CIRC. 1046

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The Alaska Mineral Resource Assessment Program: Background Information to Accompany Folio of Geologic and Resource Maps of the Ugashik, Bristol Bay, and Western Part of Karluk Quadrangles, Alaska

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The Alaska Mineral Resource Assessment Program: Background Information to Accompany Folio of Geologic and Resource Maps of the Ugashik, Bristol Bay, and Western Part of Karluk Quadrangles, Alaska

By R.L. DETTERMAN, J.E. CASE, S.E. CHURCH, J.G. FRISKEN, F.H. WILSON, and M.E. YOUNT

U.S. GEOLOGICAL SURVEY CIRCULAR 1046

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

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By R.L. Detterman, J.E. Case, S.E. Church, J.G. Frisken, F.H. Wilson, *and* M.E. Yount

Abstract

The Ugashik, Bristol Bay, and western part of Karluk quadrangles (1:250,000) are a part of the Alaska Peninsula in southwestern Alaska. This circular, in conjunction with a companion folio of MF–series maps, two I-series geologic maps, and three bulletins, represents the results of integrated field and laboratory studies on the geology, geophysics, geochemistry, paleontology, geochronology, and mineral resources of the quadrangles. These studies were undertaken to provide a modern assessment of the mineral and energy resources of the quadrangles. Each map contains descriptive text, explanatory material, tables, diagrams, and pertinent references. This circular provides background information for the mineral resource assessment map (MF–1539–I) and integrates the component MF– and I–series maps. A comprehensive bibliography cites both specific and general references relevant to the geology and resources of the quadrangles.

INTRODUCTION

Purpose and Scope

This circular and the companion folio of related maps are a part of a series of U.S. Geological Survey reports designed to provide an inventory of Alaska's mineral resources. The reports furnish information for mineral and energy policy-making decisions by Federal and State governments, native corporations, and industry concerning the future use of Alaskan land and resources. This report and the folio of maps were prepared under the auspices of the Alaska Mineral Resource Assessment Program (AMRAP) by a multidisciplinary team of earth scientists. Field and laboratory studies were conducted between 1979 and 1982.

The folio consists of nine maps that provide information on the geology, geochemistry, geophysics, geochronology, paleontology, and mineral resources of the quadrangles (table 1). The primary intent of the folio and circular is to furnish mineral and energy resource data for land-use planning and long-term national resource policy decisions. Additional aims are to determine the time and type of mineral emplacement and to increase the geologic knowledge of an actively accreting continental margin and volcanic arc.

This circular contains references relevant to the Ugasik, Bristol Bay, and western part of Karluk quadrangles. Individual maps of the folio contain additional references applicable to their subject matter.

In addition to the folio maps, which are printed in black and white, two companion multicolor Miscellaneous Geologic Investigations Series Maps (Detterman and others, 1987a, b) have been published. Topical studies conducted during the investigations also resulted in three bulletins (Allaway and others, 1984; Riehle and others, 1987; Church and others, 1989b), one masters thesis (Allaway, 1982), two circular articles (Detra and others, 1981; Allaway and Miller, 1984), and five open-file reports (Detterman and others, 1980, 1981b, 1982; Wilson, 1982; Wilson and O'Leary, 1986).

Geography and Access

The Ugashik, Bristol Bay, and western part of the Karluk quadrangles encompass about 12,670 km^2 (4,892 mi^2) on the Alaska Peninsula (figs. 1 and 2).

The study area is bounded by 57° and 58° N. lat. and by 155° and 158°41′ W. long. (fig. 2). The Pacific

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Table 1. Component maps of the Ugashik, Bristol Bay, and western part of Karluk quadrangles, Alaska

U.S. Geological Survey Miscellaneous Field Studies Map MF–1539	Subject
–A (Detterman and others, 1983)	General geology
–B (Detterman and others, 1985)	Fossil locality map, checklists, and stratigraphic sections
–C (Wilson and O'Leary, 1986)	Bedrock geochemistry
–D (Case and others, 1988)	Aeromagnetic map and interpretation
–E (Wilson and Shew, 1988)	Geochronology and major-element geochemistry
–F (Church and others, 1988)	Geochemical distribution in stream sediments
–G (Frisken and others, 1988a)	Geochemical distribution in pan concentrates
–H (Frisken and others, 1988b)	Mineralogy of pan concentrates
–I (Church and others, 1989a)	Mineral and energy resource assessment map

Ocean side of the peninsula is dominated by the rugged mountains of the Aleutian Range, which rise abruptly from the sea and are cut by numerous fjords and bays. The highest peaks are in the southeastern part of the map area, where the Quaternary volcanoes Mount Kialagvik, Mount Chiginagak, and Mount Yantarni dominate the skyline. Mount Chiginagak (2,120 m) is the highest peak in the area. Small valley glaciers radiate from these volcanoes, and a small (50 km^2) ice field lies east of Mount Kialagvik. From Wide Bay to Puale Bay the mountains gradually decrease in height. North of Puale Bay they merge with the Kejulik Mountains of the Mount Katmai quadrangle. Mount Peulik (1,475 m), a Holocene stratovolcano, dominates the west side of this northern segment of mountains.

A broad, low, coastal plain west of the Aleutian Range slopes gradually northwestward from the mountains to Bristol Bay. Most of the low, rolling hills that dot the plain are remnants of glacial moraines that rarely exceed 100 m in elevation. Ash-flow tuff from Aniakchak Crater to the south covers the southwestern part of the map area, burying morainal ridges. The ash-flow-tuff plain, extending nearly 20 km into the area, was formed by a major eruption of Aniakchak Crater about 3,400 years ago (Miller and Smith, 1977, 1987).

Becharof Lake (1,175 km^2), the second largest lake in Alaska, is mostly within the study area. Other large lakes include Upper Ugashik, Lower Ugashik, and Mother Goose. Hundreds of small glacial lakes and ponds dot the Bristol Bay Lowland. The large lakes are all confined behind terminal moraines of Pleistocene glaciers and are remnants of formerly much larger lakes (Detterman and others, 1987b). Becharof Lake and the Ugashik Lakes are less than 5 m above modern sea level, and most of the numerous other lakes and ponds are within 30 m of sea level.

Three major river systems, the Ugashik, King Salmon, and Dog Salmon, drain the western part of the map area. All three empty into Ugashik Bay after following meandering courses across a nearly flat, former lakebed deposit (Detterman and others, 1987b). The three rivers combined drain about two-thirds of the map area and, even though they are low-gradient streams, carry a large volume of water. Another major west-flowing stream, the Kejulik River, flows into Becharof Lake and drains the northeastern part of the map area. The Egegik River, north of the map area, runs from Becharof Lake to Bristol Bay. Streams draining into the Pacific Ocean are all short with steep gradients.

