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Invoice 7939
January 1988**Project: Faro Northwest**

40 samples of intrusive rocks, pelitic and calc-silicate schists

Summary:

1.0 Igneous and Metamorphosed Igneous Rocks**1.1 Quartz Diorite to Quartz Monzonite, Andesite**

A deformation foliation was seen only in sample 88-90. However, textures of 88-169 also suggest metamorphism. Modes of major and minor minerals are shown below.

Sample	Plag	K-fs	Qtz	Musc	Bio	Chl	Hbl
88-90	28	38	27	2	6	-	-
88-169	45*	16	27*	-	8*	0.5	m
88-413	65*	4	17	-	7*	-	5*
88-414	30*	34	25*	3	3*	s	-
Faro NW	62	3	23	-	11	2	-
Faro Div	78*	-	-	-	14	s	9*

* includes some phenocrysts

s secondary after biotite

- 88-90 regionally metamorphosed quartz monzonite gneiss; megacrysts of K-feldspar of metamorphic origin; micas concentrated in seams parallel to gneissic foliation
- 88-169 metamorphosed, porphyritic granodiorite; metamorphic textures shown by biotite
- 88-413 porphyritic potassic quartz diorite; dominant phenocrysts of hornblende; possibly metamorphosed
- 88-414 leucocratic quartz monzonite, slightly porphyritic; unmetamorphosed
- Faro NW slightly porphyritic quartz diorite dike; unmetamorphosed
- Faro DIV porphyritic andesite dike, unmetamorphosed

In samples 88-169, 88-413, 88-414, Faro Div, and Faro NW, plagioclase shows strongly zoned crystals. This is the major similarity between these five samples, and on this basis, all but 88-169, which was metamorphosed, could be from the same igneous suite. Correlation of Faro DIV is weak, and it may be from a separate, more mafic source.

1.2 Ultramafic Rocks

No metamorphic foliation was recognized. Foliation in 88-477 probably is primary igneous layering.

- 88-470 relic olivine, altered clinopyroxene, and opaque are set in a groundmass of tremolite-chlorite-opaque; vein of chlorite/serpentine and tremolite
- 88-477 foliated feldspathic dunite; altered to tremolite; veins of serpentine/chlorite-magnetite

2.0 Pelitic Schists

Pelitic schists show a wide range in composition, and are dominated by quartz, micas, and plagioclase. Typical metamorphic minerals include abundant andalusite, much less cordierite, and minor staurolite and sillimanite. Where these minerals are present, the metamorphic grade can be established to a certain degree. In several samples, sericite is secondary after one or both of plagioclase and andalusite. Mineral X is an unknown metamorphic mineral altered completely to cryptocrystalline to extremely fine grained chlorite/sericite.

Most show effects of strong deformation, with original foliation contorted strongly, and phyllosilicate recrystallized moderately in axial planes of folds to define a second, spaced foliation.

Modes of major and minor minerals are shown below. Included in the list are schist lenses interlayered with calc-silicate rocks.

Sample	Plag	Qtz	Musc	Bio	Chl	Trem	K-Fs	And	Ser	Other
88-33	33	18	4	18	3	-	-	18	-	1 (Sta)
88-115	8	37	16	20	-	-	-	13	-	-
88-137	s	33	43	-	-	-	-	s	16	-
88-144	2+s	57	16	12	-	-	-	2+s	11	0.5 (Cor)
88-151	8+s	37	2	17	-	-	0.5	18+s	16	2 (X)
88-189	13	37	11	11	s	-	-	0.2	-	5 (Cor)
88-214	s	16	-	3	4	-	-	9+s	67	2 (Sil) 0.1 (Cor)
88-227	0.5	33	33	13	s	-	-	16	-	-
88-229	3	42	43	11	-	-	0.5	-	-	0.2 (Epi)
88-258	9	33	3	27	-	-	-	18	-	3 (X), t (Sil)
88-260-1	57	-	-	16	-	-	5	-	-	-
88-365-1	-	-	-	-	1	98	-	-	-	-
88-383	37	6	5	-	18	3	-	-	-	0.3 (Epi)
88-400	23	16	1	0.7	13	3	2	-	-	13 (Epi)
88-422-2	30?	5	13	-	23	-	30?	-	-	-
88-428	37	16	-	m	27	-	m	-	-	18 (Ct)
88-433	37	23	13	-	4	-	0.2	-	-	-
88-468-3	37	37	3	16	2	0.2	4	-	-	-
88-483	s	33	33	6	2	-	-	13+s	13	-
88-544	55	20	-	20	-	-	-	-	-	5 (Dio)

In Sample 88-137, plagioclase and andalusite are altered completely to sericite. The sample is strongly weathered, with replacement patches and veins of limonite-kaolinite.

Sample 88-214 is similar to many of the other samples, with the following distinct features: It contains moderately abundant sillimanite (the only sample to contain much of this mineral), and plagioclase and andalusite are both replaced completely by sericite.

3.0 Calc-silicate Rocks

Calc-silicate rocks show a moderate variation in composition. Many are dominated by plagioclase and diopside, with lesser quartz and chlorite. Some have interlayers of marble containing calc-silicates and K-feldspar. Many show similar effects of deformation as do the pelitic schists, with a second foliation less strongly developed because of the relative shortage of phyllosilicates.

Sample	Plag	Diop	Qtz	Chl	Bi/Ph	Ct	Tr/Ac	Epi	K-fs	Sph	Gar
88-105	37	16	5	4	2	27	-	1	8	m	-
88-183	42	23	18	8	-	-	2	m	5	0.7	-
88-260-1	57	23	13	-	-	-	3	-	-	0.3	-
88-365-2	M	M	M	m	-	-	m	M	m	-	m
88-422-1	-	M	(see 5.0 Skarn)								
88-422-2	6	77	m	-	-	0.2	-	-	-	0.2	16
88-450	e	-	2	11	-	2	9	73	3	-	-
88-464-1	42	33	8	8	-	3	2	0.5	3	m	-
88-468-1		M	(see 5.0 Skarn)								
88-468-3	42	18	13	-	-	2	2	13	3	0.5	-
88-544	42	18	4	t	-	-	-	-	-	1	-

Samples 88-180 and 88-203 are grossly similar in that they are marbles with abundant, intimately intergrown lenses of silicates. The silicate assemblages are distinctly different; in Sample 88-180 the assemblage of plagioclase-quartz-biotite-tremolite is more typical of the pelitic schists, and in Sample 88-203, the assemblage of diopside-(plagioclase-epidote-K-feldspar-chlorite) is more typical of the calc-silicate.

Samples 88-260-2 and 88-464-2 are grossly similar, in that they are marbles with abundant calc-silicates in irregular lenses. In Sample 88-260-2 the dominant calc-silicate is diopside with lesser tremolite, whereas in Sample 88-464-2, the dominant calc-silicates are garnet and diopside (with lesser phlogopite).

Carbonaceous opaque was recognized in significant abundance in Sample 88-365-1 and Sample 88-433.

Samples 88-365-2 and 88-450 are both strongly contorted calc-silicate rocks. Zone 1 of Sample 88-365-2 is very similar to much of Sample 88-450. Based on this similarity, the two samples could be correlated.

4.0 Marble with Calc-silicates

Samples of marble contain lenses or disseminated grains of a variety of calc-silicates. Some samples consist of interbanded calcite-rich layers and calc-silicate layers; modes given below are for total rocks, where no strong layering is present, and for calcite-rich layers in layered rocks.

Sample	Ct	Diop	Plag	K-fs	Qtz	Epi	Trem	Gar	Chl	Bi/Ph
88-105	M	M	-	M	m	-	-	-	-	-
88-203	42	37	8	5	-	5	-	1	3	0.2
88-260-2	62	11	-	-	-	-	m	23	0.7	4
88-464-2	57	33	0.3	4	0.5	-	5	-	1	0.5
88-468-2	89	5	2	0.5	0.3	-	1	-	-	2

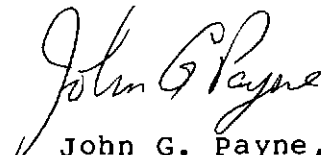
5.0 Skarn

Samples in which calc-silicate is replaced by skarn assemblage. Relic calc-silicate is finely banded granular diopside, whose texture was preserved in part during skarn formation. This suggests that skarn was formed after at least one period of deformation, but possibly not the one which deformed the rocks into shear folds.

Sample	Gar	Dio	Ct	Qtz	Epi	Chl	Spl (relic Dio)
88-422-1	65	5	1	1	1	0.3	-
88-468-1	77	3	5	5	-	-	m

Symbols in Tables

- M over 10% in sample in which mode was not determined
 m 2-10% in sample in which mode was not determined
- s plagioclase or andalusite altered to sericite;
 biotite altered to chlorite
- e plagioclase altered to epidote


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Sample 88-33**Deformed Schist: Plagioclase-Biotite-Andalusite-Quartz-Muscovite-(Staurolite)**

The rock is dominated by plagioclase with less biotite, quartz, and andalusite, with much less muscovite and chlorite/sericite, and minor staurolite (in cores of andalusite porphyroblasts). A moderate compositional banding is defined in hand sample by variation in the biotite:plagioclase+quartz ratio. A second deformation event warped this foliation, and produced a moderate lineation parallel to axes of the kink folds.

plagioclase	30-35	staurolite	1%
biotite	17-20	ilmenite	0.3
andalusite	17-20	apatite	minor
quartz	17-20	tourmaline	trace
muscovite	3- 4	zircon	trace
chlorite/sericite	3- 4		

plagioclase forms anhedral grains averaging 0.2-0.5 mm in size. Some grains contain minor subrounded to lency quartz inclusions. Alteration of plagioclase is slight to sericite.

Biotite forms anhedral flakes averaging 0.2-0.8 mm in length, with a few up to 1.2 mm long. Pleochroism is from pale brown to medium/dark red to brownish red. A few grains are altered completely to pseudomorphic chlorite.

Andalusite forms ragged, equant to elongate porphyroblasts averaging 0.7-2 mm in size. Many contain abundant poikilitic inclusions of quartz and/or biotite, and less abundant tabular grains of ilmenite. A few porphyroblasts consist of extremely fine intergrowths of about equal amounts of andalusite and quartz.

Quartz forms anhedral, equant grains averaging 0.05-0.2 mm in size. It is concentrated in a few quartz-rich lenses up to several mm across, and elsewhere forms interstitial patches to plagioclase and andalusite. Quartz-rich lenses contain minor plagioclase and disseminated flakes of muscovite and biotite. One quartz-rich lens or veinlet is dominated by grains averaging 0.5-0.8 mm in size.

Muscovite forms flakes averaging 0.1-0.7 mm in length intergrown with biotite.

Chlorite/sericite(?) forms cryptocrystalline to extremely fine grained aggregates in patches averaging 0.07-0.15 mm in size, generally intergrown with biotite. These may be after Mineral X.

Staurolite forms anhedral grains averaging 0.1-0.5 mm in size in cores of andalusite grains. One ragged core is up to 1.3 mm across. Some grains are very pale yellow and non-pleochroic and others are weakly pleochroic from very pale to light yellow. Optical properties which fit those of staurolite are: R.I. about 1.75, birefringence about 0.010, optic sign: biaxial positive.

Ilmenite forms tabular grains up to 0.6 mm in size, commonly intergrown with andalusite. Opaque of uncertain composition forms anhedral grains averaging 0.05-0.15 mm in size associated with micas and andalusite.

Apatite forms subhedral to euhedral prismatic grains averaging 0.05-0.12 mm in length, with a few up to 0.3 mm long, and a few, anhedral, equant grains up to 0.15 mm across.

Tourmaline forms subhedral prismatic grains up to 0.06 mm long; pleochroism is from light to medium green.

Zircon forms anhedral grains averaging 0.01-0.03 mm in size, with a few up to 0.07 mm long. They are associated with biotite, in which are formed dark pleochroic halos around the zircon grains.

The sample contains megacrysts of K-feldspar, concentrated in certain bands, and intergrown with finer grained aggregates of plagioclase and quartz, with much less biotite and muscovite concentrated moderately in seams parallel to foliation.

K-feldspar	35-40%
plagioclase	25-30
quartz	25-30
biotite	5- 7
muscovite	1- 2
hematite	0.2
apatite	minor
zircon	trace

K-feldspar forms anhedral to euhedral megacrysts up to 4 cm in size, some of which are Carlsbad twins. Many contain irregular, very fine grained patches of plagioclase, probably of exsolution origin. Inclusions consist of subhedral to euhedral grains of plagioclase, anhedral grains of quartz, and minor ragged flakes of micas.

Plagioclase forms a few subhedral to euhedral prismatic grains up to 1.7 mm long enclosed in K-feldspar megacrysts. They show weak compositional growth zoning with some oscillatory zones. Alteration is weak along fractures to cryptocrystalline to very fine grained sericite. Outside K-feldspar megacrysts, plagioclase grains are more irregular in outline, and commonly more strongly altered to very fine grained sericite and dusty opaque (hematite?). Grain size ranges from 0.3-3 mm. On borders of K-feldspar grains are numerous patches of myrmekitic plagioclase up to 0.7 mm in size.

Quartz forms patches up to a few mm across of anhedral, slightly to moderately interlocking grains with slightly wavy extinction. In several patches, textures suggest that coarser grains were recrystallized to finer grained aggregates under weak shear deformation.

Biotite forms ragged flakes averaging 0.2-1 mm in length, with a few up to 2 mm long. Pleochroism is from pale brown to medium reddish brown. Much of the biotite is partly altered along cleavage to pseudomorphic, pale green chlorite, with ragged patches of cryptocrystalline Ti-oxide. A few patches are altered to pale to light brownish green biotite/chlorite with properties intermediate between those of biotite and those of chlorite. One patch 1 mm long consists of an aggregate of radiating patches of grains grading from chlorite to biotite/chlorite. In one large patch, biotite flakes are altered completely to strongly to chlorite with abundant patches of Ti-oxide.

Associated with biotite are flakes of muscovite of similar size and texture. A few muscovite flakes are intergrown with quartz.

Micas are concentrated moderately in irregular seams parallel to foliation. A few mica-rich seams consist of very fine to fine grained biotite and muscovite intergrown with plagioclase and quartz.

Hematite forms a few patches up to 0.15 mm in size of single opaque grains or deep red-brown, cryptocrystalline aggregates and a few slender flakes up to 0.05 mm long, mainly associated with biotite.

Apatite forms a few anhedral to euhedral grains up to 0.2 mm in size with biotite.

Zircon forms grains averaging 0.01 mm in size in biotite. Many of these have dark pleochroic halos. A few stubby subhedral grains in plagioclase are up to 0.03 mm long, and one slender prismatic grain in quartz is 0.05 mm long.

