DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-880-H
PAMPHLET

Metalliferous mineral resource potential of the Seward and Blying Sound quadrangles, southern Alaska

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1982

INTRODUCTION

This mineral potential map is the final report in a series of publications that makes up a folio on the Seward and Blying Sound quadrangles of southern Alaska. It draws on data largely presented in previous publications of the folio. The studies were undertaken as part of the Alaska Mineral Resource Assessment Program (AMRAP), a program designed to provide information for Federal, State, local, and industry decisions concerning the future uses of Alaskan lands and resources.

PUBLICATIONS IN THE AMRAP FOLIO OF THE SEWARD AND BLYING SOUND 1^{o}x 3^{o} QUADRANGLES, ALASKA

(Complete citation is given in reference section at end of pamphlet)

I-1150	Tysdal, R. G., and Case, J. E., 1979, Geologic map
MF-880-A	Tysdal, R. G., 1978a, Mines, prospects, and occurrences map
MF-880-B	___ 1978b, Map showing placer deposits
MF-880-C	Case, J. E., Sikora, Robert, and others, 1979, Geologic interpretation of the gravity anomaly map
MF-880-D	Case, J. E., Tysdal, R. G., and others, 1979, Geologic interpretation of the aeromagnetic map
MF-880-E	Tripp, R. B., and others, 1978a, Geochemical map showing the distribution and abundance of copper in stream sediments
MF-880-F	___ 1978b, Geochemical maps showing the distribution and abundance of gold in stream sediments and silver in heavy-mineral concentrates
MF-880-G	Tripp, R. B., and Crim, W. D., 1978, Mineralogical map showing the distribution and abundance of gold, scheelite, chalcopyrite, arsenopyrite, minium, and sapphire corundum in heavy-mineral concentrates
MF-880-H	This report
OF-78-1102	O'Leary, R. M., and others, 1978, Spectrographic and atomic-absorption analyses of geochemical samples

One of the main tools used in this report to outline areas of potential for mineral deposits is the abundance of elements in stream sediments and heavy-mineral concentrates from stream sediments. Reconnaissance geochemical and mineralogical samplings were undertaken in the Seward and Blying Sound quadrangles during 1975 and 1976 and the results reported in the following publications of the folio: Tripp and others (1978a,b), Tripp and Crim (1978), and O'Leary and others (1978). No systematic sampling of rocks for geochemical analyses was undertaken.

The geochemical maps (maps B-I, on sheet 2) in this report utilize selected geochemical data from the above mentioned publications on copper, lead, zinc, and manganese in stream sediments and gold, silver, and arsenic in heavy-mineral concentrates. Heavy-mineral concentrates were used for gold and silver because analyses of stream sediments yielded few detected values. Arsenic, not analyzed for by atomic absorption, largely was undetected by spectrography of stream sediments but was relatively common in the concentrates.

Because one of the chief purposes of these maps is the selection of target areas for mineral exploration, we have used a drainage technique to portray areal element concentrations rather than simply placing values at sample sites. Outlines of the individual drainage areas sampled are shown on the map of sheet 1. With this method there is only one sample per area, and only the bedrock within the boundary is represented in the sample. The larger the area the less likely the data will be representative of it; thus the smaller the areas the more site specific but expressive the data are.

The method is used to show trends and favorable areas. It is not intended, or expected, that any one value is of great significance; the collective use of data from several adjacent areas is considered more useful for delineation of a prospective region. Patterns that emerge in areas of known mineralization are compared with like or similar patterns from elsewhere in the Seward and Blying Sound quadrangles in order to outline areas that may have potential for mineral deposits. The fact that we have excluded large parts of the Seward and Blying Sound quadrangles from the regions of mineral resource potential is not a prediction that the excluded areas lack metalliferous mineral resources. They do not qualify for inclusion on the basis of geochemical, geologic, and geophysical criteria presently available for our use.

Regions that are considered prospective for mineral deposits are outlined on the map on sheet 1. Criteria used to draw the outlines are presented in table 1, the headnotes of which give threshold values considered anomalous for each of the elements.

Table 2 provides data on mineral resource potential for the types of mineral deposits present within each region. Information about expected grades and tonnages of several mineral deposit types has been prepared for use in mineral resource assessment studies of Alaska, and summaries of distribution of ore tonnage and ore grade for these deposit types have been presented in several reports (for example, Hudson and DeYoung, 1978; and MacKevett and others, 1978). The grade and tonnage model used here (shown on the following page) is for one of the mineral deposit types presented in the aforementioned publications. The following description of this model is from Hudson and DeYoung (1978, p. 53, 55):

> A specified deposit type can be characterized as having a restricted range of size, which, if known, can be used in conjunction with an estimate of the number of occurrences of deposits of this type to produce a resource estimate. This estimate describes the amount of the commodity or commodities contained in deposits of the specific type that may occur in a specific region, the range in size of a particular deposit of tons of ore, and the range of ore grade of deposits. For instance, 100,000 metric tons of copper might be distributed in 100 million tons of ore (a grade of 0.1% copper) or in 10 million metric tons of ore (a grade of 1.0% copper).
>
> The collection and analysis of data used to construct the statistical sample for the deposit type follows the procedure used by Singer and others (1975) in their analysis of different types of copper deposits. The data used to prepare the model shown on the following page is from mineral deposits elsewhere in the North American Cordillera that belong to the Alaskan deposit type and that have available grade and tonnage estimates, derived, where possible, by combining estimates of past production and present resources. The summary statistics in the model show the median value of the tonnage, grade, or contained metal (column 5) and the range within which 80% of the deposits are expected to be (this range is between the values given in columns 4 and 6). Thus, 80% of mafic volcanogenic deposits are expected to contain between 0.24 and 22 million metric tons of ore, 10% are expected to contain more than the upper limit, and 10% are expected to contain less than the lower limit. These suppositions are based upon the observation that the grade and tonnage can be characterized by a lognormal statistical distribution. A more complete description of this type of analysis is contained in Singer and others (1975; 1980).

Mineral provinces

The western part of the Prince William Sound region of coastal southern Alaska is composed of two extensive and distinctive mineral belts or provinces defined by the preponderance of either gold or copper mineralization. In the Seward and Blying Sound quadrangles, the main division of the two belts is approximately along the Contact fault, which trends northeast across the quadrangles. Except for an area of mafic igneous rocks and associated flysch on the Resurrection Peninsula, the copper province lies east of this fault and includes the copper deposits on Latouche, Elrington, Bainbridge, Knight, Chenega, and Glacier Islands, and the mainland between Columbia Bay and the Unakwik Inlet area.

The gold province includes the Port Wells district, which lies both east and west of the body of water known as Port Wells, and the Moose Pass-Hope district in the Kenai Lake to Turnagain Arm region. A third area of mineralization that is discussed in the text, the Girdwood district, lies chiefly in the Anchorage quadrangle only a few kilometers due north of the town of Girdwood, on the north shore of Turnagain Arm.

Brief descriptions of the individual mines, prospects, and mineral occurrences in the quadrangles were presented by Tysdal (1978a). A description of the gold placers of the map area, along with a discussion and evaluation of prospective drainages, was presented by Tysdal (1978b).

Regional geology

Rocks of the gold province are chiefly slate and sandstone of the Upper Cretaceous Valdez Group. The copper province is underlain by both flysch of the Valdez Group and the lower Tertiary Orca Group, and includes abundant mafic igneous rocks that form sequences of sheeted dikes, pillow besalts, sills, tuffs, gabbro intrusives, and locally ultramafic rocks. The igneous rocks are in part interlayered with, as well as intrude, the host sedimentary strata (Tysdal and others, 1977; Tysdal and Case, 1979). This terrane is part of a highly deformed sequence of rocks that extends along the north side of the Gulf of Alaska; the sequence was rotated 90° counterclockwise and accreted to the continent in the Late Cretaceous and early Tertiary (Plafker and others, 1977; Winkler and Plafker, 1975; Tysdal and Case, 1979).

COPPER PROVINCE

The areas of known copper deposits and regions of copper potential, as outlined on the

GRADE AND TONNAGE MODEL FOR MAFIC VOLCANOGENIC DEPOSIT TYPE

Tonnage and grade variables (units in parenthesis)	Number of deposits used in developing model	Correlation coefficient of listed variable with variable on line with it in column 2	90 percent of deposits have at least	50 percent of deposits have at least	10 percent of deposits have at least
Tonnage of ore (millions of metric tons)	37		0.24	2.3	22.0
Average copper grade (percent)	37	with tonnage of ore = -0.13*	1.1	2.2	4.1
Average zinc grade excluding deposits without reported grades (percent)	19	with tonnage of ore = 0.03*	0.3	1.3	5.5

*not statistically significant

maps, show a close spatial relation to the distribution of mafic igneous rocks. In the following section the areas of mafic rocks within the copper province, referred to as the Knight Island area (regions 1A, 1B, and 1C), the Glacier Island area (regions 2A and 2B), and the Resurrection Peninsula area (regions 3A and 3B), are discussed separately. The rocks and mineral deposits of the Knight Island area have undergone more extensive study than those of the other two areas and are used as a "model" for comparative purposes.

