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MINERAL RESOURCE POTENTIAL OF THE SURVEY PASS QUADRANGLE, BROOKS RANGE, ALASKA

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INTRODUCTION

This study of the Survey Pass quadrangle in the central Brooks Range, Alaska, is part of the Alaska Mineral Resource Assessment Program (AMRAP), which is a long-range effort to assess the mineral resources of Alaska by systematic study of 1:250,000-scale quadrangles with multidisciplinary teams of geologists, geochemists, and geophysicists. Field work on the Survey Pass quadrangle was carried out in 1977 and 1978; most of the work has been published as part of the MF-1176 folio. This report on the mineral resources in the quadrangle is for the most part based on earlier published parts of the series: geologic map (Nelson and Grybeck, 1980), structural geology (Grybeck and Nelson, 1981a), metamorphic rocks (Nelson and Grybeck, 1981), geochemical studies of stream-sediment samples and heavy-mineral concentrates (Cathrall and others, 1981) and rock samples (Grybeck and others, 1981), mineral deposits (Grybeck and Nelson, 1981b), aeromagnetic interpretation (Cady and Hackett, 1982), and Landsat (satellite) imagery interpretation (Le Compte, 1981). Unless otherwise mentioned, those reports are the basis for the statements about the geology, geochemistry, and geophysics of the quadrangle that are made repeatedly in this report. To avoid constant repetition, those publications will not be cited unless a particular point is to be made.

This assessment is confined to nonfuel, metallic minerals. No known deposits of coal, petroleum, or natural gas are present in the Survey Pass quadrangle and apparently no one has predicted any might be present. It is unlikely that significant resources of any of these commodities exists in the study area. The overpowering, largely implicit conclusion of industry with which we concur is that the study area has no potential for coal, petroleum, or natural gas, although some uncertain but probably negligible potential may exist for oil and gas at depth beneath regional thrust faults. Sand and gravel resources exist in practically unlimited quantities at numerous localities in the quadrangle. However, the value of sand and gravel resources depends on access to markets and transportation to reach them. There are no known or likely markets for any significant quantities of these commodities in or near the quadrangle that could remotely bear the cost of transport. Barite is found in several places in the quadrangle and it might be recovered as a by-product of base- or precious-metal production. However, the geochemical data indicate that large deposits of barite are unlikely in the quadrangle. There is little indication of resources of any other industrial mineral. Considerable work was done on the uranium potential of the quadrangle in the late 1970's by the Department of Energy (DOE) under the National Uranium Resource Evaluation (NURE). Some NURE data has been released (Los Alamos National Laboratory, 1981; Oak Ridge Gaseous Diffusion Plant (1981) but the results of that work have not been evaluated in detail. The NURE data indicate considerable variation in the uranium content of the rocks, and further work may be warranted, but there is presently little evidence of significant resources in the quadrangle.

The terms "mineral deposit" and "deposit" in the report are used in the general sense to include mineral occurrences, prospects, claims, and mines; this convention follows the use by Grybeck and Nelson (1981b) in the compilation of mineral deposits for the project. The classification of deposits and ore deposit models generally follows Skinner (1981), Cox and Signer (1986), Roberts and Sheahan (1988), and Sheahan and Cherry (1993). For lack of definitive data, especially for buried or speculative types of deposits, some deposit types are described in general terms. More detailed references are added as appropriate for specific types of deposits in the discussions of individual tracts of mineral resource potential. Statements about geochemical associations follow Boyle (1974), Levinson (1980), and Rose, Hawkes, and Webb (1979).

HISTORY OF EXPLORATION

Although a few prospectors may have worked in the Survey Pass quadrangle earlier, systematic mineral exploration in the central Brooks Range began only after the discovery of gold in the Klondike in 1898 and at Nome a few years later. Prospectors moved eastward into the Brooks Range from Kotzebue and northward up the Alatna River. Several short-lived settlements resulted, some for little more than a season, and most of the creeks in the quadrangle were probably prospected for placer gold by 1905. Several lode prospects were also found in the Survey Pass quadrangle at about the turn of the century; none of them has been active since and several cannot now be located. The central Brooks Range was relatively inaccessible in this early exploration compared to other areas of Alaska, and the early prospector's lack of success in locating gold placers could have been due to superficial prospecting. However, the fact that exploration to date has proved no more successful in finding significant gold placers indicates that there are none of significant size. Between World Wars I and II, itinerant prospectors visited the quadrangle intermittently, and the mineral industry may have done some exploration, but little information about that work has been recorded, and it is unlikely that any now-forgotten major deposits were found during this period.

Prior to World War II, the USGS mounted several epic expeditions through the Brooks Range to establish its geologic framework Most notable of these were the 1901 journey of W. C. Mendenhall down the Kobuk River (Mendenhall, 1902) and the 1923-1926 work of P. S. Smith and his colleagues (Smith and Mertie, 1930). Despite this early work, the geology of the Survey Pass quadrangle was largely unknown as late as 1954, when only a small segment of the large granite plutons in the center of the quadrangle was shown on the geologic map of Alaska (Dutro and Payne, 1954).

Modern mineral exploration in the central Brooks Range started after World War II, beginning with Reinhard Berg, who restaked an old lode-copper prospect in the Cosmos Hills about 50 km west of the southwest corner of the quadrangle. In 1957, the Bear Creek Mining Company optioned this property, now called the Ruby Creek prospect (or sometime "Bornite" from the name of the exploration camp) and began an extensive program of drilling and underground exploration. A considerable tonnage of ore was defined during the exploration of the Ruby Creek prospect from 1958 to 1963, but there has been no production to date from the deposit. Encouraged by the size of the Ruby Creek prospect, the Bear Creek Mining Company began regional exploration throughout the Brooks Range in the 1960's, and several other companies and individuals followed. However, Brooks Range exploration in the early 1960's was tempered by the common perception of many geologists that the Brooks Range was geologically unfavorable for the occurrence of mineral deposits of any significant size or was too isolated for a viable mine.

In 1965, the Bear Creek Mining Company discovered a large massive-sulfide, copper-zinc deposit, the Arctic prospect, about 15 km west of the Survey Pass quadrangle in the belt of pelitic schists that forms the southern flank of the Brooks Range. The mineralized part, which includes parts of the Ambler and Survey Pass quadrangles, is now known as the Ambler district (an informal designation rather than a legally established mining district). The Ambler district was first defined by Sicherman and others (1976) and its geology has subsequently been studied in considerable detail (as will be discussed later), largely as a result of work by the Anaconda Minerals Company and various other companies. By the mid-1970's, a major claim-staking rush was taking place along the southern flank of the Brooks Range, well into the Survey Pass quadrangle, as several companies attempted to establish a position in what had become one of the major mineral belts of Alaska.

However, in the late 1960's, events initiated elsewhere in the state greatly influenced mineral exploration in the central Brooks Range and in the Survey Pass quadrangle in particular. The discovery of oil at Prudhoe Bay gave Alaska's native people a lever to establishing their legal ownership of Alaskan lands. The results was the Alaska Native Claims Settlement Act of 1971 (ANCSA). Among the results of ANCSA, the Federal government withdrew 80 million acres of Federal land in Alaska from mineral entry for consideration as national parks, wildlife refuges, and various other uses that would preclude mineral exploration or development.

In particular, much of the Survey Pass quadrangle was closed to exploration and mineral entry. During the negotiations that followed the passage of ANCSA, the state of Alaska expressed interest in the Ambler district as part of their entitlement under the Alaska statehood act. By the late 1970's, the state had gained title to most of the belt of pelitic schists (unit Pzs) on the accompanying map) in the southern part of the Survey Pass quadrangle between the west boundary of the quadrangle and the Reed River, and between about long 153° 45" W., and the east boundary of the quadrangle. (This belt of schist if often referred to informally as the "schist belt"; however, it has not been defined uniformly and some workers extend the "schist belt" more widely to the north.) This state land is mostly open to mineral exploration and includes most of the part of the Ambler district in the Survey Pass quadrangle.

