

APPENDIX 2: THIN SECTION DESCRIPTIONS

611-1-1 Altered olivine gabbro

Plagioclase - about 75%. Large grains, mostly untwinned, some with tapered twins. Some show undulose extinction, but no sign of zoning. Grain shape is generally anhedral with sharp-and-straight to very curvilinear and muted boundaries with other plagioclase grains. Boundaries with mafic phases obscured by incipient alteration. Much of the plagioclase is fractured. Some of the larger fractures contain alteration phases such as serpentine, chlorite and sericite(?). With recrystallized plagioclase.

Olivine - less than 10%. Medium-grained, subhedral, granoblastic. Interstitial to plagioclase; in some places including clinopyroxene or intergrown with it. Ubiquitously cracked, with opaques and/or alteration phases filling these cracks in clusters of grains.

Clinopyroxene - less than 10%. Medium-grained, subhedral; some contain abundant stringers of a very reddish-brown phase (oxide of some sort?) which may or may not be parallel to the parting. Parting is very fine and closely spaced. Generally occurs as cluster of smaller grains, with indistinct grain boundaries. There has been some minor recrystallization along a few grain boundaries. The new pyroxene is much clearer and may contain inclusions of opaques and brown hornblende.

Orthopyroxene - less than 5%, with textures of the clinopyroxene.

Brown hornblende - about 1%. (possibly primary); forms thin rims around pyroxene and olivine; also laths in areas of alteration, here

it may be optically continuous with blue-green hornblende. In one instance shows twinning. May be reaction rim on plagioclase-pyroxene, plagioclase-olivine or pyroxene-pyroxene boundaries. Often includes or adjoins subhedral opaques.

Blue-green hornblende - less than 1%. Found in isolated patches as well as in coronas of primary mafic minerals. Perhaps slightly less abundant than brown hornblende. Rarely is found with opaques, but otherwise similar in shape and habit to brown hornblende.

Actinolite - about 1%. Colorless to blue-green. Forms fibrous aggregates radiating from or parallel to the boundaries of altering mafic phases. Often associated with chlorite and/or talc. In areas of extensive alteration (end of slide away from numbers) intergrown with various unidentified phases.

Talc - forms aggregates as alteration of olivine. Almost always surrounding secondary, anhedral opaques. May also be present in veins.

Chlorite - about 1%. Occurs as outside rim in alteration coronas and as vein material. May cover small or extensive areas in a given field or vein. Forms somewhat acicular mats.

Opaques - may be included in pyroxene, brown hornblende as anhedral grains. Forms in cracks of olivine also as anhedral blebs in talc aggregates. About 1%. Several unidentified alteration phases.

Textures:

Plagioclase forms the primary mineral, and is included in aggregates of olivine and pyroxene. In places appears to have been resorbed by

interstitial liquid. Olivine and pyroxene formed interstitial to plagioclase.

Plagioclases show coarse-grained recrystallization in most areas of the slide. Twin lamellae appear to be of deformation origin - they may be tapered, bent and/or offset (some twins are not clearly defined). Minimal deformation of the mafic phases is detected. It appears that no deformation has occurred since alteration.

Alteration primarily along cracks in plagioclase grains and perimeter of mafic phase groups. Only minor alteration occurs within a cluster of mafic minerals, and that which exists is usually confined to a crack or vein originating in the plagioclase. More hydrous, fibrous or amorphous phases tend to surround less hydrous, more massive mafic minerals. There is some staining and oxidation visible, probably due to weathering in outcrop.

Comments

Alteration of mafic phases in the areas away from the scribed numbers is almost complete, whereas the area near the numbers suffers from some weathering, shows considerably less thermal metamorphism.

611-2-1 (A & B) Olivine-bearing Metagabbro

Plagioclase - 70-80%. Large grains, .2-1.2 cm, may be zoned due to alteration and are highly strained. They have polysynthetic tapered twins, some of which are bent, some kinks and undulose extinction. Some large grains have traits of apatite and rutile needle inclusions. Grain boundaries between large plagioclase grains and mafic minerals or their alteration products are sharp and regular. Boundaries between neighboring large plagioclases may be sharp, almost indistinguishable, or they may contain recrystallized plagioclase grains of less than .5 mm forming mortar texture. Minor sericitic alteration occurs preferentially in the cores of relict grains.

Olivine - about 5-10%. Grains, 1-5 mm, appear as glomerocrysts interstitial to plagioclase. Some larger grains exhibit undulose extinction, kink bands, and/or deformation lamellae. Mesh texture with opaques and talc-chlorite developed. Alteration to amorphous talc + opaques, surrounded by chlorite; or to iddingsite or fibrous pale brown amphibole. A few grains rimmed by orthopyroxene.

Pyroxene - about 5-10%. Grains 1-4 mm, predominantly recrystallized to aggregates of clinopyroxene, and interstitial brown hornblende, some orthopyroxene. Many large relict grains appear zoned and commonly have lamellae. Clinopyroxene grains may have stringers of brown hornblende and/or opaques and may also have rims of these two minerals. Aggregates and separate grains are apparently interstitial to plagioclase. Some of the orthopyroxene is altered to fibrous tremolite-actinolite and amorphous chlorite.

Amphibole - about 3%. Most is granoblastic and some size as or slightly smaller than recrystallized plagioclase and pyroxene in zones of recrystallization; predominantly brown. Some forms rims around pyroxene; fibrous pale brown amphibole rims altered olivine. Less than 20% is green or blue-green. May include or be included in plagioclase; also includes opaques or is associated with them.

Opaques - 1-5%. Grains up to .5 mm, euhedral to anhedral. Occur as bands in zones of recrystallization, rims to clinopyroxene, inclusions in clinopyroxene grains and in hornblende, plagioclase and talc fields.

Chlorite - Minor. Colorless to pale brown, non-fibrous chlorite is associated with smectite (?) and pale brown amphibole. Outside talc rims of olivine it may be blue-green.

Epidote - very minor. Anhedral, associated with opaques.

Zircon - Scattered small, euhedral to subhedral grains in plagioclase and opaque bands; somewhat fractured also associated with late amphiboles and pyroxenes.

Talc - amorphous and fibrous, usually associated with olivine, also in zones of recrystallization. In some places pleochroic to pale brown - phlogopite? Associated with olivine - plagioclase boundaries, and in places appears optically continuous with chlorite.

Apatite - Small angular grains in rows or rounded grains in opaques.

Textures - Very little remains of the primary igneous texture. Grain size was large, but has been reduced by alteration and recrystallization.

The mafic phases were interstitial to the plagioclase. Deformation textures include tapered, kinked, and warped twin lamellae in plagioclase, undulose extinction in both plagioclase and olivine, and deformation lamellae in olivine. Plagioclase and olivine are variably fractured; some of the fractures in plagioclase are annealed. Many fractures are apparently pre-recrystallization. One fracture through an olivine grain has an apparent offset of 1.5 mm. Zones of recrystallization are sometimes quite narrow and traverse originally continuous grains. Some deformation was syn or post-tectonic as recrystallized grains may also be mechanically twinned. Hydration of the olivine and some of the pyroxene formed rims of alteration products around these phases. One chlorite vein that is not visibly correlated with other alteration.

611-3-1 (A & C) Micrometagabbro

Plagioclase - 50-60%. Predominantly lath-like microphenocrysts with ragged grain boundaries; few phenocrysts. Many grains exhibit simple twinning, though some show polysynthetic twinning within a simple twin. Both zoning and undulose extinction are common. In some grains, inclusions may be abundant in the center, sparse in the rim. Some grains are slightly gray in plane light. Plagioclase shows minor alteration to clays and chlorite along cracks within grains.

Clinopyroxene - 15-20%. Intergrown with plagioclase, sometimes completely including the plagioclase. May contain small subhedral to euhedral grains of opaques. In various stages of alteration to green or blue-green amphibole.

Amphibole - Green fibrous amphibole, frequently associated with opaques, appears to be an alteration product of pyroxene. Boundaries between the alteration products and neighboring primary minerals are usually ragged. About 30% of the amphibole is more massive. Some of massive amphibole is partly or completely light brown. Very minor brown hornblende as small grains associated with clinopyroxene; altering to actinolite or grading into blue-green hornblende.

Chlorite - 2-5%. Euhedral to subhedral grains occurring as inclusions in pyroxene, amphibole, and plagioclase. Some anhedral grains are mixed with alteration phases such as fibrous amphibole and talc.

Talc - There is a minor amount of amorphous talc occurring in patches with some opaques. No primary phase is relict.

Chlorite - In veins; in some places small tabular flakes. Iddingsite with some opaques.

Textures - The igneous texture is clearly subophitic, a rarity in this suite. Xenocrysts or phenocrysts of plagioclase are evident. Little polysynthetic twinning of plagioclase and lack of other deformation textures indicates insignificant deformation.

Most of the alteration visible is of mafic phases. The alteration appears to attack grains from one side, rather than surround them. Most of the alteration is of a high-temperature, hydration-type. There does not appear to be any systematic variation in amount of alteration, although small sections of the slide are significantly less altered than the remainder.

611-4-1A Altered Orthopyroxene Gabbro

Plagioclase - about 60%. Grains 2-6 mm, contain rutile needles, show some polysynthetic twinning and undulose extinction. Less than .5 mm, granoblastic plagioclase makes up matrix (about 30% of slide). The texture of this plagioclase is polygonal and its size varies. It is closely associated with opaques. The large-grained plagioclase apparently is calcic.

Pyroxene - about 15%. Grains 3-8 mm. Both clino- and orthopyroxene are present, about 60/40. Exsolution of either opaques or pyroxene is common. Opaques are also present in cracks. Some of the pyroxenes have a mottled pattern; some are rounded and appear to float in the recrystallized matrix. Others, in zones of little recrystallization are large grains possibly interstitial to the plagioclase. Orthopyroxene is pink, clinopyroxene pale green.

Zircon - less than 1%. A few large, euhedral grains which may be mimetic or strained.

Opaques - about 10%. Anhedral grains of opaques are associated with the zones of recrystallization and also with the alteration of the mafic phases.

Apatite - about 5%. Subhedral grains are associated with the plagioclase and opaques in the recrystallized zones.

Amphibole - Total amphibole about 5%. Bladed brown amphibole rims some of the less disturbed pyroxene. In places brown grades into blue-green hornblende. Fibrous and massive green to blue-green amphiboles are associated with altering pyroxene. In some instances there is no

relict mafic phase left, in others a substantial amount. Alteration to amphibole appears to be restricted to areas of reasonably large cracks.

Iddingsite and hematite are associated with some altering pyroxenes and opaques. These minerals usually rim the primary phase or are present in cracks within the grains.

Carbonate - very minor. Present interstitially within surrounding blue-green amphibole.

Talc.

Textures - This rock was originally coarse-grained and consisted of two pyroxenes, olivine and plagioclase. Relict igneous textures suggest that the mafics may have been interstitial to the plagioclase. The plagioclase grains show some polysynthetic twinning, undulose extinction and bent crystals. Most prominent, however, are the zones of fine-grained, recrystallized or broken minerals (some small pyroxenes appear to be broken) and large, rounded pyroxenes. Portions of these zones are fine-grained enough to be termed mylonitic. Rimming of mafic minerals by alteration products is very common. Opaques may rim grains and their alteration and are also present in cracks within the mineral. One sequence observed is (core to rim) clinopyroxene to talc + opaques to green amphibole to brown phyllosilicate. Most rims consist of one or two minerals. There is a weak foliation defined by shape of relict grains.

The chemical analysis of this rock should show a lot of P_2O_5 . Textures are not atypical, but the presence of apatite in such large quantities is amazing.

611-5-1 Altered Olivine Gabbro

Plagioclase - about 50%. Grains 2-3 mm and about .25 mm. Most of the plagioclase is recrystallized with fairly well developed granoblastic texture. A number of subgrains are simply and polysynthetically twinned. Only a few fractures visible in the plagioclase.

Olivine - about 15%. Grains less than 3 mm. In places apparently rimming clinopyroxene. Granoblastic recrystallization is masking original textural relationship, probably interstitial to pyroxene and plagioclase. Undulatory extinction and cracks are common and a few deformation lamellae are visible.

Clinopyroxene - about 30%. Grains 2-6 mm. Possibly inverted subcalcic augite. Cleavage, exsolution lamellae and minor alteration along cracks are prominent features of the clinopyroxene. It is the coarsest-grained mineral in the rock, but there is some recrystallization.

Amphibole - A minor amount of brown amphibole, in places grading into green, rims and is present in cracks in clinopyroxene. This hornblende is considered primary.

Opaques - A minor amount of opaques occurring as small anhedral to subhedral grains are included in pyroxene or hornblende or are closely associated with these minerals. Grains are less than .2 mm.

Opaques and talc together are associated with the alteration of olivine. Both are very fine grained and occur as aggregates. The opaques are usually between the olivine and the talc, in cracks in the olivine, or in linear clumps in the talc. A very narrow rim of serpentine may surround the talc.

Recrystallization masks primary igneous textures. Polysynthetic twinning, kinking, undulose extinction and the clear development of subgrains indicate some deformation has occurred. A very faint banding has developed or been emphasized by deformation. Very minor late fracturing has occurred. This rock is one of the freshest in terms of alteration, but is not one of the least deformed in the collection.

611-5-2A Altered Olivine Gabbro

Plagioclase - about 50%. Average grain size less than 5 mm. Interlocking equant grains due to recrystallization after (during?) deformation. Grain size quite uniform. One kink band partially annealed. A few relict grains. Polysynthetic twinning common in old and new grains, so is undulose extinction. Many of the grain boundaries are sutured, subgrain relationships abundant. Very minor alteration to chlorite and sericite(?) along straight cracks and some grain boundaries.

Clinopyroxene - about 40% - larger grains 3-5 mm; recrystallized grains less than .5 mm. In unrecrystallized grains, exsolution not common; appears to be clinopyroxene exsolved in orthopyroxene, wide lamellae, one case even appears to be two intergrown grains. In recrystallized grains interstices have small amounts of brown hornblende or opaque. Aggregate distribution and relict textures suggest a few boundaries are resorbed, plagioclase occurs as inclusions in some relict grains. Recrystallization obscures many plagioclase-pyroxene boundaries.

Olivine - about 10%. Grains apparently once about 4-5 mm, now kinked and recrystallized, aggregates of grains .5-1 mm. Undulose extinction and kinking common. Cracks filled with opaque material. Aggregates occur as elongate blebs in plagioclase and as partial rims to, or zones adjacent to clinopyroxene. Less than 5% altered to talc and opaques, almost exclusively on plagioclase-olivine boundaries. Very minor orthopyroxene partial rims (reaction rims?).

Brown hornblende and opaques - about 1%. Hornblende + opaques rims orthopyroxene and rarely olivine. Hornblende more common than opaques. Also occurs in interstices of recrystallized clinopyroxene.

Textures - High temperature recrystallization pervasive, little primary texture preserved. Foliation not readily apparent. Alteration minimal (change in mineralogy), limited to olivine and plagioclase along cracks. Brittle deformation.

611-6-1 Altered Olivine Gabbro

Plagioclase - about 65%. Massive crystals 1-2.5 cm. Irregular boundaries, subsequent granular aggregates. Some tapered twins and annealed kink bands in various crystals. Penetrative cracks associated with zones of recrystallization and incipient recrystallization. Poikilitic with opaques. Idiomorphic needles not very abundant, possibly of apatite. Particularly odd zone of plagioclase within plagioclase, twins nonparallel.

Olivine - about 30%. Individual areas up to 1 cm x 2.5 cm. Some twinning, a few kink bands; has a slight color which may indicate a good percentage of Fa. Many grains have cracks with alteration to opaques + hematite + sheet silicates. Almost all grain boundaries in contact with plagioclase show reaction. Some orthopyroxene rims the olivine grains. Serpentine, talc, and actinolite are alteration products. Twinning abundant. Apparently poikilitic about plagioclase, possibly all one grains.

Clinopyroxene - about 5%. .3-1.2 cm. Some undulatory extinction, many grains totally anhedral and some overgrow olivine most grains are associated with the olivine, rarely totally surrounded by plagioclase. Some "uralite" type alteration of pyroxene to pale greenish amphibole as per DHZ v. II, p. 307-308. Some grains appear to fill cracks or zones of separation in olivine.

Amphibole - as above under uralite. Also some isolated brown and green hornblende, small grains.

Minor zircon, apatite, opaques - good dendrites within olivine alteration zones; chlorite.

Opaques - mostly present in olivine breakdown zones, although there are a few grains of what may be primary oxide.

Section gives the impression of olivine as first crystallizing phase, followed by pyroxene, then plagioclase with accessory zircon, opaques, etc. floating around. Subsequent deformation and introduction of water has caused the ubiquitous development of deformation textures, recrystallization and breakdown reaction relationships. Well-developed tapered twins in plagioclase, fracturing abundant throughout the phases in the slide, forming the prime sites of incipient recrystallization. Well developed weathering rind apparent by viewing thin section in hand in ordinary room light. Oxidation of ferromagnesian phases near the edge of the sample (north and east). Good development of typical olivine breakdown products in the rough cracks and grain boundaries.

Sample appears to be a typical olivine gabbro which has undergone fairly severe tectonic crushing.

611-7-2 Amphibolite

Plagioclase - less than 35%. Grains about .2 mm, granoblastic and equant. All partially sericitized. Textures suggest recrystallization. A few grains show multiple twinning, which may indicate continued deformation during recrystallization.

Amphibole - 55 to 60%. Grains 1-3 mm are green and brown and show cleavage and exsolution textures that suggest replacement of pyroxene. These grains rounded but with jagged edges. Some amphibole is extremely pleochroic. Some grains are slightly zoned at their rims. Amphiboles not associated with opaques are less strongly colored and greener. Fine-grained amphiboles are .2 mm, subgranoblastic. They are often associated with fine-grained opaques in mafic domains.

Opaques - 5-10%. Grains about 2 mm but variable, anhedral.

Apatite - minor, subhedral to equant. In feldspathic domains.

Sheet silicates - minor. A light-colored domain of mixed chlorite/other sheet silicates matrix with spatite grains. Also smectite(?) veins that are parallel to the foliation.

Textures - There are no relict igneous textures in this rock. The texture is blastomylonitic with no apparent preferred orientation of individual mineral grains.

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612-1-1 Amphibolite

Plagioclase - about 55%. Relict grains 4 mm. Most grains about .5-2 mm; some less than .05 mm which form poorly developed mortar. Most grains have sutured grain boundaries. Some optical zoning around boundaries of medium grains, probably a deformation feature because irregular and indistinct. Polygonization apparent. Twinning in less than 30% of grains. All grains are dusted by very fine opaques; old grains are sometimes gray due to impurities. Some irregular clearer parts possibly due to metasomatism. Sericite dusting is only alteration. Fractures scarce, only have oxide stains.

Clinopyroxene - less than 5% now. Relicts finely cleaved grains, some with stubby inclusions of now-oxidized material. Most badly stained. Alteration to colorless amphibole + opaques; green, blue-green and green-brown hornblende. Pseudomorphs are poikiloblastic-massive or somewhat fibrous. One relict encloses a plagioclase.

Hornblende - About 35%. Brown, green and blue-green. Pseudomorphic aggregates after clinopyroxene(?) up to 1 cm, anhedral; poikiloblastic with relict clinopyroxene, fine opaques and medium inclusions of plagioclase. Some grains somewhat fibrous, others massive. Euhedral blades along fractures(?) are brownish-green.

Pale to colorless amphibole - about 10%. Actinolitic amphibole forms core of many pseudomorphic aggregates, associated with small irregular opaques. Actinolite amorphous or somewhat fibrous, sometimes more massive. Usually rimmed by blue-green hornblende.

Textures - igneous textures almost completely obliterated. Clinopyroxene

with some exsolution and plagioclase that was sometimes enclosed by mafics is primary. Possibly two major mafic phases - clinopyroxene and another mafic. Foliation not developed, but cataclasis of minor extent obvious. Some high-temperature brittle fracture which was filled by euhedral hornblende. Very little chlorite, minor carbonate assemblage therefore almost exclusively high temperature.

612-1-2 Amphibolite

Plagioclase - about 55%. Relicts up to 1 cm diameter, average less than 5 mm. All have undulose extinction, show polygonization, some show deformation bands and incipient recrystallization along grain and sub-grain boundaries. Apparently brittle mortar texture developed along narrow zones. Mechanical twins very narrow, rare. Grains have highly irregular boundaries and are usually elongate. Some optical zoning that may be due to deformation. Sericite liberally dusts predominantly larger grains.

Brownish green hornblende - about 45%. Usually grains less than 5 mm, often in aggregates. Apparently pseudomorphs after clinopyroxene, since they retain fine cleavage, occasional red-brown hornblende exsolution blebs. Some kinking and bending of cleavage observed, timing of deformation relative to alteration unclear. Grain boundaries almost all very irregular as a result of cataclasis, but some suggest subpoikilitic relationship to lathlike plagioclase. Very fine grained and/or lozenge-shaped in high strain zones. Demarcates these zones under plane light. Large grains sometimes show interlocking textures, rimmed by granoblastic grains similar to recrystallized pyroxene textures.

Very minor inclusions of opaque in hornblende - irregular.

Textures - Cataclastic overprint on primary textures, where clinopyroxene probably subpoikilitic about subhedral plagioclase laths. Some plagioclase at least 1 cm, probably most was smaller. Amphibole probably replaced clinopyroxene, apparently without accompanying deformation, followed by high strain. It is also probable that the rock was at least somewhat strained prior to amphibolization. Very high strain zone

truncates oblique foliation of plagioclase and hornblende in middle of slide.

612-3-1 A & B Olivine-bearing Metagabbro

Plagioclase - about 45%. Relict grains up to 2 mm, predominantly about .5 mm granoblastic grains. Both sets at least 50% mechanically twinned, all show undulose extinction. Subgrain development in both grain sizes common but zonal, in some areas complete - "high strain zones." Near high strain zones, progressive amount of subgrain development and also some ribboning of plagioclase. Grain boundaries become more serrated as well. Mortar texture developed in some areas. Apparently extremely little alteration of plagioclase to other minerals, but may be involved in talc formation around ex-olivines?

Clinopyroxene - now about 30%, probably at one time close to 45 - aggregates of up to 4 mm. Grain size now about .1-.2 mm. Texture is usually granoblastic with brown hornblende in interstices. A few grains contain elongate exsolution blebs. Not all of the pyroxene is recrystallized, especially in 612-3-1B. Must be a function of very local strain gradients. In zones of high strain, amount of recrystallization and/or cataclasis of the pyroxene grains increases. Alteration of the pyroxene is very zonal, primarily to brown hornblende when accompanying recrystallization but also to green hornblende and brown hornblende due to introduction of H_2O along cracks. Some of the replacement is complete and pseudomorphs the clinopyroxene internal texture; some is incomplete and aggregate. Brown hornblende appears to remain stable in areas where there is also green hornblende replacement. Some cracks or veins are filled with actinolite and blue-green hornblende and talc(?) which also appear to be alteration products of adjacent pyroxenes. Exact relations are unclear - it is possible that these are alteration products of another phase (e.g. olivine), or perhaps both. Alteration is incredibly

limited - in high strain zone one mafic band may be completely altered and the next only deformed.

Olivine - perhaps originally as much as 5% - now mostly small relicts in aggregates associated with clinopyroxene. Alteration clearly to talc + opaques in some areas, late-stage to oxides; but possibly also to actinolite - blue-green hornblende - chlorite areas. Alternatively, some of these may be after orthopyroxene and/or clinopyroxene. Extremely hard to give evidence one way or the other.

Opaques - generally associated with clinopyroxene as "dust" around grains, some more massive, anhedral opaques in high strain zones. Also with some of talc after olivine? Textures in this rock are very complex. Where igneous textures somewhat preserved, apparent that clinopyroxene was interstitial and poikilitic around plagioclase. Recrystallization to form granoblastic texture in clinopyroxene and plagioclase (and olivine?) occurs over much of slides. Subsequent high strain was in some areas accompanied by alteration of mafic phases - blue-green and green hornblende also later? Actinolite and chlorite alteration. Veins of alteration minerals of both types also present. Alteration of olivine likely occurred primarily during first alteration phase, though evidence sparse. Very little, if any, annealing after last observed phase of high strain. Also very little very late cracking - actually little small scale cracking at all - little expansion due to alteration or enough subsequent recrystallization to eliminate evidence.

612-3-2 Weathered Metagabbro - probably orthopyroxene gabbro or clinopyroxene norite

Plagioclase - 65-70%. Relict grains less than 4 mm, elongate parallel to a weak foliation. Fine mortar common around many grains. Twinning only moderate. Polygonization and subgrain development common. All grains anhedral, almost all grain boundaries very irregular. Alteration of plagioclase to sericite very minor. Crosscutting fractures filled with blue-green amphibole in turn cut by smectite are moderate in number. Blue-green veins crosscut cataclastic mortar texture with little apparent effect on plagioclase texture. Some of the larger grains of plagioclase are gray under plane light.

Orthopyroxene - 5-10%. Relict grains elongate, 2-8 mm. Fractured and oxidized along fractures and perimeters. Alteration to pale blue to blue-green to colorless, fibrous to amorphous mineral, possibly talc or actinolite, accompanied by a few tiny opaques. Outer rims of massive blue-green hornblende are narrow. Red-brown hornblende as rims and inclusions in grains about .5 mm, and rather common. Alteration of orthopyroxene about 5% of slide. Fabric in alteration may be randomly felted or moderately parallel to orthopyroxene cleavage but does not mimic it very faithfully. Some undulose extinction and strained and broken inclusions of plagioclase indicate deformation of orthopyroxene. Some orthopyroxene with clinopyroxene and opaques, about 30% altered to talc and actinolite.

Clinopyroxene - about 5%. Round grains about 3-.5 mm diameter, almost all badly stained. Finely cleaved, some with exsolution blebs of opaques (once orthopyroxene?). Mostly associated with spacefilling

opaques, round grains of orthopyroxene. Minor alteration to fibrous blue-green amphibole, no rims of hornblende observed. Some larger grains contain small inclusions of plagioclase and may be embayed, suggesting resorption.

Amphiboles - About 10%. Red-brown, limited rim to areas with orthopyroxene. Blue-green massive amphibole outer rim of clinopyroxene coronas; small prismatic in veins. Fibrous blue-green amphibole with high birefringence occurs as alteration of orthopyroxene, minor alteration of clinopyroxene, and as pseudomorphs after an unknown mineral.

Opagues - less than 5%. Occurs as matrix enclosing individual grains of clinopyroxene, orthopyroxene, minor apatite and plagioclase. Usually in aggregates elongate parallel the foliation and in areas rich in mafics. Restricted to areas with clinopyroxene.

Minor anhedral apatite and sphene(?) or zircon. In clinopyroxene-opaque-plagioclase area of slide.

Textures - Relict orthopyroxene suggests once coarse grained. Apparently compositionally layered as about half the slide has almost no clinopyroxene and opaques, the rest has clinopyroxene-opaques-plagioclase-minor orthopyroxene. Cataclastic deformation evident, but continuous zones of very fine-grained plagioclase is not yet developed. Alteration to blue-green amphibole apparently post cataclasis as veins cut cataclastic mortar without disruption. Later veins of smectite cut everything.