Knight Island area: Regions 1A, 1B, and 1C

Geologic mapping (Tysdal and Case, 1979) and an analysis of minor folds (Richter, 1965) indicate that the rocks of Knight Island form a doubly plunging anticline. The anticline is composed of a core of sheeted basalt dikes, sills, and small gabbro intrusives flanked by younger strata of pillow basalts and flysch. The pillows locally are interbedded with flysch, and dikes and gabbro intrude both the pillow basalt and flysch units. A positive gravity anomaly of more than 50 mgals over the central part of Knight Island (Case and others, 1966; Case, Sikora, and others, 1979a) suggests that a mass of mafic rock as much as 10 km thick, or a thinner mass of ultramafic rock, underlies the island. The anomaly continues southward, decreasing in amplitude to 25 to 30 mgals over the flysch and mafic rocks of Elrington, Evans, and Bainbridge Islands. This suggests that the exposed rocks of these islands represent a stratigraphically younger and structurally higher sequence than the rocks of Knight Island. The sequence of rocks in the island group could be representative of the sequence that has been eroded from Knight Island.

Latouche Island (region 1C) apparently lies on the eastern limb of the anticline and is underlain by flysch and mafic igneous rocks high in the sequence. It is economically significant because it is the site of the now depleted Beatson mine (loc. 256), which yielded the second largest amount of copper produced in Alaska when operating in the first third of this century. Few mafic rocks occur on Latouche Island, but sills are present on the southeastern corner (Moffit, 1954), pillow basalts occur on Danger Island to the south, and an olivine-bearing dike ("lamprophyre dike," Bateman, 1924, p. 346) is present in the Beatson mine.

Mineral deposits

The sulfide deposits of Knight Island (region 1A) consist principally of massive pyrrhotite intimately associated with lesser amounts of chalcopyrite and cubanite (Richter, 1965). The most studied sulfide deposit within mafic igneous rocks of the island is the Copper Bullion prospect at Rua Cove (loc. 213). It consists of several lenses of massive pyrrhotite that contain veinlets of chalcopyrite and minor sphalerite; the lenses are surrounded by disseminated sulfides (Stefansson and Moxham, 1946). Richter's (1965) study also showed that at least one of the deposits (Bay of Isles, loc. 205) on the island contains pyrrhotite and chalcopyrite disseminated throughout a magnetite-bearing sheeted dike.

The paragenetic sequence for deposits of Knight Island shows, in general, that the volumetrically abundant pyrrhotite formed first, followed by chalcopyrite and cubanite. All three minerals ceased precipitating at about the same time. Pyrite deposition overlaps the depositonal phase of the above three minerals but is largely in veins that formed later. Sphalerite occurs only locally, in late-formed veins (Richter, 1965).

The Beatson deposit (loc. 256, region 1C) on Latouche Island is the most studied of all the sulfide deposits in the Prince William Sound area and is considered to be representative of deposits that might be found in sedimentary strata in the copper province. It was composed of about 50 percent chalcopyrite and 50 percent pyrrhotite and pyrite. Pyrite was subordinate to pyrrhotite and was the first sulfide to form. Sphalerite, widely distributed in the deposit, occurred mainly as small blebs of microscopic size within the pyrrhotite and pyrite. Cubanite, associated with chalcopyrite and pyrrhotite, was rare, and galena very rare. Gold and silver were recovered as by products from smelted ore but their forms are unknown (Bateman, 1924).

The Beatson ore body was lens-shaped with a maximum width of about 120 m and a maximum length of about 300 m. A fault formed a sharp western limit to the ore body, but the eastern boundary was gradational and marked by decreasing chalcopyrite disseminated in sandstone of the lower Tertiary Orca Group. The richest ore consisted of veinlets and blebs of chalcopyrite in "greenschist" (sheared mafic rocks?) immediately adjacent to the fault. A massive body of pyrrhotite and pyrite also occurred immediately adjacent to the fault, and formed a lens about 250 m long and 0.6 to 12 m thick.

Origin

Early studies of the sulfide deposits in mafic rocks of Knight Island led to conclusions that the mineralization took place largely after formation of the host rock units (Stefansson and Moxham, 1946; Richter, 1965). Later studies (Wiltse, 1973; Wiltse and McGlasson, 1973; McGlasson, 1976), utilizing more recent mineralization concepts associated with plate tectonic theory, attributed their formation to volcanogenic processes wherein the ores were deposited directly onto the sea floor or at least formed at the same time as the igneous host rocks.

The deposits of Latouche Island also have been ascribed to post-host rock formation (Bateman, 1924; Stejer, 1956) and synsedimentary origin (Wiltse and McGlasson, 1973). Near the Ellamar mine in northeastern Prince William Sound (Cordova quadrangle) sulfide minerals occur in the troughs of ripple marks in the flysch sediments, supporting a synsedimentary origin (G. R. Winkler, oral commun., 1976). However, on the east side of Latouche Island there are mineralized zones where the flysch definitely has been altered hydrothermally after sedimentation took place.

The arguments cited by the above workers and the complex field relationships of the sulfide deposits and the host rocks were summarized by Tysdal (1978a). It is apparent that deposition of sediments, mafic intrusive activities, mineralization, deformation, and perhaps metamorphism and remobilization of sulfides were simultaneous processes creating complex relationships.

The stratiform copper deposits of the map area were classified as Besshi-type massive sulfide deposits by Sawkins (1976). According to Sawkins, the association with mafic volcanic rocks and thick sequences of flysch, in a structurally complex setting, serves to distinguish them from the massive sulfide deposits of ophiolite complexes.

However, some of them do appear to have features associated with Cyprus-type (ophiolite) deposits. As described previously, Knight Island, Glacier Island, and the Resurrection Peninsula are comprised largely of mafic rocks of basaltic composition that formed sheeted dikes, pillow basalts, tuffs, gabbro intrusives, and locally serpentinite dikes (Tysdal and others, 1977; Tysdal, 1978a). No extensive ultramafic mass is exposed at any of the three localities, but gravity and magnetic data suggest that such masses could exist at depth (Case, Sikora, and others, 1979; Case, Tysdal, and others, 1979; Tysdal and others, 1977). In addition, both the Knight Island and Latouche Island deposits have a clear preponderance of Cu over Zn, a feature of Cyprus-type deposits (Sawkins, 1976).

Geochemistry

Stream sediment copper values exhibit a well defined zonation pattern for the mafic igneous rocks of Knight Island (map B). Highest values (>70 ppm) generally are within the sheeted dike complex of region 1A, reflecting both the mineralogy of the deposits and the trace element chemistry of the igneous rocks. Chalcopyrite is the chief sulfide mineral in deposits associated with the sheeted basalt dikes, whereas pyrite is dominant in deposits in the pillow basalts (Tysdal, 1978a). Analyses of rocks on Knight Island indicate that the dikes contain a higher intrinsic copper content than the pillow basalts. Region 1B stream sediments and heavy-mineral concentrates, in general, show higher background values of copper (>30 ppm) than the neighboring flysch and granite bearing terrain (<30 ppm) and locally show some high copper anomalies (>50 ppm) from drainages that contain basaltic rocks in sedimentary/igneous rock units. In region 1C copper values range from less than 30 ppm to more than 80 ppm, with the main anomalous area including the site of the Beatson mine (loc. 256).

Zinc values (map C) reveal a marked zonation pattern, but in general show a trend opposite to that of copper. Zinc values for the sheeted dikes of region 1A generally are low (<50 to 75 ppm), increasing somewhat in value (50 to >75 ppm) in the adjacent pillow basalt of region 1B. A major exception exists at the south end of region 1A where anomalous values (>100 ppm) near the edge of the sheeted dike rock unit are interpreted as part of the fairly broad area of anomalous zinc values in regions 1B and 1C. The broadest area of highest zinc values (>150 ppm) is in flysch in region 1C, on Latouche Island near the Beatson and associated mines.

Lead values (map D) do not show as great a contrast as copper and zinc; nevertheless some generalizations can be made. Low values (<20 ppm) are characteristic of the sheeted dikes in region 1A, with the lowest values (<10 ppm) obtained from small drainages within the central part of the dike unit. Values are slightly higher in regions 1B and 1C, especially in the northern part of Evans Island and the northern part of Latouche Island where values of more than 30 ppm are common. This same area generally has high values of copper and zinc.

