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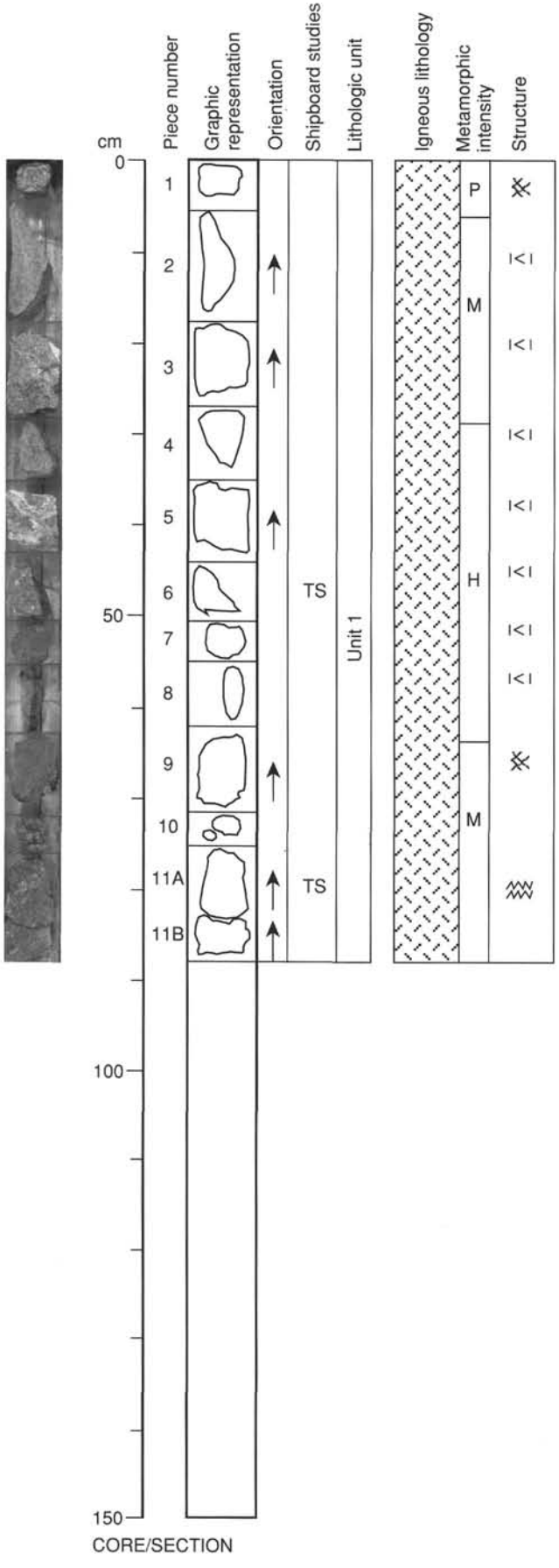

UNIT 1: GABBRO-GNEISSIC GABBRO

Pieces 1–11B

COLOR: Gray-green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 55%–68%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Clinopyroxene - Mode: 30%–48%.
Crystal Size: 2–15 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Olivine - Mode: 0–10%.
Crystal Size: 2–4 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Iron oxide minerals - Mode: 0–2%.
Crystal Size: 1–2 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Apatite - Mode: Trace%.
Pyrite - Mode: Trace%.
Comments: The section is a wash core consisting of irregular pebbles and cobbles. The clasts include a heterogeneous mixture of deformed and undeformed gabbro that is highly altered. Piece 1 contains a small (2–3 cm wide) mylonitic zone that cuts relatively undeformed, but highly altered gabbro. Piece 2 is an undeformed gabbro with a 15 mm wide alteration halo that contains abundant epidote. The plagioclase is highly altered, but there is considerable fresh clinopyroxene in the sample. Piece 3 is an olivine-bearing poikilitic gabbro with oikocrysts of clinopyroxene up to 15 mm wide enclosing plagioclase. Alteration of the plagioclase is strong in this sample. Pieces 4, 5, and 6 consist of metagabbro. Piece 5 is a very coarse-grained (crystals up to 15 mm) vein several cm in width that cuts a finer grained gabbro with a possible contact exposed at one end of the unoriented piece. The sample contains minor magnetite, pyrite and apatite as accessory phases. Piece 6 contains a pegmatitic vein and is characterized by large pyroxene grains. Piece 9 is a foliated gabbro, cut by an oxide-bearing gabbro "pegmatite" vein. Piece 10 is gabbro rubble. Piece 11 is a gneissic gabbro with finely recrystallized plagioclase and pyroxene surrounding large elongate to equant porphyroclasts of clinopyroxene and plagioclase. In general, the heterogeneity of the lithologies recovered combined with the overall high degree of alteration indicates that most of the pieces look like they were recovered from rubble.
SECONDARY MINERALOGY:
Actinolite-tremolite
Mode of Occurrence: Replacing olivine.
Chlorite.
Mode of Occurrence: Replacing olivine, clinopyroxene, plagioclase.
Iron oxide minerals
Mode of Occurrence: Replacing olivine and clinopyroxene.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Epidote.
Mode of Occurrence: Replacing plagioclase.
Prehnite.
Mode of Occurrence: Replacing plagioclase.
Comments: Piece 1 is pervasively altered (98%) with intense alteration associated with mylonite development. The mylonite zone is composed of anastomosing "veinlets" of pale green actinolite, which alternates with lenses of neoblastic plagioclase, clay minerals, prehnite(?), and chlorite. The low-temperature mineral phases overprint the high-temperature ductile deformation. Away from the shear zone, plagioclase is chalk white and pervasively replaced by secondary plagioclase, with minor epidote. Clinopyroxene is pervasively altered to actinolite and chlorite. Rare pods of chlorite, tremolite(?), and oxide minerals replace olivine. Piece 2 is a highly altered gabbro (45%) in which the upper 1/3 is pervasively replaced by epidote and secondary plagioclase

after plagioclase. The epidote alteration halo is associated with a 2 mm wide epidote vein exposed on the broken surface of the sample. The lower 2/3 of the sample contains minor epidote and abundant chlorite and secondary plagioclase (50%). Clinopyroxene is moderately altered (20%) to actinolite and a trace of brown amphibole. Piece 3 is moderately altered (40%). Olivine is pervasively altered (100%) to chlorite, with a trace of tremolite, and iron oxide minerals. Clinopyroxene is moderately altered (20%) generally, except near veins where it is pervasively replaced by actinolite. Plagioclase is commonly chalk white due to replacement by secondary plagioclase and locally epidote. Pieces 4–8 are highly altered (50%–70%). Clinopyroxene is moderately (30%) altered to actinolite, a trace of brown amphibole and iron oxide minerals. Plagioclase is pervasively altered (90%–100%) to secondary plagioclase, abundant chlorite, and minor actinolite and epidote. Plagioclase grains are commonly crosscut by chlorite netveins. Piece 9 is moderately altered (20%) with clinopyroxene replaced by actinolite, minor brown amphibole, and iron oxide minerals. Plagioclase is slightly to moderately altered (10%) to chlorite, and secondary plagioclase. Piece 11 is moderately altered (25%). Plagioclase is moderately altered (30%) to secondary plagioclase, chlorite, and actinolite when adjacent to clinopyroxene and cut by actinolite and chlorite veinlets. Clinopyroxene is 10% altered to actinolite, brown amphibole, and fine-grained iron oxide minerals.

Veins

Piece 1 is cut by a 1 mm wide epidote veinlet. Piece 2 contains a wide alteration halo (15 mm), composed of epidote and plagioclase which offsets a 1 mm wide chlorite veinlet, and which is associated with a 2 mm wide epidote veinlet. Piece 3 is cut by a chlorite veinlet (<1 mm wide) which contains minor epidote, and a veinlet of prehnite(?) and clay minerals (<<1 mm wide). The edge of the piece contains an 8 mm wide band of chalk white plagioclase, minor epidote, and prehnite(?). Piece 4 is cut by 1 mm wide veinlet of chlorite and prehnite(?) Piece 5 contains a 5–6 mm wide, irregularly shaped vein of prehnite(?) plagioclase, actinolite, and epidote which cuts coarse-grained gabbroic material. Fine, <1 mm wide veinlets of chlorite form en echelon structures cutting plagioclase. Piece 6 contains a <<1 mm wide veinlet of prehnite(?) with a narrow alteration halo turning the wall-rock plagioclase chalk white secondary plagioclase and minor epidote. Piece 11 is cut by 5–6 subparallel dark green veinlets (< 1 to 1 mm wide) of chlorite and actinolite.

VEIN/FRACTURE FILLING:

Epidote.

Size: 1 to <1 mm.

Actinolite and chlorite.

Size: <1 to 1 mm.

Chlorite and prehnite.

Size: <<1 mm.

ADDITIONAL COMMENTS: *Structure*

This is a structurally heterogenous section. Piece 1, a small unoriented piece, is about 50% by volume a semibrittle (possibly fully ductile?) shear zone. The elongate and fractured plagioclase are set in a matrix of fine grained altered yellow green minerals (fault gouge?). Piece 8 has a 1 cm band of coarse-grained, aligned plagioclase and pyroxene grains cutting it. All of Piece 11 is strongly deformed with elongate pyroxene, recrystallized plagioclase strung out and stingers of oxide minerals forming a strong foliation that dips 30°–40°. The texture of the rock changes from very coarse-grained at the top of the piece grading down to fine-grained matrix with coarse embedded pyroxene. The elongation of recrystallized(?) plagioclase seems to increase with the gradation to finer grained material. Several vertical thin (<1 mm) actinolite and chlorite veins cut the foliation. Piece 5 has a thick (1 cm) branching vein composed mostly of plagioclase that is cut by three small (<1 mm thick, 12 mm long) veins, one of which apparently offsets the large vein by 2 mm in a normal sense. Other thin actinolite and chlorite veins cut Pieces 2, 3, 4, 8, and 9.

