

GEOLOGY OF THE WILLIAMS CREEK
COPPER PROSPECT

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ABSTRACT

The Williams Creek Copper Prospect, discovered in the summer of 1970 is located in central Yukon near Carmacks. Disseminated primary chalcopyrite and bornite occur in two showings about two miles apart. Zone #1 is restricted to an elongated roof pendant of biotite and/or hornblende gneiss. Zone #2 is restricted to a biotite-rich porphyritic diorite. Both showings are enclosed by granodiorite and possibly diorites which are members of a Mesozoic intrusive complex. A porphyry type deposit is suggested by the mineralogy but the apparent lack of extensive hydrothermal alteration and elongation of the mineralized zones indicates another mode of origin. As much as 75% of the primary sulphides have weathered to form an oxidized zone at least 50 feet deep (in Zone #1) but there is little evidence of leaching or supergene enrichment.

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INTRODUCTION

Foreword

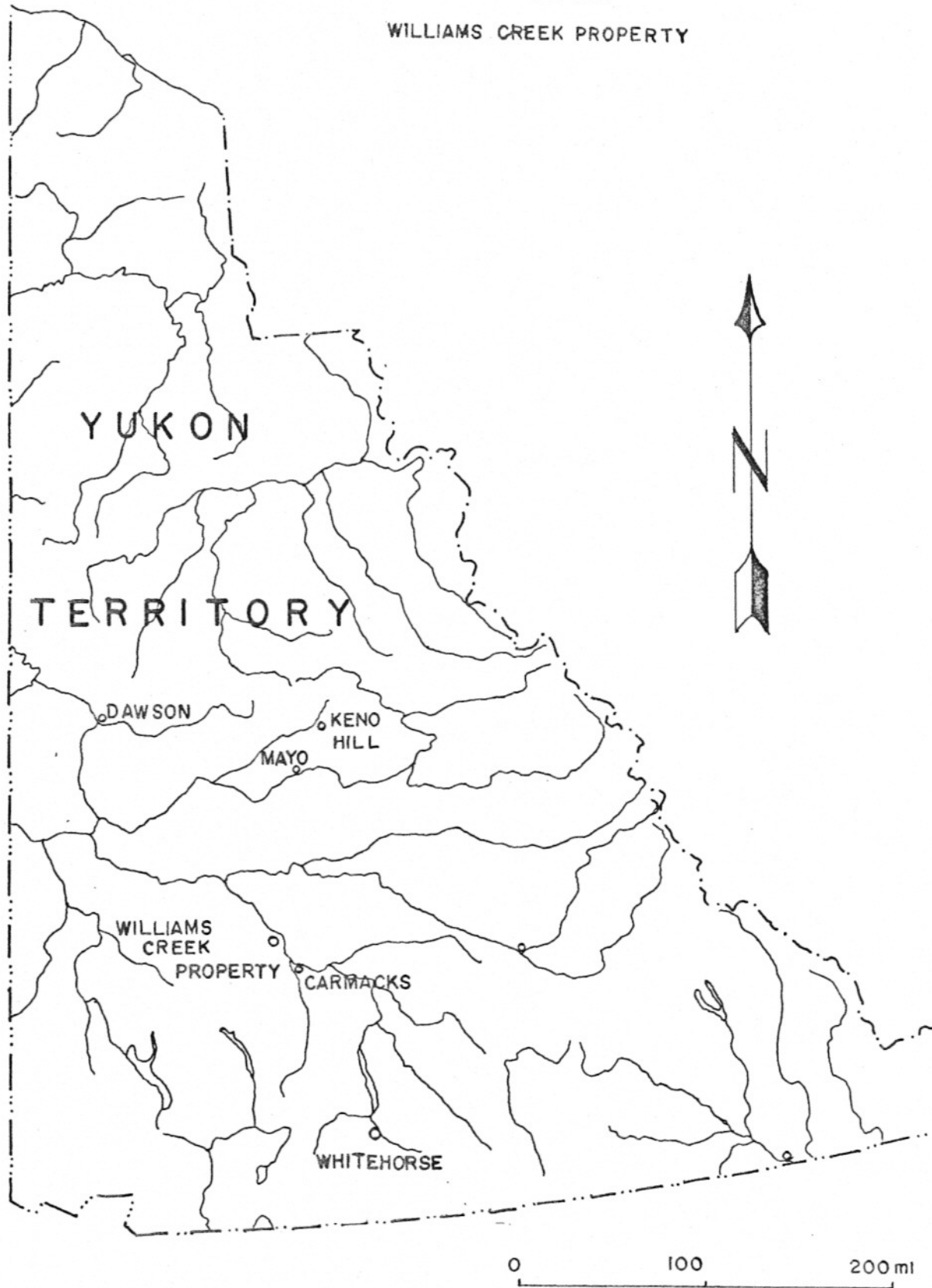
The Williams Creek property is a copper prospect found by the writer in central Yukon during the summer of 1970 while employed by Archer, Cathro & Associates Ltd., project managers for the Dawson Range Joint Venture. This thesis is based on data collected during reconnaissance mapping, bulldozer trenching of two mineralized showings and two short diamond drill holes. Outcrop in the area is less than five percent and the geology is only known in a general way. Petrographic and mineralographic data are presented which describe the host rock, mineralization and alteration and relationships between them.

Location and Access

The Williams Creek property is located in central Yukon at latitude $62^{\circ}21'N$ and longitude $136^{\circ}42'W$, about four miles west of the Yukon River at a point 20 miles north of Carmacks (Figure 1). The property consists of 327 claims which form a single block that straddles Nancy Lee Creek and Williams Creek. Two mineral showings have been found which are about two miles apart. Mineral Zone #1 is located on a south-facing slope immediately north of Williams Creek. Mineral Zone #2 is two

LOCATION MAP

WILLIAMS CREEK PROPERTY



miles north of Zone #1 on the crest of a north sloping ridge near Nancy Lee Creek.

A gravel road running from Carmacks, on the Dawson-Whitehorse Highway, to Revenue Creek passes six miles south of the property. Access is presently by helicopter.

History

The Williams Creek copper occurrences were probably the earliest base metal showings to be reported on in Yukon or northern B.C. The first geologist to travel through the country, G.M. Dawson in 1887, noted the presence of copper sulphides and stain in "Hoocheekoo Bluff", which is probably the hill which follows the west side of the Yukon River between Minto and Crossing Creek. Copper bearing quartz veins in the canyons on Williams and Merrice Creeks were staked in 1898 by placer miners enroute to the Klondike. Their development, which included several short adits, was completed prior to 1910, and almost all the claims were later consolidated under the ownership of Dr. J.O. Lachapelle, a Dawson dentist. A few tons of ore was shipped to the Granby Smelter in 1917¹. No record exists of work in this vicinity during the past fifty years.

