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GEOLOGY OF THE ARCTIC CAMP PROSPECT, AMBLER RIVER QUADRANGLE, ALASKA

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This report is preliminary and has not been edited or reviewed for conformity with Alaska Division of Geological and Geophysical Surveys standards.

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INTRODUCTION

Purpose and Scope

Beginning in June 1974, the Alaska Division of Geological and Geophysical Surveys (DGGS) undertook a study to determine the genesis and geologic controls of the Arctic Camp copper-lead-zinc deposits, as well as similar deposits in the Ambler River and Survey Pass quadrangles. One purpose of this work was to obtain data useful to the public for further mineral exploration in other Paleozoic(?) rocks within Alaska. Of equal importance has been an attempt to arrive at some sense of the magnitude of the deposits with respect to their impact on regional land-use planning.

Location

The Arctic Camp deposit is located in the northeast corner of the Ambler A-1 quadrangle (pl. 1). It is 16.8 miles away, on a bearing N 60° E from Bornite in the Cosmos Hills to the south. Access to the deposit may be obtained via helicopter or by ground transportation along a 7.5-mile-long gravel road connecting Arctic Camp to a short air strip located at the mouth of Arctic Camp valley. The airstrip is suitable for only small fixed-wing aircraft.

History

Mineralization was found on the ridge east of Arctic Camp by Bear Creek Mining Co. geologists in the summer of 1965. Since then, extensive ground has been claimed to the west and east. Exploration work has included geophysical induced-potential surveys and an extensive 37-hole drilling program. To date, neither Bear Creek Mining Co. nor its parent company, Kennecott Copper Corp., have publicaly released any figures regarding tonnage and grade.

Method

Field work in the Arctic Camp area was conducted by the author and a field assistant from June 16 to June 27, 1974. Snow cover hampered work for the first half of this period. A map scale of 1:12,000 was used to collect and compile field data relating to the lithologic and structural setting of the mineral deposit, and all movement within the area was made on foot. In addition to the field work, a preliminary study has been made of thin sections of rock specimens collected at over 100 map stations. Seven polished sections of grab samples of Arctic Camp mineralization also were examined with reflected light microscopy.

Previously Published Work

Previously available data on the geology of the Arctic Camp area are limited. The 1:63,360 scale map of Pessel and others (1973) provides information on the regional geologic setting of Arctic Camp. The map of Brosge and others (1975) shows the regional geology pertinent to the extension of the Arctic Camp type of mineral occurrences to the east in the Survey Pass quadrangle.

Fritts (1969, 1970b) reported on the geology and mineralization of the Cosmos Hills, located southwest of Arctic Camp. Runnells (1964) discussed some of the geology of the copper deposits at Bornite in the Cosmos Hills. The geology of the Cosmos Hills must be considered in arriving at an understanding of the tectonic setting for the Arctic Camp deposits.

A brief summary of the geology of the Angayucham Mountains south of the Survey Pass quadrangle is given by Fritts (1970a) and some of the results of the Alaska DGGS field studies in the southwestern Survey Pass quadrangle are included on a simplified map by Fritts (1971).

The 1972 Annual Report of the Alaska DGGS includes a simplified map and a brief summary of regional geologic features in that portion of the Brooks

Range located between Mauneluk River on the east and the Redstone River on the west. Turner (1973) reported on the geochronology of some of the metamorphic rocks collected from the schist belt. Forbes and others (1973) summarized their traverse along Ruby ridge west of Arctic Camp and listed several of the metamorphic mineral assemblages encountered in the schists.

BEDROCK GEOLOGY - REGIONAL GEOLOGIC SETTING

Arctic Camp is located within the western Brooks Range schist belt as defined by Fritts (1971), Pessel and others (1973), and Brosge and others (in preparation). The camp is about 2 miles south of the crest of the proposed Kalurivik Arch of Pessel and others (1972). The schist belt is separated from the extensive marble, calcareous schist, and Cretaceous intrusive terrains to the north by the Walker Lake fault (lineament) of Fritts (1971) and Pessel and others (1972, 1973).

The metamorphic history of the schist belt has not been adequately documented. There are, however, indications of several significant geologic events recorded in these rocks. The work of Turner (1974) emphasizes the probable completion of two distinct periods of metamorphism of the southern Brooks Range rocks. Interpretation of an actinolite-paragonite isochron derived from schist belt specimens indicates the culmination of an early metamorphic event 213 million years ago. A second, younger period of local thermal metamorphism is suggested by an age of 96 m.y. derived from the Shishakshinovik pluton and a mica schist within the border zone of that pluton. The thermal event associated with the intrusion of the 96-m.y.-old Cretaceous plutons is believed to have locally reset the $^{40}K/^{40}Ar$ of the schists for an undetermined distance around the intrusions. The present interpretation thus infers a regional metamorphism of Permo-Triassic age with a later, local thermal overprint occurring adjacent to approximately mid-Cretaceous granite plutonism.

There is some controversy concerning the age of the parent rocks involved in the 213-m.y.-old metamorphic event. Consideration of $^{40}K/^{40}Ar$ derived from schist-belt glaucophane-bearing metamafics led Turner (1974) to suggest that although there is a possible argon-excess problem, some of the schist-belt rocks may be Precambrian. Forbes and others (1973) have found jadeite in metagraywackes exposed near VABM Ruby. The jadeite had undergone considerable replacement by actinolite. If the jadeite was formed during the earlier regional metamorphism, the replacing actinolite may simply represent the waning retrogressive stages of that event. However, Turner's (1973) data suggest the possibility that the jadeite may have developed during a much older Precambrian metamorphism which subsequently was retrograded 213 m.y. ago.

Other geologists have been working with the hypothesis that greenstones (metamafics) in the southern Brooks Range are equivalent to the predominantly basaltic terrain of the Angayucham Mountains, to the south. Based in part on fossil evidence in the Wiseman quadrangle, the Angayucham basalts have in turn been correlated by Patton and Miller (1973) with volcanics of Permian or Jurassic age, or both, in the eastern Brooks Range. Fritts (1971) and Eakins (personal communication) have collected possible Devonian(?) or Silurian(?) coral fossils from carbonate lenses apparently conformable to the volcanics and schists of the Angayucham Mountains and Brooks Range, respectively. However, the fossils were poorly preserved, and identification is tenuous. Proponents of a Permian age for the Angayucham Mountains (and by extension, the metamafics of the Brooks Range schist belt) have hypothesized that the Devonian(?) or older carbonates of both areas have been emplaced tectonically either by thrust faulting or by enfolding.

The author visited several of Fritt's Angayucham and Ambler River lowlands fossil localities in 1974 and saw no compelling evidence that the carbonates were tectonic slivers. On the contrary, they appear to be conformable and in stratigraphic continuity with the surrounding rocks. In some cases they exhibit gradational contacts with what have been interpreted as primary volcaniclastic breccias. There is little if any deformation of these small (scale of a few tens to a few hundreds of feet) carbonate lenses, a fact difficult to reconcile with tectonic emplacement in an otherwise competent volcanic pile.

On the basis of 1) 213-m.y.-old actinolite-paragonite isochron of Turner (1974) and numerous Devonian(?) fossil localities in the Angayucham Mountains, Ambler River lowland, and Brooks Range schist belt; and 2) the probable correlation of the Angayucham basalts with the schist-belt metamafics, the author believes the weight of evidence is in favor of the schist belt in the vicinity of Arctic Camp being composed of mid-Paleozoic rocks of probable Devonian age or older.

Present petrographic studies have not progressed sufficiently for more than a crude delineation of the metamorphic environment of the Brooks Range schists. Brown and green biotite is a common occurrence in the dominant quartz-chlorite-muscovite schists of the belt. As first brought to the attention of the author by I.L. Tailleur of the U.S. Geological Survey, there appears to be marked chemical control to the presence of brown biotite. This biotite is usually found in or near felsic meta-igneous rocks. Its presence indicates at least a local attainment of a quartz-albite-muscovite-biotite-chlorite subfacies of metamorphism.