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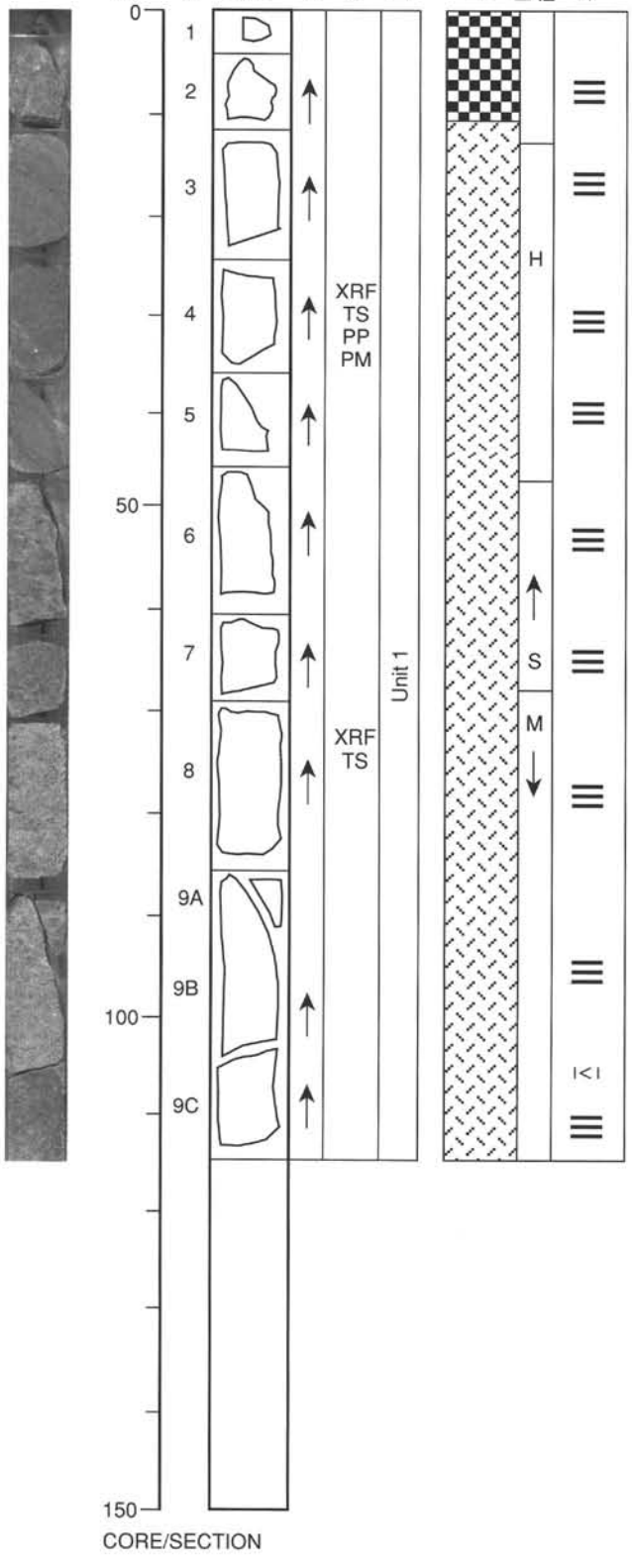
UNIT 1: GNEISSIC GABBRO AND MICROGABBRO

Pieces 1–9C



COLOR: Gray-green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Iron oxide minerals - Mode: 0–6%.
Crystal Size: 2 mm.
Crystal Shape: Anhedral.
Crystal orientation: Tectonic alignment.
Clinopyroxene - Mode: 30%–45%.
Crystal Size: 12–35 mm.
Crystal Shape: Anhedral.
Crystal orientation: Tectonic alignment.
Plagioclase - Mode: 49%–70%.
Crystal Size: 1–15 mm.
Crystal Shape: Anhedral.
Crystal orientation: Tectonic alignment.
Comments: The section consists of foliated and lineated gabbro and fine-grained foliated and lineated microgabbro. Pieces 1, 2, 6, 7, 8, and 9 are foliated gabbro. Olivine is largely absent from foliated gabbro, and pyroxene tends to occur as large (8–35 mm) brown crystals throughout the gabbro. They are generally not recrystallized. Plagioclase is largely recrystallized throughout the section and textures grade to porphyroclastic in pieces adjacent to the microgabbro. Orientations of the lineations and foliations vary through the core from vertical in Piece 2, to inclined at 25° adjacent to the microgabbro, and to subhorizontal in Pieces 6–9. Piece 2 is an oxide gabbro with 5%–6% oxide minerals that are elongated in a vertical orientation. Pieces 3, 4, and 5 are fine-grained (<1 mm) microgabbro that are rich in plagioclase (~70%) and brown amphibole with minor clinopyroxene and opaque oxide minerals. Piece 3 contains a contact between a highly sheared gabbro with a low abundance of secondary hydrous phases and fine-grained microgabbro. There is grain-size reduction in the gabbro as the contact with microgabbro is approached. Sulfide minerals are associated with chlorite veins and replacement of pyroxene (Pieces 7–9).
SECONDARY MINERALOGY:
Iron oxide minerals.
Mode of Occurrence: Replacing clinopyroxene.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Chlorite.
Mode of Occurrence: Replacing clinopyroxene and plagioclase.
Comments: Also occurs replacing brown amphibole.
Brown hornblende.
Mode of Occurrence: Replacing clinopyroxene.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene.
Comments: Also occurs replacing brown amphibole.
Comments: Pieces 3–5 are moderately foliated microgabbro which is slightly to moderately replaced by greenschist facies mineral assemblages. Foliation is defined by fine-grained brown amphibole segregations alternating with fine-grained plagioclase. Amphibole is slightly to moderately altered to actinolite. At the contact in Piece 3 between the microgabbro and highly deformed gabbro, rare olivine is pervasively replaced by chlorite and pyrite, clinopyroxene is slightly to moderately altered to actinolite with brown hornblende and plagioclase is extensively recrystallized. The foliated gabbro is comprised of recrystallized plagioclase, oxide mineral stringers, brown amphibole, and porphyroclasts of clinopyroxene with narrow actinolite rims. Piece 6–9 are slightly to moderately altered (10%–15%). Clinopyroxene is slightly to moderately altered (10%–15%) to actinolite, minor fine-grained blebs of brown amphibole, and fine-grained magnetite. Adjacent to chlorite ± actinolite veinlets, clinopyroxene is pervasively altered to chlorite and actinolite, forming dark green irregular patches. Plagioclase is slightly to moderately altered (10%–15%) to minor secondary plagioclase, and actinolite and chlorite where adjacent to pyroxene.

Veins

Piece 4 is cut by a branching subhorizontal chlorite veinlet which is <1 mm wide and bifurcates at the contact with the coarser grained gabbro. Piece 5 is cut by a diffuse 1–2 mm wide actinolite veinlet with a subhorizontal orientation. The backside of the sample exhibits multiple fine vein sets of chlorite ± actinolite.

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Piece 8 is cut by fine, discontinuous, subparallel veinlets of chlorite with minor actinolite which are oriented subhorizontally. Adjacent clinopyroxene is pervasively altered to actinolite ± chlorite.

The bottom Piece 9 is cut by a fine (<<1 mm wide) chlorite ± actinolite veinlet, oriented subhorizontally and a similar veinlet, <1 mm in width, which is discontinuous and oriented at ~45° angle.

VEIN/FRACTURE FILLING:

Chlorite and actinolite.

Size: <1 mm.

ADDITIONAL COMMENTS: Structure

Intense to moderate plastic deformation overprints primary magmatic textures throughout all this section, except in Piece 1 which is a small pebble of coarse-grained gabbro. A coarse-grained to pegmatitic protolith can also be inferred for Pieces 2 and 8 where large (3 cm) pyroxene porphyroclasts are preserved. Porphyroclastic texture is common in this section (Pieces 2, 6, 7, 8, and 9). It is characterized by abundant weakly to moderately elongated pyroxene porphyroclasts ranging in size from a few mm to about 1 cm, and rarely larger. These porphyroclasts are embedded in a matrix of finely recrystallized plagioclase (with minor olivine, pyroxene, and amphibole?). Locally, this matrix is highly sheared and defines mm- to cm-sized anastomosing mylonitic shear bands. Deformation is very intense in Pieces 2, 3, and 4 where highly deformed porphyroclastic gabbro grades into mylonitic gabbro (described as amphibolite by petrologists). In the highly deformed porphyroclastic texture, recrystallized tails develop around pyroxene crystals. Mylonite is characterized by rather uniform fine grain sizes (a few hundred microns). Pyroxene (amphibole?) is relatively elongated in the mylonite. The transition between strongly deformed porphyroclastic gabbro and mylonitic gabbro is sharp and planar. In the mylonite and highly deformed porphyroclastic rocks, the foliation dip is moderate (around 30°). In porphyroclastic rocks, it is more irregular, varying from subhorizontal (Piece 6) to subvertical (Piece 2). A few subhorizontal mm-wide actinolite and chlorite veins crosscut the foliation plane in Pieces 4, 5, 8, and 9.