Only two permanent villages exist in the map area: Pilot Point with a population of 66, and Ugashik with 13 residents (year-round population from 1980 census). Populations of both towns increase markedly during the summer months owing to commercial fishing. Numerous hunting and fishing camps near the major lakes and rivers are occupied seasonally. At the present time (1988) there are no settlements on the Pacific Ocean side of the peninsula within the map area. The former village of Kanatak, at the head of Portage Bay, has been abandoned for many years.

Access to the area is only by aircraft or boat. Moderate-sized twin-engine aircraft can land at Pilot Point and near Painter Creek, but other landing areas are usable only by smaller aircraft. Most of the hunting and fishing camps maintain small, private airstrips. There are no public roads within the map area. A few miles of

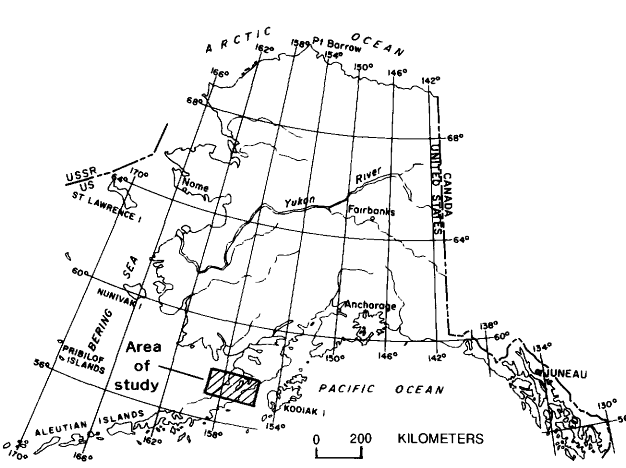

Figure 1. Index map showing location of study area.

gravel roads are present around Pilot Point and near the camps. Most were constructed during exploration for petroleum.

Summary of Mineral and Petroleum Investigations

The Ugashik and western part of Karluk quadrangles have been the site of intermittent exploration for minerals and petroleum since the early 1900's, but no economic deposits have been located. The earliest authenticated exploration for minerals occurred in 1915, when placer gold claims were established at Cape Kubugakli (fig. 3). These claims were reported to have produced about 160 ounces of gold (Smith, 1925). Nothing is known concerning more recent activity on these claims, but mining equipment was found when the site was visited in 1977. Copper ore containing minor amounts of gold and silver was reportedly found near the head of Puale Bay in 1920 (Berg and Cobb, 1967). Our investigations failed to locate this deposit.

Recent mineral exploration was confined to the southern part of the area. Bear Creek Mining Company did some diamond drilling in 1977 and 1978 on a molybdenum porphyry prospect (Mike prospect) in the mountains near the head of Painter Creek. During this same period they discovered a gold, silver, and copper prospect (Rex prospect) in the mountains between Volcano Creek and Dog Salmon River.

Exploration for petroleum in the Ugashik and Karluk quadrangles has been much more intense than that for minerals, probably because the presence of oil seeps and the exposure of a thick sedimentary rock section. The first wells in the area were drilled between 1902 and 1904 near oil seeps on Oil Creek (Martin, 1904, 1905; Capps, 1923; Smith, 1926). The locations of these wells and nearly all others are shown on the generalized geologic map prepared by Detterman and others (1983). Since the publication of that map, AMOCO Production Company completed the drilling of the Becharof #1 well in 1985. Data for exploratory wells drilled in the map area are listed in table 2.

Despite the presence of oil and gas seeps in the area, exploration to date has yielded only a modest show of oil. Diagenetic alteration of the abundant volcanic debris in the sediments has greatly reduced the porosity and permeability of these rocks. Thus, rocks with good reservoir characteristics have not been encountered in drilling. Most of the oil and gas seeps are located near faults that probably provide a pathway to the surface.

