



Vancouver Petrographics Ltd.

JAMES VINNELL, Manager
JOHN G. PAYNE, Ph. D. Geologist

P.O. BOX 39
8887 NASH STREET
FORT LANGLEY, B.C.
VOX 1J0

PHONE (604) 888-1323

Report for: Ragnar Bruaset,
Chevron Standard Ltd.
901 Marine Building,
355 Burrard Street,
Vancouver, B.C.
V6C 2G8

Invoice 3661

842049

December 9, 1982

Samples: 21 rocks from project M-518 (Cataract)

Summary

The rocks are grouped into the following types:

1) Tuffaceous quartz breccia.

These are pyroclastic rocks consisting of angular fragments of quartz, quartzite and quartz-mica schist and more rounded fragments of volcanic rocks (andesites and dacites) which are set in a fine grained feldspathic or siliceous matrix. The fragments make up almost half of the rock. The matrix consists of varying proportions of feldspars, quartz, sericite and biotite. Garnets may be present. Most of these, associated with biotite have grown in situ ie. these rocks have been thermally metamorphosed. Those samples with a dominantly siliceous or micaceous matrix are probably sedimentary breccias with a volcanic component.

Samples: 1212C, 12170, RB8218, RB8208, RB8219, TL8202, RB8213, TL8233, TL8208.

2) Tuff

These consist mainly of fine grained feldspars with a chert component. Small quartz and/or plagioclase phenocrysts are present. Quartz and volcanic fragments occur. They range in composition from andesite to rhyolite.

Samples: RB82118, RB8205, RB8202, TL8238

3) Volcanic conglomerate

The sample consists of rounded fragments of andesite in a glassy/andesitic matrix. The fragments make up a significant part of the rock. Tourmaline is a late forming mineral - due to proximity of an intrusion??

Sample: RB82126

4) Porphyritic andesite

These consist of plagioclase and quartz phenocrysts in a fine grained plagioclase matrix. Biotite is disseminated through the matrix. Sample TL8244 has been feldspathised and is cut by thin veinlets of pyrrhotite.

Samples: TL8244, RB82123, RB82124

5) Rhyolite

These are very fine grained, banded flow rocks rich in K-spar and quartz. Small plagioclase phenocrysts are present.

Samples: RB82122B, RB82116

(continued)

Summary (cont.)

6) Exotic rocks

Sample TL8245 is a quartz-magnetite-amphibole rock, possibly from a vein or perhaps a cumulate?

Sample TL8295 is a garnet peridotite. Tourmaline is a minor mineral and is late forming.

Alteration, mineralization and metamorphism.

Some sulphide (particularly sphalerite) mineralization occurs in quartz and schist fragments in the breccias and has been dispersed into the matrix during breakdown of the fragments. Other sulphide mineralization is disseminated through the breccia or occurs in fractures. Here it is associated with late epidote-chlorite-K-spar alteration. Disseminated sulphide mineralization is associated with thermal metamorphism in some cases. Garnets and biotite have grown in spots within the matrix or around some of the fragments. Some breccias contain garnets derived from the metamorphic basement - these are cloudy and are being altered. These samples contain the sulphide-quartz fragments.

The sulphide-quartz mineralisation could be associated with the source magma at depth and fragments have been caught up in the volcanic rocks. As the magma rose into the overlying volcanic pile thermal metamorphism and the same mineralising fluids have affected the breccias. *It perhaps the sulphides were redistributed during metamorphism.*

A. L. Littlejohn
A.L. Littlejohn, M.Sc.

1217C Tuffaceous quartz breccia - metamorphosed

This rock is crowded with small fragments of quartz, quartzitic metasediments and volcanic rocks in a fine grained matrix consisting mainly of K-spar, biotite. The rock has been metamorphosed and small garnets are scattered through the groundmass. Minerals are:

biotite	19%
K-spar	12
quartz	5
garnet	7
green biotite	4
opaque	2 - mainly sulphide
epidote	1
Fragments	
quartz	22
quartzite	8
dacite +	
andesite	16
schist	3

Quartz fragments are angular and range in size from 0.05mm to 0.5mm, averaging about 0.3mm. A few rounded grains about 0.1mm in size have a rim of secondary quartz and appear to be from a sedimentary environment. The angular fragments are often strained and are probably from a metamorphic environment.

Quartzite are composed of rounded interlocking grains of quartz about 0.05mm in size. A few fragments have slightly coarser or finer grain size. Fragments are usually less than 1.0mm in size and tend to be rounded. They grade into quartz-mica schist in which thin streaks of biotite form along the foliation between the quartz grains. These fragments tend to be larger than the quartzites.

Volcanic fragments are usually less than 0.8mm in size and are ovoid or rounded in shape. They are composed of fine grained interlocking plagioclase grains with or without quartz. They have been altered during metamorphism and have acted as nuclei in the formation of garnet and biotite.

Much of the quartz in the groundmass is from the breakdown of the fragments but there are one or two patches where the quartz forms a fine grained intergrowth with the biotite and K-spar. Most of the groundmass consists of very fine grained K-spar with fine grained biotite disseminated through it. The biotite occurs in streaky patches around the fragments and small patches penetrate into them. Some fragments are partly replaced by biotite. Some biotite patches contain rounded garnets about 0.1mm in size. Smaller garnets are scattered about the groundmass. In places the small garnets form a "necklace" around a biotite patch or a fragment. Some garnets occur in the volcanic fragments.

Large garnets up to 1mm in size occur elsewhere in the rock. They have formed from the aggregation of smaller one. Relatively coarse grained biotite, about 0.05mm in size, occurs around the larger garnets. There is one large garnet, about 2mm in size, which is fractured and is a slightly different colour and partly altered along the fractures. This is probably a xenocryst.

Epidote occurs in small prismatic grains in some biotite patches and volcanic fragments.

Opaque minerals (probably sulphides) form subcubic grains about 0.05mm in size which are scattered around the groundmass and concentrated in and around the biotite patches.