612-4-1 Weathered Metagabbro

Plagioclase - 35-40%. One grain about 8 mm long, very little larger than .5 mm. Undulose extinction and polygonization common, mechanical twinning also common in larger grains. Perhaps 95% of plagioclase is very fine-grained, a result of cataclastic strain. Some small grains do not have undulose extinction [suggesting some recovery if not grain growth]. Most grain boundaries are highly irregular. Much of plagioclase has heavy dusting of fine opaques. Alteration to sericite very minor, oxide stains along grain boundaries quite common; alteration to yellowish green layer silicate, probably smectite, is common around mafics, both as "veins" parallel foliation and along grain boundaries across foliation.

Relict pyroxene - about 5-10%. Grains are round, less than 3 mm, augen-shaped. One grain orthopyroxene. Most is badly stained reddish-yellow so identification on the basis of internal texture. One or two grains show poikiloblastic replacement by red-brown hornblende. It is possible that much of the pyroxene is now epidote, as birefringence is quite high with plagioclase showing normal colors. Grains usually associated with brown hornblende, and often surrounded by opaques. Tiny opaque inclusions are also common.

Brown hornblende - about 1%. Where distinct, grains less than .25 mm, usually with other mafics and around clinopyroxene. Grains are massive, anhedral and fairly clear.

Biotite - probably less than 5%. Surprising amount, rounded grains which are pseudomorphs, up to .5 mm. Some grains are quite dark and most contain opaque inclusion, a few have small apatites.

Apatite - at least 1%, grains less than .25 mm, concentrated in zones with opaques. Anhedral grains.

Opaques - greater than 5%? As vein(?) filler parallel to foliation, also as inclusions. Much is probably hematite now. Individual grains are small and highly irregular in shape.

Mixed clays and other unidentifiable material - about 40% of slide - apparently alteration products of primary and some secondary minerals. Most of the stuff formed after the cataclastic deformation, except perhaps some of the pseudomorphic material, although it was undoubtedly weathered late. Smectite is probably appropriate classification.

Textures - Cataclastic deformation produced good foliation and well-developed gneissic texture. Grain size was greatly reduced. Much of the mineralogy and mineralogical relationships are obscured by heavy oxidation.

612-4-2 Weathered Metagabbro

Plagioclase - about 45-50%. All grains less than 1 mm. Larger grains have undulose extinction and are elongate. Twinning is very rare. Most grain boundaries are quite irregular although there are patches where mortar is not developed and textures approach granoblastic. Most of the plagioclase, however, looks very milled. Some of the larger grains have gray cast in plane light. Areas that are less milled have inclusions or grains of tiny prismatic or anhedral apatite. Opaques along grain boundaries and as inclusions are small but quite common. Some grain boundaries have iron staining. Alteration apparently to smectite in vicinity of mafics, but extent of alteration hard to judge because it is not possible to tell where original plagioclase/mafic boundary was.

Relict clinopyroxene - 5-10%. Rounded to elongate grains usually .5-3 mm, two greater than 5 mm. Most badly stained and badly altered to brown hornblende and/or unidentified material. Some coarse exsolution textures, but most finely cleaved. Many tiny opaque inclusions in grains. One large grain, mostly altered to green and brown hornblende, has larger inclusions of anhedral opaques. Individual grains of clinopyroxene are not internally deformed, but appear as augen in a matrix of alteration minerals, opaques, and plagioclase.

Amphiboles - up to 20%. Alteration of pyroxene as massive pseudomorphs; separate grains, often quite clear. Colors reddish-brown to green. Often forms coronas around other mafic minerals.

Other alteration - some smectite-like substance occurs as pseudomorphs of individual grains up to .5 mm. Usually pretty reddish-orange. The rest appears to be high birefringent, yellowish to brown, and very

fine-grained, and occurs as coronas around mafic pseudomorphs and as matrix between films of opaques.

Textures - highly strained at relatively low temperatures. No clear evidence for crosscutting alteration of any kind. The well-developed foliation is defined by opaque films and mafic and felsic layers. Some of the larger mafic grains form aggregates which may represent fragments of a previously recrystallized rock, but textures are obscured by weathering and alteration.

613-1-1 Altered orthopyroxene gabbro - possibly clinopyroxene norite

Plagioclase - about 60-65%. Well-developed granoblastic texture. Grains .2-.7 mm. Most grains polysynthetically twinned, a few in 2 directions (less than 10% of grains); minor simple twinning. Very minor incipient sericitization along intragrain cracks. Minor interstitial opaques and blue-green to green hornblende. Small inclusions of opaque or apatite are rare.

Orthopyroxene - 10-15%. Grains 1-2 mm. long aligned subparallel to lineation. Often crystallographic as well as shape preferred orientation. Relatively little recrystallization. Slight bending of grains with cleavage subparallel to lineation, subgrain development common in the rest. Little evidence of exsolution along cleavage. Some grains contain minor blebs of opaque and/or clinopyroxene. Cracks and partings often emphasized by dark oxide.

Clinopyroxene - 10-15%. Grain size and texture comparable to that of plagioclase, i.e., about .5 mm and granoblastic. A few grains show simple twinning. Aggregates of clinopyroxene usually contain .01-.02 mm blebs of orthopyroxene(?) which is altered to very dark oxide.

Brown and green hornblende - 2-3%. Partial rims to about half the orthopyroxene grains, usually enclosing blebs of opaque. Isolated grains in plagioclase matrix with rectilinear boundaries. Brown hornblende predominates over green, some crystals zoned. No good correlation between distribution and color.

Apatite - very minor. Small rounded grains in or near mafic domains.

Opaques - about 1%. Average about .2 mm. Usually blebby inclusions in

mafic minerals, interstitial grains and very rarely inclusions in plagioclase. Originally probably late-stage magmatic with possibly some consolidation during deformation.

Blue-green and colorless fibrous amphibole common as alteration rim around orthopyroxene and along cracks. Possibly some antigorite and talc, almost no chlorite. Clinopyroxene rarely slightly altered to hornblende. Fibrous alteration in small patches has completely removed original mineral, after deformation.

Textures - This rock is foliated and recrystallized. Very little brittle deformation apparent. Some hornblendes may be a result of high temperature alteration. Other alteration of orthopyroxene unaffected by deformation. Very late oxidation not particularly strong.

613-1-2 Olivine-bearing Metagabbro

Plagioclase - about 60%. Maximum grain size about 5 mm, relict and elongate grains. About half of the slide has grains about .5-1 mm size in granoblastic texture, with a few relicts. Many grains show mechanical twins and slightly undulose extinction. Some of the relict grains are clearly bent. In the rest of the slide, there is no granoblastic texture - relict grains of .5-2 mm are subdivided and surrounded by very small plagioclase or have been polygonized in an irregular manner. Some of the relicts are optically zoned, both concentrically and along internal "zones of weakness," ("plagioclase metasomatism"). The fine-grain plagioclase (due to very high strain?) probably post-dates "metasomatism" but evidence is not clear cut. Also cores show some mechanical twins not seen in "altered" rims. All plagioclase in this realm (of distinguishable size) has some degree of undulose extinction. Alteration in this portion - very minor sericite. In granoblastic area, actin or blue-green hornblende and chlorite? in cracks and along isolated grain boundaries. Relatively few cracks. Relicts are more birefringent and have higher relief than clear secondary material. Boundary between two regions is razor sharp but not straight (the curvature poses somewhat of a problem since there is no indication of cataclastic(?) texture on the other side and granoblastic on other, but about 1 mm across has "metasomatic texture").

Clinopyroxene - about 30% - relict grains 1-10 mm, anhedral, but a few suggest ophitic recrystallized plagioclase. Many of the relicts show good cleavage and little or no exsolution. Other grains were apparently intergrown or exsolved clinopyroxene. Remainder of clinopyroxene is granoblastic, .25-.5 mm in size, with minor interstitial brown

hornblende in triple junctions. Textures are quite clear in granoblastic part of slide. Other phases interstitial are smectite?, opaques. Granoblastic grains may completely or partially armor relicts. About 30% of large clinopyroxene remains in high strain slide, none is granoblastic. Most is pseudomorphed or altered to green or brown hornblende.

Olivine - less than 1%, probably less than 5% originally - only remains on granoblastic side; grains about 2 mm. Altered to talc, colorless → blue-green amphibole, some opaques and some serpentine? Talc inside and outside amphibole rim. Relict shows kinking and undulose extinction, no evidence for recrystallization.

Amphiboles - in recrystallized zone about one half of mafics - a couple of pale brown rims around clinopyroxene, but for the most part grains about 1 mm or less, alone or as aggregates, brown-green hornblende. Many are clearly massive pseudomorphs of clinopyroxene (texture), some may be new grains (especially those that are poikiloblastic). There is a strong-moderate preferred orientation of hornblende in high strain zones, both dimensional and crystallographic, parallel to zone. Grain shapes are usually like lozenges, but it is not clear when formation of hornblende took place - pre, syn or post tectonic. Irregularity of grain boundaries and lack of plagioclase recrystallization suggests post-tectonic growth of hornblende is unlikely.

Olivine? pseudomorphs show alignment of mineral grains in zones of high strain, but not elsewhere, suggesting that at least some deformation took place after alteration.

Good study in contrasts in one slide.

613-1-3 Metagabbro - probably once clinopyroxene norite.

Plagioclase - 45%. Granoblastic texture well developed; grain size .4 mm or smaller. Polysynthetic twinning common but only a few with tapered ends. Undulose extinction is slight to absent. Minor sericitization along grain boundaries and in intragrain cracks. Blue-green amphibole and opaques in interstices in some plagioclase domains.

Clinopyroxene - about 10%. In aggregates or as separate equant grains in recrystallized plagioclase, less than 5mm. Also larger grains (1 cm) poikilitic to plagioclase, partly recrystallized into granoblastic texture and containing inclusions and/or exsolution blebs of orthopyroxene and brown hornblende. Cleavage is bent in unrecrystallized areas. Rims of strongly pleochroic and sometimes zoned brown-green hornblende common, and appear as both discrete rims and alteration rims with indistinct outlines. There are some opaques associated with larger hornblende, but not abundant. Some smaller isolated clinopyroxene almost completely replaced by green hornblende. Remaining clinopyroxene often clouded by oxidation.

Orthopyroxene - at least 10%. Originally orthopyroxene/clinopyroxene about 15/10 or higher? Orthopyroxene occurs as grains up to 1.5 cm long, possibly elongated by slip along cleavage prior to alteration. Also occurs in recrystallized aggregates with clinopyroxene and as exsolution blebs. Most larger crystals have slightly undulose extinction and bent cleavage; also they are broken along their length. Some crystals are slightly poikilitic about plagioclase. Orthopyroxene appears to alter to amorphous or fibrous talc + opaques and/or to actinolite,

either colorless or blue-green. Often pseudomorphs have outer rim of green, blue-green, and/or brown hornblende and opaques. (In some places this may be "primary", in other places looks quite "secondary".) Alteration not distinct from olivine alteration, possible some of it is olivine alteration. In some places outermost rim to orthopyroxene is bluish green talc, formed by reaction with plagioclase.

Textures: What remains of igneous texture indicates plagioclase, orthopyroxene and clinopyroxene all major primary phases and probably coarse-grained. Recrystallization has reduced grain size of all plagioclase, most clinopyroxene, and some orthopyroxene. Exsolution in clinopyroxene has also occurred. Alteration to blue-green and green hornblende most likely during or prior to recrystallization, although some after. Alteration of orthopyroxene probably late. Formation of opaques and apatite in some mafic domains occurred during recrystallization. Apparently little strain post-recrystallization. Moderate foliation developed.

613-2-1 Altered Olivine Gabbro

Plagioclase - 70%. Relict grains 1-2 mm; about .5 mm for coarsely recrystallized and equant; very small (less than .05 mm). Result of grain boundary recrystallization. Medium size probably first phase of recrystallization. Some twins in these may be due to growth; some, however, show tapered boundaries, therefore probably deformation related. Large and some smaller grains suggest original texture probably tabular surprisingly few of largest grains show bent twinning. Some of the two larger sizes of plagioclase are zoned, with grayish cores obvious under plane light. Optical zoning under crossed polars also seen, sometimes associated with cloudy cores, sometimes not. Zoning probably due to alteration of preexisting grain rather than simple overgrowth because cores have very irregular outlines.

Clinopyroxene - about 10%. 1-5 mm relict large grains; .2-.5 mm recrystallized and equant grains. Slightly bent cleavage of some larger grains. Also some appear to have been fractured into smaller pieces. Most smaller grains quite equant with granoblastic texture. Minor bleb inclusions of brown amphibole. Where clinopyroxene retains igneous boundaries, most are curvilinear and have very narrow rims of brown hornblende. Elsewhere, alteration to brown and brown-green hornblende has created wider, irregular rims. A couple of grains appear to be optically zoned; this may be in part due to incipient alteration to amphibole.

Olivine - less than 5%. Much is already altered to tremolite and talc + opaques (outer-most edge blue-green). Some of the relics are replaced by carbonate (inside other alteration rims and preserving dark alteration

along cracks). Some grains originally about 2 mm; at least one was 1-5 cm. Large one now kinked and subdivided. Has pyroxene and hornblende on rim, also modest amount alteration. Original grain shapes not discernible.

Greenish brown hornblende - rims around pyroxene usually have very irregular boundaries.

Hornblende is massive in plagioclase matrix, boundaries a bit more regular; may contain small inclusions of apatite. Also associated with minor amounts of epidote and irregular grains of opaques.

Talc, blue-green hornblende and colorless amphibole coarsely mixed in rims around olivine - all alteration products and not apparently in any particular order, though blue-green tends to be outside the colorless amphibole.

Textures - original texture probably plagioclase with interstitial pyroxene and olivine. Static recrystallization and growth of brown hornblende, apatite and epidote? Then grain-boundary recrystallization of plagioclase and alteration of olivine to talc, etc. Carbonate - probably very late, very isolated. Alteration of olivine and pyroxene variable within slide - due to availability of H_2O ? Also zonal grain boundary recrystallization.

613-3-1 Weathered Metagabbro

Plagioclase - About 45-50%. Relicts less than 1 mm, elongate with irregular boundaries. A few boundaries approach good granoblastic texture. Undulose extinction ubiquitous; minor twinning. About 50% of plagioclase consists of grains less than .2 mm; irregular grain boundaries. High strain with some recrystallization and/or recovery? Some undulose extinction and rare twinning but some unstrained. Unevenly distributed opaque dust. Some stained grain boundaries and very minor sericite alteration.

Clinopyroxene - 25-30%. Relict grains 8-.5 mm, rounded, most are badly stained. Usually finely cleaved and contain equant inclusions of opaque. Some obviously recrystallized aggregates which mostly don't show cleavage; also rims relict pyroxene. Almost all grains have orangish stain to them, which appears to affect interior of grains before affecting rims. Some grains grade into blue-green or green amphibole, although this is minor. Also pseudomorphs of smectite(?).

Opaques - about 15-20%. As irregular sheets and fracture filling, most parallel to and helping define the foliation. Irregular but equant inclusions in clinopyroxene.

One olivine grain, and orthopyroxene(?) with slight oxide alteration.

Textural comments - very little evidence for high temperature alteration. Very probably recrystallization after one deformation episode at high temperature with no water, then more strain, possibly accompanied by recrystallization of plagioclase. Late and very low temperature alteration to smectite(?) and oxides. Foliation is curved, well defined.

614-1-1 Amphibolite

Plagioclase - now about 20%, originally maybe 35-40%. Relict lozenge-shaped grains less than 4 mm long. Undulose extinction fairly common, mechanical and simple twinning, rare. Some cataclastic mortar texture and tiny grains in narrow high strain zones. Polygonization and optical zoning common. Some zoning is metasomatic, some indistinct. Grain boundaries are quite irregular. Most grains dusted with opaques and abundant sericite alteration. Chlorite fractures cross all structures but primarily follow foliation.

Greenish brown hornblende - about 45%. Most grains 1-3 mm. Equant anhedral grains most likely pseudomorphs after clinopyroxene as they mimic fine cleavage. Often appear broken, probably after formation of amphibole. Lots of very small grains, similar to fine plagioclase, as mortar in aggregates. Very minor dark brown hornblende as inclusions and rims, apparently relict. Also minor amounts of very pale to colorless amphibole in pseudomorphs, usually as cores of grains or aggregates. May be a function of orientation or trace element chemistry.

Chlorite - more than 5%. Aggregates of subcircular flakey sheaves in cracks and as alteration of plagioclase. Appear to be concentrated in zones which run parallel to foliation and do not appear to crosscut amphibole grains.

Bizarre association - about 10-15%. Bands of high-relief mineral, reasonably clear, which encloses anhedral grains of an orange massive mineral and opaques. The orange mineral is always enclosed. All three minerals are anhedral, although one aggregate appears to be somewhat subhedral-prismatic. Occur as stringers surrounding amphibole aggregates,

also parallel to foliation. High-relief, clear mineral possibly carbonate or sphene; orange mineral smectite, perovskite, hematite, rutile, anatase or brookite.

Textures - Igneous texture completely obliterated. Foliation apparent, though not strongly developed. Alteration apparently static and 2-stage: 1) high temperature, preceding the last deformation with formation of amphibole; 2) formation of chlorite and maybe sericite after brittle deformation.

614-2-1 Amphibolite

Plagioclase - 50-55%. Largest grain about 3.5 mm long, most are 1-.25 mm; some are extremely small. Mortar texture with foliation very cataclastic. Relict grains are lozenge-shaped or elongate parallel to the foliation. Grain boundaries are very irregular. Individual grains show undulose extinction, polygonization, little twinning. Relict grains have a grayish cast in plane light. All dusted by fine opaques. Alteration to sericite patchy. Many fine fractures crosscut foliation, some are restricted to one or two grains. Fractures are usually dark (filled by opaques?).

Hornblende - 25-30%. Most is brownish green. Aggregates up to .5 cm of finely cleaved green amphibole, with inclusions of red-brown hornblende. Larger grains usually in the center of aggregate. All aggregates elongate parallel to foliation, slight crystallographic orientation. Individual grains in aggregates are subequant and irregular. Brown hornblende sometimes in separate grains, often optically continuous with green. Timing of replacement of clinopyroxene relative alteration unknown.

Actinolitic amphibole and minor blue-green hornblende - about 15%. Aggregates of about 1 cm of colorless amphibole ± chlorite + minor opaques. Where no chlorite, amphibole reasonably aligned to poorly aligned. Where chlorite, amphibole + chlorite in separate patches. Amphibole is prismatic acicular, sometimes radiating, not aligned. Edges of amphibole patches often grade into blue-green hornblende. Some red-brown hornblende spots. Chlorite around amphibole + chlorite patch etches plagioclase.

One patch of carbonate within yellowish serpentine(?) about 5 mm. Inclusions of irregular opaques and straight lines of fine-grained colorless

amphibole(?) running through aggregate. Rim of fibrous to bladed, colorless to blue-green amphibole also fine-grained.

Textures - Cataclasis obvious, but extent of alteration prior to cataclasis is in question. Chlorite and amphibole patches appear unaffected by deformation, probably formed after deformation.

615-1-1 (2x3) Altered Olivine Gabbro

Plagioclase - 60%. Subhedral tabular grains with simple and polysynthetic twins. Grain boundaries in long direction slightly scalloped; more pronounced at termination. Some amount of accumulation plagioclase very likely. There is zoning of some grains, inside boundary is quite diffuse. Rim appears to be widest at ends of laths. Considering lack of alteration, zoning unlikely to be due to alteration. Trails of tiny inclusions, not crystallographically oriented. Very minor sericitization. Through-going cracks contain brown-green and blue-green hornblende; chlorite and talc in vicinity of olivine. Grain size 1-2 cm.

Clinopyroxene - 30%. Subophitic grains about 1-2 cm, enclose plagioclase, sometimes with rounded boundaries (resorption?); exsolution predominantly vermicular; worms are mostly brown hornblende. Vermicular pyroxene may be enclosed by unexsolved clinopyroxene (zoned?) or in separate grains. Some of separate grains also include other vermicular clinopyroxene - 2 stages of grain growth? Patches very irregular. Non-vermicular pyroxene often has inclusions of opaques, blebs of orthopyroxene? Very narrow rims of red-brown hornblende; some minor alteration to green hornblende near brown hornblende and cracks. Some inclusions and along portions of grains boundaries, alteration to smectite?, serpentine? and opaques.

Olivine - about 5%. Anhedral grains less than 1 cm, enclosing some plagioclase; boundaries curvilinear. Some development of subgrains, no kinking, minor undulose extinction. Alteration minor; dark material along cracks, very little "smectite." Rims have primary(?) brown hornblende and outside little chlorite?

Hornblende - Mostly brown, occurs as inclusions in clinopyroxene, and as rims, sometimes with opaques, around clinopyroxene and olivine. Also occurs as separate blebs in interstices of plagioclase. Blue-green does not occur as inclusions but in all other situations. Also occurs in cracks - often clearly associated with cracks and may be alteration of brown hornblende in a couple of places. One interesting relation is opaque → green hornblende → brown hornblende at a rim. No apparent reason for zonation.

Alteration - very few patches of amphibole and talc + opaques, possibly alteration of olivine. Similar areas associated with clinopyroxene - alteration of clinopyroxene or olivine rim now gone?

Textures - Clearly at least two stages of growth for plagioclase and some clinopyroxene. Overall texture is subophitic, with resorption boundaries among the various phases (except between olivine and clinopyroxene).

Deformation is very slight - mainly tapered twins; no apparent bent crystals. Cracks occurred prior to blue-green hornblende alteration. No apparent deformation syn or post alteration.

615-2-1 Altered Olivine Gabbro

Plagioclase - 60%. Grains less than 1 cm, euhedral to subhedral. Excellent example of fault through plagioclase; kinking or other type of displacement in pyroxene-hornblende. Most of the plagioclase simply twinned (growth twins); later polysynthetic twinning quite common, often bent. No zoning apparent. Minor kinking, also small displacements along cracks. Very small amount of sericitization along some cleavage traces, smaller inclusions (look opaque) in trails. Voids in later cracks filled with blue-green hornblende.

Clinopyroxene - Grain size about 1 cm. Subpoikilitic about plagioclase. Clinopyroxene exsolves clinopyroxene in elongate plates or blebs. Some finely cleaved texture. Possible intergrowth texture also seen with alternating extinction across aggregate. Intergrowths are irregular in shape (pyroxene-pyroxene boundaries). Minor subgrain development attributable to local deformation and associated with cracks in plagioclase. Exsolution lamellae may be of brown hornblende or brown hornblende and clinopyroxene. Two areas with small patches of serpentine? Narrow rims of brown hornblende, very minor opaques. In zones of cracking, complete pseudomorph of clinopyroxene by pale green to brown, massive hornblende which preserves clinopyroxene to brown hornblende textures.

Olivine - less than 5%. One grain about 4 mm. Interstitial-subpoikilitic to plagioclase altered to talc-tremolite and opaques. Large grain very little altered; small grains moderately altered to above assemblage, completely oxidized. Narrow rims of brown hornblende associated with boundaries near (with) clinopyroxene. Cracks contain opaque material but very little other alteration. Minor blue-green hornblende at rims of some alteration of olivine.

Textures - good ophitic texture well preserved. Alteration minor and 152
confined to grain boundaries and zones of cracking. Bending and
cracking occurred at blue-green temperatures or higher (probably fast
strain rate).

615-2-2 (2X3) Amphibolite

Plagioclase - 45-50%. Grains from .5 to .05 mm, rounded with irregular boundaries. Undulose extinction ubiquitous. A very few grains on the large end of range which show polygonization, indication of metasomatism around boundaries, and ghosts of granoblastic textures. Some areas of plagioclase mortar, generally plagioclase grains and aggregates separated by interlocking network of fine-grained brown hornblende and opaques. Twinning is rare, even in larger grains. Light dusting of sericite.

Brown hornblende - about 45-50%. Large relict porphyroblasts up to 1.2 cm are rounded with irregular boundaries and contain inclusions of opaques and apatite which are equant and subhedral. They may have spots of reddish hornblende. These porphyroblasts may have minor undulose extinction and may be cut by narrow zones of finer grained hornblende. Some mimic clinopyroxene internal textures. Surrounded by about .2 mm grains which are approximately granoblastic and/or by very small hornblende and opaques. The small grains are anhedral and lack a strong preferred orientation, but in some areas a weak foliation is observed. Some hornblende poikiloblastic about plagioclase.

Opaques - about 5-10%. Highly irregular, usually enclosed by or associated with fine-grained hornblende.

Apatite - 5-10%. Grain size comparable to plagioclase except not quite so small. Usually anhedral. Grains may be undulose. May partially enclose very small plagioclase, suggesting apatite formed during or after strain. Because hornblende encloses apatite as often as plagioclase and in similar manner, suggest apatite at same time or after hornblende.

One narrow vein of sphene (high birefringence, but doesn't change relief like carbonate).

Textures - No relict igneous textures. Relict grains rounded and enclosed in hornblende + opaque "matrix." There is a very weak foliation developed on mesoscopic scale defined by elongate, narrow zones of hornblende and slightly elongate plagioclase grains.

615-2-3 Metagabbro

Plagioclase - about 40%. Grains 1-4 mm are grayish and apparently relict. About 70% of plagioclase is smaller grains (.3-.01 mm) that are secondary. Domainal partially cut by what are apparently extensional fractures filled with amphibole and minor opaques. These fractures are approximately perpendicular to domain boundaries.

Clinopyroxene - about 20%. Grains .3-1.6 cm, predominantly rounded. Alteration to hornblende is quite extensive.

Amphibole - about 30%. Predominantly olive green, grains about the same size as clinopyroxene. Pseudomorphs and recrystallized aggregates after clinopyroxene; also fill fractures through felsic domains and, in a few places, through mafic domains.

Opaques - about 5%. Irregular grains in recrystallized mafic domains and as filling in crosscutting fractures.

Apatite - minor. Medium-sized grains are subhedral. Some grains are elongated in zones of recrystallization. These apparently formed prior to some strain.

Textures - Moderately foliated sample has no relict igneous textures but relict grains indicate originally coarse-grained. Fractures perpendicular to the foliation indicate possible stretching at high strain rates because sample was still hot enough to produce hornblende. No strong mineral lineation apparent.

615-3-1 Metagabbro

Plagioclase - 50%. Some relicts about 6-7 mm long, most grains .5-1 mm. Grain boundaries irregular and shapes suggest granoblastic texture. Size of grains is varied. Larger grains show kinked or bent mechanical twinning and undulose extinction. Smaller grains also have internal strain. One region toward number end of slide where long straight cracks have been sealed with plagioclase, grains in the vicinity are brecciated as well. Interstitial brown and blue-green hornblende appears to be related to granulation of plagioclase. Minor sericitization along grain boundaries. Mafic minerals also appear to form along cracks through plagioclase domains.

Clinopyroxene - 30%, originally 5% or higher? Large rounded grains 1-2 cm diameter, also .5 cm grains which are also rounded. Grains poikilitic, enclose irregular grains of opaques. Also exsolved brown hornblende and elongate stringers of opaque. In some areas, clinopyroxene now has granoblastic texture. Clinopyroxene often rimmed by abundant opaque, brown hornblende may or may not be present as minor outer rim. Green + blue-green hornblende forms as alteration of clinopyroxene along fractures. Most clinopyroxene has moderate hematite stain. Other alteration of clinopyroxene to brown hornblende along cleavage traces.

Orthopyroxene - originally perhaps more than 1%. Relicts of large grains (estimate about 5 mm), one bent and broken grain. Alteration to low birefringent, fibrous, colorless mineral + opaques, minor talc and serpentine (?) Pseudomorph felted rather than mimicking original internal structures. Almost exclusively large grains in mafic domains - with clinopyroxene and "interstitial (?)" opaques.

