley south to Trail Glacier. Stibnite was observed in some of the anomalous concentrate samples. Antimony is also enriched in concentrate samples from an area east of Miners Lake (area 16B) near Miners Bay. Here, however, it is associated with galena, sphalerite, and high silver contents in corresponding sediment samples. Gold, detected in area 16A, is absent from area 16B. Thus, the occurrence of antimony in area 16B is more likely to indicate a base-metal zone than serve as a pathfinder for gold.

Areas geochemically favorable for gold within regions underlain by the Orca Group are much less extensive. Gold, with associated silver, is characteristic of the McKinley Lake region (area 22). Samples with anomalous gold, silver, and arsenic values are scattered about the northern (area 11, and Falling Glacier in 6A), eastern (centered around Jackpot Bay in 13), and southern (area 7) borders of the Sargent Icefield. While the first two regions are spatially associated with intrusive bodies, area 7, which contains extensive glaciers, is apparently underlain by Orca Group flysch. The highest gold favorability within this area is shown by samples from Excelsior Glacier and from the coast between Auk Bay and Cape Puget.

Stream-sediment and moraine samples provided the most useful geochemical data for detecting the base-metal deposits. Sediments in drainages containing probable flysch-hosted deposits are characteristically enriched in various combinations of Cu, Co, Pb, Mn, and Zn. Sediments derived from volcanic source areas are enriched in Fe, Mg, Ti, Co, Cr, Cu, Ni, Sc, and V. This mafic volcanic association of elements cannot actually identify the presence of base-metal sulfide mineralization, but it aids in the recognition of the volcanic terrane. The heavy-mineral concentrate samples were poor indicators for base-metal sulfides. Goldfarb and Tripp (1983) show the widespread distribution of chalcopyrite and pyrite throughout the national forest. Panning of sediments will concentrate anomalous amounts of these minerals, but not necessarily proportional to the amounts originally present in the source rock. Thus, chemical data for concentrates from flysch with minor chalcopyrite and pyrite may show iron and copper concentration levels similar to those from the areas of massive sulfide mineralization, as well as from apparently barren areas.

Latouche Island (area 14) shows the highest geochemical favorability for flysch-hosted massive sulfides. Ellamar (especially areas 18C, 18E), southeast Knight Island (area 12C), and a belt to the east of Orca Inlet (area 21) are characterized by signatures (anomalous element suites) somewhat similar to Latouche Island. Weaker flysch-hosted base-metal sulfide associations appear around Thumb Cove on Resurrection Peninsula (area 4) and from southern Chenega Island south to about Whale Bay (area 13).

A strong flysch-hosted sulfide association seems not only to exist from Latouche Island to southeast Knight Island, but also continues northeast across Green Island and includes northern Montague Island. The geochemical anomalies on the latter two islands are predominantly the result of sediments enriched in manganese and zinc. The southern part of Montague Island also is characterized by scattered zinc anomalies in sediments, some with sphalerite observed in corresponding heavy-mineral concentrates. Furthermore, excluding the northern part of Montague Island, which is characterized by anomalous values of manganese and zinc, greater than 50 percent of the concentrate samples from the island contain chalcopyrite. This is the only locality in this part of Prince William Sound where abundant chalcopyrite was found in flysch lacking any extensive volcanic units. Thus, reconnaissance geochemical data suggest that Montague Island has a geochemical signature similar to the sediment-hosted sulfide deposits, but the significance of this similarity is uncertain.

Anomalous concentrations of a suite of elements (Fe, Mg, Ti, Co, Cr, Cu, Ni, Sc, and V) in sediments delineate almost the entire surface of Knight Island (area 12), Glacier Island (area 17), and Ragged Mountain. Chalcopyrite, though, was observed only from areas 12A, 12B, and 12C. These three regions contain many of the base-metal massive sulfide deposits on Knight Island.

A mafic volcanic geochemical signature occurs for a part of the Resurrection Peninsula (area 4) and to the east of Ptarmigan Lake (area 6). In addition, heavy-mineral concentrates from these two localities lack chalcopyrite.

Within the eastern part of Prince William Sound, the interbedded volcanic and sedimentary rocks on Hinchinbrook Island (southern part of area 21) appear geochemically indicative of base-metal sulfide mineralization, although no significant mineral occurrences are known. Additionally, favorable geochemical signatures in sediments with chalcopyrite in corresponding concentrates characterize the glacier-covered greenstone belt in area 19A. Within this area, localities such as Solomon Gulch, Brown Basin, and Wortmanns Glacier, immediately north of the national forest boundary, and Heney and Allen Glaciers within the national forest, show a geochemical favorability for volcanic-hosted base-metal sulfide mineralization.

Shale beds within the Yakataga and Poul Creek Formations on Kayak Island (area 25) and the adjacent Don Miller Hills (area 24) are possible hosts for zinc-rich sulfide deposits. Heavy-mineral concentrate samples from the two areas contain abundant sphalerite and barite. Some concentrates were found to contain greater than 50,000 ppm barium and as much as 50,000 ppm zinc. Cadmium and molybdenum values were also enriched in the concentrate samples. More significantly, stream-sediment samples contain up to 9000 ppm barium. Bedded barite is commonly found in the stratigraphic column near zinc-rich massive sulfides (Theobald, 1982). Plafker (1974) noted intercalated basaltic fragmental rocks and minor pillow basalts in the Poul Creek Formation, suggesting evidence of a possible volcanogenic source for the zinc. The resource potential of this geochemical anomaly remains to be determined.

A number of areas that do not show a strong geochemical signature for gold, do show geochemical signatures indicative of base-metal vein deposits. For instance heavy-mineral concentrates from the Girdwood-Crow Pass area (1B), as well as areas southeast to Twentymile Glacier and Carmen Lake, lack abundant gold and (or) silver anomalies. However, they are enriched in zinc, barium, and cobalt, and they were observed to contain abundant chalcopyrite, sphalerite, galena, and barite. The additional presence of minor arsenopyrite and anomalously high boron values in corresponding stream-sediment and moraine-sediment samples is not typical of gold mineralization in the area. Geochemical signatures from upper College Fiord (area 8), mainly from numerous moraine samples on Harvard and Yale Glaciers, are identical to those from the Girdwood-Crow Pass region. The presence of numerous samples that contain sphalerite in concentrates from both area 1B and the upper part of area 8 seems to be an important distinguishing characteristic of the two localities. The only region that has abundant sphalerite in the Orca Group is the area east of Miners Lake (16B).

In the eastern part of the national forest, a zone of galena-bearing samples trends east-west between Cordova Glacier and Allen Glacier. This trend is superimposed on a larger distribution of samples containing chalcopyrite with minor gold and arsenopyrite in area 19A. To the south, a strong distribution of barite-bearing samples trends down the entire length of area 21 and Montague Island.

Three regions were found to contain minor geochemical indications of uranium mineralization. Heavy-mineral concentrates from watersheds underlain by the Sheep Bay pluton were enriched in thorium and contained monazite and thorite. Uranium concentrations up to 35 ppm, as well as uranium-thorium ratios greater than 1.0, were obtained for stream sediments collected as part of the U.S. Department of Energy's NURE program (U.S. Department of Energy, 1981). A region between Kadin and Terentiev Lakes (area 16) yielded anomalously high thorium values for heavy-mineral concentrate samples. These were related to the presence of uranothorite within an intrusive body. The NURE data for the Seward 1:250,000-scale quadrangle (U.S. Department of Energy, 1982) showed uranium values in stream sediments as great as 75 ppm along the east side of Resurrection Creek (area 2E). The source of the uranium for these anomalies is unknown.

Minor geochemical evidence exists for strategic metals. Nickel and chromium silicates were noted within concentrate samples from three localities. One of these areas, the Miners Bay region, is known to be partly underlain by a mafic intrusive body. Nickel and chromium silicates were also observed from two samples approximately 3 mi east of Grant Lake and just west of the West Finger Inlet within Kings Bay (area 6). The latter might be especially significant as it is located near a geochemical anomaly for nickel below the toe of Cotterell Glacier.

GEOPHYSICS

Gravity interpretation

Gravity data consist of about 750 measurements, which are sufficient for a regional appraisal but inadequate for detailed analysis or detection of local mineral deposits. Although the earliest measurements were made more than 25 years ago, most of the available data were obtained during shoreline and shipboard traverses following the 1964 earthquake (Case and others, 1966). More recent data collection has concentrated on inland regions, but few measurements are yet available for the Sargent Icefield and parts of the Chugach Mountains.

Changes in the gravity field reflect density variations within the earth's crust and provide criteria for delineating rock distribution and structures at greater depth than the other exploration techniques used in this mineral assessment. The most obvious feature of the Bouguer gravity map (Barnes and Morin, 1984) is a regional decrease from south to north and west of about 130 mGal, which probably represents an approximate 12-mi increase in crustal thickness between the continental shelf and Chugach Mountains. However, any relation of this crustal thickening to the mineral deposits is still unknown.

A second regional gravity feature is the arcuate Prince William Sound gravity high that trends northward from Elrington Island, through Knight Island, and then eastward through Glacier Island, Ellamar, and probably much further. Within Prince William Sound the high roughly coincides with outcrops of mafic volcanic rocks of the Orca Group, which must reach depths as great as 6 mi to explain the 50 mGal magnitude of the anomaly. Many of the copper mines, prospects, and occurrences lie within a region defined by the gravity high and, thus, may be related to the rock types causing the high. Scattered data in the mountains east of Ellamar suggest that the gravity high extends eastward across the Contact fault and through the mountains south of the Tasnuna River. Here the same rocks are probably more deeply buried, but the gravity data provide evidence of deep mafic igneous rocks that could help to explain the geochemical anomalies for copper encountered on the same trend.

Another conspicuous gravity feature that has some similarities to the Prince William Sound high is a shorter high associated with mafic volcanic rocks of the Valdez Group on the Resurrection Peninsula. This high has an amplitude of about 30 mGal and probably represents about a 3-mi thickness of mafic rocks. The gravity high does not seem to extend as far north as the aeromagnetic high (Barnes and Case, 1984), which may suggest that the mafic rocks thin significantly to the north, although the limited gravity data permit various interpretations. A thinner section of mafic rocks or their lack of outcrops might help to explain the lack of geochemical anomalies encountered on the northern end of the aeromagnetic feature.

Aeromagnetic interpretation

Much of the aeromagnetic data were collected by two contractors and were later interpreted (Case and others, 1979, 1984). The data permit magnetic rocks, some of which are associated with mineral deposits, to be traced beneath surficial deposits, water, and glaciers. In other areas, the magnetic data provide a means of estimating the extent and thickness of overlying sedimentary and other nonmagnetic rocks.

Two of the most extensive magnetic features of the area (Barnes and Case, 1984) are a pair of regional gradients defined by contours that almost parallel the northern and western boundaries of the map and indicate a decreasing field of strength to the north and west. The gradients probably represent very deep magnetic variations within the crust beneath the Chugach Mountains—perhaps a bent slab of magnetic rock that dips downward. Almost all of the other important aeromagnetic features seem to be associated with the distribution of mafic volcanic rocks and related intrusive rocks, some of which have associated base-metal sulfide deposits.

The most prominent aeromagnetic feature is an arcuate belt of high-amplitude magnetic values that stretches northward from Elrington Island, through Latouche and Knight Islands before trending eastward through Glacier Island, Ellamar, and the mountains south of the Tasnuna River. The magnetic highs are caused by the mafic volcanic rocks of the Orca and Valdez Groups. The aeromagnetic data suggest that these volcanic rocks form a belt that is significantly wider and more extensive at depth than their outcrop distribution. The associated resource areas (12, 13, 14, 17, and 18) have been restricted by water cover and by geochemical and geologic data. Changes in the width of the magnetic belt and in the amplitude and character of the magnetic highs suggest definite structure changes and possible discontinuities along its length. The high-amplitude magnetic values associated with the sheeted dikes and pillow basalts of Knight Island do not extend north of Eleanor Island, but instead a broad and deep anomaly seems to occupy the adjacent offshore area near Naked Island. Other high-amplitude values are found closer to the north shore of Prince William Sound and lie mostly offshore, to the west of Glacier Island, where the highs are associated with the sheeted dikes on the south tip of the island (area 17). However, this high-amplitude trend does not cross the deep-water entrance of Valdez Arm. Here bathymetry cannot explain the absence because high-amplitude negative values resume to the east over the deep-water entrance to Port Fidalgo. North of the entrance the highs do not correlate well with the outcrops of the mafic volcanic rocks on Bligh Island and near Ellamar (area 18). The continuity is again broken near the Contact fault east of this trend, but more high-amplitude values were measured south of the Tasnuna River (area 19).