With the enactment of the Alaska National Interest Lands Conservation Act of 1981 (ANILCA), most of the Survey Pass quadrangle was put into the Gates of the Arctic National Park and Preserve. It is closed to mineral exploration by industry, and there is little indication that its status will change. The boundaries of the Gates of the Arctic Park and Preserve are shown on current USGS topographic maps. The only land that remains outside the park in the Survey Pass quadrangle are the blocks of state land noted in the previous paragraph in the southwest and southeast corners of the quadrangle; these areas compose about one-fifth of the quadrangle.

During much of the 1980's and to the present (1995), exploration in the Ambler district was moderate to minor compared to the intense interest in the area in the 1970's. In general, mineral exploration in Alaska dropped dramatically in the early 1980's mainly because of depressed metal prices. Activity in the Ambler district in particular was also inhibited by the realization that the development of a mine in so isolated an area would require considerable negotiations and a heavy investment to establish a transportation corridor into the area, by the considerable work that would be necessary for an environment assessment for any mining development in the area, and by the need for a major capital investment for a mine if one was to be developed. By no means has the Ambler district been written off by industry. Most exploration geologists would consider it to have excellent potential for massive-sulfide, base-metal deposits in particular. Rather, most exploration work has shifted elsewhere to areas that are more favorable logistically or to metals that are more attractive, gold in particular.

The basis for a mineral resource assessment of an area is geologic information. This study was designed to provide the minimum level of data necessary for a credible *regional* mineral resource assessment. But any such assessment is greatly improved by contributions of data by the minerals industry who have conducted detailed work on specific mineral deposits, work such as they have carried for decades in most area of the conterminous United States.

To summarize, since the 1970's, industry has carried out considerable exploration in the Ambler-district part of the Survey Pass quadrangle west of the Reed River. The rest of the quadrangle was examined only in reconnaissance, if even that, by the minerals industry before 1971 and has been effectively closed to mineral exploration since then.

CRITERIA FOR ASSESSMENT

This mineral resource assessment is largely based on information that was collected specifically for this purpose in the field in 1977 and 1978, review of the published literature, and discussions with industry geologists who have worked in the quadrangle.

A preliminary geologic map of the quadrangle was published by Brosgé and Pessel (1977). Much of the effort of this project was devoted to preparing a more detailed map (Nelson and Grybeck, 1980). It forms the framework for interpreting the geochemistry and geophysics and interpreting and predicting the type and extent of mineralization in the quadrangle. A simplified version is shown on this map. More than 1,200 geologic stations were studied, about half of these along foot traverses and the rest at sites visited by helicopter to fill in between the traverse. The goal of the study was not to find mineral deposits let alone locate all the mineral deposits in the quadrangle--a job that would normally be done by the minerals exploration industry and far beyond the resources available for this study--but to define tracts of land with mineral resource potential. Because the types of deposits, their sizes, and their geologic associations are key factors in mineral resource assessment, considerable emphasis was placed on visiting and sampling known mineral deposits and examining areas or sites that showed evidence of mineralization or alteration that might be associated with mineralization.

Systematic geochemical sampling is a powerful tool for mineral resource assessment because it provides direct evidence of metals in undiscovered mineral deposits, reveals elemental associations that may indicate the types of mineral deposits in an area, and helps define the boundaries of the tracts with mineral resource potential. We collected stream-sediment and panned-concentrate (heavy-mineral) samples at 623 sites in the quadrangle. In the southwestern part, we used comparable data on samples collected by the Alaska Division of Geological and Geophysical Surveys and analyzed in USGS laboratories (see Cathrall and others, 1981, for details). In all, the geochemical synthesis is based on samples collected at 1,505 sites or about one for each four square miles. The stream-sediment and heavy-mineral samples underwent routine semi-quantitative spectrographic analysis for silver, arsenic, gold, boron, barium, beryllium, bismuth, cobalt, chromium, copper, lanthanum, molybdenum, niobium, nickel, lead, antimony, tin, strontium, vanadium, tungsten, and zinc. Zinc was also analyzed to greater sensitivity by atomic absorption analysis.

After our field work, the Department of Energy released raw analytical data from 1,249 stream-sediment samples collected in the Survey Pass quadrangle under the NURE program (Los Alamos National Laboratory, 1981; Oak Ridge Gaseous Diffusion Plant, 1981) Although their analytical methods vary considerably from ours, most of the same elements were analyzed. Because of the information that it could contribute to this study, the NURE stream-sediment data were plotted and synthesized by the U.S. Geological Survey (Chazin and others, 1983). In general, the NURE data support our conclusions and do not indicate any additional areas of mineral resource potential.

In conjunction with geologic mapping, rock samples were collected at all the geologic stations, especially at known or suspected mineral deposits and submitted for the same multi-element analysis as the stream-sediment and heavy-mineral samples. The rock geochemistry (Grybeck and others, 1981) provides background data that help interpret the stream-sediment and heavy-mineral analyses, establishes areal variation in the trace-metal content of the rocks, and, in several cases, identifies previously unknown mineral deposits.

An aeromagnetic map was prepared under contract from 1974 to 1978 by the Alaska Division of Geological and Geophysical Surveys and provides the data for interpreting subsurface geology (Cady and Hackett, 1982). The main constraint on the aeromagnetic interpretation is the three-quarter-mile spacing between flight lines.

Interpretation of satellite (Landsat) imagery provides a synoptic view of linear and arcuate features in the quadrangle and highlights areas of discolored or altered rocks (Le Compte, 1981).

THE MINERAL RESOURCE ASSESSMENT

This study involved three years of field and laboratory investigations by a team of geologists and technicians; it culminated in a meeting of the principal scientists to integrate the data and produce the final mineral resource assessment that is represented in this report. Assessments for individual tracts varied from quantitative where considerable data were available and the types of deposits were well known, to qualitative, where the data were sparse to ambiguous.

The tracts show on the map are the surface projections of three-dimensional bodies of rock that have mineral resource potential. It is difficult to project the boundaries of these bodies into the subsurface, especially as depth increases. In some cases, these bodies may be truncated at depth by unsuspected faulting, although faulting can also serve to increase the size of the bodies at depth. In other cases, surface information may suggest that the area of mineral resource potential expands at depth or that deeper parts of the tract are more favorable for mineral deposits than are surface parts.

Our fundamental criteria for defining tracts of mineral resource potential is deposit type. Two types of deposits are particularly important in the quadrangle: (1) metamorphosed, volcanogenic, copper-zinc-lead, massive-sulfide deposits associated with metarhyolite, that is Kuroko-type massive-sulfide deposits and (2) polymetallic, epigenetic deposits associated with felsic plutonic rocks. Volcanogenic, massive-sulfide deposits are well represented in the southwestern part of the quadrangle in the Ambler district. And several of the tracts of mineral resource potential identified in this study are marked by clusters of skarn or contact metasomatic deposits at the peripheries of the granite plutons of Mount Igikpak and Arrigetch Peaks. The details of these deposit types will be discussed subsequently by tract.

Worldwide, felsic plutons are widely associated with a variety of types of deposits including skarns of diverse type, porphyry copper and porphyry molybdenum deposits, hydrothermal veins and replacement deposits, and disseminated deposits. Typically the deposits include various combinations of copper, lead, zinc, iron, gold, silver, tin, tungsten, beryllium, molybdenum, antimony, arsenic, and other elements. Various evidence, including suites of these elements in the geochemical data, suggest that felsic plutons are buried beneath several areas in the quadrangle. They are likely to form a favorable environment for mineral deposits similar to those adjacent to the Mount Igikpak and Arrigetch Peaks plutons. However, the suspected buried plutons may not be comparable to the plutons exposed in the quadrangle and other types of deposits related to felsic plutons are possible. Where specific evidence is not available to classify the deposits over the proposed buried plutons with assurance, they are collectively termed "felsic plutonic".