Sample 88-105**Calc-silicate Rock with Interlayers of Calcite-Diopside-K-feldspar-(Quartz) = Impure Marble**

A calc-silicate rock dominated by plagioclase with much less biotite, chlorite and diopside, contains interlayers averaging a few mm wide of impure marble composed of calcite-diopside-K-feldspar-(quartz). A few fold noses are preserved in the rock, suggesting that it was strongly deformed, and that the present compositional banding represents a foliation formed during intense shear deformation.

plagioclase	35-40%
calcite	25-30
diopside	15-17
K-feldspar	7- 8
quartz	4- 5
chlorite	3- 4
biotite	1- 2
epidote	1
Ti-oxide	1
opaque	0.5
sphene	minor
veinlets epidote	trace

Plagioclase forms aggregates of slightly interlocking grains averaging 0.05-0.1 mm in size; grains commonly are slightly elongate parallel to foliation. Intergrown with plagioclase are moderately abundant wispy seams of Ti-oxide-opaque(ilmeneite?) and minor chlorite parallel to compositional banding. Layers are warped slightly to moderately, with fold axes averaging 0.5-1 mm apart and oriented perpendicular to the compositional banding. This deformation is shown well by the seams of Ti-oxide/opaque in plagioclase/rich layers.

Biotite forms moderately abundant, disseminated, very fine grained flakes oriented parallel to foliation in some plagioclase-rich layers. Pleochroism of biotite is from nearly colorless to light or medium brown. Some biotite is altered to chlorite-(Ti-oxide). In a few layers up to 2 mm wide, chlorite forms unoriented clusters of flakes averaging 0.05-0.1 mm in size, intergrown with very fine grained plagioclase and minor epidote. Chlorite forms several clusters up to 0.5 mm in size of slightly coarser grained flakes.

Diopside forms irregular, in part skeletal grains averaging 0.1-0.5 mm in size intergrown with plagioclase in a few layers. In some of these layers, plagioclase may be altered to extremely fine grained epidote. Elsewhere it forms finer grained, granular aggregates intergrown with plagioclase.

Opaque (pyrite?) forms irregular clusters up to 0.3 mm across of grains averaging 0.05-0.1 mm in size intergrown with chlorite.

Sphene forms subhedral grains averaging 0.02-0.05 mm in size, and a few very fine grained lenses up to 0.05 mm wide and 0.2 mm long.

Impure marble layers are dominated by calcite grains averaging 0.1-0.7 mm in size, with a few up to 1 mm across. Diopside forms abundant, ragged, in part skeletal grains averaging 0.1-0.8 mm in size. K-feldspar forms anhedral grains averaging 0.1-0.5 mm across, with a few up to 1 mm in size and with a few patches of extremely fine grained aggregates. Quartz forms disseminated grains averaging 0.05-0.1 mm in size.

Epidote forms wispy, discontinuous veinlets averaging 0.02-0.03 mm in width.

Sample 88-115 Quartz-Biotite-Muscovite-Andalusite-Plagioclase Schist

The rock is a well foliated, slightly compositionally banded schist dominated by quartz, biotite, muscovite and andalusite, with lesser plagioclase and patches of sericite (probably after andalusite).

quartz	35-40%
biotite (groundmass)	17-20
(porphyroblasts)	2- 3
muscovite	15-17
andalusite	12-15
plagioclase	7- 8
sericite	4- 5
opaque	0.3
Ti-oxide	0.1
apatite	trace
tourmaline	*
hematite	minor

Quartz is concentrated in lenses and layers parallel to foliation averaging 0.3-0.7 mm wide, with a few up to a few mm wide. It forms equant, submosaic grains averaging 0.05-0.1 mm in size, with a few up to 0.3 mm long.

Biotite and muscovite are intergrown in layers averaging 0.2-1 mm wide parallel to foliation as mainly subparallel grains averaging 0.05-0.3 mm in size. These bands contain wispy seams which probably were formed by later shearing. Biotite is pleochroic from light brown to medium orange-brown. Scattered porphyroblasts from 0.1-0.5 mm in size are oriented at moderate to high angles to foliation; pleochroism of these is from light brown to medium reddish brown.

Plagioclase is concentrated in some bands with biotite or quartz as grains averaging 0.02-0.05 mm in size. Some patches of extremely fine grained sericite may be after plagioclase.

Andalusite is concentrated strongly in some layers as anhedral, commonly ragged porphyroblasts averaging 0.7-1.5 mm in size, with one composite grain 2.5 mm across. Some smaller grains are moderately poikilitic, with irregular, extremely fine grained inclusions of quartz. A few grains are altered slightly to extremely fine grained sericite.

Sericite occurs in patches and lenses as extremely fine grained, unoriented aggregates; some have rectangular outlines and some are intergrown coarsely with biotite. Sericite probably is secondary after andalusite.

Opaque forms disseminated tabular grains and clusters of subparallel grains averaging 0.1-0.3 mm long, with a few up to 0.4 mm long. Opaque is concentrated in biotite-muscovite-rich layers.

Ti-oxide forms a few equant grains averaging 0.1 mm across, mainly associated with muscovite and biotite-rich layers.

Tourmaline forms a few euhedral, prismatic grains up to 0.03 mm across associated with biotite-muscovite-rich layers. It is light green in color in cross section.

Apatite forms a few equant grains averaging 0.02-0.05 mm in size.

Hematite occurs in late seams parallel to foliation.

A few minor kink folds are at right angles to the main foliation.

Deformed Schist: Muscovite-Quartz-Sericite (after Plagioclase/Andalusite), secondary Patches and Seams of Limonite and Kaolinite

A well foliated schist is dominated by muscovite and quartz, with lesser patches of sericite (probably after plagioclase or andalusite), and abundant lenses and seams of limonite-(kaolinite). Kink folding produced strong contortion of primary foliation and a weak second foliation at a moderately high angle to the primary foliation.

muscovite	40-45%
quartz	30-35
sericite	15-17
limonite	7- 8
kaolinite	0.5
Ti-oxide	0.5
late seams	
limonite-(kaolinite)	1- 2

Muscovite is concentrated in layers up to 3 mm wide as subparallel flakes averaging 0.5-1 mm in length, with a few up to 3 mm long. These layers are contorted moderately to locally strongly, with bending and recrystallization of muscovite flakes.

Quartz forms lenses of anhedral, equant grains averaging 0.03-0.15 mm in size, with a few from 0.3-0.7 mm across.

Sericite is concentrated in a few lenses and patches up to a few mm across as aggregates of grains averaging 0.01-0.03 mm in size. Sericite patches contain scattered flakes of muscovite averaging 0.2-0.7 mm in size, and lenses of quartz, Ti-oxide and limonite averaging 0.1 mm long. Textures suggest that these patches of sericite may be secondary after porphyroblasts of andalusite or aggregates of plagioclase. Smaller patches averaging 0.1-0.5 mm in size are intergrown with quartz, and probably are secondary after plagioclase.

Kaolinite forms patches up to 0.6 mm in size of extremely fine to very fine grained, unoriented flakes, commonly intergrown coarsely with limonite.

Ti-oxide forms tabular grains averaging 0.05-0.12 mm long mainly oriented parallel to cleavage in muscovite, and less commonly in sericite.

Limonite is concentrated in seams averaging 0.1-0.3 mm in width along cleavage planes of muscovite flakes, and as irregular patches intergrown with quartz and muscovite. It is cryptocrystalline and deep orange-brown in color.

A few late seams averaging 0.1-0.4 mm wide are dominated by limonite with patches and lenses of kaolinite.

Sample 88-144Quartz-Muscovite-Biotite-Sericite-Andalusite-
(Cordierite) Schist

The sample is a well foliated, lensey schist dominated by quartz with lesser muscovite, biotite and sericite (probably mainly after plagioclase), and minor andalusite. Micas are concentrated in seams parallel to foliation. Late seams are of hematite/limonite.

quartz	55-60%
muscovite	15-17
biotite	12-15
sericite	10-12
andalusite	2- 3
plagioclase	1- 2
cordierite	0.5
ilmenite/Ti-oxide	0.3
tourmaline	trace
zircon	*
late seams	
hematite/limonite	1

Quartz forms anhedral, equant grains averaging 0.07-0.3 mm in size. In quartz-rich lenses, biotite and muscovite each form disseminated, ragged flakes averaging 0.05-0.1 mm long.

Muscovite forms clusters of flakes and seams parallel to foliation, with grains averaging 0.2-0.8 mm long.

Biotite forms flakes averaging 0.2-0.7 mm in size. Some are porphyroblasts which are oriented at a high angle to foliation. Pleochroism is from pale brown to medium reddish brown. In a few large patches several much of the sample, biotite is altered to pseudomorphic chlorite with lenses of Ti-oxide. A few biotite grains also contain abundant Ti-oxide needles in hexagonal crystallographic directions of biotite.

Plagioclase forms disseminated grains averaging 0.05-0.1 mm in size in some quartz-rich layers. In some layers, extremely fine grained sericite is intergrown with biotite and muscovite. Textures suggest that much of the sericite is secondary after plagioclase. Some lenses of sericite are stained light yellow by limonite.

Andalusite forms ragged porphyroblasts up to 1.2 mm in size. Many are intergrown with quartz, and contain a few lenses of Ti-oxide (after ilmenite) parallel to foliation. Several andalusite grains are fractured strongly and altered partly to extremely fine grained, pale green chlorite.

One cordierite(?) porphyroblast 2 mm across contains minor cores of andalusite up to 0.15 mm in size, and abundant poikilitic inclusions of quartz and muscovite averaging 0.02-0.03 mm in size.

Both andalusite and cordierite commonly are surrounded by aggregates of extremely fine grained sericite, some of which may be secondary after them.

Ilmenite (opaque) forms lenses parallel to foliation up to 0.8 mm in length, mainly associated with muscovite-rich lenses, and less commonly in andalusite and cordierite.

Tourmaline forms subhedral to euhedral, stubby prismatic grains up to 0.1 mm long. Pleochroism is from pale to medium yellowish green.

Zircon forms anhedral grains averaging 0.01-0.02 mm in size in biotite; they are surrounded by dark pleochroic halos.

Hematite/limonite forms late, braided seams averaging 0.02-0.1 mm wide.

Sample 88-151**Contorted Schist: Quartz-Biotite-Andalusite-Sericite-Plagioclase-(Mineral X)**

The rock is a strongly folded, banded schist/gneiss with layers and lenses rich in quartz and in biotite-andalusite-sericite, with lesser plagioclase and Mineral X. Andalusite and plagioclase are altered partly to sericite.

quartz	35-40%	muscovite	1- 2%
biotite	17-20	K-feldspar	0.5
andalusite	17-20	ilmenite(opaque)	0.5
sericite	15-17	apatite	minor
plagioclase	7- 8	tourmaline	trace
Mineral X	2- 3		
seams			
hematite/limonite	0.3		

Quartz forms anhedral, slightly interlocking grains averaging 0.1-0.25 mm in size, with a few coarser grained patches in which grains average 0.2-0.4 mm across. Quartz-rich layers contain disseminated, irregular patches of biotite flakes averaging 0.05-0.2 mm in size. Much of this biotite is altered to pseudomorphic muscovite with abundant extremely fine grained needles of Ti-oxide.

Plagioclase forms anhedral grains averaging 0.1-0.12 mm in size, commonly intergrown with minor to abundant quartz and lesser biotite. Some patches of plagioclase are relatively fresh and others are altered completely to extremely fine grained sericite.

Andalusite forms anhedral, commonly ragged porphyroblasts averaging 1-1.7 mm in size, with a few up to 3.5 mm long. Some contain abundant poikilitic inclusions of quartz, and some contain moderately abundant tabular grains of ilmenite. Some are altered slightly to moderately to extremely fine grained sericite, and many are surrounded by dense patches of similar sericite, which probably formed by replacement of andalusite.

Biotite forms ragged flakes and aggregates of subparallel flakes averaging 0.3-0.7 mm in size. Pleochroism is from pale brown to medium/deep red or brownish red. Some biotite flakes contain abundant Ti-oxide needles; these were altered slightly, and grade sharply into altered aggregates of muscovite-Ti-oxide. Much finer grained biotite commonly is intergrown with sericite and with Mineral X.

Sericite f(after plagioclase and/or andalusite) forms extremely fine grained patches up to a few mm across, commonly intergrown with minor to abundant flakes and aggregates of biotite. Mineral X occurs in a lens up to 5 mm long intergrown intimately with very fine grained biotite and much less quartz. It is altered completely to cryptocrystalline chlorite and sericite, and in part contains a bright yellow limonite stain.

Muscovite forms scattered clusters of slender flakes up to 0.5 mm in size, intergrown partly with biotite.

K-feldspar forms very fine grained aggregates in wispy seams parallel to foliation (see stained offcut block).

Ilmenite forms tabular lenses averaging 0.1-0.3 mm in length included in andalusite and much less commonly associated with biotite. Opaque forms anhedral grains averaging 0.05-0.1 mm in size associated with micas.

Apatite forms anhedral to subhedral grains averaging 0.05-0.1 mm in size, mainly associated with quartz and plagioclase.

Tourmaline forms a few subhedral prismatic grains up to 0.12 mm long. Pleochroism is from light to medium yellowish olive green.

A few late, wispy, braided seams up to 0.05 mm wide consist of hematite/limonite.

Phenocrysts of plagioclase and minor ones of quartz, biotite, and hornblende set in a groundmass of plagioclase, quartz, K-feldspar, and biotite. Biotite shows metamorphic textures.

phenocrysts	
plagioclase	12-15%
quartz	1
biotite	1
hornblende	minor
groundmass	
plagioclase	30-35
quartz	25-30
K-feldspar	15-17
biotite	7- 8
chlorite	0.5
opaque	minor
apatite	trace
zircon	trace

Plagioclase forms a few subhedral to euhedral phenocrysts from 1.5-2 mm in length. Some grains are zoned strongly from cores of **An40** to rims of **An15-20**. Some grains show two distinct stages of growth. Cores of many grains are altered strongly to sericite and/or skeletal to dense patches of extremely fine grained epidote. Finer grained plagioclase averages 0.5-0.8 mm in size, and shows textures and alteration patterns similar to those in coarser grains.

Quartz forms a few phenocrysts up to 1.5 mm in size, with irregular borders against the groundmass.. Most quartz occurs as equant, anhedral grains averaging 0.1-0.3 mm in size, commonly intergrown with K-feldspar.

K-feldspar forms anhedral grains averaging 0.2-0.5 mm in size containing abundant dusty hematite inclusions. It commonly forms in intergrowths with finer grained quartz in patches interstitial to plagioclase.

Biotite forms a few phenocrysts up to 1.2 mm in size. Several patches up to 1.5 mm in size may have been original phenocrysts. They are replaced by finer grained, metamorphic biotite, which commonly has very irregular outlines and is intergrown with extremely fine grained quartz. Pleochroism is from straw to medium brown. A few flakes are altered strongly to completely to pseudomorphic chlorite and patches of epidote.