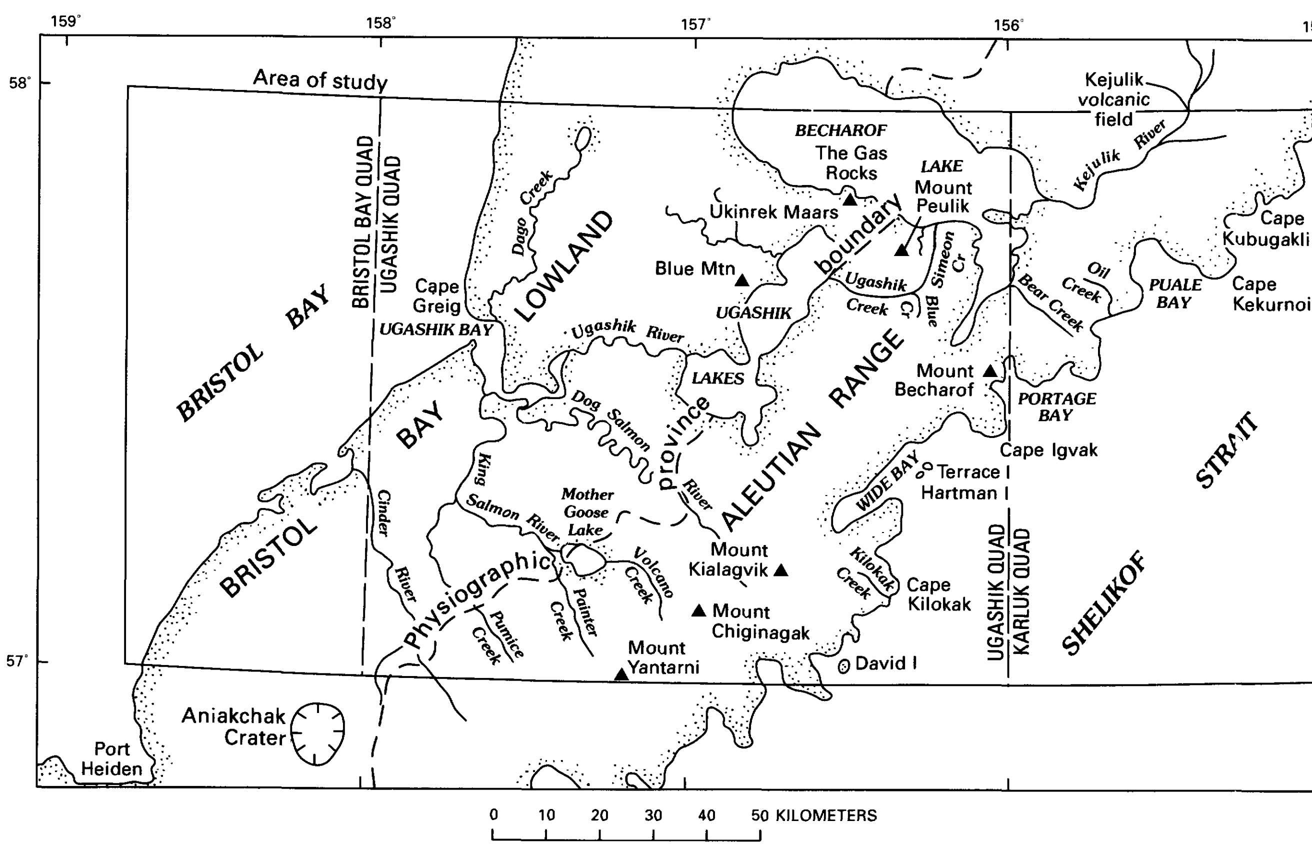

Figure 2. Area of study showing geographic features and physiographic provinces.

Two areas of oil seeps are located within the quadrangles. The main area is along the crest of the Bear Creek anticline where it crosses Bear Creek and Oil Creek. These seeps were reported as early as 1869 (Capps, 1923). The oil is seeping from rocks of the Shelikof Formation and has formed areas of tarlike residue on the surface. A second area of seeps is southeast of Mount Peulik, near the crest of the Ugashik anticline in an area known as Pearl Creek dome. Patches of bright-green, fresh oil can be seen on Ugashik Creek and Blue Creek. Areas of residue have formed where the oil collected and was exposed to the air for long periods. These mounds of tarlike residue were used to fuel boilers during early drilling operations. One additional area of seepage was found along Simeon Creek during the current investigation. All seeps on the Ugashik anticline are from the Naknek Formation.

In addition to seepages of oil, there are also seepages of gas in the region, some of which are associated with oil seeps and are of obvious biogenic origin. Other large seeps, such as around The Gas Rocks, are of inorganic origin. Gas collected and analyzed from The Gas Rocks seeps is about 98 percent carbon dioxide (Barnes and McCoy, 1979). The location and analyses of all oil and gas samples from the area were reported by Blasko (1976).

Acknowledgments

Geologic investigations in the Ugashik, Bristol Bay, and western part of Karluk quadrangles were facilitated greatly by the efforts of many geologists, both from the U.S. Geological Survey and private industry, whose many contributions are greatly appreciated. The work of most visiting scientists, short-term workers, and laboratory specialists is acknowledged on individual maps in the folio. The contributions of some specialists, although not mentioned specifically on the maps, were of great benefit to the project. Among those to whom special tribute is due are J.A. Wolfe, R.W. Imlay, J.W. Miller, and C.D. Blome of the U.S. Geological Survey, and John Calloman of the University of London, paleontologists whose identifications of many collections of invertebrate and plant fossils helped in determining the stratigraphic succession of the sedimentary units. J.R. Riehle, M.L. Silberman, and Nora Shew made significant contributions to our understanding of the complex eruption history of the volcanoes as well as of the numerous intrusive events.

Work in such a remote project area would be impossible without the willing assistance of local residents. Among those who were of great service to the project were the people at Painter Creek Lodge, especially J.W. Smith, who provided the project with food and

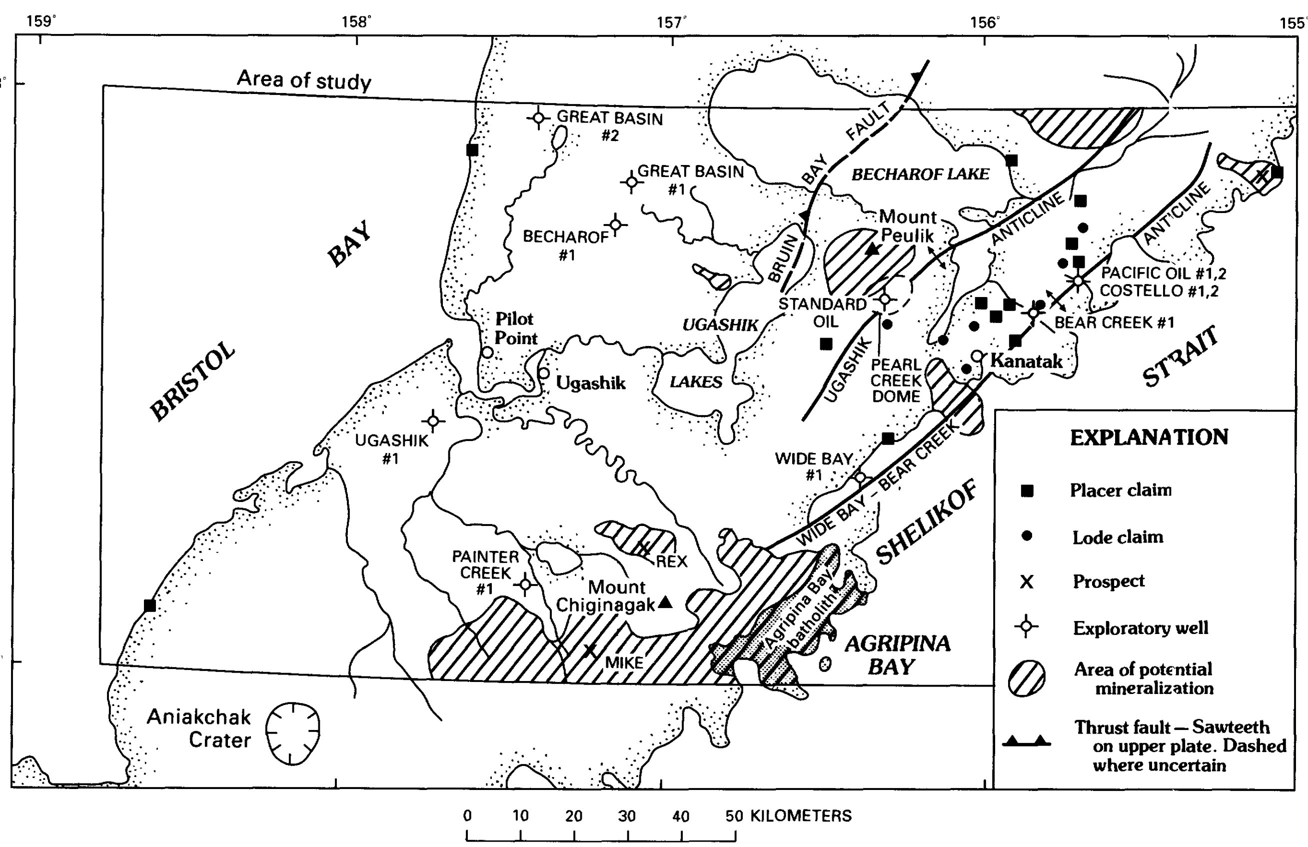

Figure 3. Area of study showing claims, prospects, exploratory wells, and areas of potential mineralization.