Another set of high-amplitude magnetic values was mapped over the Resurrection Peninsula (area 4), where rocks similar to those of Knight Island crop out.

A third large area of high-amplitude magnetic values follows a discontinuously outcropping belt of Orca Group volcanic rocks from Eyak Ridge northeast of Cordova southwestward through Hawkins Island and the southern part of Hinchinbrook Island, a long belt containing scattered small occurrences of base-metal mineralization at its northern end (area 21). Much lower magnetic values occur over small outcrops of mafic volcanic rocks on Culross Island (area 9), where gold and silver mineralization is present. Several other magnetic highs occur over other outcrops of the Orca Group volcanic rocks, such as near Gravina Point, but most of these regions lack positive geologic or geochemical evidence of mineralization. The magnetic data also indicate another group of magnetic highs that suggest that mafic volcanic rocks lie offshore from parts of Wingham and Kayak Islands. Here geochemical data suggest the possibility of barium and zinc mineralization in the younger Tertiary sedimentary rocks.

Most granitic plutons have weaker magnetic expressions than most of the mafic volcanic rocks, and laboratory measurements show that most of the plutonic rock susceptibilities are low. The granitic pluton with the strongest magnetic expression crops out on Perry Island (area 15), and it has several rather unique petrologic features, including primary clinopyroxene and minor amounts of scheelite in associated quartz veins.

STABLE ISOTOPE GEOCHEMISTRY

A preliminary study of stable isotope ratios from gold-bearing quartz veins from the Port Valdez (area 9B) and Hope-Sunrise (area 2A) districts, and from sulfide minerals from several base-metal deposits (areas 2E, 12A, 14A, and 17) was performed to aid in determining possible sources of the metal-bearing fluids and depositional environments for the deposits. Oxygen and hydrogen isotope ratios are useful in interpreting the origin of water, the dominant component of mineralizing fluids. Sulfur isotope ratios are useful in interpreting the source of sulfur and processes involving the formation of sulfide deposits.

Gold-quartz veins in the Valdez Group

Within the sedimentary rocks of the Valdez Group, the gold-bearing quartz veins occur principally along fractures and shear zones that crosscut the regional structure and fabric. Regional structure is east-west in the Valdez area and north-south in the Hope-Sunrise area. In contrast, barren quartz veins normally parallel the local structure and fabric, but do commonly resemble the mineralized veins. Preliminary oxygen and hydrogen isotopic analyses of these two types of quartz veins in the Port Valdez district (area 9B), and to a limited extent in the Hope-Sunrise district (area 2A), were performed to interpret their origins (Pickthorn, 1982; Mitchell and others, 1981).

Results and discussion

Waters in equilibrium with the barren quartz veins have isotopic ratios that are within the area of overlap between the isotopic compositions of metamorphic and magmatic waters. Structural and petrographic evidence indicate that these veins formed from a metamorphic fluid during, and in response to, regional metamorphism (Pickthorn, 1982). Data from the mineralized vein samples indicate that the mineralizing fluid was comprised of a significant component of meteoric water. Since geologic evidence indicates that the mineralized veins all formed after metamorphism, Pickthorn (1982) and Mitchell and others (1981) have proposed models in which post-metamorphic uplift and dilation of the Valdez Group allowed meteoric water to circulate through deep fractures and faults. Hydrothermal convection cells were probably formed, heated, and driven by the still high-temperature metamorphic rocks at depth. Conceivably, the gold and other vein constituents were leached from the metamorphosed sedimentary rocks and deposited as fissure veins near the surface.

Of particular importance from an exploration standpoint is the difference in measured δ values for the barren and mineralized quartz veins. The mineralized quartz veins have slightly lower $\delta^{18}O$ and significantly lower δD values compared to those of the barren veins.

Sulfide deposits

The analyzed Orca Group volcanic- and sediment-hosted base-metal sulfide deposits are localized within the volcanic rocks of Knight Island and sedimentary rocks of Latouche Island (areas 12 and 14). Many of these deposits are found in shear zones. Recent interpretations suggest that some of these deposits were formed in and on the ocean floor during a period of active volcanism in the early Tertiary (Tysdal and Case, 1979; R. A. Koski, written commun., 1982). A reconnaissance sulfur isotope study of several of these sulfide deposits was made in order to discern their origin and depositional history. In addition, samples from the Ready Bullion deposit (area 2E) and pyrite from Valdez Group host rocks were also analyzed. Only one sample was analyzed from each of the studied deposits. No detailed geochemical or isotopic work was done on any of these occurrences.

In the submarine environment the only two reasonable sources of sulfur for sulfide minerals are magmatic sulfur and ocean-water sulfate. Magmatic sulfur includes sulfur released from magmas and sulfur leached from igneous rocks; sulfide minerals deposited from magmatic sulfur generally have $\delta^{34}S$ values near or slightly above 0 $^{o}/_{oo}$ relative to Standard Mean Ocean Water (SMOW). Ocean water is a huge reservoir of sulfur present as dissolved sulfate (SO_4^{2-}) with a fairly constant $\delta^{34}S$ of +20 $^{o}/_{oo}$. This sulfate must first be reduced to hydrogen sulfide (H_2S) before the sulfur can combine with metallic ions to form the sulfide minerals. One method of reduction of ocean-water sulfate is by interaction of the water with hot rocks (>250°C). As ocean water comes in contact with hot volcanic rocks on the ocean floor, reaction with iron II (Fe^{2+}) will produce H_2S (Ohmoto and Rye, 1979):

$$SO_4^{2-} + 8Fe^{2+} + 10H^{+} \rightleftharpoons H_2S + 8Fe^{3+} + 4H_2O$$

Sulfides formed by this process generally have $\delta^{34}S$ values ranging from +5 $^{o}/_{oo}$ to +20 $^{o}/_{oo}$ (Ohmoto and others, 1978). Under low-temperature conditions (<50°C), the only mechanism for the reduction of sulfate is by sulfate-reducing bacteria. The range of $\delta^{34}S$ values for sulfides produced by this method are variable and reflect the environment in which reduction took place. In open systems where the supply of sulfate is unlimited, biogenic or sedimentary sulfides will generally have $\delta^{34}S$ values ranging from -20 $^{o}/_{oo}$ to -40 $^{o}/_{oo}$ (Schwarcz and Burnie, 1973). In a closed or reducing environment, such as a closed or shallow basin, the supply of sulfate is limited, and $\delta^{34}S$ values for sedimentary sulfides can range from near 0 $^{o}/_{oo}$ to over +20 $^{o}/_{oo}$, which is above the original value of the ocean-water sulfate (Schwarcz and Burnie, 1973). But no matter what the reduction method or source of the sulfur, there must also be a source and mechanism for supplying and concentrating the metallic ions (Cu, Fe, Pb, Zn) in sufficient quantities to form an ore deposit.

Results and discussion

The samples occurring in mafic volcanic rocks, areas 12A, 12C, and 17, have $\delta^{34}S$ values of +1 $^{o}/_{oo}$ to +6 $^{o}/_{oo}$, which is within the range expected for magmatic sulfur. In addition, oxygen isotope ratios in quartz veins closely associated with sulfide mineralization within the mafic rocks of area 12C suggest that the quartz formed from a magmatic hydrothermal fluid. The sulfide samples from deposits hosted in sedimentary rocks (area 14A) have $\delta^{34}S$ values of +8 $^{o}/_{oo}$ and +11 $^{o}/_{oo}$, which fall within the range of sulfides formed by either thermal or biogenic reduction of ocean-water sulfate in a closed basin. High $\delta^{34}S$ values (+14 $^{o}/_{oo}$, +23 $^{o}/_{oo}$) for sedimentary-hosted pyrite analyzed from Jeanie Point on Montague Island and the occurrence of pyrrhotite in the base-metal deposits suggest that deposition probably took place in a closed reducing environment. This does not, however, preclude the possibility that these deposits formed by thermal reduction of ocean-water sulfate. These sedimentary-hosted deposits may represent sites of submarine thermal springs, which would not only provide a source of reduced sulfate but also of metallic ions leached from the ocean-floor sediments and underlying rocks.

The Ready Bullion copper occurrence near Lynx Creek (area 2E) is the only known copper sulfide deposit within the Valdez Group that lacks a close spatial relation to volcanic rocks. A $\delta^{34}S$ value of +1.7 $^{o}/_{oo}$ was measured and would normally indicate a magmatic sulfur source. An alternate source of sulfur here is offered by a $\delta^{34}S$ value of -0.9 $^{o}/_{oo}$ from pyrite in shale of area 2. This value suggests that hot spring activity may have leached sulfur from the surrounding sedimentary rocks.

ORGANIC GEOCHEMISTRY

The data presented here summarize the results of a limited study carried out to further refine the hydrocarbon source-rock potential of the Katalla-Kayak Island area. Twenty-three shale and mudstone samples from all the Tertiary formations were analyzed by six separate techniques designed to evaluate the amount and type of organic material contained within the sedimentary rocks and to document the thermal history of the sedimentary rocks. Collectively, these techniques combine to indicate the hydrocarbon source-rock potential.

Amount and type of organic material

Organic carbon content

The observed organic carbon content, in weight percent, ranges from a low of 0.2 percent to a high of 4.83 percent, with about 75 percent of the samples containing less than 1 percent total organic content. A commonly accepted lower limit of organic carbon for a hydrocarbon source rock is 0.4 percent (Dow, 1977a, p. D2). On the basis of this criterion, much of the Tertiary section contains potential hydrocarbon source rocks. An organic shale horizon in the upper part of the Poul Creek Formation contains 4.82 percent organic matter. Based only upon its organic richness and thickness the horizon would be considered an excellent hydrocarbon source.

Visual kerogen

Four kerogen constituents can be visually identified by microscope: (1) amorphous, (2) herbaceous, (3) woody, and (4) inert. Amorphous material is algal material or sapropel of marine or lacustrine derivation and is oil prone. Herbaceous material includes pollen, spore and plant cuticle, or waxy material; it is generally considered oil prone, but may also contribute methane gas. Humic material constitutes the structural material of land plants and makes up a large percentage of humic coal. This constituent is gas prone. Inert coal is solid black, dead carbon, which contributes neither oil nor gas to the hydrocarbon system.

The visual kerogen estimates of the samples from the Tertiary sequence of the Katalla-Kayak Island area show that in about 75 percent of the samples 50 percent or more of the total organic content consists of amorphous and herbaceous material. The abundance of amorphous and herbaceous organic material suggests that the rocks are oil-prone source beds, but this appears to contradict other data (discussed later) that suggest that only one third of the samples are even gas-prone source rocks. Only nine of the samples contain amorphous organic material, which is considered to be the most oil-prone source material, and there are none in which the total organic content consists of as much as 50 percent amorphous material. The relative lack of amorphous kerogen may account for the low oil-prone character indicated by other analyses.

TEA-FID

Thermal-evolution analysis employing a flame ionization detector (TEA-FID) was used to evaluate the richness, type, and thermal maturity of organic matter in the sedimentary rocks. In the Katalla area, with the exception of a sample from the organic shale horizon of the Poul Creek Formation, all of the samples from the Tertiary sedimentary section overlying(?) the Orca Group have pyrolitic hydrocarbon to organic carbon ratios suggesting that the outcropping rocks are effectively non-source horizons. The organic shale of the Poul Creek Formation has a pyrolitic hydrocarbon to organic carbon ratio indicative of an excellent gas-prone section having some oil potential. Two samples from the Orca Group, normally considered to be basement for hydrocarbons, have ratios suggestive of gas-prone potential. This anomaly may result from the combination of low total organic content and the late mature or post-mature thermal history suggested by the vitrinite reflectance and thermal alteration index values. It is probably not indicative of any significant hydrocarbon potential in the Orca Group.