One patch 1.5 mm long at the edge of the section may be secondary after a subhedral, prismatic hornblende phenocryst. It is dominated by very fine grained biotite with lesser quartz, and minor patches of opaque and single grains of apatite. Apatite grains are prismatic and up to 0.2 mm long. Elsewhere, apatite forms a few subhedral grains in quartz and feldspars averaging 0.05-0.07 mm in size.

Several interstitial patches averaging 0.1-0.2 mm in size consist of subradiating to irregular aggregates of very fine grained flakes of chlorite with pleochroism from pale to medium green. One irregular patch up to 1.3 mm across consists of extremely fine grained, radiating clusters of chlorite averaging 0.03 mm across, with minor interstitial Ti-oxide between the clusters.

Opaque forms anhedral equant grains averaging 0.02-0.05 mm in size, and a few tabular grain up to 0.15 mm long, both mainly with biotite.

Zircon forms one acicular grain up to 0.07 mm long in a few quartz grains and and in the hornblende(?) phenocryst.

The rock is a medium grained marble containing abundant wispy lenses of plagioclase-quartz-biotite schist from 0.3-1 mm in width, and some bands up to 3 mm wide containing intimate intergrowths of calcite and silicates. Tremolite forms a few porphyroblasts and fibrous clusters.

calcite	65-70%
plagioclase	12-15
quartz	8-10
biotite	7- 8
tremolite	3- 4
Ti-oxide	0.3
opaque	0.2
sphene	0.1
apatite	trace

Calcite-rich lenses consist of grains averaging 0.2-0.5 mm in size, with a few grains up to 1.5 mm across. Some of these layers contain patches of quartz averaging 0.1-0.2 mm in size. In layers intergrown with silicates, calcite commonly forms elongate grains averaging 0.05-0.1 mm in length oriented parallel to foliation.

Plagioclase occurs in lenses averaging 0.2-0.8 mm in width. Grains are oriented parallel to foliation and elongate, averaging 0.05-0.2 mm in length. Intergrown with plagioclase are wispy streaks of Ti-oxide parallel to foliation.

Some lenses and layers are dominated by quartz with lesser calcite and silicates. Quartz grains average 0.05-0.15 mm size.

Biotite is concentrated in layers up to 3 mm wide in which it is intergrown intimately with calcite. Biotite flakes average 0.05 mm in size. Pleochroism is from pale to medium brown. In these layers, plagioclase forms disseminated, extremely fine grains containing moderately abundant dusty opaque. Biotite also is moderately abundant in a few plagioclase-rich lenses; in these it forms flakes averaging 0.05-0.2 mm long oriented parallel to foliation.

Tremolite occurs as subradiating to radiating patches averaging 0.1-0.3 mm in size of fibrous grains averaging 0.1 mm long. A few lenses up to 2 mm long consist of these aggregates. Bordering a few calcite-rich layers are scattered aggregates of subradiating, prismatic grains from 0.5-1.2 mm long.

Opaque is concentrated in a few lenses as anhedral grains averaging 0.03-0.1 mm in size. It also forms disseminated grains averaging 0.03-0.07 mm in size.

Sphene forms irregular grains averaging 0.05-0.2 mm in size.

Apatite forms subhedral grains averaging 0.05-0.07 mm long.

Sample 88-183**Banded Calc-silicate Rock: Plagioclase-Diopside-Quartz-Chlorite-K-feldspar-Tremolite/Actinolite; Veins and Veinlets of Epidote-K-feldspar-(Tremolite)**

The rock is strongly compositionally banded, with layers rich in one or more of plagioclase, diopside, quartz, chlorite, and K-feldspar, with lesser, disseminated tremolite/actinolite and sphene. A vein and a few veinlets are of epidote-K-feldspar.

plagioclase	40-45%	sphene	0.7%
diopside	20-25	Ti-oxide	0.2
quartz	17-20	hematite	minor
chlorite	7- 8	epidote	minor
K-feldspar	4- 5	apatite	trace
tremolite/actinolite	1- 2		
veins and veinlets			
epidote-K-feldspar-(tremolite)	2- 3		

Plagioclase forms anhedral grains averaging 0.03-0.08 mm in size in most layers, with slightly coarser or finer grains dominant in a few layers. Alteration is slight to sericite.

Diopside is concentrated in a few layers as anhedral granular grains averaging 0.02-0.2 mm in size and locally as subhedral prismatic grains averaging 0.3-0.7 mm in size. Larger prismatic grains generally are oriented parallel to foliation. In one coarser grained layer, it forms several porphyroblasts averaging 1.5-2 mm across.

Quartz is concentrated in layers up to 1.5 mm wide as anhedral, equant grains averaging 0.0005-0.1 mm in size. In many of these layers it is intergrown intimately with K-feldspar grains up to 0.5 mm in size. A few quartz-rich layers contain moderately abundant tremolite/actinolite grains averaging 0.1-0.2 mm in size; some of these have skeletal outlines.

K-feldspar is concentrated in seams up to 1 mm wide, with or without quartz, as grains averaging 0.05-0.3 mm in size, and in finer grained seams with quartz, chlorite, and plagioclase.

Chlorite is concentrated in some layers with plagioclase as clusters of very fine grained flakes, commonly containing patches of Ti-oxide. It is colorless to very pale green.

Tremolite/actinolite forms scattered, commonly ragged prismatic grains averaging 0.1-0.2 mm in size in quartz and plagioclase. Pleochroism is from pale to light yellowish green. A few clusters up to 0.3 mm in size are of extremely fine grained, fibrous aggregates.

Sphene forms moderately abundant, anhedral, equant to slightly elongate grains up to 0.4 mm across, mainly associated with coarse grained diopside.

Epidote forms a few lensy aggregates up to 1 mm long parallel to foliation adjacent to the vein.

Ti-oxide (semiopaque) is concentrated moderately in cryptocrystalline seams associated with some finer grained layers dominated by plagioclase and lesser chlorite.

Hematite forms a few patches up to 0.03 mm in size of cryptocrystalline aggregates, mainly in K-feldspar and quartz.

Apatite forms subhedral prismatic grains averaging 0.08-0.12 mm long.

A vein averaging 0.5 mm wide is dominated by fine to very fine grained epidote, with scattered patches of very fine grained K-feldspar, and local patches of extremely fine grained, fibrous tremolite(?).

Layers averaging 0.5-1.5 mm wide of quartz-(plagioclase) are interlayered with layers dominated by muscovite, biotite, and sericite. A few layers contain moderately abundant porphyroblasts of cordierite (partly altered to sericite-chlorite), and minor porphyroblasts of andalusite.

quartz	35-40%	ilmenite	0.2%
muscovite	10-12	Ti-oxide	minor
biotite	10-12	tourmaline	minor
plagioclase	12-15	zircon	trace
cordierite	4- 5	pyrite	*
sericite	8-10	(after cordierite and plagioclase)	
sericite-chlorite(?)	1- 2	(after cordierite)	
andalusite	0.2	veinlets	
clinozoisite(?)	0.1	hematite/limonite	0.5

Quartz forms anhedral grains averaging 0.05-0.3 mm in size.

Plagioclase forms anhedral grains averaging 0.05-0.1 mm in size, intergrown with quartz. Alteration is slight to sericite. In mica-rich layers, some extremely fine grained aggregates of sericite probably are secondary after very fine grained plagioclase.

Muscovite is concentrated in certain layers up to 2 mm wide as subparallel flakes averaging 0.3-1.5 mm in length.

Biotite is concentrated in some layers as anhedral flakes averaging 0.1-0.2 mm in size. Scattered, commonly ragged porphyroblasts averaging 0.2-0.5 mm in size commonly are oriented at a high angle to the foliation. Pleochroism is from nearly colorless to light reddish brown. In a few narrow layers, biotite is altered strongly to pseudomorphic chlorite.

Cordierite forms elongate porphyroblasts averaging 0.5-1 mm long, with a few up to 2 mm across and 1 cm long (in hand sample); these are concentrated in a few layers and are intergrown intimately with sericite and biotite. Cordierite commonly is altered to pseudomorphic aggregates of extremely fine grained to cryptocrystalline sericite-chlorite(?), with minor to moderately abundant limonite giving it a light to medium yellow color in thin section. The dark green color in hand sample comes from chlorite.

Andalusite forms one ragged porphyroblast up to 1 mm across intergrown in a muscovite-rich layer with ragged porphyroblasts of altered cordierite.

Clinozoisite (or possibly andalusite) forms equant, subhedral grains averaging 0.12-0.15 mm across in mica-rich layers. The mineral has moderately high relief (1.70) and low birefringence (0.010), with no cleavage.

Ilmenite forms tabular grains averaging 0.08-0.15 mm long, commonly oriented parallel to cleavage of micas. Ti-oxide forms subhedral prismatic grains averaging 0.07-0.1 mm long concentrated with micas.

Tourmaline forms subhedral prismatic grains up to 0.1 mm long. Most grains are perpendicular to the section, with euhedral cross sections up to 0.07 mm across. Pleochroism is from pale to medium yellowish green. Zircon forms anhedral to subhedral prismatic grains averaging 0.01-0.02 mm in size in biotite; grains commonly have dark pleochroic halos. Pyrite forms a very few grains up to 0.01 mm across in quartz.

Limonite forms irregular patches averaging 0.1-0.5 mm in size, and bright reddish orange in color. Hematite/limonite forms wispy, late seams averaging 0.02-0.03 mm wide parallel to foliation.

The rock is well banded and consists of intimately intergrown, irregular lenses of about equal amounts of calc-silicate and marble. The calc-silicate is dominated by diopside and lesser plagioclase/epidote, with lesser K-feldspar and chlorite, and accessory garnet, biotite/phlogopite, and opaque.

calcite	40-45%
diopside	35-40
plagioclase	7- 8
epidote	4- 5
K-feldspar	4- 5
chlorite	2- 3
garnet	1
opaque/hematite	0.2
biotite	0.2
sphene	0.1
veinlet	
epidote	0.2

Calcite forms equant grains averaging 0.2-0.5 mm in size. Calcite-rich lenses generally are relatively free of calc-silicates.

Diopside forms irregular, interlocking aggregates of grains averaging 0.1-0.5 mm in size.

Plagioclase forms anhedral to subhedral grains averaging 0.05-0.2 mm in size. Some patches of plagioclase are altered to extremely fine grained to cryptocrystalline patches of epidote.

K-feldspar forms equant grains averaging 0.05-0.2 mm in size, and locally is concentrated in lenses of interlocking grain averaging 0.1-0.3 mm in grain size.

Chlorite is concentrated in a few layers as clusters of flakes averaging 0.07-0.15 mm in size, mainly intergrown with plagioclase and lesser diopside.

Garnet forms a few patches of anhedral grains with anomalous extinction up to 1.5 mm in size, intergrown with diopside, and in part containing extremely fine grained inclusions of diopside(?).

Opaque (pyrite?) forms grains averaging 0.03-0.1 mm in size. Some are replaced in part by red-brown hematite. Lenses up to 0.1 mm long of ilmenite(?) are parallel to foliation in a few plagioclase-rich lenses. Some of these are rimmed by and altered to Ti-oxide. Several wispy lenses contain disseminated grains of opaque averaging 0.01 mm in size in diopside and in calcite.

Biotite forms flakes averaging 0.05 mm in size concentrated in a few seams parallel to foliation with Ti-oxide and minor opaque. pleochroism is from pale to light/medium brown.

Sphene forms subhedral to anhedral grains averaging 0.05-0.3 mm in size.

A veinlet 0.1 mm wide is of very fine grained epidote.

The rock is dominated by aggregates of sericite-(muscovite-chlorite-biotite), in part after andalusite, plagioclase and possibly other alumino-silicates, with less abundant patches of quartz, concentrations of ragged, relic andalusite grains, and disseminated clusters of sillimanite and flakes of biotite. Limonite forms late seams and patches.

sericite	65-70%
quartz	15-17
andalusite	8-10
chlorite	3- 4
sillimanite	2- 3
biotite	2- 3
tourmaline	0.3
cordierite/plagioclase	0.1
ilmenite	0.2
Ti-oxide	0.1
apatite	minor
limonite	1

Sericite and much less muscovite, chlorite, and biotite forms patches up to several mm across of extremely fine to very fine, unoriented grains. Some of the patches contain moderately abundant, relic, ragged, strongly fractured fragments of andalusite, which suggests that andalusite grains were up to 2 mm in size. Some sericite patches may be secondary after plagioclase.

Quartz is concentrated in lenses and patches as anhedral, equant grains averaging 0.1-0.2 mm in size, with a few up to 0.6 mm across.

Biotite forms scattered ragged flakes averaging 0.1-0.3 mm in length. Pleochroism is from pale brown to medium brownish red.

Sillimanite forms subradiating clusters of elongate prismatic grains up to 0.5 mm long.

Chlorite forms a few patches of extremely fine to very fine grained aggregates intergrown coarsely with sericite, and disseminated flakes in other sericite-rich patches.

Opaque (ilmenite?) forms tabular grains averaging 0.07-0.15 mm in length. It is common in andalusite. Ti-oxide forms prismatic grains up to 0.1 mm long, and a few equant grains up to 0.35 mm across.

Tourmaline forms subhedral to euhedral, prismatic grains averaging 0.05-0.15 mm in size, with a few ragged grains and aggregates up to 0.7 mm across. Pleochroism is from nearly colorless to medium brownish green.

One cluster up to 1 mm across consists of anhedral grains of cordierite or plagioclase averaging 0.1-0.4 mm in size; they are altered moderately to sericite, and contain minor dusty opaque inclusions.

Apatite forms anhedral to subhedral grains averaging 0.03-0.07 mm in size, mainly associated with quartz.

Limonite forms disseminated patches and seams, which give the rock a pale brown color. Seams average 0.02-0.1 mm in width.

The sample is a well foliated, slightly banded schist dominated by muscovite and quartz, with porphyroblasts of andalusite (altered strongly to sericite) and of biotite (altered moderately to chlorite). Locally the rock contains relic fold noses outlined by aggregates of muscovite-(quartz) oriented roughly perpendicular to foliation.

muscovite	30-35%	late seams	
quartz	30-35	hematite/limonite	2- 3%
andalusite	15-17		
biotite	12-15		
plagioclase	0.5	(possibly 3-4% if some sericite is	
limonite/hematite	1- 2	after plagioclase)	
ilmenite/Ti-oxide	0.5		
tourmaline	*		
zircon	*		

Muscovite forms subparallel flakes averaging 0.2-0.7 mm long, which define the prominent foliation in the rock. Some layers are dominated by muscovite with scattered to abundant grains of biotite, and others consist of intimate intergrowths of muscovite and quartz.

Quartz forms anhedral grains averaging 0.05-0.15 mm in size, commonly intergrown with muscovite.