Table 2. Data on exploratory wells drilled for petroleum in the Ugashik and western part of Karluk quadrangles

[U., Upper; Do. (do.), ditto]

Well	Company	Year completed	Location	Depth (in feet)	Formation at total depth
Pacific Oil #1	Pacific Oil & Commercial	1903	NW¼ sec. 3, T. 29 S., R. 40 W.	1,421	Shelikof
Pacific Oil #2	do.	1904	SE¼ sec. 3, T. 29 S., R. 40 W.	1,542	Do.
Costello #1	J.H. Costello	1903	NW¼ sec. 10, T. 29 S., R. 40 W.	728	Do.
Costello #2	do.	1904	SE¼ sec. 10, T. 29 S., R. 40 W.	Unknown	Unknown
[1]Lathrop #1	Standard Oil Calif.	1923	SE¼ sec. 17, T. 29 S., R. 43 W.	500	Nakrek
[1]McNally #1	do.	1925	NW¼ sec. 29, T. 29 S., R. 43 W.	510	Do.
Lee #1	do.	1926	SW¼ sec. 20, T. 29 S., R. 43 W.	5,034	Unknown
[2]Finnegan #1	Tidewater Associated	1923	NE¼ sec. 30, T. 29 S., R. 43 W.	560	Nakrek
[2]Alaska #1	do.	1926	SW¼ sec. 20, T. 29 S., R. 43 W.	3,033	Shelikof
[2]Grammer #1	Standard Oil Calif.	1940	SE¼ sec. 10, T. 30 S., R. 41 W.	7,596	Unknown
Bear Creek Unit #1	Humble Oil & Refining	1959	NE¼ sec. 36, T. 29 S., R. 41 W.	14,375	Unnamed U. Triassic
Great Basins #1	General Petroleum Co.	1959	SW¼ sec. 2, T. 27 S., R. 48 W.	11,080	U. Jurassic batholith
Great Basins #2	do.	1959	SE¼ sec. 35, T. 25 S., R. 50 W.	8,865	Do.
Wide Bay #1	Richfield Oil and others	1963	NW¼ sec. 5, T. 33 S., R. 44 W.	12,568	Unnamed U. Triassic
Ugashik #1	Great Basins Oil Co.	1966	SE¼ sec. 8, T. 32 S., R. 52 W.	9,476	Meshik
Painter Creek #1	Cities Service Oil Co.	1967	NW¼ sec. 14, T. 35 S., R. 51 W.	7,912	Shelikof
[2]Becharof/State #1	AMOCO Production Co.	1985	NW¼ sec. 10, T. 28 S., R. 48 W.	9,023	Unknown

[1]General location of Standard Oil wells shown on map 1539-A (Detterman and others, 1983).
[2]Locations not shown on map.

lodging during 1982 and 1983 and aided in many phases of the logistic support that made completion of the project possible. Thanks are due also to the personnel at Ugashik Lake Lodge, who provided similar services in 1979.

Special commendations are due Captain A.C. "Frosty" Frothingham and the crew of the U.S. Geological Survey Research Vessel *Don J. Miller II*, who cheerfully provided us with a base of operations during the 1980 and 1981 field seasons. Our helicopter pilots Lucky Wilson, Richard Rossiter, Edward Svec, and Tom Robbins often flew in adverse weather conditions to take us to our work sites, and we greatly appreciate their skill and professionalism.

GEOLOGIC INVESTIGATIONS

Previous Investigations

The first important generalized contributions to the geology of this area were by Dall and Harris (1892) and Dall (1896). More detailed geologic investigations by Capps (1923), Smith and Baker (1924), and Smith (1925, 1926) were made following the early petroleum exploration at Bear Creek anticline and Pearl Creek dome. Martin (1926) made the first major attempt to correlate the Mesozoic stratigraphic units and show how they relate to the rest of Alaska.

The first modern synthesis of the stratigraphy and structure of the Alaska Peninsula, including part of the Ugashik quadrangle, by Burk (1965) provided the foundation for the present geologic investigation.

Present Investigation

Field work and laboratory analyses for the present study were started in 1979 and completed in 1982. The geologic mapping was at a scale of 1:63,360 (1 inch=1 mile). Both geologic mapping and geochemical sampling were helicopter supported. Mapping of the Mounts Peulik and Chiginagak volcanoes, begun by T.P. Miller during 1974 and 1975, was continued during the present investigation.

This study was a part of the Alaska Mineral Resource Assessment Program (AMRAP) for the Alaska Peninsula and was supervised by R.L. Detterman. Most of the field-mapping personnel were also responsible for a particular topical phase of the work. F.H. Wilson obtained potassium-argon ages for the intrusive and extrusive rocks, J.E. Case was responsible for aeromagnetic interpretations, M.E. Yount and J.R. Riehle mapped the Quaternary volcanic rocks, and J.W. Miller carried out paleontological investigations.

During the course of this study, 1,360 sites were occupied for geologic data, and 585 stream-sediment samples and 569 heavy-mineral pan-concentrate samples were collected to provide a data base for the mineral resource assessment. In addition, 337 bedrock samples were collected at geologic stations for semiquantitative spectrographic analysis; these include both mineralized samples and unmineralized specimens for a background data base. Prior to the present study, only four published potassium-argon (K-Ar) ages were available for the rocks of the Ugashik and western part of Karluk quadrangles (Reed and Lanphere, 1969, 1972; Brockway and others, 1975; Wilson and others, 1981). A total of 57 new K-Ar ages have been added (Wilson and Shew, 1982, 1988). These ages permit a determination of the intrusive and extrusive history of the quadrangles, as well as of the time of mineral emplacement. During the present investigation, 376 collections of fossil megafauna and megaflora were made from sedimentary rocks of the quadrangles; these collections provide a strong framework for relative dating of the sedimentary sequence and form a means of correlating the potassium-argon (K-Ar) ages from associated igneous rocks. Data from these fossil collections were listed by Detterman and others (1985).