During the 1930's, placer and lode gold occurrences were discovered at Mt. Nansen and Mt. Freegold, 24 miles and 10

1. Letter to the Office of the Gold Commissioner of the Yukon Territory--August 3, 1918.

miles southwest of the Williams Creek property, respectively. Both areas reached production in a minor way between 1966 and 1969. In the late 1960's low grade porphyry copper prospects were found on Granite Mountain and at Revenue Creek, nine miles and 17 miles west, respectively. The Casino porphyry copper deposit, 65 miles to the northwest, is the only major discovery in this district to date.

In the summer of 1970 the writer, accompanied by two assistants, discovered the two mineralized outcrops while conducting reconnaissance prospecting and geochemical sampling.

GEOMORPHOLOGY

The property lies at the western margin of Pleistocene glaciation. Evidence of weak valley glaciation in the form of small lateral moraines and kame terraces can be seen up to an elevation of 2500 feet above sea level. On the #1 Zone, glacial material was found in trenches 4S and 8S but not in the remaining trenches which are further up the hill. The terrain is subdued with maximum relief of 1000 feet. Drainages are little affected by the valley glaciation and have a rectilinear pattern reflecting structural features. The area lies on the west side of the Yukon River valley on the northeast flank of the Dawson Range mountains. A weather station at Pelly Farm, 35 miles to the northwest has compiled the

following data which is typical of the region:

Mean total annual precipitation	11.2 inches
Mean daily temperature	23.9° F
Mean daily maximum temperature	36.3° F
Mean daily minimum temperature	11.2° F
Extreme temperature range	-76° F - 95° F

Vegetation ranges from willows and alder in the swampy valleys to spruce thickets on the dryer hillsides. Outcrops, or areas of felsensmeer, are rare and the subdued, rolling topography suggests thick overburden. Trenching on the #1 Zone showed, however, that this is not so. A typical profile has several inches of moss and organic material overlying two to eight inches of volcanic ash, which in turn overlies several inches of organic material (peat) and six to 18 inches of red brown soil. The ash is from a volcanic explosion that occurred near White River (about 180 miles to the southwest) perhaps in historic times. The ash is very fine and has accumulated, probably by wind action, in surface depressions where thicknesses of several feet are common. Permafrost is now rare and occurs only on northern slopes. Intense frost action in the recent past is evidenced by numerous small pingos.

REGIONAL GEOLOGY

The oldest rock units in the Carmacks area are metasediments and granite and diorite gneisses comprising the Yukon Group. The oldest members of this group which is Cambrian or

older in age, consist largely of quartz-mica schist, hornblende schist with lesser amounts of quartzite, gneiss and limestone. Succeeding these are a similar series of Paleozoic schists, quartzites, limestones and greenstones. Both members are cut by granite and diorite gneisses which were metamorphosed at the same time as the sediments.

The Yukon Group is overlain by the Triassic Lewes River series, Jurassic Laberge series and Jura-Cretaceous Tantalus Formation. These are largely clastic sequences ranging from shale to conglomerate with some limestone, tuffaceous clastics and coal measures. These are overlain by the Mt. Nansen Group which is a Jura-Cretaceous series of basic volcanics ranging in composition from basalt to dacite. Some minor breccia tuffs, sediments, and diorite plugs are also included in this group.

During the Late Mesozoic, the region was intruded by a series of coarse-grained plutons. The oldest of these are small plugs of diorite and gabbro. These were followed by a variety of intermediate to moderately alkaline stocks which have been grouped as syenites. The youngest and by far most extensive intrusions are stocks and batholiths which range in composition from granite to quartz diorite.

Several different stages of Tertiary and Recent volcanic rocks cut the older units. The Carmacks Group which is the oldest and most widespread is mainly andesitic but has a wide

range of compositions. Rhyolitic dikes and flows are possibly associated with the major period of Mesozoic intrusion but their relationship with the Carmacks volcanics is uncertain. Composition is relatively constant but the rock textures vary from a cherty rhyolite to a quartz porphyry and granophyre. The youngest rock unit in the Carmacks mapsheet is the Selkirk Group, which are recent basalt lava flows which are confined to a small area near the junction at the Pelly and Yukon Rivers.

GEOLOGY OF THE WILLIAMS CREEK PROPERTY

The oldest rock units on the property are bodies of quartz biotite feldspar gneiss of the Yukon Group. They occur throughout the property but lie mainly in a band between the two showings. The distribution of these metasediments is not clear because of the ^{scarcity} lack of outcrop but they probably occur as small isolated roof pendants. Also, near the northeast corner of the property is a small pendant of coarse-grained amphibolite. This is probably the metamorphosed equivalent of the Mt. Nansen volcanics.

The predominant rock type on the property is a coarse-grained hornblende and biotite-rich intrusive containing large white phenocrysts of feldspar. A fresh specimen from adjacent to Zone #1, examined in thin section, is a coarse grained, weakly foliated, leucocratic granodiorite.

Aplite and pegmatite dikes are moderately common and cut both the Yukon Group and intrusive rocks. They are common as swarms in and near the roof pendants. Pegmatites are largely composed of coarse grains of pink feldspars and quartz. Aplites are creamy white with a fine-grained sugary texture.

The only rock type seen, younger than the intrusives is a small outcrop of dacite porphyry, probably of the Carmacks Group, which is located halfway between the two showings.

Zone #1

Zone #1 is a mineralized area closely associated with a roof pendant of Yukon Group gneisses. The discovery outcrop is composed of biotite gneiss and is about 150 feet wide and 300 feet long. It is entirely devoid of vegetation and may represent a vegetation anomaly. The mineralized zone as now exposed by trenching is some 1600 feet long and up to 200 feet wide and is well defined by assays from chip samples of the trenches, taken in 50 foot intervals. Within it assays range from .27 - 1.2% copper, with short sections going as high as 1.65% and average .8%. Values in drill hole #1, mainly in biotite gneiss, assayed in five foot intervals, ranged from .39 - 1.70% and averaged 1.26%. Values in drill hole #2, mainly in diorite gneiss, ranged from .04 - 1.06% and averaged .47%.

Foliation is roughly parallel to the trend of the zone, which strikes about N35W and dips steeply to the east. On airphotos the mineralized zone is represented by extremely weak linears. The zone is open to the north and is probably terminated to the south by a left hand fault. Displacement appears to be about 600 feet.

Petrology

Irregular dikes of leucocratic quartz diorite which are often moderately foliated, intrude the biotite gneiss. The quartz diorite contains very little orthoclase, and only a little biotite. It may be related to the granodiorite but has been altered in composition due to the assimilation of Yukon Group rocks.

The major rock type within the mineralized zone is a medium to coarse-grained biotite-feldspar-quartz gneiss (Plate 1). The biotite and quartz contents vary greatly within individual layers of this unit with the biotite-rich layer predominant. The quartz-rich layers occasionally define tight isoclinal folds in hand specimen and lenses of pure quartz, up to a foot in width and roughly parallel to the foliation, are occasionally present.