Andalusite(?) forms porphyroblasts up to several mm long, elongated parallel to foliation. Many occur in muscovite-rich layers. Most are altered completely to extremely fine grained sericite, and a few contain minor relic patches of original andalusite up to 0.25 mm across. One porphyroblast 1.3 mm long is relatively fresh; it contains abundant inclusions of quartz and a few veinlets and patches of sericite. One large porphyroblast contains abundant ragged, relic patches of pink andalusite(?) averaging 0.05-0.1 mm in size surrounded by sericite. Altered porphyroblasts commonly contain abundant inclusions of extremely fine grained quartz and extremely fine to very fine grained muscovite, and subparallel, slender plates of ilmenite, all elongated parallel to foliation. Borders against the groundmass of quartz-muscovite are gradational with increasing abundance of quartz and muscovite inclusions in the porphyroblasts. Some aggregates of sericite intergrown more finely with quartz and muscovite may be secondary after plagioclase; however, textures are gradational from these to andalusite porphyroblasts.

Biotite forms porphyroblasts averaging 0.3-0.8 mm in size, commonly oriented at a moderate angle to foliation. Pleochroism is from pale brown to medium reddish brown. About one-third of the grains are altered moderately to strongly to chlorite with minor patches of Ti-oxide.

Plagioclase forms a cluster of anhedral grains averaging 0.2-0.3 mm in size in one lens with biotite. Alteration is slight to sericite.

Ilmenite (in part altered to Ti-oxide) forms lenses averaging 0.1-0.2 mm in length, and locally up to 0.6 mm long, oriented parallel to foliation, and concentrated in andalusite porphyroblasts.

Hematite/limonite forms ragged patches averaging 0.1-0.4 mm in size, commonly associated with biotite.

Tourmaline forms a few subhedral grains averaging 0.03-0.05 mm in size, with pleochroism from light to medium olive green.

Zircon forms anhedral grains averaging 0.01 mm in size, enclosed in biotite and surrounded by dark, pleochroic halos.

Late fracture-filling seams averaging 0.01-0.05 mm wide are filled with opaque hematite/limonite. One large patch is up to 0.5 mm wide and several mm long.

The schist is dominated by muscovite and quartz with lesser biotite and minor feldspars. It was deformed strongly by shear folds, with development of closely spaced (0.2-0.7 mm) folds with moderate recrystallization of micas along the axial planes.

muscovite	40-45%
quartz	40-45
biotite	10-12
plagioclase	2- 3
K-feldspar	0.5
epidote	0.2
opaque	0.2
apatite	trace
hematite	0.1
veinlet	
K-feldspar-(sphene)	0.1

Quartz forms anhedral grains averaging 0.02-0.07 mm in size, with a few coarser grained lenses and layers in which grains average 0.05-0.1 mm in size.

Muscovite forms flakes averaging 0.05-0.1 mm in length intergrown with quartz, and coarser grained aggregates parallel to the secondary foliation. The ratio of quartz to muscovite varies moderately between broad diffuse layers.

Biotite forms ragged to subhedral flakes averaging 0.05-0.3 mm in size, with a few up to 0.8 mm long. Pleochroism is from pale brown to medium orangish brown. Some coarser grains and clusters of grains are porphyroblasts which are oriented at a high angle to the secondary foliation. Many coarser biotite grains are concentrated in one folded primary (?) layer averaging 0.5 mm in width, and along a few axial planes of secondary folds.

Epidote forms cryptocrystalline to extremely fine grained aggregates, moderately concentrated along wispy seams parallel to original foliation (primary layering?).

Plagioclase and lesser K-feldspar form patches up to 0.3 mm in size of extremely fine grained, interlocking aggregates. They are moderately concentrated in layers averaging 0.15 mm with quartz.

Opaque forms disseminated grains and clusters up to 0.6 mm long of grains averaging 0.03-0.07 mm in size. Many are replaced by red-brown hematite.

Apatite forms disseminated, subhedral to anhedral grains averaging 0.02-0.03 mm in size.

Tourmaline forms a very few euhedral to subhedral prismatic grains with cross sections averaging 0.02 mm across. Cross sections are medium green in color. All grains are oriented perpendicular to the plane of the thin section.

Fold axes commonly are defined by seams of hematite/limonite. In some fold axes, micas are recrystallized into very to fine grained aggregates parallel to fold axes and up to 0.2 mm wide.

A late discontinuous veinlet up to 0.07 mm wide cuts across the folded rock at a high angle. It is dominated by very fine grained K-feldspar, with scattered, subhedral grains of sphene averaging 0.02-0.05 mm in size.

The sample is a well foliated schist dominated by quartz and biotite with much less plagioclase and minor muscovite, and with moderately abundant porphyroblasts of andalusite, and minor ones of an unknown, altered mineral, Mineral X.

quartz	30-35%	sillimanite	trace
biotite	25-30	tourmaline	trace
andalusite	17-20	zircon	trace
plagioclase	8-10		
Mineral X	3- 4		
muscovite	2- 3		
ilmenite/Ti-oxide	1- 2		
limonite/hematite	1		

Quartz forms anhedral, equant grains averaging 0.05-0.12 mm in size. A few coarser grained quartz-rich lenses contain grains up to 1 mm long; these lenses commonly are bordered in part by thin zones of plagioclase.

Plagioclase forms anhedral, equant grains averaging 0.05-0.08 mm in size. Some are fresh and some are altered moderately to strongly to sericite.

Biotite forms ragged flakes averaging 0.2-0.7 mm in size. Many are parallel to foliation, and a moderate number appear to be porphyroblasts at a high angle to foliation. Pleochroism is from pale brown to medium to deep red or brownish red. Some biotite flakes contain moderately abundant needles of Ti-oxide averaging 0.02-0.05 mm long oriented along hexagonal crystallographic directions of biotite.

Andalusite forms ragged to subhedral porphyroblasts averaging 0.7-2.5 mm in size, with a few up to 5 mm long. Many are elongated parallel to foliation, and many contain moderately abundant inclusions of groundmass minerals, mainly biotite, quartz, and ilmenite. Some are twinned or strained, and contain zones of slightly different extinction positions.

In a few layers are elongate, ragged grains (probably porphyroblasts) up to 2.5 mm long of an unknown mineral, Mineral X. It is altered completely to cryptocrystalline to extremely fine grained aggregates of chlorite(?) with the following optical properties: pale pinkish to yellowish grey color, moderate R.I. (1.60), very low birefringence (0.003). Mineral X contains minor to moderately abundant inclusions of micas. Elsewhere, much finer grained clusters of Mineral X are intergrown with biotite in biotite-rich layers. In a few layers, Mineral X occurs as very fine grained aggregates intergrown with quartz and lesser biotite; in these it is altered to chlorite, which in turn appears to be altered to extremely fine grained sericite.

Muscovite forms scattered, commonly slender porphyroblasts up to 1 mm long, commonly oriented at a moderate angle to foliation.

Ilmenite forms tabular grains averaging 0.07-0.15 mm long, with a few up to 0.4 mm long, commonly oriented parallel to foliation.

Sillimanite forms a few clusters of prismatic grains up to 0.15 mm in length.

Tourmaline forms scattered, anhedral prismatic grains up to 0.1 mm long. Color is light to medium olive green.

Zircon forms anhedral grains averaging 0.01 mm in size in biotite; they are surrounded by prominent, dark, pleochroic halos.

Limonite and/or hematite are concentrated in some layers and seams parallel to foliation, where they probably formed by alteration of biotite and remobilization of iron.

Sample 88-260-1

**Plagioclase-Diopside-Quartz-Opaque Calc-silicate
Rock; Lenses of Feldspar-Biotite Schist; Veins of
Quartz-Opaque-Epidote-Tremolite/Actinolite-Diopside**

The rock is a variably banded calc-silicate dominated by plagioclase, diopside, quartz, and opaque, with lesser tremolite/actinolite and minor sphene. A few lenses up to a few mm wide (7 mm in hand sample) are of feldspar-biotite schist. Veins of quartz-opaque-epidote-tremolite/actinolite-diopside-biotite cut the rock in several directions. Some veins have alteration halos in the schist in which biotite is altered to chlorite.

<u>calc-silicate rock</u>	(80% of sample)
plagioclase	55-60%
diopside	20-25
quartz	12-15
opaque (hematite)	4- 5
tremolite/actinolite	2- 3
sphene	0.3
apatite	trace

Plagioclase forms anhedral grains averaging 0.02-0.05 mm in size.

Diopside forms anhedral, equant grains averaging 0.03-0.2 mm in size intergrown with plagioclase. Larger grains (0.3-1 mm) are concentrated moderately in a few layers parallel to foliation; associated with diopside in these layers is minor to moderately abundant opaque, and minor sphene and quartz. A few ragged porphyroblasts are up to 1.5 mm long, and elongated parallel to foliation.

Quartz is concentrated in several patches and lenses as grains averaging 0.05-0.08 mm in size.

Opaque forms irregular patches up to 0.8 mm in size of extremely fine grained aggregates, commonly associated with diopside..

Actinolite/tremolite forms ragged to subhedral porphyroblasts and clusters of porphyroblasts averaging 0.3-0.5 mm in grain size. Pleochroism is from pale to light green. A few grains up to 0.1 mm in size of actinolite/hornblende have pleochroism from light/medium yellowish green to medium green to slightly bluish green.

Sphene forms equant grains averaging 0.1-0.15 mm in size, commonly associated with diopside.

Apatite forms anhedral, equant grains averaging 0.1-0.25 mm across.

schist (12% of sample)

plagioclase	55-60%
biotite	15-17
K-feldspar	4- 5
opaque	1-

Plagioclase and K-feldspar occur as anhedral grains averaging 0.01-0.02 mm in size, intergrown intimately with biotite flakes and much less opaque lenses of similar grain size. Aggregates are strongly foliated. Some layers are gradational between the two main types, being well foliated and dominated by extremely fine grained plagioclase, with lesser very fine grained quartz and diopside. In few layers and in broad halos bordering some of the veins, biotite is altered to pseudomorphic chlorite.

(continued)

<u>veins</u>	(8% of sample)
quartz	55-60
opaque	17-20
tremolite/actinolite	12-15
epidote	4- 5
diopside	3- 4
biotite	1- 2

Veins up to 0.8 mm wide are dominated by fine grained quartz with patches dominated by one or more of opaque, tremolite/actinolite, epidote, and diopside. Tremolite/actinolite is pale to light green as in the host rock.

Opaque forms ragged patches averaging 0.1-0.5 mm in size in many veins. In the largest quartz-rich vein, it forms aggregates of fine to medium grains, which in places occupy the entire width of the vein. Interstitial to opaque in this vein are grains of epidote up to 0.6 mm in size, and a few grains of sphene up to 0.2 mm across.

Epidote also forms several, commonly braided veinlets up to 0.1 mm wide, in which it is associated with tremolite/actinolite, opaque and lesser biotite.

Diopside forms several patches of grains averaging 0.1-0.3 mm in size in one of the larger veins.

Biotite forms very fine to extremely fine grained aggregates in lensy patches with epidote or tremolite/actinolite. Pleochroism is from pale to light greenish brown.

Sample 260-2

**Marble: Partly Replaced by Garnet-Diopside with
Phlogopite-rich Seams**

The sample is a very fine to fine grained marble which is moderately replaced in irregular patches by garnet and lesser diopside. Seams and lenses are dominated by phlogopite-(opaque), with lesser ones of chlorite-(tremolite).

calcite	60-65%
garnet	20-25
diopside	10-12
phlogopite	3- 4
chlorite	0.7
opaque	0.1
tremolite	minor
Ti-oxide	minor

Calcite forms submosaic aggregates of grains averaging 0.1-0.3 mm in size, with a few patches of grains up to 0.7 mm in size.

Garnet forms anhedral, commonly irregular grains averaging 1-3 mm across. Extinction generally is slightly anomalous. Garnet and diopside commonly contain abundant dusty inclusions.

Diopside forms disseminated, anhedral grains averaging 0.05-0.3 mm in size, in part associated with garnet.

Phlogopite is concentrated in wispy, slightly warped seams up to 0.5 mm wide as flakes averaging 0.05-0.1 mm in length. Pleochroism is from nearly colorless to light orangish brown.

Chlorite forms clusters up to 0.3 mm in size of very fine grained flakes. The clusters contain minor interstitial patches of Ti-oxide. Some of these are associated with phlogopite-rich seams, suggesting a common origin or that chlorite was formed by replacement of phlogopite.

Opaque forms wispy lenses in the cores of phlogopite-rich seams.

Tremolite forms a few prismatic grains up to 0.08 mm long associated with chlorite.

Sample 88-365-1**Strongly Deformed Carbonaceous Tremolite Schist**

The sample is a deformed, lensey schist composed of tremolite with minor chlorite and opaque and a trace of apatite. The rock was deformed strongly, producing a lensey texture parallel to a moderately prominent foliation.

tremolite	93-94%
opaque	3- 4
chlorite	1- 2
semiopaque (Ti-oxide?)	1- 2
apatite	0.1

Tremolite forms fibrous to prismatic, generally unoriented aggregates of grains averaging 0.07-0.15 mm in length. Lenses and patches up to 1.5 mm wide which are free of opaque inclusions are intergrown with others containing disseminated opaque in a wide variety of textures and abundance. In some patches tremolite forms subparallel aggregates of fibrous grains; these commonly have a light orange color.

Chlorite forms lenses up to 0.3 mm across of very fine grained flakes intergrown with tremolite.

Opaque occurs in two main textures. Some patches and lenses up to 1 mm wide contain very abundant dusty to extremely fine grained, disseminated opaque and/or semiopaque intergrown with chlorite and lesser tremolite. Opaque also is concentrated in wispy lenses parallel to foliation as anhedral grains averaging 0.02-0.05 mm in size intergrown intimately with tremolite. Much of the dusty to extremely fine grained opaque probably is carbonaceous. Coarser grained opaque probably is oxides. The semiopaque mineral may be Ti-oxide.

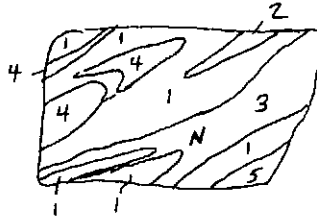
Apatite forms disseminated, euhedral to subhedral prismatic grains up to 0.12 mm long.

Tight warps and minor fold noses on the scale of 0.2-0.5 mm are common in the foliation plane as defined by tremolite elongation and by thin bands containing moderately abundant to abundant dusty opaque. These textures indicate that the rock was strongly sheared and partly recrystallized.

In the weathered zone at one end of the section are several limonite veinlets averaging 0.03-0.05 mm wide, and a few patches of red-brown hematite and brown limonite averaging 0.1-0.5 mm in size. Surrounding the veins, tremolite is stained yellow by limonite.

Sample 88-365-2 Deformed Banded Calc-silicate: Plagioclase-Epidote-Diopside-(Garnet-Quartz-Chlorite-Tremolite); Replacement Patches of Epidote-Calcite, Veinlets of Epidote

The rock is strongly folded and compositionally zoned as indicated in the sketch below (Note: replacement patches of epidote-(calcite) are not shown on the sketch).