Garnet is found in various degrees of abundance usually associated with metamafic rocks or compositionally banded schists inferred to represent meta-argillites. Because it is not yet known whether the garnet is a low-temperature spessartine variety or is predominantly almandine, the garnets can-not yet be used to determine the rank of metamorphism.

Albite porphyroblasts are abundant in many of the schists. This mineral, however, is very late in the paragenesis and there is some indication that it may be related to the younger (Cretaceous age) metamorphism. If this is the case, the albite is not of value in determining the metamorphic rank of the Arctic Camp rocks.

Turner, Forbes, and Gilbert (personal communication) have collected specimens of metasediments from just south of VABM Ruby which contained jadeite. Glaucophane also has been found to be quite common in many of the schist-belt greenstones since it was first reported by Fritts (1971). These two minerals are indicative of a high-pressure metamorphic environment and, considered with the absence of recognizable lawsonite or arngonite and the presence of biotite, would seem to narrow the pressure-temperature conditions of metamorphism to an environment indicative of a high-pressure Barrovian greenschist facies to glaucophanitic greenschist facies.

Forbes (personal communication) believes that some of the glaucophane-bearing greenstones may represent retrogressively metamorphosed eclogites. The eclogites could well have been developed from premetamorphic basalt flows and intrusions. Primary pillow structures were observed at Horse Creek within the schist belt. W.M. Cox of Sunshine Mining Co. (personal communication) also has reported pillow structures in greenstones near Picnic Creek in the Survey Pass quadrangle, to the east. The author believes that the present glaucophane-bearing greenstones exhibit a range of field relationships which indicate that the parent rocks were emplaced as hypabyssal dikes, sills, and pillowed submarine basalt flows. The volcanic and subvolcanic type of field relations exhibited by these rocks is compatible with the typical field occurrence of eclogites found in other regions of the world.

A successive south-to-north increase in metamorphic rank has been postulated by Forbes and others (1974) from a traverse made on Shungnak spur in the Ambler River A-2 quadrangle, northward across VABM Ruby as far as the Walker Lake fault (Pessel and others, 1972). Only incipient recrystallization is reported for the southern part of this traverse, whereas biotite-stable conditions are attained in the pelitic schists just to the north of the westward projection of the fault.

The most pronounced structure near Arctic Camp is the Kalurivik Arch (Pessel and others, 1972). This antiformal feature has been hypothesized to be either an anticlinorium (by Pessel and others, 1972) or part of the folded root zone of a nappe, which has been overturned to the north (Forbes and others, 1973). Tailleur (personal communication), however, has remarked on the coincidence of granitic intrusions and inferred regional antiformal upwarps (Pessel and others, 1973; Fritts, 1970) which persist from the Redstone and Shishakshinovich plutons on the north to the core of the eastern Cosmos Hills on the south. A reconnaissance traverse north of Arctic Camp near the crest of the Kalurivik Arch by Tailleur in 1973 revealed magnetite-garnet-epidote- and actinolite skarns developed in an impure marble. These skarns are similar to those commonly seen around the Redstone and Shishakshinovik plutons to the north. The skarns at the head of Arctic Camp Valley imply the presence of a similar granitic intrusion in the core of the Kalurivik Arch. As suggested by Tailleur (personal communication) one has permissive evidence of subparallel antiforms and synforms created in a previously metamorphosed terrain by up-arching associated with the emplacement of Cretaceous plutons. The Kalurivik Arch could represent such a feature.

The Walker Lake thrust fault (Fritts, 1971; Pessel and others, 1972, 1973) was identified and named near Walker Lake in the Survey Pass quadrangle. Subsequent work in the area has led some investigators to question the magnitude and significance of this feature. Fritts (1971, p. 22) believed the fault to be regional and to effectively separate the schist belt on the south from the "carbonate.rich strata" to the north. More recently Forbes, Pessel, and Tailleur (personal communication) have expressed doubt with regard to the existence of the Walker Lake fault north of Arctic Camp or VABM Ruby. Forbes and others (1973) mentioned that the inferred projection of the fault separates biotite-stable schists on the north from biotie-free schists to the south. This suggests that the Walker Lake fault may be represented north of VABM Ruby by a metamorphic isograd. Pessel (personal communication) has suggested that the fault seen at Walker Lake may die out to the west in the Ambler River quadrangle as an unconformity between the schist-belt lithologies and the carbonate-dominated terrain to the north.

The queried thrust fault of Fritts (1971), which projects into the Ambler River lowland, was not accepted for that locality by Pessel and others (1973). On their map, the lowland is the locus of a synclinal trough. To the east, this thrust fault would correlate with the inferred Malamute fault shown on the map of Patton and Miller (1973). Recent aeromagnetic data for the Ambler River A3, A4, B3, and B4 quadrangles (to be released) tend to support the presence of a linear discontinuity in the Ambler River lowland, which separates terrains of distinctly dissimilar magnetic signature. The aeromagnetic anomaly is located approximately on the westward projection of the fault postulated by Fritts (1971). Additional aeromagnetic surveys planned for the summer of 1975 should be of aid in resolving the structural character of the lowland.

ARCTIC CAMP GEOLOGY

Location

Arctic Camp is located on the south flank of the Kalurivik Arch approximately 3 miles from its crest (fig. 1). The gossan zone, associated with the ore, crops out on the scarp side of the ridge east of Arctic Camp (pl. 1). This deposit occupies a central position in a schist belt containing known anomalous mineralization that extends from VABM Sleet on the west to Reed River on the east, a distance of 60 miles. To date, Arctic Camp is the largest proven deposit of over 25 distinct prospects with similar characteristics.

Lithologies

The rocks exposed along Arctic Camp ridge consist predominantly of porphyroblastic micaceous quartzose schists, graphitic schists, metamafics (greenstones) and blastoporphyritic micaceous quartzo-feldspathic schists. Minor calcareous marbles, calcareous micaceous schists, and meta-argillites also are found in the section. Petrographic descriptions of these rocks are included as the units first appear on the map explanation (pl. 1).

Pzs: Graphitic pelitic schist

Brown-weathering graphitic pelitic schist with minor calcareous quartzites, graphitic schists, and minor glaucophane-bearing greenschists constitute the major volume of rocks underlying the area south of Arctic Camp to the Ambler River lowland. Fresh surfaces of this rock are light gray to brown. In outcrop, this unit has a slabby appearance and forms long, exposed dip slopes. A well-developed schistosity is characteristic, as is a well-defined set of penetrative crenulations with axes plunging 20-30° to the southeast. Localized areas of small-scale complex folding are common.

Anhedral porphyroblastic albite 1 to 2.5 mm in the largest dimension is often present but is not as abundant as in the prophyroblastic schist units to the north. Here, as always observed to date, albite is late in the paragenesis.

Major minerals which constitute the groundmass are equant quartz grains (0.1-0.5 mm in diameter), muscovite (0.3-0.7 mm in greatest dimension), and epidote---occasionally its variety allanite (0.1-1.6 mm, most 0.5 mm in greatest dimension). Chloritoid is found only occasionally in trace amounts within the Pzs unit on Arctic Camp ridge. However, to the west at Dead Creek, chloritoid is an abundant characteristic mineral in many of the schists.

Included in the Pzs unit are lenses or layers of graphitic schist (Pzgs), the contacts of which appear to be conformable with the attitude of schistosity in the surrounding rocks. Some of these graphitic units contain helicitic albite porphyroblasts preserving the previously crenulated schistose texture defined by muscovite and graphite.

Significant differences between this unit and the lithologies exposed to the north are: 1) a lack of felsic meta-igneous rock associations; 2) the absence of abundant albite porphyroblasts; and 3) an abundance of graphite distributed pervasively throughout the unit rather than primarily in isolated lenses.

Pzcq: Calcareous micaceous quartzite

Lenses or layers of calcareous micaceous quartzite constitute minor occurrences within the graphitic pelitic schist (Pzs) unit south of Arctic Camp. In outcrop, these rocks are light-tan to brown weathering because of limonitic staining, and their surfaces are often porous because of leaching of interstitial calcite. Although the quartzites exhibit a distinct foliation, they are not schistose. A fresh surface shows a light tan—gray color. In thin section one can see well-developed ternary boundaries among fine- to very fine-grained quartz grains. Patches of limonite, calcite, and muscovite are interstitial to quartz. Chlorite is present in the rock but is not abundant. The average modal composition of two thin sections is: quartz, 62 percent; calcite, 15 percent; muscovite, 10 percent; chlorite, 3 percent; and limonite, 10 percent.