Opaque - 10%. Inclusions in clinopyroxene about 1-2 mm, as rims, and interstitial material may be as wide as .5 cm. Hard to tell if all primary. Probably ilmenite or titanomagnetite. Usually in mafic domain. Sometimes associated with massive hornblende, but more often with alteration material. Seldom appears to be altered itself. Occasionally next to sphene with sharp, curved grain boundaries.

Brown hornblende - less than 1%. Massive, subhedral grains .5-1 mm, associated with clinopyroxene and opaque, usually together. Also as "exsolution" in clinopyroxene. Often zoned to green on rims or along cracks. Seldom clearly secondary.

Green and blue-green hornblende - Massive mineral in "rims" or in cracks, with .3-.4 mm grain size. Also pseudomorphs clinopyroxene in situ, most often restricted to cracks and grain boundaries, but may alter entire grain. Usually does not affect brown hornblende present.

Other alteration minerals: Some small patches of greenish material, moderately birefringent - possibly serpentine or actinolite, possibly after orthopyroxene. Patches of talc may be after orthopyroxene or even olivine, though no olivine in slide. Some talc (?) along cleavage planes in clinopyroxene - possibly orthopyroxene exsolution now altered. Minor "smectite" around opaques from reaction of plagioclase and opaque?

Textures - Overall texture looks conglomeratic, opaque + plagioclase matrix with rounded grains. Distinctly domainal but not particularly foliated. Brittle fabric toward numbered end of slide suggests planar orientation subparallel to compositional domains. Degree of alteration higher in this area. Inclusions in clinopyroxene and minimum estimation of maximum grain size only relict igneous textures.

615-3-2 Weathered Metagabbro

Plagioclase - about 40%. One relict grain 1.5 cm long, fractured, twinned, distorted and grey. About half the rest of the grains 1-.1 mm with granoblastic texture and signs of slight to moderate strain. The rest show very fine mortar texture with lots of larger grains - narrow zones of high strain. In these zones there is some relict granoblastic texture. Inclusions of opaques and large opaques between grain boundaries common. Staining along grain boundaries moderate and sericite, smectite and uralite minor.

Clinopyroxene - about 30%. Large grains up to 1 cm, have 1 mm size inclusions of euhedral to subhedral opaques and plagioclase. Grains are rounded and in places look somewhat embayed. Most grains well stained. Exsolution textures not very evident - a couple of coarse inclusions. Recrystallized aggregates have grains about .3 mm, often with opaques along grain boundaries. Less than 10% alteration to amphiboles, usually brown and/or green along boundaries and fractures.

Opaques - about 20%. Many opaques anhedral and as "layers" and along grain boundaries. Definitely oriented parallel to moderate foliation. Inclusions in clinopyroxene - unusually large.

Amphibole - about 10%. Massive pseudomorphs of clinopyroxene, also some fibrous, blue pseudomorphs with opaques possibly after some other mafic. Some granoblastic aggregates. Minor veins and pockets of bluish-green actinolite(?). Some colorless amphibole or talc; extremely minor.

Textures - Mostly coarse-grained mafics, relict coarse plagioclase, and granoblastic mafics and plagioclase. There are patches of fine-

grained plagioclase and mixtures of fine opaques and fine mafics. Foliation is moderately developed, wraps around large relict clinopyroxene grains. Many relict plagioclase and clinopyroxene have a preferred dimensional orientation. No chlorite; blue-green, green and brown hornblende indicate minimum recrystallization temperature upper greenschist facies.

615-4-1 Olivine-bearing Metagabbro

Plagioclase - about 65%. Size about 1-7 mm; most about 4-5 mm. Often lath-shaped, but with anhedral boundaries. Mechanical twinning and undulose extinction are very common (almost ubiquitous). Zoning is apparent in some of the larger crystals (concentric, and usually gradual rather than sharply defined). Grains contain numerous cracks, most are very narrow and have little or no alteration (if so, sericite). Larger ones have blue-green amphibole (actinolite?), sericite, very minor chlorite.

Olivine - about 15%, originally about 25%. Predominantly aggregates or individual grains of .5 to 4 mm in size. Grains usually equant, but as a whole ophitic to plagioclase. Undulose extinction, kink bands and polygonization apparent, especially in aggregates. Some rims of clinopyroxene and also sometimes intergrown with clinopyroxene. Alteration usually slight - talc + opaques and smaller amount of bladed colorless amphibole. In more altered areas (50-75% of olivine gone), some blue-green hornblende or actinolite with or without outer rims of talc or chlorite into plagioclase. Some opaques associated with olivine are subhedral and a bit larger (about .2 mm) and may be primary.

Clinopyroxene - about 5%. Small rims around olivine, interstitial grains and large (about 1 cm) ophitic grains around plagioclase. No exsolution, moderate or little alteration to brown and actinolitic hornblende (massive pseudomorphs). No hornblende rims.

Amphiboles - about 5-10%. All apparently secondary. Bladed colorless to blue-green aggregates associated with olivine alteration. Brown,

green and blue-green massive replacement of clinopyroxene. Also along cracks and in zones of alteration, not obviously associated with any particular mafic. Grains less than .3 mm.

Texture - Probably good example of "adcumulate" although ophitic textures suggest that not strictly so (mesocumulate?). Alteration most likely post-solidification and due to moderate T introduction of water along cracks. Deformation probably at high T and not at all extensive - olivine only recrystallized(?) (polygonized anyway). Lack of rims around clinopyroxene indicates magma quite dry.

615-5-1 Amphibolite

Plagioclase - about 40%. Relict grains about .3 mm, rounded and slightly elongate parallel to foliation. Undulose extinction very pronounced, twinning very rare. Matrix of extremely fine grained plagioclase and hornblende. Moderate sericitization (dust).

Brown hornblende - about 60%. Porphyroclasts of less than 5 mm, elongate parallel foliation and/or rounded. Usually have trails of fine grains parallel to plane of foliation. Most grains about .3 mm, size and texture comparable to plagioclase. Only in a few areas is there a preferred crystallographic orientation. Minor spots of redder hornblende in grains suggest pseudomorphing of clinopyroxene. One large grain has simple twins; others show undulose extinction.

Opaques - about 1%. Irregular stringers scattered in rock concentrated in zones parallel foliation. Shape suggests same strain affecting plagioclase; elongation and chewing up.

One grain of subhedral sphene.

Texture - Foliated and cataclastic, no apparent recrystallization.

Timing of alteration relative to deformation unclear.

616-1-2 Altered Troctolite

Plagioclase - about 60%. Grain size 1-3 mm. Grains anhedral to subhedral, stubby or equant. A couple of grains poikilitically enclose olivine. Abundant simple growth twins, undulose extinction. Mechanical twins also common. There is no clear evidence for recrystallization. Grains are often traversed by irregular cracks, some of which are loci for minor sericitization.

Olivine - 35%. Same grain size as plagioclase, usually in aggregates. Some undulose extinction and kink bands visible in larger grains. Shape is subhedral to anhedral, often appears to be somewhat interstitial to plagioclase, or perhaps just intergrown with plagioclase (not ophitic, though). Some reaction rims of orthopyroxene, with outer rim of clinopyroxene or brown hornblende are observed. In places the rimming mineral embays the olivine. Alteration of olivine is about 5% serpentine \pm opaques. Altered along cracks and primarily along grains boundaries. Possibly also to tremolite (fibrous, but slightly higher birefringence than serpentine).

Orthopyroxene - less than 1%. Exclusively as reaction rims around olivine. No apparent alteration.

Clinopyroxene - about 1-2%. Rims olivine or orthopyroxene, also minor interstitial grains. No exsolution. Narrow brown hornblende rims.

This slide represents a relatively undeformed and unaltered troctolite. Good for igneous petrogenesis. (Texture does not suggest accumulation of either plagioclase or olivine, although possible that there is a bias due to orientation of section.)

616-2-1 (2x3) Olivine-bearing Metagabbro

Plagioclase - about 65%. Subhedral plagioclase, often zoned, up to 7 mm in length. Most are elongate, some are subequant, minimum about 1 mm, average about 3-4 mm. Possibly 2 generations of larger crystals - some are distorted, show bent polysynthetic twinning. Twinning is not common except in obviously deformed crystals. Associated with large deformed crystals are narrow zones of equant, much smaller grains - look like recrystallized grains. Most of these smaller grains, less than .3 mm, are not strain-free. The most euhedral grains are moderately sized, occur in separate areas, often in a subophitic? texture. Optical zoning usually limited to 1 rim, which, in places, acts as a space filler. This rim tends to be more resistant to alteration. Also minor amounts of "metasomatic" alteration, predominantly affecting the inner portions of plagioclase grains. Alteration is primarily a very fine-grained material, which may be only primary inclusions. Also alteration to sericite along fractures and some internally. Some smectite or antigorite alteration encroaches on plagioclase from alteration of mafics. Also some chlorite(?).

Relict olivine - about 5%. 2-6 mm grains, now rounded due to alteration coronas. Also oxidation patches where once was olivine. Some olivine has undulose extinction, deformation lamellae, but no apparent annealing. Small inclusions of plagioclase, brown hornblende, biotite, apatite. Coronas of talc, talc + opaques, smectite; also serpentine and brown to green hornblende. Some amphibole rims are colorless and/or blue-green and bladed. Not clear why change in color from brown and green to blue-green. Colored rims outside colorless, colorless appear to be from talc. Some patches not clearly from olivine - no remnant textures,

but sequence of mineralogy the same as coronas around relict olivine grains.

Clinopyroxene - relict, less than 5%. Grains about 2.5 mm. Altering to opaques and red-brown hornblende and brown and green hornblende. Pseudomorphs predominantly massive. Alteration along cleavage planes. Original grain shape obscure.

Brown and green hornblende - about 10%. As rims around olivine, pyroxene and also interstitial to plagioclase, especially where plagioclase 1-3 mm and quite euhedral. Hornblendes often zoned red-brown and green to blue-green, but no consistent color pattern - zonation often quite irregular. Often contain small elongate inclusions of opaques.

Other amphiboles - about 5-10% colorless, blue-green. Most often associated with alteration, but not always. Both massive or bladed and acicular (mostly colorless).

Apatite, zircon, sphene, opaques - As a group less than 5%. Subhedral grains less than .5 mm, often close together. In plagioclase or with other mafics. Usually in finer-grained areas (not the recrystallized zones, though), so likely late stage. Associated with some of hornblende strongly suggests that many amphiboles in this slide are primary.

Other alteration products - brown to clear fibrous radiating mineral, probably aggregate, alteration product after an interstitial mineral. Also found in some veins.

Patches of irregular shape about 5 mm diameter with inner portion of chlorite(?) ± colorless or blue-green amphibole, outside very similar

to olivine coronas, possible also olivine pseudomorphs.

Textures - some deformation (semi-ductile) evident in large grains, olivine and plagioclase. Apparently 2 stages of crystallization - later was much quicker or had more water - subophitic textures then, also accessory minerals. Alteration predominantly replacement type, moderate temperatures for bulk - talc instead of serpentine, also hornblende? very low temperature alteration during final oxidation of olivines.

616-2-2 (2x3) Olivine-bearing Metagabbro (2 sections)

Plagioclase - 65-70%. Grains 5-25 mm in length, subhedral to anhedral, elongate to subequant. Also a population of about .25 mm equant grains - probably recrystallized, but not necessarily strain-free. Large grains show bent polysynthetic twinning, cracking and zones of recrystallization. Some medium-sized grains also show polygonization; are optically zoned and also have "metasomatic" plagioclase in cores. Outer rims may appear to grade into recrystallized or more "ophitic" textures. Magmatic history possibly two-stage, as described in 616-2-1. Second set of plagioclase about 1-.5 mm grain size and may also be optically zoned. Alteration primarily sericitic, in cores and along cracks, varies from slight to moderate. In some more altered areas also epidote. Also "metasomatic" alteration. Fractures through less altered plagioclase (often where largest grains) contain chlorite or oxide staining.

Clinopyroxene - about 5%. Interstitial, about 1 mm, some anhedral grains about 4 mm. Some zoned with cores of mottled clinopyroxene, clearer rims. Altering to hornblende, brown, rims of red brown. Also inclusions along cleavage of unidentified maroon material. Pyroxene-hornblende intergrowths also in some grains.

Relict olivine - less than 1%. Grains 5 mm, squarish, almost completely oxidized. Coronas of talc and tremolite, also later pseudomorphed by serpentine and some serpentine outer rims. Patches of chlorite + tremolite to colorless to brown hornblende without cores also present.

Amphiboles - 5-10% brown and green as rims of pyroxene and ex-olivine. Separate interstitial grains .5-4 mm. Green, colorless, brown in color. Often multicolor, but no clear pattern.

Filled void spaces - up to 15% of slide - green or colorless amphibole, usually subhedral and brown fibrous material seen in other slides.

Textures - some high strain but not very much. Two phases of crystallization; second, wetter phase possibly post-deformation. Quite likely deuteric alteration. Some spaces perhaps remained unfilled. Late-stage cracking and low-temperature alteration, especially of olivines.

Alteration products occurring within veins and cracks: chlorite, hornblende, actinolite, magnetite, epidote.

Accessory minerals occurring with plagioclase: apatite, rutile, zircon.

Textures - mortar texture. Subophitic texture. Many small cracks occur only within the plagioclase phenocrysts, and do not continue into the surrounding material. Several large cracks and veins crosscut the entire slide, and are of random orientation. One large vein cuts through mortar without cutting a larger crystal: its symmetric morphology from the center, is chlorite, actinolite, minor epidote and opaques, brown and blue-green hornblende. Most of the smaller veins contain only a deep reddish-brown mineral (smectite?) and chlorite. Plagioclase twin lamellae are warped and bent and along some small fractures the lamellae are "swollen" Some of the fracturing is brittle; in one instance the lamellae are offset by a crack filled with brown and blue-green hornblende.

Most of the secondary minerals associated with olivine appear to be also associated with the large veins which occur along boundaries between the large plagioclase phenocrysts. Much of the chlorite in the veins appears to be fibrous along the vein walls and perpendicular to

them; actinolite occurs occasionally as isolated clumps of radiating needles. Plagioclase phenocrysts appear to be the earliest formed phase.

616-2-3 Altered Olivine-bearing Gabbroid

Plagioclase - 55%. Occur in two modes: large phenocrysts (.3-1.7 cm) with warped twins and wavy extinction, cut by veins and fractures which are generally not continuous into the surrounding material; and 1-.01 mm, primarily untwinned plagioclase crystals as mortar between large plagioclase and mafic phenocrysts. The margins of the large plagioclase phenocrysts are irregular. The smaller crystals are generally rounded. The 1.7 cm grain is cracked and offset.

Pyroxene - 15%. Grains 1-3 mm. Clinopyroxene: diallage with very prominent parting. Alters along cleavage traces (exsolution) to reddish-brown hornblende. Embayed by opaques and slightly pleochroic red-brown hornblende. Alters along margins to strongly pleochroic brown hornblende. In one instance clinopyroxene almost surrounds a badly altered olivine phenocryst. Margins of pyroxene crystals are resorbed, embayed; embayments are filled with plagioclase mortar. Orthopyroxene (less than 5% of total pyroxene) alters along margins to strongly pleochroic brown hornblende. Interstitial to plagioclase and rimming olivine.

Olivine - 10%. Grains 2-4 mm. Almost completely altered. Alteration products (from core): opaques, talc, smectite, epidote, actinolite, brown hornblende, blue-green hornblende, chlorite \pm serpentine.

Hornblende - about 8%. Brown hornblende margins impinge on small plagioclase crystals; grains contain small opaques. Secondary hornblende occurs in three modes: red-brown, altering within clinopyroxene; blue-green, as reaction rims and within veins and cracks; brown, as reaction rims and in veins and cracks.

Magnetite - one crystal. Anhedral, about .5 mm.

Alteration products occurring as reaction rim minerals: talc, chlorite, actinolite, hornblende, epidote, iddingsite, smectite, magnetite, serpentine.

616-4-1 (2x3) Olivine-bearing Metagabbro

Plagioclase - 45-50%. Subsequent, anhedral plagioclase, 2-5 mm size. Texture subgranular (granoblastic?). Polysynthetic twins, some bent and tapered. Microfaulting is post-twinning. Some grains about .5 mm, in interstitial areas and between grains, but not in elongate zones resembling shear zones. Alteration restricted to mafics and veins - chlorite and sericite/talc mostly. Some blue-green hornblende and opaques also in veins.

Clinopyroxene - about 20%. 1.3-3 mm grain size, subhedral to interstitial. Some grains have exsolution lamellae, others spots of small opaque inclusions. Most are extensively (50% +) altered to hornblende, blue-green to brown and reddish-brown. Alteration is massive pseudomorph texture, starting as primary(?) hornblende rim which grew during later alteration. Boundary between two types of amphibole often distinguished by inclusions in secondary. Exsolution lamellae in some cases another pyroxene (not distinguishable as to type), also elongate opaques and/or reddish-dark brown material which is non-pleochroic and only moderately translucent.

Olivine - about 20%. 2 mm to <1 cm, large clusters. Grains euhedral to anhedral, show some signs of deformation - some kinks, moderate undulose extinction; equant aggregates suggest possible recrystallization in some areas. Usually associated with clinopyroxene but not as clearly interstitial - euhedral boundaries most often with clinopyroxene, suggesting clinopyroxene crystallized after olivine and after plagioclase (for the most part). Alteration of olivine varies from very slight to complete. Some opaques present along cracks and as tiny spot inclusions in most grains. Further(?) alteration is mostly to talc and

opaques. Pale blue-green hornblende and/or colorless amphibole may rim this and/or replace talc at later stage. Where appears to be replacement of talc, often associated with chlorite. This may be alteration of another mineral. Biotite or at least pale brown mica also present in places. Plagioclase in vicinity often also corroded. Some oxide staining of talc possibly formation of iddingsite at low temperature.

Opagues - about 1%, interstitial, up to 2 mm long.

Textures - igneous textures and coarse grain size quite well preserved. Plagioclase and olivine probably began crystallizing before clinopyroxene. Rimming by amphiboles varies from spot to spot. Blue-green amphibole rims, replaces and fills veins; chlorite secondary, as with olivine and in veins. Zone of maximum alteration runs diagonally across slide and quite restricted in extent.

616-5-2 Altered Olivine Gabbro

Plagioclase - 60% - Bimodal distribution of grain size: 2-5 mm and less than .5 mm. A couple of grains close to 1 cm. Original grain size probably 1-.5 cm. Coarse interlocking granoblastic grains - some elongate due to incomplete reorientation. Tapered twins in greater than 50% grains, including those that may be secondary (therefore deformation after grain growth). All plagioclases, regardless of size, are slightly gray in plane light, except right at grain boundaries. Relict grains appear to have been tabular. Trails of minute inclusions occur but are not common.

Clinopyroxene - about 20%. Grain about .5-1 cm, subophitic to plagioclase. Very little exsolution. About 10-20% recrystallized, usually in areas where clinopyroxene was smaller. Recrystallized size about that of new plagioclase. Very narrow rims of brown hornblende. Where exsolution; blebby, possibly orthopyroxene but fine-grained. Some brown hornblende. Almost no alteration of clinopyroxene - very minor actinolite?

Olivine - all gone, was once about 10% of rock. Anhedra, apparently interstitial. Maximum grain size about .5 cm. Sometimes rimmed or associated with minor orthopyroxene. Alteration to talc + opaques; outside rim of serpentine? Often talc + opaques now altered to hematite. Possibly plucked out during making of thin section. Estimate less than 5% olivine → talc + opaques.

Alteration - besides that described above, cracks through plagioclase and along grain boundaries filled with chlorite. Interstices of recrystallized plagioclase may contain small grains of green actinolite,

blue-green hornblende, or brown hornblende going to blue-green hornblende. Zoning of hornblende may also occur where crack meets clinopyroxene with brown hornblende rim.

Texture - possibly only very slightly deformed. Cracks possibly due to expansion rather than result of directed stress. Alteration definitely static. Igneous texture probably sub-subophitic.

616-6-1 Metagabbro

Plagioclase - less than 45%. Remnant grains .1-.8 mm in size (extreme is greater than 4 mm at non-# end), ellipsoidal, with strain features. A couple have radial twinning! Twinning is not as common as extreme undulose extinction. Matrix is extremely fine grained, irregular plagioclase - possibly cataclasite. Matrix/grain ratio varies to extremes, with packets of relatively intact grains much more common to non-# end of slide. However, foliation is still well developed. Here also there appears to have been reduction of grain size, but not so dramatic. No distinct evidence for recrystallization. Many of large grains have grayish cores under plane light. Areas of "matrix" contain fine-grain impurities.

Clinopyroxene - less than 10% present - primarily rounded relict grains less than 1 mm. Some partially altered to green hornblende. A few aggregates of about 4 mm of clinopyroxene with exsolved blebs (orthopyroxene??) and also in granoblastic texture with orthopyroxene (?) and brown hornblende interstitial to it.

Orthopyroxene - less than 1% relicts. Altered to actinolite but perfect pseudomorph - about 2 mm long.

Amphiboles - about 50% - appear to be pseudomorphs of pyroxene grains - same grain size; also as fine grain matrix. Color varies from green to brown, apparently zonal - one domain brown, the next green, but not alternating. Also some actinolite? associated in places with carbonate? and oxides; after olivine or orthopyroxene. Amphibole not fibrous - either pseudomorph, aggregate, or very amorphous.

Opaques - about 1% - occur as matrix material at number end of slide to exclusion of most of plagioclase.

Texture - Blastomylonitic rock. Domainal and well foliated. Degree of grain size reduction varied, appears to have affected plagioclase to greater extent than mafics. Alteration high temperature. Clearly variation in water content of different domains. Some alteration of mafics static? Poikiloblastic replacement of clinopyroxene by hornblende common and rather different than in other samples.

616-6-2 (3 1/4 x 4) Altered Olivine Gabbro

Plagioclase - 50%. Average grain size about 1 mm but varies from 1 cm to less than .5 mm. Predominantly granoblastic, interlocking grains with tapered twins; sometimes sets within a single grain. Alongside of slide very good mortar texture in zone. About conjugate to prominent altered cracks (probably faults) running across slide. Grain boundary cracks very abundant, often filled with blue-green mineral (not identifiable due to thickness of slide and size of grains).

Clinopyroxene - variable content within section, overall about 25%. Average grain size 2-3 mm, maximum 1.5 cm. Apparently interstitial to plagioclase. About 50% pyroxene exsolved coarse lamellae of orthopyroxene and brown hornblende. Intergrowth/overgrowth textures of pyroxene observed, but not common. Granoblastic pyroxene aggregates about 30-40% of pyroxene. Minor amounts of associated and included opaques. Brown hornblende rims minor and narrow. Alteration along cracks (faults?). Complete alteration of clinopyroxene with rims of blue-green hornblende, centers of blue-green, green or pale. Pseudomorphs of clinopyroxene preserve internal structure (cleavage) of orthopyroxene and brown hornblende usually remains. Some opaques associated with hornblende probably primary because not always there, so not likely part of reaction.

Olivine - variable 15-20%. Grain size slightly smaller than clinopyroxene, 2-2.5 mm, maximum less than 1 cm. Anhedral may be intergrown with clinopyroxene. Kinking common. Aggregates probably recrystallized from single grain. Talc+opaques generally limited to narrow coronas. Alteration to dark oxides along cracks is variable, but about 5-10%.

Areas of probable olivine show poikiloblastic blue-green hornblende, opaques, talc and chlorite.

Textures - original igneous texture preserved by outlines of aggregates of interstitial mafic minerals in most of areas. Plagioclase subhedral. Grain size variation marked. Alteration very limited except along discrete zones; blue-green hornblende is dominant mineral (plagioclase not present right along cracks). Deformation restricted to cracks - one narrow zone shows mortar texture and preferred shape orientation.

616-7-1 (A & B) Metagabbro

Plagioclase - about 45%. Most grains less than 1 mm. Derived from larger originals. Almost all grains show severe undulose extinction, but moderate amount of mechanical twinning (less than 40%). Grains are relatively equant to slightly elongate, with irregular grain boundaries. There are discrete zones with extremely fine grained plagioclase, either all fine grained or as mortar to larger grains. Cracks and voids filled with chlorite, green hornblende and brown hornblende, some cracks clearly syn or post deformation. In small areas and isolated grains, optical zoning may reflect alteration by metasomatism.

Clinopyroxene - now about 20%, once close to 40%. Primarily in aggregates of grains which are .5-1 mm and equant. Some relict grains approach 1 cm. Aggregates are rounded or elongate, suggest possible cataclastic strain. Larger grains are often finely cleaved but contain patches of pyroxene with exsolution blebs, suggesting overgrowth or intergrowth. Exsolution lamellae sometimes identifiable as clinopyroxene. In recrystallized aggregates, orthopyroxene (?) may form interstitially at triple junctions. Alteration to hornblende, both green and tannish brown, occurs throughout slide. Replacement is poikiloblastic or to complete pseudomorphs. Alteration appears to start along grain boundaries and move inward along cleavage. A few grain boundaries with plagioclase are straight and long, and suggest that clinopyroxene was interstitial to plagioclase laths.

Orthopyroxene - about 1% originally. Relict grains about .5 cm long, broken and 20-50% altered to talc + actinolite + opaques, and to hematite. Often outer rim of green and/or brown hornblende, but relation-

ship not clear. Actinolite usually colorless, bladed or needle-like and may be zoned into hornblende.

Opagues - less than 5%. Massive, poikilitic? Along strain zones in mafics, not apparently the result of alteration. Also alteration product of orthopyroxene and inclusions in clinopyroxene.

Apatite also occurs in stringers, but less than 1%.

Patches of actinolite with outer hornblende (usually green - blue-green may be after orthopyroxene, but no relict left as a clue). Sometimes occur in aggregate with altering clinopyroxene.

Deformation textures - Some small cracks filled with hornblende appear to be tension cracks perpendicular to foliation. Foliation is somewhat wavy rather than straight. In areas where mostly amphibole, some amphibole has grown approximately parallel to cracks and has been later fractured along these same zones. Degree of granulation and development of foliation is variable, from moderate to extreme. Specimen is somewhat weathered, staining clinopyroxene and oxidizing orthopyroxene.

616-7-2 A & B Olivine-bearing Metagabbro

Plagioclase - 55-60%. Relicts 2-10 mm, most grains are polygonal and less than 1.5 mm. Small areas contain very small grains due to high strain. Twinning is not particularly common; undulose extinction is ubiquitous. Optical zoning in some areas apparently due to metasomatism of plagioclase rims. Brittle fractures have been filled with secondary plagioclase and brown hornblende. [This filling is not clearly affected by granulation, so possibly occurred after much high strain, e.g. 2B X. There has clearly been at least minor recrystallization in some areas of that slide.] Some areas of all slides have straight, regular boundaries while other areas contain plagioclase with very irregular grain boundaries. Most areas have textures approaching granoblastic; some areas have a mortar texture partially superimposed.

Clinopyroxene - 10-25% depending on area of slide. Grain size up to 1 cm. Some granoblastic aggregates. Original grains often made up of irregular patches of differently oriented clinopyroxene. Some clinopyroxene coarsely exsolved, lamellae and blebs now gone to pale green chlorite or serpentine - was it orthopyroxene? Alteration in 2BX mostly to actinolite, confined to grain boundaries. In others slides also see red-brown hornblende rims and inclusions, and alteration to greenish-brown hornblende along cracks and as pseudomorphs. Some of brown hornblende patches are poikiloblastic, enclosing plagioclase or clinopyroxene where replacement is not complete. Much of massive hornblende contains inclusions of opaque.