Zone 1 Epidote-rich, extremely fine grained

This zone is strongly foliated and dominated by cryptocrystalline epidote with disseminated grains of quartz (10-12%) averaging 0.01-0.03 mm in size. Epidote probably is mainly after plagioclase. Opaque (trace) forms wispy lenses parallel to foliation. This zone commonly shows tight warps and kinks in foliation. It contains a few coarser grained patches up to 0.5 mm long of epidote (0.05-0.1 mm grain size) and a few diopside-rich lenses of similar size and grain size.

Zone 2 Quartz-Chlorite-Tremolite

This zone is enclosed by Zone 1 and is somewhat gradational in texture into it. Quartz (40-50%) forms grains averaging 0.02-0.05 mm in size. These are surrounded by extremely fine grained aggregates of chlorite, tremolite, and epidote, and enclosed in a few coarser skeletal grains of chlorite. Opaque and Ti-oxide (1-2%) form extremely fine grained lenses parallel to foliation. Foliation is warped tightly in a few kink folds whose axial planes are parallel to the main foliation in the rock.

Zone 3 plagioclase-Diopside replaced by Epidote-Calcite

This zone is composed of an intimate intergrowth of plagioclase and diopside. In much of the zone, plagioclase forms equant grains averaging 0.03-0.1 mm in size surrounded by granular aggregates of diopside averaging 0.01-0.02 mm in size. In the fold nose (marked "N") on the sketch, the zone is replaced by a fine grained aggregate of epidote and lesser, commonly interstitial calcite. Near this replacement patch are a few lenses of plagioclase-diopside averaging 0.05-0.15 mm in size. Opaque (pyrite?) forms disseminated, equant, anhedral patches averaging 0.05-0.2 mm in size.

Zone 4 Plagioclase-Diopside replaced by Epidote

This zone is similar to the coarser grained part of Zone 3. Replacement patches up to a few mm across are of fine to locally medium grained epidote, which commonly contain relic inclusions of extremely fine grained diopside.

Zone 5 Diopside-Plagioclase-Garnet-(Quartz-Epidote)

Zone 5 is dominated by granular diopside averaging 0.02-0.07 mm in grain size, with lesser plagioclase averaging 0.05-0.1 mm in size. Garnet (4-5%) forms disseminated grains and clusters of grains averaging 0.07-0.2 mm in size. Quartz and calcite are minor interstitial minerals, forming grains averaging 0.05-0.07 mm in size. Epidote (3-4%) with lesser calcite forms a few patches up to 0.7 mm long by 0.15 mm wide interstitial to garnet and diopside. Opaque (1-2%) (pyrite altered partly to hematite) forms scattered subhedral to anhedral grains averaging 0.05-0.2 mm in size.

The rock is cut by a few discontinuous, lensy veinlets up to 0.07 mm wide of epidote, and by two veinlets 0.01-0.02 mm wide of chlorite(?).

**Sample 88-383 Strongly Deformed Plagioclase-Quartz-Chlorite Schist
with Layers of Calcite-Quartz-(K-feldspar); Secondary
Tremolite and Epidote along contacts; Veinlets of Epidote**

The rock is mainly a very fine grained schist dominated by plagioclase and chlorite with lesser muscovite and quartz, each concentrated in certain layers. It contains patches up to a few cm across containing layers of coarser grained calcite and quartz interlayered with those of plagioclase-chlorite. The rock was deformed intensely by shear folding, with moderate recrystallization of phyllosilicates along axial planes of shear folds, and moderate offset of layers (at least several cm) along some shear planes.

<u>schist</u>		<u>carbonate-rich layers</u>	
plagioclase	35-40%	calcite	20-25%
chlorite	17-20	quartz	7- 8
quartz	5- 7	tremolite	1- 2
muscovite	4- 5	epidote	1
tremolite	2- 3	K-feldspar	0.5
epidote	0.3		
opaque	0.3	<u>veinlets</u>	
Ti-oxide	0.2	epidote	minor
apatite	minor		

Plagioclase forms anhedral grains averaging 0.02-0.05 mm in size. Alteration is slight to locally moderate to sericite.

Chlorite forms clusters of very fine grains (0.03-0.05 mm) intergrown with plagioclase. Associated with chlorite is minor to locally moderately abundant Ti-oxide in patches averaging 0.01-0.03 mm in size. In noses of folds, chlorite commonly forms slightly coarser grained aggregates.

Quartz forms anhedral, equant grains averaging 0.03-0.07 mm in size, and is concentrated in layers up to 1 mm wide.

Muscovite is concentrated in certain patches as grains averaging 0.02-0.05 mm in length; they are intergrown with plagioclase and are oriented parallel to primary foliation.

Tremolite forms ragged clusters of very fine, fibrous grains, concentrated in certain layers, commonly with quartz, and along the border of the calcite-quartz patches. Epidote forms very fine grained, irregular patches averaging 0.1-0.2 mm across, mainly near the calcite-quartz layers. Much or all of the tremolite and epidote probably were formed by metasomatism associated with deformation.

Opaque forms lenses averaging 0.05-0.1 mm long, largely concentrated along axial planes of shear folds. Phlogopite forms scattered flakes averaging 0.05 mm in size; pleochroism is from pale to light orange-brown. Apatite forms subhedral to euhedral, equant grains averaging 0.05 mm in size.

Calcite and lesser quartz form layers(?) up to several mm wide. Calcite forms grains averaging 0.1-0.7 mm in size. Quartz forms grains averaging 0.1-0.2 mm in size. Bordering these layers and within both calcite-quartz layers and plagioclase-chlorite layers are abundant, irregular aggregates of very fine grained, fibrous tremolite, with a pale to light brown color, probably caused by limonite, and lesser patches of cryptocrystalline to very fine grained epidote. K-feldspar is concentrated as very fine grains and aggregates near the borders of the calcite-quartz patches.

The rock was cut by closely spaced (0.01-0.07 mm) similar folds. Axial planes of many were sheared out, and chlorite, Ti-oxide, and locally muscovite were recrystallized into very fine grained aggregates parallel to fold axes.

Epidote forms very fine grained veinlets averaging 0.02-0.03 mm wide; these cut axial planes of shear folds.

Sample 88-400**Plagioclase-Chlorite-Quartz-(Tremolite-Muscovite-Phlogopite-Epidote-K-feldspar) Schist; Replacement Lens of Epidote-(Quartz-Calcite); Veinlets of Epidote**

The rock is a well foliated schist dominated by plagioclase and chlorite, with lenses rich in quartz. It was strongly deformed with a prominent foliation developed along axial planes of shear folds, and original layers largely obliterated, except in a few fold noses. Parallel to foliation is a lens several mm wide of epidote with much less quartz and calcite, surrounded by an alteration halo rich in epidote. A few wispy veinlets are of epidote.

plagioclase	20-25%
quartz	15-17
chlorite	12-15
epidote	12-15
tremolite	2- 3
muscovite/sericite	1- 2
K-feldspar	1- 2
phlogopite	0.7
Ti-oxide	0.5
opaque	0.3
fluorite	minor
apatite	trace
replacement lens	
epidote	17-20
quartz	3- 4
calcite	1
opaque	0.1
veinlets	
epidote	minor

Plagioclase forms slightly interlocking grains averaging 0.03-0.12 mm in size. Alteration is slight to moderate to sericite and epidote, with more intense alteration to epidote near the epidote-rich replacement lens.

Chlorite forms clusters of flakes averaging 0.05-0.15 mm in size, and locally up to 0.3 mm in size (with quartz). Intergrown with it is minor phlogopite, with textures suggesting that both may be secondary after biotite. Ti-oxide forms extremely fine grained patches intergrown with chlorite.

Quartz is concentrated in certain lenses up to 1.5 mm wide as slightly interlocking grains averaging 0.05-0.15 mm in size. Interstitial to quartz are flakes and clusters of flakes of chlorite of similar grain size.

Epidote is concentrated in a few wispy seams parallel to foliation along one side of the section, and in irregular patches bordering the replacement zone. Grains are irregular and average 0.02-0.1 mm in size.

Tremolite is concentrated in a few seams up to 0.5 mm wide as fibrous, very fine grained aggregates intergrown with plagioclase, epidote, and quartz.

Muscovite and much less phlogopite occur along one side of the section in a few thin layers interlayered with similar ones of epidote (after plagioclase). Muscovite flakes average 0.05-0.2 mm in length.

Opaque and semiopaque form lenses up to 0.1 mm long parallel to foliation, and are concentrated in wispy seams along foliation. Opaque also forms anhedral patches up to 0.4 mm in size, mainly associated with quartz and chlorite.

(continued)

K-feldspar forms a few patches up to 0.7 mm in size of grains averaging 0.2-0.3 mm in size, mainly associated with quartz-rich lenses and intergrown with finer grained quartz. It also is concentrated with epidote in the halo bordering the replacement lens.

Fluorite forms a few lenses and patches up to 0.9 mm long of anhedral grains 0.1-0.2 mm in size. Associated with the largest lens is an irregular patch of opaque (pyrite?) up to 0.25 mm across.

Apatite forms subhedral, prismatic grains up to 0.2 mm long.

The replacement zone is dominated by submosaic to irregular, moderately interlocking epidote grains averaging 0.5-1 mm in size. These grade into finer grained aggregates of epidote and quartz, in which skeletal to interstitial epidote surrounds subrounded quartz grains averaging 0.03-0.1 mm in size. Bordering this zone, plagioclase is altered moderately to strongly to epidote and much less K-feldspar. Interlocking epidote grains commonly contain abundant dusty opaque inclusions. Calcite forms anhedral, interstitial grains averaging 0.15-0.5 mm in size.

Epidote forms wispy veinlets averaging 0.02-0.03 mm in width.

Sample 88-413 Porphyritic Hornblende-Biotite Potassic Quartz Diorite

Phenocrysts of hornblende, clusters and minor phenocrysts of biotite, and minor phenocrysts of plagioclase are set in a groundmass of plagioclase and quartz, with lesser biotite and minor K-feldspar.

phenocrysts			
hornblende	4- 5%	(in rock; 1-2% in section)	
biotite clusters	2- 3		
plagioclase	2- 3		
groundmass			
plagioclase	60-65	opaque	0.3%
quartz	17-20	apatite	0.2
biotite	4- 5	zircon	trace
K-feldspar	3- 4		

In the hand sample, hornblende forms subhedral phenocryst up to 1.3 cm long. These are poorly represented in the thin section. Some are recrystallized moderately to much finer grained aggregates in slightly disoriented positions. Along their borders are replacement patches and overgrowths of aggregates of fine grained biotite, with lesser opaque and apatite. Pleochroism of hornblende is from pale to medium green. Some grains are replaced by pseudomorphic actinolite with pleochroism from pale to light green.

A few ragged clusters up to several mm across consist of biotite flakes averaging 0.5-1 mm in size. Biotite also forms a few phenocrysts up to 2 mm across. Phenocrysts commonly have very irregular outlines. Pleochroism is from light to medium/dark brownish green to brown. Some of the clusters contain a few ragged grains of hornblende averaging 0.15-0.2 mm in size.

Plagioclase forms anhedral to subhedral grains averaging 1-2 mm in size. Many show strong compositional zoning from broad cores of about **An40-45** to narrow rims of about **An30-35**. Alteration is concentrated in cores of grains and is weak to moderate to sericite and much less epidote. Many grains appear altered in very irregular, very fine patches to more-sodic plagioclase or possibly K-feldspar.

Quartz forms anhedral grains averaging 0.5-2 mm in size, commonly interstitial to subhedral plagioclase. Some grains contain minor inclusions of plagioclase averaging 0.1-0.2 mm in size.

Biotite forms subhedral to anhedral flakes averaging 0.3-0.1 mm in size. Pleochroism is from pale to medium/dark greenish brown to brown, with a few grains having a slightly reddish brown color. A few flakes are altered in ragged patches along cleavage to pseudomorphic chlorite and minor Ti-oxide, and a few of these contain a few anhedral grains up to 0.3 mm in size of epidote.

K-feldspar forms interstitial grains averaging 0.5-1.5 mm in size. Many contain inclusions of subhedral to euhedral prismatic, and anhedral, equant plagioclase grains averaging 0.1-0.2 mm in size.

Hornblende forms a few grains in the groundmass averaging 0.1-0.3 mm in size. Pleochroism is from light to medium green or bluish green.

Opaque forms anhedral grains averaging 0.07-0.2 mm in size, mainly associated with biotite. One elongate patch 1 mm long occupies an interstitial wedge among plagioclase grains. It is altered to deep red-brown hematite along its borders.

Apatite forms subhedral to euhedral prismatic to equant grains averaging 0.05-0.15 mm in size, mainly associated with biotite. A few subhedral apatite grains in feldspars and quartz average 0.07-0.2 mm in length, with one subhedral prismatic grain up to 0.4 mm long.

Zircon forms a few anhedral grains up to 0.02 mm in size in biotite; they have weak pleochroic halos.

Sample 88-414**Leucocratic (Biotite-Muscovite) Quartz Monzonite**

Scattered phenocrysts of quartz, plagioclase, K-feldspar and biotite are set in a groundmass of K-feldspar, plagioclase, and quartz, with minor biotite and muscovite.

phenocrysts	
quartz	2- 3%
plagioclase	2- 3
K-feldspar	1
biotite	1
groundmass	
K-feldspar	30-35
plagioclase	25-30
quartz	20-25
biotite	2- 3
muscovite	3- 4
apatite	minor
hematite	minor

K-feldspar forms a few anhedral phenocrysts up to 1.7 mm long; these are Carlsbad twins with somewhat irregular twin contacts. Dusty hematite inclusions are common. In the groundmass K-feldspar forms anhedral grains averaging 0.5-1 mm in size.

Plagioclase forms anhedral to subhedral grains averaging 0.5-1.5 mm in size, with a few up to 2 mm across. Some grains show strong growth zones, with broad cores of **An35-40** grading sharply to thin rims of **An15-20**. Alteration is slight to locally strong to sericite, and is concentrated in cores of grains. Some grains are replaced moderately to strongly by irregular patches of K-feldspar.

Quartz forms a few, equant, anhedral phenocrysts from 1.5-2.5 mm in size; these have irregular borders intergrown with the groundmass, and a few contain moderately abundant inclusions of groundmass minerals. In the groundmass, quartz forms anhedral grains and patches averaging 0.2-0.5 mm in grain size.

Biotite forms ragged flakes averaging 0.5-0.8 mm in length, with a few up to 1.5 mm across, in part concentrated in clusters up to 2 mm in size. Alteration is strong to complete to pseudomorphic chlorite with lesser Ti-oxide, and locally minor epidote. In some grains, wispy lenses parallel to foliation contain extremely fine grained sericite and/or quartz and plagioclase.