On Kayak Island the pyrolitic hydrocarbon to organic carbon ratios suggest a gas-prone potential for both the Yakataga and Poul Creek Formations.

Indicators of thermal history

TEA-FID

Thermal analysis can be used empirically as an indicator of thermal history. In general, temperatures below 460°C suggest thermal immaturity and above 480°C suggest maturity (Claypool and others, 1977).

Generally, the temperature in the Katalla and Kayak Island area increases downward in the stratigraphic section to the Stillwater Formation and presumably indicates increasing depth of burial and heating of the older formations. The samples from the Orca Group, which is in part (?) older than the Stillwater, have evidence of a cooler thermal history than samples from the Stillwater, Kulthieth, and Tokun Formations; this apparent anomaly is discussed in a following section of this report.

The TEA-FID data suggest that the Poul Creek, including the organic shale unit, Redwood, and Yakataga Formations are thermally immature, and that the Tokun, Kulthieth, and Stillwater Formations are sub-mature to mature and within or near the zone for gas generation. The data suggest a slightly cooler thermal history for Kayak Island than for the apparently coeval rocks of the Katalla area.

Vitrinite reflectance

Vitrinite, a type of coaly particle, is identified by microscope and the percentage of reflected light measured. The vitrinite reflectance data indicates a higher thermal history for the older rocks than for the younger part of the stratigraphic section. General criteria for the threshold of maturity for vitrinite reflectance vary with authors (Dow, 1977b; Hood and others, 1975), but values range from 0.5 to 0.65. Following these criteria, the vitrinite reflectance data indicate thermal maturity for the entire Tertiary sedimentary section.

TAI (thermal alteration index)

As the constituents of visual kerogen are being determined, the thermal alteration index (TAI), a color variation, is observed and subjectively measured against a standard on a scale from 1 to 5. Kerogen coloration ranges from a pale yellow (1) to black (5), with 2 to 4 being the mid-range. The TAI for the samples from the Katalla area varies between 2.1 and 3.6, with higher values found in the older rocks. On Kayak Island the TAI varies from 1.9 to 2.3.

Summary of thermal indicators

The three independent indicators of thermal history of the Tertiary rocks of the Katalla-Kayak Island area show close similarities throughout the section. However Magoon and Claypool (1979) point out that caution must be exercised in using these parameters of thermal maturity until they have been calibrated for a basin by comparison with the hydrocarbons extracted from the rocks. Until this calibration is completed these indices of maturity are empirical.

Taken together the three sets of data suggest that the Yakataga, Redwood, and Poul Creek Formations, including the organic shale unit, in outcrop are thermally immature or approaching the threshold of maturity. Where it is more deeply buried and with a longer burial history, part of the Poul Creek Formation, in particular, may be thermally mature and capable of generating hydrocarbons. The data suggest that the Tokun, Kulthieth, and Stillwater Formations in outcrop are thermally mature and would be within the zone of hydrocarbon generation if adequate amounts of organic material were present. This evaluation is supported by the presence of the seeps and shallow oil production from the fractured shales of the Katalla area. In addition, George Plafker (oral commun., 1982) observed an oil seep from the Tokun Formation in the intertidal zone off the south tip of Wingham Island.

Anomalous Orca Group thermal maturity

A major anomaly in the indicators of thermal maturity of the Orca Group is evident in all three thermal maturity indicators. The Orca Group is in part (?) older than the other Tertiary rocks and has been presumed to structurally underlie them throughout the Katalla-Kayak Island areas. If this is true, the Orca Group should show evidence of a higher level of thermal maturity than the younger units. The markedly lower level of thermal maturity of the Orca Group suggests that the outcrops sampled near Point Martin, 2.6 mi southwest of Katalla, have had a shorter, or shallower and cooler, burial history than the younger Stillwater, Kulthieth, and Tokun Formations. In the Katalla area, the contact between the Orca Group and younger rocks is always a fault – the Ragged Mountain fault on the west and the Chugach fault to the north. The Orca has not been seen stratigraphically underlying younger rocks anywhere in the Katalla area or in the Yakataga area to the east. A speculative interpretation is that the Orca Group does not underlie the Stillwater and younger Tertiary rocks and that the Stillwater and younger formations were emplaced against the Orca Group as a result of long distance thrust faulting. Alternatively, it is possible that a combination of unexplained geochemical relationships in the Orca Group result in the lower indications of thermal history, since the high thermal values in the Kulthieth and Stillwater are supported by petrographic observations in the Stillwater and Kulthieth showing zeolite facies metamorphism and quartz overgrowths (Winkler and others, 1976). Analyses of additional samples from the formations will be required to confirm the apparent relationships in thermal history indicated by this limited study.

MINES AND PROSPECTS

Mining activity and production

Lode and placer gold, base-metal, coal, sand, gravel, and minor building-stone extraction have taken place historically in the national forest. In addition, oil was produced and refined at Katalla from 1904 to 1933. Gold mining operations have been small scale with only a handful of operations producing most of the placer and lode gold (tables 1 and 2, respectively). Copper has been the only base-metal produced for sale. Only the Beatson operation could be classed as significant; the Ellamar and Schlosser were minor and the rest were sporadic producers. Sand and gravel deposits serve local requirements including highway construction and maintenance. High potential exists for mining of gold and copper deposits. Moderate potential exists for developing previously or newly identified resources, including lead, silver, and zinc. Some potential exists for developing antimony, molybdenum, manganese, and nickel resources. Individual mines, prospects, and occurrences are located on the accompanying map sheet and described in Jansons and others (1984).

Placer gold mining

Placer gold mining has occurred mainly in the north-central Kenai Peninsula (areas 2 and 3) and near Girdwood along Crow Creek (area 1). Significant placer gold mining has not been reported elsewhere. The major producing streams and estimated production are shown in table 1.

In the late 1840's, the Russian-American Company attempted to systematically evaluate the placer gold potential of its concessions in North America. Gold was discovered on the Kenai and Russian Rivers in 1848 and was mined by the company in 1850 and 1851 near Kenai Lake but the extent of the mining and evaluations is not well known. Since the Alaska Purchase in 1867, individual prospectors were apparently active in the area because there were sporadic reports of gold discoveries between the 1860's and 1900's. A placer gold discovery on Cooper Creek (P-86, map sheet) was reported in 1884, and discoveries on Resurrection (P-90) and Sixmile Creeks (P-72) were reported in 1888 (Tuck, 1933). In about 1896, zones of high-grade gold were discovered and mined on Bear (P-91) and Palmer (P-90) Creeks. Soon afterwards, gold placers were discovered on Mills (P-79), Canyon (P-76), Crow (P-93), and other subsequently productive creeks.

Since 1980, 15 to 20 placer operations have been active during the 3 to 4 month mining season in the Kenai Peninsula area. The operations range from small (4-in. to 8-in.) suction dredge and pick-and-shovel operations processing 10 to 15 yd^3/day to a backhoe, bulldozer, washing-plant operation that could process up to 2,000 yd^3/day.

In 1982, approximately 1,860 placer claims were located within the study area. Numerous recreational miners work along the gold-bearing streams, but their aggregate production is small.

Although production figures are incomplete, an estimated 133,000 oz of placer gold were produced since 1895; the majority of this has come from the north-central Kenai Peninsula and Girdwood areas. Of the total placer production, 67,450 oz of placer gold, or nearly half, was recovered between 1895 and 1910. More recently, placer gold has been produced at an estimated rate of 1,000 to 2,000 oz/yr.

Lode gold mining

Lode gold was explored for, or mined, on a small scale in the Kenai Peninsula, Girdwood, Port Wells, Valdez, Jack Bay, Culross Island, Bligh Island, and McKinley Lake areas. Although production figures for these areas are incomplete, an estimated 132,400 oz of gold were produced. An additional estimated 51,800 oz of gold were recovered from sulfide ores from the Beatson (S-17) and Ellamar (C-19) mines. The major producing lode mines and their production are shown in table 2.

On the Kenai Peninsula, the possibility of gold-bearing veins was noted in the Summit Creek area in 1896, and lode claims were located on Bear, Palmer, and Sawmill Creeks in 1898 (Tuck, 1933). Claims at the Falls Creek area were located in 1905 and at Slate and Summit Creeks in 1906. The first notable production occurred in the Falls Creek area in 1911. Between 1911 and 1930, lode gold production from the Kenai Peninsula fluctuated from a few hundred ounces to

1,500 oz/yr. During this period about 15,000 oz, or an average of 750 oz/year, were mined. The longest continuous lode gold production apparently came from the Lucky Strike veins (S-289) on Palmer Creek. Other producers include the Primrose (S-214), Skeen-Lechner (S-225), East Point (S-226), Crown Point (S-227), Grant Lake (S-231), Gilpatrick (S-253), Heaston-Oracle (S-255), and Ronan & James (S-256) mines.

In the Girdwood district between 1931 and 1942, lode gold was mined from several veins near Crow Pass at the Monarch (A-38) and Jewel (A-37) mines.

In the Port Wells area, with the exception of the Granite mine (S-147), lode gold prospects are small. The date of the discovery of lode gold in this area is unknown because little interest was shown in lode mining until 1910, when the mineralized quartz veins at the Cliff mine (V-48) at Port Valdez proved to be excellent producers. By 1911, the Golden Eagle (S-129) property in the Port Wells area was being developed. Development of other major properties in the Port Wells area, including the Granite (S-147), Mineral King (S-156), Portage Bay (S-168), and Lansing (S-163) mines, followed soon after. The Granite mine (S-147) produced at least 24,940 oz of gold over a 30 year period of discontinuous operation and was the largest gold mine in the Port Wells area. The Mineral King mine (S-156) reportedly produced 2,783 oz of gold, mostly between 1928 and 1932. The Portage Bay mine (C-168) has a recorded production of 490 oz of gold. Ore from the early operations was treated at local mills.

The Port Valdez area, which is largely outside the Chugach National Forest, produced 61,646 oz of gold. The Cliff mine (V-48), located immediately adjacent to the national forest, produced a recorded 51,740 oz of gold in 16 years of operations. Other mines with sustained gold production in the Port Valdez area include the Ramsay-Rutherford (V-5: 5,375 oz) and Big Four (V-28: 846 oz), which are outside the Chugach National Forest, and Gold King (V-63: 1997 oz) and Cameron-Johnson (V-62: 585 oz), within or on the national forest border. The mineralization of Port Valdez extends west into the study area along Columbia Glacier and may extend east along the Lowe and Tasnuna Rivers (Fechner and Meyer, 1982). By 1912, 48 mines and prospects were located from Valdez to Columbia Glacier, a distance of about 25 miles.

In the Jack Bay area, located south of and adjacent to the Port Valdez area, minor amounts of surface work, such as pits, trenches, and adits on quartz- and gold-bearing structures, are reported. These were of limited extent, and assays did not reveal significant gold content in samples taken for this study. Records of gold production have not been located.

On Culross Island, two zones of lode gold mining are present south of Culross Bay. Both deposits, the Culross mine (S-102) and John Sells prospect (S-103), contain gold in quartz-filled fissures. Claims were first staked 1907. At least 895 ft of underground workings exist at the Culross mine (Richelsen, 1950). The Culross Island properties produced an estimated 62 oz of gold.

On Bligh Island, gold was noted in quartz in two areas. Near the entrance of Cloudman Bay, samples taken in 1905 along a 30-foot interval assayed from 0.1 to 0.24 oz gold/ton. Samples from the northeast corner of Bligh Island are said to have assayed up to 125 oz gold/ton (Capps and Johnson, 1915). No significant production has come from this area.