Several other types of deposits that occur in the Brooks Range or adjacent areas of western Canada were also specifically considered: (1) stratiform, sedimentary-exhalative, lead-zinc-barite deposits in shale or sandstone, such as occur at the Red Dog deposit in the DeLong Mountains in the northwestern Brooks Range (Lange and others, 1985; Moore and others, 1986), (2) porphyry copper and porphyry molybdenum deposits, deposits associated with skarns, and gold quartz veins, such as those in the Chandalar area to the east (Chip, 1970; Newberry, Dillon, and Adams, 1986, and (3) volcanogenic zinc-lead deposits such as the Drenchwater Creek deposits in the Howard Pass quadrangle to the northwest (Nokleberg and Winkler, 1982; Lange and others, 1985). Although geology favorable to all these types of deposits is present in the Survey Pass quadrangle, there is no supporting evidence that they do occur and, in particular, the geochemical data collected in this study indicates that none occurs near the surface.

We also considered the hundreds of others types of mineral deposits. Many, such as diamond deposits or Precambrian banded-iron deposits were quickly rejected because the geologic environments were not appropriate for their occurrence. Some, such as gold placers, were constantly kept in mind during the work, but they were eventually rejected because the systematic and thorough search for them in the quadrangle for a period of over 90 years has been unsuccessful. Other types, such as Mississippi Valley-type, lead-zinc deposits that are now not known in the Brooks Range, were considered because of the thick Paleozoic carbonate sequence in the quadrangle. However, we found no diagnostic evidence of these existence beyond the presence of the carbonate rocks.

No tract was assigned a mineral resource potential solely on the basis of favorable geology for a particular type of deposit if no deposit of that type could be located in the quadrangle or no geochemical or geophysical evidence for a deposit of that type was present. This pragmatic approach may be unduly negative in some cases because certain types of deposits in particular geologic settings have either weak or no geochemical or geophysical expressions. Furthermore, the quadrangle has not been sufficiently prospected to locate all the mineral deposits exposed at the surface or to confidently define all the types of deposits which may occur. Mineral deposits are relatively rare and small and are indicated by subtle signs, especially if deeply buried. Thus, no part of the quadrangle can to be said to be absolutely devoid of mineral resource potential without a close-spaced grid of drill holes. Accordingly, those parts of the quadrangle not shown to have mineral potential might better be considered as areas for which we have no evidence of mineral resource potential at this time.

Three categories of tracts that have mineral resource potential are distinguished on the map: (1) tracts that have substantial or highly probable potential, (2) tracts that have probable potential, and (3) tracts that have some potential, but it is based on weak or limited evidence. For instance, the mineral resource potential of tract A in the Ambler district is quite clear as defined by several known massive-sulfide deposits, continuity of the belt to the west into the Ambler River quadrangle where the world-class Arctic deposit occurs, and a pronounced geochemical signature. In contrast, potentially mineralized felsic plutons are thought to exist below several tracts based on strong geologic evidence. The possibility that these plutons occur at depth is high, but the evidence allows considerable uncertainty about the types, depths, and sizes of the deposits that might be associated with them and the subsurface structures that may have displaced them. Thus, the definition of tracts of mineral resource potential is based on our best analysis of the existing data, but that data varies considerably in individual tracts. All the tracts identified have mineral potential, but the probability that a deposit exists varies considerably.

Each tract will be discussed separately with emphasis on its particular geology, mineral deposits, geochemistry, geophysics, and mineral resource potential. Table 1 (map sheet) presents a summary of the mineral resource potential of each tract and the key data to support that assessment.

TRACT A

DESCRIPTION OF GEOLOGY AND MINERAL DEPOSITS

Tract A is confined to the schist belt (mainly unit Pzs on the accompanying map) that lies along the southern flank of the Brooks Range. The rocks consist mainly of pelitic schists, probably of Devonian and Mississippian age, but some may possibly be as old as Proterozoic. The schist belt locally includes one or more units marked by an association of mafic metavolcanic and metarhyolitic rocks interlayered with schist, and some marble. The rocks in the tract have a polymetamorphic history; most are now greenschist-facies metamorphic rocks, but blueschist-facies rocks are present in several areas. The structural history of the area is complex, probably beyond what is now recognized; several large isoclinal folds have been identified, and small-scale folds are ubiquitous at outcrop scale. An excellent detailed geologic map of the Ambler district that includes this tract has been published by Hitzman and others, 1982.

The mineral deposits of this tract are almost unanimously considered by geologists who have studied them in detail to be volcanogenic, copper-zinc-lead, massive-sulfide deposits of the Kuroko type that have values in gold and silver (Smith and others, 1977, 1979; Hitzman, 1978; Kelsey, 1979; Zdepski, 1980; and Hitzman and others, 1982). In particular, Hitzman and his colleagues (1986) have described the geology and deposits of the Ambler district in considerable detail. The deposits occur in the Ambler sequence, an informal lithologic name routinely used by most geologists working in the area and that will be used in this report. The Ambler sequence is a 1.5-km-thick section of bimodal volcanic rocks that consist of metarhyolite and basalt and subordinate carbonates and pelitic schist that formed in a Devonian to Mississippian, rift-related, tectonic environment. (The Ambler sequence is not delineated on the map with this report, but the metafelsite unit (Df) and the mafic volcanic and intrusive rocks unit (Psm) shown there are essential parts of it.)

The dominant ore mineral in the deposits is pyrite, but the main minerals of economic importance are chalcopyrite, sphalerite, and galena; tennantite-tetrahedrite, bornite, cymrite, and barite also occur locally. The massive-sulfide layers commonly have been oxidized at the surface to a quartz-rich gossan that contains tiny vugs that mirror the shape of the now-dissolved sulfides. In some cases, oxidization and dissolution of the sulfides has been nearly complete at the surface, and the gossan is nearly barren of metal values. In other words, surface oxidization has destroyed much of the surface expression of many of the known deposits, and they usually can only be located by careful mapping or drilling. Some additional deposits probably remain near the surface to be discovered in spite of the considerable detailed mapping in the tract.

The best understood and largest volcanogenic, massive-sulfide deposit in the Ambler district is the Arctic deposit (Schmidt, 1983, 1986, 1988) that occurs just west of the quadrangle in what is clearly an extension of tract A. At the Arctic deposit, 37 million metric tons of resources have been identified with an average grade of 4.0 percent copper, 5.5 percent zinc, 0.8% lead, 1.5 oz/ton silver, and 0.02 oz/ton gold. As an indication of the relatively small size of these deposits and their potential importance, the Arctic deposit covers a total area of about 250 aces (100 hectares) and has a gross metal value of about $8.4 billion at June 1, 1995, metal prices.

There has been no mineral production from tract A but, as will subsequently be documented, more than a billion dollars of mineral resources have been located by drilling. The principal known deposits are in the Picnic Creek drainage. (Picnic Creek is an informal name not shown on current USGS topographic maps that has long been used for the southward-flowing drainage in T. 19 N., R. 17 E., approximately halfway between the Reed River and Beaver Creek.) The Sun deposit is the best known; extensive drilling by the Anaconda Minerals Companies in the late 1970's outlined more than 12.5 million metric tons of resources that have a grade of 1.8% copper, 5.3 percent zinc, 1.8 percent lead, and 2.8 oz/ton silver (Hitzman and others, 1986). The gross metal values of the Sun deposit is about $2.0 billion at June 1, 1995, metal prices. Several others prospects in the Picnic Creek area have also been drilled by several companies who have been active in the area, but details about the sizes and grades of these deposits have not been made public.

The other prominent center of exploration in the tract is west of the Mauneluk River in T. 20 N., R. 13 and 14 E., where extensive drilling has been done at several locations (Hitzman, 1978). Details of the metal values on most of these deposits has not been announced, but the presence of the Ambler sequence and ore minerals locally clearly indicate that the area is favorable for the occurrence of massive-sulfide deposits. The best known deposit in this area is the BT which contains 3.4 million metric tons of resources that grade 1.7 percent copper, 2.6 percent zinc, 0.9 percent lead, and 1.3 oz/ton silver (Hitzman and others, 1986).