Muscovite forms clusters of ragged to subhedral flakes averaging 0.1-0.2 mm in size, in part after plagioclase, and in part probably primary. Some clusters have a subradiating texture. Associated with a few are a few clusters of chlorite flakes of similar grain size.

Hematite forms clusters of anhedral to subhedral grains averaging 0.03-0.05 mm in size in plagioclase.

Apatite forms anhedral, equant grains averaging 0.02-0.05 mm in size, commonly associate with biotite, and a few subhedral to euhedral prismatic grains up to 0.2 mm long..

Sample 88-422-1**Banded Diopside Calc-silicate Rock replaced by Garnet-(Diopside-Quartz-Epidote-Calcite) Skarn**

The sample contains relic, finely banded textures of the parent calc-silicate rock composed of diopside. It is replaced in irregular patches by skarn minerals dominated by garnet, with much less diopside, quartz, calcite, and epidote, and minor chlorite. A few late veinlets are of quartz-(calcite).

calc-silicate	
diopside	25-30%
skarn	
garnet	63-67
diopside	4- 5
quartz	1
calcite/aragonite	1
epidote	1
chlorite	0.3

Relic diopside aggregates occur in bands parallel to foliation. Grains are irregular to locally prismatic in outline, and range from 0.02-0.07 mm in size. Some grade into coarser grained diopside, which may have been recrystallized during skarn formation.

Garnet forms anhedral grains up to a few mm across. Locally against quartz, grains show euhedral outlines. Some grains are isotropic, and some show strongly anomalous extinction, in part associated with delicate growth zones in cyclically twinned crystals. A few, larger interstitial quartz patches are surrounded by equant garnet grains averaging 0.1 mm in size.

Diopside forms subhedral to anhedral, commonly prismatic grains averaging 0.2-0.5 mm in size. These occur in clusters, some of which may have been recrystallized from finer grained diopside of the host rock.

Quartz forms interstitial patches of grains averaging 0.03-0.1 mm in size, with a few patches containing grains up to 0.5 mm across.

Calcite/aragonite forms interstitial patches of grains averaging 0.1-0.5 mm in size. Grains commonly are elongate, prismatic in habit, suggesting aragonite. Some aggregates of very fine grained diopside contain abundant interstitial, poikilitic calcite grains.

Epidote forms a few grains from 0.2-1.2 mm in size in interstitial patches, commonly associated with lesser calcite and chlorite and minor quartz.

Chlorite forms interstitial patches of very fine to fine grained flakes associated with calcite and epidote.

Late, in part braided, crosscutting veinlets up to 0.1 mm wide are of quartz with a few lenses of calcite.

Sample 88-422-2

**Banded Diopside-Garnet-Plagioclase Calc-silicate
and K-feldspar/Plagioclase-Biotite Schist;
Replacement Patches of Plagioclase-Epidote**

The center of the sample a finely banded calc-silicate rock composed of diopside, garnet, and minor plagioclase. It is interlayered with a banded schist with layers dominated by K-feldspar or biotite. Foliation in the schist is warped slightly, especially along borders of the calc-silicate rock. A few replacement patches are of coarser grained plagioclase-epidote.

a) calc-silicate rock

diopside	75-80%
garnet	15-17
plagioclase	5- 7
spene	0.2
calcite	0.2
quartz	minor

Diopside forms aggregates of grains averaging 0.02-0.05 mm in size, with a few coarser grained patches of ragged grains averaging 0.1-0.3 mm in size.

Garnet forms extremely fine to very fine grained aggregates, intergrown intimately with diopside. These grade into diffuse porphyroblasts up to a few mm long, containing abundant diopside inclusions and oriented parallel to foliation. Extinction commonly is anomalous.

Plagioclase forms patches of anhedral grains averaging 0.05-0.08 mm in size, intergrown with lesser diopside and minor quartz.

Sphene forms anhedral grains averaging 0.05-0.1 mm in size, and a few subhedral to euhedral porphyroblasts up to 0.4 mm long.

Calcite forms interstitial grains averaging 0.1-0.2 mm in size.

Quartz forms minor interstitial grains up to 0.3 mm in size, commonly associated with interstitial plagioclase.

b) schist

K-feldspar/plagioclase	55-60%
biotite	20-25
quartz	12-15
diopside	4- 5
Ti-oxide	0.2

K-feldspar/plagioclase, with minor to moderately abundant quartz is concentrated in layers up to several mm wide as grains averaging 0.01-0.03 mm in size. Strong variation in the K-feldspar/plagioclase ratio is suggested by the banded distribution of yellow stain on the offcut block. Layers have a well developed foliation defined by elongation of feldspar grains and by wispy trains and seams of Ti-oxide and diopside.

Layers up to 1 mm wide are dominated by extremely fine grained biotite intergrown with wispy lenses of extremely fine grained quartz. Biotite is pleochroic from nearly colorless to medium reddish brown.

A few layers contain moderately abundant coarser grains of quartz averaging 0.05-0.15 mm in size intergrown with lenses of extremely fine grained K-feldspar and lesser diopside.

Diopside is moderately abundant in some K-feldspar-rich layers, either as extremely fine disseminated grains and patches, or as lenses of very fine grains.

A few replacement patches and lenses up to a few mm across consist of medium to coarse grained plagioclase bordered by anhedral to euhedral, fine to medium grained epidote.

Sample 88-428**Strongly Deformed Plagioclase-Chlorite-Quartz Schist with Interlayers of Calcite; Veinlet of K-feldspar-Chlorite-Quartz-Opaque (Pyrite?)**

The rock is a very fine grained schist dominated by plagioclase and chlorite with lesser quartz. Calcite and lesser quartz are concentrated in interlayers up to 2 mm wide. The rock was deformed intensely, resulting in closely spaced (0.1-0.5 mm) shear folds, with moderate shearing along planes parallel to axial planes of folds. Original foliation is preserved in strongly rotated fold limbs and a few fold noses between shear planes.

plagioclase	35-40%
chlorite	25-30
calcite	17-20
quartz	15-17
Ti-oxide/opaque	1
phlogopite	minor
pyrite	minor
K-feldspar	minor
apatite	*
veinlet	
K-feldspar-chlorite-quartz-opaque	0.3

Plagioclase forms anhedral grains averaging 0.01-0.03 mm in size. Alteration is slight to sericite.

Chlorite forms flakes averaging 0.03-0.1 mm in size intergrown with plagioclase and quartz. Chlorite is pale green in color.

Quartz forms grains averaging 0.03-0.05 mm in size intergrown in some layers with plagioclase and chlorite, and slightly coarser grains intergrown with calcite and in quartz-rich layers(?) bordering calcite-rich patches.

Calcite forms lenses averaging 0.5-2 mm wide of grains averaging 0.2-0.6 mm in grain size.

Phlogopite forms scattered grains averaging 0.02-0.03 mm in size associated with chlorite. Pleochroism is from pale to light orangish brown.

Ti-oxide and opaque form extremely fine to cryptocrystalline aggregates concentrated in trains parallel to shear fold axes and less commonly parallel to original, contorted layering. They generally are associated with chlorite.

Pyrite forms disseminated, subhedral grains averaging 0.02-0.07 mm in size in the nose of a fold in a fine grained patch of chlorite-quartz. Pyrite is altered strongly to red-brown hematite.

K-feldspar forms scattered very fine grains and aggregates; its distribution is shown on the stained offcut block.

Apatite forms subrounded grains averaging 0.07-0.1 mm in size.

A discontinuous veinlet averaging 0.2 mm wide consist of very fine grained K-feldspar and lesser patches of chlorite, of quartz, and of opaque, probably a sulfide.

**Strongly Deformed Plagioclase-Quartz-Muscovite-
Phlogopite Schist; Calcite-rich Layers; Carbonaceous
Opaque Seams parallel to Shear Fold Axial Planes**

The rock was a plagioclase-quartz-mica schist with interlayers of calcite (limestone). It was strongly deformed by shear folding which produced closely spaced (0.1-0.5 mm) shear folds and recrystallization of carbonaceous opaque and muscovite along axial planes of shear folds. Most of the original bedding planes were destroyed; they are preserved locally in fold noses. The rock (except calcite-rich lenses) are cut by veinlets of K-feldspar-chlorite-calcite.

plagioclase	35-40%	phlogopite	0.5%
quartz	20-25	K-feldspar	0.2
muscovite/sericite	12-15	hematite/pyrite	0.1
calcite	15-17	apatite	trace
chlorite	3- 4		
carbonaceous opaque	2- 3		
veinlets			
K-feldspar-chlorite-calcite		0.2	

Plagioclase-rich layers and lenses are dominated by plagioclase grains averaging 0.01-0.03 mm in size, intergrown with muscovite/sericite, chlorite, and minor quartz. Plagioclase is replaced slightly by muscovite/sericite.

These grade into lenses with equal amounts of plagioclase and quartz, and further into quartz-rich lenses. The latter generally contain grains averaging 0.05-0.1 mm in size.

Calcite-rich lenses are dominated by calcite averaging 0.1-0.5 mm in grain size and much less quartz averaging 0.07-0.15 mm in grain size. K-feldspar forms scattered grains up to 0.2 mm in size, and commonly is concentrated on borders of these lenses (see stained offcut block for distribution)

Chlorite forms flakes averaging 0.03-0.07 mm in size. intergrown with plagioclase and quartz. It is nearly colorless.

Phlogopite forms clusters of grains averaging 0.03-0.05 mm in size intergrown with sericite. It is pleochroic from nearly colorless to pale or light brown.

Carbonaceous opaque forms dusty to extremely fine grains concentrated strongly with muscovite/sericite in seams up to 0.5 mm wide parallel to axial planes of shear folds.

Opaque (pyrite?) forms a few clusters of grains averaging 0.05-0.15 mm in size, commonly surrounded by quartz and/or K-feldspar grains averaging 0.1-0.2 mm in size. Opaque commonly is replaced by semiopaque hematite.

Apatite forms subrounded to subhedral, equant grain up to 0.15 mm in size.

One veinlet averages 0.15-0.2 mm wide and consists of a core dominated by very fine grained K-feldspar and a rim of chlorite of similar size. In K-feldspar, a few wispy lenses of chlorite are oriented parallel to walls of the veinlet. The veinlet ends abruptly at a band of calcite-quartz, begins again on the other side, and then peters out to a stringer of K-feldspar 0.01 mm wide. In some lenses bordering the veinlet, muscovite/sericite is altered to chlorite.

A second veinlet, which begins on the other side of the broad calcite-rich lens, is 0.07 mm wide at one end and consists of calcite. It becomes narrower and turns into chlorite. On the other side of a smaller calcite-rich layer it peters out to two veinlets of K-feldspar averaging 0.01-0.02 mm wide. Both veinlets cut across carbonaceous seams parallel to shear fold axial planes.

Sample 88-450**Strongly Contorted Calc-silicate: Epidote-Chlorite-Tremolite-(Calcite-K-feldspar-Quartz);
Veinlets of K-feldspar and of Calcite**

A very finely banded calc-silicate rock is dominated by granular epidote with lesser chlorite and tremolite, and minor calcite, quartz and K-feldspar. Layers were contorted strongly and sheared moderately; the deformation is probably the same as that which produced a strong secondary foliation in the more-pelitic rocks. The prominent compositional banding seen in hand sample is much less prominent in thin section. Color variations in hand sample are reflected in thin section in rather subtle variations in proportions of epidote, tremolite, and chlorite, with darker green layers containing more abundant chlorite. Coarser grained replacement patches are of calcite-chlorite-(K-feldspar-quartz). A few veinlets are of K-feldspar and of calcite.

epidote	70-75%
chlorite	10-12
tremolite	8-10
K-feldspar	2- 3
quartz	1- 2
calcite	1- 2
Ti-oxide	0.3
replacement	
calcite	2- 3
chlorite	1
K-feldspar	0.3
quartz	minor
veinlets	
K-feldspar	0.1
calcite	trace

Epidote forms granular aggregates averaging 0.01-0.02 mm in grain size. Interstitial to epidote is minor to moderately abundant chlorite, and minor quartz, calcite, and K-feldspar in variable proportions.

Tremolite forms prismatic to acicular grains averaging 0.07-0.15 mm in length. These are concentrated in wispy seams and patches up to 0.8 mm wide. In much of the rock, tremolite grains are oriented parallel to fold axes of the shear folds. A few distinct layers up to 0.2 mm wide are dominated by tremolite with or without chlorite. Some of the layers are oriented at a high angle to foliation, and represent limbs of open folds. Other vague layers are defined by variation in tremolite abundance from 0-10%.

Chlorite forms interstitial grains averaging 0.02-0.05 mm in size, and is concentrated in a few coarser grained lenses (layers?). Ti-oxide forms disseminated, extremely fine grained patches associated with chlorite.

Interstitial calcite grains average 0.02-0.05 mm in size, and are concentrated in a few broad layers.

Replacement patches averaging 1-1.5 mm in size consist of calcite and chlorite with less abundant K-feldspar and/or quartz. Smaller replacement patches are dominated by calcite. Grain size of calcite averages 0.1-0.3 mm.

A few veinlets up to 0.1 mm wide are of K-feldspar; the largest one contains minor interstitial grains of calcite.

A few veinlets up to 0.03 mm wide are dominated by calcite with a few patches of K-feldspar.

Sample 88-464-1**Banded Calc-silicate Rock: Plagioclase-Diopside-
Quartz-Chlorite-(Calcite-K-feldspar);
Veins of Epidote-(K-feldspar)**

The rock is well foliated, with compositional banding defined by variation in the proportions of major minerals (plagioclase and diopside) and minor minerals (quartz and chlorite), and by variation in grain size. A few veins are of epidote-(K-feldspar).

plagioclase	40-45%
diopside	30-35
quartz	7- 8
chlorite	7- 8
calcite	2- 3
K-feldspar	2- 3
tremolite/actinolite	1- 2
epidote	0.5
Ti-oxide	0.2
opaque	0.1
sphene	minor
apatite	trace
veins	
epidote-(K-feldspar)	1- 2

Plagioclase forms aggregates of anhedral grains averaging 0.05-0.2 mm in size, with a few layers containing grains up to 0.5 mm across. Alteration is slight to moderate to sericite.

Diopside is concentrated in a coarser grained layer at one end of the section, in which it forms ragged, anhedral grains averaging 0.7-1.5 mm in length, with a few up to 2.5 mm. Grains are elongate parallel to foliation. Interstitial to diopside is lesser plagioclase and K-feldspar. In a few other layers, diopside forms much finer grained aggregates, and a few skeletal grains intergrown with plagioclase and quartz grains averaging 0.05-0.08 mm in size. In the calcite-rich layer it forms corroded grains up to 0.7 mm in size.

Quartz is concentrated in a few layers from 0.7-1.5 mm in width. It forms anhedral aggregates of grains averaging 0.05-0.12 mm in size. Commonly associated with quartz is much less chlorite.