A second variety of gneiss has also been recognized. In the bottom 20 feet of drill hole #1, hornblende becomes a

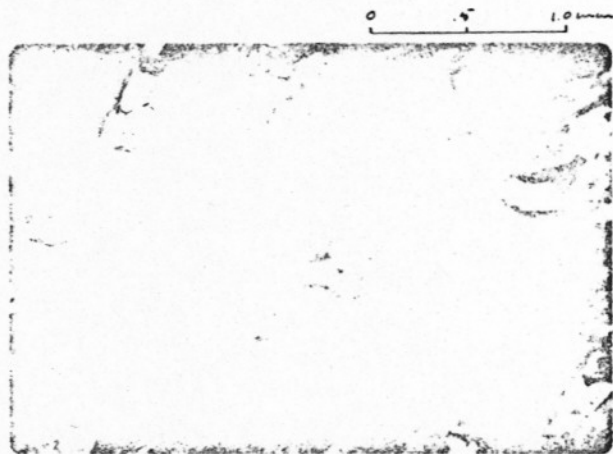


Plate 1: Biotite - feldspar-quartz-
gneiss

prominent mafic mineral and bands of almost pure hornblende are occasionally layered with plagioclase-rich layers. Also in trench 12N the gneiss contains abundant hornblende, together with orthoclase and biotite (which seem to be largely alteration minerals). This rock type could be related either to the Yukon Group or the intrusions. The presence of hornblende suggests that the association is with the granodiorite. Plagioclase in all units is oligoclase (An_{23-27}). Thus, the exact boundary of the roof pendant is not clear and might not be defined solely by gneissic texture.

Fracturing occurs throughout the zone but varies considerably in intensity. Rocks from Trench 12N are strongly fractured at angles to the foliation but undisturbed bedrock was not reached and attitudes could not be taken. Elsewhere in the zone fracturing is not as evident. Some specimens of hornblende-biotite gneiss from drill hole #1 contain narrow, unmineralized crushed zones at random orientation. Thin sections from the same unit also show narrow bands of fractures on either side of and parallel to sulphide veinlets. Samples of biotite gneiss are not obviously fractured but in thin section show minor fracturing and dislocation parallel to foliation. Quartz-rich layers show a few criss-crossing hair-line fractures in hand specimen. Nowhere could a close relationship between mineralization and fracturing be seen.

Mineralogy

The primary mineralization of the showings is simple, comprising bornite, chalcopyrite, small amounts of specularite and traces of molybdenite, all in small disseminated grains or veinlets. On surface, the mineralization has been oxidized to varying degrees. The exact composition of some of the oxidized material could not be determined but will be shown to account for a large portion of the copper values.

Chalcopyrite and bornite in the ratio of about 2:1 are the sole primary copper minerals (Plate 2). They usually occur as small interstitial grains ranging upward in size from about .1 - 2 mm. Bornite forms irregular patches in the chalcopyrite and contains abundant exsolution lamellae of chalcopyrite parallel to crystallographic directions. At depth both minerals are altered to chalcocite which forms narrow rims around grains and along fractures. Small amounts of specularite form rosettes which are occasionally intergrown with sulphides (Plate 3).

Mineral grains are roughly elongated parallel to the foliation and tend to concentrate in distinct bands, also parallel to the foliation. In two or three sections in the drill core more massive sulphides occur as veinlets, about 2 or 3 mm wide, also parallel the foliation. The sulphides show strong preference for the biotite-rich gneisses. The quartz-rich layers are less mineralized and the copper grade increases rapidly

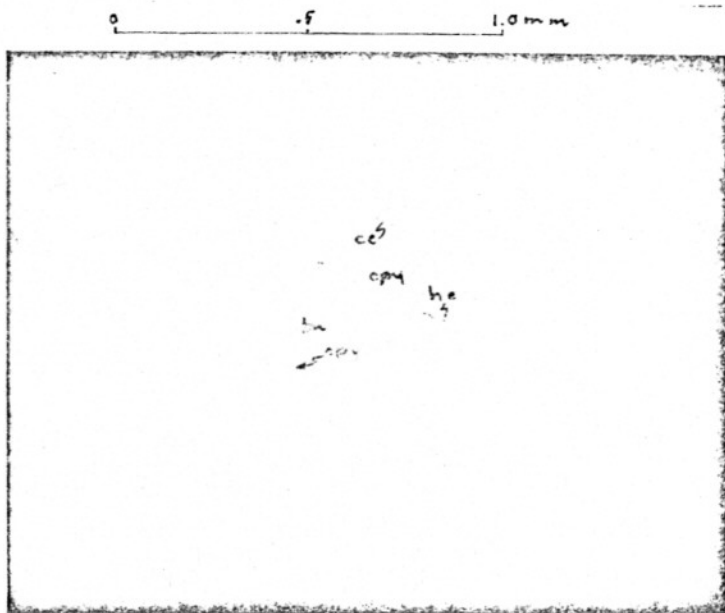


Plate 2: Bornite and chalcopyrite rimmed by chalcocite

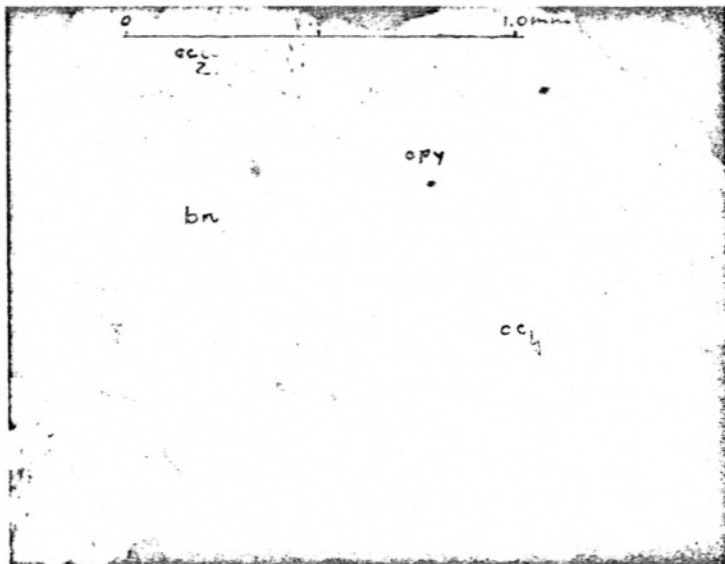


Plate 3: Bornite, chalcopyrite and specularite

with the mafic content. Quartz lenses contain some interstitial sulphides, especially near contacts with the gneiss. No mineralization was noted in the pegmatite.

Surface Oxidation of Sulphides

Most of the copper mineralization studied is in non-sulphide forms. In hole #1, for instance the total amount of copper averages 1.26% of which 1.05% is non-sulphide. It occurs as malachite, azurite and multicoloured oxides. On surface, mineralized zones display weak "limonite" and malachite staining. Chocolate brown "limonite" coats all rock surfaces which are not exposed to air while the malachite is more prevalent along foliation planes. In thin section, malachite is usually seen interlayered with biotite flakes or filling fractures and open spaces (Plate 4). In Trench 12N where the rock is highly fractured, malachite is accompanied by azurite and is most common as a fracture filling.