Pzmp: Blastoporphyritic-microcline muscovite schist

This is the southernmost of two stratigraphically distinct blastoporphyritic units found on Arctic Camp ridge. In mineralogy, these rocks are nearly identical to those designated Pzrp. This southern blastoporphyritic unit is well foliated and moderately schistose, and like Pzrp, the local exposures have a more blocky appearance than many of the surrounding schists. Outcrops have a grayish-green weathering surface, and fresh surfaces are distinctly green, a coloration derived primarily from the presence of green biotite and an apple-green mica of unknown composition. Common colorless muscovite is also present. Large (1-2 cm) megacrysts of microcline are abundant throughout the rock. These crystals exhibit embayments interpreted to be relict resorbtion channels inherited from premetamorphic sanadine crystals of hypabyssal or volcanic origin. Some microcline and dark-green biotite also are present with the abundant quartz of the groundmass. Petrographically, this blastoporphyritic-microcline muscovite schist is distinct from Pzrp in having smaller euhedral microcline blastophenocrysts, with an apparent absence of blastoporphyritic quartz. It also has a different stratigraphic setting than Pzrp in that it is enclosed by a graphitic pelitic schist rather than the quartzo-feldspathic schists to the north, many of which may represent felsic volcaniclastic material.

Pzmv: Predominant Metamafics

Of the three occurrences of metamafic rocks shown on plate 1, the two northern areas consist almost wholely of metamafic rock (greenstone). The large unit to the south is an interlayered mixture of greenstone, marble, and meta-argillites.

The metamafics are greenish gray to olive gray weathering and gray on fresh surfaces. They form massive rounded to blockily jointed outcrops which show no foliation or are somewhat schistose only near their contacts. Some outcrops exhibit concentrations of equant subrounded to subangular blocks of greenstone up to 1 foot in diameter. These masses are commonly set in a matrix of green actinolite and look like broken-pillow breccia fragments in a metamorphosed hyaloclastic matrix. Garnet ranging from 0.1 to 1.0 mm in diameter is characteristically present. Actinolite, clinozoisite epidote, and pennine chlorite are major constituents. Calcite, quartz, and porphyroblasts of albite have been observed as minor constituents in some of these greenstones. Sphene is present as an accessory mineral. Although glaucophane is a common minor mineral in similar rocks a few miles to the west, at Dead Creek and at Ruby Peak, none has been seen in the metamafics at Arctic Camp. The composition of the garnets is now being examined to refine the present estimate of local metamorphic rank.

The marbles and meta-argillites included in the southern greenstone occurrence are present as thin layers and lenses interspersed with separate metamafic units. The marbles, rarely more than 18 inches thick, are easily recognized by their light-gray abrasive and pitted surface. Closer examination commonly reveals the presence of large (1- by 0.5-cm) light-gray euhedral clinozoisite-epidote crystals in a medium-grained granoblastic groundmass of calcite. These epidote crystals occur singly and in slightly radiating clusters. Other minerals occurring in minor to trace amounts include patches of small (0.1 to 1.5 mm) equant quartz grains and trace amounts of fine-grained chlorite and muscovite associated with the quartz.

The different meta-argillites form characteristic limonitic brown to black weathering layers within this mixed unit. The outcrops vary from thin (1 to 6 feet), dense, massive blockily jointed units to thin, slaty, or semischistose occurrences having a somewhat slabby appearance. Compositional and textural banding in some of the units is suggestive of relict graded bedding. Quartz is a dominant mineral in all of these rocks but is very fine grained (0.04 to 0.07 mm). The dense, massive varieties also contain abundant epidote, chlorite, and tremolite in addition to the quartz. The more foliated types contain muscovite in major amounts, with minor biotite and pennine chlorite in small ovoid patches up to 1.5 mm long; chlorite and biotite constitute less than 5 percent of these rocks by volume. Minute anhedral sphene is sparse but present in the foliated meta-argillites, as are incipient albite porphyroblasts up to 2 mm in diameter. Disseminated specks of opaque material (graphite?) are abundant in both the foliated and massive argillites. Pyrrhotite and pyrite are common in trace amounts disseminated throughout the dense, massive units.

Pzrp: Blastoporphyritic-microcline biotite-muscovite schist

There are two distinct blastoporphyritic units exposed on Arctic Camp ridge, Pzrp and Pzmp. These units are locally referred to as "button schists" in allusion to their large (1 to 4 cm) euhedral microcline megacrysts. The microcline megacrysts of both units are blastoporphyritic as evidenced by their lack of inclusions, euhedral shapes relative to their position in the normal crystalloblastic series, and occasional fragmental habit. The microcline crystals contain marginal embayments filled with fine-grained groundmass minerals, usually muscovite and quartz. These textures strongly resemble resorbtion channels commonly seen in K-feldspar phenocrysts of volcanic and hypabyssal rocks (formed because of disequilibrium conditions prevailing in the magma prior to and during emplacement). By inference from the above observations, microcline probably represents pseudomorphs of parent sanadine which was developed in a near-surface or intrusive environment and was later recrystallized during metamorphism.

In outcrop, the two units are somewhat more resistant to weathering and have a more blocky appearance than other schists in the section. Pzrp, however, tends to become progressively more schistose away from the mineral deposit. As shown in cross-section A-A' on plate 1, unit Pzrp thickens markedly to the west and to some extent increases in thickness to the north over the gossan zone outcrop of Pztc. As indicated by late field work in 1974 and reports from other workers in the area (R. Walters, personal communication), this unit is probably a part of a large meta-igneous body located on the northwest end of Riley ridge. It is believed that this blastoporphyritic schist occurs at different levels within the section. It is not known definitely, however, whether this relative change in position reflects an intrusive character or is the result of primary deposition on an irregular surface. In support of a hypothesized extrusive genesis, a thin porphyroblastic-graphitic-schist unit has been observed at several locations to directly overlie the blastoporphyritic schist. If this unit is continuous over Pzrp as indicated, one might infer that the graphitic schist represents a carbonaceous shale deposited on submerged volcanic rhyolite porphyry flow.

In outcrop, these rocks are light-olive green to gray. The outcrops are massive with some accumulation of blocky talus at their base. Metamorphically induced schistosity is expressed by the alignment of muscovite. Foliation is further evidenced in thin section by trains of what appear to be cataclasized quartz grains. However, it is possible that this apparent cataclasis is in part an inherited feature derived from metamorphic modification of a parent volcanic rock which had a fluidal texture.

In thin section, the microcline blastophenocrysts display characteristic grid twinning. Their modal abundance may be as much as 20 percent in some parts of the unit and a few persent in other parts. Muscovite always is present in amounts from 10 to 25 percent. Its grain size ranges from 0.02 to 0.4 mm in greatest dimension. The muscovite occurs both as poorly foliated finer grained masses and as larger crystals in well-foliated incipiently segregated bands.

Quartz also has two distinct modes of occurrence in this rock. The most noticeable appearance in hand specimen is as partially resorbed subequant blastophenocrysts approximately 0.5 to 1 cm in diameter. The groundmass contains abundant quartz which exhibits the mutual ternary grain junctions characteristic of equilibrated recrystallized quartz in metamorphic rocks. Quartz constitutes about 50 percent of the rock and ranges in size from 0.03 to 6 mm.