Olivine - less than 1% even originally. Altered to talc and opaques ± narrow blue-green hornblende rim. Extensively oxidized in most cases.

Grains irregular, up to .5 cm long.

Orthopyroxene - Less than 1%. Small grains in pyroxene aggregates still remain; also possibly many of the serpentine patches in pyroxene aggregates and rimming some clinopyroxene.

Opaques - at least 1% as stringers and interstitial filler, also as inclusions in amphibole. Usually but not always in mafic domains, only rarely euhedral or even subhedral.

Textures - Clinopyroxene major mafic phase, clearly interstitial to once-larger plagioclase grains, some of which may have approached 2 cm. Some brittle fracture occurred while still quite hot - fractures spaced at least 4 cm apart, filled with brown hornblende. Probably at same time some alteration of nearby pyroxene. Development of moderate foliation affected some wide zones more than others, but effects such as polygonization of plagioclase seen throughout. On top of this and apparently at an angle about 20° narrow bands of apparent cataclasis. At some point in history serpentinization, also blue-green hornblende and actinolite alteration which occurred after formation of granoblastic in texture in pyroxenes. Other alterations include chlorite in cracks and "smectite" and chlorite replacement of plagioclase.

620-3-1 Altered Gabbro (also labeled 620-3C and 620-3A; 4 sections)

Plagioclase - originally about 50%, now less than 20%. No primary texture remains, but deformed relict grains indicate original grain size was probably .5-1.5 cm. Present grains about .2 mm or smaller, with sutured boundaries and triple junctions. Very little twinning of any kind is evident. Alteration to clay? mineral. Replacement of plagioclase is definitely post deformation - no schistosity or other preferred orientation in pseudomorph visible.

Clinopyroxene - about 30-40%. Originally very coarse-grained, some relict crystals about 1 cm in diameter. Grains now rounded with evidence of bending and breaking. Larger grains show some fine-grained exsolution to more pyroxene, hornblende and/or opaques along cleavage traces, also some relatively large (.2 mm) inclusions (?) of opaques and alteration products. Rims of brown hornblende and opaques common; smaller grains granoblastic texture with opaques and brown hornblende in interstices. Some alteration of larger grains to fibrous mineral with low birefringence, starts on grain boundaries and migrates inward along cleavage traces. Several grains show textures suggestive of chemical zonation and/or overgrowth. Exsolution confined to core of grain, rim of pyroxene has slightly different orientation. This phenomenon may be late in crystallization sequence, possibly even metamorphic in origin (especially overgrowth, as seen on small grains within opaque mass (see 620-3-C₀)).

Brown Hornblende - Grains up to .3 mm. Well-developed pleochroism. Occurs as rims around pyroxene grains in exsolution pockets, in interstices between smaller pyroxene grains as rims around opaques. A very few large prismatic grains. Along a few cracks, zoned to green

hornblende. Possibly resorption of pyroxene involved in some of hornblende formation. Most hornblende rims narrow compared to size of pyroxene grains, but in some instances pyroxene appears to be relict core. There is little evidence for instability of brown hornblende - very minor oxidation(?) or breakdown to clay or serpentine.

Opagues - less than 5%. Generally anhedral and acting as space filler. In opaque-rich domains appears to constitute "matrix" in which occur rounded grains of (pyroxene), brown hornblende, apatite and epidote. Also occurs as elongate inclusions in clinopyroxene along cleavage traces. Also is disseminated in felsic domains in interstices between grains. Grain size appears considerably smaller in felsic zones. Opagues hematized along very late cracks, otherwise appear unaltered.

Apatite - less than 1%. .1-3 mm grains, rounded, within opaque "matrix." Appear concentrated in some domains, absent from others. Usually found near abundant clinopyroxene. Origin not at all clear.

Serpentine - replacing mafic minerals, apparently mostly pyroxene, possibly olivine. Found as rims and in cracks. Yellow or greenish yellow; may be reddish if around oxidation. Found as inclusions in pyroxene (after some other mineral).

Fibrous colorless amphibole - Alteration product of pyroxene and hornblende along cracks in grains. Minor. Radiating aggregates of unidentified low-relief mineral or minerals after plagioclase. Birefringence mostly low; in some areas high and amorphous (talc?). Replacement is static, after deformation.

Texture - No primary texture remains. Deformation predominantly cataclastic, although some bending is evident in plagioclase and pyroxene

(undulose extinction). Alteration of all phases takes place along grain boundaries and cracks, so altered minerals have whole or partial reaction rims. Multiple rims of alteration minerals not present. Much of apparently lower temperature alteration is localized and quite complete in these areas, making identification of original mineral difficult.

620-5-1 Olivine-bearing Metagabbro

Plagioclase - about 65%. Most grains .15-.5 mm, relict grains up to 4 mm long. Usually interlocking or granoblastic texture, fairly equant grains. Most grains show undulose extinction, some show tapered twins. A few grains show little strain. Many intragranular cracks, mostly with no alteration, in both small and relict grains. A few through-going ~~rocks~~, cracks especially connecting altered mafic phases, filled by chlorite in vicinity of olivine; some sericite(?) pseudomorphing.

Clinopyroxene - 15-20%. Size .75-5 mm, average about 3. Anhedral, some suggestive of interstitial. Some recrystallization in zones, with red-brown hornblende in interstices. Most of the relict pyroxene is finely cleaved, with possible exsolution and/or alteration along cleavage planes. One or two examples of clinopyroxene-clinopyroxene intergrowths. Red-brown hornblende partial rims quite common; almost dots rather than rims. Deformation of grains quite apparent - one in particular is bent, others show undulose extinction. Very little alteration apparent.

Olivine - now less than 5%, originally less than 10%? - aggregates of less than 4 mm. Old and new grains show undulose extinction and some kinking. Overall shape is subequant, anhedral. Alteration to talc + opaques. Later inside and/or outside alteration to yellowish serpentine. No evidence of low temperature oxidation.

Alteration patches - talc + opaques or acicular talc? or tremolite + chlorite or serpentine surrounded by serpentine or chlorite. Some of this apparently after olivine, the rest after olivine(?) or orthopyroxene(?) Patches usually less than 5 mm, irregular in shape. Bladed tremolite may be later growth. None appear to be affected by deformation.

Patches about 5% of rock.

Textures - Plagioclase larger grained at one time. Clinopyroxene grain shapes suggest they are interstitial to plagioclase. Olivine unclear original position. Alteration mostly static, involves olivine and orthopyroxene(?) but not clinopyroxene. Significant that little alteration to hornblende. Deformation sufficient to produce recrystallization and other deformation textures, but no fabric.

620-6-1 (2x3) Rodingitized Metagabbro

Plagioclase - about 20%. Grains less than 1 mm, most somewhat elongate and lozenge-shaped. All highly strained boundaries are irregular.

Plagioclase in a zone with well-developed foliation and some variation of small to smaller grain size across the zone. Large grains are distinctly gray under plane light, finer-grained areas heavily dusted by opaque material. Little apparent alteration to identifiable minerals. Chlorite, smectite, sericite in vicinity of clinopyroxene. Zone is crosscut by veins of chlorite(?) and smectite. Within area of predominantly plagioclase, minor opaques, brown hornblende, and serpentine(?) grains, and two aggregates of clinopyroxene.

Clinopyroxene and red brown-hornblende - about 10%. Relict clinopyroxene larger than 1 cm surrounded by red-brown hornblende-clinopyroxene aggregates of grains smaller than 1 mm. Aggregates rimmed by red-brown hornblende and then green, in strain shadows. Green hornblende is bladed to fibrous, and in smaller aggregates alters clinopyroxene. These grains don't appear strained, but may be syntectonic or even pre-tectonic considering their location. Minor clinozoisite associated with bladed green hornblende. Some hornblende is parallel to high strain zone, perhaps supporting syntectonic origin. Veins of smectite cut across aggregates.

The remainder of the slide consists of "flour" of unknown mineral composition, veins of chlorite and prehnite, some stained by opaque oxidation, mostly parallel to foliation; some smectite. Prehnite veins are quite wide.

620-7-1 (2 x 3) Metagabbro

Plagioclase - originally about 50%. Relict large grains about 5 mm. Most grains are about .25 mm, granoblastic and equant with good 120° triple junctions and in places derived from larger grains by recrystallization. Some grains of both sizes shown undulose extinction and polysynthetic twinning, both mechanical and growth. After recrystallization, some fractures with plagioclase metasomatism then took place; most fractures filled with chlorite.

Clinopyroxene - about 40%. Some grains greater than 1 cm, rounded. Kinking, undulose extinction, and broken grain observed. Majority of grains about 1 mm, in plagioclase matrix. Some fine aggregates with reddish brown hornblende. Smaller grains equant and same shape as plagioclase in which they are found. Minor rims of red-brown hornblende seen where "original" boundary with plagioclase preserved. Clinopyroxene apparently not altered. However, some pyroxene grains surrounded by large areas of alteration minerals - irregular patches of chlorite(?) with felty circular amphibole. Outside this is mostly chlorite, with some higher concentration of amphibole (?) between. Possibly after orthopyroxene.

621-2 Altered Olivine Gabbro

Plagioclase - 65%. Large interlocking grains 2-10 mm. Some grains enclose smaller ones. No distinct zoning. Deformation lamellae and undulose extinction common. Some grain boundaries have apparently very low angles, indicating possible grain size reduction in these areas. A few refilled cracks just show different birefringence within continuous grain. These cracks extend into neighboring grains, where they are healed by pyroxene + hornblende + plagioclase if in pyroxene, by plagioclase if in plagioclase. Other cracks and some of these contain sericite and/or chlorite. Overall alteration very slight, less than 1%.

Clinopyroxene - about 15%. Less than .5 cm. Subpoikilitic - partially or completely encloses olivine and plagioclase. No exsolution, but very fine alteration along cleavage traces. Alteration of brown hornblende along annealed cracks. No brown hornblende rims - clinopyroxene acts in similar capacity around olivine.

Olivine - originally about 20%. About 5-10 mm anhedral. Interstitial to plagioclase, included in pyroxene. Grains enclosing other grains, also aggregates. Some larger grains have kink bands and undulose extinction. Pseudomorphing by serpentine and talc + opaques. Serpentine seems to preferentially form in the cracks. Outer rims of alteration may be tremolite. Not clear what sequence or if synchronous. One minor rim of orthopyroxene.

Textures - (probably some variation of adcumulate, with plagioclase and olivine(?) as cumulus minerals). Deformation very minor; alteration occurs preferentially along cracks. Olivine major altered mineral - extensively near cracks.

621-3-1 (2x3) Altered Troctolite

Plagioclase - about 75% Grain size about 1 cm, up to 1.5 cm. Subhedral and elongate. Grain boundaries usually straight, but in some cases very irregular. (Is this due to polygonization and grain growth? Neither side of boundary looks strain-free to suggest which way boundary may be moving.) Almost every grain has many mechanical twins. Simple growth twins occur but are not common. Polygonization may be occurring, but only little recrystallization along cracks. New grains are strained and may be associated with clinopyroxene. At least a couple of generations of through-going cracks filled with chlorite, serpentine, actinolite; one of latest ones also has carbonate.

Olivine - originally about 25%, now about 40% altered. Grain size about 5 mm, average 3-4. Anhedral grains with cusped boundaries around plagioclase. Some undulose extinction. Forms aggregates. Some veins of clinopyroxene (?) Alteration minor to complete. Corona relationship usually as follows - fibrous colorless amphibole growing inward with amorphous talc or serpentine; outer rim of serpentine. All three minerals form discrete patches inside one olivine pseudomorph. Serpentine may be brown in color. Relict olivine slightly altered along internal cracks. Opaques not abundant in this section in areas of alteration, but do occur in the internal cracks. Pyroxene rims do not appear to be much affected by olivine alteration.

Clinopyroxene - about 1% or less. Occurs as rims around olivine and as small grains in what appear to be late high-temperature cracks. Rarely associated with brown hornblende which is extremely minor in the slide.

Texture - Igneous texture well-preserved despite significant amount of olivine alteration. Alteration appears to be static and to follow cracking through plagioclase to olivine (or alteration of olivine creates through-going cracks). Crosscutting of cracks and difference in mineralogy indicates at least two episodes of cracking during alteration.

621-3-2 Olivine-bearing Metagabbro

Plagioclase - about 70% - 2-8 mm, subhedral, predominantly subequant grains, most with polysynthetic tapered twins and/or undulose extinction. Crosscutting fractures filled with chlorite, minor amount of carbonate. Some sericitization of plagioclase near mafic alteration. Fractures clearly postdate twinning. Evidence of recrystallization only along one zone less than .5 mm wide - granoblastic plagioclase about .25 mm with twins and undulose extinction including same sized grains of brown hornblende. Cuts through some larger grains and twinning not traceable across them.

Olivine - 10-15% originally, maybe higher. Anhedral relicts 1-6 mm size. Cusped shapes possibly due to resorption or due to growth around plagioclase. Polygonization and undulose extinction. Alteration to radially acicular tremolite(?), within primary brown hornblende rims. Outside some serpentine or chlorite coronas, and inside some serpentine along cracks. Some serpentine(?) brownish → yellowish, therefore idding-site(?) Minor opaques especially with tremolite.

Other pseudomorphs - about 10%. Similar to olivine alteration but no olivine left. Some also have talc instead of, or in addition to, serpentine. Tremolite nearly ubiquitous. Some pseudomorphs almost all tremolite, others less than 50%. Talc sometimes stained. Outer corona of chlorite(?) or serpentine(?) nearly ubiquitous. Most if not all are probably pseudomorphs after olivine, but cannot rule out possibility of orthopyroxene.

No pyroxene seen.

Brown hornblende - less than 1%. Rims and in narrow veins. Small and

anhedral.

Textures - Alteration strictly replacement and vein filling. No apparent change in plagioclase compositions. Igneous texture apparently granular, olivine may be somewhat interstitial. Deformation limited, except for one zone, but severe enough to cause internal responses in major phases. Alteration post-deformational, and possibly 2 phase - much less talc, though; and alteration directly to tremolite evident.

621-4-1 Olivine-bearing Metagabbro

Plagioclase - 75%. Two relict grains about 1 cm diameter, a few about 3 mm and most grains about less than .25 mm. Relict grains highly strained, with undulose extinction, mechanical twins and grain-boundary recrystallization in cracks. Small grains are also strained, though twinning is not very abundant (less than 5%). Some evidence for along-crack metasomatism in larger grains, not seen in smaller - came before recrystallization? Alteration along cracks to clays - fibrous serpentine(?) in large cracks; amorphous replacement away from the crack proper. About 1-2% altered.

Olivine - originally about 5%. Now as flattened or rounded relict grains and pseudomorphs less than 5 mm diameter. Relict grains have kink bands and undulose extinction. A few grains are subdivided. Some grains have granoblastic orthopyroxene around them, others hornblende and biotite. Alteration rims are of talc + opaques \pm colorless amphibole. Relict olivine in some areas almost entirely altered to brown oxidized serpentine inside other alteration. Mesh texture is preserved in these areas.

Ortho + Clinopyroxene - less than 1% - positive identification of orthopyroxene not clear, but by birefringence and extinction measurements, not trivial. Both occur as about .25 mm equant grains in recrystallized mafic domains, associated with brown or pale green hornblende \pm biotite. Also one relict grain about 2.5 mm long with clinopyroxene lamellae and rims of talc and opaques in a zone of brown hornblende. Two apparent clinopyroxene pseudomorphs now of brown hornblende, about 2 mm. One includes large round grain of opaque, the other has abundant opaque lamellae.

Hornblende - primarily reddish, usually less than 1 mm and most less than .2 mm. Larger grains often stand by themselves. Smaller grains form granoblastic aggregate bands or are dispersed in fine-grain plagioclase. Some hornblende is pale brown to green, usually associated with olivine along discrete domains.

Biotite - less than 1% associated with green hornblende around olivine. Elongate parallel to foliation.

Sphene - less than 1% - subhedral, associated with minor equant apatite in isolated instances. Grains about .5 mm.

Textures - primary textures not apparent. Foliation is defined by mafic and plagioclase-rich domains, grain shape, and some crystallographic mineral alignment. Deformation probably introduced some water, which went into amphibole, also talc alteration of olivine and orthopyroxene(?) which possibly occurred later. Late cracks have crossfibers of sheet silicate and related to this is replacement of plagioclase and serpentinization of olivine. Most alteration of mafics, however, seems limited and at high temperature.

621-4-2 Altered Olivine Gabbro

Plagioclase - about 65%. Grain size originally greater than 1 cm. Secondary grains less than or equal to .1 mm obscure original grain shapes and fill cracks in large grains. Large grains show irregular undulose extinction, bent tapered twins, sometimes in two directions; abundant cracking possibly result of expansion of olivine during alteration. Larger cracks have serpentine or talc(?) alteration along them, smaller ones have the same but no cross fibers are developed. There is also some alteration to a very pale chlorite(?). All alteration along cracks clearly crosscuts zones of grain boundary growth and these zones appear neither more nor less stable than the larger plagioclase grains. Only very few secondary grains show twinning of any kind (a couple of examples of deformation twinning), but most show undulose extinction, indicating continued strain. Originally at least subhedral.

Olivine - originally about 30%. Grains greater than 1 cm. Anhedral grains partially enclosed plagioclase. About 70% altered to mesh-textured serpentine and opaques. Some relics show kink bands. In region of small prong of plagioclase, high relief grains which are possibly equant grains of secondary olivine! Around olivine pseudomorphs is rim of pale hornblende - in some places slightly brown, others slightly blue-green. Usually stubby prisms; aggregates.

Clinopyroxene - about 5%. Grain size 2-4 mm. As rims around olivine and interstitial to plagioclase. Often has rim of brown hornblende which is apparently replacing clinopyroxene inward from rim - making grains look somewhat zoned. Replacement is partial to complete, with most grains about 30% altered. Green hornblende may be part of outermost rim. No exsolution lamellae.

Brown hornblende and blue-green hornblende occur as aggregates in zones of recrystallized plagioclase and appear to be synchronous with recrystallization. A couple of grains of 1 mm opaques occur as subhedral inclusions - one in olivine, the other in plagioclase. Minor fine-grained opaques are also present.

Textures - Clinopyroxene clearly interstitial; some olivine after some plagioclase. Otherwise igneous textures very hard to interpret. Little, if any, deformation after major phase of alteration, which was after grain boundary recrystallization of plagioclase.

621-4-3 Altered Troctolite

Plagioclase - originally about 60%, now about 40%. Original grain size greater than 5 mm. Relict large grains are fractured, polygonized, and show grain boundary recrystallization along internal discontinuities. Grains have mechanical twins, fractures and bends. Many new grains show undulose extinction, a few also have mechanical twins. In areas where secondary grains are common, there are also small grains of brown hornblende, often elongate parallel to zone. Large relict grains have irregular cracks with minor sericitization. Abundant through-going cracks, some of which have little alteration associated with them, others have crossfibered serpentine(?). Both these crack sets cut new plagioclase as well as old. Also patches of plagioclase altered to amorphous pale or brown material.

Olivine - originally about 40%. Subhedral grains .5-1.5 cm diameter. Parts of relict grains show deformation lamellae and undulose extinction. Primary rims of clinopyroxene and brown hornblende still visible. Other rims of colorless, massive amphibole and talc (both separate and not more than .3 mm wide); some serpentine (?) rims outside amphibole and/or talc. Majority of olivine altered to mess-texture serpentine with opaques in cracks, leaving relict polygonal olivine subgrains. Entire grain appears to be affected rather than grain boundaries.

Hornblende - at least 3-4%. Occurs as rims around olivine and its associated clinopyroxene, usually pale green or brown, and aggregate. Also occurs in zones of plagioclase recrystallization. Domainal. In vicinity of olivine where olivine is "along strike" hornblende tends to be pale and on greenish side. Where olivine not quite as abundant or where lots

of hornblende, it is reddish brown and quite dark and is associated with epidote (?).

Textures - Primarily deformed and recrystallized on small scale. Olivine shapes may retain some of original texture. Alteration is extensive and either creates cracks or originates from cracking. No distinct foliation developed.

621-5-1 Altered Troctolite

Plagioclase - about 70% Originally grain size 1-.5 cm, subhedral. Simple twins and mechanical twins (sometimes two sets); undulose extinction. Very minor possible polygonization along grain boundaries. Through-going cracks with minor sericitization and narrow cracks filled with cross-serpentine and chlorite. Cracks sometimes zoned - chlorite on outside, serpentine inside. Some mechanical twins offset by cracks.

Olivine - originally about 30% anhedral. About .5 cm, generally cusped around plagioclase. Undulose extinction common. Frequently rimmed by clinopyroxene, which itself has very narrow rim of brown hornblende. Alteration (at least 40% predominantly serpentine at opaques along cracks. Along some grain boundaries, relict gone to brownish serpentine (?) while serpentine in cracks remains pale brown or nearly colorless. Alteration to talc rare; along cracks through olivine grains (associated with opaques) and in small patch of olivine corner without opaques. Patch has colorless fibrous mineral (tremolite?), and very pale serpentine outer rim.

Clinopyroxene - less than 1%. Always rims olivine not apparently altered.

Igneous textures are well preserved, probably indicate plagioclase crystallized before and during olivine. Clinopyroxene and hornblende late minerals. Cracks may be primarily due to expansion from alteration, especially in late stages, since they have filled with more serpentine of apparently same type that is in olivine pseudomorphs.

621-6-1 (2x3) Altered Troctolite

Plagioclase - about 60%. Grain size about 4 mm. Shape anhedral to subhedral, only rarely lathlike. Grain boundaries curved into olivine, irregular against other plagioclase. Smaller later grains of plagioclase interstitial or between larger grains, not clear relationships, but probably a primary feature. Most grains are mechanical twins. All grains badly cracked. Most cracks filled with chlorite and/or serpentine, a few filled with sericite. Some massive sericite (?) replacement of plagioclase in patches. Some serpentine cracks clearly post-date chlorite.

Olivine - about 35% originally. 3-10 mm diameter. Anhedral to subhedral. Slightly undulose extinction, no noticeable aggregates. Partially encloses some plagioclase. Not sure whether late olivine or simultaneous growth. Olivine often rimmed by clinopyroxene and much lesser amounts of brown hornblende, which are almost always associated with opaques. Olivine upwards of 75% altered. Where some olivine remains, minor alteration to talc and fibrous amphibole along some grain boundaries; also serpentine + opaques in mesh texture. Serpentine along cracks is light to colorless, some of the rest and some of talc is colored brown. Elsewhere there are patches of chlorite + actinolite? with outer rims of chlorite, and of talc + actinolite + chlorite with chlorite rims, possibly alteration of olivine. A few have cross-hatch-pattern to actinolite needles, which suggest may be after orthopyroxene. Alteration in these areas is quite extensive and always oversteps original grain boundaries to alter plagioclase to chlorite and other minerals. One or two rims of clinozoisite also occur in this area (non-number end).

Clinopyroxene - about 5%. Less than 1 mm. Rims olivine, sometimes partly altered to brown hornblende. Small equant interstitial grains in plagioclase domains.

This slide is badly altered and shows whole-scale replacement of primary minerals with apparently restricted suite of secondary phases. Presence of clinozoisite vein unusual. Despite significant alteration, little deformed, and igneous textures discernible.

621-7-1 (2X3) Olivine-bearing Metagabbro

Plagioclase - 70-75%. 4-13 mm, anhedral, equant to elongate. Disrupted and displaced along zones of mortar-textured plagioclase of less than 1 mm grains. Tapered polysynthetic twins and undulose extinction present in large grains and to lesser extent in small grains. Many fractures are irregular. Some are restricted to large grains, others cut across entire section or at least several grains. Fractures filled with chlorite, mixed layer silicate, brown and blue-green amphiboles. Alteration of plagioclase is common along fractures, most commonly to some layer silicate, but does not affect the grain far in from the fracture.

Olivine - originally 15-20%. Aggregates 2 mm - 1.5 cm. Anhedral and irregular in shape. Include individual small grains of plagioclase. Some recrystallization, particularly around edges, also undulose extinction, kink bands and deformation lamellae. Rims of brown and blue-green hornblende, clinopyroxene. Alteration to talc + opaques, tremolite (fibrous or bladed), biotite, stained talc(?); veins and outer coronas of serpentine. Also some oxidation to hematite. Alteration less than 30-40%. Biotite occurs outside amphibole rim.

Clinopyroxene - less than 5%. Grains 3 mm and smaller, anhedral and apparently interstitial or partially rimming olivine. Rimmed by red-brown hornblende and also often partially replaced by it along cleavages. No exsolution, almost always finely cleaved.

Reddish brown hornblende - up to 5%. Small grains, most less than 1.5 mm. Rim other mafics and occur as independent grains in recrystallized or finer-grained plagioclase. Also replace clinopyroxene, may be poikiloblastic. Minor amounts of blue-green hornblende next to, outside, or in veins.

Opagues - more than 1%. Grains about .25 mm, anhedral, usually around mafic or surrounded by hornblende. Sometimes in finer plagioclase. Also as secondary mineral with olivine.

Sphene - less than 1%. Grains .5 mm or less, associated with brown hornblende-rich areas.

Textures - Originally quite plagioclase-rich, olivine-rich gabbroid, coarse-grained. Apparently broken, then recrystallized or added new material for fine-grained plagioclase and large amount of brown hornblende. Possibly recrystallization with high fluid content. Some later deformation, more brittle. Olivine alteration may be primarily connected with second phase of deformation. Brown hornblende well established before altered. Brown hornblende, sphene may be late-stage magmatic.

622-1-1 Olivine-bearing Metagabbro

Plagioclase - 60-65%. 1 cm laths and .5 cm subequant grains. Have badly warped twin lamellae and undulatory extinction. Many of the lamellae are thickened and thinned along their length, are often offset in a ductile fashion, but more often are brittly offset by small fractures. The plagioclase shows little alteration, but is badly fractured and the cracks are filled with acicular mats of actinolite and chlorite and with anhedral grains of epidote. Plagioclase grain boundaries are often the locus of alteration minerals such as chlorite and epidote, with possible minor brown hornblende. Plagioclase crystals grain boundaries are curvilinear; mafic minerals are subophitic about plagioclase.

Olivine - 5-10%. Forms large anhedral blebs, up to 1 cm long, usually about .5 cm. Almost completely altered and the remnant cores are badly fractured with iddingsite veins. Olivine is almost certainly an early primary phase and has been deeply embayed by or is interstitial to plagioclase. At least 50% altered to magnetite, iddingsite, talc, colorless and grey-brown amphibole, actinolite, chlorite and smectite.

Magnetite - 5%. 1 mm, anhedral to almost euhedral crystals in plagioclase. All the primary crystals of magnetite have a reaction rim which appears to be a yellow-green pleochroic amphibole. In one crystal the margin is fracturing into small bits within reaction rim.

Orthopyroxene - less than 2%. Possibly a minor primary phase, now almost completely altered. Seen only as remnants at the edge of an otherwise altered mineral.

Talc - 5%. Forms as amorphous masses, as an alteration product of olivine.

Actinolite - about 5%. Acicular rods and needles which, with chlorite, are olivine alteration products. Also occurs with chlorite in veins and cracks.

Chlorite - about 3%. Fibrous mats as alteration product of olivine, or in veins and cracks.

Other olivine alteration products - about 3%. Iddingsite, magnetite, epidote (red?), smectite, colorless and grey-brown pleochroic amphibole.

Other vein and crack material - about 3%. Epidote, magnetite.