In the McKinley Lake area, east of Cordova, most of the surface trenching and underground work had been completed by 1912. Minor gold production was recorded from the McKinley Lake Company prospects. Although gold-bearing quartz veins and stockworks are present, the gold distribution in the veins is erratic and sparse (Richelsen, 1934).

Copper mining

Copper prospects have been developed or mined in the area since 1897, principally in the Latouche Island, Knight Island, Glacier Island, Copper Mountain (4 mi southeast of Ellamar), Landlocked Bay (5 mi southeast of Ellamar), Port Fidalgo, and Cordova areas (Moffit and Fellows, 1950). Substantial amounts of copper were produced from the Beatson (S-17), Ellamar (C-91), and Schlosser (C-66) operations (table 3). Zinc, lead, silver, and gold, as well as other associated elements, are present in variable amounts in the sulfide ores.

Systematic copper mining and ore shipments started from the Beatson mine (S-17) in 1904, from the Ellamar mine (C-91) in 1905, and from the Schlosser (V-66) and Midas (V-35) mines in 1912. Base-metal mining ceased in 1930 with closure of the Beatson mine, the largest producer in the area. Since 1929, and up to about 1964, base-metal investigations have been site specific with the aim of proving ore reserves in the areas of better mineralization. In the 1930's, Solar Exploration explored underground at Rua Cove, Latouche Island, and Port Fidalgo. In the 1950's, Northern Pyrites Company evaluated the pyrite of the Duke (S-3) and Duchess (S-4) prospects on Latouche Island as potential sources of sulfur, and the Alaska Copper Company reevaluated copper occurrences at the Schlosser property (C-66) at Port Fidalgo. In the early 1960's, a limited regional reconnaissance stream-sediment sampling program was undertaken by the State of Alaska (Jasper, 1967) and private interests in drainages along highways and in other readily accessible streams, but no significant anomalies were found.

In the late 1960's, Phelps Dodge Corporation made an intensive mineral survey using modern exploration techniques on Latouche Island. Induced potential and electromagnetic geophysical systems identified and traced several chargeability and conductor zones. One conductor zone extends south from the Beatson mine through the Duke (S-3) and Duchess (S-4) prospects, at which point the conductor terminates abruptly. To the south, two additional conductor zones, conceivably southern extensions of the Beatson trend, were identified along the west side of Latouche Island. Only moderate base-metal values (a few hundred ppm) were reported in drill cores along this trend.

In the early 1970's, property owners and companies reevaluated the base-metal potential of the Duke and Duchess prospects on Latouche Island. A mineral-reserve estimate based on surface, subsurface, and diamond drill data indicated the presence of at least 1.5 million tons with a grade of 0.9 percent copper, 1.8 percent zinc, 0.9 oz silver/ton, and 0.04 oz gold/ton (Bear Creek Mining Company, unpub. data, 1972).

In 1974, Noranda Exploration Company carried out an extensive regional base-metal exploration program in the western part of Prince William Sound. As a result of this work, a large block of claims was staked on the south half of Latouche Island. Three shallow core holes, drilled in 1974-75, intercepted no significant zones of sulfide mineralization.

In the middle 1970's, Texasgulf Incorporated drilled at the Rua Cove prospect on Knight Island. These drill sites appear to have been spotted on geophysical anomalies that suggested the presence of massive sulfides. Extensive sections of low-grade pyrrhotite-filled fractures in greenstone were cored.

Copper was produced continuously from three localities and shipments were made sporadically from numerous prospects (table 3). The Beatson mine output, when combined with that of the Ellamar mine, accounted for more than 96 percent of the copper shipped from the mines of the district during the period of sustained production. Production from mines and prospects totaled about 208,700,000 pounds of copper from about 6,417,000 tons of ore. Zinc and minor amounts of lead are reported with copper ore, but production of these, if any, was not recorded. Silver and gold were recovered at the smelter.

Coal and petroleum production

Extensive coal occurrences in the Bering River area have been known since at least 1896 (Barnes, 1951). Reports indicate that rapid changes in thickness are common features of the coal seams, making them difficult to mine. However, a minor amount of coal (18,000 to 20,000 tons) (Janson, 1979) was shipped from Canyon Creek (area BG-2) probably between 1910 and 1920.

Petroleum exploration had its beginning in the Gulf of Alaska near Katalla in 1901 (Blasko, 1976). In 1902, oil was struck at a depth of about 370 ft. Exploration activity continued in this area during the early 1900's; wells were drilled on the east shore of the Bering River, on Chilkat Creek, near the mouth of Chilkat Creek, near Point Hay, on the west shore of Bering Lake, on Mirror Slough, and near Nichawak Mountain. All 44 wells drilled between 1901 and 1930 had some shows and 18 produced oil commercially at one time or another. Production from the field in the first decade of the 1900's was enough that a small refinery was built to process the crude oil. The refinery burned down in 1933 and was not rebuilt. Total production from the field amounted to 153,922 barrels.

Reserves and resources

Estimates of reserves had been determined previously for some of the larger prospects (except the Beatson mine) (Holt, 1942; Mihelich and Wells, 1957; Sainsbury, 1953; Williams, 1953, 1954) and sufficient data were acquired during this study to calculate inferred resources for some others. These results should be used only as an indication of the order of magnitude of identified resources at a particular site and are probably conservative. Insufficient data precluded estimating reserves for some previously large mines, especially the Beatson. Identified resource estimates in this summary are shown for coal, oil, and the historically important metals—lode and placer gold and volcanic- and sediment-hosted copper.

Gold deposits

A total of about 109,640 tons of identified lode gold resource in 32 deposits is present at the historical producers (table 4). More than 11,750,000 yd^3 of placer material is inferred to be present at the historic producing areas. The distribution of the placer resources is shown in table 5.

Copper deposits

The minimum copper resource identified in this study for 22 deposits is 6,251,100 tons of ore. Of this total, volcanic-hosted deposits account for 3,407,600 tons and sediment-hosted deposits account for 2,843,500 tons. Table 6 shows copper deposits that contain in excess of 1,000 tons of identified resources.

Coal and petroleum

Coal-bearing rocks underlie an area estimated to be about 70 mi^2 in the Bering River area. Coal exposures consist for the most part of isolated outcrops and prospect openings along the main stream courses. The intervening areas are covered with soil, moss, and other vegetation. Therefore, few coal seams have been traced for more than short distances and little is known of the maximum extent of the individual coal seams. Hypothetical resources of 3.6 billion tons have been estimated for the field (Sanders, 1975). An extensive drilling program by the combined efforts of the Korean-Alaskan Development Corporation and the Chugach Native Corporation is currently (1980–83) attempting to identify the minable coal reserves in the Carbon Mountain area.

Eighteen wells produced nearly 154,000 barrels of oil over 30 years in the Katalla area, but no resource data are available.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

To evaluate the regional mineral resource potential, the geologic environments favorable for mineral deposition must be identified. Favorable areas were defined largely by comparison of the geologic environments in the study area with available geologic, geochemical, and geophysical criteria from areas of known deposits. Geologic models, based on genetic concepts developed by study of known deposits in general and modified by observed characteristics of the deposits within the study area, are basic tools used in making this resource assessment.

Four stages are commonly completed to determine where a deposit might be located and how large a deposit might be. Bailey (1981) notes that a minerals exploration program progresses from: (1) regional reconnaissance, to (2) detailed reconnaissance of favorable areas, then to (3) detailed surface appraisal of target areas, and finally to (4) detailed three-dimensional sampling. Federal government resource assessment projects generally do not go beyond step 1; a few undertake step 2.

Criteria used to define and evaluate the 25 areas identified as having mineral resource potential in the national forest, the commodities, and the deposit types in each area are listed in table 7. Specific information about the criteria within each area is given in Barnes and Case (1984); Barnes and Morin (1984); Goldfarb and others (1984); Goldfarb and Tripp (1983); Nelson and others (1984); and Jansons and others (1984). The table: (1) classifies the resource areas according to their likelihood of containing certain deposit types and (2) ranks the potential (high, moderate, or low as defined below) for various mineral resources in the national forest. For example, the resource potential for gold is considered high and the likelihood for the occurrence of gold placer deposits in various resource areas can be ranked from most favorable to least favorable. The ranking is relative and only applies to this study area. Ranking could be changed by new information.

We rank mineral resource potential as high where nearly all conditions are favorable for mineral deposit formation. In these areas, geologic, geophysical, geochemical, and other data demonstrate or suggest a high probability of mineral deposits. The size, grade, and location of known deposits are important supporting data in the assessment.

We rank a mineral resource potential as moderate where favorable geologic conditions have been identified or may reasonably be interpreted to occur, but where substantiating evidence for mineral deposits is less clearcut.

We rank a mineral resource potential as low when only limited evidence supports favorable geologic conditions, and indications characteristic of mineral deposits are lacking. This is a broad category that embraces areas with obvious but dispersed and apparently uneconomic mineral occurrences, as well as areas with few indications of mineralization. It includes areas where only sparse mineral resource data exist.

Relative ranking (table 7) of the favorability of resource areas was done for volcanogenic massive sulfide, lode gold, and placer gold deposits. The ranking was restricted to these types because they have had historic production or are producing at present, and they constitute the major metallic resource potential for the area. Other deposit types were not ranked because they occurred in only one area, were incompletely studied, or were considered to have low mineral potential.

The relative ranking of favorability for the deposit types was determined by assigning points for each criterion listed in table 7. The values given to the various criteria were weighted towards those that were more significant for assessing the favorability of the deposit types. For example, the presence of mines was deemed a more significant criterion than the presence of mineral occurrences, and a geochemical anomaly for the resource under consideration was more significant than an anomaly in other elements. The summation of points for the deposit types in each appropriate area was determined. This allowed a relative and objective ranking of resource areas to be determined. The numerical value is not given here, because the important factor was the relative ranking and not the numerical value. Because of the higher value assigned to the mine and prospect criteria, some resource areas lacking mines or prospects were originally ranked lower even though they had good indications of mineral deposits based on other criteria, such as geochemistry. This lack of exploration activity could be attributed to extreme ruggedness of the area or to extensive glacial coverage. In these few cases (areas 9A,C and 19A,B), the ranking for the particular deposit type was raised to a relatively higher ranking, especially where mines and prospects were present at one end of a resource area, and where supporting evidence showed likely continuity of favorable geology and indications of mineralization.

Resources of high potential

Gold

The increase in the prices of precious metals since 1970 has resulted in a nationwide expansion of exploration for these targets. Much lode prospecting and development is underway in Alaska. In the Chugach National Forest area, where past production has largely been from small, high-grade lode deposits and small placers, current placer mining produced about 5500 oz of gold between 1980 and 1982. At present there are no active lode mines. Several potentially minable deposits still exist in the historic areas, and other deposits probably exist in areas that were covered by glaciers when the early prospecting was done during the first part of the century.

Gold production in the near future (depending on a favorable economic situation) could come from the small placer deposits located principally on the Kenai Peninsula and in the Girdwood area; larger volumes of alluvial gravels containing fine-grained free gold could be developed in the Tasnuna and Copper Rivers. Small lode gold mines (less than 50 tons/day) may become active as high-grading operations. Gold from base-metal sulfide deposits probably would be recovered as a byproduct. Small volumes of stamp-mill tailings and mine dumps at the Granite mine and elsewhere may contain recoverable gold.

The ranking of resource areas that contain placer gold and lode gold deposits is (see map sheet and table 7):

Rank	Lode gold areas	Placer gold areas
Most favorable areas	1A; 2A,C; 3A,B; 5A,B; 9B	1A; 2B,C, E,F; 3E
Moderately favorable areas	2F; 3C,E; 6B; 9A,C	1B; 3A; 6B; 19B
Least favorable areas	2D; 8; 11; 13B; 16D; 19B; 22	7; 9C

Copper

Copper has been an important resource in the study area since the early 1900's. Copper production has been entirely from volcanogenic massive sulfide deposits. Polymetallic veins in area 16 may constitute a minor copper resource.