Two varieties of biotite are present. The predominant type is brown to light yellow-brown and poikioblastic. The second variety, seen in thin section, is pale green. Biotite is not equally distributed in the unit, and some specimens lack biotite altogether. Its greatest modal abundance is approximately 3 to 5 percent. Individual grains attain 0.3 mm in largest dimension. The fabric exhibited by biotite indicates it is not a relict igneous mineral but is of metamorphic origin. Biotite occurs parallel to, and transecting foliation, suggesting a late to post-synkinematic development. The reason that biotite at Arctic Camp is restricted to meta-igneous rocks and to within a few feet of their contacts is not fully understood. It is believed that rocks of igneous parentage were able to provide the necessary chemical environment within the prevailing metamorphic pressure-temperature conditions for the formation of this mineral. There have probably been two periods of metamorphism affecting these rocks (Turner, 1973) and this may well account for the presence of the unusual coexistence of brown biotite, apple-green mica, and muscovite.

Pztc: Talc-muscovite-chlorite schist

The sulfide-bearing unit, Pztc, structurally underlies the blastoporphyritic schist Pzrp and at the surface is separated from it by a varying thickness of porphyroblastic schist, Pzps. It is not certain whether the porphyroblastic schist is always interposed between the sulfide zone and the overlying Pzrp unit.

In the field, the mineralized unit is distinguished by extensive brown limonitic to red hematitic staining. It is light gray on a fresh surface, and exhibits slabby outcrops mantled by flaggy talus. The talus is quite fissile and slippery to the touch because of significant amounts of talc in the rock. Application of dilute HCl shows the presence of calcite. The rock is extremely schistose with grain sizes varying from fine to medium. Quartz commonly constitutes over 50 percent of the mode and has a well-developed granoblastic texture with the ternary junctions common to metamorphically recrystallized quartz. Locally, however, specimens of nearly pure talc may be found. The combined talc-muscovite content of the unit is quite variable (from trace amounts to 37%) and is inversely related to the amount of chlorite present. Both the talc and the chlorite have well-developed platy habits, and have grains ranging from 0.2 to 0.8 mm in their longest dimension (thin section). Chlorite is an extremely low-iron, colorless variety, probably clinochlore. Epidote is occasionally present in trace amounts as in biotite. Abundant calcite is associated with ore-grade sulfide mineral accumulations. Sphene in anhedral to euhedral crystals (0.4 to 1.5 mm) is a common accessory mineral in this unit (as it is in all the noncarbonate units studied). A few deep-red—brown rutile crystals have been observed in thin sections of Pztc rocks. Albite porphyroblasts are locally absent in this unit and in general are less abundant in these rocks and in other schists at Arctic Camp. When present, they range from 1 to 3 mm in greatest dimension and have an anhedral to subhedral poikioblastic habit. The poikioblastic inclusions consist of quartz, talc, and muscovite. As in the other schistose units, the albite is very late in the paragenesis of these rocks.

The thickness of this unit shown on the map is approximate, and may be too great. Contacts of the talcose rocks are transitional with the obviously porphyroblastic underlying and overlying schists. Within the unit there are intercalated lithologic variations among lenslike layers of quartz-talc schist, quartz-muscovite schist, and quartz-talc-muscovite-chlorite schist. Albite porphyroblasts, if present, are usually associated with either the muscovite-or chlorite-rich lithologies. The ore minerals exposed in the prospect pits (pl. 1) appear to be concentrated in fine-grained, relatively quartzose lenses scattered throughout the unit. The dominant sulfide in most outcrops is pyrite. Ore-grade material from the prospect pits, however, contains sphalerite, chalcopyrite, galena, and pyrrhotite. In polished sections, one can see that minor tennantite is preferentially associated with the galena. Further studies may well reveal additional sulfide minerals. The ore zone, recognized surficially by limonite staining, is not confined spatially to the center of the Pztc unit but appears to cross section so that it is locally found near either the top or bottom of the unit.

The association of talc with the ore must have been created prior to the termination of metamorphism in the area because calcite and the late porphyroblastic albite replace talc. Except for talc, which is wholely or partially substituted for muscovite in the mode and calcite, which is associated with the ore, the non-ore-bearing parts of this unit closely resemble the common porphyroblastic schists of the Pzps units.

Some geologists suggest the sulfide mineralization is genetically related to the 96-m.y. intrusive episode, when several of the granitic plutons found to the north were emplaced. With regard to this hypothesis, those plutons tended to produce magnetitic garnet-amphibole-epidote skarns in spatially associated carbonate-bearing lithologies. However, although there is significant calcite in the mineralized horizon at Arctic Camp, no skarn of any kind can be seen within the unit.

There is also a lack of classical hydrothermal type of veining and progressive hydrothermal alteration haloes around the ore. Also, the ore does not appear to be discordant with the host rocks as one might expect if it had been emplaced epigenetically in association with plutonism. Rather, the ore occurrences are lensoid, are conformable with the host rocks, and appear to have much the same metamorphic character as do the enclosing schists.

Pzqm: Porphyroblastic-albite chlorite-quartz-muscovite schist

Rocks of the Pzqm unit are light gray to greenish gray weathering and light-greenish white on a freshly broken surface. Outcrops are flaggy to massive in appearance, well foliated, and usually schistose. Glomeroporphyroblasts of white untwinned albite from 1 to 4 mm in greatest dimension are almost universally present. These vary from grains having a euhedral habit to vaguely augen shaped. Occasionally, quarz augen are also present.

Quartz and muscovite dominate the mineralogy of this unit. The quartz exhibits well-formed ternary junctions characteristic of equilibrated metamorphic recrystallization. The muscovite is well formed in books up to 0.5 mm long in cross section. Much of this mica is phengite.

In thin section, individual albite porphyroblasts are commonly 0.5 to 0.75 mm in diameter. These are late in the paragenesis and replace the dominant quartz of the groundmass and crosscut the well-foliated muscovite. The albite contains abundant inclusions of quartz and muscovite grains.

Chlorite is sporadically present in the unit both as irregular greenish-gray concentrations up to 1.2 cm in diameter and as well-formed laths associated with the muscovite which it is apparently replacing. Many of the patches of chlorite are also associated with late carbonate and small grains of epidote. Graphite is present locally as black specks dusted throughout the rock. Trace amounts of zircon and sphene can be observed in thin section.

The mode of these rocks is highly variable. The basic mineral assemblage and character of occurrence of the minerals, however, gives the unit a relatively consistent appearance in both hand specimen and thin sections. This schist does not differ markedly from other albite porphyroblastic units in the mapped area, but does have less chlorite than Pzps schists and less albite than Pzms rocks.

Pzps: Porphyroblastic-chlorite muscovite-quartz schist

Porphyroblastic-chlorite muscovite-quartz schists occur at several stratigraphic levels in the Arctic Camp area. They include many local variations and at least four distinct subunits: Pzbm, Pzc, Pzcb, and Pzgs. All of the rocks in this group except Pzc are characterized by a prominent development of albite porphyroblasts. In general, the porphyroblastic-chlorite muscovite schist is greenish gray to limonitic yellow brown weathering and very light gray to greenish gray on a fresh surface. In outcrop, the rock appears slabby with distinct schistosity which becomes less pronounced as the albite porphyroblasts become more numerous. The groundmass of the schist is medium grained, with moderate to poor segregation of muscovite from quartz. The albite porphyroblasts are somewhat preferentially located within the muscovite-rich layers as anhedral to subhedral glomeroporphyroblasts up to 2 mm in greatest dimension. Epidote-clinozoisite is a common minor constituent and is generally present in amounts ranging from 1 to 2 percent. Sphene is present as an accessory mineral in trace amounts.

Albite in this unit is late in the paragenesis of minerals. Where pennine chlorite is present, its formation was apparently contemporaneous with that of albite. To date, no microcline has been found in this unit. In speculating on the parent material giving rise to unit Pzps, one must decide whether the albite and chlorite are products of metamorphic remobilization of constituents within the original rocks. The possibility exists that they might have been introduced by a later metamorphic event associated with the emplacement of the 96-m.y.-old plutons found to the north of Arctic Camp. If the components for the abundant albite were derived from the original parent rock, one might expect that the bulk chemical composition of this unit would closely approach that of a quartz-kerotophyre. If, however, the albite- and chlorite-producing components were introduced to what would otherwise be a micaceous quartzite, such a correspondence in composition would be highly fortuitous. Analytical studies are planned to provide data for testing these hypotheses.