This is a mainly sedimentary breccia with a volcanic component consisting of angular fragments of quartz and metasediments in a quartz-mica-plagioclase matrix. The metasediments are mineralised with pyrite and sphalerite and contain garnets. These minerals are scattered about the matrix. Minerals are:

quartz	11%	
plagioclase	18	
biotite	14	
sericite	5	
garnet	4	
opaque	4	- mainly pyrite and sphalerite
zircon	trace	
fragments		
quartz	20	
quartzite	3	
schist	14	
quartz + sulphide	6	
dacite	1	

Fragments are mainly angular quartz grains from 0.1 to 1.0mm in size, averaging about 0.4mm. They are often strained, indicating derivation from a metamorphic environment. A few rounded quartz grains with quartz overgrowths are probably from a sedimentary environment.

Quartzite are subrounded and tend to be slightly larger than the quartz grains. They are composed of rounded interlocking grains about 0.08mm in size.

There are few volcanic fragments and these are relatively small and consist of fine grained, shapeless plagioclase grains with or without quartz.

The quartz-sulphide fragments consist of large shapeless interlocking quartz and pyrite grains. Chlorite flakes may surround the sulphide. The schist fragments consist of layers of greenish biotite and layers of quartz, garnet and sphalerite. Pyrite occurs intergrown with the pyrite which may also occur in the biotite layers. There is greenish chlorite flakes around the sulphides and intergrown with the garnet and quartz. Fragments are variable in size ranging from a single grain to angular fragments several millimetres in size. Aggregates of sulphide and chlorite are common and these grade into the sulphide-quartz aggregates. The sulphide and garnet grains scattered about the matrix are derived from these fragments. Some schistose fragments contain muscovite.

The groundmass consists of very fine grained plagioclase and quartz with diffuse patches of sericite. Much of the quartz is probably derived from the breakdown of the fragments. Biotite is fine grained and occurs in small rounded patches within the quartz-plagioclase-sericite matrix. It may be concentrated around and partly within the fragments. It is probably metamorphic biotite since it replaces patches of the chlorite around the sulphides. The garnet is not metamorphic but it very cloudy and is altering to an unknown mineral. The garnets in the groundmass are more altered than those in the schist fragments. Many very small rounded, cubic and shapeless opaque grains are disseminated through the groundmass; some of these may be hematite and whether all have been derived from the breakdown of the fragments is not known.

The yellow stain on the offcut block appears to be due to absorption of the stain; no K-spar was recognised in the section.

RB8223 Metasediment, quartz breccia - feldspathised and metamorphosed??

This is a breccia containing large fragments of quartz-mica schist and quartz aggregates set in a fine grained matrix consisting of sericite, K-spar and biotite. The schist fragments have been feldspathised. Minerals are:

K-spar	16%
sericite	10
biotite	6
quartz	6
epidote	2
garnet	minor
opaque	minor
fragments	
schist	45
quartz	13
mudstone	2
volcanic	minor

Fragments are dominated by quartz mica schist; almost half of the section consists of one large schist fragments. It consists of slightly flattened quartz grains about 0.2mm in size with streaky lenses of biotite between the quartz. Fine grained K-spar has penetrated along the foliation and replaced the edges of the quartz grains and is mixed with the biotite which becomes very fine grained. Scattered garnets occur in the K-spar-biotite patches. Very fine grained opaque grains occur in the biotite flakes. Smaller rounded fragments of schist occur. Some of these are biotite rich and may also contain garnets. Some of the small fragments have been highly feldspathised. Ragged patches of fine grained epidote occurs in the fragments, often within the feldspathic parts and sometimes occurring at the edge of biotite patches. A few grains of apatite occur in some fragments. A few very small quartzite fragments are also present.

Mudstone (phyllite) fragments consist of extremely fine grained sericite and quartz and they are finely foliated. They generally have a rectangular outline and may be up to 1.5mm in size. Small rounded or streaky patches of K-spar and rounded patches of biotite occur in some. Sometimes these are associated with epidote which also forms around the edges of the fragment. Ragged opaque grains occur in places in these.

Several small angular fragments of quartz occur but most of the quartz fragments consist of large subrounded aggregates up to 5mm in size which are made up of large shapeles interlocking quartz grains which are slightly strained. One large aggregate is intergrown with a lath of altered plagioclase about 2mm in size. It is altered to a fine grained mixture of sericite, bright green biotite and K-spar. The K-spar occurs on the rim. Only a few remnant patches of plagioclase are left. Several small lath-like patches of K-spar occur in other fragments. The quartz fragments appear to be derived from a pegmatitic igneous source. Two rounded garnets occur in the altered plagioclase.

The matrix consists of shapeles interlocking K-spar grains with streaks and patches of very fine grained sericite sometimes mixed with bright green biotite. Small quartz fragments are scattered through this mixture and patches of fine grained quartz also occur. A few small volcanic fragments grade into the groundmass. Small prismatic epidote grains and aggregates cluster around some of the fragments within the K-spar matrix. A few garnet grains occur in the matrix. These could be metamorphic garnets (two occur in altered plagioclase) or derived from the breakdown of the schist fragments. Some garnets have grown around the mudstone fragments.

This rock is probably a rhyolitic breccia and the K-spar has reacted with the enclosed fragments.

RB82131 Cherty, rhyolitic quartz breccia - metamorphosed

This is a silica rich rock consisting of many fragments of coarse, strained quartz in a fine grained matrix consisting of cherty quartz mixed with very fine grained K-spar and sericite. Garnets occur in the matrix. Sulphides are common. Minerals are:

quartz fragments	29%
plagioclase fragments	8
cherty quartz	20
K-spar	17
sericite	12
opaque	9
garnet	5

Quartz fragments are highly variable in size and shape. Some are rounded and tend to be smaller than those with an irregular shape with many concave edges. These may be several millimetres in size. The quartz is coarse grained and highly strained, indicating a metamorphic origin. It is similar to the quartz in the other quartz-breccias in this suite of samples. Some fragments are composed of interlocking subidiomorphic grains, perhaps from a vein environment.

Plagioclase fragments are lathshaped and average about 0.6mm in size. Many of them have been partially or completely replaced by an aggregate of rounded quartz grains about 0.1mm in size.