The unidentified oxide material is the more common alteration product. It usually occurs as a colloform interstitial mass, commonly containing a core of chalcopyrite (Plate 5). In hand specimen it occurs as thin fracture fillings. Under the binocular microscope, it varies in colour from a dark pitchy brown to a dull reddish orange or yellow. In thin section, it varies from opaque through ruby red to bright yellow.



Plate 4: Malachite interlayered with biotite and copper oxides



Plate 5: Sulphides surrounded by copper oxides

The red and yellow varieties are slightly birefringent while the dark red type is dark under crossed nicols. In polished section the characteristics vary from that of goethite to earthy hematite. Commonly the internal reflection is an intense ruby red. Also, the material appears to be composed of different minerals because there are slight variations of ~~different minerals because there are slight variations in~~ colour and some layers polish better than others. In thin section the darker layers are generally closest to the sulphides and the lightest farthest away. Commonly sulphides are absent and are replaced by a void, in which case the darker layers are closest to the walls of the space and the lightest occur near the center. This is interpreted as evidence that some of the copper has been transported. Malachite is commonly associated with the oxides, either forming the core of an oxide mass, or interlayered with the oxides.

Attempts to identify the oxide material by X-ray diffraction and with the electron probe indicate it is an amorphous mixture of copper and iron oxides known as "pitch copper" or "pitch limonite" (J.A. Gower, personal communication).

Three types of colloform material, distinguished by textural differences gave the following analyses:

	%Fe	%Cu	%Si
Hard, well polished, high relief	~ 46	~ 9.0	~ 3
Dark, poor polish, low relief	~ 16	~ 5.6	-
Light, poor polish, low relief	~ 31	~ 6.2	-

No other elements were detected.

Speculation as to the minerals comprising the oxidized material can be made by examining the stability fields for various copper and iron minerals (Figures 3 & 4). Chalcocite is stable under any pH but requires both a high Eh and pH. The chemical conditions during weathering must have varied between these extremes. Because of its close association with primary sulphides, chalcocite must have been stable only during the initial stages of weathering. Malachite must have been stable during the period when most of the oxide material was precipitated because of its random distribution through it. Thus tenorite, which has the same stability field as malachite under water- and carbonate-deficient conditions, could be expected to form much of the copper oxide. Cuprite and native copper, which have stability fields between the two extremes, are probably lesser components. Hematite is stable throughout the copper oxide fields and is probably a major component but other limonite minerals are also likely. Small amounts of iron and copper silication are indicated by the presence of silicon.

Hydrothermal Alteration

The exact nature of the hydrothermal alteration in Zone #1 is still not clear. The type, intensity and pervasiveness of alteration varied considerably but no zoning or distribution patterns could be established. It is evident, however, that

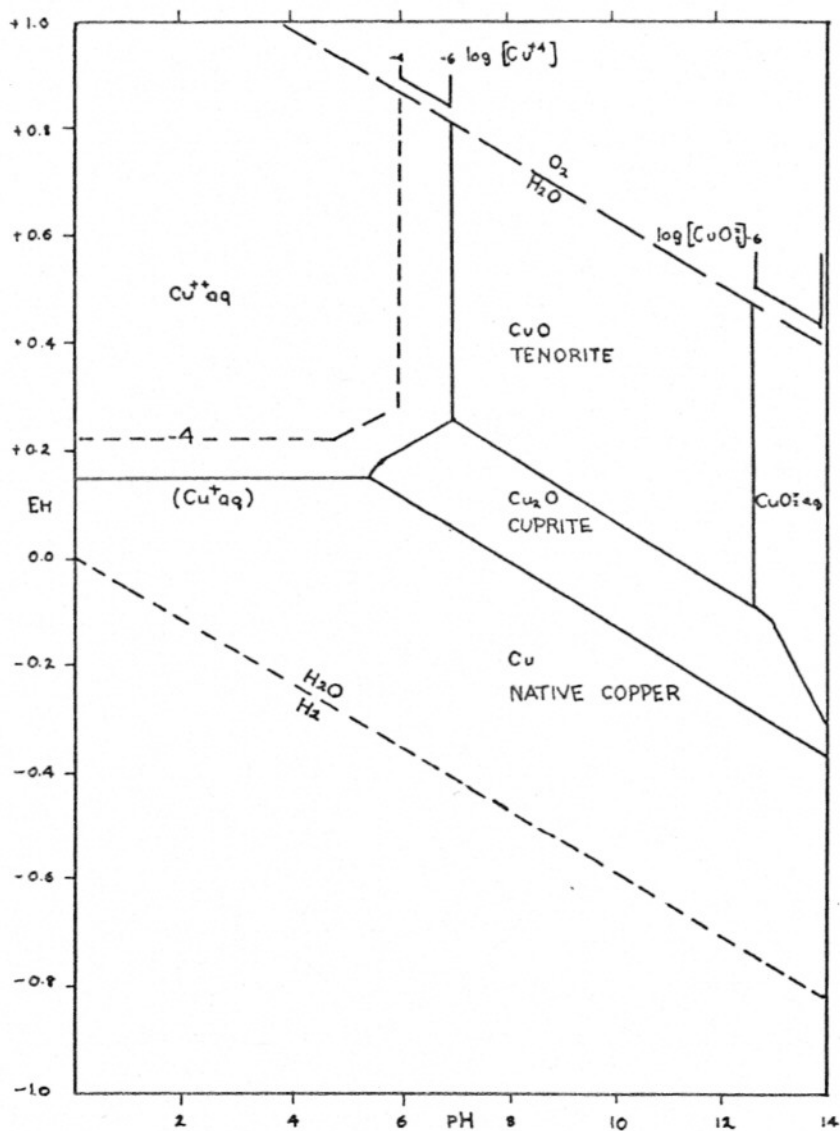


FIGURE 3 Stability relations among some copper compounds in the system Cu-H₂O-O₂-S-CO₂ at 25°C and 1 atmosphere total pressure $P_{CO_2} = 10^{-3.5}$, total dissolved sulphur species = 10^{-1} (after Garrels and Christoffersen)