Pzbm: Porphyroblastic-albite biotite-muscovite-quartz schist

Biotite-bearing schists in the Arctic Camp area are believed to be associated with, or actually constitute, premetamorphic igneous rocks. Unit Pzbm is similar to Pzps except that it lacks chlorite and contains minor amounts (2 to 3 percent) of biotite. In the field, Pzbm is found adjacent to outcrops mapped as meta-igneous rocks (Pzr) (pl. 1).

These biotite-bearing schists are green weathering and light-gray green on a fresh surface. The outcrops have a somewhat massive appearance, are distinctly foliated, and are only weakly schistose. Glomeroporphyroblasts of albite compose up to 30 percent of the rock. The porphyroblasts are contained in a fine-grained groundmass of quartz, muscovite, and accessory olive-green biotite. The albite porphyroblasts are poikioblastic with inclusion of quartz and are late in the mineral paragenesis.

Pzc: Chlorite schist

The chlorite schist found in unit Pzps appears to be a contact phenomenon related to the formation of the abundant quartz pods, lenses, and dikes found in the Arctic Camp area. Adjacent to many of these barren quartz masses, the concentration of chlorite in the rock increases to form a nearly pure chlorite selvage. Because the barren quartz masses are often discordant with the metamorphically induced foliation, the associated chlorite selvage was probably formed late in the metamorphic history also.

These chloritic rocks are dark-greenish gray weathering, and light green on a fresh surface. Although schistosity is well developed, the outcrops are blocky. The rock is composed of up to 97 percent chlorite with trace amounts of scattered muscovite. A gradation exists between this unit and the more widespread porphyroblastic schists, Pzps.

Pzcb: Porphyroblastic-albite calcite-biotite schist

Only minor occurrences of albite calcite-biotite schist have been found. These are characteristically small, olive-green, massive-weathering knobs which are somewhat more resistant than the surrounding schists. Foliation is poorly developed, and in the field the knobs resemble exposures of mafic dikes or lenses. Their mineralogy, however, is unlike the metamafic rocks of unit Pzmv. The contacts between Pzcb and the enclosing schist are sharp.

Porphyroblasts of albite up to 1 mm in largest dimension are enclosed in a fine- to medium-grained matrix of olive-green to greenish-brown biotite, chlorite, and calcite. As much as 15 percent calcite has been observed in specimens of this rock. The surrounding schists appear to be enriched in biotite, calcite, and chlorite, and appear to have relatively less quartz than the normal Pzsp unit. The percentages of biotite and chlorite within Pzcb varies inversely from 61 to 18 percent and from 22 to 37 percent, respectively. The presence of quartz in this minor unit suggests that these small isolated masses may represent the metamorphic equivalent of local accumulations of argillaceous clastic detritus.

Pzgs: Graphitic quartz-muscovite schist

Graphitic quartz-muscovite schist appears at many localities within the schist belt. At Arctic Camp, a band of graphitic schists forms a distinct local marker unit on the north end of the area. It also is found as lenses in many of the other major lithologic units. Only those occurrences of moderately well-established continuity have been included on plate 1. One graphitic schist band traced within the southern metamafic argillite sequence appears to transect the section. This map pattern suggests a local unconformity within that unit. Graphitic schist forms irregular lenses within unit Pzsp and exhibits transitional contacts with those rocks.

The graphitic schists commonly are heavily limonite stained on weathered exposures but medium to dark gray on fresh surfaces. Their schistosity is marked, giving rise to a slabby appearance in outcrop. The talus produced is sometimes nearly fissile. There is a moderate segregation of fine-grained quartz from the graphite and muscovite. Quartz is present both as an ordinary groundmass mineral and as augen up to 5 mm long and 2 mm thick. About 3 percent of the rock surface appear is covered by square, limonnite-coated vugs up to 3 mm in cross section. These imply the former presence of pyrite. A few albite porphyroblasts up to 1 mm in greatest dimension are characteristic of these graphitic schists. Minor chlorite often accompanies the presence of albite. It is believed that the graphitic schists represent premetamorphic carbonaceous pelitic sediments.

Pzpc: Porphyroblastic-albite chlorite schist

In outcrop, the porphyroblastic-albite-chlorite-schist closely resembles Pzcb (porphyroblastic-albite calcite-biotite schist). The fundamental difference between these two rocks is the complete substitution of chlorite for biotite in the mode of Pzpc. Outcrops are dark green to greenish gray weathering while fresh surfaces are dark green and have abundant white porphyroblasts of albite. The rocks are poorly foliated, massive, and crop out as small knobs or ledges. Their contacts appear to be gradational to the schists of Pzps. A nearly bimineralic albite-chlorite composition with trace amounts of calcite and epidote is characteristic. There is, however, some minor quartz and muscovite which is clearly earlier in the paragenesis than albite and chlorite. Albite porphyroblasts constitute up to 50 percent or more of the rock and range in size from 0.5 to 2.5 mm. The chlorite is a green variety of pennine and constitutes from 5 to 35 percent of the rock by volume. Sphene is present as an accessory mineral.

Pzms: Muscovite-quartz schist

The muscovite-quartz schist at Arctic Camp somewhat resembles unit Pzps. However, it contains less chlorite and the amount of albite seen as porphyroblasts is highly variable. Weathered surfaces have a brownish gray to tan color. Fresh rock is greenish gray. Outcrops are massive and somewhat blocky with distinct foliation but only moderately developed schistosity. The abundance of albite porphyroblasts ranges from a trace to 34 percent by volume. When present, albite porphyroblasts are anhedral and range from 0.5 to 2.5 mm. Glomerophorphyroblasts of albite 1 cm in greatest dimension are occasionally seen. Albite is late in the mineral paragenesis and transcects foliation.

The foliation of the rock is defined by muscovite and segregation bands of granoblastic quartz. The groundmass of quartz and muscovite is fine to medium grained. The quartz is about 0.2 mm in diameter and has well-developed ternary grain boundaries, whereas muscovite provides the lipidoblastic texture of this unit. The muscovite is subhedral and from 0.5 to 1.5 mm in longest dimension.

Olive-green biotite is sporadically present in trace amounts. Pennine chlorite also is occasionally seen in association with muscovite. Its modal abundance is variable but is usually less than 5 percent. Brown epidote, allanite(?), is present as an accessory mineral, as is colorless clinozoisite. The clinozoisite often exhibits a central brown core, suggesting its derivation from preexisting allanite(?). Sphene is a ubiguitous accessory, present as equant anhedral crystals up to 0.4 mm in diameter. Trace amounts of calcite were observed in some thin sections. Numerous limonite-stained pits 1 to 2 mm in diameter on weathered surfaces suggest the former presence of trace amounts of pyrite.

Pzr: Biotite-muscovite-metarhyolite porphyry

Small lenses of dense, banded, aphanitic quartzose rock are abundant throughout the Pzms unit and form an intergral subunit within those rocks. In the field, these lenses resemble quartzites in their resistance to weathering and their blocky, jointed outcrops. They are gray to tan on exposed surfaces but are light gray where freshly broken. A well-developed foliation is made evident by subdued color banding, but schistosity is not apparent. Individual lenses attain thicknesses of several feet to several tens of feet. The texture of these rocks is extremely fine-grained blastoporphyritic with broken anehedral and euhedral crystals of microcline. Quartz, muscovite, and fragments of microcline constitute the major minerals in the groundmass. Flaser textures (as a descriptive term only) are well defined by oriented muscovite and medium- to fine-grained trains of quartz. These sinuous textures commonly enclose rounded microcline blastophenocrysts. Enlarged granoblastic quartz grains are commonly seen in the interior of the flaser textures surrounding microcline. Although these textures resemble those produced by cataclasis in some metamorphic terrains, they may equally well have been inherited from recrystallized fluidal textures of volcanic origin.

Brown biotite 0.2 to 0.5 mm in diameter is present and can be observed to be oriented obliquely to the prominent foliation of the rocks as well as parallel to it. This observation provides a basis for the inference that biotite is somewhat later in the paragenesis than is muscovite. However, the brown biotite may be a relict primary mineral rather than one of metamorphic origin. Trace amounts of chlorite replace some biotite.