The groundmass consists of a mixture of extremely fine grained K-spar and sericite with patches and stringers of cherty quartz. Often the quartz forms a rim on the quartz fragments. The K-spar and sericite tend to wrap around the fragments and also form in a network of vein-like patches within the silicified plagioclase and to some extent in the quartz fragments. There are many rounded grains of quartz within the groundmass.

Garnet forms rounded grains about 0.05mm in size within the groundmass. They often have a small core of an opaque mineral. This could be the same mineral which forms ragged grains about 0.005mm in size which is also disseminated within the groundmass. It is possibly hematite or a very fine grained sulphide.

The sulphides (pyrite + minor sphalerite) form subcubic grains about 0.1mm in size which occur within the matrix or the feldspathised parts of the quartz fragments. Many of them are partially oxidised to hematite. A few aggregates are intergrown with garnet.

TL8232 Quartz breccia - metamorphosed

This is a sedimentary breccia consisting of angular to rounded fragments of quartz and quartzitic (meta)sedimentary rocks with minor volcanics, set in a fine grained sericitic matrix. Patches of biotite and garnet in the matrix indicate a fairly high degree of metamorphism. Minerals are:

sericite	24%
biotite	16
garnet	5
opaques	4 - mainly sulphides including sphalerite
quartz	3
muscovite	1
chlorite	1
fragments	
angular quartz	20
round quartz	6
quartzite	16
dacite	4

There are two kinds of quartz fragments. The commonest consist of angular fragments from 0.1 to 2.0mm in size, averaging about 0.3mm, which are strained and may be composed of several fairly coarse grains. These are derived from a metamorphic environment. The second type consist of rounded grains about 0.2mm in size which have a narrow rim of secondary quartz around them. These are derived from a sedimentary environment.

Quartzite fragments may be up to 4mm in size and consist of a mosaic of interlocking grains about 0.1mm in size. Some are slightly coarser or finer and may have phyllitic layers within them; others are composed mainly of phyllitic material.

Volcanic fragments average about 0.2mm in size and are composed of fine grains, feathery plagioclase with minor quartz.

The groundmass consists mainly of sericite and biotite. The biotite occurs in rounded to ovoid patches about 0.2mm in size within the fine grained sericite. Grain size is about 0.01mm. The biotite patches may contain garnets which form hexagonal grains 0.1mm in size.

Garnets also occur within the sericite. Most of them are cloudy with fine grained dark material. Some of the garnets contain small inclusions of an opaque mineral in the core of the grain. Some garnets have grown in the volcanic and sedimentary fragments. At the edge of the section adjacent to a thin limonitic fracture some of garnets have altered to a dirty yellow clay-like material. A light dirty brown mineral with low birefringence occurs in patches around some of the garnets. This is probably the mineral which is causing the cloudiness in the garnets throughout the rock. It stains yellow but is not K-spar. Small specks of yellow stain are present throughout the rock, perhaps due to absorption of the K-stain by the altered garnets.

Sphalerite is dark red in colour and forms ragged grains up to 2mm in size, usually much less, which occur within the biotite patches. They are usually partly surrounded by ragged aggregates and grains of an opaque mineral which also occurs in some biotite patches without sphalerite. Where garnet is present the sphalerite and/or opaque form around the garnet. Chlorite, sometimes intergrown with muscovite occurs around some of the opaque patches. One large opaque grain in the matrix has a partial rim of garnet. Small opaque grains about 0.002mm in size are disseminated through the matrix. This could be hematite.

This is a sedimentary breccia which consists of large angular fragments of quartz-mica schist, siltstone, quartzite and smaller angular fragments of metamorphic quartz. The fragments are crowded within a sericitic matrix with vein-like patches of garnet, chlorite and sphalerite. Minerals are:

fragments		
quartz-mica schist	28%	
quartz	17	
siltstone	18	
quartzite	7	
matrix and vein		
sericite	10	
quartz	7	
chlorite	6	
garnet	2	
opaque	2	- mainly sulphides including sphalerite
biotite	3	
K-spar	minor	
muscovite	minor	

The dominant fragments are large angular pieces of quartz-mica schist. These may be over 1.5cm in size. They consist of slightly flattened quartz grains about 0.1mm in size with biotite and muscovite along the foliation. Some of them are finer grained and may be dominantly micaceous (phyllites). They grade into the quartzites in which micas are lacking or very minor. The quartz in these tends to be more rounded.

Siltstone fragments are generally much smaller than the quartzitic fragments; maximum size is about 2mm. They are ovoid in shape with a few smaller rounded ones. They are composed of extremely fine grained sericite with some quartz and are finely foliated. Small patches of biotite are a result of later metamorphism. A few of them contain small garnets, also due to later metamorphism. These may be associated with ragged patches of chlorite at the edges of the fragment. Small ragged grains of an opaque (hematite?) occur along the foliation. The schists are not so affected by metamorphism although the biotite may have been recrystallised.

Quartz fragments are angular and range in size from 0.1 to 1.0mm. Some of the larger ones are composed of a few highly strained grains. They are derived from a metamorphic environment.

The matrix is composed of very fine grained sericite mixed with rounded quartz. Streaky patches of biotite wrap around the fragments. Many small quartzitic and silty fragments occur within the groundmass and it is often difficult to separate the groundmass from the silty material since later chloritisation has affected both.

Chlorite occurs in ragged patches between the fragments and replaces the edges of silty fragments. It is associated with garnets which form rounded grains and aggregates in the centre of the chlorite patches. Ragged sphalerite grains and other sulphides are intergrown with the chlorite and often form around the garnets.

Garnets and chlorite occur in a vein intergrown with quartz, K-spar, muscovite and sulphides.