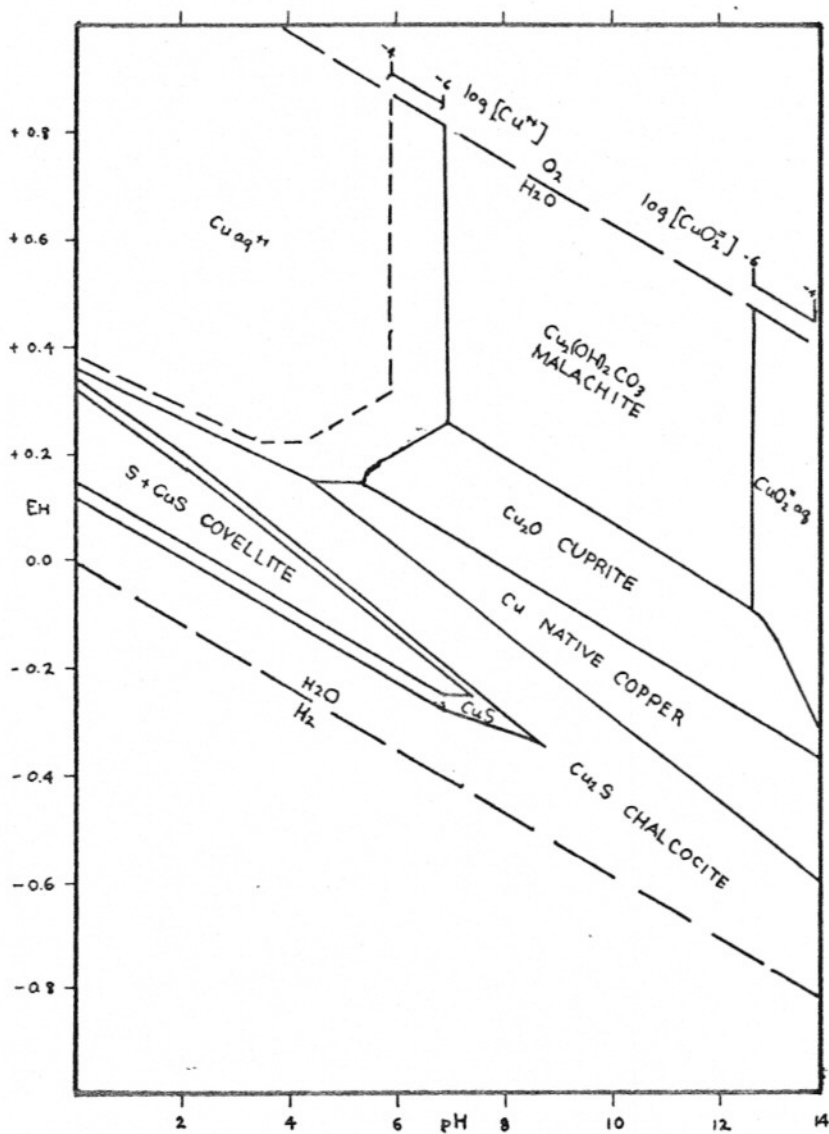


FIGURE 4 Stability relations among copper compounds in the system Cu-H₂O-O₂ at 25°C and 1 atmosphere total pressure. (after Garrels and Christ p.239)

the alteration is not widespread and is essentially confined to the mineralized areas. The only alteration away from mineralized areas is in the granodiorite and diorite dikes where biotite is partially altered to chlorite and plagioclase moderately saussuritized.

The most intense and widespread alteration is present in Trench 12. The rock was originally a slightly foliated, coarse-grained hornblende diorite or quartz diorite gneiss. Whether it belongs with the granodiorite or Yukon Group is uncertain. There appear to be two phases of alteration in these rocks. In one specimen containing less than 10% quartz and 10% orthoclase, alteration is confined solely to hornblende. All minerals are equigranular, and anhedral, but straight sided and elongated parallel to the gneissosity. Plagioclase is only slightly saussuritized. The hornblende has been partially altered to an unidentified mineral which forms very fine-grained felted masses, with high birefringence and medium brown colour. Small amounts of prehnite also fill fractures in the plagioclase and minor amounts of sphene and apatite are present.

In another specimen, alteration of hornblende is still present but has another phase of alteration superimposed. The hornblende is completely altered and encloses anhedral grains of quartz and voids. The quartz and orthoclase con-

tents are each about 15 - 20%. Plagioclase, although still unaltered forms very irregular grains less than 2 mm in diameter. Quartz and orthoclase form fine-grained, somewhat intergrown aggregates which enclose the larger plagioclase grains. Orthoclase often replaces plagioclase and myrmekite forms around the edge of plagioclase grains. Fresh, unaltered biotite flakes are common, usually in contact with the altered hornblende (Plate 6). Strong fracturing is present with both alteration types but is accompanied by orthoclase and quartz veins with the biotite, quartz, orthoclase alteration.

In the biotite-rich gneisses near the surface and in the upper 50 feet of hole #1, alteration is not at all obvious. The plagioclase is slightly sausseritized. Biotite is unaltered and strongly aligned yet is in contact with primary sulphides and secondary oxides. Very small amounts of orthoclase can be seen replacing plagioclase and, in one quartz-rich rock specimen, fine grains of orthoclase are present along hairline fractures. The only possible alteration which could have occurred is the recrystallization or addition of biotite and the possible addition of small amounts of orthoclase.

The lower 20 feet of drill hole #1 contains sulphide veinlets as well as more typical disseminations. The plagioclase grains in the gneiss are completely altered to albite and sericite along small bands less than 2 cm wide usually (but not necessarily) around sulphide veinlets (Plate 7). Hornblende



Plate 6: Altered hornblende and
secondary biotite

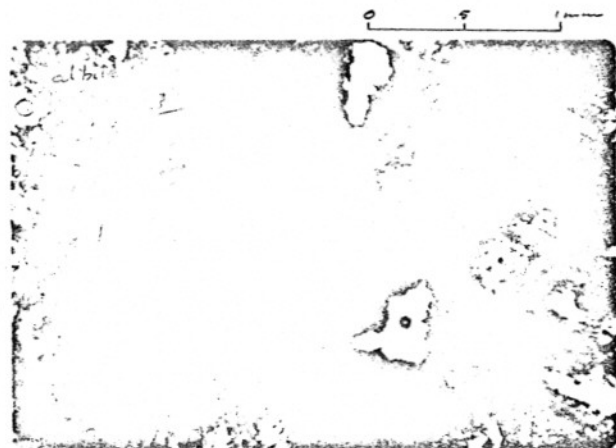


Plate 7: Sulphide veinlet bounded
by albitized zone

which is present in the gneisses in thin section is generally unaltered while the biotite is strongly altered to chlorite. One section contains unaltered and unoriented biotite although the plagioclase is still highly altered. Also an unidentified mineral (Plate 8) fills fractures and open spaces and often occurs with malachite. It is transparent with a slight greenish tinge in thin section and forms colloform layering. Relief is very low, extinction probably parallel, birefringence moderate with middle second order colours. It is possibly a zeolite with birefringence increased due to adsorption of copper in the crystal lattice (J.A. Gower, personal communication). Diorite cutting gneiss contains moderately saussuritized plagioclase and chlorite altered from biotite.

Zone #2

The discovery outcrop measures about 50 x 400 feet and forms a 10 foot bluff which trends N65W. The mineralized zone has been partially outlined by trenching and seems to be confined to a small area around the original outcrop. There are no nearby outcrops to give any additional indication of the extent of the zone. Only three rock samples were available, limiting the amount of petrographic work which could be done.