The ratio of lead+zinc/copper in stream sediments (map E) reveals quite remarkably the mafic rock units of regions 1A, 1B, and 1C, and the zonation of these elements in the sheeted dikes, pillow basalts, and flysch units. In region 1B, south of Knight Island, this map also illustrates some relationships better than the individual element maps for copper, lead, or zinc. For example, the gravity high that is so well defined over Knight Island and that decreases in amplitude over the islands to the south (Case and others, 1966; Case, Sikora, and others, 1979) is marked by a low Pb+Zn/Cu ratio that probably reflects the existence of buried mafic rocks and their high copper content. The area of the Beatson mine on the eastern flank of the high is an exception to this generalization, as its ratio is similar to that of the area of the gravity high.

Silver (map F) was detected in only one heavy-mineral-concentrate sample from the sheeted dike terrain of region 1A. Anomalous values (>1 ppm) were found in the area of sedimentary strata and areas where sedimentary strata are intruded by dikes. In region 1C a high silver value was found in only one drainage; no anomalous silver was detected in drainages that contained the Beatson mine and other nearby deposits.

Manganese in stream-sediment samples (map G) primarily reflects the existence of mafic or mixed mafic igneous/sedimentary rock sequences. In the sheeted dike complex of region 1A, manganese values generally are somewhat lower than in the adjacent pillow basalts or the mixed igneous/sedimentary rock units of region 1B. In region 1B, exclusive of the pillow basalts of Knight Island, and in region 1C, there is a high correlation of highest manganese values with highest copper values, suggesting that manganese in stream sediments may be useful for locating areas of potential copper mineral deposits, particularly in rocks above mafic sequences, where the mafic rocks are not exposed. However, mafic igneous grains in sedimentary rocks may cause similar high manganese values in the stream sediment. For example, in the northwestern corner of the map area where streams drain across rocks of the McHugh Complex, which contains abundant mafic igneous grains as well as a few outcrops of mafic rocks, the manganese content tends to be high (map G). Hence, one needs to know the general composition of the sedimentary rocks before attempting to use manganese as a guide to potential copper mineral deposits.

Regions 2A and 2B

Glacier Island (regions 2A and 2B) in the northeastern part of the Seward quadrangle, is similar to Knight Island in that it is comprised of a sheeted dike sequence flanked on the north by pillow basalts and flysch (across the waterway) (Tysdal and others, 1977). It also is marked by a gravity high of about 35 mgal, over the sheeted dike unit, which decreases to the north (Case, Sikora, and others, 1979), and by a positive magnetic anomaly that has amplitudes of as much as 400 gammas (Case, Tysdal, and others, 1979). The geologic terrane within region 2B is similar to that of the western part of region 1B.

Geochemistry

The highest copper values (map B) of the Glacier Island area are within region 2A, closely reflecting the sheeted dikes and pillow basalts immediately adjacent to the dikes. This distribution of copper is similar to that of region 1A on Knight Island. Region 2B has geochemical patterns similar to those of region 1B in the Knight Island area where copper values in the pillow basalts decrease away from the sheeted dike complex. The one high value (>50 ppm) on the peninsula north of Glacier Island coincides with high zinc (>200 ppm) and lead (>40 ppm) geochemical values.

Zinc values (map C) in stream sediments from region 2A generally are less than 125 ppm--although somewhat higher than in region 1A. In region 2B, however, zinc exhibits a distribution pattern and values similar to those of the southern part of region 1B and of region 1C. The area of highest zinc values in region 2B, on the peninsula north of Glacier Island, coincides with the high copper value. Zinc values west of the Eocene(?) Cedar Bay Granite are similar to those north of Glacier Island, and it is reasonable to assume that these two areas were continuous prior to intrusion of the granite body. All of the zinc values from streams draining the granite were less than 50 ppm.

Lead values (map D) for the sheeted dikes and adjacent pillow basalts of region 2A exhibit moderate values (20 to <40 ppm), in contrast with the low values (<20 ppm) of region 1A. Region 2B shows a pattern of lead values similar to that for zinc, including the highest lead values, north of Glacier Island, coinciding with high zinc and copper.

The ratio of zinc + lead to copper (map E) in region 2A is low (<3), like that of region 1A. The pattern in region 2B is similar to that of the western part of region 1B; no concealed mafic sequence is indicated as in the southern part of region 1B. On the peninsula north of Glacier Island the drainage with the high copper, zinc, and lead values exhibits a moderate ratio (<4) of zinc + lead to copper, and is flanked by drainages with a high ratio (>6) for these elements. This pattern is similar to that of drainages near the Beatson mine (loc. 256, region 1C) which have a low to moderate ratio (<2 to <4) of zinc + lead to copper, and are flanked north and south by drainages with a high ratio (>5 to >8) for these elements.

No silver (map F) was detected in region 2A, but two highly anomalous silver values (>500 ppm) were recognized in region 2B, one of which is on the peninsula north of Glacier Island associated with the copper, lead, and zinc anomaly. Manganese values (map G) of region 2A are moderately anomalous (<1,000 ppm), as in region 1A. In region 2B, manganese values also are generally moderate; the only high value (>2,000 ppm) is on the peninsula north of Glacier Island.

Regions 3A and 3B

The rocks, structure, and geophysical patterns of the Resurrection Peninsula area (regions 3A and 3B) exhibit many similarities with the Knight Island area (regions 1A, 1B, and 1C). The rocks of the Resurrection Peninsula are of Late Cretaceous age, however, whereas those of Knight Island are early Tertiary (Tysdal and others, 1977).

The sequence of rocks in region 3A of the Resurrection Peninsula area consists of, from west to east, flysch, mafic tuffs, pillow basalt, sheeted basalt dikes with some pillow screens, and a large gabbro pluton that is intruded by small bodies of dunite and serpentinized dunite. The tuffs are interbedded with the flysch, and pillow basalt locally is interbedded with flysch. The gabbro pluton intrudes flysch, with a contact metamorphic aureole as much as up to 200 m across (Tysdal and others, 1977); the pluton also intrudes the sheeted dike complex.

A positive gravity anomaly of more than 30 mgal and a series of high and low amplitude magnetic anomalies (Case, Sikora, and others, 1979) overlie region 3A. Northward into region 3B, which is underlain by flysch, a positive magnetic anomaly of nearly 400 gammas suggests the presence of a concealed ultramafic mass (Case, Tysdal, and others, 1979).

Rocks of the Resurrection Peninsula form a broad anticline, which plunges gently to the north and has several large folds superimposed on its west flank. The east side of the anticline is truncated by the Placer River fault, a structural pattern similar to that of the eastern limit of regions 1A and 1C.

Geochemistry

Region 3A of the Resurrection Peninsula area shows geochemical patterns that are comparable to those of the previously described regions of the copper province. Region 3B, however, is not readily compared via geochemistry of stream sediments, except where it overlaps region 3A, because the geochemical patterns of region 3B are not anomalous. Region 3B is outlined on a magnetic anomaly (Case, Tysdal, and others, 1979) that reflects a concealed ultramafic mass that could contain nickel and (or) chromium. Chromium in excess of 1,000 ppm was detected in gabbro, and values ranging from 1,000 ppm to more than 5,000 ppm were detected in serpentinized dunite exposed in the southern part of region 2B; nickel values of 2,000 ppm to 5,000 ppm also were obtained from the serpentinized dunite (Tysdal, 1978a).

Copper values of greater than 60 ppm (map B) in region 2A correspond to the area of sheeted dikes, as in region 1A of Knight Island. Zinc values (map C) are low to moderately anomalous (<100 ppm) in the area of the sheeted dikes and increase into the pillow basalts and flysch as in region 1A. Lead values (map D) are low (<20 ppm) throughout the region, corresponding to region 1A. The ratio of zinc + lead to copper (map E) is low (<3), with the lowest values from the sheeted dikes. No anomalous silver values (map F) were detected in the region. Manganese values (map G) are high in the region and decrease away from it.

GOLD PROVINCE

The gold province of the Seward and Blying Sound quadrangles can be divided into two broad areas that have somewhat different mineralized patterns. One broad area consists of regions 4A, 4B, and 4C, which includes the Moose Pass-Hope district (Martin and others, 1915), in the western part of the province and region 4D in the eastern part of the province. The other broad area consists of regions 5A and 5B in the Port Wells gold district in the northeast part of the province. A third area of mineral deposits, the Girdwood district (just north of the map area), is described briefly because its distinct mineral deposits, setting, and mineral paragenesis provide a useful comparison to the deposits within the map area.

Gold deposits of the province occur in quartz veins that fill fractures in country rock of flysch and locally granite to quartz diorite intrusives and diorite dikes. The gold deposits are of epigenetic hydrothermal origin and contain a variety of associated sulfide minerals.