Minor accessory minerals in plagioclase - rutile and apatite.

Textures - Subophitic texture, with resorption of early mafics by plagioclase. Plagioclase twins and crystal edges exhibit brittle deformation, in having been shattered or broken or offset. There is also some ductile twin lamellae deformation. One interesting observation: plagioclase twin lamellae in a large crystal are warped and bent around a smaller crystal; the lamellae in the large crystal are also thickened at that point, thinned to either side.

Fractures and cracks traverse the entire slide and most are filled with epidote, or actinolite and chlorite (which seem to occur everywhere together). One set of fractures is subparallel, and traverses the width of the slide (this can also be seen in the hand specimen).

All of the mafic phenocrysts have large fractures associated with them, which may represent the manner in which water entered the system.

Chlorite seems to rim all of the mafic minerals; however, in one case, a pseudomorph composed of chlorite and actinolite is surrounded by concentric rings of an amorphous mineral. This material has a bluish color under crossed nicols and a greenish tinge under plane light;

could it be extremely fine-grained chlorite?

The relative lack of pyroxene and hornblende is interesting, as is the presence of good primary opaques.

622-1-2 Metagabbro

Plagioclase - about 80%, originally 90+. Grains 5-10 mm long, subhedral to anhedral. Irregular grain boundaries, some grain boundary recrystallization. Grains have undulose extinction, mechanical twinning. A lot of cracks, especially in vicinity of pseudomorphs, which are filled with chlorite, "smectite" or chlorite first and "smectite" in center.

Alteration - about 20%. Pseudomorphs are anhedral, with sculpted boundaries. Centers of chlorite and "woven" needles of actinolite. Borders of sheets of colorless amphibole growing inward, outer rim of clinopyroxene and/or pale brown hornblende. Other patches of "smectite" or oxidized talc (?) ± opaques, with hint of mesh texture. Possibly even very little relict olivine; clinopyroxene rims are preserved.

Clinopyroxene - less than 1%. Rims mafic pseudomorphs, also a few grains interstitial to plagioclase.

Textures quite simple - two types of pseudomorphs, cracks with abundant alteration; very little recrystallization; some strain in plagioclase.

622-2-1 (3 1/4 x 4) Metagabbro

Plagioclase - about 40%. A few clasts .5-5 mm with rounded, irregular shapes. The rest is mass of very small grains, often surrounded by fine-grain opaque mineral, looking very mylonitic. Number end of slide has relatively clean plagioclase domains, remainder of slide has mixed opaque and plagioclase. One relict grain surrounded by small grains obviously developed from relict grain. Zones of recrystallization through grains. Some sericitization of fine grained plagioclase likely.

Clinopyroxene - about 15%. Relict rounded grains .5-5 mm, most on smaller end of scale. Unbent and clean extinction and only rarely recrystallized. Some grains contain large inclusions of opaques, others have exsolution of other clinopyroxene and brown hornblende. Alteration appears to be to green hornblende. Clinopyroxene appears to be most abundant in unnumbered end of slide.

Hornblende - about 5-10%. Brown hornblende is closely associated with clinopyroxene. Where alteration of clinopyroxene evident, color usually drab green. In numbered end of slide, brown hornblende, with green hornblende in larger patches and in cracks.

About 5% serpentine pseudomorphs, possibly after orthopyroxene. Texture is fibrous; shapes and sizes of pseudomorphs comparable to other minerals and indicate post granulation alteration. Serpentine also occurs in cracks cutting across foliation. Serpentine appears to be concentrated in the numbered end of slide, possibly indicating primary compositional difference which was parallel to foliation.

Non-numbered half of slide is less altered but better foliated than the numbered half. There are three large cracks with associated alteration perpendicular to and not offset by foliation.

Opagues - about 10%. Finely disseminated in fine grained plagioclase and mafics; also occur as inclusions in relict mafic grains.

Other alteration - Some smectite? in matrix, patches of chlorite? and serpentine after mafic and plagioclase. Possibly some epidote.

622-2-2 (2 x 3) Metagabbro

Plagioclase - about 50%. A few relict grains about 5 mm longest dimension, undulose extinction some bent twins. Rest of plagioclase less than .25 mm, mostly granoblastic texture, probably from recrystallization. Most small grains twinned and/or show undulose extinction. Grain boundaries usually regular. One small area where obvious brittle breaking of larger grain at edge of slide, with chlorite in crack. In some places irregular plagioclase metasomatism. Minor sericitization in plagioclase domains long grain boundaries of small plagioclase in mixed domains. (Moderate amount of chlorite alteration, plagioclase and brown hornblende and opaques and epidote).

Clinopyroxene - at least 25%. Relict grains are rounded "clasts" 2 cm - 1 mm. Larger grains show zones of granoblastic pyroxene. Some grains have unmixing textures (clinopyroxene-clinopyroxene and clinopyroxene-orthopyroxene) and opaque lamellae and inclusions. Some grains appear zoned - clear rims, cleaved cores.

Orthopyroxene - A few clasts about 1 mm, same textures as clinopyroxene. Also some bastite(?) "clasts".

Brown hornblende - about 5%. Inclusions and rims to clinopyroxene; separate grains in mixed domains. All brown hornblende is reddish.

Opaques - some inclusions in clinopyroxene, most abundant as small irregular grains in mixed domains. Epidote less than 1%, in mixed domains. Possibly some actinolite with chlorite in mixed domains. Greenish mineral, which may be green hornblende.

A few patches of serpentine + opaques ± needles of actinolite after olivine? Large patches of pseudomorphs near broken plagioclase - chlorite, chlorite + actin(?), serpentine(?). Area looks moderately undeformed; one grain of sphene, and some unaltered clinopyroxene and brown hornblende.

Overall texture blastomylonitic. Most alteration at least epidote-amphibolite. Chlorite and serpentine alteration apparently late.

622-3-1 Rodingitized Metagabbro

Quartz - about 25-30%. Grains less than 1 mm; texture almost granoblastic, but with irregular grain boundaries. All grains show undulose extinction. Forms interstitial matrix to spherulitic and irregular patches of brownish aggregate.

Aggregate - 70-75%. Possibly a mixture of talc or smectite and chlorite. Concentric zoning of light and dark repeated; some zoning is irregular. Aggregate shapes are varied, but overall impression is that quartz acts like a vein matrix to broken pieces of previous mineral. No relics nor their textures remaining.

This rock will not provide much information about origin. Can only be used as description of what can be found in oceans.

623-1-1 Olivine-bearing Metagabbro

Plagioclase - 60-65%. Grains are anhedral, mostly subequant, 5-15 mm. Simple growth twins and bent, tapered mechanical twins both quite common. Grain boundaries are cusped (especially around mafics) to irregular. [Reduction in grain size in some areas probably due to deformation (polygonization?).] Only one zone with much smaller grain size and granoblastic texture. Many small grains show undulose extinction in this area. Plagioclase mixed with various alteration minerals. Large plagioclase crystals crosscut by myriad chlorite and tremolite veins at relatively constant orientation - two sets about perpendicular. Some appear to predate others; some are hematized. Fractures cut but seldom offset mechanical twins. One case of chlorite vein cut by blue-green amphibole grain (therefore syn- or post-chlorite). Minor sericitization of plagioclase, some mafic pseudomorph extend considerably into plagioclase with chlorite coronas.

Olivine - about 5%, originally. 15-20% or more. Up to 8 mm, average 3. Anhedral, with cusped or rounded boundaries. Kinks and undulose extinction common. Alteration to talc + opaques area. Clinopyroxene and brown hornblende associated with some grains. Fibrous tremolite sometimes seen growing into talc + opaques area of pseudomorph and outermost corona of chlorite very common.

Clinopyroxene - less than 5%. Small grains about less than 1.5 mm. Interstitial and as rims. Contain small elongate opaque inclusions and almost always rimmed by red brown hornblende. Apparently relatively unaltered.

Hornblende - about 1%. Rims to clinopyroxene and olivine, usually red-

brown. Some blue-green hornblende rims olivine and in veins with chlorite, most probably secondary. Usually quite clear and anhedral or euhedral, depending on location.

Pseudomorphs - complete pseudomorphs include those very similar to alteration coronas around olivine, with no relict olivine. Also chlorite and acicular tremolite surrounded by fibrous tremolite, or pseudomorphs of mostly tremolite. Some also have a little smectite(?). All have outer rim of chlorite, after orthopyroxene or olivine. Some hints of relict orthopyroxene in some rims but not conclusive identification. Definitely not from clinopyroxene.

Minor opaques and sphene - much less than 1%.

Textures - Plagioclase dominant primary mineral. Olivine and orthopyroxene(?) next, clinopyroxene and then hornblende fill in the interstices. Alteration static, as result of or causing fractures. Deformation very restricted at higher temperatures. (Fracturing not necessarily stress-induced.)

623-1-2 Metagabbro

Plagioclase - about 60%. Grains 2-5 mm, subhedral, stubby to equant. Regular grain boundaries. Moderately strained crystals - mechanical twinning and moderate undulose extinction but no subgrain development nor recrystallization evident. Grain boundaries with mafics marked by about .25 mm chlorite rim which appears to be alteration into plagioclase grains. Cracks in plagioclase also filled with chlorite. This is only alteration of plagioclase and makes up about 5% of slide.

Pseudomorphs of mafic mineral - about 30% of slide. 1-3 mm size, anhedral grains apparently interstitial to plagioclase. All pseudomorphs have mats of bladed to acicular, colorless, actinolite with interstitial chlorite or talc. A few have thin prisms of blue-green hornblende growing in chlorite rim but from pseudomorph outward. No remnant internal structure of primary mineral obvious.

Texture - Igneous texture of plagioclase with interstitial mafic well preserved. Alteration clearly static. Uniform mineralogy suggests originally a two-phase rock.

623-1-3 Olivine-bearing Metagabbro

Plagioclase - about 60%. .5-2 cm, subhedral to anhedral grains showing resorption and interlocking boundaries. Abundant tapered polysynthetic twins, in some cases overprinting simple twins. Some undulose extinction. No apparent zoning. Plagioclase is badly fractured, possibly due to expansion from hydration of mafic phases. These fractures contain actinolite, chlorite, hornblende and other unidentified phases. Plagioclase may be included within a cluster of mafic minerals. Contains many tiny inclusions, sometimes in linear trails which may be aligned to crystallographic axes.

Olivine - about 20%. A few 2-3 cm long grains, apparently interstitial to the plagioclase, possibly one poikilitic grain, contain resorbed inclusions of clinopyroxene and plagioclase. Are cracked, with the larger cracks containing fibrous and opaque alteration phases.

Clinopyroxene - about 1%. 1-3 mm grains included in or closely associated with olivine. Anhedral, usually with very finely spaced parting. Most grains contain opaque inclusions along parting, particularly where parting is not as well defined. Alteration to brown or pale green amphibole may be minimal to complete.

Brown hornblende - less than 1%. Subhedral grains in plagioclase; rims around olivine, clinopyroxene and opaques. Very massive to somewhat fibrous, and varying in color intensity. Replaces clinopyroxene as partial or complete pseudomorphs. May grade into blue-green amphibole.

Actinolite (or various lightly colored amphiboles) - about 5-10%. Make up about 60% of fields of acicular mats of alteration minerals. Some laths. Fibers of colorless amphibole radial outward from pyroxene, but

radial inward toward olivine when in reaction coronas.

Chlorite - about 40% of altered fields. Replaces plagioclase in mats or along veins. Intergrown with actinolite or in discrete group of fibrous grains within altered fields.

Talc - Amorphous, forms as alteration of olivine. Associated with opaques.

Opaques - Possibly a few grains are primary - they are euhedral, but occur in fields of alteration. Most grains are anhedral. Occurs as inclusions in clinopyroxene, and within talc and chlorite fields.

Epidote - About 1%. In cracks in plagioclase grains; sometimes forming veinlets. Small anhedral crystals.

Carbonate - one small veinlet.

Textures - Plagioclase grains are large, with interlocking boundaries. May be included in olivine and show some resorption. Clinopyroxene is included in olivine or adjacent to it, and appears resorbed. Possible primary zonation in plagioclase, somewhat disrupted by deformation. Conjugate fractures visible with naked eye. One of pair is wider, less closely spaced. Twin lamellae in plagioclase are usually tapered, and may be bent and/or offset along cracks. Mosaic recrystallization of plagioclase is almost completely absent. Olivines are cracked, but otherwise show no deformation. Alteration minerals in cracks, especially of olivine and plagioclase. Also .6-1 cm diameter fields of nothing but alteration minerals (predominantly talc + opaques or actinolite + chlorite). Olivines may have a corona of talc + opaques followed by intergrown actinolite + chlorite. A chlorite rim may be present outside this, possibly due entirely to chlorite replacement of plagioclase, as

the chlorite + actinolite/chlorite boundary is usually well defined, whereas the chlorite/plagioclase boundary is very jagged. Chlorite also forms discrete patches within actinolite + chlorite fields of alteration. The phase that appears completely altered may be orthopyroxene or olivine. If it was olivine, this rock is troctolitic, as there is only a minor amount of clinopyroxene.

623-1-4 Metagabbro (2 sections)

Plagioclase - 65-70%. Grains 3-10 mm, mostly subequant, and anhedral. Plagioclase-mafic boundaries straight to slightly irregular, plagioclase-plagioclase boundaries irregular to curvilinear. Simple and multiple twins and undulose extinction common. Little indication of recrystallization. Chlorite very common in fractures and along grain boundaries, minor amounts of brown amphibole. Sericite alteration minor.

Clinopyroxene - greater than 1%. Grains less than 2 mm, narrow bands. Clearly interstitial to plagioclase and altered mafics. Finely cleaved, mostly unaltered. Some have very narrow green or brown hornblende rims; others have tremolite; this probably due to alteration of adjacent mafic mineral.

Pseudomorphs - about 25%. Chlorite + needles or talc + opaques inside colorless fibrous amphibole inside sheet silicate rim. Needles vary in amount, amphibole forms moderate rim growing inward. Pyroxene usually outside amphibole - inside corona. Chlorite + needles have woven texture in some cases. Some talc pseudomorphs appear to have replaced olivine, but no relics remain.

Textures - Plagioclase and ultramafic, with clinopyroxene interstitial. Texture basically equigranular. Deformation apparently limited and pre-alteration. Alteration static, very little hornblende.

623-2-1 (2 x 3) Metagabbro

Plagioclase - now about 40%, originally about 50%. Most grains about 1 cm long, subhedral to anhedral, with regular curvilinear boundaries. Some interlocking of grains. Grains show undulose extinction and some mechanical twinning, but no recrystallization. Plagioclase is quite fractured, with irregular cracks and conjugate sets of cracks filled with chlorite. Some small patches appear to have undergone metasomatism and these areas may also show incipient sericitization. There are minor amounts of blue-green hornblende and actinolite (?) in a few cracks. A few inclusions of round opaques with very narrow rim of brown hornblende.

Clinopyroxene - about 1-2%. Grains 2-3 mm, rimmed by brown hornblende. Apparently interstitial to other mafic and plagioclase. Good cleavage developed. Alteration to green and brown hornblende along cleavage traces. Little exsolution, one grain contains tiny opaque inclusions.

Hornblende - about 1%. Mostly brown rims both clinopyroxene and pseudomorphs of mafic minerals. Also separate grains of interstitial hornblende in plagioclase - about 1.0 mm or smaller. Apparently unaffected by alteration although may grade into blue-green or colorless amphibole which appear to be overgrowths.

Pseudomorphs - 1) Anhedral patches of amorphous talc, some with relict cracks reminiscent of olivine, with narrow rims of ingrowing blades of actinolite, outer rims of chlorite \pm blue-green amphibole. 2) Patches of bladed actinolite and outer rims of chlorite. Actinolite usually colorless. Some patches have cores of sheet silicates or chlorite. A

couple have opaque inclusions similar to those in plagioclase. Patches appear semi-continuous and may have poikilitically enclosed plagioclase. Boundaries regular but curvilinear (excluding chlorite rim). Brown hornblende (\pm clinopyroxene) rim occurs inside some chlorite rims.

Textures - Deformation seems predominantly restricted to cracking during which water was introduced. At least some of mafic pseudomorphs suggesting olivine have "mesh" texture. Cracking may have been intensified by expansion during alteration. Actinolite may grow after alteration to talc; degree of replacement varies across slide.

623-3 Olivine-bearing Metagabbro (3-1?)

Plagioclase - 80%. Stubby grains about 4-8 mm long are anhedral and have highly irregular boundaries due to cataclasis(?) and new grain formation. About 5% of plagioclase is grains less than .1 and some less than .01 mm which are found as mortar to many large grains, not well developed. Both grain sizes have tapered mechanical twins and undulose extinction. Most grain boundaries quite irregular to serrated. One area of optical zoning in a large grain may be metasomatic alteration. This may post-date very small grain development as fewer in this region and those somewhat enclosed. Plagioclase of all sizes has lots of tiny needly opaque inclusions. Alteration predominantly as fracture fillings. Very minor sericite alteration. Chlorite coronas around olivine also etch plagioclase.

Olivine - about 10%. Anhedral, mostly interstitial grains - less than 4 mm. Undulose extinction ubiquitous, some kink bands and deformation lamellae. Alteration about 30% to talc + opaques → tremolite → chlorite. Minor rims of primary red brown hornblende and .25 mm opaque grains.

Clinopyroxene - about 1%. Interstitial, usually less than 2 mm. Some apparently the same orientation so "poikilitic" about plagioclase. Some inclusions of elongate opaques. Predominantly unaltered. Frequently with red brown hornblende as rims and intergrown with it.

Hornblende - less than 1%. Red brown rims olivine, pyroxene and euhedral opaques. One fragment has euhedral core of green hornblende! Blue-green hornblende found as rims and to very slight extent with alteration of olivine.

Pseudomorphs - some pseudomorphs identical to talc + opaques alteration of olivine and similar coronas.

Textures - Interstitial texture of mafics fairly well preserved.

Plagioclase apparently slightly elongate, very clearly dominant mineral.

Deformation predominantly cataclastic with no recrystallization, internal slip in plagioclase and olivine also occurred. Fracturing post-dates this deformation and close to time of alteration. Alteration primarily affects mafics - static replacement and mostly olivine - alteration almost exclusively higher temperature. Chlorite and blue-green hornblende indicate probably greenschist facies.

623-3-2 (2X3) Altered Troctolite

Plagioclase - about 85%. Subhedral prisms; mostly anhedral, grains .5-1.2 cm, subhedral to anhedral grains are dominant, but a small fraction (10-15%) of the total plagioclase is much smaller (about .2 mm) grains or clots of grains (with glomerocrystic appearance) filling in among larger grains. There is some tendency for these clots to form interstitially with the mafic phases (olivine and clinopyroxene), but the correlation is not exact. Twin lamellae, both straight and tapered, are abundant but zoning is completely absent. There are many small, irregular, cross-cutting fractures, but no large through-going breaks or segmentation.

Olivine - about 10%. .3-1 cm anhedral grains occur in the interstices between large plagioclase grains. They are generally elongate in very irregular shapes defined by the void in which they formed. They tend to be glomerocrystic, though less markedly than the small plagioclase grains, and may be intergrown with clinopyroxene. The olivine is commonly veined or broken, with opaque material filling some veins. Contacts with the surrounding plagioclase are everywhere altered along very thin to modest zones. The little brown hornblende present in the slide is in these zones, together with talc and other unidentified alteration products.

Clinopyroxene - much less than 5%. Clinopyroxene is relatively scarce, occurring like the olivine in irregular interstices between plagioclase either as isolated grains rimming olivine. It is easily distinguished from the olivine by the general lack of fractures, abundant parting, occurrence of patches of brown amphibole within as well as around the margins of grains, and frequent "clean" contacts with the surrounding plagioclase (plus, of course, relief and 2V).

Brown amphibole - Small patches of this material occur as an apparent alteration product around olivine and clinopyroxene and within clinopyroxene as well. It also occurs respectively within or around larger patches that have two apparent origins: (1) nearly complete replacement of olivine(?) by a colorless to slightly greenish, fibrous and radiating mineral (actinolite?), or (2) vein-filling fibrous material and a variety of other unidentified phases (including apatite?).

Tremolite? - this is a ubiquitous phase, occurring as just noted adjacent to olivine and in larger masses of altered material as very fine radiating bundles of moderate relief and birefringence; extinction angle of about 12-15°.

Talc - There are a few patches of fine, felted material of high birefringence around the olivine and intergrown with the tremolite(?).

The texture is controlled by the large interlocking plagioclase grains. There is a hint, however, that these could have been more "discrete" prior to deformation. The distribution of olivine and clinopyroxene (or rather their habit) is very much what would occur if this rock were a cumulate of some sort.

Plagioclase displays abundant bent and tapered twin lamellae and undulose extinction is also prevalent. Many of the olivine grains also show undulose extinction that is modestly to strongly developed. There is no sign of 120° triple-junction grain boundaries among the large plagioclases, though there are a very few such boundaries among 2 small plagioclase grains and one mafic grain. There are no such triple junctions among 3 small plagioclase grains. This indicate probable lack of recrystallization. As noted, alteration is largely along margins of olivine and clinopyroxene, veins cutting olivine or in separate dots

(that may represent completely replaced mafics). There are also many fine veins cutting the plagioclase, some of which are filled with what appears to be recrystallized plagioclase and some with an unidentified crystalline material.

623-4-1 Metagabbro

Plagioclase - about 30-40%, originally probably greater than 50%.

Grains up to 5 mm, anhedral, equant to slightly elongate. Mechanical twins common, extinction only slightly undulose. Recrystallization and subgrain development not evident. Cracks filled with chlorite and very minor acicular amphibole. Replacement of plagioclase by chlorite around mafic pseudomorphs account for about 10% of slide. This type of alteration does not occur along clinopyroxene-plagioclase boundaries.

Clinopyroxene - less than 5%. Grains up to 4 mm long, clearly interstitial to plagioclase and altered mafic mineral(s). Narrow pale hornblende rims rare. Some very fine lamellae either exsolution or alteration. Little alteration is evident. Cuspate grain boundaries resembles olivine textures in troctolite rocks. Minor brown and blue-green hornblende associated with clinopyroxene.

Pseudomorphs - about 50%. Colorless, bladed-to-acicular actinolite defines outer boundary of pseudomorphs and may make up almost entire pseudomorph or only outermost part. Cores of either fine-grained actinolite and/or chlorite or other sheet silicate. Some dirty areas with very low birefringence may be partly oxidized chlorite. Where pseudomorph against clinopyroxene, actinolite grows inward as sheet, and follows orientation of clinopyroxene. Pseudomorphs probably greater than 1 cm in size, poikilitically enclosing plagioclase.

Textures - Static alteration may have caused expansion forming cracks. Very little hornblende.

623-4-3 Metagabbro

Plagioclase - about 30%, originally greater than 40%. Grains about 2-5 mm, subhedral, elongate. Tapered and stubby polysynthetic twins, moderate undulose extinction. No apparent recrystallization and sub-grain development. Cracks filled with chlorite and/or blue-green or brown hornblende. Trails of (cubic) opaque inclusions common. Dusting of alteration minerals associated with some apparently discontinuous cracks. Replacement of plagioclase by chlorite growing out from mafic pseudomorphs.

Pseudomorphs - 70% including chlorite rims, about 50-60% excluding chlorite. Predominantly bladed colorless actinolite. Some brown and blue-green hornblende in chlorite zone or as outer rims to pseudomorphs. Cores of pseudomorphs may be 70-80% chlorite. Apparently original mineral ophitic around plagioclase laths. Brownish tinge to some of pseudomorphs possibly due to slight oxidation along grain boundaries.

Texture - Ophitic texture despite alteration. Deformation limited to a few cracks and minor strain in plagioclase.

623-5-1 (2 x 3) Metagabbro

Plagioclase - about 60%. Grains 5-15 mm, subhedral, equant to elongate. Kinks, mechanical twins and undulose extinction; later cracking has offset some kinks and twins. Very little polygonization, very slight recrystallization. Some hypidiomorphic plagioclase, some almost euhedral and enclosed in mafics. Late cracks filled with chlorite, pale amphibole and/or brown and green hornblende. Some patchy replacement of plagioclase by chlorite cracking is quite abundant.

Pseudomorphs of clinopyroxene - 10-15%. Retain cleavage characteristics and some rims of brown hornblende of dull brown color, with some green blades of actinolite growing inside. Grains about 5 mm, clearly interstitial to plagioclase and perhaps to other mafic. No original exsolution apparent.

Pseudomorphs of another mafic mineral - 10-15%. Predominantly inward-growing or felted blades and needles of colorless actinolite, some brownish, amorphous sheet silicate, some chlorite in core matrix, rare chlorite rims. Grains anhedral, relatively equant and sometimes interstitial to plagioclase, often apparently surrounded by clinopyroxene? Some outer rims of pale blue-green amphibole. Many minerals cloudy due to dusting of oxides.

Texture - Probably plagioclase first to crystallize. Alteration static, apparently after deformation and related to brittle cracking. Cracking extensive, with several examples of slight displacement.

623-6-1 Altered Olivine Gabbro

Plagioclase - 70%. Originally tabular, sub- to euhedral grains up to 1 cm long. These now cracked and faulted and partially recrystallized. Recrystallization to very small grain boundary grains some of which have annealed cracks. Bent, tapered twin lamellae not as abundant as in some sections; highest concentration in areas where grain-boundary recrystallization is most intense. Apparently very little ductile flow as no foliation is developed and along most plagioclase/mafic borders igneous textures are well preserved (unless masked by an alteration corona). A few of the very small grains have tapered twins.

Clinopyroxene - originally about 20%, now less than 10%. Grains up to 1 cm, interstitial to plagioclase - grain boundaries long and straight, set by plagioclase. All the pyroxene left is clinopyroxene, and alteration mineralogy (predominantly blue-green and brown hornblende) suggests very little if any orthopyroxene originally. Relict clinopyroxene shows no exsolution but one grain includes two other irregular, rounded grains. Where pyroxene associated with olivine, interstitial-to-rimming relationship. Narrow rims of brown hornblende nearly ubiquitous. Where clinopyroxene altered, blue-green is dominant replacement mineral, and also forms second rim around brown hornblende (brown hornblende appears jacketed or zoned, but stable anyway). A paler brown hornblende may also pseudomorph the clinopyroxene inside its primary brown hornblende rim.

Olivine - originally about 10%, now 5-8%. Grain size .5-1 cm. Grains more equant than pyroxene. Olivines show abundant kink bands and parallel deformation lamellae. Most grains are aggregates. Alteration of the olivine is almost entirely confined to grain boundaries

with other minerals and there is relatively little internal cracking compared to other samples. One grain shows complete alteration, with relict mesh texture and remnant olivine replaced by carbonate inside alteration rim. Alters to talc + opaques inside rim of blue-green to colorless amphibole (most color on outside). Talc in some areas apparently being replaced by poikiloblastic colorless amphibole (tremolite?) which includes talc remnants.

Talc and chlorite are also found outside amphibole rims near olivines, apparently replacing plagioclase.

Both blue-green and brown hornblende occur as separate grains in plagioclase as fillings in cracks and as grains within recrystallized zones. Blue-green is more abundant and when it occurs with brown hornblende is usually the outer part of the grain or aggregate of grains.

Textures - plagioclase most euhedral mineral, dominates texture. Much of the plagioclase textures still discernible, especially near pyroxene. Deformation was apparently brittle - involving cracking with movement along some cracks. However, this occurred while rock was hot enough to precipitate blue-green hornblende as crack fillers. Minor amount of grain boundary recrystallization has annealed most of these cracks. Alteration of pyroxene occurred at this time; alteration of olivine probably as well, but not clear. Last thing that happened is serpentinization of olivine and final, limited replacement of it by carbonate.