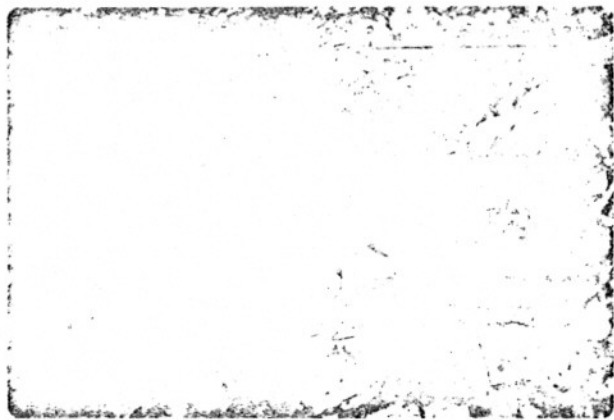


Plate 8: Unidentified fracture filling

Petrology

Zone #2 is considerably different in petrology, mineralogy and alteration from Zone #1. The country rock, although not examined in thin section, is similar in hand specimen to the granodiorite surrounding Zone #1 and has been given the field name granodiorite. Four other units were mapped. All units except the pegmatites have been hydrothermally altered and quite possibly all are altered equivalents of the surrounding granodiorite.

The most highly altered unit, classified as a porphyritic diorite forms the outcrop. The rock is locally foliated and varies considerably in mafic content. Abundant mafic minerals, mainly biotite and hornblende in approximately equal amounts form a matrix around coarse anhedral plagioclase grains. Small amounts of fine-grained quartz and orthoclase form interstitial aggregates between plagioclase phenocrysts and mafic minerals. Iron-rich epidote, which can be easily seen in outcrop as fracture fillings appears in thin section as isolated coarse grains usually in contact with biotite or hornblende. Apatite and sphene are abundant in smaller grains enclosed by or interstitial to hornblende and biotite.

There is evidence that some of the rocks in this unit have undergone two phases of hydrothermal alteration. In both specimens studied, biotite occasionally fills fractures cutting

plagioclase possibly indicating it is secondary. In only one specimen another more obvious phase of hydrothermal alteration has been superimposed (Plate 9). Biotite is partially altered to chlorite and plagioclase moderately to strongly altered to sericite. Coarse rosettes of white mica fill fractures and line cavities. Small amounts of a mineral tentatively identified as barite occurs as fine clusters of grains occupying cavities sometimes lined with white mica.

A short distance east of the porphyritic diorite outcrop are two small exposures of mineralized diorite which contain less mafic minerals and are finer grained. In outcrop, potash feldspar is abundant and epidote noticeable. Plagioclase forms large fractured grains which are essentially unaltered. Biotite which is the only mafic mineral, occurs as unaltered moderate sized grains interstitial to the feldspars. Fine-grained aggregates of quartz and small amounts of orthoclase occur in the interstices between the plagioclase and biotites. Orthoclase occasionally replaces plagioclase. Small amounts of coarse-grained epidote are also present, invariably in contact with red copper oxides (Plate 10).

Limonitic, strongly weathered rocks containing some potash feldspar are exposed in several areas surrounding the porphyritic diorite and diorite. No specimens were studied but this rock is possibly an equivalent of the granodiorite which has undergone a different type of hydrothermal alteration than the other



Plate 9: Sericitized porphyritic diorite



Plate 10: Diorite showing epidote, biotite and copper oxides

units. The altered units are usually bounded by sections of unaltered granodiorite or large coarse grained pegmatites containing potash feldspar, biotite and quartz.

Mineralogy

Most of the copper mineralization is confined to the porphyritic diorite unit. Chip channel sampling over the width and length of the showing gave consistently high copper assays with an arithmetic mean of 1.05% Cu. The only other mineralized area is on the east side of the mafic diorite in the two small exposures of diorite.

No chalcopyrite or bornite was seen in the mafic diorite but red oxides similar to those in Zone #1 are abundant. Malachite staining is abundant in hand specimen but not in thin section. Oxides form colloform interstitial fillings up to 1 or 2 mm across in the biotite- and hornblende-rich portions. Magnetite is abundant in the mafic sections but is not closely associated with the copper minerals. It commonly occurs as large euhedral grains up to 1 mm across. Small patches of hematite alteration form along the edges of the grains.

In the small area of diorite, primary chalcopyrite forms anhedral grains up to 1 mm in diameter. Much of the chalcopyrite is altered to oxides which form rims around grains and bands along fractures.

DISCUSSION

The mineralogy and mode of occurrence in the two zones are similar to those of a porphyry copper deposit. However, lack of intense hydrothermal alteration and the linear shape of the showings suggests some other mode of occurrence. A few tentative conclusions and speculation are as follows.

Control of mineralization, whether structural, and/or petrological, is one of the least known features of the property. Zone #2 may be related to an alteration zone while Zone #1 may be related to rock type. The linear shape of the two zones and strong fracturing in parts of Zone #1 hint at structural controls. Despite these differences the showings presumably are related in origin because of their proximity to one another, association with a common intrusive complex and similar mineralogy. Whether the intrusive complex merely acts as a host unit or contains an undetected igneous phase genetically associated with the mineralization is not known. A transition to an intrusive host rock to the north of Trench 12 in Zone #1 is indicated by the less mafic, more massive rocks in Trench 12. This possibility can only be proven with further exploration work, however.

Much more work is required to establish a pattern of hydrothermal alteration. Weathering effects and changes in rock type seem to be the main complicating factors. One

noticeable feature is the absence of strong alteration short distances away from the mineralized area in Zone #1, but the occurrence of relatively widespread peripheral alteration around the mineralized area of Zone #2. One possible explanation for this is that biotite-rich gneisses common to Zone #1 were more permeable than the surrounding intrusives and attracted the flow of hydrothermal solutions. Thus mineralization and hydrothermal effects were confined to the gneissic rocks.

The arid climate, lack of ^pleistocene glaciation and relatively high permeabilities of the biotite-rich rocks are favourable to leaching and supergene enrichment. However, the presence of remnant traces of primary sulphides at surface shows that leaching was not intense. The close association of primary sulphides, secondary chalcocite, copper oxides and carbonates indicates the environment is favourable to the weathering of sulphides but not to solution and transport. This is probably best explained by the absence of pyrite to produce the acids required for leaching. Pyrite is very noticeably absent from both showings and the country rocks.

CONCLUSIONS

(1) Mineral Zones #1 and #2 appear to be genetically related hydrothermal deposits with slightly different altera-

tion characteristics because of differences in host rock.

(2) Mineralization in Zone #2 is essentially confined to mafic diorite which may be an alteration product of the country rock.

(3) Mineralization in Zone #1 is confined to the mafic-rich gneisses which may be a roof pendant of Yukon Group rocks.

(4) The lack of pyrite in the mineral zones has prevented total leaching or formation of a significant supergene zone. It is probable that the copper grade of the oxidized capping will not vary greatly from deeper unoxidized material.

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APPENDIX

Polished and Thin Section Description

Specimens of similar rock type are grouped together. Polished specimens were made for most specimens. The mineralogy of those specimens without polished sections was determined by using reflected light on thin sections.