Albite is present sporadically and crosscuts the flaser texture at random, indicating that it is late in the mineral paragenesis. Clinozoisite is common in trace amounts and sphene is nearly ubiquitous as an accessory mineral. Occasionally small (1 mm) anhedral grains of pyrite are present at less than 1 percent of the rock volume.

The presence of brown biotite and the occurrence of microcline as both blastophenocrysts and in the groundmass implies that the Pzr rocks were originally of igneous origin. The relict porphyritic rock textures further indicate a hypabyssal or volcanic environment for the parent material.

Pzlm: Calcite marble

A thin, apparently continuous unit of gray calcite marble is interposed between the metamafic rocks and calcareous schists seen in the north end of the area mapped and the predominantly quartzose schists to the south. On closer inspection, the distinctively sheeted outcrop characteristic of the marble exhibits isoclinal intraformational folding of 1-2 feet. The rock is essentially monomineralic with crystalloblastic fine- to medium-grained calcite forming distinct layers enclosed by thin surfaces of more carbonaceous and pelitic marble. Minor amounts of granoblastic fine-grained quartz also are present in some of the marble layers.

Very fine-grained isolated grains of tremolite and muscovite have been seen in trace amounts and constitute less than 1 percent of the rock by volume. Scattered minute specks of pyrite (0.01 mm) are sparse but can be observed.

A brief helicopter reconnaissance to the west of Arctic Camp indicates that this marble unit may terminate in some fashion near the vicinity of inferred metavolcanic pile indicated on plate 1.

Pzcm: Calcareous schist

On both Arctic Camp and Riley ridges calcareous schist has been observed to conformably underlie the calcareous marble unit (Pzlm). The thickness of the calcareous schist unit is unknown, and although it is shown on the map as overlying the metamafics exposed at the head of Arctic Camp valley, it is possible that those rocks are enclosed within the unit. Mapping planned for the summer of 1975 should resolve this question.

In outcrop, the rocks have a banded brownish-gray and gray weathering surface reflecting small-scale compositional layering within the rock. On a fresh surface, the color variation is one of light- and dark-gray tones. The outcrops have a slabby character with complex internal folding on scales ranging from a few centimeters to about 1 meter. Schistosity is imparted by fine-grained muscovite in the tan layers and by graphite and muscovite in the light-gray layers. To date, no detailed petrographic study has been made of this unit.

<u>Albite</u>

Untwinned albite porphyroblasts are nearly ubiquitous throughout the Arctic Camp schists and are seen at least in the contact margins of even the distinctly meta-igneous units. Albite porphyroblasts have also been reported in the marbles of the Cosmos Hills to the south (Fritts, 1971) and in the schists exposed in the vicinity of the gold mineralization in the Chandalar quadrangle to the east (Chipp, 1970). The albite observed in the present study is very late in the paragenesis and is usually accompanied by some of chlorite (pennine or prochlorite). Clinochlore appears to be associated more often with the pre-albite rock fabric. Many thin sections show that both albite and Fe-chlorite have developed at the expense of the older dominant quartz and muscovite. A modal abundance of 30 percent albite is common. Only the marble units at Arctic Camp (Pzlm) seem to lack albite porphyroblasts.

Albite also is found in nearby areas as a major constituent of albite-chlorite-carbonate dikes. These dikes range in thickness from 1 to 18 inches. They are markedly discordant to the compositional contacts of the schists and the dominant foliation. There is often a spatial association between the dikes and metamafic rocks which the albite dikes often transect. The albite within these pegmatitic occurrences ranges in size from a fine-grained border facies to euhedral medially located crystals up to 2 inches in the longest dimension. Within these dikes, green chlorite is present as a fine-grained groundmass. Calcite pods are found somewhat randomly distributed in the general transition zone between the fine-grained margin and the pegmatitic medial zone. The total length of any single dike is unknown but one occurrence was observed to extend for approximately 100 feet.

Quartz Pods and Dikes

Barren quartz dikes and lenses may be observed throughout the section at Arctic Camp. There is some suggestion of a greater abundance of these occurrences in the distinctly porphyroblastic quartzo-feldspathic schists. The lenses range in size from small pods a few inches in length to conformable and discordant lenses several tens of feet long and several feet thick. The larger pods tend to be discordant with the foliation of the enclosing schists, the dikes markedly so. Some of the dikes are exposed for over 100 feet and are 20 feet or more in thickness.

It is characteristic of the quartz bodies that they are enclosed in a chlorite-rich marginal zone which is transitional to the normal host rock over a distance of a few inches to a few feet. Minor copper oxide can be observed in the chlorite envelope surrounding some of the quartz bodies located close to the massive sulfide horizon.

Skarns

North of Arctic Camp near the crest of the Kalurivik Arch, skarn type of mineral assemblages have developed in an impure marble (pl. 1). These skarns contain abundant octahedra of magnetite, pink to red garnet, actinolite, and epidote. There is some evidence to suggest the location of the skarns has been locally controlled by steeply dipping fractures. Observations which support this hypothesis include the spatial distribution of the skarn mineralization and progressively zoned mineral assemblages crosscutting the host-rock foliation at a steep angle.

I.L. Tailleur of the U.S. Geological Survey has suggested (personal communication) that the Kalurivik Arch may be underlain by a Cretaceous granitic pluton like those exposed to the north. This hypothesis is based on the similarity of the skarns just north of Arctic Camp and those found associated with the Shishakshinovik and Redstone plutons. If this inference is correct, the skarns are much younger than the 213-m.y.-old metamorphism affecting the Arctic Camp schists.

STRUCTURE

Kalurivik Arch

The axis of the Kalurivik Arch passes approximately 3 miles north of Arctic Camp. The effect of this regional antiform is reflected in the attitude of the dominant foliation exhibited by the Arctic Camp schists (pl. 1). As stated earlier, it has been suggested that the arch may owe its origin to an intrusive core of granite (I.L. Tailleur, personal communication). Skarns observed near the crest of the arch tend to support this hypothesis. The author believes that there is no genetic association between the proximity of the Kalurivik Arch and the mineral deposits of Arctic Camp. The arch may, however, be responsible for upraising the significant sulfide-bearing schists within the section and thus preparing them for exposure by subsequent erosion.

Observations to date indicated that the Kalurivik Arch north of Arctic Camp can be readily interpreted as a simple antiform. This interpretation, however, is based on mapping in a very restricted area and is not conclusive. A test of the nappe-root hypothesis proposed by Forbes and others (1973) can only be made by additional detailed mapping of the rocks exposed north of Arctic Camp and along strike to the west.

Minor Folds and Crenulations

Minor folds occur at several scales within the mapped area. These range from mesoscopic folds, a few inches to a few tens of feet in wavelength and amplitude, to the single antiform shown on plate 1, which has a wavelength of about 1 mile. The large antiform is a gentle flexure which appears to have only local extent. However, it involves the ore-bearing unit Pztc along with other Arctic Camp schists. It is possible that the presence and orientation of this fold is in some way controlled by the considerable thickness of competent blastoporphyritic schist (Pzrp) occupying part of Arctic Camp valley and perhaps the northwest end of Riley ridge to the west. The axis of this fold is nearly perpendicular to that of the Kalurivik Arch.

Most of the minor folds at Arctic Camp plunge to the west or southwest. Most of these appear to be intraformational and have little effect on units lying above or below the contact of the unit. They are usually isoclinal to rucumbently isoclinal. The folds are defined by the attitude of the prominent schistosity of the region and therefore postdate the formation of that structural element.

Crenulations of the schistosity are commonly seen. To date, no detailed studies have been made to relate the orientation of these crenulations with those of the minor fold axes. A cursory examination of the map (pl. 1), however, indicates that the minor-fold axes and the crenulations within the schistosity may constitute subparallel structural elements.

