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

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ABSTRACT

Analysis of the geochemical data obtained from exploration geochemical studies of the Bristol Bay, Ugashik, and western Karluk quadrangles, Alaska, defines the general limits of several porphyry copper-molybdenum target areas, at least some of which were previously known. Widespread geochemical anomalies and hydrothermally altered rock are associated with an inferred Oligocene to Pliocene intrusive complex in the southern part of the Ugashik-Karluk study area. Two of these areas, one a porphyry copper-molybdenum system associated with a composite Oligocene intrusion (the Rex prospect), and the other a porphyry molybdenum system associated with Pliocene intrusive activity (the Mike prospect), are outlined by copper-molybdenum-tungsten anomalies, surrounded by drainage basins containing base- and precious-metal anomalies. Of the two areas, the Mike prospect appears to have the more favorable geochemical expression for mineralization. Aeromagnetic studies of this area suggest several buried plutons beneath these and adjacent geochemical anomalies. Suites of elements present suggest porphyry-type mineralization. Further examination of several of these areas may be warranted.

Additional evidence of mineralization is associated with an area of possible hydrothermal alteration on Cape Igvak and may be associated with a pluton of Pliocene age. Miocene mineralization on 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. Cape Kubugakli has produced an estimated 5 kg (160 oz) of placer gold.

Factor analysis of the stream-sediment data defines one general mineralization factor, whereas the data from the nonmagnetic heavy-mineral concentrates panned from stream sediments define several mineralization factors. Two of the factors defined by the stream sediments outline areas of hydrothermal alteration; a zone of propylitic alteration associated with the early Tertiary volcanic and hypabyssal rocks is suggested by boron in the nonmagnetic heavy-mineral concentrates.

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INTRODUCTION

The U.S. Geological Survey is required by the Alaska National Interest Lands Conservation Act (ANILCA, Public Law 96–487) to survey certain Federal lands to determine their mineral resources. As a part of the Alaska Mineral Resource Assessment Program (AMRAP), a multimedia, multidisciplinary study of the geology, geophysics, and geochemistry of the Ugashik, Bristol Bay, and western Karluk quadrangles (together referred to as the "Ugashik-Karluk study area" in this report) was undertaken during the summers of 1979–1982. Two days of additional work were done in the summer of 1986. This report presents an interpretation of the semiquantitative geochemical data collected during the course of this investigation. We refer extensively to geochemical maps (Church and others, 1988; Frisken, Church, and others, 1988; Wilson and O'Leary, 1986, 1987) and to mineralogical maps of the nonmagnetic heavy-mineral concentrates panned from stream sediments (Frisken, Church, and Willson, 1988). In addition, we have included results of evaluations of the Mike and Rex properties made by the exploration group at the Kennecott Corporation.

Geographic Setting

The Ugashik-Karluk study area is on the Alaska Peninsula (fig. 1) between lat 56° and 57° N. The northern boundary of the study area cuts across Becharof Lake and the southern boundary is just north of Aniakchak Crater. The eastern and western boundaries