Specimen

GA-71-3

Location

Adjacent to Zone #1 in unmineralized rock

Hand Specimen

- fresh, coarse grained, equigranular leucocratic intrusive.

Thin Section

Mineral

Mode

- | | | |
|-------------|---|--------|
| Plagioclase | - large anhedral grains <5 mm
- slight normal zoning
- slight, patchy saussuritization, especially cores of grains
- oligoclase (An ₂₈) | 65% |
| Orthoclase | - large interstitial anhedral grains <5 mm
- poikilitically encloses anhedral quartz and plagioclase
- also occurs as small anhedral interstitial to plagioclase
- occasionally replaces plagioclase | 15-20% |
| Hornblende | - subhedral grains <3 mm
- strongly pleochroic | 5-10% |
| Biotite | - isolated anhedral flakes <2 mm
- strongly pleochroic | 1- 2% |

Accessories

- Apatite - occasional subhedral grain
- Sphene - occasional subhedral grain
- Epidote - occasional anhedral grain associated with hornblende

Alteration

Chlorite - incipient alteration of biotite
- forms narrow rims around biotite flakes

Texture - granitic

Rock Name - leucocratic granodiorite

SpecimenLocation

GA-71-1	Zone #1 near Trench 0+00N
GA-71-15	Zone #1 near Trench 0+00N
GA-71-8	Zone #1 DDH#1 - 12'
GA-71-11	Zone #1 DDH#1 - 62'
GA-71-12	Zone #1 DDH#2 - 8'
GA-71-14	Zone #1 DDH#2 - 25'

Hand Specimen

- medium to coarse-grained leucocratic intrusive

Thin SectionMineralMode

Plagioclase - coarse-grained subhedral grains < 5 mm - moderately zoned - oligoclase (An ₂₇) - moderately saussuritized (especially GA-71-11 & 14)	70%
Orthoclase - usually small anhedral grains 1 mm - associated with quartz or replacing plagioclase	5%
Quartz - medium to fine anhedral grains - common as intergrown mosaic	15-20%
Biotite - isolated flakes or small clusters	5%

Accessories

Apatite - occasional small anhedral grains

Sphene - occasional small anhedral grains

Alteration

- irregular and unpredictable
- Chlorite - incipient alteration of biotite in some specimens
- Epidote - occasional small clusters of anhedral grains in specimens containing altered biotite
- Sericite - associated with saussuritization
 - very fine-grained flakes in plagioclase
 - a few larger isolated flakes

Mineralogy

- GA-71-1 is only specimen to contain mineralization

- in this specimen the intrusive is only about 3 inches wide and bounded by biotite gneiss
- Chalcopyrite - anhedral grains <5 mm
 - roughly elongated parallel to foliation
- Bornite - uncommon
 - forms individual anhedral grains <.5 mm
 - sometimes contacts chalcopyrite
 - no exsolution lamellae of chalcopyrite
- Oxides - dull grey banded layers surrounding chalcopyrite or bornite

Texture - granitic

Rock Name - leucocratic quartz diorite

SpecimenLocation

GA-71-2 Zone #1 mineralized outcrop near Trench 0+00N
 GA-71-4 Zone #1 mineralized outcrop near Trench 0+00N
 GA-71-9 Zone #1 DDH#1 - 23'
 GA-71-10 Zone #1 DDH#1 - 55'
 GA-71-23 Zone #1 DDH#1 - 52'

Hand Specimen

- medium grained mafic-rich biotite gneiss
- subordinate coarse grained leucocratic, quartz-rich layers

Thin SectionMineralMode

- Plagioclase - anhedral grains, variable size, <1 mm 55-65%
 in biotite-rich layers, <5 mm in
 leucocratic layers
 - slight saussuritization and normal
 zoning
 - somewhat irregularly fractured
 - oligoclase (An₂₇)
- Orthoclase - small anhedral grains <.5 mm 5%
 - replacing plagioclase
 - locally abundant in some leucocratic,
 quartz-rich layers (GA-71-10) as larger
 anhedral grains
- Quartz - variable size and abundance
 - forms anhedral grains and intergrown
 mosaics when abundant
 - <1 mm in biotite-rich layers
 - <2 mm in leucocratic layers
 - grains roughly elongate parallel to foliation
 - slightly fractured
- Biotite - elongate flakes <3 mm 10-50%
 - strongly aligned
 - commonly forms zig-zag patterns
 - strongly pleochroic
 - distinct boundary between biotite-rich
 and biotite-poor layers
 - a few minor dislocations along foliation
 planes

Accessories

Sphene - occasional small anhedral grain .5 mm
 Apatite - occasional small anhedral grain .5 mm

Alteration

- little obvious alteration
- possibly addition of biotite and small amounts of orthoclase

Mineralography

Chalcopyrite - anhedral grains < 2 mm
- roughly elongated parallel to foliation
- forms abundant exsolution lamellae in bornite

Bornite - not present in surface specimens
- usually forms irregular patches in grains of chalcopyrite
- always in contact with chalcopyrite
- ratio of chalcopyrite to bornite

Chalcocite - present only in below surface specimens
- secondary after bornite and chalcopyrite
- forms narrow rims around grains and along fractures

Malachite - fine-grained felted masses interlayered with colloform oxides and biotite flakes

Oxides - colloform layers and massive grains in interstices
- either surrounding sulphides or with an open core
- < 3 mm across but commonly elongated parallel to foliation
- poor polish, low reflectivity, often bright red internal reflection isotropic, hardness
- in thin section - bright red, orange or yellow

Hematite - 1. primary - very small blades .1 mm in radiating clusters in close contact and often intergrown with chalcopyrite and bornite
2. secondary - irregular masses and colloform layers
- have all the properties of hematite in polished section but a high copper content indicated by the electron probe

Molybdenite - one very small blade identified in polished section (GA-71-23)

Texture - gneissic

Rock Name - biotite-feldspar-quartz gneiss

SpecimenLocation

GA-71-24
 GA-71-25
 GA-71-26

DDH#1-59
 DDH#1-64
 DDH#1-74.5

Hand Specimen

- medium to fine-grained gneiss
- patchy alteration, feldspars milky white, soft
- small veinlets of chalcopyrite occasionally occur with alteration
- red oxides abundant in veinlets and small irregular masses

Thin SectionMineralMode

Plagioclase - anhedral grains <.5 mm		60%
- slightly elongated parallel to foliation		
- slight normal zoning		
- oligoclase (An ₂₅)		
- grains commonly fractured		
Orthoclase - rare small anhedral grain		1%
Biotite - isolated flakes and clusters	unalbitized	
- distinctly aligned but not as strongly as in most biotite gneiss	zones	35%
- strongly pleochroic	albitized	10%
- in albitized zones flakes have frayed appearance and irregular edges	zones	
Hornblende - irregular anhedral grains	unalbitized	
1 mm	zones	5%
- strongly pleochroic	albitized	
- usually isolated grains but occasional band of almost pure hornblende <2 mm wide (GA-71-25)	zones	25%

Accessories

Apatite - relatively abundant small anhedral grains
 Sphene - relatively abundant small anhedral grains