CRITERIA FOR DEFINITION OF TRACT

The most obvious and probably the best guides to define the extent of tract A are the distribution of known massive-sulfide deposits and the associated Ambler sequence. The stream-sediment geochemical anomalies of copper, zinc, lead, barium, and silver, and to a lesser extent molybdenum, antimony, and bismuth (Cathrall and others, 1981) also help to define the boundaries of the tract. The aeromagnetic data are ambiguous (Cady and Hackett, 1982). A pronounced aeromagnetic high over the Picnic Creek area coincides with a prominent area of exploration but the overall aeromagnetic contour pattern within the tract shows little correlation with the surface geology. We cannot explain this discrepancy. The surface geology may be more complex than presently recognized, or the subsurface geology may have a structural complexity that appears in the aeromagnetic data but is not reflected at the surface.

ESTIMATION OF UNDISCOVERED MINERAL RESOURCES

We estimated the number of undiscovered volcanogenic massive-sulfide orebodies in the tract--that is bodies of mineralized rock of sufficient tonnage and grade to be economically viable now or in the future--by considering several factors. The geology, particularly the distribution of the Ambler sequence, and the stream-sediment geochemical anomalies define a very large area relative to the size of known deposits, which may be less than 9 hectares (20 acres) in surface area. The only reliable way to define an economically significant deposit in this geologic environment is by drilling. But only a small part of the tract has been drilled and that only to shallow depth relative to the depth that deposits might be mined with current technology. One of the best guides to the discovery of additional deposits in the absence of drill information is detailed surface mapping, and several companies have done considerable detailed mapping in the tract. However, detailed geologic mapping is not in itself definitive because the sulfide-bearing zones do not always crop out at the surface or may be obscured by surficial material or oxidization. To estimate the undiscovered deposits, we considered the large size of the tract, the probable small sizes of undiscovered deposits, the limited resolving power at depth of the exploration tools that have been used in the tract, the large amount of surficial cover, and the relatively youthful stage of exploration.

In addition to the Sun deposit at Picnic Creek and the BT deposit, which assuredly have substantial mineral resources, we estimate that 3 to 6 additional orebodies can be confidently predicted to be present in tract A. While a rigid statistical analysis of this prediction is probably unwarranted, the mid-point of this estimation is considered to be at about the 50 percent probability level. We further estimate that as many as 6 to 20 additional deposits may be present with the midpoint of that prediction at about the 5 percent probability. In making the estimates, we considered that economic deposits might occur to a depth of about 1,500 meters. In spite of the lack of subsurface data, it is geologically reasonable that deposits occur to that depth and that deposits to that depth are accessible by current mining technology.

The sizes of the predicted orebodies cannot be quantified exactly; they will surely vary in tonnage and grade. While every ore deposit is unique, the systematic tabulation of the tonnage and grade of volcanogenic, massive-sulfide deposits from throughout the world prepared by Singer and Mosier (1986) provides a useful approximation of the grade and size of the undiscovered orebodies in this tract. Figure 1-5 (p. 16-17) are reproduced from their work. The minimum size of our predicted orebodies is the minimum-sized deposit noted by Singer and Mosier (1986), that is about 100,000 metric tons of ore. Note that the Arctic deposit is shown on figures; it is one of the largest base-metal massive-sulfide deposits in the world and is particularly impressive in size and grade of copper.

SUMMARY OF MINERAL RESOURCE POTENTIAL

In spite of excellent geologic mapping by numerous geologists and considerable drilling, the assessment of the mineral potential of the tract much leaves much to be desired because the geology is complex, the geochemistry and geophysical data are not definitive much below the surface, and the amount of drilling is limited compared to the size of the deposits and the extent of the tract. However, tract A is part of one of the major mineral belts of Alaska, the Ambler district. Several copper-zinc-lead massive-sulfide deposits have already been identified in the tract and more than $2 billion of mineral resources have already been defined by drilling. The tract has excellent potential for the discovery of additional deposits.

TRACT B

DESCRIPTION OF GEOLOGY

Tract B is the geologic extension of tract A along the schist belt; for geologic details refer to the discussion of tract A. The main difference is that tract B has not been studied as intensively by industry, and the geologic and geochemical indications of mineralization are less striking.

CRITERIA FOR DEFINITION OF TRACT

The geology of the tract is generally favorable for the occurrence of volcanogenic, copper-zinc-lead massive-sulfide deposits; several small deposits that may be massive sulfides are known in the tract; and geochemical anomalies similar to those in tract A extend into this tract. However, no large massive-sulfide deposits are known in tract B, and industry has not drilled in the area. The major distinction between tract A and B may be the intensity of exploration rather than a lack of mineral endowment, especially since only relatively subtle indications of mineralization had been found in tract A prior to drilling. The apparent lack of the metarhyolite of the Ambler sequence in tract B is not encouraging for the presence of undiscovered massive-sulfide deposits, but this apparent absence may be due to a lack of detailed mapping. In addition, massive-sulfide deposits do not always occur within or immediately adjacent to felsic volcanic rocks. Metal-bearing solutions may move a considerable distance from a center of submarine volcanism before depositing their metals, for instance from a felsic volcanic center such as is exposed in tract A to a comparable stratigraphic horizon in tract B.

Within tract B, the geochemical data indicates that the potential for mineralization apparently decreases toward the east. There is no evidence that massive-sulfide deposits of the Ambler sequence extend east of about longitude 153° 50" W. in the Survey Pass quadrangle. However, industry has explored volcanogenic massive-sulfide deposits in the schist belt just east of the Survey Pass quadrangle in the Wiseman quadrangle (Grybeck, 1977; Bliss and others, 1988).

ESTIMATION OF UNDISCOVERED MINERAL DEPOSITS

The data are insufficient to estimate the number and size of undiscovered massive-sulfide deposits in tract B. The detailed mapping and drilling data necessary to confidently estimate the number of undiscovered deposits in tract B has not been done.

SUMMARY OF MINERAL RESOURCE POTENTIAL

Tract B is the eastern extension of tract A, but no massive-sulfide deposits are known in tract B. The area has potential for massive-sulfide deposits albeit probably at a lesser probability than in tract A. Geochemical anomalies are present that are similar to those in tract A, but they are more diffuse and less intense. There is no evidence that volcanogenic massive-sulfide deposits persist east of about longitude 153° 50' W. in the Survey Pass quadrangle.

TRACTS C AND D

DESCRIPTION OF GEOLOGY AND MINERAL DEPOSITS

The geology of tracts C and D is dominated by Devonian gneissic granite plutons that intrude a metamorphosed sedimentary sequence composed of Devonian and (or) Mississippian phyllite, marble, and conglomerate. The root of metasedimentary rocks overlying the granite is strikingly exposed in a steep slope on the north side of the Noatak River in T. 25 N., R. 17 E., where the metasedimentary rocks form an open syncline plunging gently to the north over the granite. several erosional remnants of the metasedimentary rocks are also preserved above the granite on the high peaks south of the Noatak River. Contact-metamorphic and contact-metasomatic effects--skarns, quartz veins, hornfels, silicified zones, and other zones of alteration--are ubiquitous and well preserved even though the granite and surrounding rocks have gone through at least green-schist facies regional metamorphism. The contact metamorphic and metasomatic effects usually extend no more than several hundreds of meters away from the contact, although alteration zones and quartz veins may occur farther away. The varied contact effects of the granite are generally limited in extent, geometrically erratic, and of different types, even immediately adjacent to the granite. Newberry and others (1986) have discussed the regional distribution and geology of these granite plutons in the central Brooks Range as well as their related skarns and mineral deposits in detail.

Numerous mineral deposits occur within the tract. They differ in character from veins to disseminations and in type from sulfide-bearing quartz veins to skarn deposits. The deposits contain various combinations of lead, zinc, copper, silver, gold, tin, tungsten, molybdenum, bismuth, antimony, beryllium, and fluorine; all are essentially related to each other in their common origin related to the emplacement of the granite. None of the deposits has had significant exploration and none has been productive. All the deposits are small, and most are better described as occurrences of ore minerals rather than prospects. Newberry and others (1986) makes the point that the skarns are classic tin skarns. However, they have relatively low tin values and there is little sign of the release and reconcentration of tin from the skarns that mark many (most) economic tin deposits related to granite. Our examination of the contact zones of the granite suggest that additional prospecting would almost certainly reveal more occurrences of ore minerals.