Chlorite occurs as clusters averaging 0.2-0.5 mm in size and locally up to 1 mm long of very fine grained flakes with a pale green color. It is most common interstitial to plagioclase. Associated with chlorite are patches averaging 0.02-0.03 mm in size of Ti-oxide. Some patches have a brownish green color, suggesting that chlorite was formed by replacement of biotite.

Calcite is concentrated in one layer 1-1.5 mm wide as very fine grains intergrown intimately with fibrous tremolite and coarsely with patches of epidote.

K-feldspar forms anhedral grains averaging 0.1-0.2 mm in size in irregular patches and in thin lenses parallel to foliation.

Tremolite/actinolite occurs in a few layers as aggregates of fibrous to locally prismatic grains averaging 0.1-0.2 mm in length. It is light yellowish green in color.

Epidote is concentrated in the calcite-rich layer in two patches up to 1.5 mm in size of irregular, very fine grains intergrown slightly with calcite and tremolite. Elsewhere it occurs as replacement(?) patches near the late veins. In one quartz-rich layer epidote(?) forms interstitial to skeletal aggregates intimately intergrown with very fine grained quartz.

Opaque forms a few tabular grains averaging 0.3-0.4 mm long, and more abundant equant to tabular grains averaging 0.03-0.1 mm in size.

(continued)

Ti-oxide forms lenses averaging 0.05-0.08 mm long in some plagioclase-rich layers; lenses occur within plagioclase grains and are oriented parallel to foliation.

Sphene forms scattered equant grains averaging 0.05-0.07 mm in size.

Apatite forms subhedral to euhedral grains averaging 0.05-0.07 mm in size associated with chlorite and plagioclase.

Crosscutting veins averaging 0.2-0.3 mm wide are dominated by fine grained, submosaic epidote, with scattered grains of similar texture of K-feldspar, and minor elongate grains of calcite/aragonite. A few veinlets averaging 0.02-0.05 mm in width are dominated by K-feldspar with minor epidote.

Sample 88-464-2**Banded Marble: Partly Replaced by
Diopside-(Tremolite-Phlogopite/Chlorite)**

The sample is a medium grained marble which was altered partly to calc-silicates (diopside, lesser tremolite, and minor chlorite and phlogopite), which are concentrated in layers and seams parallel to a prominent foliation. K-feldspar and minor plagioclase and quartz are of uncertain origin (primary versus secondary).

calcite	55-60%
diopside	30-35
tremolite	4- 5
K-feldspar	3- 4
chlorite	1
phlogopite	0.5
quartz	0.5
muscovite	0.5
plagioclase	0.3
opaque	0.1

Calcite forms anhedral grains averaging 0.3-0.8 mm in size.

Diopside is concentrated in bands up to 1.5 mm wide as aggregates of ragged grains averaging 0.1-0.5 mm in size.

Tremolite occurs in some layers with diopside and in some with lesser phlogopite as aggregates of fibrous to prismatic grains averaging 0.1-0.5 mm in length, with a few up to 1 mm long. Grains commonly are oriented parallel to foliation.

K-feldspar and much less plagioclase form anhedral grains averaging 0.2-0.5 mm in size and concentrated moderately in some layers associated with diopside or tremolite. The distribution of K-feldspar can be seen in the stained offcut block.

Pale green chlorite forms a few patches up to 1 mm long of flakes from 0.1-0.4 mm long. Interstitial to chlorite flakes are patches of extremely fine grained Ti-oxide. It may be secondary after phlogopite.

Phlogopite is concentrated in a few tremolite-rich bands up to 1 mm wide in which it forms elongate flakes averaging 0.3-0.7 mm in length parallel to foliation. It also forms a few patches up to 0.6 mm in size of flakes averaging 0.05-0.1 mm in size. Pleochroism is from pale to light or medium brown.

Muscovite/sericite is concentrated at one end of the section as a lens 2 mm long and 0.8 mm wide in a tremolite-rich band. Very fine grains are in subparallel orientation. This patch may be secondary after an alumino-silicate porphyroblast.

Quartz forms equant, interstitial grains averaging 0.1-0.2 mm in size.

Opaque forms wispy seams and trains of grains averaging 0.005-0.015 mm in size, mainly associated with diopside and tremolite.

Sample 88-468-1

**Diopside-rich Calc-silicate replaced by
Garnet-(Quartz-Diopside-Calcite-Sphalerite)
Skarn; Veinlets of Calcite**

The original rock was an extremely fine grained, well foliated calc-silicate dominated by diopside. It was recrystallized largely to skarn dominated by garnet with interstitial patches of quartz, diopside, and lesser calcite, with minor sphalerite and sphene. Calcite forms a few veinlets.

relic calc-silicate	
diopside	10-12
skarn	
garnet	75-80%
quartz	4- 5
diopside	2- 3
calcite	1- 2
sphalerite	minor
sphene	minor
veinlets	
calcite	0.2

Diopside forms aggregates of extremely fine to very fine grains, mainly in delicate bands which define the foliation and the texture of the original calc-silicate.

Garnet forms anhedral to subhedral grains averaging 1-2 mm in size. Most show weak to moderate anomalous extinction which commonly outlines fine growth zones along borders of grains.

Diopside forms ragged to subhedral interstitial grains averaging 0.1-0.5 mm in size intergrown with quartz. Quartz forms interstitial patches between garnet grains, in most patches grain size averages 0.02-0.03 mm or 0.07-0.1 mm. In a few patches, grains are up to 1 mm in length.

Calcite forms anhedral grains averaging 0.05-0.3 mm in size. In some patches, calcite contains very abundant, subrounded, tiny inclusions of diopside.

Sphene forms an anhedral grain 0.2 mm by 0.4 mm. It may form extremely fine grains intergrown with diopside.

Sphalerite forms equant, irregular grains averaging 0.1-0.5 mm long. It is dark orangish to reddish brown in color. Sphalerite grains are associated with very fine grained quartz aggregates, or less commonly intergrown intimately with diopside.

Chlorite forms minor interstitial patches up to 0.1 mm across of very fine grained, pale green grains.

Calcite forms an irregular, somewhat braided vein averaging 0.05-0.1 mm in width and several wispy veinlets averaging 0.01-0.02 mm in width.

Sample 468-2

Banded Marble with Silicates: Diopside, Phlogopite, Plagioclase, Tremolite, K-feldspar, and Quartz.

The sample is a very fine to fine grained marble containing disseminated grains and lenses dominated by silicates, including diopside, phlogopite, tremolite, plagioclase, and quartz. Seams of K-feldspar, diopside, plagioclase, and phlogopite are concentrated moderately along one side of the section. Generally tremolite is concentrated towards the other side of the section.

calcite	88-90%
diopside	4- 5
phlogopite	2- 3
plagioclase	1- 2
tremolite	1
K-feldspar	0.5
quartz	0.3
opaque	minor

Calcite forms anhedral, equant grains averaging 0.1-0.4 mm in size, with a few elongate grains commonly oriented parallel to foliation up to 0.8 mm long. A few narrow bands up to 0.3 mm wide contain grains averaging 0.05-0.1 mm in size.

Diopside forms ragged to subhedral grains averaging 0.1-0.5 mm in size. These are disseminated in the rock, and locally concentrated in lenses and seams with other silicates. Some grains are fresh, and others are altered moderately to strongly to minerals of uncertain composition, probably including tremolite and opaque (hematite?).

Phlogopite forms single flakes and clusters of flakes averaging 0.05-0.15 mm in length, with a few up to 0.35 mm long. Pleochroism is from very pale to light/medium brownish orange.

Plagioclase forms anhedral grains averaging 0.1-0.15 mm in size in a few lenses.

Tremolite is concentrated in the other side of the section as disseminated, subhedral prismatic grains up to 0.3 mm long.

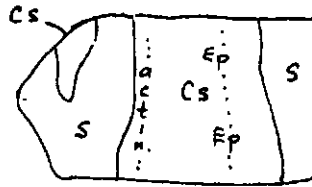
K-feldspar is concentrated in one band up to 0.3 mm wide along one side of the section as anhedral grains averaging 0.1-0.2 mm in size. Elsewhere it forms scattered grains of similar size.

Quartz forms equant grains averaging 0.05-0.1 mm in size, with a few up to 0.3 mm across.

Opaque (hematite?) forms disseminated grains averaging 0.01 mm in size and a few anhedral grains averaging 0.02-0.05 mm in size.

Sample 468-3**Contorted, Banded Quartz-Plagioclase-Biotite Schist
and Plagioclase-Diopside-Quartz-Epidote Calc-silicate**

The sample contains contorted layers of two distinct rock types, quartz-plagioclase-biotite schist and plagioclase-diopside-quartz-epidote calc-silicate (see sketch below). The schist shows numerous tight fold noses, with axial planes parallel to the major foliation. In a few places, contacts between types are gradational.

schist

plagioclase	35-40%
quartz	35-40
biotite	15-17
K-feldspar	3- 4
muscovite	2- 3
chlorite	1- 2
opaque	0.3
tremolite	0.2
apatite	minor
tourmaline	trace

In quartz-rich layers, quartz forms anhedral grains averaging 0.05-0.1 mm in size. Where plagioclase and biotite are more abundant, quartz generally is finer grained. A few coarser grained quartz-rich lenses up to 0.3 mm wide occur in the plagioclase-biotite-rich zones.

Plagioclase and K-feldspar form grains averaging 0.01-0.03 mm in size, with a few grains from 0.05-0.1 mm in size. K-feldspar is concentrated in some layers as shown in the stained offcut block.

Biotite and chlorite each form disseminated grains intergrown with plagioclase; these average 0.01-0.03 mm in size. Coarser grains of biotite commonly occur in fold noses with quartz and plagioclase; these average 0.05-0.1 mm in size. Pleochroism of biotite is from pale to medium orangish brown. Chlorite is pale green in color, and probably formed by replacement of biotite. Commonly along borders of chlorite grains are patches of cryptocrystalline Ti-oxide.

Muscovite and biotite are concentrated locally in seams up to 1.5 mm wide; grains are subparallel and parallel to foliation.

Opaque forms disseminated grains and lenses parallel to foliation, with grain size averaging 0.02-0.05 mm. Some trains of opaque outline fold axes. Some, possibly late opaque patches and lenses are replaced by red-brown hematite/limonite.

Apatite forms anhedral, equant grains averaging 0.05 mm in size.

Tourmaline forms a few prismatic grains up to 0.2 mm long. Pleochroism is from nearly colorless to medium green.

(continued)

b) calc-silicate

plagioclase	40-45%
diopside	17-20
quartz	12-15
epidote	12-15
K-feldspar	2- 3
actinolite	1- 2
calcite	1- 2
sphene	0.5
opaque	0.2
apatite	minor

Plagioclase forms anhedral, equant grains averaging 0.02-0.05 mm in size, and a few patches of coarser grains averaging 0.2-0.4 mm in size.

Diopside forms ragged grains averaging 0.1-0.4 mm in size. A few are altered to secondary minerals of uncertain composition, probably including tremolite/actinolite.

Quartz forms patches of equant grains averaging 0.05-0.15 mm in size, commonly interstitial to plagioclase-diopside aggregates.

Epidote forms a few patches of anhedral, slightly interlocking grains averaging 0.2-0.5 mm in size.

K-feldspar forms disseminated grains and clusters of grains associated with very fine grained plagioclase.

Actinolite forms subhedral grains averaging 0.1-0.2 mm in size, and fibrous aggregates up to 0.2 mm in size of extremely fine grains. Actinolite is pale to light green in color. It is concentrated mainly along one border with the schist (see sketch).

Sphene forms anhedral grains averaging 0.1-0.3 mm in size, mainly associated with diopside.

Calcite forms interstitial grains up to 0.5 mm in size, concentrated in a zone with coarser grained plagioclase and diopside.

Opaque is concentrated in one narrow diopside-rich band as disseminated grains averaging 0.01-0.02 mm in size.

Apatite forms euhedral grains averaging 0.05 mm across.

A few wispy veinlets up to 0.02 mm wide are of cryptocrystalline carbonate.

Sample 88-470**Altered Peridotite cut by vein of
Chlorite/Serpentine-Tremolite**

The sample contains ragged relic grains of olivine, opaque and possibly altered clinopyroxene in a groundmass of tremolite-chlorite-opaque. A late vein is of chlorite/serpentine and tremolite.

olivine	25-30%
serpentine	2- 3
magnetite-opaque	4- 5
clinopyroxene(?)	4- 5
tremolite	45-50
chlorite	7- 8
talc	0.5
epidote(?)	trace
apatite	trace
vein	
chlorite/serpentine	2- 3
tremolite	1- 2

Olivine forms ragged, anhedral grains averaging 0.5-2 mm in size. Grains are fractured strongly and replaced along veinlets averaging 0.03 mm wide by serpentine and magnetite. Serpentine forms aggregates oriented perpendicular to the walls of the fractures.

Tremolite forms subhedral to euhedral grains up to 1.7 mm in size. Many of these contain abundant ragged patches of magnetite. These may be secondary after original clinopyroxene.

Tremolite also forms secondary prismatic to fibrous aggregates of colorless grains in random orientation, with grain size averaging 0.2-0.5 mm in size, with a few up to 1 mm. A few of these occur in olivine, and some appear to postdate the major period of fracturing in olivine.

Chlorite forms patches of extremely fine to locally very fine grains interstitial to olivine and to tremolite. Locally it shows a subradiating texture. Chlorite is nearly colorless with grey and locally anomalous blue birefringence. Patches of chlorite interstitial to olivine generally are free of opaque inclusions.

Locally associated with chlorite are irregular patches of extremely fine grained talc. A few patches contain extremely fine grains of a mineral of high relief, possibly epidote, intergrown intimately with chlorite.

Primary opaque (partly magnetite) forms a few anhedral, equant grains averaging 0.2-0.3 mm in size, commonly intergrown with olivine.

Secondary opaque (in part magnetite), forms a few aggregates up to 0.7 mm across. It is strongly concentrated in a few other patches averaging 0.5-0.8 mm in which it is intergrown with tremolite. Elsewhere, it forms disseminated, extremely fine grains in tremolite aggregates and to a lesser extent in olivine grains.

Apatite forms a few subhedral to euhedral prismatic grains up to 0.4 mm long. They commonly have grey cores caused by abundant dusty opaque inclusions.

One late vein up to 0.8 mm wide cuts the rock. Where the vein cuts olivine, the latter is altered to light greyish brown chlorite/serpentine along a closely spaced network of parallel, braided fractures. Where the vein cuts tremolite, tremolite was recrystallized into ragged, prismatic to feathery aggregates oriented more or less along the length of the vein.