Alteration

Albite - alteration of oligoclase

- composition gradational from An_0 in most intensely altered areas to unaltered oligoclase (An_{24})
- patchy areas in drill core usually less than a few cm wide

Sericite - alteration of plagioclase
 - very fine flakes and rosettes throughout grains of albite

Chlorite - incipient alteration of biotite in albitized zones

Clay(?) - in most intensely albitized areas
 - white almost amorphous material forms patchy alteration of plagioclase

Unknown - transparent with pale greenish tinge
 - colloform layers and granular aggregate along fractures
 - very low negative relief
 - moderate to high birefringence
 - extremely fine grains
 - possibly length fast

Mineralography

Chalcopyrite - small veinlets < 2 mm wide, granular aggregates

Bornite - small patches in grains of chalcopyrite
 - contains exsolution laths of chalcopyrite

Chalcocite - secondary after chalcopyrite and bornite
 - thin rims around grains of bornite and chalcopyrite and along fractures

Oxides - typical colloform masses surrounding sulphide grains

Malachite - mainly fracture fillings

Texture

- individual minerals not always strongly aligned but changes in concentration of mafics and plagioclase produces banding
- small fractures abundant parallel sulphide veinlets near contact
- a few narrow crushed zones cut across foliation but relationship to sulphides not seen

Rock Name - biotite hornblende gneiss

SpecimenLocation

GA-71-17

Zone #1 Trench 12

Hand Specimen

- medium grained leucocratic granular gneiss
- strongly fractured at angles to foliation
- prominent malachite and "limonite" staining

Thin SectionMineralMode

Plagioclase - anhedral grains < 3 mm - strongly fractured - oligoclase (An ₂₅)	65%
Orthoclase - occasional small anhedral grains	5%
Quartz - occasional small anhedral grains	5%
Hornblende - anhedral grains < 2 mm - strongly pleochroic	20%

Accessories

- Apatite - commonly small subhedral grains
- Sphene - commonly small subhedral grains

Alteration

- Prehnite - small amounts along fractures in plagioclase
- acicular clusters
- Unknown - alteration of hornblende
- extremely fine-grained masses along cleavage
of hornblende
- brown colour
- moderate birefringence
- probably parallel extinction

Mineralogy

- Malachite - abundant in fractures and open spaces
- Azurite - common in fractures
- Oxides - red and pale brown copper oxides fill
fractures and voids
- associated with malachite

Texture - equigranular, gneissic texture defined by
elongation and alignment of mineral grains

Rock Name - hornblende diorite gneiss

Specimen

GA-71-16

Location

Zone #1 Trench 12

Hand Specimen

- medium grained, leucocratic granular gneiss
- strongly fractured in one direction roughly perpendicular to foliation

Thin SectionMineralMode

- Plagioclase - irregular anhedral grains <.5-2 mm
 - slight saussuritization
 - oligoclase (An₂₃)

40%

Accessories

- Apalite - isolated anhedral grains <.5 mm
 Sphene - isolated anhedral grains <.5 mm

Alteration

- Orthoclase - irregular anhedral grains <.5 mm
 - replaces plagioclase along grain boundaries
 - present with quartz as very fine grains filling fractures

15-20%

- Quartz - irregular anhedral grains <.5 mm
 - closely associated with orthoclase
 - also poikilitically enclosed in relict hornblende grains

15-20%

- Unknown - alteration of hornblende, identical to that described in section GA-71-16
 - hornblende completely altered
 - skeletal structure created by relict cleavage of hornblende and presence of voids and enclosed quartz grains

10%

- Biotite - flakes < 2 mm, usually aligned parallel to foliation
 - usually in contact with altered hornblende

10%

Mineralogy

- Malachite - abundant along fractures in coarse needles and fine-grained masses

Azurite - common fracture filling

Oxides - occasional red or brown grain

Texture - gneissic texture poorly defined, mainly by large plagioclase grains, biotite and relict hornblende grains

Rock Name - altered hornblende diorite gneiss

Specimen

GA-71-5

Location

Zone #2 0+00S, 110E

Hand Specimen

- medium grained granular leucocratic intrusive
- weak malachite staining

Thin SectionMineralMode

Plagioclase - subhedral grains 1-3 mm - slightly zoned - noticeably un-aussuritized but often cracked and stained - oligoclase (An ₂₆)	70%
Orthoclase - occasional very small anhedral grain	5%
Quartz - small grains < .5 mm forming interlocking mosaics interstitial to plagioclase grains	5%
Biotite - abundant anhedral flakes - strongly pleochroic	15%

Accessories

- Apatite - common small subhedral grains
- Sphene - common small subhedral grains

Alteration

- Chlorite - occasional incipient alteration of biotite
- Epidote - anhedral aggregates < 1 mm
- always associated with sulphides or oxide alteration

Mineralogy

- Chalcopyrite - anhedral grains < 1 mm
- Oxides - typical red colloform material surrounding sulphides

Texture - medium grained, equigranularRock Name - diorite

SpecimenLocation

GA-71-6

Zone #2 Main Outcrop

GA-71-7

Zone #2 Main Outcrop

Hand Specimen

- coarse grained, mafic-rich porphyritic intrusive
- mafic concentrations variable, locally foliated

Thin SectionMineralMode

Plagioclase - large subhedral, fractured phenocrysts < 4 mm	60%
- lesser amounts of fine interstitial grains	
- oligoclase (An ₂₆)	
Orthoclase - a few small grains < .5 mm	1%
- interstitial to fine plagioclase grains	
Quartz - fine-grained < .5 mm	1%
Hornblende - anhedral grains < 2 mm	15%
- strongly pleochroic	
Biotite - anhedral flakes < 2 mm forming aggregates with hornblende	15%
- possibly secondary, because fills small fractures cutting plagioclase grains	
Epidote - iron-rich, abundant anhedral grains < 1 mm	2%
- usually associated with hornblende and biotite	

Alteration (Specimen GA-71-6 only)

Chlorite - partial alteration of biotite

Sericite - moderate to strong alteration of plagioclase

- coarse rosettes of white mica fill fractures and line cavities

Unknown - (barite?) - occasional small, fine, colourless grains or clusters of grains completely or partially filling cavities

- sometimes surrounded by a narrow rim of white mica

- crystals are elongate
- biaxial positive, $2V \sim 30^\circ - 40^\circ$
- at least two cleavages at 90°
- fairly high relief
- low birefringence, first order greys
- extinction parallel to best cleavage
- slow ray parallel to best cleavage

Mineralography

Magnetite - abundant subhedral grains < 2 mm
 - not closely associated with copper minerals

Hematite - after magnetite
 - small patches around edges of magnetite grains

Oxides - abundant
 - typical colloform material

Malachite - Specimen GA-71-6 - very fine-grained
 felted masses filling cavities
 - Specimen GA-71-7 - trace amounts along
 biotite cleavage

Texture - coarse grained porphyritic

Rock Name - porphyritic diorite