The Beatson mine, the second largest copper producer in Alaska, on Latouche Island yielded 80-85 percent of the copper from the area. The other principal producing massive sulfide deposits include the mine at Ellamar, the Midas mine near Valdez, the Threeman mine at Landlocked Bay (6 mi southeast of Ellamar), and the Schlosser mine at Port Fidalgo.

The large number of copper prospects and occurrences imply that considerable copper-bearing sulfide resources still exist. For example, the Rua Cove prospect has indicated resources of 1,125,000 tons with a grade of 1.25 percent copper (Richter, 1965). Several million tons of material with a grade between 0.8 percent and 1.25 percent copper also is present in smaller sulfide bodies from this prospect. The lower grade parts of sulfide bodies both at Ellamar and on Latouche Island are still present (Moffit and Fellows, 1950). Our own geochemical sampling and geologic mapping suggest that low-grade copper resources associated with mafic volcanic rocks may exist in area 19A.

In contrast with the volcanogenic deposits, copper and other base-metal sulfide-bearing veins in sedimentary rocks in area 16B are high grade, but individually are low in tonnage.

The copper and iron sulfide body at the Ready Bullion prospect at Lynx Creek (area 2E) is the only deposit of this type that is far from any known volcanic rocks. This occurrence, coupled with the difficulty of detecting a similar deposit by reconnaissance geochemical techniques implies a potential for similar deposits in other areas lacking volcanic rocks.

The ranking of resource areas that contain copper sulfide deposits is:

Rank	Areas with copper Sulfide deposits
Most favorable areas	12A; 14A; 18A;B,E
Moderately favorable areas	4; 12B,C,D; 14C,D; 19A; 21
Least favorable areas	2E; 13B; 14B; 17; 18C

Coal

The Bering River coal field encompasses an area of about 70 mi^2 centered about 60 mi east of Cordova (area 23, map sheet). Physiographically, the area consists of low (2,000-4,000 ft), steep-sided and rugged mountains lying south of the Martin River Glacier and north of the Bering River (Sanders, written commun., 1978). The coal field, defined by the outcrop area of the Kulthieth Formation, is a wedge-shaped area about 20 mi long and from 2-5 mi wide.

Locally, coal seams are characterized by a lack of continuity and structural complexity with isoclinal and chevron-like folds and imbricated bedding-plane faults (Sanders, 1976). The rank of coal varies from bituminous, to semianthracite, to anthracite. Coals are greatly devolatilized due to low-grade regional metamorphism (Holloway, 1977). Hypothetical resources of 36 million short tons were determined by Holloway (1977). However, Gates (1946) and Sanders (1975) reported up to 3 billion tons of coal resource.

Resources of moderate potential

Lead

Lead occurs principally in the sulfide mineral galena. In the national forest, galena in minor amounts is found associated with iron, copper, and zinc sulfide deposits. Galena is also present in trace to minor amounts in some of the lode gold deposits, but these deposits have a low potential for resources of lead because of their low grade and small size.

By far the most favorable location for lead resources is area 16B where galena and sphalerite occur in polymetallic veins cutting sedimentary rocks. Values in surface samples from these veins range up to 17 percent lead. The amount of the lead mineralization in the veins is small, but the abundance of the veins and their tenor indicate that this area has the highest potential for lead resources in the study area.

Silver

Silver was recovered as a byproduct from both lode and placer gold and from the copper sulfide ores and concentrates, and these constitute the most likely sources of silver in the future. Production from massive sulfide deposits on Latouche Island alone yielded nearly two million ounces of silver, a total far in excess of that recovered from all gold mines combined. There are no deposits in the area that were worked primarily for silver.

Silver is found in both gold-bearing quartz veins and gold-free quartz veins. The silver in quartz veins from Gulch Creek (P-73) contains no gold values, but the veins do contain galena, stibnite, and arsenopyrite. The location warrants further investigation.

Zinc

Zinc occurs primarily in the mineral sphalerite which is frequently associated with the copper sulfide deposits. Sphalerite also occurs in trace to minor amounts in the gold-quartz lodes of the Kenai Peninsula. It is present as a major constituent in the polymetallic veins in area 16. Area 16 appears to be more zinc-rich than other areas, as determined from this study, and several prospects were developed in the past for this commodity.

Geochemical sampling in the Don Miller Hills and on Kayak Island (areas 24 and 25) has identified significant geochemical anomalies in zinc and barium (Goldfarb and others, 1984). Sphalerite and barite were identified in heavy-mineral concentrates from these samples. The Poul Creek Formation appears to be the source of the zinc and barium, especially the limonite-stained beds in the Poul Creek Formation from Kayak Island.

Sphalerite and barite from Kayak Island were identified (Goldfarb and Tripp, 1983) only in concentrated geochemical samples—no zinc or barium minerals were observed in rocks in this area. The marine sedimentary rocks, organic-rich shale, and thin interbeds of mafic volcanic rocks in the Poul Creek Formation are similar to lithologies associated with organic-rich sediments and coal in the Illinois Basin (Cobb, 1981) and to lithologies containing shale-hosted lead and zinc deposits from the western Brooks Range of Alaska (Nokleberg and Winkler, 1982).

The source of the sphalerite and barite in the pan-concentrate samples from the Don Miller Hills and Kayak Island may be weakly mineralized beds in the Poul Creek Formation. Further assessment of these anomalies is warranted.

Resources of low potential

Antimony

Antimony occurs in stibnite-bearing veins in the national forest (Johnson, 1914, 1915; Brooks, 1916) at occurrences in the Kenai Lake (localities S-234, S-236, map sheet) and Barry Arm (A-27, A-31) areas, but the veins are small and of local extent. Stibnite also occurs as an accessory mineral in gold-bearing veins elsewhere in the Seward quadrangle (S-1, S-152, S-281).

Barium

Barite has been identified in pan-concentrate geochemical samples from Kayak Island and the Don Miller Hills. The barite is dark gray and occurs with sphalerite. Limonite-stained siltstone in the Poul Creek Formation exhibits weak zinc and barium anomalies and may be the source of the minerals in the pan samples. Barite prospects are reported (U.S. Bureau of Mines, 1973; State of Alaska, 1982) along Puget Bay; however, field investigations there in 1979 did not reveal any barite. Tysdal (1978) reported barium in volcanic rocks in amounts greater than 5000 ppm from Mummy Bay on Knight Island (S-34).

Chromium

Chromium in amounts greater than 1000 ppm was detected in numerous samples of mafic and ultramafic rocks. However, chromite was not seen in most of these samples and much of the chromium may occur in silicate minerals. Chromite was observed in small ultramafic bodies on the Resurrection Peninsula, Knight Island, near the head of Port Fidalgo, and in the mafic phases of the Miners Bay pluton. At these localities chromite crystals are sparsely disseminated throughout the rock, and no podiform or layered concentrations of chromite were seen.

Cobalt

No cobalt minerals were observed; however, cobalt is anomalous in numerous geochemical samples (Goldfarb and others, 1984). High cobalt values (to 3000 ppm) have been reported from base-metal sulfide samples from Glacier Island, Port Fidalgo, Miners Bay, and samples associated with ultramafic rocks on the Resurrection Peninsula.

Manganese

Two occurrences of manganese have been identified: one on Chenega Island (S-90) and one on Hinchinbrook Island (C-98). The Chenega Island occurrence (Kurtak, 1982) is 6 by 50 ft in outcrop area and contains an unknown amount of rhodochrosite and pyroxmangite. A 3.5-ft chip sample contained 17 percent maganese, and two grab samples contained 36 percent and 37 percent manganese. The average grade and extent of the occurrence was not determined. The Hinchinbrook Island occurrence (R. W. Goodfellow, personal commun., 1983) consists of a 30- by 90-ft rubble outcrop and may be unique because it is the first recognized occurrence of nodular forms of manganese in the area. Studies of the mineralogy indicate submarine volcanic hot springs as a source (R. W. Goodfellow, personal commun., 1983). The manganese content of one grab sample was 35 percent.

Geochemically anomalous amounts of manganese occur in geochemical samples from streams draining areas of sedimentary rocks interbedded with, or at least near, volcanic rocks. These anomalies may result from occurrences similar to those on Chenega and Hinchinbrook Islands.

Molybdenum

Molybdenum has been detected in low concentrations in a few limonite-stained zones and as an accessory element associated with the lode gold deposits on the Kenai Peninsula (Tysdal, 1978) and at Crow Pass near Girdwood.

A unique occurrence in the area is in the Billings Glacier pluton (S-169; Hoekzema and Sherman, 1981) near the terminus of Billings Glacier approximately 5 mi northeast of Whittier. The granitic rock is uniform in texture and contains sparsely disseminated pyrite and chalcopyrite that, on weathered surfaces, are oxidized to limonite. Disseminated and fracture-filling molybdenite, ranging from millimeter-sized single crystals to crystal aggregates 2 cm across, are sparsely distributed throughout the granite. The lack of extensive stockwork veining and of fractures, alteration, and through-going dikes in the exposed outcrop suggests that this may not be a highly mineralized system. Two out of 18 samples of the plutonic rocks had appreciable molybdenum (2000 and 1400 ppm) and six others had molybdenum values ranging from 7 to 98 ppm.

Nickel

Nickel in anomalous amounts is associated with ultramafic rocks on the Resurrection Peninsula, Knight Island, Port Fidalgo, and mafic rocks of the Miners Bay pluton. Although nickel sulfides have not been positively identified at all of these localities, pentlandite (NiS) was found in some of the pyrrhotite ores of Knight Island (Johnson, 1919; Martin, 1919; McGlasson, 1976). Nickel probably also occurs in other sulfide and silicate minerals. Its presence probably reflects a source in the ultramafic inclusions in shear zones within the sheeted dike unit on Knight Island.

Tungsten

Tungsten occurs in heavy-mineral concentrate samples from the Port Wells district, in a few samples from quartz-healed fractures in the Perry Island pluton, and in quartz veins peripheral to the Billings Glacier pluton. Float samples of scheelite-bearing granitic rocks were found along the Gravina River (C-55). Skarns with substantial tungsten mineralization are not present due to the lack of carbonate rocks intruded by granitic plutons.

Radioactive minerals

Several investigations for radioactive minerals were conducted in the area. One was a reconnaissance investigation made by Wedow and others (1953) of the copper and gold lodes, granitic intrusive rocks, and adjacent contact-metamorphosed sedimentary rocks. No significant radioactivity was found. Recent radiometric surveys conducted over the entire area by the U.S. Department of Energy in the NURE program detected anomalous radioactivity near the Sheep Bay pluton in the Cordova area and along Resurrection Creek on the Kenai Peninsula (U.S. Dept. of Energy, 1981). Dickinson and Morrone (1982) evaluated several radioactive anomalies in the Orca Group in the Cordova quadrangle. They determined that the anomalies resulted from contrasts between mafic volcanic rocks, sedimentary rocks, plutonic rocks, and ice fields as reflected in the reconnaissance airborne gamma-ray survey.

In 1979, Bureau of Mines field parties took scintillometer readings on many traverses and at prospects. These readings showed no areas of high radioactivity, and the minor changes were attributed to changes in background radiation levels of various bedrocks.

Geochemical surveys revealed three regions containing minor geochemical indications of uranium or thorium. Heavy-mineral concentrates from watersheds underlain by the Sheep Bay pluton were enriched (as compared to the other plutons) in thorium, and contained monazite and thorite. Uranium concentrations up to 35 ppm, as well as uranium to thorium ratios above 1.0, were obtained for stream sediments collected as part of the U.S. Dept. of Energy's NURE program (U.S. Dept. of Energy, 1981). A region east of Unakwik Inlet (between Kadin and Terentiev Lakes), that is underlain by a uranothorite-bearing pluton, yielded anomalous thorium values for heavy-mineral concentrate samples. The NURE data for the Seward 1:250,000-scale quadrangle (U.S. Dept. of Energy, 1982) showed uranium values in stream sediments as great as 75 ppm along the east side of Resurrection Creek (area 2E). The source for these uranium anomalies is unknown.