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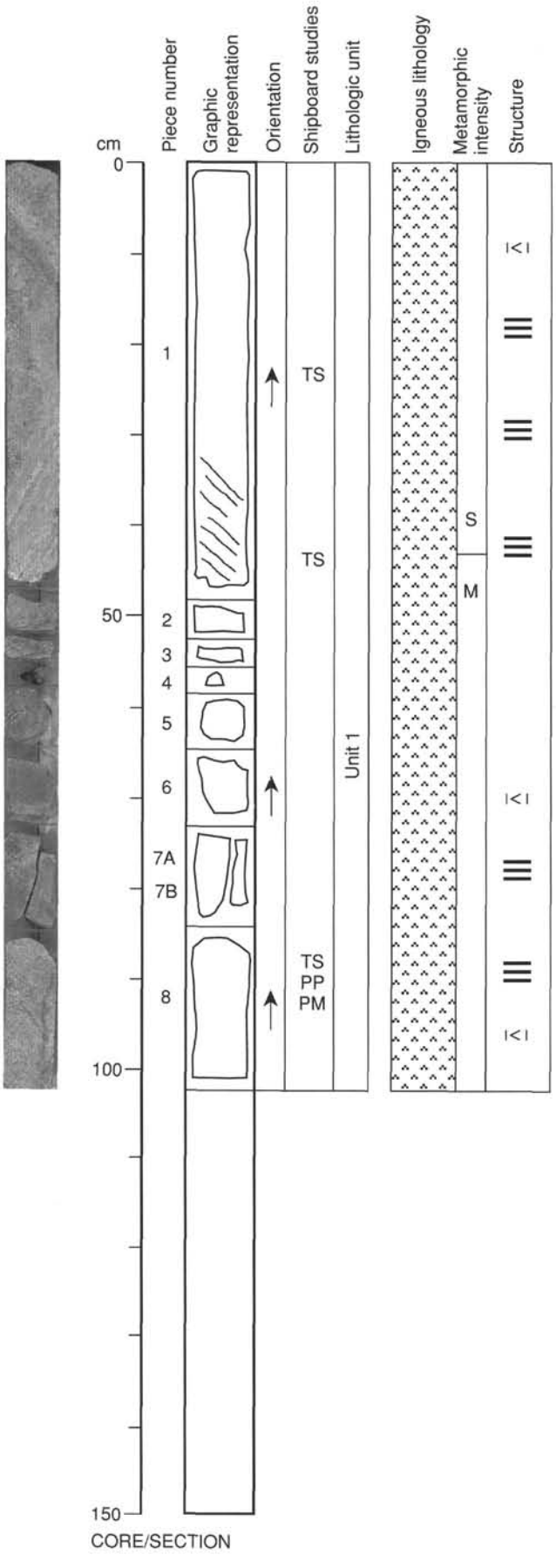

UNIT 1: OLIVINE GABBRO AND AMPHIBOLITE

Pieces 1–8

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 57%–61%.
Crystal Size: 1–7 mm.
Crystal Shape: Anhedral to subhedral.
Crystal orientation: Tectonic alignment.
Clinopyroxene - Mode: 23%–30%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Crystal orientation: Tectonic alignment.
Olivine - Mode: 12%–18%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral.
Crystal orientation: Tectonic alignment.
Iron oxide minerals - Mode: 0–1%.
Crystal Size: 0–1 mm.
Crystal Shape: Anhedral.
Comments: This section is dominated by variably sheared olivine gabbro that is modally homogeneous. Specifically, Pieces 1–5 and Piece 7 are olivine gabbro. Piece 6 is amphibolite, probably with a gabbroic protolith. Clinopyroxene is brown and varies in grain size throughout the section. Plagioclase appears to be strongly recrystallized, so that plagioclase grain size mostly reflects deformation rather than primary igneous size variability. In Piece 1, within the interval 26–44 cm, steeply dipping shear zones transform the rock into gneissic gabbro (minor hornblende), with severe reduction of the grain sizes of all phases within this interval. Above 26 cm in Piece 1, clinopyroxene grain size reaches up to 6–8 mm, and pyroxene size reduction is minimal; the most strongly sheared, finest grained intervals within this piece strongly resemble the amphibolite in Piece 6. A steeply dipping, 1–3 mm thick oxide mineral rich layer(?) cuts across Piece 7. Remnants of primary igneous grain-size layering are preserved in Piece 7. This layering is oblique to the dip of the lineated fabric. Piece 8 is a medium-grained lineated gabbro which is crosscut by a 5 mm wide gabbroic veinlet (clinopyroxene and plagioclase).
SECONDARY MINERALOGY:
Hornblende.
Total Percent: 0–15
Mode of Occurrence: Replacing clinopyroxene.
Secondary plagioclase.
Total Percent: 2
Mode of Occurrence: Replacing plagioclase.
Chlorite.
Total Percent: <1
Mode of Occurrence: Replacing clinopyroxene and plagioclase.
Comments: Occurs rimming clinopyroxene at pegmatitic contact; also occurs overgrowing plagioclase.
Talc.
Total Percent: <1
Mode of Occurrence: Replacing olivine.
Iron oxide minerals.
Total Percent: Trace.
Mode of Occurrence: Replacing olivine.
Smectite.
Total Percent: <1
Mode of Occurrence: Replacing plagioclase.
Comments: Occurs overgrowing plagioclase.
Comments: The alteration downsection is variable and mainly recorded by mafic phases. Piece 1 is a strongly foliated olivine gabbro; at the bottom of the piece a metamorphic banding of alternating leucocratic and melanocratic layers results. In the sheared rock, flattening and grain-size reduction of plagioclase occurs, with likely recrystallization to secondary plagioclase. Clinopyroxene and olivine are relict porphyroclasts, with (actinolite) and minor brown amphibole in the tails. At the bottom of the piece, clinopyroxene ribbons lay along the foliation, or occur as rotated porphyroclasts. The most intense grain-size reduction is recorded at the contact with less deformed

gabbro. Alteration of clinopyroxene and plagioclase can be as high as 5%. Clinopyroxene is rimmed by amphibole, and plagioclase exhibits alteration to brown smectite. Tiny disseminated primary sulfide minerals occur in clinopyroxene. Clinopyroxene is extensively altered where crosscut by thin plagioclase and actinolite veins. Pieces 2 and 3 are lineated olivine microgabbro. Clinopyroxene is very fresh, whereas plagioclase exhibits chloritization, or recrystallizes to secondary chalky white plagioclase. Olivine is surrounded by amphibole and/or replaced by talc. Minor hydration of Fe-oxide minerals induces staining. In Piece 3, chlorite patches occur along foliation. In Piece 5, the top is marked by a foliated gabbro, whereas the center and the bottom of the piece are an undeformed gabbro. Primary sulfide minerals occur included in clinopyroxene; olivine is rimmed by talc and tremolite. Plagioclase is very fresh, locally chloritized at the contact with mafic phases. In the deformed top of piece, chlorite and actinolite crystallizes in the pressure shadows around clinopyroxene. Piece 6 is a fine-grained, melanocratic, foliated metagabbro. Flattened and elongated clinopyroxene is generally slightly altered with minor brown amphibole. Plagioclase is relatively fresh, and is finely recrystallized to chalky white grains. Sulfide minerals are disseminated in plagioclase, and included in olivine. Piece 7 is a foliated gabbro, where a coarse-grained band is developed at the middle and at the top of the piece, within a finer grained gabbro. In the coarser bands, clinopyroxene is flattened and elongated and rimmed by green amphibole. Olivine is rimmed by talc. Plagioclase is recrystallized to secondary plagioclase. Sulfide minerals recrystallized in the tails of the porphyroclasts. Larger clinopyroxene grains are replaced by actinolite. In the finer grained portion, the same textures and alteration features occur, except for a greater degree of replacement of pyroxene by actinolite (up to 70%). Piece 8 is a foliated, fine- to medium-grained metagabbro. Fresh clinopyroxene occurs as elongated ribbons and is rimmed by brown amphibole. Oxide mineral stringers coat clinopyroxene and oxide and sulfide minerals are included in clinopyroxene. Clinopyroxene is replaced by brown amphibole and rimmed by chlorite and actinolite in pressure shadows and around porphyroclasts. In the undeformed gabbro, clinopyroxene is partially rimmed by amphibole. Plagioclase is recrystallized to a gray to colorless fine-grained matrix. Local limited hydroxide mineral staining occurs on the back of the piece.

Veins

In Piece 1, irregular mm-sized plagioclase and actinolite, and very thin monomineralic actinolite veins, crosscut larger clinopyroxene grains. An irregular composite vein is composed of a core of amphibole and plagioclase. In Piece 2, clinopyroxene is crosscut by a composite extensional green fibrous chlorite vein. In Piece 5, a thin, chlorite and actinolite vein cuts across the sample. In Piece 7, a parallel set of actinolite veins develops. At the bottom of the piece, a thin actinolite vein is parallel to the foliation. In Piece 8, on the back of the piece, at the top and across the coarse-grained portion, actinolite veins are abundant.

ADDITIONAL COMMENTS: Structure

Intense plastic deformation overprints primary magmatic textures throughout all this section. The lower half of Piece 1 is highly deformed porphyroclastic to mylonitic gabbro. In the mylonite, recrystallized tails develop around highly elongated pyroxene crystals and define a very faint compositional layering. This mylonitic horizon is referred to as a "shear zone" for the sake of description. However, it is concordant with the foliation in the less deformed porphyroclastic texture (upper half of Piece 1) and the contact between the two is gradational over a few cm. Both the porphyroclastic and mylonitic textures belong to the same high-grade deformation event (upper amphibolite to granulite facies, as indicated by the paragenesis). The porphyroclastic texture (all pieces except the lower half of Piece 1) is characterized by abundant weakly to moderately elongated pyroxene porphyroclasts ranging in size from a few mm to about 1 cm. These porphyroclasts are embedded in a matrix of finely recrystallized plagioclase (with minor olivine and pyroxene (and amphibole?). In Piece 1, the foliation dip is about 50° in the mylonitic and porphyroclastic gabbro. The mylonite has a well-defined lineation trending downdip. Evidence for normal shear sense is found on asymmetrical tails around pyroxene porphyroclasts. In the other pieces, foliation dip ranges from 30° to 50°. A few subhorizontal to moderately dipping (less than 50°) mm-sized actinolite and chlorite veins crosscut the foliation plane (porphyroclastic and mylonitic) in Pieces 1, 2, 5, 6, 7, and 8. In Piece 1, they define an en echelon pattern. In Piece 8, a magmatic(?) hornblende vein crosses cut the foliation at a weak angle (its dip is 50°).