624-2-3 Olivine-bearing metagabbro

Plagioclase - 35-40% originally, now about 5%. Grains may have been as large as 4 mm, only relicts left. Undulose extinction and rare twinning of unknown origin. Alteration predominantly to amorphous and sheaf-like sericite, some chlorite, clinozoisite and fine-grained opaques. Little coherent pattern to alteration. Some veins of cross-fiber serpentine(?).

Olivine - about 20-25%. One aggregate about 1.5 cm, unknown overall shape, made up of less than .4 mm grains, possibly neoblasts. Aggregate encloses clinopyroxene grains of approximately same size. Grains show undulose extinction. Outlines of grains with plagioclase pseudomorphs, embayed suggesting resorption. Moderate amount of serpentine veining and no talc + opaques alteration apparent; distinct from the bulk of the gabbroic population.

Clinopyroxene - less than 5%. Relatively unaltered, rounded anhedral grains about 3 mm in diameter. Inclusions in olivine or surrounded by plagioclase alteration. Finely cleaved, possibly finely laminated exsolution. Some apparent intergrowth textures, very minor rims and inclusions of red-brown hornblende. Several grains fractured and subsequently filled with serpentine. One grain apparently kinked and then fractured.

Plagioclase much more unstable than mafics. No amphiboles particularly not actinolite-tremolite or blue-green hornblende. Alteration of olivine predominantly serpentinization, primarily localized along fractures. Clinopyroxene broken but unaltered. Except for undulose extinction in olivine, most textures seem to indicate only moderate amount of very brittle deformation. Since plagioclase mostly gone, evidence for higher

temperature recrystallization and other ductile deformation may have been lost.

624-3-2 Rodingitized Metagabbro

No plagioclase.

Relict clinopyroxene - less than 1%. Moth-eaten grains less than 2 mm, mostly relict slivers parallel to cleavage. May be misidentified.

Radial chlorite or smectite - greater than 50%. In snaky lines and circular aggregates. Circular areas usually enclose euhedral to subhedral grain of hydrogrossular(?). This chlorite(?) is partially replaced by carbonate.

Hydrogrossular(?) - about 25-30%. Euhedral to subhedral single crystals surrounded by chlorite(?); also anhedral aggregates forming much of matrix.

Epidote - minor; fine-grained in matrix.

Colorless amphibole(?) - greater than 1%. Tiny needles scattered through hydrogrossular(?), also growing into coronas around euhedral hydrogrossular.

Much of rock is very fine-grained and rusty brown, so identification is difficult.

Relict clinopyroxene suggests that rock was once coarse-grained, but beyond that no textures perceptible. Corona texture and euhedral crystals indicate static growth of secondary minerals without subsequent deformation. No real veining or fracturing of rock apparent.

623-4-2 Metagabbro

Plagioclase - about 70%. 3 mm diameter, up to 2.5 cm long. Large anhedral grains, many of which are untwinned. Twins are bent and tapered. Extinction is generally undulating. Boundaries with mafics tend to be obscured by alteration, but there is some evidence of a limited amount of recrystallized plagioclase. Grains are fractured, with alteration occurring along fractures. General dusty appearance due to sericitization. Contain inclusions of alteration pseudomorphs.

Augite - about 12%. Grains 1-5 mm, interstitial to plagioclase. Generally medium grained, subhedral to anhedral. Diapiric parting is fine and closely spaced, with alteration along it. Grains tend to be quite thoroughly altered. Occasional inclusions of plagioclase.

Olivine - about 1%. Fine to medium anhedral grains, which occur as inclusions in pyroxenes.

Tremolite - about 8%. Colorless, generally forms fibrous aggregates, though somewhat blockier grains exist. Tremolite surrounds relict pyroxenes. In association with chlorite, it is an alteration product. Occasionally tremolite shows preferred orientation along pyroxene cleavages, but often replaces the whole grain.

Chlorite - about 5%. Essentially colorless with slight yellow or green tint and low birefringence. Two varieties exist, one of which is yellower. The yellow one may occur in veins and often shows the anomalous blue birefringence, though the blue birefringence is not wholly confined to this variety. Chlorite occurs in very fine aggregates and larger grained aggregates of feathery flakes. These latter grains may be oriented parallel to one another, but generally show random orientation. It is usually

associated with tremolite and often surrounds it, separating it from plagioclase in rims .5-2 mm wide. Chlorite also occurs within veins in plagioclase.

Hornblende - about 2%. Both brown and blue-green varieties appear, but brown is dominant. They are most commonly rims around the pyroxenes and patches on them. When they form rims, blue-green lies outside the brown hornblende. In a few instances, both varieties occur in veins within the plagioclase. Blue-green hornblende also forms small anhedral grains within the chlorite alteration rims. Where both varieties occur, they grade into each other and have no optical discontinuity to mark the boundary.

Textures - Alteration of pyroxenes has been sufficient to obscure primary textures. However, clinopyroxene may have formed interstitially to the plagioclase laths. Olivines occur as inclusions in clinopyroxene. Deformation is most apparent in the plagioclase, and has had little effect on the mafics. The plagioclase is cracked and veined and twins are bent, broken and tapered.

Clinopyroxenes have undergone varying degrees of alteration. A few have undergone little alteration except along their cleavage. Others have been totally altered to tremolite and, in most instances, chlorite. Where alteration is incipient, tremolite forms within the pyroxene cleavage. When it is more abundant, and occurs around the edges of a pyroxene, tremolite tends to radiate inward from those edges. The fine-grained chlorite generally occurs further toward the center of the clinopyroxene than does this tremolite. Near the interface between these two zones, individual tremolite needles can be seen within the chlorite zone. When alteration of pyroxene is complete, tremolite is the only remaining phase. Secondary hornblende generally rims clinopyroxene and

if the pyroxene is altered, hornblende occurs outside the tremolite zone. The coarser grained, feathery chlorite generally occurs outside this hornblende reaction rim, between it and the plagioclase. Plagioclase appears to be somewhat sericitized and also contains veins of chlorite, hornblende and other alteration products. Pseudomorphs are .3-1 cm in diameter and are almost always rimmed by chlorite. Many of the smaller cracks are parallel to each other, but few are visible within pseudomorphs (predate them?).

624-5-1 Altered Gabbroid

Clinopyroxene - about 60%. Grains about 2.5-3 cm diameter. Altering along cracks to brown and blue-green hornblende which retains the clinopyroxene parting.

Plagioclase - about 40%. Grains about 3 cm, anhedral. In some portions of slide quite altered. Usually have tapered, bent and kinked twins. Some grains twinned in two directions. One grain shows discontinuous twinning. Minor recrystallization along some plagioclase-plagioclase grain boundaries.

Blue-green and brown hornblende - Partially rims clinopyroxene in discrete grains. Also pseudomorphs clinopyroxene; in places, are blue-green and brown, optically continuous. Under manganese crust, some euhedral crystals with brown centers and blue-green rims. In veins as subhedral grains of varying color.

Colorless amphibole - radiating needles in areas with chlorite or in veins.

Chlorite - Anhedral aggregates in veins and in areas of alteration minerals.

Epidote - Discrete grains in plagioclase; in veins and in fields of alteration.

Zeolite - a minor discrete field between plagioclase grain boundaries. Unidentified brown fibrous alteration product.

Textures - Grain boundaries between plagioclase and clinopyroxene usually cusped; irregular along plagioclase/plagioclase. Plagioclase

has smaller grain size than clinopyroxene. Overall textures not clear due to small sample size and large grain size. Deformation predominantly brittle. Plagioclase more cracked than clinopyroxene. A minor amount of fine-grained mortar texture along plagioclase-plagioclase grain boundaries, but not particularly well developed.

Alteration primarily restricted to fractures and holes. Some internal alteration of plagioclase grains, apparently not crack-related.

624-6-1 Metagabbro

Extremely altered - apparently fine-grained epidosite, with clasts of smectite(?). Some chlorite(?), amphibole and opaques present, grain size less than .3 mm.

737-1-1 Metagabbro

Plagioclase - 50%. Relicts up to 3 mm are irregular and elongate to rounded. Optical zoning suggests metasomatic alteration. Twinning occurs, sometimes bent; undulose extinction is common. Subgrain development and brecciation of grains observed, less than 5% volume. The rest are tiny grains less than .1 mm which appear to be interlocking, equant granoblastic grains. These grains are not twinned, but many exhibit undulose extinction.

Clinopyroxene - now less than 5%, originally at least 20%. Relict grains from 1 mm to 4 mm. Apparently subhedral. Contain exsolution lamellae of opaques and brown hornblende and some elongate inclusions of opaques. May have also exsolved orthopyroxene, now altered. Cleavage bent at margin of largest grain indicating significant strain. Altered "fibrous" green pseudomorph.

Amphiboles - about 40%. Less than 1% brown hornblende as inclusions in clinopyroxene or clinopyroxene pseudomorphs. At least half of amphibole is green to bluish-green, fibrous to bladed hornblende replacing clinopyroxene and possibly another mafic mineral. Also occurs as separate grains or aggregates. Actinolite (?) may be colored or colorless; and forms aggregates of small, bladed crystals after primary mafics. Minor amount of brown hornblende in massive grains has irregular boundaries and is surrounded by actinolite.

Opaques - about 5%. Numerous small inclusions in clinopyroxene and clinopyroxene pseudomorphs, and an opaque-rich domain through center of thin section. Opaques are irregular and presumably aggregate.

Closely associated with opaques in domain are aggregates of sphene - about .5 mm average grain size, subhedral to anhedral.

Very minor chlorite associated with mafics as inclusions and partial rims.

Moderately developed aggregate foliation. Brittle vs. ductile deformation unclear. Relict igneous textures absent. Alteration apparently syntectonic, no late cracking and accompanying static alteration.

737-1-2 Altered orthopyroxene gabbro

Plagioclase - 60-70%. Grains .5-2 mm, most about 1 mm. Granoblastic texture. Most grains twinned, some in 2 directions. Some sutured grain boundaries and subgrain development. Apparently randomly oriented lines of tiny inclusions which are preferentially altered. Very minor sericitic alteration. Possibly crystallographically controlled. Splayed through-going cracks filled with chlorite.

Clinopyroxene - 10-15%. Originally grains average 5 mm; now 1 mm due to recrystallization and alteration. One relict grain shows clear zoning. Recrystallization possibly promoted by zoning. Interiors of grains preserved, although often bent and sheared along cleavage planes. One example of clinopyroxene exsolving clinopyroxene with stringers of brown hornblende, opaque and (?) talc. Where clinopyroxene now granoblastic, usually associated with lesser amounts of orthopyroxene (partially oxidized) and opaques.

Orthopyroxene - less than 5%. Larger relict grains about 1 mm. Exsolve orthopyroxene is blebby, less than .5 mm, and in some areas completely pseudomorphed by chlorite or serpentine. Large grains sheared where cleavage close to foliation of rock. Almost all orthopyroxene at least 10% altered to talc + opaques or pale amphibole, outside rims are usually bluish green in color. Chlorite may form as far outer rim.

Hornblende - less than 5%. Brown blebs in clinopyroxene crystals, with recrystallized pyroxene, and as cores to blue-green hornblende either replacing a mafic mineral or rimming it. Blue-green hornblende much more common than brown, may approach prismatic, fills cracks. Outermost rim on almost all altering pyroxene; width of rim variable.

Opagues - less than 1%. Grains less than .2 mm, anhedral included in pyroxenes, amphiboles and alteration aggregates.

Alteration minerals - about 5%. Patches of fibrous amphibole mimic pyroxene cleavage, usually pale and cloudy. Some patches suggest alteration after recrystallization. Some patches of serpentine(?) pseudomorphing orthopyroxene(?). Kinking of some of fibrous material indicates some deformation after alteration. Late cracks filled with chlorite, some blue-green amphibole.

Primary textures obscured, although zoning clinopyroxene still observed. Some of larger grains suggest primary prismatic shapes. Foliation and coarse granoblastic texture developed, similar to 613-1-1. Alteration moderately domainal, static and a bit more intense than 613-1-1.

737-2-1 Amphibolite

Plagioclase - about 45%. Maximum grain size less than 5 mm. Most grains less than 1 mm, equant to stubby-elongate, with smooth to irregular grain boundaries. Some of the larger grains consist of sub-grains or form broken aggregates. Many grains are in weakly developed granoblastic texture. Plagioclase metasomatism is very abundant in this rock, affects primarily grain boundaries and intergrain fractures; usually zone of alteration is very narrow. More than 75% of grains of all sizes have multiple mechanical twins which are crosscut by metasomatism. Many areas of twin offset unaccompanied by alteration. A few veins have green amphibole in them, with a few subhedral to anhedral, 1 mm crystals of sphene. Light dusting of fine opaque inclusions; very minor sericitization.

Hornblende - about 45%. Aggregates of 8 mm or less, anhedral and slightly elongate. Brown hornblende primarily as rims to green hornblende, apparently pseudomorphs after clinopyroxene. Grain boundaries are spikey where amphibole has grown into plagioclase. Some lamellae apparently sphene, possibly alteration of opaques. Small inclusions of euhedral plagioclase. Aggregates of green hornblende are of equant and interlocking grains. Very little apparent deformation of hornblende. Pseudomorphs sometimes extend into veins of hornblende through plagioclase. Some of the green hornblende pretty bluish, random distribution.

Other amphiboles - about 10%. Patches of felted mat of actinolite less than 4 mm, are rimmed by green hornblende. Actinolite is bladed and colorless to pale blue-green or brown. The pseudomorphs are closely associated with other mafics, usually as small pockets or outside rims.

Opaques and sphene - Less than 1%. Inclusions in hornblende and in veins. Where opaques and sphene together, sphene rims opaque.

Texture - There is no clearly defined foliation. Mafic grain shapes suggest they were subpoikilitic about subhedral plagioclase laths. Brown hornblende and opaques were interstitial to clinopyroxene(?) Alteration reasonably static, postdates deformation that destroyed most of original plagioclase textures and created subgranoblastic texture and mechanical twins. Subsequently introduced fluids produced green hornblende and metasomatized plagioclase. Perhaps opaque-to-sphene transformation took place at this time. Little apparent deformation after alteration. No chlorite; very minor apatite - 4 or 5 grains.

738-1-1 Altered Olivine Gabbro

Plagioclase - about 55%. 2-4 mm; subhedral originally. Also less than .1 mm new grains due to grain boundary recrystallization. Bent tapered twins common in larger grains; subgrain development as well as grain boundary recrystallization. Twins sometimes in two perpendicular sets. Grain boundary recrystallization appears better developed in some patches, but no pattern clearly discernible. Plagioclase-to-plagioclase alteration along cracks subsequently partially altered to smectite(?). Very minor sericitization; large short cracks filled with chlorite.

Clinopyroxene - 30%. Grain size 1.5-5 mm. Poikilitic and interstitial to plagioclase. Some overgrowth and intergrowth of pyroxene grains. Exsolution primarily coarse blebs, now altered to pale brown hornblende. A few with plates of opaques and hematized(?) opaques, especially those with fine-spaced cleavage. Rims of pale brown to green hornblende. Alteration is to hornblende, pale brown, green and sometimes blue-green. Often on outside or where more altered, greener is more, but where not very altered, no apparent pattern.

Olivine - about 10% originally, greater than 50% altered. Grain size averages 4 mm. Interstitial to plagioclase. Some undulose extinction. Alteration: olivine → talc + opaques → colorless actinolite (sometimes radial, usually acicular) → blue-green hornblende. Relict olivine altered along cracks to grungy serpentine. In some areas olivine all gone. Talc rim variable in size. Talc may also occur outside amphibole rim (minor amounts) or large patches of chlorite.

One area near pyroxenes where outside rim of hornblende contains amorphous chlorite with sheaves of actinolite - not clear at all after which

mineral - guess is either olivine or pyroxene.

738-1-2 Altered Gabbro

Plagioclase - about 60%. Grains about 1-3 mm. Most have polysynthetic twinning, several are kinked. Minor development of smaller grains. Alteration to clay(?) or brownish smectite in spots and along cracks less than 1%. Original grain shape equant to prismatic, with no apparent preferred orientation. Most boundaries with plagioclase straight, some rounded corners. Many boundaries with pyroxene curvilinear and irregular, and obscured due to alteration reactions of mafics and plagioclase. One zone of (.1-.2 mm) grains have undulose extinction and are not abundantly twinned, so probably secondary. Fine disseminated opaques in plagioclase.

Clinopyroxene - about 30%. Grains 1-3 mm subequant. Boundaries generally curvilinear. May contain small inclusions of plagioclase. Fine cleavage contains exsolution lamellae in most grains. Several grains contain fine vermicular patches, irregular in outline, with different optical orientation. Pyroxene-pyroxene boundaries often contain many smaller pyroxene grains. Pyroxene rimmed with less than .01 mm rims of blue-green to pale brown hornblende; a few are almost completely altered. Some fine rectangular opaques along cleavage planes.

Amphiboles - greater than 5%. Primarily narrow rims to pyroxene grains. In areas of more extensive alteration, may completely replace pyroxene as prismatic pseudomorph or as an aggregate. Greater than 50% of amphibole is blue-green. Brownish hornblende associated with pyroxene. Colorless, acicular or massive amphiboles rim and core masses of chlorite and brownish aggregates of smectite. Acicular actinolite in cores often grades outward to blue-green hornblende.

Chlorite - about 1%. Along cracks in plagioclase and as inside rims to

pseudomorphs after unknown mafic.

Smectite - less than 1%. Essentially same as chlorite.

Opaques - much less than 1%. Inclusions in plagioclase and clinopyroxene and slightly larger grains associated with hornblende.

Textures - Good relict igneous textures indicate plagioclase preferentially euhedral. Pyroxene not clearly interstitial, however. Resorption of one or the other possible. High-temperature deformation minimal. Recrystallization primarily attributed to alteration. Late cracks in plagioclase and a few in pyroxene are filled with chlorite and lesser amphibole. Cracks appear to be crystallographically controlled in many plagioclase grains. Some alteration is intragranular. Multiple-rim pseudomorphing of clinopyroxene and unknown mineral consists of chlorite on very outside, colored amphibole, colorless amphibole, and chlorite and/or smectite to colorless amphibole cores.

739-1-1 Altered Olivine Gabbro

Plagioclase - 70%. Grains originally about 1-1.5 cm long, tabular crystals. Most grains now less than 1-3 mm, equant. Bent tapered twin lamellae are common in both relict large and in medium-sized. Bending more common in relicts. About 50% grains have deformation twinning. Undulose extinction also noted, even in some untwinned grains. Curiously, some grains don't show any deformation features although they abut deformed grains. No clear compositional zoning. Through-going cracks contain minor sericite; larger ones may also have serpentine(?). Many of the cracks connect olivines or radiate out from them, and are probably expansion cracks?

Olivine - originally about 20%, now about 10%, large grains about 1 cm, also about 1 mm. grains making up aggregates. Some olivine apparently interstitial to plagioclase. Partial rims of orthopyroxene are likely reaction rims - total aggregate preserves better crystal outlines.

Kink bands and undulose extinction in large grains and in some smaller ones. Smaller ones could be partly result of recrystallization similar to plagioclase. Alteration to very narrow rims of acicular, colorless tremolite(?), and sometimes subsequent chlorite rims. Internal alteration is to serpentine + opaques along cracks in mesh texture (forms total pseudomorph in some cases). Minor rims of clinopyroxene and brown hornblende and opaques.

Clinopyroxene - about 10%. Clearly interstitial grains about 1-3 mm. Rims of brown hornblende and brown hornblende + opaques; lamellae mostly fine with opaques, some brown hornblende. Some cleavage planes bent. Very minor alteration to low birefringent fibrous amphibole, pale brown to colorless.

Orthopyroxene - about 1%. Exclusively as rim to olivine. Altered to pale fibrous amphibole or non-meshy serpentine.

Textures - Plagioclase and olivines both non-interstitial minerals, at least primarily; secondary growth likely. Orthopyroxene from olivine and brown hornblende from clinopyroxene likely late magmatic reactions - this taken from grain boundary character. Alteration - olivine grain boundaries, serpentinization along cracks.

739-2-1 Metagabbro

Plagioclase - less than 50%, possibly up to 65% originally. Grains up to 1 cm, most less than 4 mm. Considerable polygonization and subgrain development; new grains usually greater than 1 mm. Undulose extinction and twinning common. Granoblastic texture in some of smallest grains which appear less strained than the rest. There are chlorite-filled cracks across the plagioclase, predominantly at numbered end. In this area plagioclase metasomatism has affected about 50% of plagioclase. It is very irregular and does not appear to follow any crack system. Some patchy alteration to smectite(?), possibly more often after higher An plagioclase.

Clinopyroxene - less than 5%. One relict grain 7 mm, subhedral with fine cleavage; contains fine inclusions of opaque and is partially replaced by brown fibrous amphibole? Partial rim of massive reddish-brown and then blue-green hornblende. Elsewhere surrounded by chlorite or plagioclase.

Alteration patches - about 50%. These patches have curvilinear boundaries, primary minerals were anhedral and about 5 mm. Patches contain pale brown amphibole, chlorite + smectite, or colorless amphibole. Some patches have rims of amphibole and interiors of chlorite ± smectite. One patch of talc next to clinopyroxene may be after olivine.

Opagues - less than 1%. A few anhedral grains about .5 mm, apparently interstitial to other minerals. Grain boundaries quite regular around mafics.

This slide strained at high temperature, with apparently moderate re-crystallization. Chlorite and actinolite(?) alteration considerable,

accompanied by metasomatism and other alteration of plagioclase.

739-2-2 Altered Troctolite

Plagioclase - 70%. Elongate grains 4-5 mm; more equant grains 1-1.5 mm diameter. Grain shape anhedral, boundaries usually cusped to irregular. Most grains have mechanical twinning and/or undulose extinction. Some polygonization has taken place, but difficult to distinguish from apparently primary granular texture. Grain boundary recrystallization very rare. A few cracks in plagioclase filled with chlorite (?) or sericite, but usually very small amounts of either. Plagioclase seems to be replaced by sericite (?) in whole-scale way, working away from a plagioclase-olivine boundary.

Olivine - originally about 25%. 1-3 mm grains poikilitic about plagioclase. Grains are anhedral with very curvilinear outlines. Larger patches of olivine are aggregates, but individual grains show strain features (kink bands, undulose extinction). Minor rims of clinopyroxene; brown hornblende and opaques a bit more common. Some clinopyroxene with indistinct grain boundaries appears to be reaction product of olivine. Alteration of olivine about 10-15%. Some patches to talc + opaques, but more common radiating needles of actin-trem (?) along grain boundaries. Where a little more altered, serpentine (?) joins fibrous mineral. Cracks through olivine altered to serpentine and opaques; degree of alteration varies but usually very minor. Clinopyroxene and brown hornblende in "crack" through plagioclase grains connecting one olivine to another.

Opaques - about 1%. About .2 mm; subhedral; associated with olivine and usually completely enclosed in hornblende.

739-3-1 (1x3) Olivine-bearing Metagabbro

Plagioclase - 55-60%. Many laths up to about 1.3 cm long, simply twinned; some subhedral. Most grains anhedral. A population of grains about .5 mm, and some smaller ones. The medium-sized grains are quite equant and have regular boundaries, either due to recrystallization or last bit of fluid - nothing in their texture is distinctive. There is relatively little polysynthetic twinning on any scale. Some of the smaller plagioclases occur along relatively straight, narrow zones suggestive of high strain and/or fracture with subsequent healing. Supporting this is the fact that adjoining large grains are optically zoned. Minor resorption of large grains next to mafics is seen. Alteration is minor - mostly a bit of sericite. Some "cracks" filled with red-brown hornblende and/or pyroxene. Fractures filled with chlorite, blue-green hornblende.

Olivine - about 10-15%, originally about 25%. Irregular poikilitic grains, now deformed. Patches about 8 mm or less. Undulose extinction and kink bands common. Aggregate forms moderately well developed. Rims of clinopyroxene which in turn are rimmed by red-brown hornblende are common. These often include anhedral blebs of opaques. Depending on location, olivine only partially altered to serpentine + opaques, or extensively to completely altered to talc \pm opaques with outer rims of colorless amphibole, \pm inner alteration to yellowish serpentine.

Clinopyroxene - 5-10%. Interstitial, up to 4 mm size. Small patch in one grain of vermicular texture. Often rimmed by brown hornblende. Apparently mostly unaltered, but some brown hornblende along cleavage traces. Some inclusions of opaques and dark brownish mineral. Little evidence of pyroxene-pyroxene exsolution. Slight undulose extinction,

one grain slightly bent.

Some pseudomorphs apparently after olivine, mostly talc - tremolite type. Small blobs of tremolite and/or blue-green hornblende. Pseudomorphs and some coronas to olivine surrounded by chlorite.

Textures - some flattening apparent, but not great. Most overall igneous textures preserved - long laths of plagioclase, interstitial to olivine and clinopyroxene. Surprisingly few deformation twins in plagioclase. Some resorption suggested. Healed fractures filled by late magma or annealed by recrystallization. Alteration static, probably overprints talc. Filled fractures as in other rocks.

739-4-1 Metagabbro

Plagioclase - about 10% in thin section, but grain size much too large for meaningful mode. Subhedral grains up to 1.5 cm long, only 2 large grains. Two directions bent twins and undulose extinction. One grain surrounded by opaque and opaque fills crack produced by bending of crystal! Lots of tiny needle inclusions in plagioclase. Minor alteration to smectite from grains boundaries inward along cracks.

Clinopyroxene - 2 very large grains (greater than 2 cm) enclose plagioclase. Cleaved, abundant blebs of brown hornblende, opaques and intergrown clinopyroxene. Grain shape approximately equant with irregular boundaries. Opaques also surround clinopyroxene and are intergrown. Brown and green hornblende appear inside and outside opaque rim.

Patches of colorless fibrous to bladed actinolite, with minor serpentine?, hornblende, and opaques, apparently after non-clinopyroxene. From cleavage and distribution of some oxides probably orthopyroxene grains less than 4 mm.

Apatite - patch greater than 5 mm, of 2 large grains and some mosaic textured grains with veins of opaques and green hornblende. Probably interstitial to clinopyroxene.

Textures indicate plagioclase probably crystallized before clinopyroxene, clinopyroxene before orthopyroxene. Extremely difficult to identify relationships - simply not enough material. Alteration minor except for orthopyroxene. Oxidation has stained clinopyroxene and has highlighted cracks and grain boundaries.

739-4-2 (2X3) Altered Gabbro

Plagioclase - 50-60%. Some plagioclase laths up to 2 cm long, somewhat bent and kinked; originally probably subhedral to euhedral, now recrystallized along borders. Large crystals show undulose extinction, some twinning and some kinking. Secondary grains about .05 mm, restricted primarily to narrow bands. These grains may be twinned and show undulose extinction, but to a lesser degree than large grains. Some areas of the slide have greater than 70% plagioclase recrystallized with relict grains less than 5 mm. Where large grains remain, less than 10% plagioclase is recrystallized. Alteration to reddish-brown clay(?) mineral(s) less than 5% more abundant where cracks more common.