Geochemical zonation

This report makes use of the zonation concept to interpret geochemical patterns of the map area. Geochemical zones, or halos, commonly surround hydrothermal metalliferous deposits or ore bodies, and are composed of rock enriched in chemical elements (minerals) as a result of ore-forming processes. Zones typically extend vertically far above and laterally beyond mineral deposits and, therefore, can be used as guides in exploration for concealed mineral deposits. Zones of ore deposits can be divided into three graditional classes (Park and MacDiarmid, 1964, p. 161): (1) regional zones, such as the southeastern United States, (2) district zones, such as a mining district; and (3) ore-body zones, which reflect changes in element distribution within a single ore deposit. Only district and ore-body zones are discussed in this report. The classic zonation of sulfide minerals found in epigenetic hydrothermal sulfide deposits throughout the world is shown in figure 1. The sequence of minerals is the same in both vertical and lateral directions from a mineral deposit, but only some of the minerals shown in the figure will be found in a single deposit or district.

Zonation patterns result from the precipitation of minerals and reflect the paragenetic sequence, or order, in which the minerals were deposited. The paragenetic sequence and the zoning sequence are the same (Barnes, 1975). No study of the zoning sequence was made on deposits of the map area, but a detailed paragenetic study was made by Park (1933) on deposits in the Girdwood district. There, the main ore minerals include molybdenite, arsenopyrite, pyrrhotite, pyrite, sphalerite, galena, chalcopyrite, and gold. The molybdenite occurs in several veins but was not seen in polished sections, hence its time of deposition relative to other sulfide minerals is unknown. Arsenopyrite is the most abundant metallic mineral and was one of the earliest vein minerals formed. Pyrrhotite is plentiful and was deposited slightly later than arsenopyrite. Pyrite is younger than arsenopyrite, with which it is closely associated, but its relation with pyrrhotite is uncertain. The next youngest sulfide minerals are sphalerite, galena, and chalcopyrite. Gold is believed to be the latest metallic mineral deposited, occurring sporadically through the veins, locally associated with galena, chalcopyrite, and arsenopyrite. In some places gold occurs in quartz stringers and is independent of the sulfide minerals.

The paragenetic sequence of the Girdwood district is in general agreement with the zoning shown in figure 1. The main difference is that the chalcopyrite of the Girdwood district formed after sphalerite and galena instead of before. According to Taylor (1963), sphalerite precedes

PERIPHERY

Cinnabar	HgS	Hg
Stibnite	Sb_2S_3	Sb
Gold tellurides	Au-Te	Au
Acanthite	Ag_2S	Ag
Galena	PbS	Pb
Tatrahedrite	Cu_3SbS_3	
Sphalerite	ZnS	Zn
Chalcopyrite	$CuFeS_2$	Cu
Stannite	Cu_2FeSnS_4	Sn
Pentlandite	$(Ni,Fe)_9S_8$	Ni
Pyrrhotite	$Fe_{1-x}S$	
Arsenopyrite	$FeAsS$	Fe
Molybdenite	MoS_2	Mo

SOURCE

Figure 1. Typical zoning sequence of epigenetic hydrothermal deposits (from Barnes, 1975, based principally on Park, 1955).

chalcopyrite in deposits that are zinc-rich; thus the positions of these minerals in the sequence is dependent on chemical composition of the ore fluids.

No studies of rock geochemistry were undertaken to determine if individual ore bodies of the map area show lateral zonation. However, suites of stream sediments and heavy-mineral concentrates from stream sediments do show elemental variations in different regions of a single district and from one district to another. This is believed to indicate zoning within and between districts because (1) only one type of mineral deposit occurs within the gold province (exception--local overlap of volcanogenic deposits in regions 3A and 3B); thus (2), the elements in the sediments and concentrates were derived from the gold mineral deposits; and (3) the ultimate source of elements in the gold deposits was the flysch, and perhaps concealed mafic igneous rock, that underlie the gold province. These points are valid whether one invokes melting, metamorphic differentation, or some other mechanism to release the metallic elements from the bedrock. Each region of a district could overlie its own hotspot, or localized source of elements, such that there need not be a systematic, continuous lateral mineral zonation from one region to another.

Each suite of elements then should represent a different position in the zonation/paragenetic sequence shown in figure 1. The suite from a molybdenite-bearing gold deposit would be different from that of a stibnite-bearing gold deposit, and the two suites should represent minerals deposited at different positions relative to the source (hotspot) of the elements. Vertical zonation in individual ore deposits may be too gradual or too subtle to be detected within the exposed vertical limit of an ore body.

Regions 4A, 4B, 4C, and 4D

Region 4A offers the greatest potential for placer-gold deposits in the map area and, along with the northern half of region 5A, probably has the highest potential for lode-gold deposits. The mineral deposit data for each region will not be described separately, as the mineral deposits of region 4A are considered typical for the other regions. No mine or prospect data exist for region 4D.

Country rocks of regions 4A, 4B, 4C, and 4D are composed of a thick sequence of flysch, consisting of rhythmically interbedded sandstone and siltstone with minor mudstone and pebble conglomerate. These strata regionally are metamorphosed to the lowermost greenschist facies (Tysdal and Case, 1979) and the entire sequence is intensely folded. Regions 4A, 4B, and 4C appear to be within a broad complex synclinorium that extends north and south from the Turnagain Arm area (Tysdal and Case, 1977; Tysdal and Plafker, 1978). Felsic diorite dikes and locally nonmineralized quartz veins intrude faults and other fracturs that formed with, and subsequent to, folding.

Mineral Deposits

Mines and prospects in the drainages of Palmer and Bear Creeks, in the northern part of region 4A were studied by Mitchell (1979) as a part of the AMRAP investigations of the Seward and Blying Sound quadrangles. This is the only study of any detail since the early 1930's on mines in the gold province of the map area.

Lode deposits within the Hope area of region 4A are primarily fissure fillings in which native gold is hosted in a quartz ± calcite gangue. Arsenopyrite, galena, sphalerite, and silver commonly accompany gold throughout the district. Pyrite and chalcopyrite also are present, but not abundant, and pyrrhotite was observed in only one polished section (Mitchell, 1979). In addition, Tuck (1933) reported tetrahedrite and covellite. Tetrahedrite, covellite, tellurides, and molybdenite were not seen in polished section by Mitchell (1979) although trace tellurium and molybdenum were detected in some of the geochemical analyses. Sulfide and precious minerals comprise a very minor volume percent of the total vein material, typically less than 1 percent; however, in some of the richer ore shoots these minerals formed up to 20 percent (by volume) of the total vein (Tuck, 1933).

Veins range from 15 cm to 1 m wide, persist for 10 to 15 m along strike, and typically pinch and swell, primarily due to post-mineralization fault movement. Some large veins are laterally continuous for more than 100 m and as much as 100 m in depth (Tuck, 1933). The veins have sharp walls and commonly show slickensides along both walls. The larger veins are sheared (sheeted and brecciated), with clay gouge preferentially developed along the hanging wall, although footwall gouge-zones do occur. Three periods of vein formation, each related to a distinct set of fault or joint planes, are apparent. The high-grade gold quartz deposits are, in general, confined to two groups of steeply dipping (50-90°) faults which strike N80°±10°W and N-S±5°. Faults and joints developed preferentially in the more brittle sandstone and felsic intrusive dikes, but the higher grade mineral deposits occur in the weaker, thinly interbedded rocks (Mitchell, 1979). Hydrothermal muscovite from an altered felsic dike cut by mineralized quartz veins yielded a potassium-argon age of 52.2 million years (Mitchell and others, 1981).

Mitchell (1979) found that hydrothermal alteration of the country rock is not extensive, as unaltered plagioclase feldspar grains are common immediately adjacent to the quartz veins. The low porosity and permeability of the tightly folded and metamorphosed flysch, and the low temperature (about 125°C) of the ore-bearing solutions, were probably the principal factors preventing extensive ingress of solutions beyond the open fractures.

Geochemistry

Geochemical patterns of stream-sediment and heavy-mineral-concentrate samples from the western part of region 4A provide a model for comparison with other regions because (1) the area is at, or near, the level of gold production; (2) mines and prospects are widespread, providing a broad area for stream sediment and concentrate samples to be representative; (3) the number of streams sampled is higher; and (4) the drainage area represented by each sample is small, hence the data tend to be site specific. This region yielded most of the placer gold from the map area (Tysdal, 1978b) and was second in production of lode gold (Tysdal, 1978a).

Gold in heavy-mineral concentrates from region 4A (map H) is widely distributed and shows the highest values of all the regions in the gold province. Silver from heavy-mineral concentrates (map F) has a distribution pattern similar to that of gold and shows highly anomalous values that are widely distributed. Arsenic values (map I) in the western half of region 4A are low (<2,000 ppm) except for a few very high values from drainages in the immediate areas of mines and prospects.

Region 4A contains the most widespread distribution of zinc values (map C) greater than 100 ppm. The local very high values are mainly from the lode-mining part of the district and all occur in drainages that yielded very high gold values; however, a significant number of zinc values of less than 100 ppm occur within drainages that have high gold values. We interpret this to mean that at the level of optimum gold mineralization, zinc values are locally high immediately near the gold veins, whereas regionally zinc values are at or slightly above background levels (>100 ppm).