RB8219 Quartz breccia (tuffaceous?) - metamorphosed

This rock consists of angular fragments of quartz and siliceous (meta)sediments in a matrix of fine grained quartz, muscovite (and sericite), biotite and garnets. The groundmass has been metamorphosed. Patches of K-spar also occur. Minerals are:

quartz	14%	
biotite	16	
K-spar	8	
muscovite -		
sericite	6	
garnet	6	
epidote	1	
opaques	2	- mainly sulphides
zircon	trace	
apatite	trace	
fragments		
quartz	36	
quartzite	8	
phyllite	3	
volcanic	minor	

Quartz fragments are highly angular and range in size from 0.05 to 5.0mm in size. Many of the larger ones are aggregates of a few grains. They are highly strained suggesting that they are derived from a metamorphic environment. A few of the more rounded, smaller fragments have a quartz overgrowth, perhaps from a sedimentary environment. Rock fragments are mainly siliceous metasediments ranging from quartzite to phyllite. The quartzites consist of rounded quartz grains about 0.1mm in size; the phyllites consist of fine grained sericite and quartz. There are some fragments intermediate between the quartzites and the phyllites (quartz-mica schist). A few small volcanic fragments consisting of fine grained interlocking plagioclase also occur. The rock fragments tend to be rounded and range in size from 0.3 to 1.0mm.

The groundmass consists of extremely fine grained quartz with reddish brown biotite disseminated between the quartz grains; small rounded quartz fragments are mixed in with this mixture. Small zircons and apatites are scattered around the groundmass. The other minerals occur in patches within the quartz-biotite. The biotite is also concentrated in patches, often within a rock fragment and some patches may be completely altered fragments.

Sericite occurs in diffuse patches and is associated with fine grained K-spar which replaces the quartzitic groundmass. It is not mixed with the biotite.

Muscovite occurs in rounded patches about 0.5mm in size associated with K-spar. A bright green biotite is often intergrown with the muscovite. These patches appear to have nucleated around small quartzites or quartz-mica schists. Fine grained prismatic epidote grains occur in the feldspar and quartz within the micaceous patches. Many of these patches have a partial rim of small rounded garnets. A few of the larger ones have garnets in the core. Garnets ranging in size from 0.01 to 0.2mm are scattered around the groundmass.

Two large garnets about 0.5mm in size appear to be different from the smaller ones. These are cracked and altered and have an overgrowth of the more normal garnet. These are probably xenocrysts.

Opaque minerals are mainly sulphides (including sphalerite). They form ragged subrounded grains up to 0.2mm in size, but usually much less, which are scattered about the groundmass. One grain has a rim of garnets. The sphalerite tends to occur within the muscovite patches. Very small disseminated grains in the biotite patches and micaceous metasediments are probably hematite.

TL8208 Tuffaceous(latite) quartz breccia - metamorphosed.

This rock consists of subangular to subrounded fragments of quartz and a few andesitic fragments in a matrix of plagioclase and K-spar with disseminated biotite and scattered garnets. Minerals are:

plagioclase	22%
biotite	27
K-spar	19
garnet	3
epidote	3
opaque	3 - mainly sulphide
apatite	trace
fragments	
quartz	14
quartzite	3
dacite	4
andesite	2

Quartz fragments are subrounded to subangular and range in size from 0.2 to 4.0mm. Most of them are aggregates of a few strained, interlocking, shapeless grains; they are probably from a metamorphic environment. They have been rounded by the action of the enclosing material. Andesite and dacite fragments are about 1mm in size and are rounded. They consist of a mass of fine interlocking plagioclase laths with, in the case of dacite, quartz. A few quartzitic metasediments also occur consisting of small rounded quartz grains; some have interstitial biotite.

The groundmass consists of ragged plagioclase laths about 0.1mm in size with interstitial biotite forming very fine grains. The biotite may occur in patches, often around the volcanic fragments. K-spar also occurs as fine interstitial grains between the plagioclase laths. It occurs in patches in the groundmass and may penetrate the quartz and volcanic fragments along grain boundaries. Two thin veinlets about 0.04mm in width cut the rock; these contain K-spar.

Small subidiomorphic apatite grains are scattered through the groundmass.

Garnet forms rounded grains about 0.1mm in size which occur scattered around the groundmass. It is sometimes concentrated in biotite patches.

Epidote forms very small grains which occur in ragged patches at the edges of the volcanic fragments and sometimes in the quartz fragments. It also occurs in some of the biotite patches where it is slightly coarser.

Opaque minerals (sulphides?) form cubic grains 0.01 to 0.05mm in size disseminated in the groundmass. It often clusters around the garnets, particularly where associated with biotite.

RB8218 Tuffaceous quartz breccia - metamorphosed

This rock consists of angular fragments of quartz and rounded fragments of quartzite, quartz-mica schist and andesite crowded in a tuffaceous matrix which has been metamorphosed to a fine grained mixture of sericite, plagioclase and biotite with scattered garnets. Minerals are:

sericite	12%
plagioclase	17
garnet	5
biotite	9
muscovite	3
chlorite	1
opaque	1
zircon	trace; apatite trace
fragments	
quartz	24
schist	6
andesite	5
quartzite	17

Quartz fragments are angular and range in size from 0.05 to 0.5mm in size with a few which are several millimetres in size. The quartzites are generally more rounded and consist of a variety of types, ranging from a few medium-grained interlocking grains to finer grained fragments. Size varies from 0.1 to 1.0mm. Many of these may be smaller pieces of quartz-mica schist which consist of rounded quartz grains with interstitial biotite and muscovite. In some of the fragments there is a remnant foliation. Some fragments consist almost entirely of micas, particularly muscovite. Chlorite occurs between the muscovite flakes. These minerals have been formed during metamorphism, the original interstitial minerals between the quartz grains in these fragments having been recrystallised. Quartzitic and quartz-mica schist fragments vary in size up to 2.5mm; larger fragments are present in the hand specimen.

Volcanic fragments consist of shapeless interlocking plagioclase grains about 0.05mm in size. There is some variation in grain size between the fragments. Some of them contain interstitial sericite. They are generally rounded in shape and vary in size from small patches which grade into the groundmass to pieces 2mm in size.

The groundmass consists of a mixture of extremely fine grained sericite and plagioclase. Scattered flakes of muscovite occur within the groundmass but most of the muscovite in the rock occurs in quartzitic fragments or has nucleated around these. Around many of these there is a narrow corona of sericite-free groundmass.