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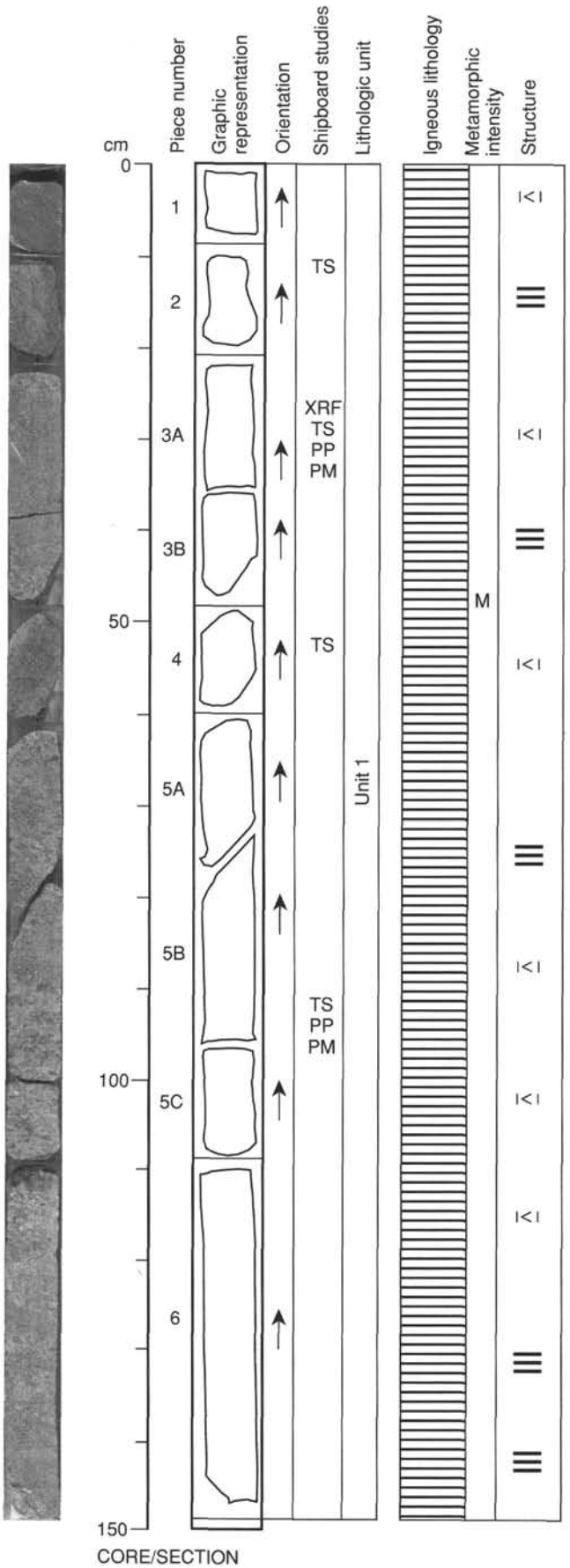

UNIT 1: GNEISSIC OLIVINE GABBRO-OXIDE GABBRO

Pieces 1–6

COLOR: Pink/gray.
PRIMARY STRUCTURE: Igneous layering.
SECONDARY STRUCTURE: Gneissic deformation.
PRIMARY MINERALOGY:
Clinopyroxene - Mode: 28%–35%.
Crystal Size: 1–28 mm.
Crystal Shape: Anhedral.
Crystal orientation: Tectonic.
Plagioclase - Mode: 59%–64%.
Crystal Size: 1–15 mm.
Crystal Shape: Anhedral.
Crystal orientation: Tectonic.
Olivine - Mode: 5%–7%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral.
Crystal orientation: Tectonic.
Iron oxide minerals - Mode: 1%.
Comments: This section is predominantly medium- to coarse-grained olivine gabbro that is modally homogeneous, but texturally variable from magmatic, allotriomophic granular to strongly foliated gneissic. In Piece 1, olivine gabbro displays a gneissic texture in which clinopyroxene and plagioclase porphyroclasts occur in a very fine-grained matrix of recrystallized plagioclase, olivine, clinopyroxene, and hornblende. A fine-grained olivine gabbro layer (5 mm thick) cuts Piece 1 slightly obliquely to both the foliation and other shallowly dipping (<20°) layering. Piece 2 consists of medium-grained gneissic oxide gabbro that is layered on the scale of 1–2 cm. The layering has a steep dip (75°) and contains 5%–10% iron oxide minerals concentrated within vertical layers; outside the layers, the piece is modally similar to other pieces in the section. Pieces 4 and 5 are strongly lineated, and display an augen gneissic texture. The section below Piece 5 is grain-size layered on scale of 1–2 cm from medium- to very coarse-grained, although the base of Pieces 5B, 5C, and 6 are a single very coarse-grained augen gabbro containing augen consisting of plagioclase laths up to 25 mm in size with very coarse, interstitial brown clinopyroxene. The layer is augen rich, containing only 30% fine-grained deformed matrix. In these pieces, clinopyroxene porphyroclasts are commonly accompanied by coarse polygonal grains of recrystallized olivine and plagioclase within the augens. The layering dips approximately 20°. Piece 5 contains a 5–6 mm thick, fine-grained oxide olivine gabbronorite (orthopyroxene-bearing) dikelet oblique to the foliation.
SECONDARY MINERALOGY:
Actinolite.
Total Percent: <3
Comments: After clinopyroxene.
Talc/magnetite.
Total Percent: <2
Comments: After olivine.
Sulfide minerals.
Total Percent: <1
Hornblende.
Total Percent: 0.5–1
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Clay minerals.
Mode of Occurrence: Replacing plagioclase.
Comments: The foliated gabbro shows strong metamorphic recrystallization linked to plastic deformation, overprinting magmatic textures in the most deformed zones. Subsequent, lower temperature alteration of recrystallized or magmatic minerals is weak (<15%) and independent of grain size. Clinopyroxene porphyroclasts are slightly to moderately altered to brown hornblende patches within the mineral and along rims. Narrow actinolite rims overgrow the brown amphibole or clinopyroxene. In the most deformed rocks, small grains of clinopyroxene recrystallize as stringers in the tails of these porphyroclasts (Piece 1). Plagioclase is extensively recrystallized. Very local alteration to a clay mineral occurs near veins. Oxide mineral stringers, present in Pieces 2 and 5A are relatively fresh and exhibit in Piece

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2 very local oxidation and brown staining due to oxidation. Olivine is pervasively replaced by talc, oxide minerals, and disseminated pyrite. Adjacent to chlorite ± actinolite veinlets, clinopyroxene is pervasively altered to chlorite and actinolite, forming dark green irregular patches. Plagioclase is slightly to moderately altered to minor secondary plagioclase, and actinolite and chlorite when adjacent to pyroxene.

Veins

Less than 1 mm wide veins, filled by actinolite and chlorite are present in Pieces 1, 2, 3A, 4, 5C, and 6. In Piece 6, a 2 mm thick horizontal vein is marked by recrystallized secondary plagioclase at its selvages. In Piece 2, a high angle, dipping shear zone exhibits strongly elongated clinopyroxene in a very fine dynamically recrystallized plagioclase matrix. A poikilitic oxide grain encloses the recrystallized plagioclase.

VEIN/FRACTURE FILLING:

Chlorite and actinolite.

ADDITIONAL COMMENTS: Structure

A lineation defined by the elongation of pyroxene defines an L-S fabric in Piece 1. A thin (1.5 cm) zone of foliated gabbro, dipping at about 75° has localized in a plagioclase-rich band in Piece 2 where recrystallized plagioclase surrounds strongly attenuated clinopyroxene porphyroclasts. In Piece 3, the only mineral fabric is a weak lineation evident on the back of the piece that plunges at about 50°. A moderate L-S fabric is also present in Pieces 4 and 5 (dipping at about 30°) and Piece 6 (dipping at about 20°). Textural variations, caused by changes in grain size from medium to coarse grained occur within Pieces 5 and 6 on a scale of 1 to 2 cm. The approximate orientation of these gradational boundaries is about 25° to 30°. Piece 5 also contains a 5 mm thick dikelet that is oriented slightly oblique to the foliation (10° to 15°). Several thin (1 to 3 mm), discrete actinolite and chlorite veins occur in pieces except Piece 3B and have a wide range of dips showing no preferred orientation.