Aeromagnetic surveys were flown for the eastern part of the map area by Fugro Geometrics Inc. in 1980 and by Diversified Technical Services, Inc. in 1982 (U.S. Geological Survey, 1984), under contract to the U.S. Geological Survey. The aeromagnetic interpretation map was compiled by Case and others (1988). Scintillometer data were collected at many of the bedrock sample localities (Detterman and others, 1981b, 1982).

DESCRIPTION OF COMPONENT FOLIO MAPS

Geology (MF–1539–A)

The Ugashik, Bristol Bay, and western part of Karluk quadrangles form a transverse segment across the active Aleutian volcanic arc. This map area also includes a segment of a middle Tertiary volcanic arc and plutonic rocks of a still older Mesozoic magmatic arc. The entire area is part of a collage of fragments sutured to Alaska during Jurassic and later time (Jones and others, 1978; Coe and others, 1985). Paleomagnetic data suggest that some Mesozoic rocks of the Alaska Peninsula may have originated a considerable distance south of their present latitude (Packer and Stone, 1974; Stone and Packer, 1979). Continuing subduction of the Pacific plate beneath the North American plate along the Aleutian Trench at a rate of about 5 cm/yr (Kerr, 1987) accounts for numerous Pleistocene and Holocene volcanoes and for the earthquakes common to the area.

The oldest rocks of the Alaska Peninsula are exposed in this map area at Puale Bay. Permian limestone crops out on one small island at the mouth of Puale Bay. Along the north shore of the bay are exposures of a thick section of Upper Triassic limestone and volcanic rocks of an old magmatic arc. Both the Permian and Triassic limestones were probably deposited far to the south in seas warmer than the modern North Pacific Ocean.

We have determined, as a result of our investigations, that a nearly continuous sequence of Jurassic sedimentary rock is exposed within the Ugashik and Karluk quadrangles. Minor hiatuses are present in the stratigraphic record, but no major unconformities are represented. This depositional record coincides with the period during which the land fragment that is now the Alaska Peninsula drifted from more southerly latitudes northward to near its present latitude. Ammonites from the Lower Jurassic strata at Puale Bay show a close correlation to forms now found in Lower Jurassic strata at the latitude of Mexico (Imlay, 1980). Ammonites of Middle Jurassic age correlate more closely with those from areas north of Mexico. The Late Jurassic megafauna of the Ugashik and Karluk area consist almost entirely of the bivalve *Buchia*, found worldwide only in the boreal regions. Many changes in depositional environments accompanied the northward shift in latitude. The Permian and Triassic limestone was deposited on an open, shallow-water shelf in tropical seas. The Lower Jurassic sediments were also deposited in shallow water. But by the Middle Jurassic, deep-water turbidites were being deposited in part of the area. Upper Jurassic strata are shallow-water shelf to nonmarine deposits.

Intrusive and extrusive igneous rocks of Jurassic age are also exposed in the map area, northwest of the Bruin Bay fault. A small exposure of Middle Jurassic plutonic rocks formed an island in Becharof Lake near The Gas Rocks (Reed and Lanphere, 1969, 1972). Similar Jurassic plutonic rocks also have been encountered in boreholes on the Bristol Bay coastal plain (Brockway and others, 1975).

An extended period of erosion and nondeposition followed the Jurassic, and thus the next overlying strata preserved are of Late Cretaceous age. Continued tectonic activity has caused the removal of most Upper Cretaceous shelf and slope deposits, leaving no more than 50 to 75 m of strata. Lower Tertiary strata unconformably overlie the older beds. The oldest Tertiary strata in the map area are early Eocene continental deposits commonly containing abundant petrified logs and coal seams. Orogenic activity during the Tertiary probably resulted from subduction along the proto-Aleutian Trench.

Meshik arc volcanism (as defined by Wilson, 1985) started in the late Eocene and deposited a thick sequence of subaerial basaltic-to-andesitic fragmental volcanic rocks and massive lava flows from vents along the west side of the modern mountains. Activity along the arc continued for 12 to 15 m.y. and tapered off during the Oligocene. A thick section of these volcanic rocks is exposed in the southwestern part of the map area. Owing to the strong magnetic character of these rocks (Case and others, 1981), it is possible, based on aeromagnetic data, to trace them partly across the map area beneath a mantle of glacial drift.

Volcanic activity along the Meshik arc ceased in this area about 24 to 23 m.y. ago (Wilson, 1985). Thereafter, these deposits, along with the older rocks, were uplifted and reworked by erosion into the overlying sedimentary sequence. A thick late Tertiary sedimentary section is preserved mainly in the subsurface of the Bristol Bay coastal plain, where it is covered by glacial drift but has been penetrated by the Great Basins #1 and #2 wells and by the Ugashik #1 well (Brockway and others, 1975). A thin sequence of the Upper Miocene Bear Lake Formation is exposed along faults near the Ugashik Lakes.

Volcanic activity along the Aleutian volcanic arc probably originated about 10 to 5 m.y. ago with the renewal of igneous activity along the Alaska Peninsula. In the Ugashik and Karluk quadrangles area this was restricted mainly to the emplacement of quartz diorite plutons, such as the Agripina Bay batholith, along the Pacific coast side of the mountains. Dacite intrusions associated with mineral deposits also occurred during this interval. Minor extrusive activity accompanied the emplacement of these plutons. Large-scale volcanic activity along this part of the arc commenced about 1.9 to 1.5 m.y. ago at Blue Mountain, The Gas Rocks, Mount Yantarni volcano, and possibly other sites; it has continued until the present with the eruption at Ukinrek Maars in 1977.

Tectonic activity associated with subduction along the proto-Aleutian Trench has resulted in numerous high-angle reverse faults and some thrust faulting. The Bruin Bay fault, a major fault in southern Alaska, enters the northern edge of the study area, but disappears beneath surficial deposits south of Becharof Lake. Transverse faulting and fracturing is very common. The northeast trend of Aleutian Range volcanoes is offset about 20 km in the Ugashik and Karluk quadrangles. This may be due to plumbing or structure of the downgoing slab rather than offset of crustal segments.