Hydrocarbons

On the basis of our limited organic geochemical data, we can make the following generalizations regarding the hydrocarbon potential in the national forest:

1. The Yakataga and Redwood Formations are weak source horizons, with substantially less than 1 percent organic content. Both formations are probably thermally immature.
2. The Poul Creek Formation contains some rich source beds with organic content ranging up to greater that 4 percent, but averaging about 1 percent. Thermal indicators suggest that the formation is approaching the zone of thermal maturity and some parts of the formation may be capable of generating gaseous hydrocarbons, particularly where more deeply buried. The horizon with the highest organic content also contains the greatest percentage of amorphous and herbaceous kerogen, and may thus be a source for oil generation where more deeply buried.
3. The Tokun Formation has organic contents of around 1 percent but has a low pyrolytic hydrocarbon to organic carbon ratio suggestive of a very weak source horizon. The entire horizon is probably thermally mature.
4. Beds in the Kulthieth Formation have greater than 1 percent organic content. However, the formation is low in amorphous kerogen and has a generally higher content of woody and inert organic material than other rock units in the area. In addition, it has a low organic hydrocarbon to organic carbon ratio. In outcrop, the formation is thermally mature to post-mature. In the Katalla area, the Kulthieth Formation can be considered to be a non-source horizon.
5. The Stillwater Formation, represented by only one sample, has a low pyrolytic hydrocarbon to organic carbon ratio and is within the post-mature zone of high temperature methane production. It is a non-source horizon.
6. The organic geochemical data for the Orca Group appear to be anomalous compared to the data from other formations in the area. Its organic content is very low, as is typical of flysch sequences, and, on this factor, the formation would be classified as a non-source or very weak source horizon. It is thermally immature to submature and has a high pyrolytic hydrocarbon to organic carbon ratio, well within the gas-prone zone. Although on these criteria the Orca Group might be classified as a source horizon, the low total organic content suggests that the gas generated would be volumetrically insignificant.

Numerous oil and gas seeps in the western part of the Gulf of Alaska Tertiary province led to the discovery and development of the Katalla oilfield. Minor production lasted about 30 years. Continued exploration and drilling in the area have taken place at various times up to the present because of the abundant surface evidence of petroleum seepage and the presence of some suitable hydrocarbon source rocks. However, the potential for significant oil and gas is lessened by unfavorable geologic conditions that are: (1) lack of suitable reservoir rocks; (2) complex geologic structure; and (3) complex diagenetic histories that may have led to destruction or migration to the surface of some of the hydrocarbons generated (Plafker, 1971).

Other resources

Rock, sand, and gravel

Rock suitable for use as building-stone, riprap, aggregate, and facing stone occurs in most areas of the Chugach National Forest and to date has been used only for local purposes, such as for the recently completed breakwater in the Cordova boat harbor. Sand and gravel are present for local use.

The study area has a high potential for more sand and gravel extraction along the rail belt between Seward, Portage, and Whittier as existing supplies near Anchorage become depleted or unavailable. To date the use of sand and gravel has probably been most affected by local construction and road development and maintenance.

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TABLE 1.--Principal streams producing placer gold, Chugach National Forest area, Alaska (1895-1982)

Streams	Locality No.[1]	Estimated production (oz)
Crow Creek	P-93	42,500
Canyon Creek	P-76	37,700
Resurrection Creek/ Palmer Creek	P-90	26,800
Lynx Creek	P-61	7,500
Bear Creek	P-91	5,000
Mills Creek	P-79	4,000
Gulch Creek	P-73	2,150
Sixmile Creek	P-72	1,750
Cooper Creek	P-86	1,150
Quartz Creek	P-81	800
Bertha Creek	P-64	700
Silvertip Creek	P-75	650
Crescent Creek	P-83	350
California Creek	P-92	300
Hargood Creek	P-82	300
Seattle Creek	P-70	200
Falls Creek	P-55	200
Stetson Creek	P-85	200
Kenai River	P-87	100
Others		650
Total		133,000

[1] Refers to map sheet; localities described in Jansons and others (1984).

TABLE 2.--Major lode gold mining operations, Chugach National Forest area, Alaska (1910 - 1982)

Mines	Locality No.[1]	Reported/recorded* production (oz)
Cliff	V-48	51,740
Granite	S-147	24,940*
Hirshey-Lucky Strike	S-289	5,545
Ramsay-Rutherford	V-5	5,375
Monarch, Jewel	A-38, 37	4,932
Primrose	S-214	4,000
Gilpatrick	S-253	3,405*
Crown Point	S-227	3,125*
Mineral King	S-156	2,783*
Gold King	V-63	1,997
Skeen-Lechner	S-225	1,796*
East Point	S-226	1,725*
Heaston-Oracle	S-255	1,274*
Big Four	V-28	846
Grant Lake	S-231	792*
Cameron-Johnson	V-62	585
Ronan & James	S-256	557*
Portage Bay	S-168	490*
Hirshey & Carlson	S-292	408*
Little Giant	V-21	367
Hercules	V-27	269
Tomboy Ledge	S-162	219*
Downing	S-294	150*
Nearhouse	S-299	102
Alaska Homestake	A-30	83*
Lansing	S-163	81
Rough & Tough	V-64	76
Falls Creek	S-224	65
Seward Bonanza	S-221	65
Culross Mine	S-102	62

[1] Refers to map sheet; localities described in Jansons and others (1984).
* Records of production available.

TABLE 3.--Copper mines with production records from the Prince William Sound region, Alaska (Data from table by Fellows, no date, USGS and BOM records)

Mines	Locality No. [1]	Tons produced or sold	Cu metal(lbs)
Beatson Copper Co.	S-17	5,992,941	182,600,000
Ellamar Mining Co.	C-91	301,835	15,761,337*
Schlosser Mine	C-66	21,434	4,160,820
Midas Mine	V-35	49,350	3,385,680*
Threeman Mine	C-73	6,196.5	1,159,660*
Blackbird Properties	S-19		
Latouche Mining Co.		29,209*	52,000*
Blackbird Mine		5,150*	547,118*
Girdwood, Barrack		600*	72,510*
Fidalgo Copper Co.	C-63	2,747	360,376
Reynolds-Alaska (Boulder Bay)	C-87	2,850	215,000
Duchess Claim (Reynolds-Alaska)	S-2, 4	1,850	215,000
South Landlocked Bay Mining Co.	C-70	928	74,240
Standard Copper Co.	C-77	1,100	32,000
Dickey Copper Co. (Irish Cove)	C-65	293*	29,346*
Harry Moore Prospect	S-47	20	1,452
Alaska-Pioneer-Sourdough	C-72	6	720
Knight Island Copper Mining Co.	S-52	1	240
Hogan Bay Properties	S-26		
Patten Cooperating Co.		0.3	57
Happy Jack Mining and Development		+	
Copper Queen Mine		+	
Alaska Commercial Co.	C-75	70	
Pandora Claim	S-65	+	
Latouche Is. Copper Mining Co. Ltd.	S-7	+	
Knight Is. Consolidated Copper Co.	S-61	+	
Copper Coin (Russell Ball Copper Co.)	S-50	+	
Buckeye Claim (Landlocked Bay)	C-69	+	
Duke Claim	S-3	+	

1 Refers to map sheet; localities described in Jansons and others (1984).
* Estimated.
\+ Indicated in publications as having shipped some ore.

TABLE 4.--Identified lode gold resources at larger prospects, Chugach National Forest area, Alaska

Prospect	Locality No. [1]	Resources (tons)
Golden Eagle	S-129	21,000
Crown Point	S-227	15,000
Portage Bay	S-168	10,000
Skeon-Lechner	S-225	10,000
Culross Mine	S-102	9,800
Seward Bonanza	S-221	7,400
Nearhouse	S-299	7,000
East Point	S-226	3,700
Summit Vein	S-254	3,400
Monarch, Jewel	A-38, A-37	3,100
Donohue	V-8	2,500
Hirshey-Lucky Strike	S-289	2,000
Gilpatrick	S-253	2,000
Granite	S-147	1,900
Cameron-Johnson	V-62	1,800
Primrose	S-214	1,300
Brewer-Alaska	S-205	1,100
Nugget	S-136	900
Mayfield	V-67	600
Lansing	S-163	500
Mineral King	S-156	500
Mountain	S-133	500
Sweepstake	S-140	500
Hirshey & Carlson	S-292	500
Hercules	V-27	450
Shall	S-266	420
Minnie	V-39	400
Bahrenberg	A-40	340
Tomboy Ledge	S-162	300
Grant Lake	S-231	270
McMillan	S-249	250
Ivanhoe	V-60	200
Total		109,630

1 Refers to map sheet; localities described in Jansons and others (1984).

TABLE 5.—Placer gold resources at major drainages, Chugach National Forest area, Alaska

Drainage	Locality No.[1]	Minimum estimated gravel resource (yd^3)
Sixmile Creek	P-72	3,000,000
Canyon-Mills Creek	P-76, P-79	2,000,000
Resurrection-Palmer Creeks	P-90	2,000,000
Crow Creek	P-93	1,000,000
Lynx Creek	P-61	1,000,000
Bear Creek	P-91	1,000,000
Silvertip Creek	P-75	1,000,000
Quartz Creek	P-81	750,000
Total		11,750,000

1 Refers to map sheet; localities described in Jansons and others (1984).

TABLE 6.—Identified copper resources at major copper deposits, Chugach National Forest area, Alaska

Deposit	Locality No.[1]	Tons	Cu (%)
Volcanic-hosted deposits (over 1,000 tons identified resources)			
Threeman	C-73	1,900,000	1.0
Rua Cove	S-67	1,325,000	1.2
Pandora	S-65	85,000	1.3
Fidalgo	C-63	45,000	.3
Cordova Copper Co.	C-34	18,000	.6
Hemple	C-74	6,300	1.3
Copper Coin	S-50	5,900	2.4
Galena Bay	C-83	5,800	7.9
Standard Copper	C-77	4,300	2.8
Ibeck	C-17	3,900	2.8
Reynolds-Alaska, Landlocked Bay	C-79	3,000	4.6
Seattle-Alaska	BS-2	2,900	3.0
Jonesy	S-59	1,300	3.3
Chisna	C-69	1,200	.3
Subtotal		3,407,600	
Sediment-hosted deposits			
Beatson	S-17	Probably large	(no data)
Duchess	S-4	1,700,000	1.2
Ellamar	C-91	536,000	.6
Duke	S-3	269,000	1.3
Schlosser	C-66	224,000	3.2
Midas	V-35	62,000	1.6
Four-in-One	A-8	33,500	.2
Scott Glacier	C-16	19,000	1.1
Subtotal		2,843,500	
TOTAL		6,251,100	

1 Refers to map sheet; localities described in Jansons and others (1984).

Table 7. Criteria used to define resource areas shown on mineral resource potential map.