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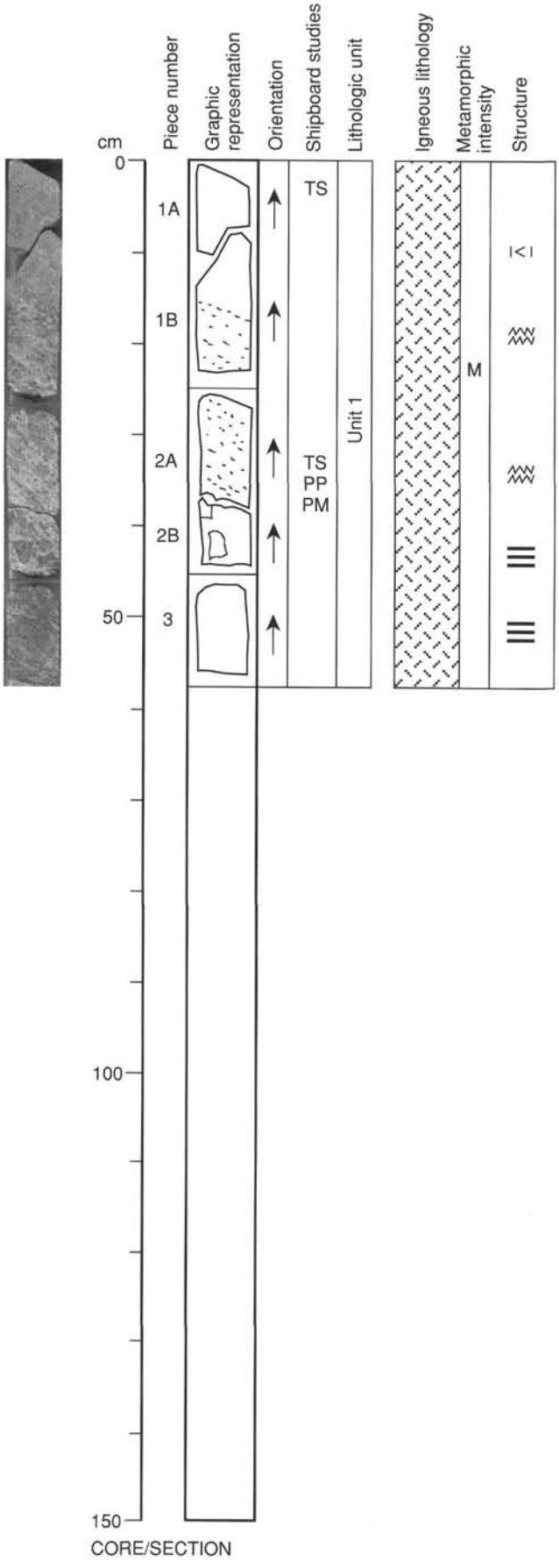

UNIT 1: GNEISSIC GABBRO

Pieces 1A–3

COLOR: Gray.
PRIMARY STRUCTURE: Igneous layering
SECONDARY STRUCTURE: Strong plastic deformation, porphyroclastic to fine-grained equigranular texture.
PRIMARY MINERALOGY:
Sulfide minerals. - Mode: <1%.
Crystal Size: <0.1 mm. Iron oxide minerals - Mode: <1%.
Crystal Size: <0.3 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 0–10%.
Crystal Size: 0.1–5 mm.
Crystal Shape: Anhedral.
Crystal orientation: Elongated.
Clinopyroxene - Mode: 3%–30%.
Crystal Size: 0.2–30 mm.
Crystal Shape: Anhedral.
Plagioclase - Mode: 60%–67%.
Crystal Size: 0.2–3 mm.
Crystal Shape: Anhedral.
Comments: This section is gneissic gabbro consisting of interlayered gabbro and olivine gabbro that is intensely deformed. Brown clinopyroxene is the dominant mafic phase. Olivine varies from 3%–10% of the mode on average, but within a single 1 cm thick layer, 1–2 cm from the base of Piece 1B, it is the only mafic mineral present. Clinopyroxene is present as porphyroclasts up to 30 mm in size, but ranging from 3–10 mm on average. Olivine is strongly deformed in both clinopyroxene-bearing and clinopyroxene-free layers, ranging in habit from fine-grained (0.1–0.5 mm) aggregates in strain shadows on clinopyroxene, to augen with olivine cores (5 mm) and fine-grained highly elongate tails. Plagioclase is never present in its original grain size, but forms a fine-grained neoblast aggregates with rare relict grains (<3 mm). Disseminated iron oxide minerals (<0.3 mm) and sulfide grains (<0.2 mm) are present.
SECONDARY MINERALOGY:
Talc/tremolite/smectite.
Total Percent: <3
Comments: After olivine and clinopyroxene near fractures.
Brown/green amphibole
Comments: After clinopyroxene.
Secondary plagioclase.
Comments: After plagioclase.
Secondary clinopyroxene.
Comments: After clinopyroxene.
Sulfide minerals.
Comments: Along microcracks.
Iron-hydroxide minerals.
Comments: Alteration of sulfide and oxide minerals.
Clay minerals.
Comments: After plagioclase.
Comments: The section is intensely deformed gabbro and olivine gabbro. The pieces shows a strong grain-size variability, from Piece 1 (3/4 of which1s fine grained) to Piece 2, which is very coarse grained, to Piece 3, which is medium to coarse grained. The intensity of alteration is more or less related to the grain size. The finer grained portion of Piece 1 is strongly foliated and shows alignment and orientation of clinopyroxene, and recrystallization of plagioclase. Clinopyroxene is altered to actinolite, either rimming, or extensively replacing the grains. In the coarser grained portion, the foliated texture is not pervasive, and recrystallization occurs only along a 0.5 cm wide shear zone. Clinopyroxene is elongated and altered to brown and green amphibole. Away from the shear zone, clinopyroxene is overgrown by brown amphibole along cleavages. Piece 2A is a coarse-grained gabbro. A 1 cm wide shear zone occurs at bottom of the piece, where clinopyroxene and plagioclase occur as thin elongated ribbons. Clinopyroxene is replaced by brown amphibole. Sulfide minerals (primary) included in clinopyroxene are oxidized and stain plagioclase. Plagioclase is chalky white and exhibits grain-size reduction. In the undeformed gabbro, brown amphibole only locally replaces the clinopyroxene. Piece 2B is a very coarse grained to pegmatitic lineated gabbro. Clinopyroxene is relatively unaltered. It generally has a continuous rim of green and lesser brown amphibole. Green amphibole also

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recrystallizes in the pressure shadows around clinopyroxene. Plagioclase is finely recrystallized. Larger (up to 3 cm length) clinopyroxene exhibits internal fracturing along cracks, where actinolite is common. Piece 3 is similar to the coarse-grained portion of Piece 2, but clinopyroxene is more extensively rimmed. Clinopyroxene porphyroclasts are generally preserved, and green actinolitic amphibole recrystallizes syn- and post-kinematically in their tails and rims. In larger, fractured grains, brown amphibole is present. Sulfide minerals occur as stringers along the foliation surface.

Veins

Less than 1 mm to 1 mm wide actinolite veins cut across Piece 3.

VEIN/FRACTURE FILLING:

Actinolite and chlorite.

Size: <2 mm.

Orientation: None preferred.

ADDITIONAL COMMENTS: Structure

Grain size and compositional layering that is almost certainly igneous in origin is well developed in this section, despite the intense structural overprint. The layering varies on the scale of 1–15 cm, with a fine to medium-grained layer of olivine-free gabbro (Pieces 1A and the top of 1B, 15 cm) overlying with a sharp contact interlayered (1–5 cm), coarse-grained to pegmatitic gabbro and olivine gabbro. This latter association shows ?gradational compositional and grain-size layering, with the most conspicuous zone being a pegmatitic gabbro layer (clinopyroxene up to 30 mm, 5 cm). The layering dips at around 45°–45°, and appears to be slightly shallower than the most obvious structural lineation (especially Piece 1B). Primary igneous texture is completely overprinted by high-grade plastic deformation. A pronounced grain-size variation occurs in Piece 1 with fine-grained gabbro above coarse-grained gabbro which continues to the base of the section. The boundary between the two grain sizes is sharp and parallel to the high-grade deformational fabric. A comparison of pyroxene shapes in both lithologic types suggests that grain size reflects primary igneous texture: aspect ratios, degree of recrystallization and development of tails are roughly equivalent. Strain in the fine-grained gabbro appears to be homogeneous at the mesoscopic scale, whereas strain in the coarse-grained gabbro is heterogeneous and focused into 1) anastomosing plagioclase rich "shear" zones that wrap around pyroxene porphyroclasts and 2) discrete cm-sized submylonitic shear zones, where tectonic grain-size reduction of pyroxene is observed. Moderately dipping (50°) cm-sized submylonitic shear zones are found in the lower part of Piece 1 and the middle part of Piece 2. Very few veins are observed in this section. There are two, 1 mm wide, subhorizontal, chlorite and actinolite veins in Piece 1, one of them corresponding to a joint surface.

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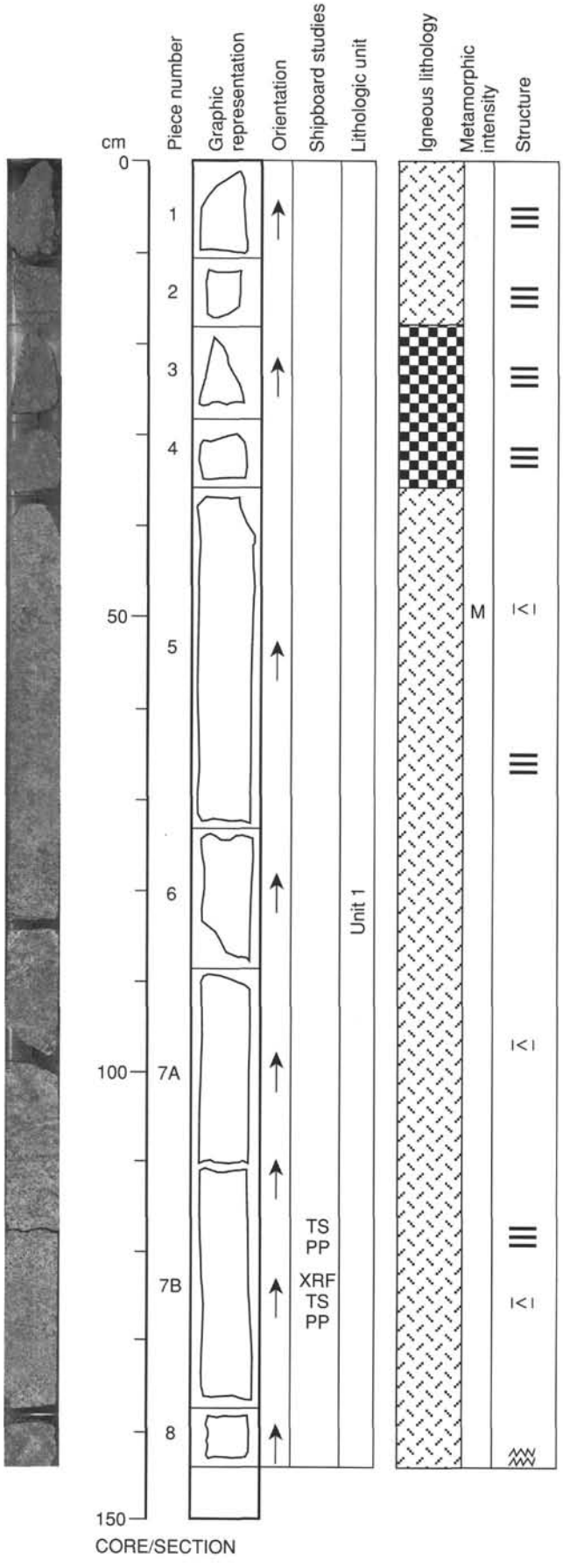