Copper values (map B) in much of region 4A are above background level (>40 ppm), with the greatest values in the western part of the region forming narrow highs localized about mines and prospects. These probably reflect chalcopyrite in the narrow veins of the region. In the eastern part of region 4A an area of moderate (50-60 ppm) and locally higher copper values is in part coincident with high gold and silver values, and in the Lyons Creek to Spokane Creek drainages with high arsenic values.

Lead values (map D) in region 4A are largely at background levels (<30 ppm) except for a few anomalous values localized along the north-south trend of mines and prospects in the western part of the region. The anomalies probably reflect galena in gold ores of the area.

The patterning exhibited by gold and silver in regions 4B and 4C is similar to that in the western part of region 4A. The greatest cluster of stream drainages with high gold and silver values (maps H and F) occurs in the western part of region 4B in an area that has only two known prospects.

Arsenic values (map I) are widespread and high (5,000 ppm or greater) throughout region 4C and much of region 4B. Some of these values are from previously mined areas, but more than half of them are not. Arsenic distribution patterns differ from those of region 4A in that the high values are spread over broad areas, and are not confined to localized drainages that contain mines and prospects. Zinc values (map C) greater than 100 ppm characterize much of the area in regions 4B and 4C, but zinc is not necessarily high in drainages where heavy-mineral concentrates yielded high gold and silver values. This pattern is similar to that found in the eastern part of region 4A. Copper values (map B) are generally similar to those of region 4A, with areas of copper values above background level (>40 ppm) generally coinciding with areas of high silver and gold values. Lead (map D) exhibits local concentrations greater than the background values (<30 ppm), but localized higher values present in region 4A do not occur in regions 4B and 4C.

The stream-sediment and heavy-mineral-concentrate data of regions 4B and 4C probably represent mineralized rock deposited higher in the epigenetic hydrothermal zoning scheme (fig. 1), thus more distant from the source than the mineralized rock deposited in the western part of region 4A. This is based in part on the limited occurrence of stibnite in two prospects (loc. 63, 64) just north of region 4B, on the north shore of Kenai Lake, and associated with gold in the Primrose mine (loc. 81) in the south-central part of region 4B. Stibnite, absent from region 4A, commonly is deposited late in the zoning sequence (fig. 1) and more distant from the source.

Many detailed investigations of trace element halos in rocks associated with vein gold deposits have been made in the last 10 to 15 years, chiefly by geologists in the Soviet Union, whose efforts have been directed toward finding concealed ore zones. These studies show that antimony (stibnite) occurs above the gold-ore zone and becomes concentrated high above the zone, thus agreeing with the zoning scheme of figure 1. In addition, arsenic almost invariably is concentrated in halos above gold-ore bodies but below halos of antimony (Polikarpochkin and others, 1965; Polikarpochkin and Kitaev, 1971; Tauson and others, 1971; Beus and Grigorian, 1977; Kudryavtsev and Zubov, 1979; Boyle, 1976, 1979). Thus region 4C and the western part of region 4B may be above gold-bearing rocks and warrant further exploration.

Region 4D, which contains no known lode or placer mines or prospects, is delineated as a potential resource area chiefly on the basis of the widespread distribution of arsenic. Arsenic values (map I) are generally low to moderate (<5,000 ppm); higher values in the northern part of the region coincide with rocks that contain abundant widely distributed quartz veins. Gold values are almost nonexistent and silver values, although widespread, generally are below 10 ppm. Copper, zinc, and lead values are at background levels or slightly above. These data suggest that if gold deposits do occur at depth under the region, erosion has penetrated only the uppermost element halos.

Regions 5A and 5B

Country rock in regions 5A and 5B is chiefly flysch that has been intensely folded, metamorphosed to the lowermost greenschist facies and, in contrast to regions 4A, 4B, 4C, and 4D, intruded locally by granitic plutons of Oligocene age. Potassium-argon dates range from 34.4 to 36.6 m.y. (Lanphere, 1966). Gold-bearing quartz veins occupy fracture and shear zones that cut the granite and also the flysch, which suggests that mineral deposits in regions 5A and 5B may be more than 15 million years younger than those of region 4A.

Mineral Deposits

The lode gold deposits in regions 5A and 5B occur in quartz or quartz-calcite veins, emplaced in joints and faults, with dimensions similar to those of the veins in regions 4A, 4B, 4C, and 4D. Pyrite, the most abundant vein sulfide mineral, generally is associated with chalcopyrite, arsenopyrite, and pyrrhotite and, to a lesser degree, sphalerite and galena. Stibnite was reported in at least two mines and two prospects in the northern half of region 5A, and the telluride mineral nagyagite was reported in the part of region 5A that probably lies in the Anchorage quadrangle (Mines Handbook, 1927, p. 158). Silver was an important commodity in the two regions (Johnson, 1914, p. 217), where it generally occurred amalgated with gold.

Pyrrhotite is a common sulfide mineral in region 5B and in the southern half of region 5A (fig. 2). In the part of region 5A north of Hummer Bay, however, pyrrhotite is unreported and stibnite is present in at least two prospects and two mines. The richer ore from the Granite mine (loc. 120), which was the largest producer of lode gold in the map area (and in all of the Prince William Sound area), was closely associated with stibnite (Johnson, 1915, p. 138). Farther north, gold-bearing veins of the Homestake mine reportedly contain nagyagite, a sulfotelluride of lead, antimony, and gold. The exact location of this mine is uncertain, other than it is along Harriman Fiord and probably in the Anchorage quadrangle, but the mine reportedly produced a small amount of ore and more was blocked out (Mines Handbook, 1927; Johnson, 1919, p. 150).

This regional distribution of pyrrhotite, stibnite, telluride minerals, and gold in the mines and prospects of regions 5A and 5B, when considered in terms of the general zoning scheme of epigenetic hydrothermal deposits (fig. 1), suggests that the northern part of region 5A should be the most favorable area in which to prospect for gold. No streams in the district have yielded placer gold, and because of their short length, limited area of drainage, steepness, and the fact than many of them empty directly into the sea, it is doubtful that much placer gold could be concentrated in them.

Geochemistry

Gold (map H) in region 5A was detected in only a few streams, and those drain small areas that contain mines and prospects. Silver (map F), on the other hand, occurs throughout a broad system of drainages. Arsenic values (map I) are locally anomalous in the southern part of the region but are below the limit of detection (200 ppm) throughout much of the remainder of the region.

Zinc (map C) and copper (map B) values are at background levels for some local drainages that contain mines and prospects. An exception is in the western part of the region (Upper Carmen River and South Fork drainages) where copper values are in excess of 50 ppm. Lead values (map D) are low to very low (<30 ppm).

The contrast in abundances of silver and gold differs from the western part of region 4A where both elements exhibit high values in the same general areas. As discussed previously, some of the mines and prospects in the northern part of region 5B have stibnite associated with the gold mineralization, and stibnite commonly is deposited late in the sequence of minerals and distant from the source materials (fig. 1). The widespread silver anomalies may reflect a high level of mineralization not closely related to the gold-silver deposits formed at deeper levels and closer to source materials in the vein deposits. Copper, zinc, and lead concentration patterns are similar to those of the western part of region 4A where high values occur most commonly in local drainages that contain mines and prospects.

The near absence of arsenic from the northern part of region 5A may be due to its generally low concentration at the high level of mineralization, in accordance with findings of the previously cited Soviet studies. The presence of arsenic, and copper values above background levels in the southern part of region 5A, supported by the occurrence of pyrrhotite and arsenopyrite in the mines and prospects of the area and by the absence of stibnite, suggest that this area represents a deeper level of mineralized rock.

In region 5B low gold values (<50 ppm) and a few high silver values (all >20 ppm) were detected in a few drainages, none of which are known to contain any mines or prospects. Arsenic values in the heavy-mineral concentrates (map I) are about 2,000 ppm or less and occur mainly in the same drainages that exhibited anomalous gold and silver. Except for a few small drainages, copper values are at background levels (<40 ppm) and zinc and lead values are low.