Megafossil Data (MF-1539-B)

Considerable amounts of new data on the fossil megafauna and megaflora were obtained during the present investigation. A total of 353 collections of marine megafauna and 23 collections of megaflora from nonmarine Tertiary strata were made during the investigation, adding considerably to the data base for the area. Collections were made from rocks ranging in age from Late Permian to Eocene. These collections permit time-stratigraphic correlations to be made for the various rock units.

The Kialagvik, Shelikof, and Naknek Formations, of Middle and Late Jurassic age, are abundantly fossiliferous and account for 67 percent of all fossil collections. Ammonites constitute the main elements of the megafauna in the Talkeetna, Kialagvik, and Shelikof Formations, including 36 species belonging to 23 genera. Marine bivalves of the genus *Buchia* are the age-diagnostic fossils in the Upper Jurassic Naknek Formation. Four species from closely controlled sections permit a precise zonation for this genera that can be used throughout the Alaska Peninsula (Miller and Detterman, 1985).

Nonmarine megaflora obtained from the Tolstoi Formation were identified by J.A. Wolfe (written commun., 1985) as early Eocene. This indicates that the Tolstoi Formation in the Ugashik and Karluk quadrangles is equivalent to only the upper part of the same formation exposed farther south on the peninsula (Detterman and others, 1981c).

Bedrock Geochemistry (MF-1539-C)

As an aid to the mineral resource assessment of the mapped area, 337 rock samples were collected and analyzed using 30-element semiquantitative emission spectrometry, additional atomic absorption spectrophotometry, and other analytical methods. Sampling was conducted throughout the area in an effort to determine background concentrations; however, sampling was concentrated in areas of known or suspected mineralization and may be somewhat biased.

Anomalous samples were collected in a number of areas on the periphery of the Agripina Bay batholith, near the plutons at Mount Becharof and Cape Igvak, and at Cape Kubugakli. Additionally, numerous anomalous samples were collected at the Mike and Rex prospects. No sampling or mapping was able to locate the reported copper mineralization at the head of Puale Bay (Berg and Cobb, 1967).

The data were statistically analyzed to select background and anomalous levels. Anomalous metal assemblages are consistent with mineralization models predicting copper and molybdenum porphyry-type mineralization with associated gold and silver. However, it was not possible to evaluate the background levels of metals in individual stratigraphic units because of insufficient sampling for statistical validity.

Aeromagnetic Map and Interpretation (MF-1539-D)

Aeromagnetic surveys of most of the Ugashik and western part of Karluk quadrangles were flown in 1980 and 1982. The data obtained from the two surveys were combined, and some data from National Uranium Resource Evaluation (NURE) surveys were incorporated to produce a smoothed final map for publication.

Over the Bristol Bay Lowland, broad ovoid highs of 200 to 500 gammas are produced by deep-seated granitoid plutonic bodies, which are thought to be part of the Alaska-Aleutian Range batholith of Jurassic to Tertiary age (Reed and Lanphere, 1969, 1972). Gentle gradients on the flanks of the anomalies indicate that the sources of the anomalies are buried at depths of 3 to 4 km or more. One of the anomalies, near Cape Greig, coincides with a positive gravity anomaly of about 15 mGal (Barnes, 1977b), and the source may be a dense and magnetic phase of the batholith, perhaps dioritic or gabbroic.

Conglomerate and sandstone derived by erosion of the batholith form the Upper Jurassic Naknek Formation. The conglomerate and some of the sandstone contain a high proportion of magnetite. Elongate northeastern-trending magnetic highs of 200 to 500 gammas are produced by magnetite-rich sandstone in the Naknek near the Ugashik Lakes. Another northeast-trending high of 400 gammas over covered areas to the northwest is interpreted to be caused by the Naknek on the northwest limb of an anticline.

Volcanic rocks of the Meshik Formation (Eocene and Oligocene) produce elongate positive anomalies as much as 1,000 gammas in amplitude along the northwestern front of the mountain belt. Other Tertiary volcanic rocks elsewhere in the Ugashik and Karluk quadrangles cause irregular highs and lows of about 50 to 200 gammas.

Many of the Tertiary granitoid plutons cause ovoid magnetic highs of 200 to 1,000 gammas or more. Similar anomalies are in water-covered areas east of Cape Kilokak, east of Hartman and Terrace Islands, and elsewhere, and these are interpreted to result from Tertiary plutons. Most of the known ore deposits, prospects, and geochemical anomalies of the area are associated with the Tertiary plutons or their hornfelsed and altered wall rocks. Thus, the ovoid magnetic anomalies constitute guides to exploration, as in the Chignik and Sutwik Island quadrangles to the south (Case and others, 1981). A few magnetic lows or magnetically flat areas associated with Tertiary intrusive and extrusive rocks may indicate hornfelsing or hydrothermal alteration and may serve as a secondary guide to exploration.

Quaternary volcanic centers at Mount Chiginagak, Mount Kialagvik, Mount Peulik, and Blue Mountain cause short-wavelength positive anomalies of 200 to 1,000 gammas or more.

Regional Gravity Anomalies

Gravity data are sparse in the mountainous parts of the Ugashik and western part of Karluk quadrangles. Barnes' (1977b) map shows a negative anomaly of about 10 mGal in the southwestern part of the Bristol Bay Lowland, continuing northeast to near the Kejulik River. This low is caused by the thick accumulation (3 to 4 km or more) of Tertiary sedimentary rocks of low density. The relative gravity high of 10 to 15 mGal in the northwest, near Cape Greig, may indicate a mafic pluton at depth, or shallower depth to basement.

A positive anomaly of 30 to 50 mGal trends northeast along the mountainous part of the peninsula. This positive anomaly is an extension of the major gravity high over the Aleutian Islands and may be caused by oceanic crust at depth (Case and others, 1981).

Geochronology and Major-element Geochemistry (MF-1539-E)

A total of 57 new K-Ar ages were determined in conjunction with the AMRAP mapping studies and help to provide a well-constrained time scale for Tertiary and Quaternary events and stratigraphic relations. In addition, 54 new and 12 previously reported major-element chemical analyses were compiled and analyzed.

The ages are approximately evenly divided in number between the late Tertiary Aleutian magmatic arc and samples representative of the Meshik (early Tertiary) and Jurassic magmatic arcs. A number of samples were collected to date hydrothermal alteration associated with mineralization. Significant among these were samples collected on the periphery of the late Pliocene Agripina Bay batholith at Kilokak Creek and south of Mount Kialagvik. In both cases, hydrothermally altered phases yielded Oligocene ages, equivalent to that of the Meshik arc, which suggests that the area of the batholith was the site of magmatic activity and alteration during the timespan of both Tertiary magmatic arcs. Age determinations of Meshik-age plutonic rocks at the Rex prospect indicate hydrothermal and magmatic activity occurred in multiple phases, spanning approximately 4.5 m.y.