UNIT 1: GABBRO, OXIDE GABBRO AND GNEISSIC GABBRO

Pieces 1–8

COLOR: Gray-green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 50%–65%.
Crystal Size: 1–3 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 27%–50%.
Crystal Size: 1–22 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 0–3%.
Crystal Size: 2–3 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: 0–10%.
Crystal Size: 1–3 mm.
Crystal Shape: Anhedral.
Comments: The section consists predominantly of gabbro (Pieces 2, 5, 6, and 7) and oxide gabbro (Pieces 1, 3, and 4), with some foliated gabbro (Piece 8). Plagioclase occurs in similar modal proportions throughout the section. In the oxide gabbros, iron oxide minerals vary from 5%–10% of the mode; clinopyroxene ranges from 27%–40% and olivine occurs only in Piece 1 (3%). In Piece 1, oxide minerals occur as vertical streaks in the sample giving an apparent foliation to the rock. In general, the abundance of oxide minerals increases from the top to the bottom of the piece. Pieces 3 and 4 show similar features. Pieces 2, 5, 6, 7, and 8 are gabbroic in composition with only small amounts of olivine (1%) observed in Piece 8. Pyroxene content ranges from 27% to 50% and increasing abundance usually correlates with increasing grain size of this phase. Grain size varies through the section from medium grained in most pieces to coarse, e.g., in Piece 8. In places, the gabbro is somewhat deformed and the plagioclase is recrystallized to a finer grain size. For example, the top of Piece 5 is foliated (horizontal foliation) and the base of Piece 8 is foliated. The foliation at the base of Piece 8 is related to a shear zone which is inclined at 45° in the core. Sulfide minerals are present in Pieces 5 and 6.
SECONDARY MINERALOGY:
Talc.
Total Percent: <2
Mode of Occurrence: Replacing olivine.
Iron oxide minerals
Total Percent: Trace
Mode of Occurrence: Replacing olivine.
Brown amphibole.
Mode of Occurrence: Rimming clinopyroxene.
Smectite.
Mode of Occurrence: Overgrowing plagioclase.
Hydroxide minerals.
Mode of Occurrence: Replacing sulfide\minerals.
Epidote.
Clay minerals.
Secondary plagioclase.
Comments: Alteration is limited but variable. Piece 1 exhibits alteration mainly of the mafic phases. In the oxide gabbro, olivine is largely altered to talc, oxide minerals, and tremolite. Clinopyroxene is replaced by brown amphibole along cleavages and discontinuously rims the grains. Plagioclase is altered to fine-grained, chalky, secondary plagioclase. In the finer grained rocks, clinopyroxene is altered to brown amphibole. Hydration of oxide mineral stringers produces staining. Piece 2 is a coarse-grained oxide gabbro. Plagioclase is stained. Olivine is altered (~50%) and replaced by talc and tremolite. Plagioclase is negligibly altered. Sulfide minerals are present in microcracks. Piece 3 is more altered than Piece 2. Olivine is altered to talc. Clinopyroxene is replaced by brown amphibole, and rimmed by actinolite. Plagioclase alters to secondary plagioclase. Piece 4 is similar to Pieces 2 and 3. Piece 5 is a foliated metagabbro. Talc after olivine exhibits minor topotactic replacement. Plagioclase shows grain size reduction. In the more leucocratic rocks, thin rims of chlorite and actinolite surround clinopyroxene. Piece 6 is a troctolitic gabbro, and olivine is pervasively altered to talc and oxide minerals. Olivine in contact with plagioclase is rimmed by pale green tremolite and talc. On back of the piece, deep green hornblende occurs

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within the plagioclase. Brown amphibole rims clinopyroxene and olivine. Pieces 7A and 7B are foliated, medium-grained metagabbro. Olivine alters to tremolite and iron oxide minerals. In Piece 7A, clinopyroxene is locally rimmed by actinolite. Piece 8 is a foliated metagabbro, with 20% alteration.

Veins

In Piece 5, thin, << 1 mm wide veins cut across the top; and a 1 mm wide clay mineral vein is present.

VEIN/FRACTURE FILLING:

Sulfide minerals.

Size: <<1 mm.

Orientation: Random.

Chlorite, epidote, and actinolite.

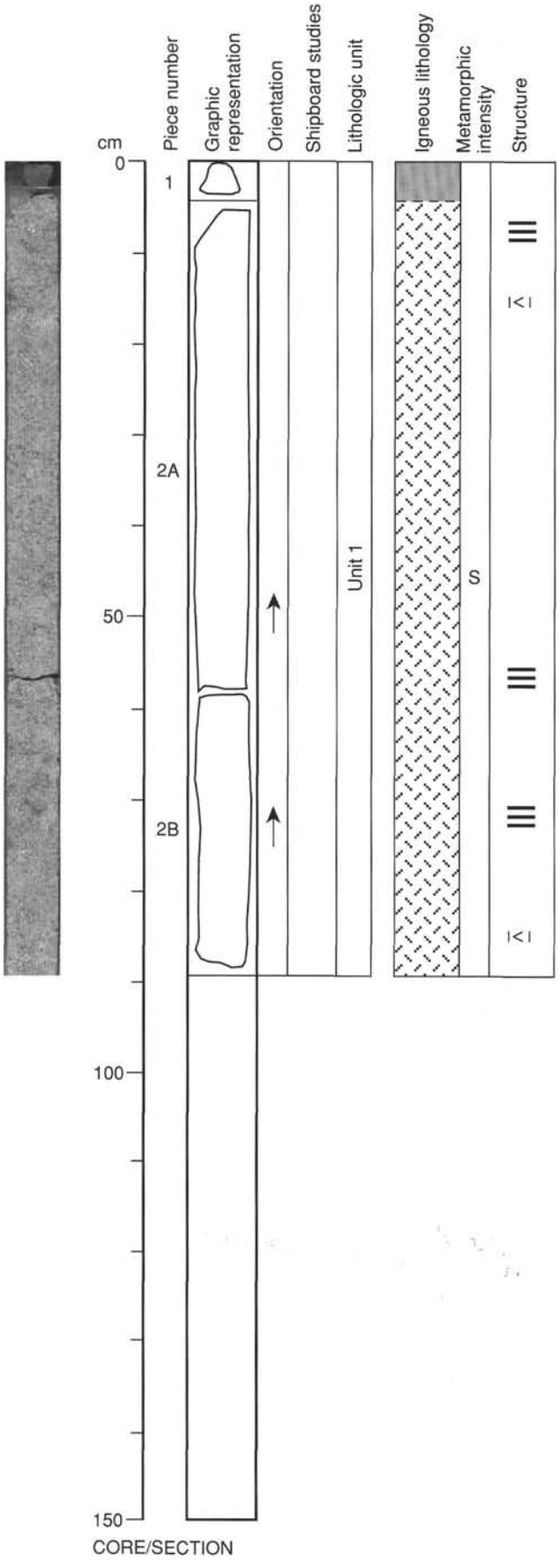
Size: <1 mm.

Albite and clay minerals.

Size: <<1 mm.

ADDITIONAL COMMENTS: Structure

This section is made of coarse- to medium-grained gabbro and oxide gabbro. Subtle, irregularly distributed, grain-size variations are present throughout the section. At the bottom of Piece 5, an increase in modal plagioclase defines subhorizontal layering. The overprint of plastic deformation seems to be very moderate throughout this section. In the oxide gabbro (Pieces 1, 2, and 3), it is heterogeneous and focused into anastomosing plagioclase-rich "shear" zones; these are irregularly oriented but on average subvertical. In the gabbro (all other pieces), plagioclase looks pervasively recrystallized but pyroxene has a very weak shape fabric, except at the very bottom of Piece 5, where an elongated porphyroclastic texture is present. For the sake of description, this is called a shear zone, although it is concordant with the faint fabric above and corresponds to a local increase in the primary fabric intensity, dipping 20°. Piece 8 contains a moderately dipping (45°), 7 mm thick shear zone; it has a porphyroclastic texture and marks the transition between medium-grained gabbro at the top and finer grained gabbro at the bottom. Very few veins are observed in this section (Pieces 3,5 and 7). These are ~1 mm actinolite and chlorite veins, with subhorizontal to subvertical orientations.