Foliation

The foliation exhibited by the schists at Arctic Camp is approximately parallel to contacts between lithologic units. Where the rocks are tightly folded, as in the noses of small isoclines, the schistosity still retains its parallelism to the compositional banding. For the most part, it appears permissable to assume that the foliation is nearly coincident with original bedding planes (S_0). This assumption should not be unconditionally accepted, however, because in this metamorphic terrain there remains the possibility that bedding has been transposed. Especially for more detailed mapping, this assumption should be carefully tested. For example, it is known that some of the large massive greenstone bodies at Dead Creek, to the west of Arctic Camp, have locally influenced the orientation of foliation in the immediately adjacent schists. There, the schistosity of rocks within approximately 15 to 20 feet of greenstone contacts is often distorted so that it closely conforms to the irregular surface of those masses. Outside of this local zone of influence the schistosity retains its more normal relationship to compositional layering.

Faults

Only two (apparently minor) faults have been observed at Arctic Camp in this study. These both occur at the southern edge of the area mapped. From the linear character their surficial traces, they are both inferred to be steeply dipping. The faults also are characterized by the presence of small but well-developed limonitic gossans along their projected trace. The easternmost of these two faults shows a clearly defined offset with the south side being downthrown. Where observed, displacement was on the order of a few feet to a few tens of feet.

METAMORPHISM

Geochronologic data (Turner and others, 1973) indicates that the rocks of the Brooks Range schist belt, including those at Arctic Camp, have undergone at least two separate periods of metamorphism. Data suggests that the two metamorphic thermal events occurred at about 213 and 96 million years ago. If this hypothesis is true for Arctic Camp, it may help to explain some of petrographic observations made of these rocks.

A consideration of the mineral assemblages present in the schist units emphasizes the importance of muscovite-phengite, chlorite, quartz, albite (porphyroblasts), biotite, and epidote. If these minerals had all formed at the same time and in mutural equilibrium, they would clearly indicate a metamorphic rank within the quartz-albite-epidote-biotite subfacies of the Barrovian greenschist facies (Winkler, 1967). With certain qualifications, the regional metamorphism at Arctic Camp probably does approach a classification to this subfacies. However, the albite and much of the pennine chlorite which commonly accompanies it probably did not form simultaneously with the Mg-chlorite, muscovite-phengite, biotite, and the recrystallization of quartz. Petrographic and field evidence indicates that albite and pennine chlorite were introduced into the rocks after prior metamorphism had created the dominant schistosity (S_1) and those minerals which define it.

It is believed that the mode of genesis of the albite and chlorite within Arctic Camp rocks is in some way associated with the presence of the late discordant albite-chlorite dikes found in nearby areas and commonly throughout the schist belt. The origin of the sodium necessary to form the albite porphyroblasts in the schist, and the pegmatitic albite in the dikes, is highly conjectural. One possible hypothesis is that both occurrences of albite were formed by a late metamorphically derived intergranular fluid migrating through the rocks to zones of low P_{H_2O}. It might be inferred that within the schists, porphyroblasts were formed at multiple nucleation sites, while pegmatitic albite dikes were formed in discordant fractures which provided the primary loci for the low P_{H_2O}. An extension of this hypothesis might explain the presence of the barren quartz bodies as the final representatives of this metamorphic fluid from which all sodium had been removed by the crystallization of albite. The more common association of the pegmatitic albite dikes with greenstones might be interpreted as resulting from an original spilitic composition for those rocks. The more common association of the quartz bodies with the felsic schists might, in turn, be inferred to result from the abundance of silica in their hosts.

If the above hypotheses are true, then they must explain the presence of similar paragenetically late albite and quartz occurrences throughout the schist belt and possibly the Cosmos Hills as well. The occurrence of porphyroblastic albite schists has been reported from as far away as the Chandalar quadrangle to the east (Chipp, 1970). Fritts (field samples) found pegmatitic albite, and barren quartz dikes in the Survey Pass quadrangle east of Arctic Camp, and porphyroblasts of albite in the marbles of the Cosmos Hills to the south (Fritts, 1970).

An alternative hypothesis consistent with the paragenetically late position of the albite and quartz bodies has been suggested by I.L Tailleur (personal communication), who considers the presence of felsic Cretaceous intrusions found throughout the region from west of Arctic Camp to Chandalar quadrangle on the east; felsic stock is also present in the core of the Cosmos Hills. According to his hypothesis the albite pegmatite would be genetically related to the Cretaceous plutons as satellite dikes, and the albite porphyroblasts would represent the mineralogic overprint of a 96-m.y.-old metamorphic event associated with the emplacement of the intrusions. Several lines of evidence tend to support this hypothesis. For example, there are Cretaceous intrusions throughout the schist belt and in the Cosmos Hills to the south, and similar albite pegmatites have been observed in great abundance within the recognizable contact metamorphic zone surrounding some of these plutons. The hypothesis is weakened by the fact that the Cretaceous intrusions do not appear to be particularly rich in sodium (Pessel and others, 1973), and the common, clearly related metasomatic alteration associated with the plutons commonly manifests itself by the formation of garnet, actinolite, epidote, and magnetite skarns.

A hypothesis which perhaps best accounts for the several observations bearing on this problem would infer that a metamorphic event associated with the emplacement of the 96-m.y.-old plutons provided the heat, and perhaps some of the fluids necessary, to mobilize sodium and silicon from within the older schists. The fundamental source of the chemical components would be the schists themselves. A positive spatial association of porphyroblastic schist, pegmatitic dikes, and barren quartz bodies with the vicinity of the plutons would result from the close proximity of the appropriate host rocks and a late heat source. In terms of metamorphic rank, therefore, the albite present in the section may not be significant for defining the rank of the 213-m.y.-old metamorphism.

It is believed that the massive garnet found in the skarn north of Arctic Camp also is associated with the 96-m.y.-old intrusives, and therefore has no bearing on the metamorphic rank attained during the older regional metamorphism. The small garnets found disseminated in the metamorphic rocks, however, will be of aid in defining the degree of metamorphism attained. It is expected that these will prove to be spessartine, a lower temperature garnet compatable with the biotite-stable subfacies of Barrovian greenschist metamorphism.

Glaucophane and chloritoid, although seldom observed in specimens so far collected from the area mapped at Arctic Camp, are common minerals in metasediments and metamafic rocks only a few miles distant. Jadeite also has been reported as a constituent of some metasediments found within a few miles of Arctic Camp (Forbes and others, 1973). The author, therefore, believes that these minerals must be considered when defining the metamorphism history of the local area. Forbes and others (1973) stated that jadeite found near VABM Ruby occurs "in a relict fabric cut by a later foliation defined by paragonite and actinolite." If this foliation is the dominant schistosity (S_1) seen in the Arctic Camp area, it would mean that in general the Brooks Range rocks have been subjected to three distinct metamorphic events. These would be 1) an initial high-pressure metamorphism, of unknown temperature maximum, necessary to form jadeite; 2) a higher temperature high-pressure glaucophane greenschist metamorphism which partially replaced the jadite and induced a general schistosity in the rocks; and 3) a late and somewhat localized metamorphism associated with Cretaceous plutonism.

Only the last two events are evident at Arctic Camp. One must also consider that although the development of glaucophane-greenschist to Barrovian-type greenschist is a distinguishable metamorphic event in the area, it may represent a retrogressive event which is a continuation of the metamorphic pulse which formed the jadeite originally. There is a persistent and intriguing suggestion, however, that the three distinguishable metamorphic events coincide with the three distinct groups of age dates obtained to date from Brooks Range rocks. That is, jadeite forming metamorphism in the Precambrian; greenschist metamorphism in Late Paleozoic to Triassic time, and thermal metamorphism in Cretaceous time.

SULFIDE MINERALIZATION

Character of Arctic Camp Mineralization

Because of a lack of public drilling and limited ore-grade exposures, only a perfunctory statement can be made at this time concerning the characteristics of the mineralization at Arctic Camp. The following information is based on an examination of sulfide mineralization exposed in the project pits shown on plate 1. In general, the sulfides observed are fine to medium grained. They consist of abundant amounts of pyrite, sphalerite, chalcopyrite, and minor pyrrhotite chalcocite, bornite, and galena with traces of tennantite. Very minor copper oxide staining is visible on some of the planes of schistosity in near-surface rocks adjacent to the sulfide concentrations. A small gossan cap is present over massive sulfide occurrences and may be as thick as 10 to 15 feet. Locally this cap has been removed by trenching or pitting. Downslope from the sulfide zone, one can find abundant ferricrete in the talus, and some boulders and cobbles of ore-grade sulfide mineralization.