Tract C, of all the areas near exposed granite in the quadrangle, seems to have the greatest potential for hydrothermal, vein, skarn, or contact-metamorphic deposits. The apex of the granite pluton is exposed beneath an extensive, flat-lying cap of shale and carbonate rocks that is particularly favorable. The numerous mineral deposits that have been found in the tract attest to its potential and the geochemical anomalies are particularly well marked and intense.

The largest and most conspicuous indication of mineralization in the tracts is a yellow-orange altered zone on the northeast side of the prominent peak just east of Angiaak Pass. Our (admittedly limited) examination of several localities within this altered zone and of float below the peak revealed little sign of ore minerals. Disseminated pyrite is locally present and a few grains of molybdenite, arsenopyrite, or fluorite were found, but the area has been extensively silicified. Although the altered zone as now exposed has few ore minerals, the alteration suggests that the area may mark the top of a deeper igneous-hydrothermal system. The mineral resource potential of this particular area lays in the possibility that the alteration is related to a buried porphyry molybdenum deposit, or less likely, a porphyry copper deposit. (In general, copper minerals are not prominent near the granites in the quadrangle.)

CRITERIA FOR DEFINITION OF TRACTS

The outlines of tracts C and D are defined by: (a) proximity to gneissic granite bodies, (b) the numerous mineral deposits, and (c) the numerous and strong geochemical anomalies in the suite of element typically related to felsic plutonic rocks. The aeromagnetic data allow and possibly support the idea that the granitic rocks that form the core of the tracts plunge gently to the north beyond the Noatak River. The somewhat arbitrary boundary around tract C encloses most of the visible exposures of the contact zones of the upper parts of the granite bodies, numerous mineral deposits related to the plutons, and widespread geochemical anomalies. Tract D has much the same geology and mineral resource potential as tract C, but the contacts of the metasedimentary rocks with granite are largely buried, especially north of the Noatak River. Undiscovered mineral deposits in tract D are probably also buried near this contact.

ESTIMATION OF UNDISCOVERED MINERAL RESOURCES

The data are insufficient to estimate the number and size of undiscovered mineral deposits in tracts C and D. Mineral deposits and occurrences similar to those already identified almost certainly can be found with further work. The small size of the known deposits suggests that additional deposits would also be small. But the favorable geologic environment for additional deposits is areally extensive, and it is possible that at least one deposit of substantial size occurs in the tracts.

SUMMARY OF MINERAL RESOURCE POTENTIAL

Tracts C and D have particularly favorable geology for the occurrence of polymetallic veins, skarn deposits, and various other contact-metamorphic deposits associated with the upper parts of the Devonian gneissic granite intrusions exposed in the tracts. Numerous small mineral deposits or occurrences are known in the tracts, and more are likely to be present. The data are insufficient to determine if any of the undiscovered deposits are of sufficient size and grade to be economically viable.

TRACT E

DESCRIPTION OF GEOLOGY AND MINERAL RESOURCES

Tract E comprises two areas that wrap around the north sides of gneissic granite plutons that form the Arrigetch Peaks and the northwest lobe of the Mount Igikpak pluton. The metasedimentary rocks consist mainly of massive Devonian marble, as well as medium-grade gneiss and schist and interbedded calcareous layers. The general discussion of the geology and mineral deposits of tract C and D applies equally to this tract as well.

Several mineral deposits occur, all near the contact of the metasedimentary rocks with the granite. The deposits are of several types: irregular, thin, sulfide-bearing quartz veins; irregular mass of ore minerals replacing marble; and skarns.

The mineralogy of the deposits differs considerably, but sphalerite, magnetite, chalcopyrite, and galena are commonly present, and various combinations of tin, beryllium, bismuth, arsenic, fluorine, and molybdenum are often present in analysis of samples from the deposits. The most reasonable interpretation is that all or the great majority of these deposits are genetically liked to the granite. During this study, the contact between the metasedimentary rocks and the granite were examined at numerous places. Our work was by no means exhaustive, but ore minerals were often found near the contact. Our impression is that the ore minerals could be found in almost any 200- to 400-m exposure of the contact that could be examined in detail. However, the deposits we found were small, most being little more than mineralogical occurrences. The most notable deposit within the tract is a magnetite-bearing skarn in the north-central part of T. 22 N., R. 22 E. Selected samples collected in this 400- by 150-m area contained as much as 0.7 percent arsenic, 0.1 percent beryllium, and 0.1 percent tin, as well as visible sphalerite, fluorite, and magnetite.

CRITERIA FOR DEFINITION OF TRACT

The boundaries of tract E are largely determined by the contact of the granite and the metasedimentary rocks. No indication of mineral deposits or alteration is present within most of the granite adjacent to the tract in spite of many spectacular exposures. In one area of granite south of Arrigetch Peak (in the southwest corner of T. 23 N., R 22 E., and the northwest corner of T. 22 N., R. 22 E.), orange staining is widespread. The outline of the tract was drawn to include this altered zone. However, examination of this zone revealed little more than sparse disseminated pyrite and silicification along fracture zones. Stream-sediment and heavy-mineral analyses of samples collected from within the tract or adjacent to it confirm the presence of a suite of elements characteristic of a felsic pluton.

ESTIMATION OF UNDISCOVERED MINERAL RESOURCES

Data are insufficient to predict the magnitude of undiscovered mineral resources within the area of tract E. It is likely, indeed almost inevitable, that additional mineral deposits or occurrences or ore minerals can be found by further examination of the contact zones of the granites. But these will probably be small for the most part. The steepness of the contact of the granite and the metasedimentary rocks argues against large deposits being found in the tract. The upper parts of the granite pluton and the cap above it, theoretically the most promising environment of a felsic pluton for minerals has been eroded away, and only the deeper parts of the pluton are exposed. Nevertheless, the skarn deposit mentioned previously in T. 22 N., R. 22 E. has considerable size and metal content, and other substantial deposits may occur elsewhere in the tracts.

SUMMARY OF MINERAL RESOURCE POTENTIAL

Several small deposits in tract E have various combinations of sphalerite, magnetite, chalcopyrite, and galena, together with anomalous values in tin, beryllium, bismuth, arsenic, fluorite and molybdenum. The deposits are peripheral to a Devonian gneissic granite pluton and are almost certainly related to it. Similar deposits can probably be found with additional search, but there are insufficient data to forecast whether any might be economically viable.

TRACT F

DESCRIPTION OF GEOLOGY AND MINERAL DEPOSITS

Tract F lies in the south-central part of the quadrangle between the schist belt and the Devonian gneissic granite plutons. The rocks consist mainly of interlayered medium-grade pelitic gneiss and schist and prominent gray- to orange-weathering marble. The rocks are presumed to be Devonian in age, but the evidence is meager and largely circumstantial. The geologic structure is complex, and numerous isoclinal to open folds are present from outcrop to regional scale. Skarns and contact effects of the granite in this tract are not nearly so well developed or obvious as on the north side of the plutons (for example, in tracts C, D, and E). One reason is that the southern contacts of the Mount Igikpak and Arrigetch Peaks plutons are at least partly and probably frequently thrust faults rather than intrusive contacts. In addition, this area is well into the zone of Cretaceous, regional, medium-grade metamorphism that developed a pervasive metamorphic fabric in the rocks that probably has obscured much of the effects of the Devonian plutonism. The few mineral deposits are small and contain various combinations of copper, lead, zinc, silver, tin, bismuth, beryllium, molybdenum, antimony, and arsenic. We interpret this association of elements and the deposits that contain them to be genetically related to the Devonian gneissic granite. The beryllium occurrence in the northwest part of the tract in T. 21 N., R. 18 E., that is near several small tongues of Devonian granite, and several other deposits near the contact of the granite and the metasedimetary rocks support this interpretation.