Biotite forms fine flakes about 0.01mm in size which occur in rounded patches about 0.5mm in size within the sericite-plagioclase matrix. Smaller diffuse patches occur throughout the matrix and around quartz grains. It is sometimes intergrown with muscovite in the micaceous fragments and in the matrix.

Garnet forms rounded to idiomorphic grains from 0.01 to 0.1mm in size, averaging about 0.06mm. The smaller ones are disseminated through the groundmass. The larger ones are associated with the biotite. They occur in the core of the biotite patches and cluster around them. Some patches have a discontinuous rim of small garnets. In rare cases a quartz aggregate has a rim of garnets. A few garnets occur in fragments.

Scattered zircon and apatite grains up to 0.1mm in size occur within the sericite-plagioclase groundmass. The apatite is full of small inclusions of an unknown mineral.

Opaque minerals (sulphides?) form subcubic grains up to 0.2mm in size which occur within the matrix and fragments, usually the former. Smaller ragged shapeless opaques are disseminated within the rock. These are probably hematite. Traces of reddish sphalerite occur in quartzitic fragments. One grain of sphalerite about 0.3mm in size is surrounded by chlorite with garnets clustering around the chlorite.

The rock consists of plagioclase phenocrysts set in a fine grained feldspathic matrix. Biotite alteration(metamorphism?) is pervasive,affecting both groundmass and phenocrysts. Thin pyrrhotite veinlets associated with quartz and chlorite cut the rock. Minerals are:

K-spar	20%
plagioclase	
phenocrysts	23
plagioclase	
groundmass	21
biotite	10
quartz	16
chlorite	5
opaques	2 - mainly pyrrhotite
rutile	1
epidote	1
apatite	1
sphene	minor
fragments	
volcanic	minor
quartzitic	minor

Plagioclase phenocrysts form subidiomorphic rounded laths ranging in size from 0.3 to 1.5mm, averaging about 1mm. A few rounded fine grained quartzitic and volcanic fragments are also present in the fine grained groundmass.

The groundmass consists of a mixture of plagioclase and K-spar which form shapeless interlocking grains about 0.01mm in size. The distribution of K-spar is patchy and it replaces the plagioclase. It also occurs in the phenocrysts in patches. Very fine grained biotite is disseminated between the feldspars in the groundmass and is concentrated in diffuse patches up to 2mm in size where it is slightly coarser. The biotite also occurs along the cleavages and in fractures in the plagioclase phenocrysts and in the rock fragments. It is associated with K-spar. A few small phenocrysts have been totally replaced by biotite. Most of the biotite is greenish in colour but several of the patches within the groundmass are reddish brown in colour. This biotite could be a metamorphic biotite formed after the biotite associated with the feldspathisation. The greenish biotite tends to occur in diffuse streaky patches, whereas the reddish biotite occurs in more rounded patches.

Apatite forms idiomorphic grains about 0.2mm in size scattered within the feldspars in the groundmass.

A network of thin discontinuous quartz stringers cuts through the rock. Thicker ones contain chlorite and pyrrhotite. Scattered patches of chlorite occur throughout the rock sometimes enclosing rounded grains of pyrrhotite about 0.2mm in size. Epidote occurs with chlorite in some of the veinlets and in small aggregates within the groundmass and the phenocrysts. Some of the chlorite patches contain very small rutile grains and aggregates, These also occur in the biotite patches and some are crowded with rutile. Sphene is also associated with chlorite but occurs in clusters of grains around the chlorite patches and rarely in the chlorite in the veinlets.

Very fine grained opaque grains are disseminated through the rock and may be concentrated in a small phenocrysts or with biotite. Some of these are probably pyrrhotite but most of the finer ones are probably hematite

This rock is composed of rounded to shapeless fragments of andesitic material (sometimes porphyritic) which are crowded in a glassy matrix. The fragments range in size from 0.2 to 4mm, averaging about 1.5mm. Plagioclase, derived from the porphyritic andesite, and fragments of quartz occur throughout the glassy matrix. Minerals are:

andesite fragments	40%	- plagioclase, chlorite, glass, minor sphene, quartz
matrix	25	- glass, quartz, plagioclase, chlorite, biotite, sericite
plagioclase	20	
chlorite	5	
quartz	8	
epidote	1	
opaque	minor	
sphene	minor	
tourmaline	1	
calcite	trace	

The andesitic fragments consist of thin plagioclase laths about 0.05mm in size in a glass-chlorite matrix. Some of them are crowded with plagioclase phenocrysts up to 0.5mm in size and have ragged patches of chlorite 0.1mm in size; others have few or no phenocrysts. In a few of them there are small rounded quartz grains. Sphene occurs in some, forming shapeless grains about 0.2mm in size. The smaller fragments grade into the matrix.

The matrix consists of extremely fine grained crystallites of plagioclase set in a glassy matrix with interstitial biotite and diffuse patches of quartz. Small ragged patches of chlorite are present but most of the chlorite in the matrix is derived from the andesite fragments. Scattered patches of sericite occur throughout the matrix.

One large andesitic fragment consists of a felted mass of plagioclase laths with scattered small plagioclase phenocrysts. This could be a more crystalline equivalent of the main type.

Plagioclase in the matrix consists of idiomorphic grains similar in size and morphology to the plagioclase in the andesitic fragments. Some of them are normally zoned. Most are partly broken.

Quartz forms angular to rounded grains from 0.2 to 2.0mm in size. Some have undulose extinction, suggesting derivation from a metamorphic environment; there are a few aggregates of fine quartz grains which could have been from a quartzite.

Chlorite and sphene form grains similar in size and shape to those grains within the andesitic fragments and have been derived from the breakdown of these, as has the plagioclase. Chlorite sometimes is intergrown with small sphenes.

Opaque minerals occur in the matrix and occasionally in the andesitic fragments. Ragged grains and patches form around the chlorite; more well formed, cubic grains form in and around some sphenes.

Epidote, tourmaline and calcite are late forming minerals. Calcite is rare and occurs in ragged patches within a few of the plagioclase phenocrysts, both in the matrix and in the andesite fragments. Epidote forms small grains and aggregates within and around the chlorite in the matrix and the fragments. Small patches about 0.1mm in size occur within the matrix of the fragments and the rock itself.