The ore minerals are found in calcareous talcose to quartzose lenses which are conformable with the foliation of the enclosing schists. Much of the ore-grade material contains appreciable calcite along with the abundant talc, as does some of the surrounding talc schist of unit Pztc. There is not a definite single layer of sulfides, rather there are lenses of massive sulfides arranged en-echelon through a zone several tens of feet thick. This entire zone of mineralization is surrounded to a talc and carbonate-rich schist. In many respects, including the presence of albite porphyroblasts, the talcose schist resembles other rocks in the Arctic Camp section. However, the presence of talc appears to be uniquely characteristic of proximity to mineralization. The massive sulfide-bearing horizon is contained between two units of blasto-porphyritic schist, as shown diagramatically in cross-section A-A' on plate 1. No vein formation has been noted in association with the mineralization at Arctic Camp. Any surficial evidence of progressive hydrothermal alteration zonation around the sulfide lenses also is lacking. Although there is considerable calcite in the host rocks of the sulfides, no skarn mineralization like that seen on the north end of Arctic Camp ridge has been found in the close vicinity of the ore-grade material.

Because talc is not found elsewhere in the section, it is believed that its presence is genetically related to the occurrence of sulfide mineralization. The development of talc predates the formation of albite porphyroblasts. The inference is thus made that sulfide mineralization associated with the talc also formed prior to the albite. No criteria have been observed which would suggest that talc developed in the schists by postregional metamorphism hydrothermal or metasomatic replacement of preexisting muscovite or chlorite. Rather, the talc has the same textural relationships to the other minerals within the host rock as does muscovite in the surrounding porphyroblastic schists. This implies, although it does not prove, that the talc has developed from the regional 213-m.y.-old greenschist metamorphism acting upon a parent material of different composition than that of the surrounding schists. This local difference in composition may well have resulted from a premetamorphic rock alteration genetically associated with the sulfide mineral emplacement.

Genesis of Arctic Camp Ore Minerals

A hypothesis for the genesis of the mineralization at Arctic Camp includes observations made throughout the 60-mile-long mineralized schist belt. Some of the more pertinent of these collective observations are discussed below.

Blastoporphyritic quartz microcline schists have been observed near most of the apparently economically significant mineral deposits. An examination of the texture and field occurrence of these schists strongly suggests that the parent rocks had a hypabyssal to volcanic origin. Relict partially resorbed blue quartz and K-feldspar phenocrysts are abundant. Mapping of these rocks indicate that these units have a lensoid shape and that multiple levels of the blastoporphyritic schists may occur at a given locality. Felsic schists, which usually are found in those stratigraphic sections having blastoporphyritic units, occassionally have been observed to contain both fragments of K-feldspar and intact blastophenocrysts of quartz. These felsic schists occur as sheet-like or lensoid bodies. In some cases they can be followed through a transition in rock texture to what appears to be a stock-like source. Other felsic schists found near the deposits are extremely fine grained to aphanitic and consist predominantly of muscovite and quartz. Examination of these rocks with a petrographic microscope, however, often reveals the presence of considerable amounts of very fine-grained K-feldspar. One location on the north end of Riley Ridge, northwest of Arctic Camp, provided specimens of what appears to be a metamorphosed volcanic breccia, or a lahar. From these observations it is inferred that many of the felsic and blastoporphyritic schist units in the section near the mineral deposits were originally metavolcanic domes, volcanoclastic piles, and flows of quartz-latite or rhyolite composition. The irregularities in thickness and apparent changes in stratigraphic level exhibited by single continuous units are inferred to be a function of proximity to source, deposition on an irregular surface, and perhaps in some cases, hypabyssal intrusion.

The greenstone and glaucophane-bearing greenstones found in the mineralized portion of the schist belt occur in a variety of forms. Record has been made of plug-like bodies, discordant and concordant planar bodies, large apparently detached lenses up to several hundred feet in greatest dimension, and some relict pillowed structures. The inference made from these observations is that the metamafic rocks seen in the section are of both hypabyssal and volcanic origin, with the pillow structures indicating a submarine setting for at least some original basalt dikes and flows.

Both of the above types of inferred metavolcanic rocks have undergone greenschist facies metamorphism to at least the quartz-albite-epidote-biotite subfacies (Winkler, 1967). They display, to varying degrees, foliation and schistosity which is conformable with that of the surrounding schists and with the regional structural trends. They also contain porphyroblasts of albite. Because it is believed that the prominent foliation, schistosity, and greenschist rank mineral assemblages within the schist belt were developed during the older 213-m.y.-old metamorphism, these observations suggest that the metavolcanic rocks are more than 213 million years old.

The sulfide-bearing horizons at six out of seven prospects visited in 1974 were spatially associated with felsic schists or blastoporphyritic felsic schists (metavolcanics ?). At Arctic Camp, the ore horizon is found between two layers of blastoporphyritic schist (pl. 1). The Picnic Creeksun claims in the Survey Pass quadrangle are found just beyond the southeastern margin of an extensive felsic schist unit. The sulfide mineralization exposed at Dead Creek and Ruby Peak to the west of Arctic Camp is not far removed from blastoporphyritic or felsic schists. The Smucker and Ambler claim groups overlooking the Kaluriwik River both enclose blastoporphyritic schists and extensive associated felsic schists. Further mapping will help to clarify the exact distribution of the inferred metavolcanics with respect to the mineral occurrences. At present, however, it appears that the sulfide mineralization is preferentially located on the flanks or just off the edges of small pre-metamorphic felsic volcanic domes or volcaniclastic piles.

The mineralization exposed at Dead Creek is extensively folded in a style consistent with the surrounding host rocks. At Arctic Camp, gangue mineral assemblages of quartz, muscovite, chlorite, calcite, and porphyroblastic albite are consistent (except for talc) with the mineralogy of the surrounding schists and marbles. The deformation of the ore and the similarity between the mineralogy of the gangue and host rocks are interpreted to mean that the ore was subjected to the same 213-m.y.-old dynamothermal metamorphism as were the surrounding schists. The talc and possibly some of the carbonate characteristically associated with the ores are believed to represent the metamorphic end product of pre-metamorphic alteration accompanying the original emplacement of the sulfides.

Sulfide mineralization has been found in a variety of host-rock types, including calcareous talcose to quartzitic units at Arctic Camp, graphitic micaceous schists at Horse Creek, and the Picnic Creeksun claims, and calcareous quartzitic lenses east of VABM Ruby. At present, it does not appear that the original parentage of the host rocks was critical (other than having been some form of clastic or volcaniclastic sediment).

In spite of the calcareous nature of some of the host rocks, including those at Arctic Camp, none of the mineral occurrences known to the author display any of the skarn development characteristically produced by the Brooks Range Cretaceous intrusives. Massive garnet, magnetite, epidote, and actinolite are all absent. The portions of the deposits observed lack well-defined systems of veins. In fact, no veining was seen in the exposed mineralization. Except for the common enclosing halo of talcose rocks, no evidence of hydrothermal alteration has been found. Noticeably absent is a lack of any postfoliation hydrothermal alteration.

The sulfide minerals tend to occur in lensoid bodies of varying dimension. These are conformable with the foliation of the host rocks. No apparent symmetrical zonation has been observed within these lenses as might be expected if they owed their origin to epigenetic vein formation. Assay data from systematically sampled diamond-drill cores will be necessary to determine whether there is assymmetrical zonation of metals within the deposits.

Based on the above observations and interpretations made to date, the author believes that the genesis of the sulfide mineralization at Arctic Camp can best be attributed to submarine felsic volcanism. This genesis would apply as well to the other conformable mineral deposits within the 60-mile belt from VABM Sleet on the west to Reed River in the Survey Pass quadrangle. This belt, therefore, is believed to constitute a volcanogenic massive sulfide province of at least as old as Paleozoic age.

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