CRITERIA FOR DEFINITION OF TRACT

The boundaries of this large tract are limited by the Devonian granite on the north, the schist belt on the south, and the limits of the geochemical anomalies on the east and west. Specific diagnostic criteria are the known deposits and the numerous geochemical anomalies in various combination of copper, lead, zinc, silver, molybdenum, barium, tungsten, beryllium, and antimony. Aeromagnetic data suggest an extension of the Devonian granite plutons southward beneath this tract but do not substantiate it.

ESTIMATION OF UNDISCOVERED MINERAL DEPOSITS

The data are insufficient to estimate the undiscovered mineral deposits within Tract F. Additional deposits probably can be found within the tract and even more may be present at depth, but their sizes and grades are unknown.

SUMMARY OF MINERAL RESOURCE POTENTIAL

The geochemistry and occurrence of several mineral deposits suggest potential for additional mineral deposits related to the extension of the Devonian granite pluton beneath tract F. However, the data are more permissive than strongly suggestive that the granite might extent beneath the tract, and the mineral resource potential of the tract is probably largely dependent on the presence of this pluton at depth beneath the tract.

TRACTS G AND H

DESCRIPTION OF GEOLOGY AND MINERAL DEPOSITS

Tracts G and H are marked by area of complex geology that has numerous thrust faults that intricately imbricate Devonian and Mississippian phyllite and schist, thick Silurian and Devonian marble, and Paleozoic chloritic quartzite. No plutonic rocks crop out in the tract but evidence is present that a felsic pluton underlies tract G.

The few mineral deposits in tract G are small; most were found during this study and their significance was apparent only when they were considered with other data. The deposits cannot be characterized by type with certainty. Most seem to be epigenetic; the elements involved are various combinations of silver, copper, zinc, arsenic, and antimony.

CRITERIA FOR DEFINITION OF TRACT

The principal criteria for defining tracts G and H are the geochemical data. The stream-sediment and heavy-mineral-concentrate analyses exhibit a number of anomalies in a diverse suite of elements--barium, zinc, molybdenum, and silver--an elemental association which suggests that their source may be a felsic pluton. The possibility of a pluton beneath these tracts is indicated on Landsat images by circular patters of arcuate features. Comparable features are seen over exposed gneissic granite plutons in the center of the quadrangle and over the Shishakshinovik pluton about 32 km to the southwest in the Ambler River quadrangle (Mayfield and Tailleur, 1978; Mayfield and Grybeck, 1978). This interpretation is further strengthened by the presence of several mineral occurrences that by themselves would not have been particularly diagnostic. An aeromagnetic low over tract G suggests a buried pluton; if this interpretation is correct, the several aeromagnetic highs over tract H may be related to buried magnetite-bearing contact-metamorphic rocks. The distinction between tracts G and H is one of degree and is highly subjective. Tract G may overlie a felsic pluton and has most of the more pronounced geochemical anomalies and known mineral deposits present in the two tracts. Tract H includes several peripheral geochemical anomalies and several aeromagnetic highs that may be skarn related.

ESTIMATION OF UNDISCOVERED DEPOSITS

The data are insufficient to estimate the magnitude of undiscovered mineral deposits in tracts G and H. However, they do suggest a favorable geologic environment at depth for mineral deposits over a deeply buried felsic pluton.

SUMMARY OF MINERAL RESOURCE POTENTIAL

The geochemistry, mineral deposits, and aeromagnetic data in tracts G and H reinforce each other to suggest a buried felsic pluton, probably at considerable depth. On the basis of analogy with other plutons in the area and with felsic plutons worldwide, the top of the proposed pluton would be a favorable site for the occurrence of a wide variety of mineral deposits.

TRACT I

DESCRIPTION OF GEOLOGY AND MINERAL DEPOSITS

Tract I lies just north of the schist belt near the southwest corner of the quadrangle. Thick sections of light-gray carbonate are prominent in the tract, but most of the rocks consist of interlayered gray- and orange-weathering marble, chloritic quartzite, garnet-biotite-quartz schist, chlorite schist, and greenstone. Two small prospects in carbonate rocks cannot be classified with assurance. One is apparently a stratiform, massive-sulfide copper deposit; the other is a lead-zinc-copper-silver deposit of unknown type, possibly epigenetic.

CRITERIA FOR DEFINITION OF TRACT

The outline of tract I is subjective, and the evidence that it has significant mineral resource potential is weak. The boundary of the tract is defined by a combination of the two known mineral deposits, several silver anomalies in the stream-sediment samples, and several circular patterns of arcuate features on the Landsat images that suggest the presence of a buried pluton.

ESTIMATION OF UNDISCOVERED MINERAL DEPOSITS

The data are insufficient to make a definitive statement about the type or amount of mineral deposits in tract I.

SUMMARY OF MINERAL RESOURCE POTENTIAL

The evidence is inconclusive but the known deposits, geochemistry, and satellite imagery indicate that tract I has potential for mineral deposits, possibly related to a buried felsic pluton.

TRACT J

DESCRIPTION OF GEOLOGY AND MINERAL DEPOSITS

Tract J is centered around two small Devonian granite plutons and associated skarn that intrudes the schists and gneisses of the schist belt. One prospect with argentiferous galena in skarn is probably related to granite as is the molybdenum in a sample of hornfels collected near it.

CRITERIA FOR DEFINITION OF TRACT

Tract J is defined by the small exposures of Devonian granite and the mineralized skarn around them. Stream-sediment samples (heavy-mineral concentrates were not collected in this area) support this conclusion. This small tract, however, is surrounded by tract A, which has widespread geochemical anomalies that make it difficult to define the extent of tract J on geochemical criteria. The area coincides with an aeromagnetic high and an elongate aureole(?) of medium-grade metamorphic rocks that suggests that the granite persists at depth. Aeromagnetic data also suggests a subsurface extension of the granite to the west.

ESTIMATION OF UNDISCOVERED MINERAL DEPOSITS

Data are insufficient to make a quantitative estimate of undiscovered mineral deposits within tract J. The geology, geochemistry, and known mineral deposits support our interpretation that a favorable environment exists for additional undiscovered mineral deposits. However, the mineral potential of the tract depends greatly on the subsurface geometry of the small granite plutons that are exposed at the surface, a geometry that is unclear. The geochemical expression that might be expected of such a pluton or the mineral deposits related to it is probably masked by similar and much more extensive anomalies associated with the copper-zinc-lead, massive-sulfide deposits of tract A. The aeromagnetic data indicates that the subsurface geology in this part of the schist belt is more complex than can be fully explained by the surface mapping to date. The aeromagnetic data suggests that the small exposure of granite at the surface may be part of a larger pluton at depth.

SUMMARY OF MINERAL RESOURCE POTENTIAL

The mineral resource potential of tract J is related to the top of a Devonian granite pluton, barely exposed at the surface, which is associated with a small silver-lead skarn prospect. The geologic and geochemical environment is favorable for the occurrence of additional mineral deposits, but the mineral resource potential of the tract is largely dependent on the subsurface extension of the granite pluton, which is indeterminate.

TRACT K

DESCRIPTION OF GEOLOGY AND MINERAL DEPOSITS

Tract K lies in the western headwaters of the Alatna River in an otherwise monotonous, thick section of Upper Devonian feldspathic sandstone, mudstone, and shale of the Hunt Fort Shale. Some of the rocks are at best weakly regionally metamorphosed, but most retain their original sedimentary structure and texture. The structural geology of the area is obscured by the monotony of the rocks and the lack of marker horizons, but the great thickness of the unit is probably due in part to repetition by folds and thrust faults.