Clinopyroxene - 20%, originally 30-40%. Grains 2-3 cm. Shapes appear to have been subhedral, boundaries somewhat irregular. Contain blebs and lamellae (exsolution?) of orthopyroxene, lesser opaques and brown hornblende. Opaques and brown hornblende much finer grained than orthopyroxene. One grain twinned or kinked. Pale green fibrous amphibole mimics pyroxene where altering along cracks. Hematization in cracks where no other alteration and in center of amphibole cracks. Very minor hornblende rims around clinopyroxene associated with abundant opaques and often seem to have embayed or filled irregularities in crystal outline. Hornblende usually prominently zoned brown to green. No apparent compositional zoning in clinopyroxene.

Orthopyroxene - less than 5%. Occurs as discrete prismatic crystals, .5-1 cm long and as irregular .5 mm blebs in clinopyroxene. Often partially altered to pale fibrous amphibole, not to serpentine. Hematized on grain boundaries and along cleavage traces and cracks. Distinctive

pinkish color under plane light. Fibrous amphibole possibly intergrown with talc; edges of alteration zone often blue-green in color. Estimate about 30% of orthopyroxene altered.

Opaques - 1 mm or smaller. Blebs occur along plagioclase-pyroxene boundaries, may approach euhedral outlines if enclosed in hornblende. Exsolved rectangular grains in clinopyroxene. Where clinopyroxene altered to amphibole, opaque is linearly oriented and much more euhedral; separate grains clearly late stage magmatic. Interstitial in plagioclase domains.

Apatite - about 1%. Grains up to 1 cm. Anhedral to subhedral. Recrystallized in zones of plagioclase recrystallization, approximately the same size as plagioclase. Occurs near clinopyroxene grain boundaries, but not always closely associated with opaques as in previous slide. Some grains have irregular extinction.

Amphiboles - 10-15%. About 50% fibrous pale to green amphibole after ortho- and clinopyroxene. Massive brown and green hornblende partially rims clinopyroxene and fills cracks. External boundaries of rims very euhedral and crystals zoned toward green hornblende on outside. Grains greater than 2-3 mm. Fibrous amphibole usually very fine grained, only rarely bladed.

Other alteration minerals - Minor green to blue-green serpentine or chlorite in small discrete patches and associated with alteration of orthopyroxene. One elongate grain of very reddish biotite surrounded by green fibrous amphibole and chlorite(?). Talc associated with pale fibrous amphibole is bluish green and pale. Chlorite found in a few cracks. Hematite alteration stains most minerals, including cracks

between plagioclase grains.

Textures - Some primary igneous texture is discernible, particularly clinopyroxene-plagioclase boundaries. Recrystallization of plagioclase and alteration of pyroxene phases have obscured much of primary texture. Alteration of plagioclase is along cracks and of mafic phases along grain boundaries, cracks and cleavage traces. Alteration apparently from boundaries inward. Multiple rims not particularly evident in this section. Brittle fracture minor.

739-4-3 Altered Troctolite

Plagioclase - about 65%. Large grains about 5 mm, most .5-1.5 mm. Shape is subhedral. Boundaries straight to very irregular. Most grains equant, a few somewhat elongate. Almost all grains (greater than 90%) show mechanical twinning and undulose extinction. In some grains twinning increases in vicinity of intragrain cracks. Some areas have good granular texture, probably primary. In other areas, apparent polygonization has created somewhat granoblastic texture with serrated grain boundaries. Clear evidence for recrystallization only in one zone.

Olivine - about 30% Grain size 5 mm - 2 mm. Elongate grains with usually curved boundaries, interstitial to enclosing plagioclase. Rimmed by clinopyroxene and pale hornblende. Only very minor alteration to talc. Most alteration is to serpentine + opaques, about 30% of olivine affected. Near zone of recrystallization is most olivine → talc. Also some alteration of plagioclase here.

Mineralogically fairly uncomplicated, but textures hard to interpret. Many late cracks may be due to expansion of olivine. In plagioclase these cracks contain sericite.

739-4-4 Altered Troctolite

Plagioclase - about 55%. Primary grains subhedral, elongate, and 4-9 mm long. Polygonization has created grains about 1 mm and recrystallization seen in narrow long zones of grains about .1 mm size. Some of medium size grains primary. Larger grains often have simple twins. Many mechanically twinned, and undulose extinction. Grain boundaries irregular except along some boundaries with mafics. Zones of recrystallization appear to have been cracks which have subsequently been closed by plagioclase and pale brown hornblende. These are straight and can be followed across several grains, including some olivine. Offset of up to about .5 mm can be shown on one such crack. Alteration of surrounding plagioclase to (probably) lower An content visible. Later cracks likely associated with olivine alteration have sericite and serpentine in them. Isolated large areas of plagioclase replaced by amorphous sericite (?).

Olivine - originally about 40%. Anhedral grains and aggregates about 1-.5 cm. Poikilitic and interstitial to plagioclase. Most boundaries curve around plagioclase, some straight along side of lath. Relict shows some undulose extinction but no kinking. Narrow rims of pale, massive amphibole common, very minor orthopyroxene and clinopyroxene (?). Minor talc or muscovite occurs as blades or sheets. Olivine greater than 50% altered to mesh-texture serpentine + opaques. Alteration appears more complete along zones through several grains and intervening plagioclase also often completely replaced. Some serpentine is greenish, most is relatively colorless.

A couple of grains of subhedral opaques with hornblende.

One patch of orthopyroxene not rimming olivine, about 1 mm; aggregate. Altering to serpentine.

Plagioclase grain shape more dominant than olivine. Clearly high-temperature faulting which was subsequently mended at at least clinopyroxene and brown hornblende temperatures.

739-5-1 (2X3) Weathered Metagabbro

Plagioclase - about 50%. One grain at least 4 cm long, 2 cm wide. Other relict grains over 1 cm long, with a undulose extinction and faint twins, are surrounded and crosscut by zones of coarse mortar with equant grains showing twinning and undulose extinction. Large grains have randomly oriented needles as inclusions; these are absent in small grains. Alteration minimal, limited to a few veins of smectite(?) and prismatic pale amphibole(?); and smectite in vicinity of altered mafics.

Opagues - 10-15%. Large areas of ore concentrated with other mafics, enclosing or partially enclosing grains. Some boundaries straight, others follow grain boundaries of small plagioclase and mafic aggregates. In many places opaque-plagioclase boundary has very narrow rim of smectite(?) and/or bluish-green amphibole. Some very small inclusions (exsolution?) in clinopyroxene.

Clinopyroxene - about 10%. Round grains and aggregates 2-12 mm diameter. Contain abundant blebs of red brown hornblende and opaques. Red-brown hornblende zoned to green hornblende common as rims, especially near opaques. Some replacement of clinopyroxene by red-brown and pale-green hornblende. Patches within clinopyroxene grains stained yellow.

Orthopyroxene - less than 5%, probably 15-20% originally. Round and irregular grains about 8 mm, appears with other mafic minerals. Badly altered to aligned or felted sheaves of pale amphibole(?) or antigorite or both. Relict orthopyroxene badly oxidized; about 30% altered to silicates, 40-50% to oxides.

Apatite - Less than 1%. Inclusions in opaques.

Textures - Large grains of plagioclase strained; grain size reduced by strain. Apparent partial recrystallization of major phases prior to bulk of alteration. Some strain after recrystallization - twinned plagioclase. Orthopyroxene replacement appears static. Opaques perhaps residual or introduced immiscible liquid. Smectite and staining apparently last phase. Rock was probably a pegmatite considering grain size. Opaque/clinopyroxene relationship has unknown origin.

739-6-1 Altered Olivine Gabbro

Plagioclase - 55-60%. Average grain size about 1 mm. Grains predominantly equant, texture granoblastic. Near some mafic minerals, straight boundaries suggest that texture is due to recrystallization. Greater than 75% grains have tapered twins; larger, more elongate grains have bent twins. A few grains have two directions of twinning - very good example. One grain has long needle inclusions. Labeled end of slide has well-developed mortar texture with very fine-grained secondary plagioclase. Amount of fine-grained plagioclase varies from one grain width around plagioclase to approximately .1 mm zones which also have rounded grains of pyroxene and hornblende, both of which may be poikiloblastic; elongate aggregates of elongate amphibole grains slightly larger than the plagioclase grains. Very minor sericitization of larger grains in cracks; chlorite along plagioclase-plagioclase grain boundaries. There are also sealed cracks along which plagioclase to plagioclase alteration has occurred.

Clinopyroxene - about 30%. Predominantly very large grains (greater than 1 cm) poikilitically enclosing plagioclase or interstitial to it. Many of the larger grains enclose remnants of other clinopyroxene and plagioclase; some are aggregates of many grains. Most grains have fine cleavage, but a few irregular intergrown grains have exsolution lamellae of orthopyroxene and/or brown hornblende. Narrow rims of pale brown hornblende very common. Grains in aggregates are about same size as plagioclase and olivine. Alteration to pale brown hornblende is very minor.

Olivine - 5-10%. Aggregates generally about .5 cm. Subgrain or

aggregate development ubiquitous. Undulose extinction and kink bands are common. Texture is subpoikilitic about plagioclase, rimming to pyroxene. Very minor grain boundary alteration to talc + opaques and colorless amphibole with outside rims of chlorite; incipient alteration to serpentine and opaques along internal cracks. Some apparently primary rims of brown hornblende and opaques, very minor amounts of orthopyroxene.

Textures - this slide shows a wide variety of textures. Igneous textures are poikilitic, interstitial and rimming. Deformation textures include evidence for static recrystallization and cataclastic deformation. Mineralogical alteration is minimal, usually confined to grain boundaries and cracks and apparently took place under quite high temperature and with very little water. This rock probably crystallized from a magma with some phenocrysts already present (overgrowth textures).

740-1-1 Metagabbro

Plagioclase - about 80%. Approximately bimodal grain size: 1) 2-3 mm relict grains, very irregularly shaped and strained with bent twins and undulose extinction. 2) less than .25 mm, secondary grains which are granoblastic and interlocking with straight grain boundaries. Many of small grains are apparently mechanically twinned. Some grain boundaries very serrated. Relict grains have many tiny dot-like inclusions. Some of smaller grains have considerably fewer. Some areas of the slide have plagioclase with plagioclase metasomatism. No other alteration has taken place. Recrystallization predominantly along grain boundaries - mortar texture. No foliation nor lineation visible in thin section.

Clinopyroxene - originally about 20%. Grains .5-4 mm. All altered to pale brown and green fibrous amphibole. Subophitic about smallish plagioclase grains but interstitial to large ones. Narrow rims of reddish-brown hornblende still visible. Some cleavage bent (pre or post alteration??); lamellae of opaques.

Some amphibole in irregular aggregates with no particular orientation.

Interstitial brown hornblende and opaques - less than 1%. Less than 1 mm grains.

Probably altered anorthositic gabbro - must be plagioclase cumulate of some kind.

740-2-1 Metagabbro

Plagioclase - about 50%. Grain size about 4-6 mm. Stubby to equant, subhedral to anhedral. Lots of strain: mechanical twins offset by later brittle fracture and predated by fractures filled with hornblende, subgrain development, undulose extinction. Grain boundaries mostly irregular, annealing not evident. Abundant cracks offset mechanical twins and are filled with chlorite, blue-green to green hornblende, and smectite.

Clinopyroxene - about 30-40%. Poikilitic with plagioclase inclusions, also somewhat interstitial to plagioclase. Grains .5-.8 cm. Finely cleaved with possible clinopyroxene exsolution lamellae but hard to tell due to alteration along cleavage. Narrow rims of hornblende common, reddish brown with blue-green overgrowths.

Orthopyroxene(?)/olivine(?) - about 10%. Patches of nearly colorless bladed actinolite, outer rims sometimes blue-green. May also contain talc (amorphous) and chlorite. No relict primary mineral, but based on other thin sections could have been orthopyroxene and/or olivine. Plagioclase outside hornblende rim has partially gone to chlorite in many cases. Where chlorite and actinolite intergrown, or chlorite by itself, some preferred orientation apparent, suggesting orthopyroxene as parent. Patches apparently interstitial to plagioclase, sometimes associated with clinopyroxene.

Textures - mafics interstitial to plagioclase, or at least plagioclase first-crystallizing phase. Deformation not enough shearing to produce fine scale granulation. Alteration apparently static. Little or no recrystallization.

740-3-1 (2x3) Metagabbro

Plagioclase - 50% - relict large grains 2-2.5 cm long, very elongate and obviously reduced in width by subgrain and small new grain development in response to strain. Some bent mechanical twins, undulose extinction and recrystallization along internal and external boundaries. Relict grains and very small (less than .2 mm) new grains predominant in numbered half of slide. Across opaque-rich domain, sharp decrease in fine-grained plagioclase, predominantly 1-4 mm, granular-textured plagioclase. Grain boundaries here regular, mechanical twinning and undulose extinction very common, but few subgrains. Granular texture may be primary as opposed to result of recrystallization and continued or renewed strain. Cracks in plagioclase narrow, not overly abundant, filled with chlorite and minor blue-green hornblende and sericite. In more deformed part of slide, large grains contain many dark needle-like inclusions (rutile?); small grains are relatively inclusion-free in granular part of slide. This may mean that "granular" texture is, in fact, "granoblastic."

Clinopyroxene - about 15% - Grains up to 1.5 cm, mostly 2-5 mm. Anhedral, some with no inclusions, others poikilitic. Some grains are regularly cleaved, others have exsolved hornblende and opaques, and some are intergrowths of these two types. One grain is twinned. Brown hornblende and brown hornblende + opaque rims are very common. Some of brown hornblende has altered to actinolite and some has outer rim of blue-green hornblende. Some grains of clinopyroxene appear to be reacting to brown hornblende (possibly deuteric alteration); also alteration to actinolite. Inclusions in clinopyroxene are opaques, hornblende, plagioclase, and ex-olivine(?) all about .5 mm diameter. Some boundaries are regular, others are quite irregular, and this is not only due to alteration. Some grains

are rounded due to deformation, particularly in deformed part of slide. In one area near boundary, apparent granoblastic and secondary clinopyroxene in zone around altering orthopyroxene.

Orthopyroxene - 10-15% originally - grains mostly elongate, 3-9 mm. A few in granular relationship to clinopyroxene. Boundaries not clear due to alteration rims. Some brown hornblende rims. Most alteration to oxides, blue-green to colorless fibrous actinolite + opaques, and minor serpentine. Alteration probably 35-40% of original amount. Amorphous oxide most abundant alteration. There are a few small patches of talc + opaques, bladed actinolite + talc, and serpentine + talc which appear to have been olivine or for some reason different type of orthopyroxene alteration (not considered likely). Less than 1% section.

Amphiboles - probably greater than 10% of slide. Brown, green and blue-green rims on clinopyroxene and orthopyroxene; also occur as semi-separate grains. Brown hornblende usually closest to clinopyroxene, but zoning can then go to blue-green or to green and back to brown. One area of separate hornblende, cores of bluish-green surrounded by brown. All brown hornblende in slide is reddish-brown. Primary vs. secondary nature of hornblendes not clear; actinolite is clearly an alteration product.

Alteration is patchy and, except along in center of section, does not appear to follow any path or pattern. It is more intense in central zone, but is by no means restricted to it. There is a small amount of serpentine(?) next to some pyroxene, which appears to be quite late. Actinolite alteration probably post-tectonism. "Primary" textures very hard to read, if they are present. Clinopyroxene encloses plagioclase and olivine?, there is very little olivine, and probably

clinopyroxene and orthopyroxene were co-crystallizing phases. Deformation textures are also indistinct in this section.

740-4-1 Olivine-bearing Metagabbro

Plagioclase - about 70%. Subophitic texture with subhedral laths up to 1.5 cm long. Grains are simply and mechanically twinned. Ubiquitous undulose extinction. Mortar texture is moderately well developed around many grains, new grains irregular and about .3 mm size. Many small grains strained, possibly broken rather than grown - have mechanical twins and undulose extinction, grain boundaries irregular. One zone of granoblastic plagioclase cuts across whole slide, contains brown hornblende and clinopyroxene, where passes through clinopyroxene, clinopyroxene also granular. Minor metasomatism observed. Possibly a pre-deformation fracture filled with residual magma or annealed somehow. Some deformation definitely after as new plagioclase grains are strained. Alteration primarily confined to late fractures filled with sericite, smectite?, carbonate, and relatively minor chlorite (see other slides). Wide fractures lead from (or to) altered olivine, which are filled with serpentine(?) are latest veins.

Clinopyroxene - about 10%. Interstitial poikilitic grains, cross section up to 1.5 cm long, but most in slide is all one grain. Most is finely cleaved with possible fine exsolution lamellae, but not distinct. Patches of clear clinopyroxene with vermicular intergrowths (exsolution?) of red-brown hornblende within large grains. Rims of red-brown hornblende ubiquitous to large clinopyroxene. Also less than .3 mm clinopyroxene in zone described above - granular, not cleaved, and little brown hornblende associated directly. Alteration partial, quite common, to paler red-brown hornblende, starting at rims and moving along cleavage planes, but maintains optical separation from primary rim. Also minor alteration to pale blue-green hornblende as massive pseudomorph. Where apparently recrystallized or annealed, a few grains altered to serpentine? -

was this orthopyroxene or olivine?? Minor opaques associated with clinopyroxene. Clinopyroxene and brown hornblende rim olivine.

Olivine - originally about 10%. Anhedral grains less than 1 cm, apparently interstitial to plagioclase. Undulose extinction visible in relicts. Rimmed by clinopyroxene and red-brown hornblende. Alteration coronas of talc + opaques, minor secondary olivine(?), colorless acicular amphibole. Inside, substantial alteration to serpentine + opaques, both now mostly oxidized. Greater than 70% olivine now gone. Several complete pseudomorphs. Less amphibole present than in most slides. Outer rims of chlorite or serpentine present, but not well developed.

Red-brown hornblende and opaques - about 5%. Rim olivine and clinopyroxene, also occur as separate, anhedral to subhedral grains. Opaques usually surrounded by red-brown hornblende when obviously primary. (Not talc + opaques). Both apparently late-stage magmatic. One example of opaque rim outside hornblende rim.

Textures - Igneous subophitic texture still well preserved. "Vein" of late crystallization. Subsequent deformation with some mortar texture developed. Alteration static but fracture-related, serpentine after sericite and talc by crosscutting relationships. Chlorite relatively minor in this slide.

740-6-1 (1x3) Metagabbro

Plagioclase - about 50% - grain size greater than 1 mm, up to 1 cm long, but most about 3-5 mm subhedral and subequant. Shape elongate to granular. Almost all grains show twinning, infrequently in two directions, and of both mechanical and growth type. Most grain boundaries and intragranular cracks contain pale green chlorite. All grains contain tiny dark inclusions. In some areas, pseudomorphing of plagioclase by chlorite.

Clinopyroxene - about 25% - grains predominantly .5-1 cm, poikilitic and interstitial. Narrow rims of reddish brown, brown and green hornblende almost ubiquitous. Internal texture either finely cleaved or with numerous blebby lamellae of brown hornblende. Blebby texture predominantly in outer parts of grains. Alteration of clinopyroxene is to massive hornblende - usually green to bluish-green, some almost colorless with low birefringence. Some of pseudomorphs described below may also have originated as clinopyroxene since they adjoin with no clearly defined boundary.

Pseudomorphs - 15-10% - primarily chlorite with rim of actinolite and/or blue-green hornblende. Shapes anhedral and about 4 mm size. Actinolite usually bladed and growing inward from rim or from clinopyroxene adjacent to pseudomorph. In some cases actinolite also grows outward from amphibole rim. These pseudomorphs are sometimes associated with replacement of plagioclase by chlorite. Except for alignment of amphibole, no internal fabric.

One pseudomorph of fibrous brown amphibole with numerous elongate opaques does not conform to any other alteration texture in slide.

Hornblende - 5-10% - all colors, but primarily reddish brown, brown and green. Rims pyroxene and pseudomorphs. Also found as less than .5 mm to 1 mm grains interstitial to plagioclase and pyroxene. In some cases suggests secondary replacement of pyroxene, but especially where medium sized, can't tell. Zoning common where just hornblende, usually cores of brown or green, rims of blue-green or nearly colorless hornblende.

Small patches of smectite(?) with hornblende or actinolite. Extremely little deformation, apparently static alteration. Water probably entered along grain boundaries and later cracks. Not clear whether hornblende primary or secondary - although clearly not continuous growth. Actinolite may have grown subsequent to chlorite alteration (ingrowing textures in pseudomorphs).

740-7-1 (1x3) Metagabbro

Plagioclase - about 55% - most plagioclase in elongate grains 5-10 mm, but badly broken and metasomatized. Breaks annealed with metasomatic plagioclase, also rims of same material. Original grains twinned, everything polygonized. Some fine-grained plagioclase, in places as mortar texture. There appears to be a preferred dimensional orientation in some parts of the slide. Small patches look recrystallized with granoblastic textures. In some areas relict grains are preferentially altered, in others "secondary" plagioclase is preferentially altered. Alteration is to sericite; also inclusions of tiny dark specks (not needle-like). Around some pseudomorphs, alteration to chlorite.

Clinopyroxene - about 10% - interstitial, subhedral grains of mostly 2-3 mm, up to 1 cm. Rimmed by brown or green hornblende and invariably partially altered. Alteration to brown hornblende, blue-green hornblende and maybe actinolite. Typically replacement occurs along closely spaced cleavage traces. Apparently no exsolution.

Pseudomorphs - 15-20% - 4-6 mm patches of talc or chlorite and actinolite inside hornblende rim. One also has carbonate after olivine. Actinolite is bladed or massive and grows inward. Some patches of blue-green + colorless hornblende only, especially in more recrystallized zones. Aggregates of hornblende narrow away from pseudomorphs into zones of plagioclase.

Amphibole - some rims are zoned, with brown usually nearer core. Zoned to both green and blue-green, blue-green predominates. Many elongate grains and grain aggregates, less than 1.5 mm, in plagioclase domains, interstitial to plagioclase or suggestive of once-interstitial grains.

Individual grains may also be zoned, brown usually inside.

Textures indicate complex strain history. First brittle deformation, then annealing fluids, followed by slow strain and some high in restricted zones. At some point, some zones recrystallized, probably after or during annealing episode.

741-1-1 (2x3) Altered Olivine Gabbro

Plagioclase - 65%. Maximum grain size 5 mm, average size 2-3 mm. Estimate original grain size greater than 1 cm. Grain size reduction due to subgrain development and grain boundary recrystallization. Sutured boundaries very common. Well developed granoblastic texture absent. Bent and tapered twins and/or undulose extinction common. Recrystallization appears to be dominant in elongate zones; grains may be preferentially elongate in this direction.

Clinopyroxene - 20-25%. Average grain size about 1 cm. Interstitial to original plagioclase. Internal textures of clinopyroxene include fine cleavage, little or no cleavage and exsolution of clinopyroxene and hornblende (also very minor orthopyroxene?) in elongate to vermicular blebs. Clinopyroxene may be recrystallized to much smaller grains in areas where plagioclase is also considerably recrystallized; here often intergrown with hornblende - brown or green. Irregular trails of opaques through some clinopyroxene. Narrow rims of brown or green hornblende around clinopyroxene; alteration along cracks also to hornblende. Intergrowth textures between clinopyroxene grains, especially where more deformation apparent.

Olivine - about 10% originally. Grain size estimated about 1 cm. Somewhat elongate, hematized aggregates. Associated with orthopyroxene or alone in plagioclase field. Alteration to talc + opaques relatively minor in most areas. Some outside rims of pale to colorless hornblende. Vermicular alteration in surrounding plagioclase. Late serpentinization and hematization has replaced most of the relict olivine. Olivine alteration products in long narrow stringers. Whether this

took place before or after talc alteration is unclear, probably before or during.

741-1-2 (2x3) Olivine-bearing Metagabbro

Plagioclase - 55-60%. Relict plagioclase about 5 mm long, very irregular shapes. The rest .5 and less than .2 mm grain size; granoblastic to irregular texture. Many medium-sized grains have mechanical twins; undulose extinction common but not ubiquitous. Mortar texture common in areas with more medium and large grains. Medium-sized grains in some areas have regular granoblastic texture, suggesting two episodes of deformation separated by recrystallization. Many small grains have regular and sharp grain boundaries suggesting grain boundary migration after last episode of high strain. Alteration quite limited, mostly sericite along grain boundaries and internal cracks. Very few throughgoing cracks; one filled with blue-green hornblende. Some grain boundaries have green-blue-green hornblende. Plagioclase-mafic boundaries often have myrmekitic intergrowths of clinopyroxene(?) and/or amphibole(?) with plagioclase.

Clinopyroxene - about 25%. Many grains 1-2 cm, anhedral, most subequant. Small grains less than .5 mm granoblastic in texture. Clinopyroxene rimmed by red-brown and green hornblende. Many grains, particularly large ones, have very fine exsolution lamellae. In granoblastic areas, hornblende-pyroxene aggregates \pm opaques. Very minor interstitial orthopyroxene. Also some mottled areas where clinopyroxene grains intergrown. Much of clinopyroxene has pinkish tinge. Alteration is replacement by hornblende as massive pseudomorphs. Some oxidation along cleavage planes. Some zoning along "fractures" which are filled with plagioclase, hornblende, opaques and other clinopyroxene. Large grains have some bent cleavage/exsolution. Often larger grains at least partially replaced by or broken down to granoblastic texture.

Olivine - about 5% originally. Anhedral, about 5 mm. Only relicts left, some apparent undulose extinction and probable breakdown to aggregates. Alteration to talc + opaques as coronas inside rim of brown and blue-green hornblende. Some talc recrystallized to prismatic blades, some slightly colored so phengite(?). Talc contains abundant opaques - this rock may be quite iron-rich. Also minor biotite. Coarse sheet silicates apparently unaffected by deformation [the rest ambiguous] Late oxidation has almost completely removed olivine. Almost no indication of serpentine and chlorite.

Orthopyroxene - less than 1%. Small grains about .5 mm. Oxidizing and altering to blue green amphibole. Usually granoblastic texture with other mafic minerals. Sometimes outside part of an aggregate - originally rim or interstitial?

Hornblende - about 5-10%. Red-brown, green and blue-green, sometimes reversely zoned, occurs as rims to all mafic minerals, usually less strongly colored around olivine areas. Also in aggregates, often encloses opaques. With plagioclase in rims as myrmekitic or bladed intergrowths and as separate grains in recrystallized plagioclase. Infrequently appears to have preferred shape orientation parallel to narrow finer-grained.

Opaques - greater than 2%. Anhedral in brown hornblende, interstitial grains in mafic aggregates. Less than .3 mm size. Also as tiny subhedral inclusions in clinopyroxene, as irregular needles in amorphous talc in olivine coronas. A few tiny grains interstitial in plagioclase.

Apatite - less than 1%. Minor, secondary, anhedral, subequant grains in narrow zones associated with opaques and brown hornblende - residual

magmatic material?

Textures - Large pyroxene grains suggest their shape affected by plagioclase laths, i.e., plagioclase dominant and at least subhedral, clinopyroxene space-filling. Deformation apparently two-stage with annealing [and/or recrystallization] after each episode. Foliation moderately developed in about 1/2 slide, poorly developed in rest. Alteration of olivine essentially static, but other minerals recrystallized with substantial reduction in grain size. Chlorite, serpentine scarce and late filled fractures almost non-existent. Pyroxene considerably more resistant to deformation than plagioclase, preserving some primary texture.