Major-element chemical analyses show rocks of both arcs to be of calc-alkaline affinity, though a few samples, including some from the Kejulik volcanic center of Quaternary age, lie in the tholeiitic field on a SiO_2 versus FeO*/MgO plot. The samples collected can be divided into a number of suites on the basis of age and geologic setting. These suites are chemically distinct on many elemental plots and indicate varying ranges and trends of major elements with respect to silica. Both the Agripina Bay batholith suite and the suite of plutons at Mount Becharof and Cape Igvak intrude similar rocks, are compositionally similar, and are of essentially the same age, yet they differ chemically. The Agripina Bay suite has the highest K_2O level (1.8 percent at 57.5 percent SiO_2), whereas the Mount Becharof-Cape Igvak suite has the lowest K_2O level (0.9 percent at 57.5 percent SiO_2) of all suites.

Geochemistry (MF–1539–F, –G, –H)

A reconnaissance exploration geochemical study was undertaken during the 1979 and 1980 field seasons. Two diffferent media were sampled: (1) stream sediments and (2) heavy-mineral concentrates panned from the stream sediments. A total of 585 minus-80-mesh stream-sediment samples and 569 panned-concentrate samples were collected from active channels of streams draining 5–16 km^2. The minus-80-mesh stream-sediment medium reflects changes in bedrock geology and geochemistry and indicates areas of extensive exposed mineralization. A 14-in. gold pan full of minus-2-mm stream sediment was collected from the high-energy part of the stream to obtain each panned-concentrate sample. Each sample was further processed in the laboratory through heavy liquids to remove the light-mineral fraction (sp gr <2.8) and through a magnetic separation process to remove magnetite as well as many of the more magnetic mafic minerals. The nonmagnetic, heavy-mineral fraction analyzed for this study contained high-specific-gravity, rock-forming minerals such as apatite, zircon, rutile, and sphene; the sulfide, sulfosalt, and some oxide minerals; and several of the accessory minerals associated with mineralization and alteration such as scheelite, fluorite, barite, epidote, and tourmaline. The nonmagnetic fraction of the heavy-mineral concentrates should reflect the presence of ore-related minerals and therefore may be useful in delineating areas of poorly exposed mineralization. All analyses were by the semiquantitative emission spectrographic method described by Grimes and Marranzino (1968) and by Motooka and Grimes (1976); supplementary determinations of Cu, Pb, and Zn concentrations were made by atomic absorption (Ward and others, 1969). A detailed description of the geochemical sampling, sample preparation, and analytical methods utilized is presented, along with the tabulated geochemical data and sample-locality maps, by Detra and others (1981).

Stream Sediments

The distribution of the elements Cu, Mo, Ag, Pb, Zn, B, Ni, and Co are shown on MF–1539–F (Church and others, 1988). Anomaly thresholds were chosen from an analysis of the bedrock geochemistry and vary depending upon the bedrock. Three classes of anomalous values for each element are shown using vectors surrounding a central point that indicates the sample locality. Elemental groupings can be determined from the pattern of the "star" at each sample locality. Histograms of these eight elements are also shown. A statistical summary is also given for the entire set of data reported by Detra and others (1981).

Pan Concentrates

For the nonmagnetic heavy-mineral concentrates, the distribution of the elements Cu, Mo, Ag, Pb, Zn, B, Ni, and Co is shown on map A and of the elements As, W, Au, Bi, Cd, Ba, Nb, and Sn on map B of MF–1539–G (Frisken and others, 1988a). Thresholds were chosen from an analysis of the distributions of each element from the data and are shown on histograms. Three classes of anomalous values for each element are shown using the "star" diagram; elements are grouped so that geochemically coherent sets of elements are presented on maps A and B. The set of elements displayed on map A of MF–1539–G is identical to that on the stream-sediment geochemical map (MF–1539–F).

Mineralogy

Spatial distribution and abundance of pyrite, chalcopyrite, molybdenite, galena, sphalerite, cinnabar, barite, gold, tourmaline, zircon, and mafic minerals are presented in MF–1539–H (Frisken and others, 1988b). Abundances were determined by microscopic examination of the nonmagnetic heavy-mineral concentrates. Relative abundance is indicated by the length of the vectors of the star diagrams, and the mineral vectors are chosen so that they correspond to the associated vectors on nonmagnetic heavy-mineral concentrate maps (MF–1539–G).

Mineral and Energy Resource Assessment (MF–1539–I)

The mineral potential of the study area is summarized on MF–1539–I utilizing the mineral-deposit models outlined by Cox and Singer (1986). The geothermal, oil and gas, and coal resources of the area are also assessed on MF–1539–I.

Previous mineral-exploration activity in the Ugashik-Karluk area was limited largely to gold prospecting near the turn of the century and to regional reconnaissance by major mining companies in the 1970's for porphyry deposits and related mineralization. Nine lode claims and 13 placer claims have been staked in the area. Detailed field mapping and geochemical sampling by Kennecott Corporation on the Mike and Rex prospects were made available to the U.S. Geological Survey.

Eight tracts of land, each having somewhat different geologic characteristics, have been outlined as potential mineral resource areas. On the basis of our work in the area, the geochemical anomalies directly associated with young intrusives, of observed patterns of alteration, and of permissive geologic criteria, we estimate that there is a 10-percent chance for two or more undiscovered porphyry copper deposits in the Ugashik-Karluk study area. From the limited drilling information on the Mike prospect, we estimate that there is a 90 percent chance of one or more porphyry molybdenum deposits and a 10 percent chance of two or more such deposits in the study area. Based on the Cu/Au ratio in surface rock samples from the Rex prospect, we estimate a 90 percent chance of one or more porphyry copper-gold deposits in the study area.

The estimate of the abundance of smaller deposits is less concise because of the reconnaissance nature of our studies. The geologic environment in many of these tracts is permissive for polymetallic vein and epithermal gold-vein deposits. The mineralization exposed on David Island indicates a volcanic-hosted copper-arsenic-antimony deposit. The large magnetic anomalies surrounding the pluton at Cape Igvak and the geochemical signature associated with them suggest that an iron or tungsten skarn may be present.

Small gold placers may exist in the study area, particularly around the area of the Rex prospect, where gold was seen in several panned samples.