Area		Commodities present	Deposit type and ranking	Mine	Prospect	Observed resource occurrence	Stream-sediment sample	Pan concentrate sample	Rock sample	Bulk placer sample	Observed ore minerals in concentrate	Type host rock	Host structure	Recognized isotopic signature	Aeromagnetic host rock definition	Gravity association
1	A	Au (Ag, Cu, Mo, As)	Vein (1)	3	3	0	ND	ND	Au, Ag, Cu, Mo, As	NA	ND	P, S	S	ND	NA	NA
		Au	Placer [1]	1	2	0	ND	ND	NA	X	g, gn	NA	NA	NA	NA	NA
	B	Au	Placer [2]	2	1	1	Zn, Sb, B	[illegible]	NA	X	[illegible]	NA	NA	NA	NA	NA
2	A	Au (Ag)	Vein (1)	1	15	2	Zn	W, Sb, Mo	Au, Ag	NA	gn, as, sch, g	F, S	S	MH	NA	NA
		Au	Placer	5	10	1		Au, As, Pb	NA	ND		NA	NA	NA	NA	NA
	B	Ag	Vein	0	0	3	NC	Ag	Ag	X	g, gn, sch	S	S	ND	NA	NA
	C	Au (Ag)	Vein (1)	3	18	0	Sb, Au, Ag, Zn	Sb, Au, Ag, Pb	Au, Ag	X	gn, sch, as, g	F, S	Fr	ND	NA	NA
		Au	Placer [1]	5	3	1			NA	X		NA	NA	NA	NA	NA
	D	Au (Ag)	Vein (3)	1	0	0	ND	ND	Au, Ag	NA	ND	S	ND	ND	NA	NA
	E	Cu (Zn, Pb)	Massive Sulfide Δ	0	1	0	Zn	Au, Ag	Cu, Zn, Pb	X	gn, as, cp	S	S	MH	NA	NA
		Au	Placer [1]	1	1	0		Sb	NA		g, sch	NA	NA	NA	NA	NA
	F	Au (Ag)	Vein (2)	0	7	7	Ag, As, Sn	W, Mo, Ag	Au, Ag	X	gn, as, cp	F, S	S, Fr	MH	NA	NA
		Au	Placer [1]	5	8	3	Zn, Au	Au, Pb	NA	X	sch, mn, g	NA	NA	NA	NA	NA
3	A	Au (Ag)	Vein (1)	5	2	1	Ba	Au, Ag, As	Au, Ag	X	gn, as, cp	S	S	MH	NA	NA
		Au	Placer [1]	1	2	0			NA	X	mn, sch, g	NA	NA	NA	NA	NA
	B	Au (Ag, As)	Vein (1)	1	2	1	Ba, B	Ba, B	Au, Ag, As	X	ND	S	S	ND	NA	NA
	C	Au (Ag, As)	Vein (2)	0	3	2	ND	ND	Au, Ag, As	NA	ND	S	S	ND	NA	NA
	D	Sb	Vein	0	1	1	ND	ND	Sb	NA	gn, cp, g	F	Fr	ND	NA	NA
	E	Au (Ag)	Vein (2)	0	7	7	Cd, Ag, B	[illegible]	Au, Ag	X	gn, as, cp, mn, sp, ba, g	S	S, Fr	ND	NA	NA
		Au	Placer [1]	2	3	5			NA	X		NA	NA	NA	NA	NA
4		Cu	Massive Sulfide Δ	0	0	0	Cr, Zn	NC	Cr, Ni	NA	cp	M	ND	ND	AE	GE
		(Cr, Ni)	Disseminated	0	0	12		NC	Cu, Zn	NA		M	NA	ND	AE	GE
5	A	Au (Ag, As)	Vein (1)	2	0	2	Cd, Ag, As, Sb	Zn, W, Au, Ag, Pb	Au, Ag	X	gn, as, sch, g	P, S	S, Fr	ND	NA	NA
		Au	Placer	0	0	0			NA	X		NA	NA	NA	NA	NA
	B	Au (Ag)	Vein (1)	1	0	4	As, Sb, Ba	As, W, Cu, Pb	Au, Ag	X	as, cp, sch	P, F, S	Fr	ND	NA	NA
		Mo (W)	Disseminated	0	0	2			Mo	NA		P	Fr	ND	NA	NA
		Au	Placer	0	0	1			NA	X		NA	NA	NA	NA	NA
	C	Au (Ag)	Vein	0	4	9	As, Sb, Ag	[illegible]	As, Ag	X	[illegible]	S	Fr	ND	NA	NA
		(Sb)	Vein	0	0	1	Cd, Pb, Zn		ND	NA		S	ND	ND	NA	NA
6	A	(Au, Cu, Pb, Ag, Zn)	Vein	0	0	3	Mo, As, Sb, Pb	[illegible]	ND	X	[illegible]	F, S	S	ND	NA	NA
	B	Au (Ag)	Vein (2)	0	1	0	As, Sb	Zn	As, Mo, Zn	X	gn, as, cp	F, S	S	ND	NA	NA
		Au	Placer [2]	0	1	4			NA	X	g, sch	NA	NA	NA	NA	NA
7		Au	Placer [3]	0	1	1	Cd, As	Ag, As, Au, Mo	NA	ND	[illegible]	NA	NA	NA	NA	NA
8		Au (Ag, Cu, Zn, Sb)	Vein (3)	0	3	2	[illegible]	[illegible]	As, Sb	X	[illegible]	P, F, S	ND	ND	NA	NA
9	A	Au (Ag)	Vein (2)	0	14	0	Ag, As, Cd, Cr	Ag, Au, W	Au, Ag	X	gn, as, sch, g	S, F	Fr	ND	NA	NA
		Au	Placer	0	1	0			NA	X		NA	NA	NA	NA	NA
	B	Au (Ag)	Vein (1)	3	5	1	ND	ND	Au, As	X	ND	P, S	S	MH	NA	NA
	C	Au (Ag)	Vein (2)	0	5	4	Sb, Ag	As, Au, Zn, Pb, W, Mn, Sb, B	Au, Ag	X	gn, cp, as	P, F, S	Fr	ND	NA	NA
		Au	Placer [3]	0	0	6			NA	X	g, sch	NA	NA	NA	NA	NA
10		Au (Ag)	Vein	1	1	0	NC	NC	[illegible]	NA	sch	M, S	S	ND	AE	NA
11		(Au, Ag, As)	Vein (3)	0	1	1	Sb	[illegible]	Au, Ag	NA	[illegible]	S	S, Fr	ND	NA	NA
12	A	Cu (Zn, Ni)	Massive Sulfide Δ	0	14	1	[illegible]	Co, Cu	[illegible]	NA	as, cp	M	S	MH	AE	GE
	B	Cu (Zn)	Massive Sulfide Δ	0	2	0	Ni, Cr, Cu, Co, Zn	NC	Cu, Zn	NA	cp	M	S	MH	AE	GE
	C	Cu (Zn)	Massive Sulfide Δ	0	9	0	[illegible]	Cu	Cu, Zn, Ni, Cr	NA	cp	M, S	S	MH	AE	GE
	D	Cu (Zn)	Massive Sulfide Δ	0	8	0	[illegible]	NC	Cu, Zn	NA	cp	M	S	MH	AE	GE
13	A	Mn	Bedded	0	0	1	Cr	NC	Mn	NA	NM	S	NA	ND	AE	NA
	B	Au	Vein (3)	0	1	0	Mn, Co, Zn	Zn	Au	NA	cp	S	S	ND	NA	NA
		Cu (Zn)	Massive Sulfide Δ	0	1	0			Cu, Zn	NA		M, S	S	ND	AE	ND
14	A	Cu (Zn, Ag, Au)	Massive Sulfide Δ	2	6	0	[illegible]	[illegible]	Cu, Pb, Zn	NA	as, cp, sl	S	S	MH	AE	ND
	B	Cu (Zn, Ag)	Massive Sulfide	0	1	0	Mn, Pb, Zn	NC	Cu	NA	NM	S	S	MH	AE	ND
	C	Cu (Zn, Ag)	Massive Sulfide Δ	0	0	1	ND	ND	Cu, Zn, Ag	NA	ND	S	NA	MH	AE	ND
	D	Cu (Zn, Ag)	Massive Sulfide Δ	0	3	0	Cd	Cu	Cu, Zn, Ag	NA	gn, as, co, g	S	S, Fr	MH	AE	ND
15		(W)	Vein	0	0	2	NC	NC	W	NA	NM	P	Fr	ND	AE	NA
16	A	Ni (Co, Cu)	[illegible]	0	1	0	Ag, As	[illegible]	Cu, Ni, Cr	NA	[illegible]	P	S	ND	NA	ND
	B	Zn, Pb, (Cu, Ag)	Vein	0	2	5	As, Ag, Sb	[illegible]	[illegible]	NA	[illegible]	S, M	S	ND	NA	NA
	C	Cu (Zn, Ag, Pb, Pt)	Vein	0	9	3	Cd, Ag, As, Pb, Zn	[illegible]	Cu, Zn, Ag	X	as, cp, sl	S, P, F	S	ND	NA	NA
		Au	Placer	0	1	0			NA	X	ba	NA	NA	NA	NA	NA
17		Cu (Co, Ag)	Massive Sulfide Δ	0	5	3	NC	NC	Cu, Co, Ag, Zn	NA	NM	M	S	MH	AE	GE
18	A	Cu (Zn, Ag, Au, Co)	Massive Sulfide Δ	2	17	0	Mn, As, Cu, Co, Zn	Cu	Cu, Zn, Ag	NA	as, cp	M	S	ND	AE	ND
	B	Cu (Zn, Ag, Au)	Massive Sulfide Δ	1	0	0	Cr, Co, Zn	NC	Cu	NA	ND	S	S	MH	AE	ND
	C	Cu (Ag, Au)	Massive Sulfide Δ	0	8	0	Mn, Cd, Co, Zn	NC	Cu, Zn, Ag	NA	as, cp	M	S	ND	AE	ND
	D	(Au)	(3)	0	0	0	Ag, As	Mo, Ag	ND	ND	gn, as, sch, g	ND	ND	ND	NA	NA
	E	Cu (Zn, Au, Ag, Pb)	Massive Sulfide Δ	2	6	0	[illegible]	NC	Cu, Zn, Ag	NA	cp, sch	S, M	S	ND	NA	ND
19	A	Cu (Au, Ag, Zn, Pb)	Massive Sulfide Δ	1	5	7	[illegible]	[illegible]	Cu, Ag, Zn	X	[illegible]	S, M	S	ND	AE	GE
	B	Au (Ag)	Vein (3)	0	2	0	Ag, Cu	Co, As, Au, Ag, Cu, Pb	ND	X	gn, as, cp	S	S, Fr	ND	NA	NA
		Au	Placer [2]	0	1	8			NA	X	g, sch	NA	NA	NA	NA	NA
20		Cu	Vein	0	3	0	Mo, Mn, As, Ag, Cr, Pb	Th, Mo	Cu	NA	as, sch	P, S	ND	ND	NA	NA
		(Th, U)		0	0	0			ND	ND	th, mg	P	ND	ND	NA	NA
21		Cu (Zn, Ag)	Massive Sulfide Δ	0	30	1	[illegible]	[illegible]	Cu, Mn	NA	[illegible]	S, M	S	ND	AE	ND
22		Au (Ag)	Vein (3)	0	4	0	[illegible]	[illegible]	Au	NA	gn, as, sch, g	S	Fr	ND	NA	NA
23		Coal		1	5	0	NA	NA	NA	NA	NA	S	NA	NA	NA	ND
24		Oil/Gas		1	0	0	NA	NA	NA	NA	NA	S	NA	NA	NA	GE
		(Zn, Ba)		0	0	0	[illegible]	[illegible]	ND	NA	cp, sl, ba	ND	ND	ND	NA	NA
25		(Zn, Ba)		0	0	0	[illegible]	[illegible]	ND	NA	cp, sl, ba	ND	ND	ND	NA	NA

Footnotes on following page

[1]Byproducts are shown in parentheses.

[2]Ranking of areas (see discussion in text): 1, most favorable; 2, moderately favorable; 3, least favorable. Deposit type: 1, lode gold; $\boxed{2}$, placer gold; 3, massive sulfide.

[3]Value shown is number of mines, prospects, or occurrences within each area. Mine - any economic concentration of a metallic or non-metallic resource that had recorded production values or is presently producing. Includes placer gold mines and oil wells with past production. Prospect - metallic or non-metallic resource of such concentration and extent that exploration and assessment activity was performed; no known production. Occurrence - any anomalous concentration of useful minerals that may warrant further exploration.

[4]ND, not determined; NC, no anomalous concentrations; NA, not applicable.

[5]X indicates the presence of gold in the sample; ND, not determined; NA, not applicable.

[6]ND, not determined; NM, no ore minerals observed; NA, not applicable; g, gold; sch, scheelite; as, arsenopyrite; cp, chalcopyrite; min, minium; th, thorite; mo, monazite; sl, sphalerite; ba, barite; gn, galena.

[7]P, igneous pluton; S, sedimentary rock; F, felsic igneous dike; M, mafic volcanic rock and associated ultramafic rocks; ND, not determined; NA, not applicable.

[8]S, shear; FR, fracture; ND, not determined; NA, not applicable.

[9]MH indicates metamorphic-hydrothermal processes; ND, not determined; NA, not applicable.