Region 5B yielded very little lode gold and no placer gold during the gold rush days of the

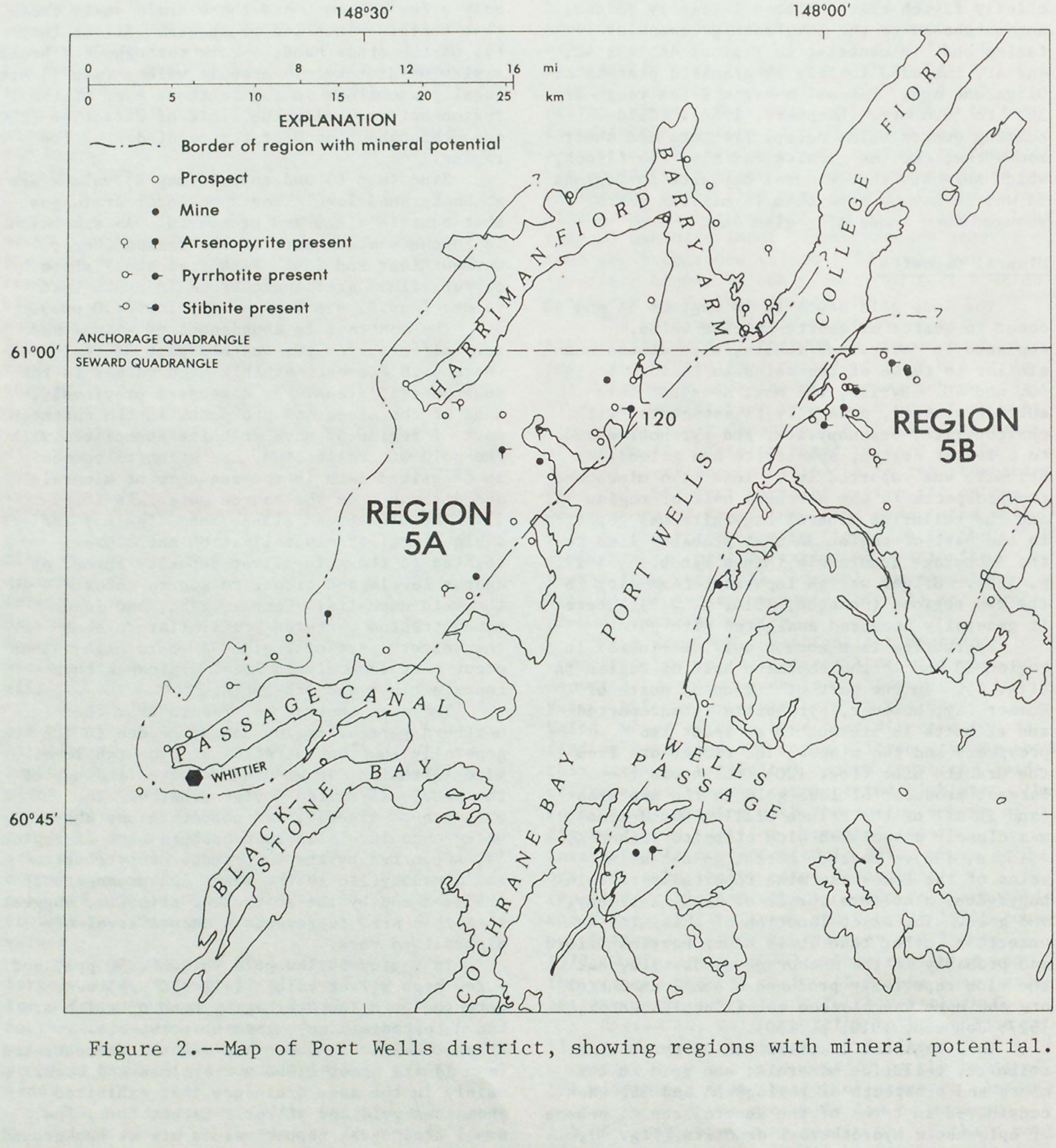

Figure 2.--Map of Port Wells district, showing regions with mineral potential.

early 1900's and probably has a low potential for significant gold deposits. Compared to the productive gold area in the western part of region 4A, the absence of gold and silver values from the well-sampled western part of region 5B where most of the mines and prospects occur is not supportive of significant gold deposits. Local low gold values (1 ppm) and 1 high value (>200 ppm) and several high values along the northeastern edge of the region show some favorability, however.

Arsenic values detected are comparable to those of the southern part of region 5A, but regional copper, zinc, and lead values are below those of the southern part of region 5A, as well as regions 4A, 4B, and 4C. This suggests that the mineral deposits of region 5B and the southern part of region 5A, as well as regions 4A, 4B, 4C, and 4D, are not at the same level of exposure. As discussed previously, stibnite and telluride minerals present in the northern part of region 5A are absent from mines and prospects in region 5B, indicating that these two regions are not at the same level of exposure. These geochemical comparisons lead us to believe that region 5B largely may be below the level of significant gold deposits.

Girdwood District

The Girdwood district of the Anchorage quadrangle has some characteristics that differ from those of the map area and provides data that will aid in discussion of regional patterns of the gold deposits. The district is immediately north of the Seward quadrangle--north of the town of Girdwood on the north shore of Turnagain Arm. No significant amount of gold was produced from lode mines of the district, although significant placer gold was recovered (Park, 1933; Tysdal, 1978b), mainly from Crow Creek within the Seward quadrangle.

The mineral deposits are similar to many of those already described in that the quartz veins occupy fracture zones of flysch, felsic dikes, and locally quartz diorite intrusive bodies. The flysch adjacent to the irregular coarse-grained plugs differs by virtue of containing hydrothermal muscovite, sericite, disseminated pyrite, and silicified and tourmalinized zones. Wall rock adjacent to the dikes is similar to that of other areas, showing few effects of contact metamorphism and commonly showing no alteration or at most slight silicification. None of the igneous rocks have been dated.

Paragenesis of the sulfide minerals, discussed in the introductory section on the gold province, showed arsenopyrite closely associated with slightly younger pyrrhotite and pyrite, followed successively by sphalerite, galena, and chalcopyrite. The minerology of the Girdwood district differs from deposits of the map area in occurrence of molybdenite, observed north of the Seward quadrangle in several veins (Park, 1933), but its position in the paragenetic sequence in unknown.

DISCUSSION

The only detailed paragenetic study of ore deposits in or near the map area was done in the Girdwood district, and it showed that arsenopyrite precipitated before pyrrhotite at the one mine where the two minerals occur together (Park, 1933). In region 4A arsenopyrite preceded pyrrhotite at the Alaska Oracle mine (loc. 51) (Tuck, 1933) and at a mine in the Palmer Creek drainage (Mitchell, 1979).

The zoning sequence of minerals present in epigenetic hydrothermal ore deposits throughout the world commonly shows this to be the case (fig. 1); this is corroborated by studies of the Fe-As-S system, which reveal that, as arsenopyrite is precipitated from a melt, the remaining melt becomes relatively richer in Fe and S (Barton, 1969; Kretschmar and Scott, 1976; Barton and Skinner, 1979, p. 381).

Arsenopyrite is the most abundant sulfide mineral in ore deposits of the Girdwood district and in regions 4A, 4B, 4C, and 4D. It is common, but not the most abundant sulfide, in region 5B and the southern half of region 5A, and is uncommon in the northern half of region 5A. Pyrrhotite also is plentiful in the Girdwood district (Park, 1933), but is known only in one polished section from the Hope area of region 4A (Mitchell, 1979); at two places north of Kenai Lake (loc. 51, 59a) and at three prospects (loc. 80, 87, 90b) between Kenai Lake and Seward. Pyrrhotite occurs throughout region 5B and in the southern half of region 5A.

These data, together with the observed paragenetic relationships between arsenopyrite and pyrrhotite, suggest that the sulfide minerals of the Girdwood district and regions 4A, 4B, 4C, and 4D are closer to source materials than the relatively Fe- and S-rich sulfide minerals of the northern half of region 5A and perhaps the remainder of regions 5A and 5B.

The minor occurrence of pyrrhotite within region 4B and the abundance of arsenopyrite indicate this district is relatively poor in Fe and S and rich in arsenic. In contrast, region 5B and the southern half of region 5A contained more equal amounts of these elements, a fact that may have a bearing on the existence of gold in the two districts.

The mode of transport and deposition of gold in hydrothermal ore solution has long been of interest to geologists, and current studies center on transport of gold in chloride or sulfide (thio) complexes. Speculation that the gold was transported in thio complexes aids in understanding the observed distribution patterns of gold and associated sulfide minerals in the map area.

Experimental study of the transport and deposition of gold in thio complexes at temperatures of 160° to 300°C, 1,000 bars pressure, and at pH values common to the majority of hydrothermal ore solutions, were carried out by Seward (1973). With respect to concentration of S in an ore fluid, his work showed that the solubility of Au increased with an increase in the S content. Based on the abundance of pyrrhotite in the map area, the S content of the southern half of region 5A and all of region 5B was relatively greater than that of regions 4A, 4B, 4C, and 4D. It follows, then, that gold in relatively sulfur-poor regions would have been less soluble, tending to precipitate, whereas gold of region 5B and the southern half of region 5A would have tended to stay in solution. Hence, under this transport mechanism region 5B and the southern half of region 5A would have a lower gold potential than regions 4A, 4B, 4C, and 4D. Gold that remained in solution, at the level of the mineral deposits now evident in these parts of regions 5A and 5B, would have been deposited later at a higher level, more distant from the source. The northern half of region 5A may represent such a depositional environment, wherein the gold was precipitated with antimony-rich, and perhaps telluride-rich fluids.