741-2-1 (1 1/2x3) Metagabbro

Plagioclase - 55-60% - grains .5-1 mm, equant, with irregular grain boundaries, mixed with subgrain and very small grains (less than .1 mm). Undulose extinction and mechanical twinning common. Twinning even visible in some tiny grains. In some patches tiny grains approach granoblastic texture, suggesting recrystallization. In some areas larger grains don't have associated small grains. These grains are granoblastic and suggest that relict grains in other areas are actually secondary, tiny grains are third-generation. Very minor sericitization along intragranular cracks and grain boundaries.

Clinopyroxene - about 20% - aggregates and relict grains about 5-10 mm. Individual aggregate grains less than .5 mm; granoblastic texture from recrystallization. Interstitial orthopyroxene and red-brown hornblende. Most non-recrystallized clinopyroxene cleaved, with bent cleavage. One grain contains two plagioclase laths. Reddish brown, brown and green hornblende rims common. Some replacement of clinopyroxene by green and brown hornblende. Some clinopyroxene have exsolution lamellae or inclusions of opaques. Some fine-grained vermicular textured zones in clinopyroxene.

Orthopyroxene - less than 5% - grains in clinopyroxene aggregates less than .5 mm. Also in own aggregates and as relict grains about 3 mm. Oxidizing, also altering to smectite?, blue-green hornblende, greenish talc or smectite and some chlorite (as rims). Other alteration patches of carbonate and oxides with similar actinolite and blue-green hornblende rims. May be after olivine or orthopyroxene. Also a patch of talc + opaques, and patches of chlorite with rhombs of brown hornblende after

unknown mineral.

Amphiboles - 75% - brown hornblende, green hornblende, blue-green hornblende all rim mafics. May include opaques. Also colorless amphibole and actinolite, obviously alteration minerals but not clear what original mineral was. Amphiboles are pseudomorphs and rims, sometimes wider in one direction than another. Semi-parallel to weak foliation.

Grain size somewhat decreased due to deformation. Deformation probably at least two stages with annealing between. Alteration spotty, apparently favors orthopyroxene (and olivine?), but very irregular. Mafics originally somewhat interstitial to plagioclase. Very little chlorite - mostly higher T and/or not enough H₂O?

741-2-2 Altered Olivine Gabbro

Plagioclase - 55%. Grain size about .2-.5 mm. Moderately to well developed granoblastic texture, with tapered polysynthetic twins in greater than 75% of the grains. At non-label end of slide is a narrow band of mortar plagioclase, with large relict grains that are elongate and cracked but not twinned, suggesting cataclasis. Sericitization in this region occurs along cracks and along grain boundaries in recrystallized areas.

Clinopyroxene - about 25% Large grains about .5 cm, small grains .5 mm. Large grains may have been interstitial to plagioclase. Large grains show little exsolution. In areas where larger grains have recrystallized to semi-granoblastic texture, some of larger "relict grains" show intergrowth texture and/or blebby exsolution. Brown hornblende may comprise up to 25% of this volume, and 10-20% orthopyroxene may also be present. Rarely olivine may be a part of the aggregate mafics. Narrow hornblende rims around pyroxene are both brown and green and may be gradationally zoned (laterally and from rim to core).

Olivine - originally about 10-15%. Olivine occurs associated with clinopyroxene, sometimes poikilitically enclosing it and plagioclase. Aggregates may be up to 1 cm, but all olivine now recrystallized into grains about .5 mm. Partially to extensively altered to talc + opaques, frequently with outer rim of blue-green massive amphibole. Also common is myrmekitic alteration into plagioclase. Alteration restricted primarily to corners of grain aggregates. Late alteration restricted to blebs in aggregates. Numerous opaques in talc + opaques area, also some along little-altered cracks.

Textures - Recrystallization to granoblastic textures quite widespread. Alteration of olivine probably took place after this, as opaque and talc orientations appear to mimic granoblastic texture. Timing of amphibole alteration is unclear. In area of mortar texture, mafics largely altered to their characteristic alteration rims (clinopyroxene → green amphibole, olivine → talc + opaques). In addition, one sees line of green amphibole and muscovite. There is a mild foliation developed throughout the slide.

741-3-1 (2x3) Olivine-bearing Metagabbro

Plagioclase - about 50%. Relict grains less than 4 mm, slightly elongate, subhedral to anhedral. Most grains 1-.2 mm, are equant and granoblastic in texture. Mortar texture not well-developed. Almost all grains show undulose extinction and/or mechanical twins. Some relicts show simple twins also. Grain boundaries are usually regular. At non-label end of slide, metasomatic plagioclase is well developed. Some plagioclase in narrower zone running between is larger and shows fewer or less intense deformation textures. One boundary is straight and sharp. "Vein" of plagioclase in plagioclase seems optically continuous with some of the adjacent non-metasomatized grains in the much cleaner zone. Considerable chlorite in fractures - across relicts but usually around grain boundaries of smaller grains. Minor sericite scattered through grains, more abundant in metasomatic plagioclase. Sericite or talc etching plagioclase around olivine pseudomorphs.

Clinopyroxene - 20-25%. Grains about 5 mm, anhedral. Poikilitic and subpoikilitic about plagioclase. Sometimes enclose small grains of plagioclase. Grain boundaries indicate much of plagioclase originally 2-8 mm. Most grains finely cleaved and exsolved. Some intergrown patches, and wide exsolution lamellae. Most exsolution apparently more clinopyroxene, minor orthopyroxene. Subsequent inclusions of brown hornblende. Rims of red-brown hornblende and opaques. Alteration to green hornblende from rim in, sometimes along cleavage, sometimes forming poikilitic, massive pseudomorphs. Aggregates of granoblastic clinopyroxene with red-brown hornblende and iddingsite(?) and opaques at triple junctions are usually uncleaved. Some of larger crystals show bent cleavage and/or undulose extinction.

Olivine - originally about 15-20%, now greater than 5%. Aggregates up to 1 cm, average less than 5 mm. Interstitial and space filling around plagioclase. Anhedral and irregular. Relicts often have undulose extinction, some kinking observed. Aggregates and pseudomorphs contain inclusions of plagioclase or plagioclase pseudomorphs of talc or chlorite. It is not clear whether aggregates are primary or due to polygonization. Alteration is predominantly to talc + opaques with colorless to blue-green amphibole rims, and serpentine, chlorite, and/or smectite rims etching plagioclase. Greater than 50% of olivine, altered and in central portion of slide, relict olivine is badly oxidized. Chlorite coronas missing. Several areas of complete pseudomorphs.

Amphiboles - about 10% now. All colors. Most common as rim. Red-brown around clinopyroxene, green around clinopyroxene, separate grains and pseudomorphs, blue-green(?) primary about olivine, colorless and fibrous or bladed growing into talc + opaques coronas to olivine. Green and brown (not reddish) in fractures from clinopyroxene to clinopyroxene. Many grains and rims have inclusions of, or are associated with, opaques.

Textures - clinopyroxene and olivine indicate plagioclase coarse but probably less than 1 cm. Inclusions generally less than 2 mm found in both clinopyroxene and olivine. Deformation has reduced grain size of plagioclase, clinopyroxene and probably olivine. New grains are also strained. No foliation development. Fractures clearly provide conduit for altering fluid. One very late vein filled primarily with carbonate. General alteration of plagioclase appears to have been static and post deformation. Extent of very late oxidation of olivines restricted.

741-4-1 Altered Olivine Gabbro

Plagioclase - 70-75%. Grain size 1-1.5 cm. Subhedral laths. Most grains show simple and tapered polysynthetic twins. Kinking and undulose extinction common, as are filled cracks. Crack fillers include plagioclase, chlorite, green amphibole. Almost no recrystallization, only a few small grains. Some cracks are continuous across slide and are everywhere associated with alteration (to blue-green amphibole).

Clinopyroxene - 7-8%. Grains less than .5 cm diameter, but up to 2 cm long. Clearly interstitial to both olivine and plagioclase. Usually very clean pyroxene with no exsolution, narrow rims of pale brown hornblende. Some inclusions of rectangular opaques. Apparently unaltered.

Olivine - about 20%. Large anhedral-subhedral grains 1-2 cm diameter, somewhat poikilitic about plagioclase. Very little evidence of deformation - only a couple of grains show undulose extinction; no formation of aggregates. Internal alteration of olivine limited to dark oxide staining, but quite well-developed rims of alteration around most olivine reverses usual sequence - bladed colorless to blue-green hornblende forms wide inner rim; talc and/or chlorite and clinozoisite form outside. This by reaction with plagioclase - degradation of plagioclase boundaries evident. Opaques very minor, generally associated with amphibole. Most hornblende in cracks blue-green; one example of colorless → brown → blue-green zoned grain interstitial in plagioclase.

Deformation must have been quite brittle at high temperature, probably due to very high strain rate.

741-5-1 Amphibolite

Plagioclase - about 55%. Grains less than 1 cm. Many grains elongate, broken. Optical zoning extensive due to metasomatism. Metasomatism at least 2-stage; there are crosscutting veins in rim of one large grain. Mortar texture moderately developed; grains less than .05 mm. Mortar grains have irregular boundaries. Apparently later than metasomatism as not cut by veins, although some may be concurrent as mortar fades into altered zones. Many of the larger grains have subgrain development and substantial fracturing and slip along fractures. Mechanical twins primarily confined to relict grains, crosscut by metasomatic veins. Relict portions of grains have greyish cast from inclusions. Sericite alteration very minor and confined to relict plagioclase.

Green and blue green hornblende - about 40%. Aggregates less than 5 mm. Some relict clinopyroxene, especially one grain which also has bent kink band in altered portion. Some grains have coarse exsolution textures with relict brown hornblende. Also some orthopyroxene intergrowth textures still remain. Blue-green hornblende usually around edges or forms around linear zones through aggregates. Some hornblende in probable veins are broken or bent and/or are weakly aligned.

Colorless amphibole - about 5%. Patches of bladed colorless amphibole, directed inward or randomly oriented surrounding cores of talc + opaques and tremolite(?) or smectite(?). Probably after olivine, perhaps orthopyroxene.

Other minerals - very minor opaques, apatite and sphene.

Textures - Plagioclase and mafics probably 1-.5 cm originally, with plagioclase subhedral. Deformation cracked plagioclase, generated a few

concurrent with some metasomatism. Hornblende veins through plagioclase being metasomatized are not apparently affected by metasomatism.

741-6-1 (1 1/2 X 3) Amphibolite

Plagioclase - originally about 65-75%. Augen up to 4 mm in size, may be quite small. Undulose extinction ubiquitous, twinning rare. Alteration to chlorite, smectite(?) intense; grains are corroded. Most grains in matrix of chlorite and other clays. A few aggregates with subgranoblastic texture and chlorite along grain boundaries.

Hornblende - less than 10%. Squarish augen after clinopyroxene; inclusions of blue-green and red-brown hornblende in pale hornblende, which is alternating to smectite.

Chlorite - 20-25%. Probably late alteration product in zones parallel to foliation and in veins crosscutting foliation. Always amorphous.

Apatite and opaques - about 5%. Elongate stringers parallel foliation. Opaques anhedral and irregular; apatite about .3 mm, euhedral to rounded.

Minor sphene appears mostly as small subhedral grains in felsic areas.

Textures - Well-developed foliation with mafic/felsic interlayering. Some augen remain. Some alteration, particularly of mafics, apparently pre or syntectonic. Much of clay alteration apparently post-tectonic. Due to high degree of alteration many textures obscured.

742-1-1 (2x3) Altered Olivine Gabbro

Plagioclase - about 75%. Most grains subhedral about 1 cm long. Some small- to moderate-sized grain boundary recrystallization. Large grains are moderately twinned and show undulose extinction. The distinctive feature in the plagioclase of this slide are the abundant cracks filled by plagioclase which may be twinned identically to host grain and are unaffected by cracks or veins. Some larger cracks cut the filled cracks. Besides plagioclase, other minerals in cracks include smectite(?), green hornblende, sericite(?).

Olivine - originally about 20%, almost all gone. Grains were anhedral, subequant, somewhat interstitial to plagioclase. Coronas of well developed talc and blue-green to colorless, massive hornblende. Some moderate grains of opaque (subhedral) associated with talc which is inside hornblende (also talc on outside); clearly breakdown of plagioclase also involved (perhaps predominant). Inside these rims, serpentine pseudomorphs with moderately developed mesh texture. Opaques abundant along ex-cracks in olivine. Some minor chlorite and serpentine as outermost corona and as fillers in cracks leading from olivine. Some brown hornblende rims around pseudomorphs, probably deuteric or late-stage magmatic and may contain inclusions of opaques. Also at least one patch acicular colorless amphibole.

Clinopyroxene - about 1-2%. Less than .5 mm, interstitial. Almost completely altered to massive blue-green hornblende, but retain brown hornblende rims and some inclusions resembling brown hornblende exsolution seen in other samples.

Hornblende - 4-5% predominantly blue-green. Brown hornblende appears to be earlier phase, but still stable or metastable center of some grains, retains rimming relationship to olivine and clinopyroxene. Hornblende occurs as pseudomorphs of clinopyroxene, discrete grains [often quite poikilitic (poikiloblastic)], as rims around olivine; and as crack filling. Hornblende is clearly cut by serpentine and chlorite-filled veins radiating from pseudomorphed olivine.

742-2-1 (2x3) Metagabbro

Plagioclase - about 60% - relict grains up to 1 cm long, but may have been considerably larger originally (see mafic grain size). The greatest volume of grains are about 1-.5 mm, with regular to irregular boundaries and modified granoblastic texture. In some places the granoblastic texture is well developed, in others there is a finer-grained mortar, superposed. Both larger and medium grains have subgrains, mechanical twins and undulose extinction. The larger grains in particular are cut by zones of finer grained plagioclase, of both medium and small size. These grains also show some plagioclase metasomatism. Sericitization is common, as small inclusions, particularly near grain boundaries and other zones of weakness in crystals. There are also areas near mafics with chlorite along grain boundaries. Plagioclase metasomatism appears to pass through secondary (medium) grains, e.g., between larger clinopyroxene and large alteration patch.

Clinopyroxene - about 25% - large grains up to 2 cm long, two are apparently part of same grain suggesting subophitic texture. One grain is equant, the other two appear elongate. Most finely cleaved and possibly altered to unknown mineral. Zones (some look like cracks) where clinopyroxene quite clear and there are blebs of opaques but mostly red-brown hornblende. A couple of small inclusions of orthopyroxene and brown hornblende (appear to be coexisting). Rims around clinopyroxene are solid, narrow, red-brown hornblende and aggregates of brown and green hornblende. Cleavage may be bent at grain boundaries. A couple of long zones of recrystallized clinopyroxene and hornblende (brown and green) (like plagioclase). Some alteration of clinopyroxene to actinolite (bladed and colorless) near patch of alteration of

another mafic.

Alteration patches - greater than 10% - smaller patches about 5 mm near clinopyroxene, and large (about 1 cm) by itself. Patches of talc + opaques with bladed actinolite, surrounded by pale to blue-green hornblende and chlorite. Actinolite is poikiloblastic and probably replaces talc + opaques assemblage. Large isolated patch predominantly chlorite and carbonate, surrounding colorless to brown amphibole. Also some opaques with the chlorite.

Hornblende - about 5% in addition to rims around mafics and their pseudomorphs, some subhedral-euhedral grains in recrystallized plagioclase matrix. Grains about 1 mm, mostly green, brownish-green and bluish-green grains. Some are in aggregates of less than .5 mm grains, and are poikiloblastic with plagioclase.

Sphene - less than 1% in zones with plagioclase and hornblende, also with some smectite?. Subhedral grains less than 1 mm. Apparently originate at the same time as recrystallization.

Textures suggests this rock once pegmatitic. Recrystallization accompanied by some amphibole alteration of clinopyroxene followed considerable strain. Strain did not end here - later strain reflected in tiny grains and strained secondary ones. Carbonate formation after this (not twinned). Otherwise, textural evidence for relation of most alteration to deformation suggests late alteration at temperatures high enough for actinolite to form.

742-3-1 Olivine-bearing Metagabbro

Plagioclase - about 40%, originally about 50-55%. Relict grains less than 5 mm long, anhedral. Most relicts 2-3 mm. Lots of small grains less than .5 mm. Mosaic texture moderately developed, grains subequant, small grains usually have regular boundaries. All of the large and most of the small grains have undulose extinction. Bent and tapered twins extremely common in larger grains; twinning in about 25% of small grains. Very minor optical zoning in larger grains, along boundaries and cracks. Red-brown hornblende accessory phase at triple junctions in some straight zones of small plagioclase - cracks filled with late magma? Chlorite in fractures and more generalized alteration product. Smectite(?)/iddingsite in veins. Fractures cut across old grains and some smaller ones but usually go around grain boundaries of small grains. A little alteration is clearly metasomatic.

Clinopyroxene - about 10%, originally about 15%. About .5 cm. Interstitial and anhedral. Fine cleavage and exsolution (mostly orthopyroxene). Rims of red-brown hornblende. Vermicular texture not uncommon with red-brown hornblende. Red-brown hornblende also forms with alteration along cleavage planes. Some replacement of clinopyroxene by brown (not reddish) hornblende preserves red-brown inclusions. Not massive but aggregate with indistinct grain boundaries. Some clinopyroxene is mottled and has fine-grained opaque inclusions.

Orthopyroxene - less than 5%. Less than 1 mm relict grains altering to fibrous amphibole which is usually plain brown. Very finely cleaved and exsolved. Also altered to yellowish brown stuff - ?oxidized serpentine. Associated with aggregated red-brown and blue-green

hornblende, relict olivine, talc in a zone of apparently high strain. Parts appear to be mixed aggregate, obscured by considerable alteration of orthopyroxene and olivine. Opaques scattered throughout, some enclosed by red-brown hornblende, others dusting serpentine(?).

Other pseudomorphs of mafics - greater than 15%. Talc + opaques resembling olivine pseudomorphs are about 5 mm, very irregular shapes. Opaques not particularly abundant. Serpentine and smectite(?)/iddingsite(?) quite common in internal cracks, considerable amount of carbonate apparently replacing relict olivine. Some fibrous colorless amphibole, also bladed talc or muscovite. Red-brown hornblende rims often with poorly developed outside rim of chlorite. Also minor amount of chlorite pseudomorphs with pale brown or colorless amphibole rims after something, possibly orthopyroxene. Amphibole sometimes needle-like or bladed.

Textures - label end has well developed foliation. The rest of the slide quite altered and/or recrystallized; dominates texturally. Most mafics quite irregular and maximum plagioclase grain size probably originally not much greater than present. Alteration predominantly static, with some in label end before and/or during deformation. Fractures provide logical fluid source and expansion mechanism. Late oxidation and/or replacement of olivine by carbonate - timing of these two unclear.

742-4-1 Altered Gabbro

Plagioclase - about 50%. Grains up to 1 cm long. Laths were originally subhedral to euhedral, have suffered ductile and brittle deformation and some modification of boundaries. Twinning varies from absent to intense with narrow lamellae; in two directions. Undulose extinction is almost always present and moderate. A few large crystals are subdivided by areas of smaller grains or by cracks. Neoblasts are less than .1 mm, are deformed and also appear on original grain-grain boundaries. Irregular zoning visible along some grain boundaries and in long zones which resemble veins. No sharp boundary between zones under uncrossed polarizers. Most plagioclase has tiny inclusions in trails, probably crystallographically controlled. A fair amount of cracking, some preferentially oriented, emphasized by chlorite alteration and some yellow-brown mineral (smectite?). Other alteration of plagioclase is small blebs of carbonate. Badly altered .2 mm inclusions in clinopyroxene.

Clinopyroxene - about 50% originally, now about 30%. Very coarse grained. Possibly one continuous grain now divided by alteration zones which poikilitically encloses all of plagioclase. Relics appear to have approximately same orientation. About 40-50% stained yellow. Clinopyroxene is finely cleaved; has altered to brown hornblende along larger cracks. Very narrow rims of brown hornblende rare. Most common alteration is to blue-green hornblende in zones about .5 mm wide. Narrower rims and larger grains in center of zones may have brown cores, grading to blue-green. These are massive hornblendes, not at all fibrous. Other alteration includes fibrous amphibole? (yellow-stained) which pseudomorphs cleavage, and carbonate in pockets of unknown origin.

Other alteration - Patches contiguous with clinopyroxene of acicular

pale yellowish amphibole(?) surrounding and growing in mass of chlorite may be alteration of clinopyroxene or of another mineral. Chlorite also found in patches without associated acicular mineral. Present in some of these patches is mineral-like smectite described with plagioclase.

742-4-2 Metagabbro

Plagioclase - about 50% - relict grains 3-10 mm long and mostly sub-hedral, elongate. Mechanical twins, slip lines (faults that aren't cracks), and undulose extinction common, also some subgrain development and polygonization. Small grains not obviously bounded by cracks usually have straight boundaries and granoblastic texture with other grains of the same size, suggesting some recrystallization. A few small grains have mechanical twins. Abundant brittle fracture giving granulated or brecciated texture unlike most sections in this suite. Cracks mostly filled with chlorite, some brown and green hornblende. A few small patches contain numerous tiny inclusions of sericite?

Clinopyroxene - about 5% now, probably at least 10% originally - grains about 5 mm average. Apparently enclosed and interstitial to plagioclase. Subhedral shapes where clearly defined. Grains show bending, kinking and severe undulose extinction. Brown hornblende rims preserved even where bulk of clinopyroxene altered to green hornblende and/or actinolite.

Patches of actinolite and chlorite show bladed actinolite growing into mixture, all inside hornblende rim (most colors present). In some patches actinolite is bent or kinked, indicating clearly post or syn-alteration deformation. Also some patches have well aligned fibrous actinolite, almost schistose.

Hornblende, besides rimming and pseudomorphing, also forms separate grains, often zoned, brown usually in center or to one side. These may be poikiloblastic if in plagioclase domain.

Continued brittle deformation, even at temperatures of actinolite formation, is most outstanding implication of this slide. Igneous

texture probably somewhat ophitic. There is some elongation of mafic aggregates, but these are not preferentially oriented to define a foliation.

742-5-1 (1 1/2 x 3) Olivine-bearing Metagabbro

Plagioclase - about 65%. Relict grains less than 1 cm long. Often simply twinned with only one twin showing additional bent mechanical twins. Most relicts irregular but elongate, occasionally relict plagioclase-clinopyroxene grain boundaries, with plagioclase subhedral, preserved in part. Mortar texture well-developed. Small grains less than .3 mm with regular, subequant grains. Despite good granoblastic texture, most grains show at least slight undulose extinction and a few have tapered twins. Moderate preferred orientation of relict grains and some later ones. Minor metasomatism of plagioclase apparently precedes some new grain growth but postdates some. [Short episode during development of mortar texture?] Very minor sericite; some chlorite in fractures and along grain boundaries. Very minor blue-green hornblende in fractures.

Clinopyroxene - originally about 20%, now about 15%. Irregular grains about 3-10 mm, poikilitic about plagioclase. Some fine exsolution lamellae, but much more common is vermicular to mottled intergrowths of clinopyroxene and red-brown hornblende. Rims of red-brown hornblende very common, some fairly wide. Also some blue-green hornblende. Several zones of granoblastic clinopyroxene intergrown with red-brown hornblende and opaques - most likely a result of deformation. Clinopyroxene also occurs as small grains in trails within mortar plagioclase. Alteration massive pseudomorphing by blue-green and brown hornblende, by expansion of a rim inward and/or by alteration along cleavage planes.

Orthopyroxene - about 1%. Grain about 5 mm long associated with clinopyroxene. Very finely cleaved. Fractures are oxidized, similar to

olivine. Some alteration to talc + opaques, most to brownish fibrous mineral mimicking cleavage. Minor patches of serpentine or chlorite around pseudomorphs. Also hexagonal minerals - clear, about 2.5 mm grains with high relief, high birefringence, in and around pseudomorphs, possibly secondary clinopyroxene or olivine. Includes iddingsitic pseudomorph after olivine(?). Brown and green hornblende partial rims.

Olivine - about 5-10% originally. Grains 2-4 mm, anhedral, subequant. Undulose extinction. Apparently interstitial and poikilitic to plagioclase and possibly to clinopyroxene. Some kinking. Alteration to talc + opaques and iddingsite, some fibrous amphibole. Rims of brown and blue-green amphibole common. Some of olivine badly oxidized. Mesh texture serpentine(?) inside talc coronas. Some replacement of relict olivine by carbonate. A couple of examples of apparent orthopyroxene partial rims - orthopyroxene slightly altered. Chlorite coronas rare.

Hornblende - now about 15%. Rims, aggregates, pseudomorphs and veins. About half is red-brown, much is blue-green. There is some zoning, both blue-green to red-brown and vice versa. Some grains subhedral. Colorless amphibole is bladed to fibrous. A lot of brown hornblende has inclusions of irregularly shaped opaques. Massive pseudomorphs are poikiloblastic with inclusions of clinopyroxene and some plagioclase (especially in veins). Some patches of pale actinolitic amphibole appear to be pseudomorphs, actually now fibrous aggregates. Possibly after orthopyroxene - not very abundant.

Textures - Igneous texture: plagioclase dominant but some poikilitic inclusions by clinopyroxene and olivine while plagioclase small. Maximum grain size probably about 1 cm. Foliation moderately developed,

particularly along narrow zones, [due to high strain]. All minerals affected by strain, plagioclase the most. Recrystallization during and after deformation, probably most alteration after deformation. Brittle deformation apparently minor.

742-5-2 Altered Olivine Gabbro

Plagioclase - 55-60%. Relict grains up to 1 cm, average about 3-4 mm. Secondary grains less than .5 mm. Relict grains most common where seemingly protected by surrounding mafic phases. Plagioclase at one time subhedral laths, partly-to-completely enclosed by olivine, clinopyroxene and orthopyroxene. Now predominantly uneven granoblastic texture - grain size is variable, not systematic. Large and small grains commonly have undulose extinction; tapered twins present but not greater than 50%. Cracks through plagioclase are late, post recrystallization, and usually filled with chlorite and a little blue-green hornblende.

Olivine - 7-8% Granoblastic aggregates usually less than 1 cm. Kinking observed in some grains. At least one grain includes some orthopyroxene due to recrystallization and alteration. Difficult to define original textural relationship of olivine to other minerals. Olivine altered around edges and especially at aggregate terminations to talc + opaques combination. Minor later alteration along cracks to dark serpentine. Brown hornblende and orthopyroxene may also be part of outside rim (-late magmatic xlation?)

Orthopyroxene - less than 5% Grain size average .5 mm. Occurs in aggregates and as separate grains which are stubby-prismatic in shape. Also associated with olivines. It usually is found in zones of extensive recrystallization where original relationships obscure. Alteration relatively minor and to serpentine without opaques and bastitic, unlike serpentine after olivine.

Clinopyroxene - 25-30% Up to 1 cm, poikilitic grains surrounding plagioclase laths, also about 50% + of aggregates of clinopyroxene and brown hornblende in recrystallized areas. Clinopyroxene may include small patches of other clinopyroxene with vermicular texture, usually in outer part of grain, but often shows no exsolution. Narrow rims of brown hornblende common, as in alteration to brown hornblende along closed fractures. Vermicular clinopyroxene contains brown hornblende rather than another pyroxene.

Some patches of alteration after unknown mineral - central core of chlorite, surrounded by inward growing blades of actinolite (pale blue-green).

Narrow rims of chlorite? also sometimes around talc + opaques corona of olivine.

Abundant recrystallization has removed many traces of apparently subophitic texture. Foliation is well-developed in portions of this slide. All phases have been affected by recrystallization. Olivine mineral most affected by alteration, perhaps about 30% altered. Source of alteration fluid not clear - not obvious from cracks.

well recovered kinked olivine,