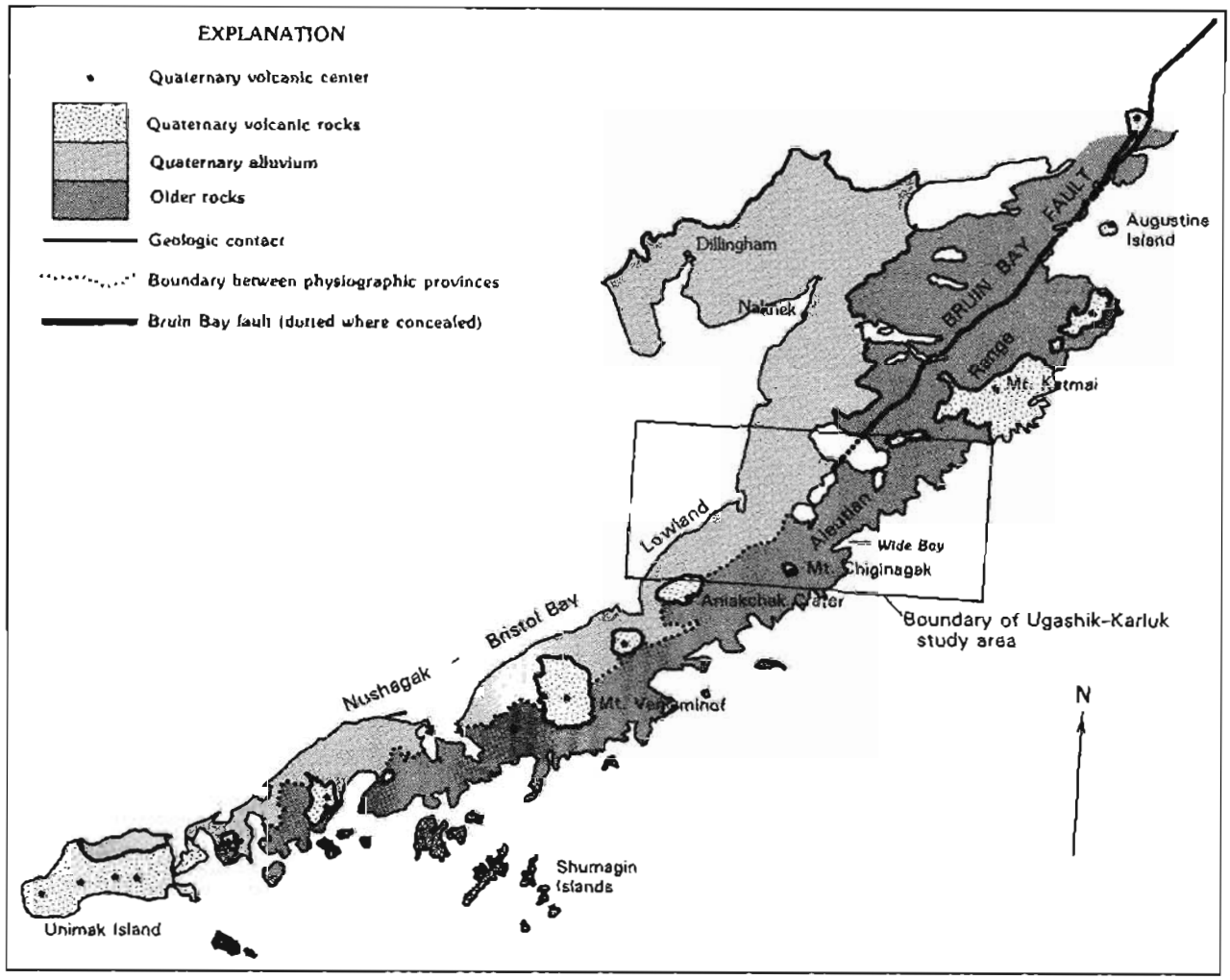

Figure 1. Index map of the Alaska Peninsula showing location of the Ugashik-Karluk study area, Ugashik, Bristol Bay, and western Karluk quadrangles, Alaska. Physiographic provinces, major faults, Quaternary volcanoes, and major geographic features of the Alaska Peninsula are shown for reference.

of the study area are the coast lines. Two physiographic provinces are present: the Nushagak–Bristol Bay Lowland, along the coast of Bristol Bay, and the Aleutian Range (Wahraftig, 1965). The Nushagak–Bristol Bay Lowland is characterized by broad coastal plains, low topographic relief, many bogs and small lakes, and slow, meandering streams. Few samples were collected in this province. In sharp contrast, the Aleutian Range is composed of Quaternary volcanic cones, flows, and stratovolcanoes that partly cover older sedimentary and igneous rocks. Elevations exceed 2,000 m (6,500 ft) at Mount Chiginagak. Streams in the Aleutian Range follow steep gradients down youthful valleys. Glaciers are present on some of the dormant volcanic peaks, where ice flows to elevations below 300 m (1,000 ft) on the coast of Wide Bay. The Aleutian Range ends abruptly at the Pacific coast, but the rocks that form the Aleutian Range appear to extend offshore into Shelikof Strait (Burk, 1965; Detterman and others, 1983; von Huene and others, 1985). The axis of the Aleutian Trench is about 320 km (200 mi) to the southeast, off the Pacific coast of Kodiak Island (Jacob and others, 1977; von Huene and others, 1985).

Regional Geologic Setting

The Alaska Peninsula marks the transition zone between the volcanic island arc of the Aleutian Islands and the continental magmatic arc of southern Alaska. At the northern end of the Alaska Peninsula, what has been

defined as the "Alaska Peninsula terrane" is structurally separated into the Iliamna and Chignik subterranes by the Bruin Bay fault, north of Becharof Lake (Wilson and others, 1985). This fault was intermittently active from Late Jurassic time to Middle Tertiary time (Detterman and others, 1987). South of Becharof Lake all exposed Mesozoic rocks belong to the Chignik subterrane. The southernmost exposure of the Iliamna subterrane is on one small island on the south side of Becharof Lake.