No mineral deposits were known in the tract prior to this study and the only deposits now known are scattered quartz veins and sparse sulfide-bearing quartz float containing galena, sphalerite, and chalcopyrite with values in silver and antimony. The only constraint on the age of the deposits is that they are younger than the Upper Devonian sedimentary rocks in which they occur. None of the deposits has any obvious sign of alteration. Detailed and systematic exploration would probably find additional similar deposits in the tract, but our impression is that the size of the deposits that might be found at the surface will generally by small and the number few. There has been no production from the deposits nor any exploration of them by industry.

CRITERIA FOR DEFINITION OF TRACT

The combination of geologic, geochemical, and geophysical evidence strongly suggests that tract K is underlain by a felsic pluton. The surface geology of the tract gives no indication of such a pluton other than the grouping of the few mineral deposits. The steam-sediment geochemical data show a concentration of lead, zinc, copper, and silver in the tract, and the heavy-mineral-concentrate data also indicate anomalies of tin, tungsten, lanthanum, and thorium--an elemental association that suggests a nearby felsic intrusion. The aeromagnetic data are permissive of a buried pluton, but they are ambiguous because the aeromagnetic signature of the Devonian sedimentary rocks exposed at the surface are essentially the same as those of the felsic plutons in the quadrangle. The presence of a buried pluton is also strongly supported by the Landsat imagery, which shows well-developed circular patterns of arcuate features in the tract that are comparable to those developed on granitic rocks elsewhere in the quadrangle, notably at Mount Igikpak and in the Arrigetch Peaks. Similar patterns are present at several places in the quadrangle (other than over the known plutons), but they are best developed in this tract, where they coincide with the locations of mineral deposits and geochemical anomalies.

A simple interpretation of a buried pluton beneath the tract is complicated by the presence of numerous thrust faults in the quadrangle. A more precise statement of the mineral potential of the tract is that the surface indications of mineralization probably are related to a granite pluton that intruded the Hunt Fork Shale, but that pluton may or may not still be physically present beneath the tract. The age of the proposed pluton is largely conjectural; for lack of a better analog nearby, a reasonable conclusion is that it is similar to the Devonian plutons exposed at Mount Igikpak and the Arrigetch Peaks in the central part of the quadrangle.

ESTIMATION OF UNDISCOVERED MINERAL DEPOSITS

Data are insufficient from tract K to estimate the number of size of the deposits that might be associated with a proposed buried felsic pluton. The mineral deposits and geochemical anomalies that occur at the surface suggest that additional mineral deposits are likely to be associated with such a pluton at depth. The most likely concentration of such deposits might be expected near the top of the intrusive body or just above it. There is no evidence of depth to the top of the proposed pluton, but the lack of contact metamorphism at the surface indicates that the pluton is not close to the surface.

SUMMARY OF MINERAL RESOURCE POTENTIAL

The distribution of mineral deposits, geochemical anomalies, and circular patterns of arcuate features on satellite imagery support each other to suggest strongly that a previously unknown felsic pluton is or was buried beneath the tract. The depth to the pluton is uncertain, but the presence of known mineral deposits and the geochemical anomalies at the surface suggest that it's apical part and the cap above it are an attractive environment for undiscovered mineral deposits.

TRACTS L AND M

DESCRIPTION OF GEOLOGY AND MINERAL DEPOSITS

Tracts L and M lie in the vicinity of Dalimaloak Mountain the northeast part of the quadrangle in a thick sequence of Devonian and (or) Mississippian calcareous phyllite with interbeds of limestone, quartz-pebble conglomerate, and schist. The rocks have been metamorphosed, at least locally, to the extent that original sedimentary structures and textures are obscured. No mineral deposits are known in the tracts, and apparently industry has made no more than a cursory attempt at mineral exploration.

CRITERIA FOR DEFINITION OF TRACTS

Tracts L and M have no known mineral deposits or aeromagnetic anomalies and are defined mainly on the basis of geochemical anomalies and the interpretation of Landsat images. The stream-sediment and heavy-mineral-concentrate data, especially in the headwaters of Coalit Creek, show a pronounced concentration of anomalous samples involving combinations of lead, zinc, copper, molybdenum, barium, bismuth, boron, lanthanum, and thorium--a suite of elements typically related to felsic igneous rocks. Landsat images of tract L show a striking circular pattern of arcuate features analogous to a similar pattern over the exposed gneissic plutons in the center of the quadrangle and similar to the buried pluton that is presumed to occur beneath tract K. Several streams in tract L, notably Coalit Creek, are stained bright orange for several miles. This staining, distinctly visible from the air and on satellite images, is so striking that we assume it is related to the proposed granite pluton beneath the tract. The distinction between tracts L and M is one of degree. Tract L has the most varied and intense geochemical anomalies, and the largest circular pattern of arcuate features on the Landsat images is centered on it. Tract M has numerous strong geochemical anomalies but in fewer elements than tract L, and tract M is peripheral to, rather than coincident with, a circular pattern of arcuate Landsat features.

ESTIMATION OF UNDISCOVERED MINERAL DEPOSITS

Data are insufficient to make an estimation of the size and location of undiscovered mineral deposits in tracts L and M. If, as we predict, the geochemical anomalies are the surface expression of a buried granite pluton, the most likely environment for significant deposits would be in the upper zone of the pluton or just above it. The depth to the top of the postulate pluton is unknown; it is unlikely to be immediately below the surface because no contact metamorphic or other alteration effects are visible at the surface.

SUMMARY OF MINERAL RESOURCE POTENTIAL

Geochemical anomalies in a suite of elements usually associated with felsic pluton rocks, as well as the circular pattern of arcuate features identified on the Landsat images, suggest with some confidence that tract L and M are underlain by buried felsic plutons. The geochemical anomalies indicate that the presumed plutons are associated with metal-bearing fluids, but the most likely environment for deposits, the region near the top of the pluton, is probably at considerable depth.

TRACT N

DESCRIPTION OF GEOLOGY AND MINERAL DEPOSITS

Tract N consists largely of Silurian and Devonian carbonate rocks and less extensive exposure of Precambrian(?) granitic orthogneiss, Paleozoic schist, Mississippian conglomerate, and the Mississippian

Kayak Shale. The tract contains several mineral deposits in different combination of silver, barium, copper, lead, antimony, and zinc, but none have any appreciable size or continuity and all are little more than occurrences of ore minerals.

CRITERIA FOR DEFINITION OF TRACT

The boundary of tract N encloses an assortment of small mineral deposits, several lead anomalies in the stream-sediment samples, and several additional zinc, barium, and silver anomalies in the heavy-mineral-concentrate samples. Geophysical data and geology had little influence on the definition of the tract.

ESTIMATION OF UNDISCOVERED MINERAL DEPOSITS

The known mineral deposits and geochemical data are insufficient to estimate the sizes or types of undiscovered mineral deposits in tract N. The limited data would permit several types of deposits--for instance, replacement lead-zinc deposits in carbonate rocks, Mississippi Valley-type lead-zinc deposits, bedded barite, and many others--but definite evidence is not present for any of these.

SUMMARY OF MINERAL RESOURCE POTENTIAL

Tract N has scattered occurrences of ore minerals and geochemical anomalies involving several combination of lead, zinc, barite, copper, and silver, that indicate the tract has a real, albeit it low, potential for the occurrence of mineral deposits.

TRACT O

DESCRIPTION OF GEOLOGY AND MINERAL DEPOSITS

The geology of the three areas of tract O is tied to several areas of Mississippian shale, sandstone, and conglomerate and Permian and Triassic sedimentary rocks that crop out discontinuously across the northern part of the quadrangle.

CRITERIA FOR DEFINITION OF TRACT

The boundaries of the three areas of tract O are subjective and enclose exposures of Mississippian and younger rocks. Their mineral resource potential is mainly based on various combinations of zinc, lead, and barium in stream-sediment or heavy-mineral-concentrate samples. At one locality, a grab sample of Devonian conglomerate contains anomalous silver, copper, lead, tin, and zinc. The aeromagnetic signature for these Mississippian and younger rocks are the same as those for the large areas of Devonian clastic rocks which surround them.

ESTIMATION OF UNDISCOVERED MINERAL DEPOSITS

Data are insufficient to estimate the number of undiscovered mineral deposits in the areas of tract O.