Epidote occurs intergrown with sphene in a few cases and this epidote is generally coarser grained and better formed than in the epidote around the chlorite and in the matrix. This epidote could have been 'primary' rather than due to later alteration. The sphene itself could be part of the metamorphic environment from which the quartz was derived. One large quartz fragment has two small sphene grains adhering to it. The andesite fragments may have incorporated the sphene before being caught up in the conglomerate.

(continued)

RB82126 (cont.)

Tourmaline occurs as ragged aggregates of bladed grains about 0.1mm in size which replace the edges of the chlorite patches in the matrix of the rock. Several well formed grains occur within the matrix away from the chlorite but most of it is associated with the latter mineral. It is rare in the andesite fragments. One large patch about 2mm in size occurs around a quartzitic patch in the matrix. The presence of tourmaline indicates proximity to an intrusion.

RB8205 Cherty dacite tuff

This rock consists of very fine grained, K-spar-rich volcanic material occurring in diffuse bands and patches up to 2mm thick which are mixed with fine grained chert. Minerals are:

K-spar	35%
chert	40
plagioclase	10
plagioclase phenocrysts	6
quartz	
phenocrysts	4
quartz aggregates	1
biotite	4
epidote	minor
goethite	minor - oxidised sulphide
chlorite	trace
opaque	trace - Fe-oxide?

The cherty patches consist of rounded to shapeless interlocking quartz grains about 0.01mm or less in size.

The volcanic patches consist of extremely fine grained K-spar (less than 0.005mm) with scattered plagioclase laths about 0.01mm in size. Very fine grained biotite is intergrown with the K-spar. A few ragged flakes and aggregates of flakes up to 0.2mm in size also occur in some patches.

Phenocrysts are common and consist of plagioclase and quartz; there are also several quartz aggregates which contain plagioclase in some cases. Plagioclase phenocrysts form squat idiomorphic laths about 0.4mm in size. Quartz phenocrysts form rounded, partially resorbed grains up to 1.5mm in size. The phenocrysts may lie partly in the chert and partly in the dacite. The quartz aggregates (with plagioclase in places) are rounded and consist of shapeless interlocking grains about 0.1mm in size; the aggregates are about 0.4mm in size and appear to be fragments of a plutonic rock. Biotite clusters around these.

An opaque mineral (hematite?) occurs as very small subcubic grains and shapeless aggregates rarely exceeding 0.1mm in size which are scattered about the dacite.

There is a thin veinlet about 0.05mm wide which consists of quartz with subcubic grains of a sulphide forming within the rock about the veinlet. The sulphide has been altered to goethite. Traces of chlorite also occur in the rock about the veinlet and rare flakes about 0.1mm in size occur elsewhere in the rock.

Epidote may be related to the chlorite and sulphide. It forms aggregates of extremely fine grains, less than 0.001mm in size, which replace small patches of the plagioclase phenocrysts or occur around biotite aggregates

RB8202 Dacite tuff

This is a fine grained porphyritic volcanic rock containing quartzitic rock fragments. Minerals are:

K-spar	33%
plagioclase	28
quartz	10
biotite	3
chlorite	1
epidote	trace
opaque	trace - Fe-oxide
zircon	trace
quartzitic fragments	22
volcanic fragments	minor

The groundmass consists of very fine grained interlocking grains of K-spar less than 0.005mm in size. Thin plagioclase laths from 0.05 to 0.1mm in size are scattered within the K-spar mass. In places there is a crude alignment of the laths.

Phenocrysts are plagioclase and quartz. The quartz forms rounded grains up to 1mm in size which have been partially resorbed by the feldspathic groundmass. The plagioclase forms laths from 0.4 to 1.2mm in length. It sometimes occurs in clusters of a few grains.

Much of the quartz in this rock appears to have been derived from the quartzitic fragments which have been broken up and the grains dispersed within the feldspathic groundmass. The fragments consist of shapeless to subrounded interlocking grains about 0.1mm in size. Some have sutured margins and are strained. They are probably derived from a quartzite. Fragments are usually rounded but a few angular ones do occur. They are less than 0.6mm in size and often consist of only three or four grains. Single quartz grains are common and some of these can be recognised as being derived from the fragments by their undulose extinction. Other single quartz grains have normal extinction and are authigenic but these are in the minority.

Biotite forms thin flakes from 0.05 to 0.2mm in size which are scattered about the K-spar groundmass. Small patches of very fine grains also occur. Much of the biotite occurs in association with the quartz fragments. It occurs in small interstitial patches between the quartz grains in some fragments or in a small patch around a single quartz grain. In many of these patches chlorite has taken the place of the biotite. Small ragged grains of hematite? occur in association with the biotite flakes in the groundmass. Zircon occurs in one quartz-biotite fragment.

Epidote forms aggregates of extremely fine grains, less than 0.001mm in size, which replace the edges of the biotite and chlorite, both in the groundmass and the quartz aggregates. Rare patches occur in plagioclase.

Volcanic fragments are minor but are relatively large. One irregularly shaped fragment is about 4mm in size. It consists of very fine grained quartz, plagioclase and glass. Biotite clusters around the edges partly within the fragment and partly within the dacite. Fine grained epidote is dispersed throughout it. One small fragment consists of plagioclase laths with interstitial quartz (quartz andesite).

Small subcubic grains of an opaque mineral are scattered within the groundmass. These could be a sulphide.

This is a cherty rock which is crowded with volcanic fragments of various types and broken plagioclase crystals. Pervasive alteration (metamorphism?) has resulted in fine grained biotite being disseminated throughout the fragments and groundmass. Several thin veinlets containing quartz, chlorite and pyrite cut the rock. Minerals are:

Cherty groundmass	14%	
biotite	12	
chlorite	6	
quartz	6	
opaque	2	- mainly sulphide
epidote	1	
sphene	minor	
rutile	minor	
fragments		
plagioclase	25	
quartz	4	
dacite	6	
andesites	18	
quartzites	6	

Plagioclase grains range in size from 0.05 to 1.5mm in size, averaging about 0.7mm. Many of the larger ones are broken. Some are thin and elongated, others are squat and they usually have a subidiomorphic outline. They are derived from a variety of sources, some of which are present in the rock. In places small laths are intergrown with the cherty groundmass and are aligned.