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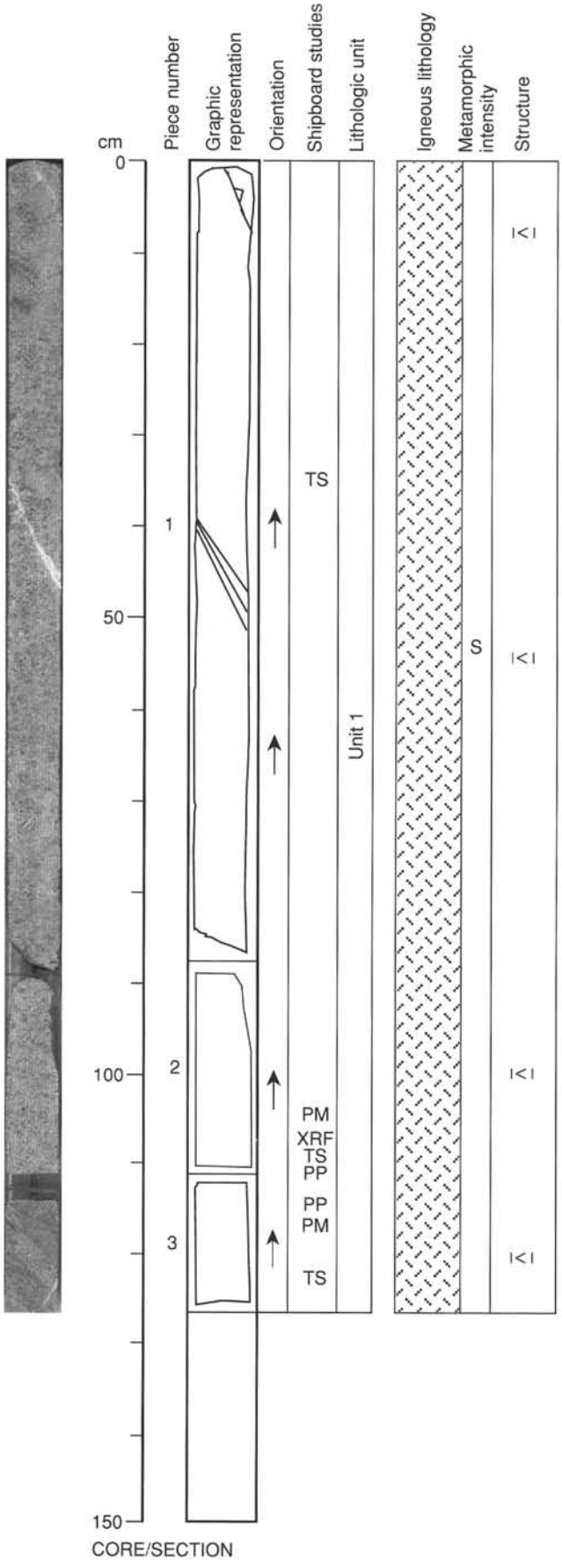
UNIT 1: GABBRO, OLIVINE GABBRO AND BASALT

Pieces 1–2B

COLOR: Gray and black-gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 50%.
Crystal Size: 4–12 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 48%.
Crystal Size: 3–15 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 2%–3%.
Crystal Size: 2–6 mm.
Crystal Shape: Anhedral.
Comments: The section is composed of two pieces. Piece 1 is an unoriented clast of sparsely olivine phyric basalt. The groundmass contains spherulites composed of acicular slender laths of plagioclase in a finer groundmass. The basalt is also slightly vesicular, and some of the vesicles are now filled with secondary minerals (i.e., amygdaloidal in part). Piece 2 consists of gabbro, with minor amounts of olivine locally (e.g, the top of Piece 2B). Otherwise, olivine is sparse to absent throughout the piece. Pieces 2A and 2B contain systematic grain-size variations. Contacts between normally graded intervals occur at 89 cm, 57 cm, and 17 cm. Grain-size changes are abrupt across these contacts. The changes in grain size through each of the graded layers is best observed in pyroxene, for which grain sizes range from 3–15 mm. Modal abundances are nearly homogeneous throughout the core with brown clinopyroxene averaging 48% of the mode. The section is undeformed and there is no foliation observed.
SECONDARY MINERALOGY:
Talc.
Total Percent: <1
Mode of Occurrence: Replacing olivine.
Iron oxide minerals
Total Percent: Trace.
Mode of Occurrence: Replacing olivine.
Brown amphibole.
Total Percent: <1
Mode of Occurrence: Replacing clinopyroxene.
Smectite.
Total Percent: Trace.
Mode of Occurrence: Replacing plagioclase.
Comments: Alteration is slight throughout the section. Piece 1 is a fragment of sparsely olivine phyric basalt. Its surficial alteration is marked by oxide minerals on the outer surface and clay minerals after plagioclase. Piece 2A is a medium-grained gabbro. Total alteration is about 5%. In the coarse-grained portion, at bottom of the piece, olivine is replaced by talc and oxide minerals. Clinopyroxene is replaced by brown amphibole. Actinolite and chlorite occur as local discontinuous rims around clinopyroxene. Plagioclase is generally fresh in Piece 2. Green amphibole is present as rims around clinopyroxene, and brown amphibole replaces clinopyroxene (up to 5%), rarely 10% in localized patches.
Veins
In Piece 2A is a <<1 mm wide actinolite and chlorite vein showing shear and moderate offset across a clinopyroxene grain.
VEIN/FRACTURE FILLING:
Clay minerals.
Size: <1 mm.
Actinolite and chlorite.
Size: <<1 mm.
ADDITIONAL COMMENTS: Structure
Piece 2 is medium- to coarse-grained gabbro which shows a largely isotropic igneous texture. Subhedral plagioclase laths are locally present but most of the plagioclase seems to be recrystallized, pointing to a moderate imprint of solid state deformation. Two mm-sized chlorite and actinolite veins are present in this section. One, dipping 15°, presents a slight (a few mm) normal fault offset. The other one is moderately dipping (35°).



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UNIT 1: GABBRO

Pieces 1–3

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 55%.
Crystal Size: 3–10 mm.
Crystal Shape: Subhedral to anhedral.
Clinopyroxene - Mode: 45%.
Crystal Size: 4–20 mm.
Crystal Shape: Anhedral to subhedral.
Crystal orientation: Possible magmatic preferred orientation.
Sulfide minerals. - Mode: 1%.
Crystal Shape: Anhedral.
Comments: The section consists of three pieces of gabbro that are texturally and modally homogeneous. The section is generally structureless except for some preferred dimensional orientation of prismatic clinopyroxene grains in a subhorizontal direction. Pyroxene is undeformed but displays an elongate habit that may be an original magmatic feature. Although there is no compositional variation, there is diffuse grain-size grading and layering in the section. The layering is subhorizontal and all contacts are gradational. The intervals from 66–82 cm and 34–45 cm are coarse grained (up to 20 mm) and layer boundaries are generally parallel to the preferred orientation of clinopyroxene. The remainder of the interval is medium grained (~8 mm or less). Small amounts of chalcopyrite are disseminated throughout the section.
SECONDARY MINERALOGY:
Chlorite.
Total Percent: <1
Mode of Occurrence: Replacing plagioclase.
Smectite.
Total Percent: <1
Mode of Occurrence: Replacing plagioclase.
Brown amphibole.
Total Percent: 3
Mode of Occurrence: Rimming clinopyroxene.
Comments: In Piece 1, clinopyroxene contains blebsot brown amphibole. Locally, actinolite and/or rarely chlorite rim clinopyroxene. The contact between plagioclase and clinopyroxene is commonly marked by chlorite. In Piece 2, clinopyroxene is moderately altered to green and minor brown amphibole. In Piece 3, alteration is slight. Clinopyroxene is replaced by brown and green amphibole around a vein. Primary inclusions of sulfide minerals are altered to iron-hydroxide minerals. Around an actinolite vein, clinopyroxene has discontinuous rims of green amphibole.
Veins
In Piece 1, between 35–48 cm, an irregular 0.5–1 cm wide composite vein contains plagioclase and quartz and actinolite At the bottom of the piece, a 2-mm-wide, irregular vein is filled by albite and actinolite. In Piece 2, a dense network of very thin actinolite veins is present all over the piece. In Piece 3 a 0.5-cm-wide vein occurs, filled with fibrous actinolite.
VEIN/FRACTURE FILLING:
Actinolite and sulfide minerals.
Size: ~1 mm.
Albite, quartz, actinolite, talc.
Size: 1–10 mm.
Comments: Occurs in the interval 35–48cm as a complete vein which crosscuts the piece obliquely and irregularly. The vein is composed of 90% feldspar, 1% quartz, 8% actinolite, and 1% talc.
ADDITIONAL COMMENTS: Structure
This section is medium- to coarse-grained gabbro which largely preserves its primary igneous texture. Subhedral plagioclase laths are locally present, but most of the plagioclase seems to be recrystallized, pointing to a possible minor imprint of ductile deformation. Locally, the clinopyroxene crystals are elongated and define a weak subhorizontal preferred orientation, particularly in the middle part of Piece 1. Two mm-sized chlorite and actinolite veins crosscut Piece 1. They dip 60° and show a well-developed white halo (several mm wide on both margins, albitization?). A few mm-sized and moderately dipping (30°) chlorite and actinolite veins crosscut Piece 2. One of these shows overlapping structures. A 3 mm thick chlorite vein crosscuts Piece 3, with a dip of 60°.