**Sample 88-477 Foliated Feldspathic Dunite altered to Tremolite;
Vein of Serpentine/Chlorite-Magnetite; Late Vein of Ankerite**

Compositional layering between bands of coarser grained olivine and finer grained bands of olivine-(plagioclase) define a prominent banding in the rock, which probably was primary. Elongation of olivine grains in the coarser layers may have formed by recrystallization during deformation, but this is not definite. Olivine (and possibly plagioclase) is altered in irregular patches to tremolite.

olivine	50-55%
plagioclase	4- 5
tremolite	35-40
opaque	2- 3
apatite	trace
veins	
1) serpentine/chlorite-magnetite	1- 2
2) ankerite	0.1

Olivine forms anhedral, elongate grains averaging 1-2 mm in size, with a few up to 5 mm long. These are concentrated in lenses and bands parallel to a moderate primary foliation. Interbanded with these are primary zones of much finer grained, equant grains of olivine averaging 0.1-0.2 mm in size, and secondary zones dominated by tremolite, possibly after finer grained olivine-(plagioclase). Coarser olivine is fractured moderately along irregular fractures, and along a few of these is altered to serpentine-magnetite.

Intergrown with some finer grained bands of olivine is interstitial plagioclase as grains averaging 0.03-0.1 mm in size.

Opaque forms primary anhedral, equant grains averaging 0.1-0.15 mm in size, with a few up to 0.7 mm in size.

Tremolite forms unoriented aggregates of extremely fine to very fine grain size, which replace olivine, partly in bands averaging 0.5-1.5 mm wide parallel to foliation, and partly in irregular patches and seams, in part controlled by fractures in coarser olivine grains. A few ragged to subhedral prismatic grains of tremolite are up to 0.7 mm long.

Apatite forms a few clusters of subhedral, prismatic grains averaging 0.15 mm in length. They contain moderately abundant dusty opaque inclusions giving the grains a light grey appearance.

Parallel to foliation are a few late, braided vein zones up to 0.6 mm wide in which olivine is altered to chlorite/serpentine and magnetite.

Two subparallel, late, crosscutting, braided veinlets up to 0.05 mm wide are of extremely fine grained ankerite. They do not intersect the other vein.

The rock is a well foliated, compositionally banded schist dominated by layers rich in one or more of quartz, muscovite, andalusite, and sericite (after plagioclase and/or andalusite). Biotite forms porphyroblasts in muscovite-rich layers.

quartz	30-35%	chlorite	1- 2%
muscovite	30-35	ilmenite/Ti-oxide	1
andalusite	12-15	tourmaline	trace
sericite	12-15		
biotite	5- 7		

Quartz is concentrated in layers up to 1.5 mm wide as equant, anhedral grains averaging 0.05-0.1 mm in size. Intergrown with quartz-rich layers are interstitial, disseminated flakes of muscovite averaging 0.03-0.07 mm in size.

Other layers contain similar quartz grains intergrown with patches of sericite of similar size (probably after plagioclase), and more abundant muscovite and biotite flakes. With increasing abundance of micas, these grade into mica-rich layers.

Some lenses and layers up to a few mm wide are dominated by parallel aggregates of muscovite, which grade outwards to intergrowths of muscovite and quartz. In the muscovite-rich zones are moderately abundant porphyroblasts of biotite averaging 0.2-0.7 mm in size, and of muscovite averaging 0.1-0.3 mm in size. A few biotite porphyroblasts up to 1.5 mm long are elongate parallel to foliation. Fresh biotite is pleochroic from light brown to medium brownish-red. In one half of the rock, many biotite flakes are altered slightly to completely to pseudomorphic chlorite; slightly altered biotite is pleochroic from pale brown to light/medium greenish brown.

As well, these lenses contain elongate, tabular grains of Ti-oxide (after ilmenite) oriented parallel to foliation. A few Ti-oxide lenses occur in biotite porphyroblasts, and are oriented parallel to cleavage of biotite. Ti-oxide also forms equant, disseminated grains averaging 0.05-0.1 mm in size.

Andalusite is concentrated in one layer up to several mm wide in which it forms porphyroblasts averaging 2-5 mm in size. It commonly contains tabular inclusions of ilmenite averaging 0.1-0.3 mm long, oriented parallel to foliation, and commonly slightly warped. Some of these extend from the porphyroblast into the host rock. Some porphyroblasts also contain abundant poikilitic inclusions of quartz, and textures in these are very similar to those in adjacent aggregates of quartz-muscovite-(ilmenite). Associated with, and commonly surrounding andalusite grains is an extremely fine grained aggregate dominated by sericite, much of which is secondary after andalusite. Some of this is intergrown with irregular, coarser flakes of muscovite, and some contains lenses of ilmenite/Ti-oxide as in the andalusite grains.

Chlorite forms irregular patches up to 1 mm in size of fine grained flakes interstitial to andalusite porphyroblasts. Some of these patches have radiating textures, and some are intergrown coarsely with patches of quartz grains averaging 0.1-0.3 mm in size.

Tourmaline forms disseminated subhedral prismatic grains averaging 0.02 mm in cross section and 0.07 mm in length. Pleochroism is from colorless to medium olive green. Zircon forms scattered grains up to 0.01 mm in size in biotite; they are surrounded by prominent dark, pleochroic halos averaging 0.05 mm across.

In a few, tight kink folds muscovite is warped strongly and recrystallized slightly along the axial plane of the kink fold.

Sample 88-544 **Well Banded Calc-silicate Rock: Plagioclase-Diopside-Quartz; replacement patch of Quartz-Diopside-Sphene; Interlayers of Plagioclase-Quartz-Biotite Schist**

The rock is dominated by a banded calc-silicate rock dominated by plagioclase and diopside with a few quartz-rich lenses. Grain size varies strongly between layers, which average 1-5 mm in width. A few layers in the sample (one in the section) are of plagioclase-biotite-quartz schist. Locally calc-silicate layers are distorted and replaced by a large patch of quartz-diopside-sphene.

<u>calc-silicate rock</u>		<u>replacement patch</u>	
plagioclase	40-45%	quartz	12-15%
diopside	17-20	diopside	5- 7
quartz	3- 4	sphene	1- 2
sphene	1		
Ti-oxide	0.1		
chlorite	trace		
apatite	trace		

Plagioclase forms aggregates of grains averaging 0.01-0.03 mm in size in some layers and up to 0.05-0.1 mm in others. Some finer grained aggregates are moderately interlocking, whereas most are granular.

Diopside forms ragged to locally subhedral, in part skeletal porphyroblasts averaging 0.3-1.5 mm in size, with a few up to 2 mm long. Finer grained (0.01-0.03 mm) granular aggregates are common in some layers, and are intergrown intimately with plagioclase.

Quartz forms grains averaging 0.1-0.5 mm in size, and is concentrated in lenses and patches averaging 0.5-1 mm wide. It also forms disseminated grains in some plagioclase-diopside layers.

Sphene forms anhedral to subhedral grains averaging 0.1-0.5 mm in size, mainly associated with diopside.

Ti-oxide is concentrated in a few finer grained, plagioclase-rich layers as lenses parallel to foliation averaging 0.07-0.1 mm long of extremely fine grained aggregates.

Chlorite forms a few patches up to 0.15 mm in size of very fine grained aggregates. Pleochroism is from pale yellowish green to medium green.

Apatite forms subhedral, prismatic grains up to 0.12 mm long oriented parallel to foliation.

An irregular replacement patch up to 1.2 cm across contains a ragged core of equant, coarse grained diopside and lesser sphene averaging 1.5-2.5 mm in grain size. This is surrounded by quartz averaging 0.2-0.6 mm in grain size containing minor to moderately abundant groundmass plagioclase. Contacts with the host rock are gradational with increasing ratio of plagioclase to quartz.

(continued)

plagioclase-quartz-biotite schist

plagioclase	7- 8%
quartz	2- 3
biotite	2- 3
diopside	1
sphene	minor
opaque	minor

Plagioclase forms slightly interlocking aggregates averaging 0.01-0.03 mm in grain size.

Quartz forms equant grains averaging 0.07-0.3 mm in size concentrated in quartz-rich lenses parallel to foliation, and containing minor plagioclase, biotite, and diopside.

Biotite forms ragged flakes averaging 0.05-0.1 mm in size, with a few coarser grains in one layer up to 0.25 mm long. Grains commonly are oriented parallel to foliation, and are concentrated in biotite-rich seams up to 0.1 mm wide or plagioclase-biotite layers up to 0.5 mm wide. Pleochroism is from pale to medium brown.

Diopside forms disseminated grains averaging 0.05-0.1 mm in size.

Opaque forms lenses up to 0.2 mm long of grains averaging 0.03-0.05 mm in size.

Sphene forms anhedral grains up to 0.05 mm in size associated with biotite.

Near the schist layer is a plagioclase-diopside calc-silicate layer containing 2-3% biotite flakes up to 0.3 mm long. In this layer plagioclase is extremely fine grained and diopside forms lensy aggregates of very fine grains parallel to foliation.

Epidote forms irregular veinlets averaging 0.02-0.06 mm wide roughly perpendicular to the foliation. Where the veinlets cut the biotite schist, biotite is altered to chlorite-(Ti-oxide). Where it cuts the calc-silicate layer containing biotite, a vein 0.1-0.15 mm wide of very grained diopside borders one side of the vein.

Sample Faro NW**Biotite Potassic Quartz Diorite Dike**

The sample contains scattered phenocrysts of plagioclase, biotite, and quartz, and clusters of biotite-opaque-(apatite) in a groundmass dominated by plagioclase with less quartz and minor K-feldspar and chlorite. Textures indicate that the rock was not metamorphosed.

plagioclase	60-65%
quartz	20-25
biotite	10-12
K-feldspar	2- 3
chlorite-(Ti-oxide)	1- 2
opaque	1
apatite	0.2
zircon	minor

Plagioclase forms minor subhedral, prismatic phenocrysts averaging 1.5-2.5 mm in size, and subhedral, stubby prismatic grains averaging 0.5-0.8 mm in length. Most show strong growth zoning with broad more-calcic cores (An₃₀) grading sharply to more-sodic rims (An₂₀). Alteration to sericite and lesser calcite and hematite is moderate to locally strong, and is concentrated in the cores.

Quartz forms a few anhedral phenocrysts(?) up to 4 mm in size, and anhedral grains averaging 0.2-0.5 mm in size commonly interstitial to plagioclase. A few coarser quartz grains up to 2 mm across contain minor inclusions of plagioclase averaging 0.1-0.2 mm in size. Grains show slightly wavy extinction, but no recrystallization.

Biotite forms scattered phenocrysts up to 1.7 mm in size and clusters up to a few mm across of anhedral flakes averaging 0.3-0.8 mm in size. Cores of some of the clusters consist of irregular opaque aggregates up to 1.5 mm across. Pleochroism of biotite is from light brown to medium/dark reddish brown or to medium greenish brown. A few biotite flakes are altered slightly on their borders or ends to pseudomorphic, light green chlorite.

Opaque forms anhedral to subhedral grains, probably mainly very fine grained in irregular patches, generally surrounded by biotite.

Carbonate (siderite?) occurs in some mafic patches, as lenses averaging 0.1-0.15 mm long in biotite, and as thin selvages on patches of opaque. It commonly is stained orange/red by limonite.

K-feldspar forms anhedral, interstitial grains averaging 0.3-1 mm in size.

Apatite forms anhedral to subhedral grains averaging 0.05-0.1 mm in size, and a few subhedral prismatic grains up to 0.35 mm long, mainly associated with biotite.

Irregular, interstitial patches up to 1 mm in size consist of very fine grained chlorite and patches of Ti-oxide. Some patches consist of an irregular intergrowth of subradiating aggregates. Chlorite also forms irregular patches and veinlets cutting plagioclase grains and interstitial to plagioclase and quartz.

Zircon forms subhedral to anhedral grains averaging 0.02-0.05 mm in size, mainly in biotite. Many of these have dark pleochroic halos. One corroded, subhedral prismatic grain is 0.25 mm long.

Opaque forms a few wispy veinlets cutting plagioclase grains.

Sample Faro Div**Porphyritic Andesite Dike**

Phenocrysts of plagioclase, hornblende, and minor biotite are set in a groundmass of plagioclase-biotite-(hornblende). A few inclusions are of metamorphic plagioclase-biotite-(opaque).

	phenocrysts	groundmass
plagioclase	15-17%	60-65%
hornblende	5- 7	
actinolite	-	2- 3
biotite	0.5	12-15
opaque	minor	minor
apatite	-	trace
inclusions		
plagioclase-biotite-(opaque)	1- 2	

Plagioclase forms euhedral to subhedral phenocrysts averaging 0.2-1.5 mm in length, and clusters up to 2 mm in size of subhedral to anhedral grains of similar size. Composition is in the andesine range, and grains commonly are strongly zoned from broad cores of about **An50** towards rims from **An45** to **An40**. Most are slightly altered to sericite and/or chlorite, and a few are strongly altered to sericite/muscovite. The latter are associated with biotite phenocrysts altered completely to chlorite-(Ti-oxide). Chlorite commonly occurs along fractures. A few plagioclase phenocrysts up to 2.5 mm in size contain abundant, secondary, extremely fine grained quartz in a sieve-like texture. In these intergrowths, plagioclase is altered moderately to strongly to one or more of sericite, epidote, and minor biotite and chlorite. One anhedral epidote grain 0.12 mm across is red-brown in color, and may be allanite.

Hornblende forms euhedral to subhedral phenocrysts averaging 0.5-1.2 mm in size. A few are relatively fresh. Most are altered to a variety of secondary minerals including pseudomorphic, fibrous tremolite and chlorite, and locally calcite or biotite. The freshest hornblende is light to medium, slightly brownish green in color.

Biotite forms a few subhedral phenocrysts with ragged terminations up to 0.8 mm long. Pleochroism is from pale brown to medium reddish brown. Many smaller biotite flakes contain abundant intergrown Ti-oxide/opaque along hexagonal crystallographic directions in biotite. A few biotite(?) phenocrysts are altered to pseudomorphic chlorite with abundant irregular patches of fine grained plagioclase, and several patches of cryptocrystalline Ti-oxide and minor ones of very fine grained epidote.

Opaque forms anhedral grains up to 0.2 mm in size, commonly associated with mafic phenocrysts.

The groundmass is dominated by anhedral to locally prismatic plagioclase averaging 0.02-0.05 mm in grain size, with disseminated flakes of biotite averaging 0.02-0.30 mm in size and scattered prismatic to locally acicular grains of actinolite averaging 0.05-0.15 mm long. Groundmass biotite is pleochroic from light to medium greenish brown. Apatite forms anhedral to subhedral grains and clusters of grains averaging 0.03-0.05 mm in grain size. Opaque forms dissent to elongate grains averaging 0.02-0.07 mm in size.

A few inclusions averaging 0.7-1.3 mm across consist of anhedral plagioclase grains averaging 0.1-0.2 mm in size intergrown intimately with very fine grained patches of biotite and lesser opaque. Some of the biotite probably is secondary after hornblende.