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Table 1.--Summary of mineral resource characteristics of regions of metalliferous mineral resource potential, Seward and Blying Sound quadrangles, Alaska

Explanatory notes

Anomalous values for stream-sediment samples used in this report are equal to or greater than the following (in parts per million, except for Ti which is in percent): Au(AA), 0.1; Be, 3; Co, 50; Cr, 300; Cr(AA), 50; Mn, 500; Ni, 100; Cu(AA), 40; Pb(AA), 30; Zn(AA), 100; Ti, 0.7%. (AA, atomic absorption; all others are semiquantitative spectrographic analyses.)

Anomalous values for heavy-mineral-concentrate samples used in this report are equal to or greater than the following (in parts per million): Ag, 1; Au, 50; As, 2,000; Cu, 1,000; Pb, 700; W, 100. (All are semi-quantitative spectrographic analyses.)

Anomalous values for rock samples used in this report are equal to or greater than the following (in parts per million): Ag, 0.5; Au(AA), 0.05; As, 200; Be, 3; Co, 70; Cr, 300; Cu(AA), 85; Mn, 1,500; Ni, 150; Pb(AA), 15; W, 50; Zn(AA), 120. (AA, atomic absorption analyses; all others are semiquantitative spectrographic analyses.) No systematic program for collecting and analyzing bedrock samples was undertaken; thus, coverage is limited, not uniform, and sample sites are scattered widely.

Region	Anomalous metal values in stream-sed. samples	Anomalous metal values in concentrate samples	Heavy minerals in concentrate samples	Anomalous metal values in bedrock samples	Surface alteration	Known lode mines and (or) prospects		Known mineral occurrences	Geophysical expression	Favorable host rocks
						Mines	Prospects			
1A	Widespread: Cu, Ni, Zn, Cr, Co, Mn, Ti.	Widespread: Cu. Local: Ag.	Widespread: chalcopyrite.	Widespread: Zn, Cr. Local: Ag, Ni, Co.	Local iron-stained zones.	7	27	Pyrite, pyrrhotite, chalcopyrite, sphalerite, magnetite, cubanite.	Pronounced positive gravity and variable magnetic anomalies.	Widespread pillow basalts, sheeted dikes, associated sedimentary rocks.
1B	Widespread: Mn. Local: Cu, Cr, Co, Ni, Pb, Zn.	Local: Cu	Local: chalcopyrite, arsenopyrite.	Local: Cu, Zn, Cr, Ni.	---do------	6	9	Pyrite, chalcopyrite, pyrrhotite, sphalerite, cubanite.	---do--------------	Pillow basalts and tuff on Knight Island. Pillow basalts and mafic dikes and associated sedimentary rocks.
1C	Widespread: Zn, Mn. Local: Cu, Pb, Co, Ni.	Widespread: Cu. Local: Ag, Pb.	Widespread: chalcopyrite.	Local: Ag, Zn	---do------	0	16	Pyrite, chalcopyrite, pyrrhotite, arsenopyrite, sphalerite, cubanite.	Local positive magnetic anomalies.	Widespread: sedimentary rocks overlying mafic igneous rocks.
2A	Widespread: Cu. Local: Co, Cr, Zn, Ti.	Local: Cu, Pb	None	Local: Zn, Co, Cr.	---do------	0	7	Pyrite, chalcopyrite, pyrrhotite.	Pronounced positive gravity and magnetic anomalies.	Widespread: pillow basalts and sheeted basalt dikes.
2B	Widespread: Zn. Local: Co, Cu, Cr, Ni, Pb.	Widespread: Cu. Local: Ag, Pb.	None	Not sampled	---do------	0	5	Pyrite, chalcopyrite, sphalerite, covellite.	No characteristic gravity or magnetic expression.	Widespread: sedimentary strata overlying and adjacent to mafic igneous rocks.
3A	Widespread: Cu, Mn. Local: Co, Cr, Ti, Zn.	None	Local: chalcopyrite.	Widespread: Cr, Ni, Co. Local: Zn, Cu, Ag.	---do------	0	11	Pyrite, pyrrhotite, chalcopyrite, magnetite, sphalerite, galena.	Prominent positive gravity and magnetic anomalies.	Widespread: pillow basalts, sheeted dikes, overlying sedimentary rocks.
3B	Local: Cu, Co, Cr.	None	Local: chromite.	Local: Cr, Ni, Co, Ag.	---do------	0	0	Chromite	---do-------------	Concealed ultramafic mass.

Table 1.--Summary of mineral resource characteristics of regions of metalliferous mineral resource potential, Seward and Blying Sound quadrangles, Alaska--Continued

Region	Anomalous metal values in stream-sed. samples	Anomalous metal values in concentrate samples	Heavy minerals in concentrate samples	Anomalous metal values in bedrock samples	Surface alteration	Known lode mines and (or) prospects: Mines	Known lode mines and (or) prospects: Prospects	Known mineral occurrences	Geophysical expression	Favorable host rocks
4A	Widespread: Au, Zn. Local: Be, Cu, Pb.	Widespread: Au, Ag, W. Local: As, Cu, Pb.	Widespread: gold, arsenopyrite, scheelite.	Widespread: Au, Ag, Zn. Local: As, Be.	Local iron-stained zones.	12*	30	Gold, silver, sphalerite, galena, arsenopyrite, chalcopyrite, pyrrhotite, pyrite.	No characteristic gravity or magnetic expression.	Widespread quartz veins.
4B	Widespread: Zn. Local: Au, Cu, Pb.	Widespread: Au, As, Ag, Pb. Local: Cu, W.	Widespread: arsenopyrite, gold. Local: scheelite.	Widespread: Zn. Local: Au, Ag.	---do------	5**	11	Gold, arsenopyrite, pyrite, stibnite, galena, chalcopyrite, sphalerite.	---do-------------	Do.
4C	Widespread: Zn. Local: Be, Cu, Pb, Au.	Widespread: Ag, As. Local: Au, Cu.	Local: gold, arsenopyrite.	Widespread: Zn. Local: Be, As.	---do------	0	2	Gold, pyrite, arsenopyrite, chalcopyrite, sphalerite, galena, pyrrhotite.	---do-------------	Do.
4D	Local: Cu, Au	Widespread: Ag, As, Cu, Pb. Local: Au.	Widespread: arsenopyrite.	Not sampled	None observed	0	0	None	---do-------------	Local areas with abundant quartz veins.
5A	Widespread: Au. Local: Cu, Pb, Zn.	Widespread: Ag, Pb, W. Local: Au, As, Cu.	Widespread: gold, scheelite, arsenopyrite.	Local: Ag, Zn, Au.	Local iron-stained zones.	6	22	Pyrite, chalcopyrite, arsenopyrite, gold, galena, stibnite, sphalerite, silver.	---do-------------	Widespread quartz veins and felsic dikes.
5B	Local: Zn, Au, Cr.	Local: Au, Ag, As.	Widespread: gold, arsenopyrite, scheelite.	Not sampled	---do------	8	14	Gold, pyrite, arsenopyrite, chalcopyrite, pyrrhotite, sphalerite, galena, silver.	---do-------------	Widespread quartz veins.

* Region also has at least 11 stream segments that supported placer-gold mining.

**Region also has at least 4 stream segments that yielded some placer gold.

Table 2.--Descriptions of regions of metallic mineral resource potential in the Seward and Blying Sound quadrangles, Alaska

Explanatory notes

As used in this report, "mineral deposit" is broadly defined as a natural concentration of valuable or potentially valuable minerals. No size, grade, tonnage, or commercial value is implied unless so stated. Mines, prospects, and occurrences are considered to be deposits, whereas anomalous concentrations of metals reported in stream-sediment and heavy-mineral-concentrate samples are not considered to be deposits. In the first column below, commodities presumed to be the primary resources are listed first, followed by potential byproducts in parentheses.

Estimates of the number of deposits of a specific type are made only for deposits with grades and tonnages comparable to those in the grade and tonnage model, which is explained in the introduction of the text of this report. These estimates are a prediction of the number of deposits likely to occur at high (90%), moderate (50%), and low (10%) levels of geologic certainty. Levels of certainty are chosen arbitrarily. The estimated number of deposits at each level of certainty is established by subjective evaluation of relevant geologic information. In this report, the estimates of deposits are cumulative; that is, estimates at each successively lower probability include the number of deposits, if any, at the next higher level of certainty. All estimates for regions in the Seward and Blying Sound quadrangles were made by D. A. Singer of the U.S. Geological Survey.

Only one estimate was made for the number of volcanogenic deposits that may occur in regions 1A, 1B, 1C, 2A, and 2B. The land area in any one of these regions by itself, or of regions 2A and 2B combined, is very small, and it is believed that the probability becomes so low as to make the predictions unreliable except when the regions are combined.

No estimates were made for the number of vein gold deposits because of the lack of adequate grade and tonnage data specific to the type of vein gold deposits present in the map area.