The Nushagak–Bristol Bay Lowland is dominantly composed of unconsolidated Quaternary alluvium and glacial deposits; however, small areas of late Tertiary and Quaternary volcanic rocks are present (Detterman and others, 1983, 1987). Plutonic rocks of Jurassic to middle Tertiary age, which form the Alaska–Aleutian Range batholith, are exposed north of lat 57° N. (Reed and Lanphere, 1969, 1973). They are also known to occur in the subsurface to the south (Brockway and others, 1975). These rocks intrude a thick section of Mesozoic and Tertiary clastic sedimentary rocks recording fore-arc basin sedimentation. The Mesozoic sedimentary rocks were derived largely from the erosion of the Jurassic volcanic arc and batholith, and they include shale, siltstone, sandstone, and conglomerate deposited in a nonmarine and nearshore marine environment; some deep-water turbidite occurs in the Middle Jurassic (Callovian) Shelikof Formation (Allaway and others, 1984; Detterman and others, 1987). Some volcanic tuffs and agglomerate are preserved in the Lower Jurassic Talkeetna Formation (Detterman and others, 1987).

Minor folding and uplift of the Mesozoic sedimentary rocks occurred prior to early Tertiary volcanism. Starting in the early Eocene, calc-alkaline volcanism commenced forming the Meshik arc (Wilson, 1985). This early phase of volcanic and intrusive activity was followed by a second pulse beginning in the late Miocene forming the Aleutian volcanic arc (Burk, 1965; Wilson and Shew, 1988; Detterman and others, 1983, 1987; Wilson, 1985). Most of the folding and faulting on the Alaska Peninsula commenced in Miocene time and continued through Quaternary time. For a regional summary of the stratigraphy of the Alaska Peninsula, the reader is referred to Wilson and others (1985).

Mineral Occurrences on the Alaska Peninsula

Known mineral occurrences on the Alaska Peninsula are dominated by porphyry-type copper-molybdenum sulfide systems. For the Chignik–Sutwik Island study area, immediately to the south, Wilson and Cox (1983) described porphyry mineralization associated with early Tertiary to Quaternary rocks of intermediate composition that intrude marine and nonmarine clastic rocks. Copper- and molybdenum-rich porphyry systems are characterized by drainage basins in which stream sediments are anomalous in copper and molybdenum, usually associated with tungsten, surrounded by drainage basins in which stream sediments are anomalous in lead, zinc, bismuth, arsenic, and precious metals. Drainage-basin anomalies show overlapping, zoned geochemical patterns. Rocks exposed in these basins typically show argillic, sericitic, or phyllic alteration associated with veins and disseminated molybdenite, chalcopyrite, and scheelite. Surrounding the exposures of intense alteration are zones of propylitically altered rock containing both disseminated and vein pyrite and lesser amounts of galena, sphalerite, arsenopyrite, precious metals, barite, and tourmaline. Minor gold is commonly associated with the porphyry systems, and some placer gold may be found in streams surrounding the centers of mineralization. Weathering and oxidation of exposed pyrite commonly produces characteristic yellow-brown and reddish color anomalies. Our observations indicate that similar geologic and geochemical features are associated with possible centers of mineralization in the Ugashik-Karluk study area.

Acknowledgments.—We thank the Kennecott Corporation and Koniag Incorporated for permission to use their unpublished geologic mapping and geochemical data from the Mike and Rex prospects in this report. A.L. Miesch and R.R. Tidball reviewed portions of the manuscript and made valuable comments on the discussion of the statistical data. Their contributions to the manuscript are appreciated.

GEOLOGY OF THE UGASHIK-KARLUK STUDY AREA

Geologic mapping in the Ugashik-Karluk study area by Detterman and others (1983, 1987) forms the geologic base for the interpretations made in this bulletin (fig. 2). The description of the stratigraphy (fig. 3) has been simplified for the purpose of clarity.

The oldest rocks exposed in the Ugashik-Karluk study area are Permian limestone (Hanson, 1957) that crops out on a small island offshore of Cape Kekurnoi on the Pacific coast. On shore are small outcrops of Triassic limestone, shale, and minor clastic and volcanic rock that were deposited in a shallow-water, quiet basin environment and that are now exposed along the Pacific coast at Puale Bay and to the north towards Alinchak Bay.