The dominant fragments are plagioclase-rich volcanic rocks of various types. Mostly these consist of fine grained andesite containing subidiomorphic plagioclase laths with or without a flow alignment. Some of them contain quartzitic fragments. Some are porphyritic with plagioclase phenocrysts up to 1mm in size. The plagioclase grains are probably derived from these. Several dacite fragments are present. These are very fine grained.

A few small quartzitic fragments occur. These are fine grained and are probably metamorphosed impure sandstones or mudstones. Small rounded grains of quartz also occur and these are probably derived from a metamorphic environment. Some of these may have been previously incorporated in the andesitic fragments.

Rock fragments are subrounded and range in size from a few tenths of a millimetre to 1cm. The quartzites are smaller than the volcanic rocks. Due to pervasive biotite alteration it is difficult to distinguish some of the smaller fragments from the groundmass; many of them have been incorporated into the groundmass during consolidation.

Biotite is very fine grained and tends to be concentrated in patches within the groundmass or within some fragments. It also occurs in the plagioclase grains along the cleavages and in fractures.

The veinlets cutting the rock are about 0.5mm wide and consist mainly of quartz, chlorite and pyrite. Minor epidote is also present in some. Ragged patches of chlorite, sometimes with epidote, occur throughout the rock. Some of the chlorite patches contain fine grained rutile. Small grains of sphene occur around some of the chloritic patches. Rutile may also occur in the biotite patches. Rounded grains of pyrite up to 0.5mm in size occur within some of the chloritic patches. Smaller disseminated opaque grains occur within the rock and these are sometimes concentrated within a rock fragment or plagioclase grain.

RB82116 Rhyolite (porphyritic)

This is a fine grained banded volcanic rock. Fine bands less than 1mm thick consist of alternating quartz-rich and K-spar rich layers. Plagioclase phenocrysts are scattered through the rock. Minerals are:

K-spar	67%
quartz	16
plagioclase	12
chlorite	2
epidote	3
hematite	trace
sulphide	trace

The groundmass consists of a felted mass of very fine interlocking K-spar grains about 0.005mm in size. They are aligned parallel to the banding. Some bands are quartz rich and in these the quartz forms shapeless interlocking grains from 0.05 to 0.1mm in size which occur in thin lenses along the layer.

Plagioclase forms idiomorphic laths from 0.2 to 1.5mm in size scattered through the rock. They tend to be aligned subparallel to the layering. The K-spar grains flow around the plagioclase.

Later alteration is weak but there is pervasive chloritisation and epidotisation. In the groundmass the epidote and chlorite forms very small grains scattered through the rock. Occasionally there is a patch of chlorite about 0.1mm in size. Coarser grained epidote replaces the plagioclase phenocrysts in patches. Chlorite may also be present and where it is it occurs around the epidote. Some plagioclase is almost completely replaced by epidote and chlorite.

Extremely fine grained hematite is disseminated through the groundmass.

A few cubic grains of a sulphide mineral, about 0.2mm in size, occur within the quartzitic lenses.

RB82118 Rhyolite tuff

This is an extremely fine grained volcanic rock. It is vaguely banded in lighter and darker shades of grey. Minerals are:

K-spar	58%
glass	20
quartz	20
hematite	2
epidote	minor
chlorite	trace

The rock consists of extremely fine grained, rounded grains of K-spar mixed with glass. Grain size is about 0.002mm.

Quartz forms rounded to angular fragments about 0.01mm or less in size which are scattered within the K-spar-glass mixture. Some layers are quartz rich, others have little quartz. A few very small patches of quartz have crystallised from the glass.

Very fine grained hematite is disseminated throughout the rock and may be concentrated along layer boundaries.

Epidote occurs in diffuse vein-like patches which cut across the layering. Small patches of chlorite occur in the rock adjacent to some of the epidote whisps.

RB82122B Rhyolite (slightly porphyritic)

This is a very fine grained volcanic rock. Fine bands less than 1mm thick consist of alternating coarser and finer grained K-spar with interbedded quartz. The banding is crenulated and in places there has been autobrecciation quartz forms vein-like patches cutting across the layers. Minerals are:

K-spar	81%
plagioclase	6
quartz	12
epidote	1
chlorite	trace
hematite	minor
sericite	trace
sulphide	trace

K-spar forms a felted mass of laths about 0.005mm in size. These grade into more rounded grains about 0.1mm in size. The laths are aligned parallel to the banding. Bands where the K-spar is rounded alternate with bands where the K-spar is lath shaped. Bands vary in thickness from 0.01 to 1.0mm.

Quartz also occurs in bands and forms shapeless interlocking grains about 0.8mm in size. Small lenses and patches occur along the layering in some feldspathic layers. Autobrecciation has occurred and the quartz occurs in vein-like stringers and patches which cut across the banding.

Plagioclase forms subidiomorphic laths from 0.2 to 1.5mm in size. Sometimes they occur in aggregates of a few grains. The K-spar wraps around the plagioclase. A few of the plagioclase phenocrysts contain small patches of epidote and chlorite. Scattered flakes of sericite also occur in some. Epidote occurs in extremely fine grains within the groundmass. It tends to be concentrated in the finer K-spar layers.

Hematite occurs in very fine grains disseminated throughout the rock.

A few grains of a sulphide occur associated with quartzitic patches. Chlorite may also occur in these patches associated with the sulphide.

RB82123 Porphyritic (quartz) andesite

This a fine grained volcanic rock with scattered phenocrysts of quartz and plagioclase. A few thin fractures filled with epidote and K-spar cut the rock. These minerals have also replaced some of the plagioclase phenocrysts. Minerals are:

plagioclase	62%
plagioclase phenocrysts	8
quartz	6
biotite	14
epidote	6
K-spar	2
opaque	2 - mainly hematite?
apatite	minor
zircon	trace
cherty fragment	minor

The groundmass consists of idiomorphic plagioclase laths about 0.05mm in size which are intergrown with more shapeless grains. Very fine grained biotite is disseminated between the plagioclase grains. Ragged rounded grains of an opaque mineral(hematite?) about 0.05mm in size are also disseminated through the groundmass. Small, scattered grains of apatite and zircon are also present.