There are adequate resources of sand and gravel, cinder, and pumice to satisfy local demand. Limestone on Cape Kekurnoi is suitable as building stone and is adjacent to a protected deep-water port. Given sufficient local demand, this limestone unit is considered marginally economic.

A geothermal energy resource at Mount Chiginagak is estimated to be similar in size (approximately 10^{19}–10^{20} cal) to that calculated for Aniakchak Crater (Smith and Shaw, 1979), located just 8 km south of the study-area boundary. Ukinrek Maars, which erupted in 1977, may represent an additional geothermal resource.

Oil and gas resources in the study area are probably small. Twelve dry holes have been drilled in the study area. The tract to the west (E1), which consists mainly of Tertiary nonmarine sedimentary and volcaniclastic rocks, has been evaluated based on the drilling. Analysis of the rocks for hydrocarbons indicates that they are immature, with an organic-carbon content of less than 2 percent (McLean, 1977). Tract E2, located on the east side of the study area, is largely a Mesozoic sedimentary province. Although this area has several small oil seeps located along the crest of two large anticlines, analysis of the rocks indicates poor reservoir characteristics for most of the Mesozoic section. Furthermore, the organic-carbon content of the Mesozoic rocks is low. Of the 12 dry holes in the study area, eight have been drilled near the surface oil seeps on the crests of these two anticlines.

Coal beds are present in the Tolstoi Formation near the southern boundary of the study area. Field data indicate that the grade ranges from subbituminous to anthracite near the contact with small intrusive bodies. One tract (A5) contains several beds 1 to 2 m in thickness that have been seen in traverses made at 5-km spacings. If these beds are continuous, they could have economic potential.

BULLETINS

Stratigraphic Clarification of the Shelikof Formation, Alaska Peninsula

(Excerpts from Bulletin 1537–A *by* W.H. Allaway, Jr., R.L. Detterman, J.W. Miller, *and* L.B. Magoon)

Field investigations during the course of this AMRAP investigation determined that the contact between the Shelikof Formation and the underlying Kialagvik Formation had been placed based on faunal zones rather than on lithostratigraphic units. This report redefines the contact between the two formations.

Capps (1923, p. C97–C98) defined the Shelikof Formation (Middle Jurassic) on the Alaska Peninsula but did not establish a type locality. He divided the formation into three members: a lower shale (siltstone) member, a middle sandstone member with conglomerate, and an upper shale (siltstone) member. Rapid facies changes make these members impractical for mapping. Capps placed the lower contact at the base of a conglomerate bed that occurs at the base of the lower siltstone member at Puale Bay. This conglomerate does not persist laterally, and as a result other workers have mapped the contact based on the change in fauna between the Bajocian and Callovian Stages (Middle Jurassic).

Smith (1925) proposed to place the contact at the base of the lowermost massive sandstone bed. This is the most easily mapped unit and is herein defined as the base of the Shelikof Formation. The type section is defined as along the northeast shore of Puale Bay, between the southern half of sec. 9, T. 28 S., R. 38 W. and sec. 19, T. 28 S., R. 37 W. in the Karluk C–4, C–5, and D–5 15-minute quadrangles.

Petrography, Chemistry, and Geologic History of Yantarni Volcano, Aleutian Volcanic Arc, Alaska

(Excerpts from Bulletin 1761 *by* J.R. Riehle, M.E. Yount, *and* T.P. Miller)

In 1979, during the course of this AMRAP study, R.L. Detterman and J.E. Case discovered a previously unknown Quaternary volcano near the south boundary of the map area, subsequently named Yantarni after the nearby bay of the same name. Yantarni volcano and neighboring Mounts Chiginagak and Kialagvik are located along the axis of the Wide Bay-Bear Creek anticline and the high-angle fault that extends southwest from the anticline; together, the three form a short segment of the Aleutian volcanic arc along which the volcanoes are approximately 35 km closer to the Aleutian Trench than those on either side. The Mike prospect, a locus of late Tertiary volcanism, is 5 km north of Yantarni dome.

Volcanic activity at Yantarni began in middle Pleistocene time with the eruption of andesite flows that now cap ridges to the west and south of the present summit. A catastrophic Holocene eruption (possibly 3,500 to 2,000 years ago; Riehle and others, 1987) breached the small, late Pleistocene stratocone, produced the present dome, and filled the valley to the east with approximately 1 km^3 of pyroclastic flow deposits.

Yantarni volcanic rocks are calc-alkaline and range from 55 to 65 percent SiO_2 (volatile free). Comparison of whole-rock chemistry and phenocryst chemistry suggests that small batches of magma feeding the volcanic system have occasionally intercepted one another beneath the volcano and mixed to form hybrid magmas (Riehle and others, 1987).

Although there is no historical record of activity at Yantarni, the possibility of future eruptions cannot be discounted.

Interpretation of Exploration Geochemical Data From the Ugashik, Bristol Bay, and Western Karluk Quadrangles, Alaska

(Excerpts from Bulletin 1858 *by* S.E. Church, J.G. Frisken, *and* F.H. Wilson)

The integration of the geochemical results from the geochemical maps (MF–1539–C, –F, –G, –H) are presented in an interpretative report in U.S. Geological Survey Bulletin 1858. Both drainage-basin analysis and factor analysis of the entire data sets are covered, and conclusions are drawn regarding the type of mineralization present.

Analysis of the geochemical data obtained from exploration geochemical studies has helped to define the limits of several porphyry Cu-Mo target areas, some of which were previously unknown. Widespread geochemical anomalies and hydrothermal alteration halos are associated with an inferred Oligocene to Pliocene intrusive complex in the southern part of the Ugashik-Karluk study area. Two of these areas are the Rex prospect, a porphyry Cu-Mo system associated with composite Oligocene intrusive rocks, and the Mike prospect, a porphyry Mo system associated with Pliocene intrusive activity. Both areas are outlined by Cu-Mo-W anomalies surrounding drainage basins that show base- and precious-metal anomalies. Aeromagnetic data suggest that there are several buried plutons in the area beneath the geochemical anomalies of the Mike prospect (Case and others, 1988). Further examination of several of these areas may be warranted.

Additional evidence of mineralization is associated with an area at Cape Igvak that shows possible hydrothermal vein or skarn mineralization, possibly associated with a pluton of Pliocene age. Gold, antimony, lead, and molybdenum mineralization at Cape Kubugakli appears to be restricted to quartz veins within the outcrop pattern of intrusive rocks. The intrusive rocks appear, from the aeromagnetic anomaly, to extend offshore to the east.

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