SUMMARY OF MINERAL RESOURCE POTENTIAL

The areas of tract O contain several geochemical anomalies in lead, zinc, and barium and at least one small mineral deposit but there is no evidence that a substantial mineral deposit occurs in any of the area. The type(s) of deposit that might occur within the tracts are uncertain, but perhaps something similar to the Red Dog zinc-lead-barite deposit that occurs in similar Mississippian rocks about 350 km west-northwest in the DeLong Mountains. The evidence that these areas contain mineral deposits is limited and weak.

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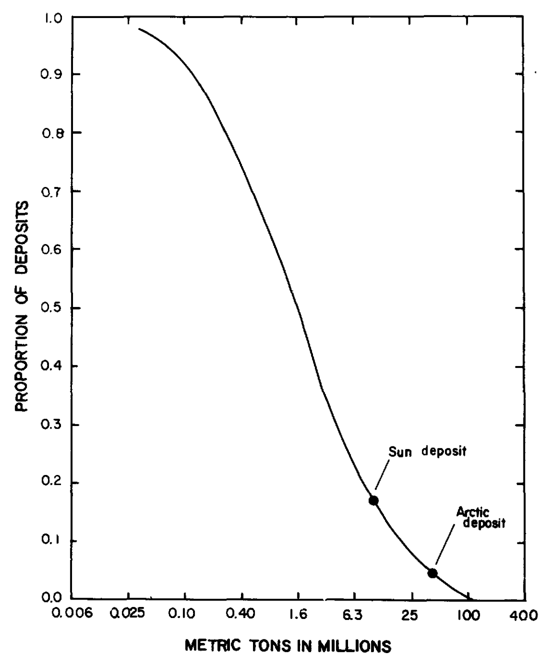

Figure 1. --Tonnage distribution of felsic intermediate massive-sulfide deposits as compiled from worldwide data for 432 deposits by Singer and Mosier (1986). Arctic deposit just west of Survey Pass quadrangle in Ambler district and Sun deposit within quadrangle are noted.

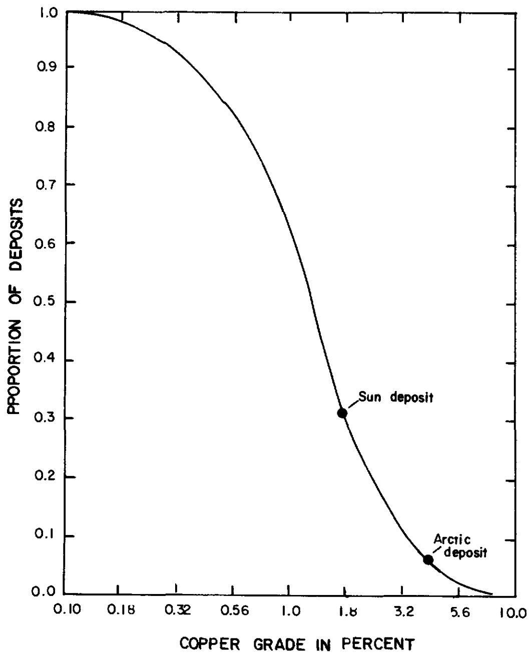

Figure 2. --Copper grade in felsic-intermediate massive-sulfide deposits as compiled from worldwide data for 432 deposits by Singer and Mosier (1986). Arctic deposit just west of Survey Pass quadrangle in Ambler district and the Sun deposit within quadrangle are noted.

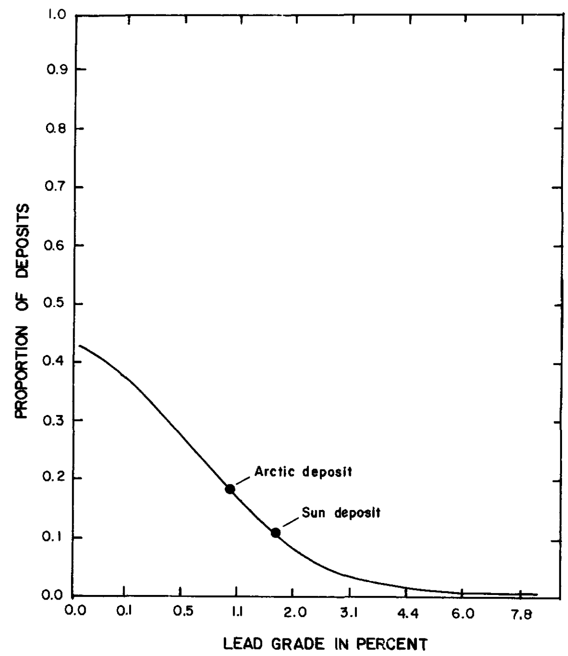

Figure 4. --Lead grade in felsic-intermediate massive-sulfide deposits as compiled from worldwide data for 432 deposits by Singer and Mosier (1986). Arctic deposit just west of Survey Pass quadrangle in Ambler district and Sun deposit within quadrangle are noted.

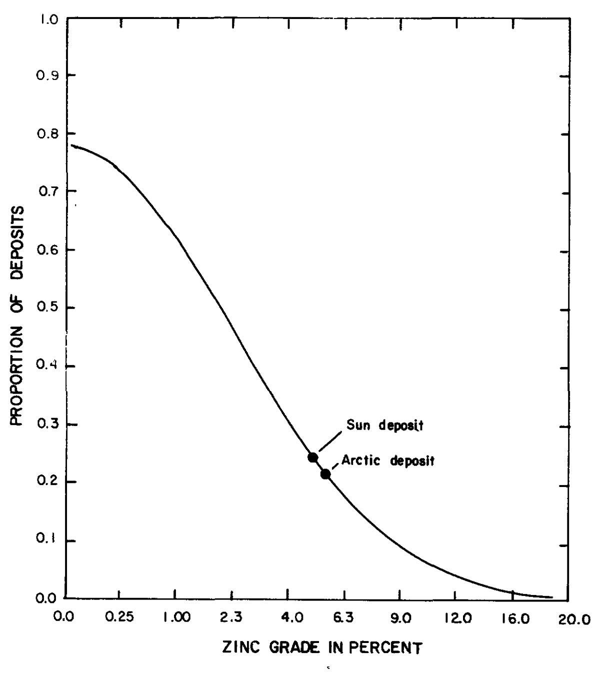

Figure 3. --Zinc grade in felsic-intermediate massive-sulfide deposits as compiled from worldwide data for 432 deposits by Singer and Mosier (1986). Arctic deposit just west of Survey Pass quadrangle in Ambler district and the Sun deposit within the quadrangle are noted.

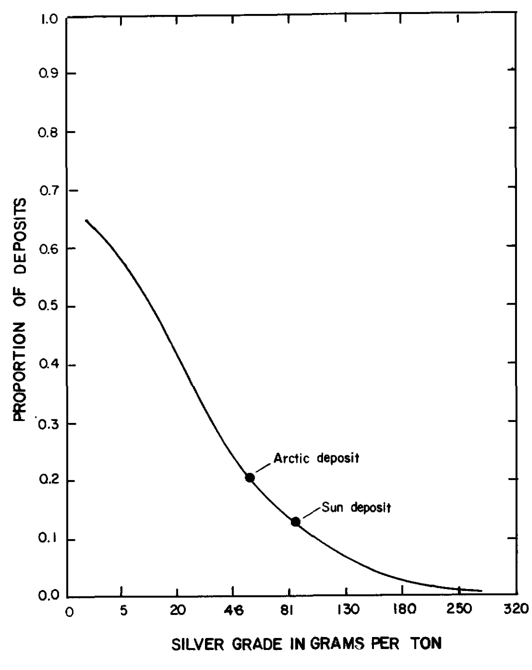

Figure 5. --Silver grade in felsic-intermediate massive-sulfide deposits as compiled from worldwide data from 432 deposits by Singer and Mosier (1986). Arctic deposit just west of Survey Pass quadrangle in Ambler district and the Sun deposit within the quadrangle are noted.