(continued)

RB82123 (cont.)

Quartz forms rounded phenocrysts (xenocrysts?) up to 1.5mm in size scattered about the rock. Several more angular, smaller quartz grains occur. These could be fragments. There is one fairly large fragment of a cherty rock.

Plagioclase phenocrysts are about 1.5mm in size. Many of them have been partially altered by epidote and K-spar. The epidote forms an aggregate of grains within the centre of the plagioclase. The K-spar forms around this and also occurs in the surrounding andesite. Minor quartz, green biotite and traces of sphene may be intergrown with the epidote. This alteration is related to narrow fractures about 0.2mm wide which contain these minerals. Small patches of epidote occur in the rock adjacent to the fracture and very small grains of epidote are disseminated through the rock. A thin film of an opaque mineral (sulphide?) occurs on the walls of the fractures.

RB82124 Porphyritic (quartz) andesite

This is a fine grained volcanic rock with scattered phenocrysts of quartz and plagioclase. Minerals are:

plagioclase	65%	
plagioclase		
phenocrysts	5	
quartz	5	
biotite	18	
epidote	2	
opaque	5	- mainly hematite?
apatite	trace	

The groundmass consists of plagioclase laths about 0.1mm in size intergrown with smaller shapeless plagioclase grains. Rounded opaque grains (hematite?) from 0.005 to 0.1, averaging about 0.05mm in size are disseminated through the groundmass. Extremely fine grained biotite is disseminated between the plagioclase grains. Biotite also occurs in lath-like aggregates up to 0.4mm in length. These have a core of an opaque mineral (also hematite?). Some are crowded with opaque grains. About half of the biotite occurs in these aggregates. The plagioclase and biotite-hematite aggregates are aligned.

Quartz phenocrysts are rounded and are up to 2mm in size.

Plagioclase phenocrysts are up to 4mm in size and are normally zoned. They often have a cloudy rim. Patches of coarse epidote occur in the cores of many of them. Thin fractures about 0.05mm thick cut through the rock. These are filled with epidote and biotite.

TL8245 Quartz-amphibole-magnetite rock

This is a massive, coarse grained dark grey rock consisting of:

opaque	35%	- magnetite?
quartz	50	
amphibole	15	

Quartz forms rounded to shapeless interlocking grains from 0.1 to 1.0mm in size. Some grains have a partial crystal outline.

The opaque forms massive aggregates between the quartz grains. Patches several millimetres in size occur. Single grains are variable in size and range down to 0.05mm. Small grains are included in the quartz. Some quartz grains are crowded.

The opaque is intimately intergrown with an amphibole which occurs in ragged grains interstitial to the quartz. Very small acicular grains occur included in the quartz. It is a clinoamphibole but the composition is unknown - it is not hornblende.

TL8295 Garnet peridotite

This is a massive, medium grained dark green rock consisting of:

olivine	74%
amphibole	12
garnet	8
sphene	5
tourmaline	1

Olivine forms a mosaic of subrounded grains about 1mm in size. There are also many grains which are elongated. A pale green amphibole is intergrown with the olivine.

Sphene forms ovoid grains which may be up to 8mm in length. Small ones occur in the olivine and the larger ones have grown across several grains.

Garnet forms rounded grains up to 0.8mm in size which are included within the olivine and within the sphene. Some large sphene grains are crowded with small garnets. The garnets in the olivine tend to occur in clusters. Most of the garnets are less than 0.5mm in size.

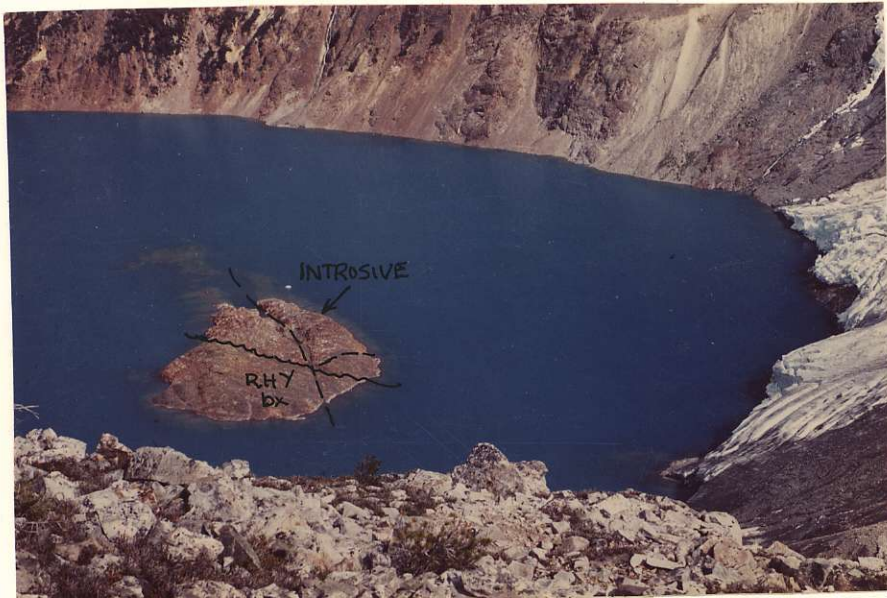
Tourmaline forms thin bladed grains up to 2mm in length. They sometimes occur in splays. They form in the olivine. The rock is vuggy and some tourmalines have one end close to a vug but most of them simply cut through the fabric of the rock.



.....
COPPER LAKE ZONE : Gossanous area east
of camp with lapilli
tuffs overlying dark
feldspar porphyry



COPPER LAKE ZONE: View looking northeasterly
 MoS₂ zone lies between two slides
 on East Lake short (arrow)



COPPER LAKE ZONE: Island with intrusive rocks in contact
 with altered rhyolite