The Alaska–Aleutian Range batholith includes rocks of Jurassic, Cretaceous, and early Tertiary age (Reed and Lanphere, 1969, 1973). The Jurassic plutonic rocks of the batholith were emplaced to form the core of the Alaska Peninsula; they are contemporaneous with

the Lower Jurassic Talkeetna Formation, which consists of volcanic rocks and tuffaceous sandstone, in part, and the Lower and Middle Jurassic Kialagvik Formation, which consists of shallow-water marine sandstone and shale. Later, the Middle Jurassic Shelikof Formation, composed of volcanically derived sandstone, conglomerate, siltstone, shale, and minor deep-water turbidite, was deposited. The Shelikof Formation is widely exposed along the Pacific coast of the study area, and the Kialagvik Formation is exposed at Wide Bay on the axis of the anticline centered in Wide Bay (Allaway and Miller, 1984). During Late Jurassic time, the Naknek Formation was deposited, derived from the erosion of the Alaska–Aleutian Range batholith, followed by nearly continuous deposition of the overlying thin-bedded feldspathic siltstone and sandstone. Detterman and others (1987) stated that in the study area the Lower Cretaceous part of the Staniukovich Formation has been removed by erosion and that the thin-bedded sandstone and shale that overlie the Naknek may be considered a member of the Naknek Formation. For simplicity, these two units will be referred to as the "Naknek Formation" in this report. The lower, conglomeratic part of the Naknek Formation was deposited in a nonmarine, fluvial environment, whereas the upper sandstone and shale, containing limestone concretions, represent a marine environment. Overlying these rocks is the Chignik Formation of Late Cretaceous age, which was deposited in a cyclical fluvial to nearshore marine sedimentary environment (Detterman, 1978). The Upper Cretaceous Hoodoo Formation, which interfingers with and overlies the Chignik Formation, is a turbidite indicating a deeper water environment.

The Meshik arc formed during Eocene to early Miocene time (Wilson, 1985). It is best exposed on the northwest side of the Aleutian Range, in the southern part of the study area. Basaltic and andesitic calc-alkaline volcanic rocks of the Meshik Formation and the volcaniclastic, nonmarine sedimentary rocks of the upper part of the Tolstoi Formation constitute the Meshik arc in the study area. The Paleocene and Eocene Tolstoi Formation is a nonmarine clastic unit, whereas the Miocene Bear Lake Formation is primarily a nearshore marine deposit containing some nonmarine rocks. In the southern part of the study area, along the Pacific coast, the Mesozoic sedimentary rocks contain many hypabyssal dikes and sills too small to be shown at the 1:250,000 scale of the published maps (Detterman and others, 1987).

Further calc-alkaline magmatism during late Miocene to Quaternary time (Wilson and Shew, 1988) formed the bulk of the plutons throughout the area. Quaternary volcanism produced the volcanic peaks and stratovolcanoes that dominate the landscape. Most of the young volcanoes lie west of the axis of the Aleutian Range, where they form two northeast-trending segments, one in the southern Ugashik quadrangle and one near the south shore of Becharof Lake. Upper Miocene and Pliocene plutons intruded folded Mesozoic sedimentary rocks along the Pacific coastline. Aeromagnetic studies (Case and others, 1987) suggest that other plutons may be present in the subsurface.

The overall geologic structure of the Alaska Peninsula north of Wide Bay is a gentle, broad arch, the axis of which parallels the Bruin Bay fault. Gentle anticlines and synclines are superimposed on this broad arch. South of Wide Bay, structures are much tighter and anticlines are aligned in a northeast-trending en echelon pattern. The folding and extensive intrusive activity has deformed rocks as young as Pliocene (Burk, 1965, p. 137). Normal faulting, largely associated with folding, has caused numerous offsets in the older lithologic contacts.

EXPLORATION GEOCHEMISTRY

Sample Media and Data Collection

Heavy-mineral-concentrate and stream-sediment samples were collected from active stream channels draining areas of 5–16 km^2 (2–6 mi^2). During the reconnaissance geochemical sampling program, 586 stream-sediment samples and 569 heavy-mineral-concentrate samples from stream sediments were collected. Both sample media were collected by wet sieving through a 10-mesh stainless steel screen. At each site, one 35-cm (14-in.) gold pan full of sediment was collected and about 0.5 kg (1 lb) of minus-2-mm material was retained as the stream-sediment sample. The remaining material was panned at the site to produce the heavy-mineral concentrate (Detra and others, 1981).

The minus-2-mm stream-sediment samples were dried in an oven and then shipped to the laboratory, and there they were sieved through an 80-mesh screen. This fraction was ground between ceramic plates to minus-150 mesh and retained for chemical analysis. The heavy-mineral concentrates from stream sediments were dried in an oven and then shipped to the laboratory, where they were sieved to minus-20 mesh. Following removal of the light-mineral fraction by flotation in bromoform (specific gravity about 2.8), the heavy-mineral fraction was separated into three magnetic splits with a Frantz isodynamic magnetic separator. The most magnetic fraction (C1) contained magnetite and rock fragments including large amounts of magnetite. The second fraction (C2) was of intermediate magnetic susceptibility and consisted of rock fragments as well as most of the more magnetic mafic silicates. The nonmagnetic fraction (C3) contained the high-specific-gravity rock-forming minerals such as