[10]AE indicates aeromagnetic expression of host rock; NA, not applicable.

[11]GE indicates gravity anomaly association; ND, not determined; NA, not applicable.

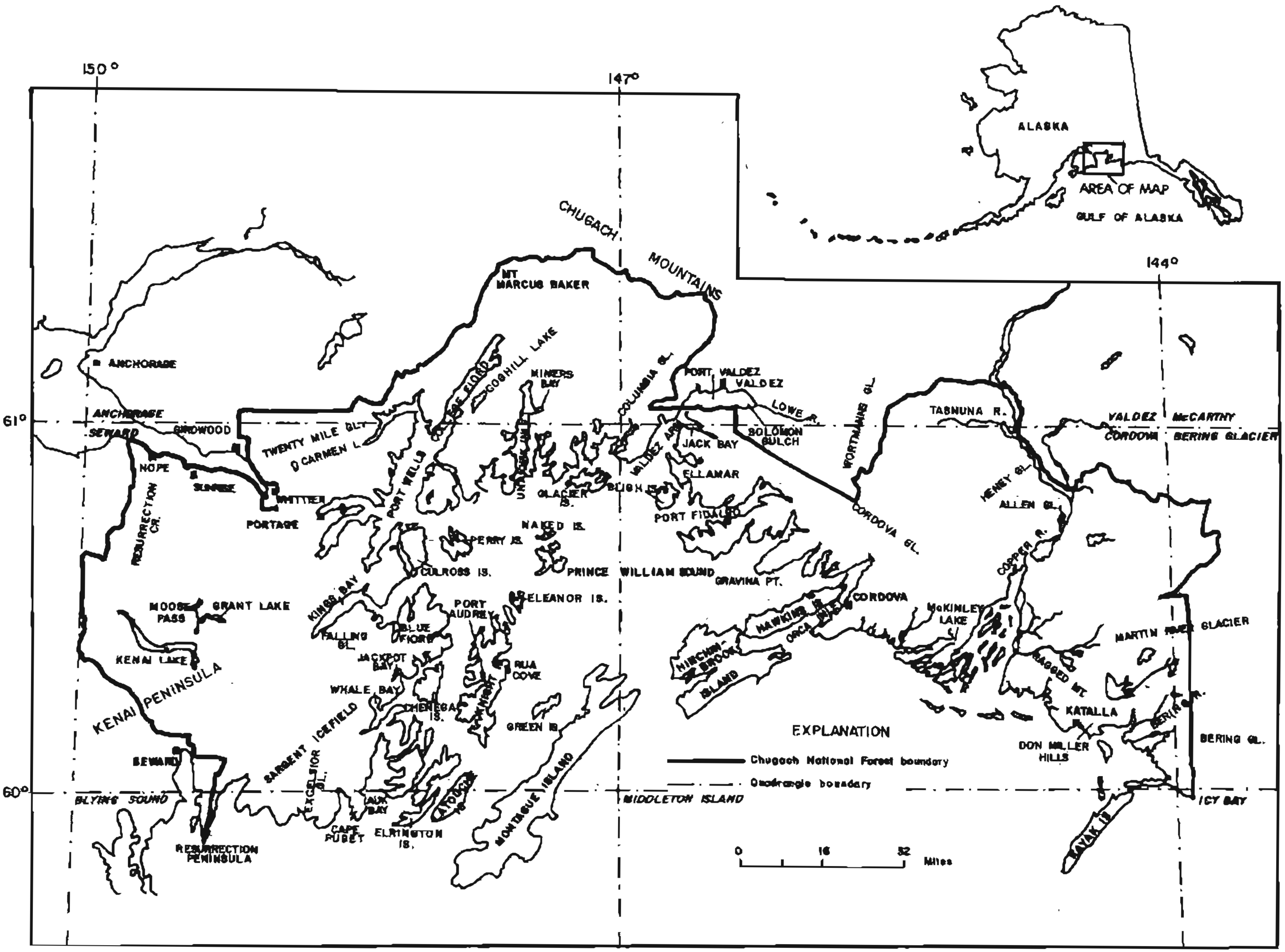

Figure 1.--Location and geographic setting of the Chugach National Forest, Alaska.

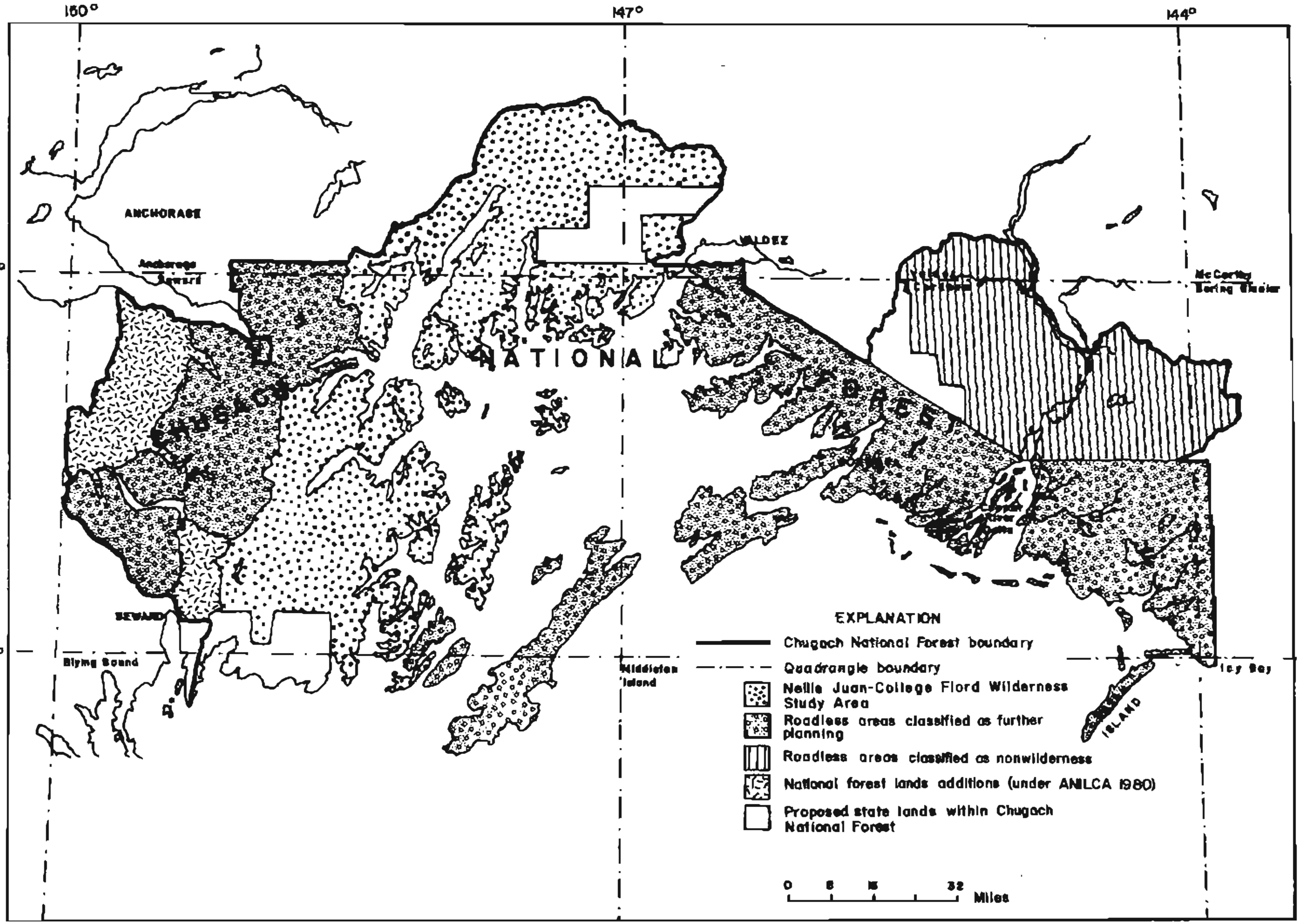

Figure 2.—Chugach National Forest land status as of December 1982.

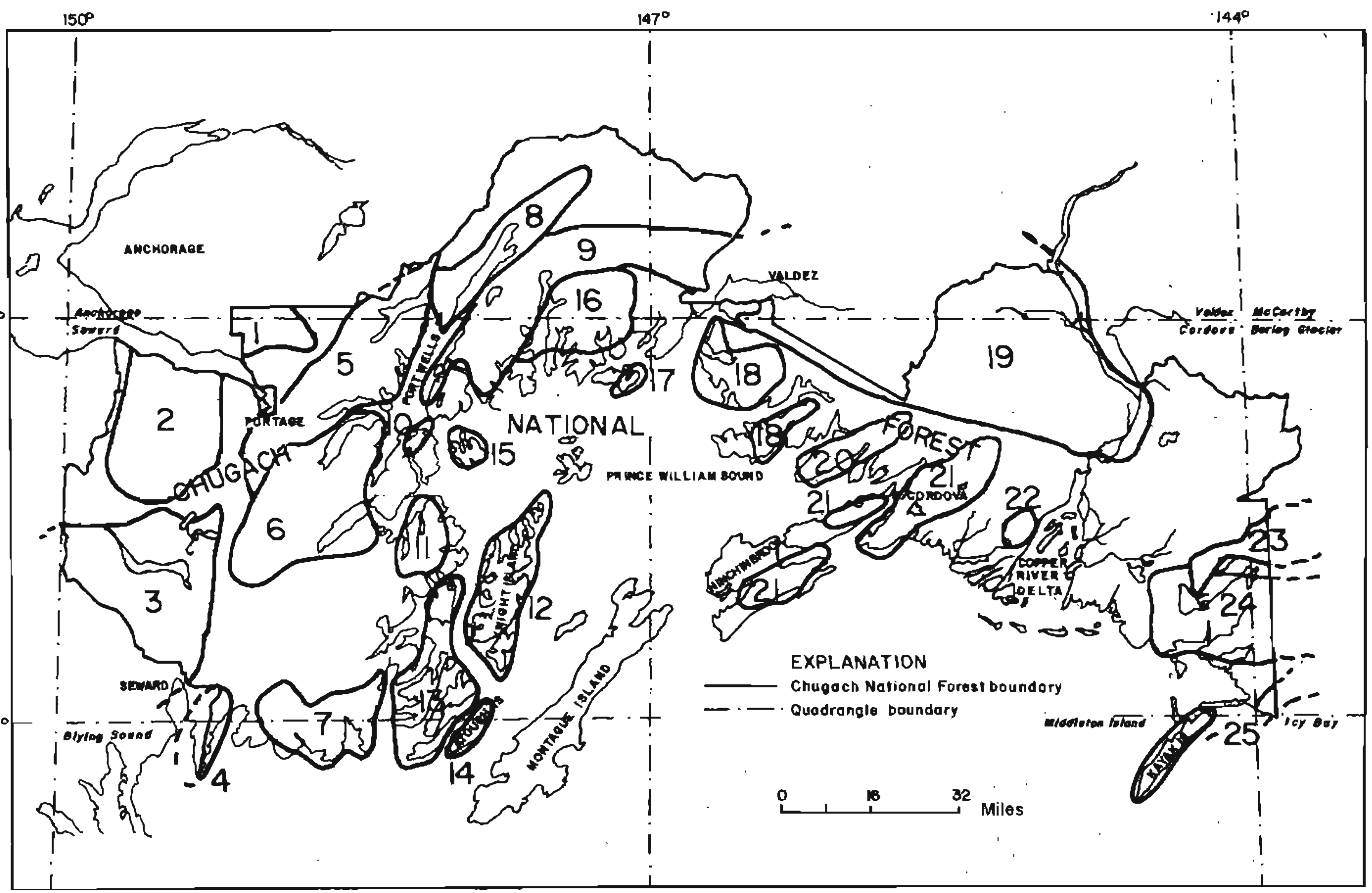

Figure 3.--Areas of resource potential in the Chugach National Forest. Some areas of resource potential are further subdivided on accompanying large map sheet. Numbers refer to table 7 and discussion in text.