Deposit type: Resources	Geologic controls of mineral resources	Production and resource information	Status of geologic information	Summary of mineral resource potential	Estimated number of deposits Percent chance that there are at least the number predicted		
					90 percent	50 percent	10 percent
REGIONS 1A, 1B, AND 1C							
Submarine volcanogenic: Cu, Ag, Au, (Zn).	Massive and disseminated sulfides, mainly chalcopyrite, pyrite, pyrrhotite, and sphalerite; generally localized in or near shear zones in mafic sheeted dikes, pillows, and tuffs on Knight Island and in structurally higher sedimentary rocks in region 1C of Latouche Island; mineralization related to submarine volcanic processes.	Between 1900 and 1930, 7 mines in region 1A and 6 mines in region 1C together produced about 90,000 metric tons of copper and subordinate amounts of silver, gold, and zinc; almost all production came from Blackbird (loc. 254), Chenega (loc. 255), and Beatson (loc. 256) mines of region 1C. Prospect at Rua Cove (loc. 213) in region 1A has estimated reserves of 1,020,000 metric tons of rock containing 1.25 percent copper.	Reconnaissance geologic, geochemical, and geophysical coverage during this study. Detailed studies in region 1A by Richter (1965), McGlasson (1976), and Moffit and Fellows (1950). Considerable industry exploration on Latouche Island and southern half of Knight Island.	More than 65 volcanogenic deposits are known; many are incompletely explored and others probably remain to be found. Estimated number of deposits is only for deposits with tonnages comparable to those used in the grade tonnage model. Regions offer potential for discovery of concealed volcanogenic deposits; most favorable areas are sedimentary rocks that overlie mafic volcanic rocks in regions 1A, 1C; region 1B has undergone no detailed exploration, but is considered favorable for volcanogenic deposits.	2*	3*	6*

Table 2.--Descriptions of regions of metallic mineral resource potential in the Seward and Blying Sound quadrangles, Alaska--Continued

Deposit type: Resources	Geologic controls of mineral resources	Production and resource information	Status of geologic information	Summary of mineral resource potential	Estimated number of deposits Percent chance that there are at least the number predicted 90 percent	50 percent	10 percent
			REGIONS 2A AND 2B				
Submarine volcanogenic: Cu, Ag, Au, (Zn).	Massive and disseminated sulfides, mainly chalcopyrite, pyrite, pyrrhotite, and sphalerite; generally localized in or near shear zones in mafic sheeted dikes, pillows, and tuffs on Glacier Island and in structurally higher sedimentary rocks to north and west; all mineral deposits related to submarine volcanic processes.	No production or known reserves.	Reconnaissance geologic, geochemical, and geophysical coverage during this study.	No large volcanogenic deposits are known, but the regions are poorly explored. Regions offer potential for discovery of concealed volcanogenic deposits.	2*	3*	6*
			REGIONS 3A AND 3B**				
Submarine volcanogenic: Cu, Ag, (Zn, Pb).	Mainly as disseminations and breccia cement in sheared sheeted dikes, pillows, and tuff of basaltic composition, and gabbro; local massive sulfides and thin veins; chiefly pyrite with subordinate chalcopyrite, pyrrhotite, sphalerite, and secondary copper minerals.	No production or known reserves.	Reconnaissance geologic, geochemical, and geophysical coverage during this study. Minor industry interest.	At least 11 incompletely explored prospects dating from early part of this century. Known mineral deposits are mainly in mafic volcanic rocks, but by analogy with region 1C, the overlying and structurally higher sedimentary rocks of region 3B may offer potential for mineral deposits. The grade-tonnage model may apply.	0	1	3

Table 2.--Descriptions of regions of metallic mineral resource potential in the Seward and Blying Sound quadrangles, Alaska--Continued

Deposit type: Resources	Geologic controls of mineral resources	Production and resource information	Status of geologic information	Summary of mineral resource potential	Estimated number of deposits Percent chance that there are at least the number predicted		
					90 percent	50 percent	10 percent
Magmatic: Cr, Ni.	Minor anomalous amounts of nickel and chromium in small irregularly shaped pods and tabular slivers of serpentinized dunite; large concealed mass of ultramafic rocks may underlie most of region 3B and the northern part of region 3A.	No production or known reserves.	Reconnaissance geologic, geochemical, and geophysical coverage during this study. Minor industry interest.	Ultramafic mass thought to underlie northern part of region 3A, and most of region 3B could contain nickel and chromium. That part of region 3B north of region 3A may have potential for mafic volcanogenic deposits, by analogy with region 1C, but the geochemical sampling is not sufficiently detailed to evaluate the possibility.	No estimate made.		
			REGION 4A				
Hydrothermal: Au, Ag.	Slate and sandstone flysch and felsic dikes, faulted and fractured, recemented by gold-bearing quartz veins.	Lode deposits of the region yielded about half of the more than 50,000 troy ounces of gold recovered from the map area.	Reconnaissance geology, geochemistry, and geophysics for this study; detailed study of mines in northern part of region by Mitchell (1979), Mitchell and others (1981).	Low tonnage lode gold deposits of region have potential for recovery of gold, but profitability is questionable because mining of vein-type deposits is labor-intensive and costs of transport to smelter in continental United States are high.	Do.		
Placer: Au.	Placer deposits in present-day streams and in fossil stream sediments of adjacent Quaternary strata.	Much of the more than 100,000 troy ounces of placer gold recovered map area came from Resurrection and Mills Creeks in this region. Mills Creek yielded the largest quantity, although the drainage contains no lode mines or prospects.	Reconnaissance geology, geochemistry, and geophysics for this study.	Region presently yields placer gold and has potential for continuation of small placer operations.	Do.		

Table 2.--Descriptions of regions of metallic mineral resource potential in the Seward and Blying Sound quadrangles, Alaska--Continued

Deposit type: Resources	Geologic controls of mineral resources	Production and resource information	Status of geologic information	Summary of mineral resource potential	Estimated number of deposits Percent chance that there are at least the number predicted 90 percent 50 percent 10 percent
			REGION 4B***		
Hydrothermal: Au, Ag, (Sb).	Slate and sandstone flysch, intruded locally by felsic dikes; rocks are cut by narrow fracture zones, cemented by quartz that forms veins, lenses, and stringers, as much as 2 m thick and 100 m long.	Several thousand troy ounces of gold recovered from lode mines in eastern part of region.	Reconnaissance, geologic, geochemical, and geophysical data obtained during this study; little evidence of industry interest.	Region has potential for low-tonnage gold-bearing quartz veins, but much of region is poorly exposed, making exploration difficult.	No estimate made.
Placer: Au.	Placer deposits in present-day streams and in fossil stream sediments of adjacent Quaternary strata.	A very small amount of placer gold recovered.	Little evidence of industry interest.	Potential for placer deposits is considered low.	Do.
			REGION 4C		
Hydrothermal: Au.	Slate and sandstone locally cut by mineralized quartz veins, stringers, and pods.	No known gold production.	Reconnaissance geology, geochemistry, and geophysics during this investigation; little evidence of industry interest.	Region has potential for low-tonnage gold-bearing quartz veins; potential for placer gold deposits is considered low.	Do.
			REGION 4D		
Hydrothermal: Au.	Slate and sandstone flysch, with locally abundant quartz veins.	No known production of lode or placer gold.	Reconnaissance geology, geochemistry, and geophysics during this study.	Potential for lode and placer gold is considered low.	Do.

Table 2.--Descriptions of regions of metallic mineral resource potential in the Seward and Blying Sound quadrangles, Alaska--Continued

Deposit type: Resources	Geologic controls of mineral resources	Production and resource information	Status of geologic information	Summary of mineral resource potential	Estimated number of deposits Percent chance that there are at least the number predicted		
					90 percent	50 percent	10 percent
			REGIONS 5A AND 5B				
Hydrothermal: Au, Ag, (Sb).	Slate and sandstone flysch and intrusive granitic bodies and felsic dikes are fractured along shear zones; sheared rock is recemented by quartz veins, as much as 1 m wide and 100 m long, and a few stringers, pods, and lenses.	Port Wells gold district produced gold between 1910 and 1940, yielding about 22,000 troy ounces of lode gold of which about 20,000 ounces came from the Granite mine of region 5A; region 5B yielded only a small percent of the remainder.	Reconnaissance geology, geochemistry, and geophysics during this study; details of mineral deposits mainly from topical studies in early part of century; little recent industry interest.	Many low-tonnage gold-quartz veins known and others probably present; region 5A is more favorable than 5B, based on geochemical data, prospects, and known production from mines.	No estimate made.		

* Estimated number of deposits for regions 1A, 1B, 1C, 2A, and 2B combined, as discussed in explanatory notes at top of table.

** Data for region 3A are for mafic volcanogenic model; data for ultramafic rocks present where regions 3A and 3B coincide is shown under region 3B. Boundary of region 3B is based mainly on magnetic pattern.

***Region is defined mainly from geochemical data common to regions of the Seward quadrangle that produced gold.