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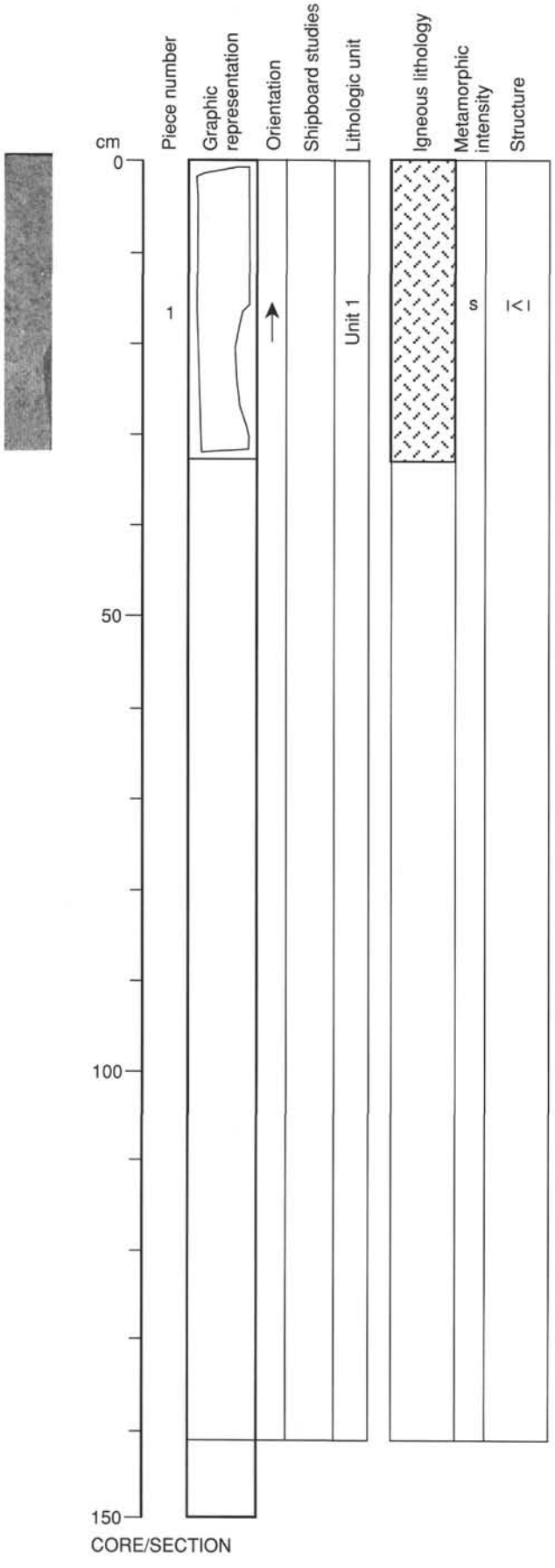
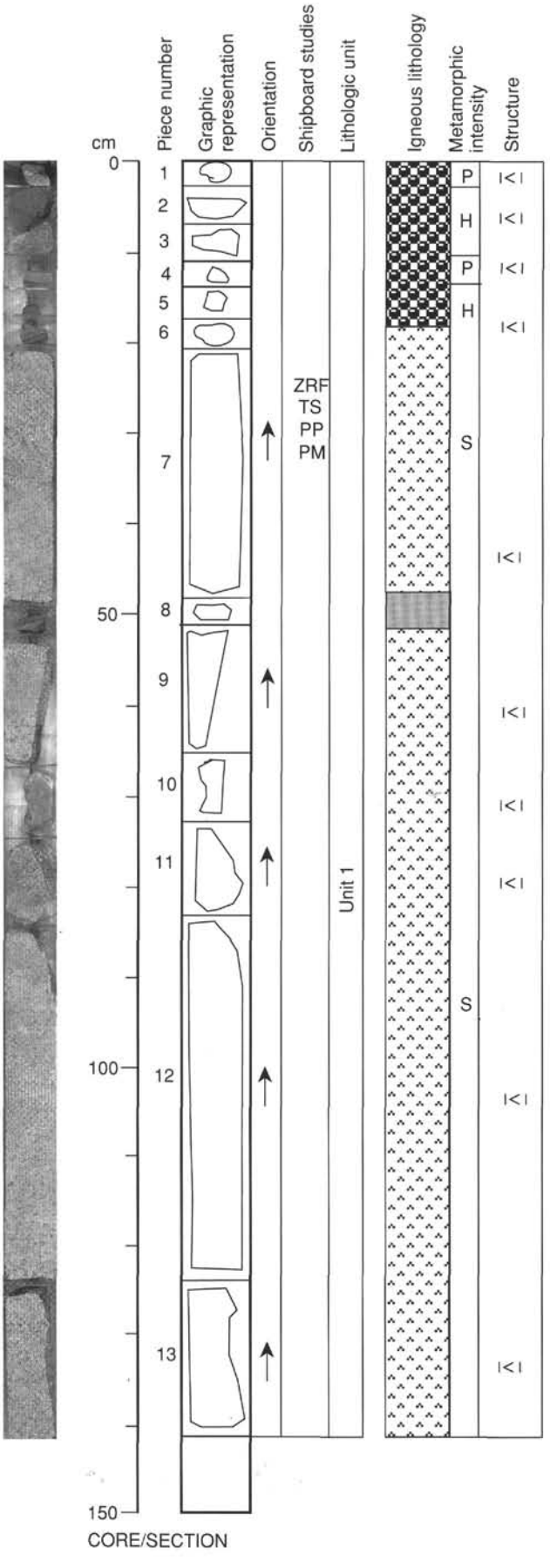


UNIT 1: GABBRO

Piece 1

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 57%.
Crystal Size: 5–10 mm.
Crystal Shape: Subhedral.
Clinopyroxene - Mode: 43%.
Crystal Size: 4–20 mm.
Crystal Shape: Subhedral to anhedral.
Crystal orientation: Elongate subhorizontally.
Sulfide minerals. - Mode: <1%.
Crystal Size: <1 mm.
Crystal Shape: Anhedral.
Comments: The section consists of one long piece of olivine-free gabbro that is homogeneous in lithology, with only slight variations in the ratio of plagioclase to clinopyroxene. The rock is generally structureless, except for some preferred dimensional orientation of prismatic and elongate clinopyroxene grains (aspect ratios up to 5:1) in a subhorizontal direction. Blocky pyroxene is also not deformed. There is grain-size grading and layering that is not well defined. Layering is subhorizontal and all contacts are gradational. The intervals 8–17 cm and 23–28 cm are coarse grained (up to 20 mm) and layer boundaries are generally parallel to the preferred orientation of clinopyroxene (distributed in a horizontal plane). The remainder of the intervals have a finer grain size (~5–8 mm or less). Small amounts of chalcopyrite are disseminated throughout the section.
SECONDARY MINERALOGY:
Brown amphibole.
Total Percent: Trace
Mode of Occurrence: Replacing clinopyroxene.
Smectite.
Total Percent: Trace
Mode of Occurrence: Replacing plagioclase.
Comments: This gabbro is very fresh, showing only minor replacement of brown amphibole on smaller clinopyroxene grains. Disseminated sulfide minerals occur in plagioclase.
Veins
No veins are present in the section.
ADDITIONAL COMMENTS: Structure
No mineral shape fabric and/or preferred orientation of the constituent minerals is present.



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UNIT 1: OLIVINE GABBRO PLUS RUBBLE

Pieces 1–13

COLOR: Gray.
PRIMARY STRUCTURE: Diffuse igneous grain-size layering.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 58%–66%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 26%–42%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 2%–10%.
Crystal Size: 1–9 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: 0.2%.
Comments: The section consists predominantly of medium- to coarse-grained olivine gabbro (Pieces 7, 9, 10, and 13) and gabbro (Pieces 11 and 12) that are diffusely grain-size layered on the scale of 2–15 cm; all contacts are gradational. Pieces 1–6 and 8 are small pebbles (2–6 cm) of olivine gabbro (Pieces 3 and 6), greenschist facies mylonite (Piece 1), and aphyric vesicular basalt (Pieces 2, 4, 5 and 8) that have probably fallen into the hole from above. The layered gabbroic rocks consist of 58%–66% subhedral plagioclase, 26%–42% anhedral brown clinopyroxene, and 2%–10% anhedral olivine. There is a weak horizontal alignment of minerals in the layering, but no deformation is visible.
SECONDARY MINERALOGY:
Brown hornblende.
Total Percent: <1
Sulfide minerals.
Total Percent: <1
Talc/magnetite.
Total Percent: <0.5
Comments: After olivine.
Actinolite/chlorite.
Total Percent: 3
Comments: After clinopyroxene.
Secondary plagioclase.
Comments: After plagioclase.
Clay minerals.
Comments: After plagioclase.
Chlorite.
Comments: The section shows variable degrees of alteration. Piece 1 is an ultramylonitic gabbro, with bands of clinopyroxene altered to green amphibole and plagioclase. Crystal grains are elongated, and strongly recrystallized. Porphyroclasts of fresh clinopyroxene are surrounded by stringers of oxide minerals. Piece 2 is an altered fragment of sparsely phyric basalt, in which plagioclase is altered to clay minerals and the groundmass is chloritized. Piece 3 is an olivine gabbro, up to 30% altered. Olivine is altered to talc and oxide minerals, and clinopyroxene is rimmed by brown amphibole. Piece 4 is more extensively altered (90%). Piece 5 is similar to Piece 2. Pieces 6–12 show moderate alteration, in the range of 3%–5%, mainly expressed as olivine altering to talc and oxide minerals. In Piece 11, around a 1 mm wide irregular actinolite vein, plagioclase is replaced by actinolite.
Veins
Clay mineral-filled microveins occur in Piece 1, and a 2 mm wide actinolite vein is parallel to the foliation. In Piece 4 a thin actinolite vein occurs. In Piece 11, a 1 mm wide irregular actinolite vein occurs.
VEIN/FRACTURE FILLING:
Clay minerals.
Size: <<1 mm.
Actinolite.
Size: <1 mm.
ADDITIONAL COMMENTS: Structure

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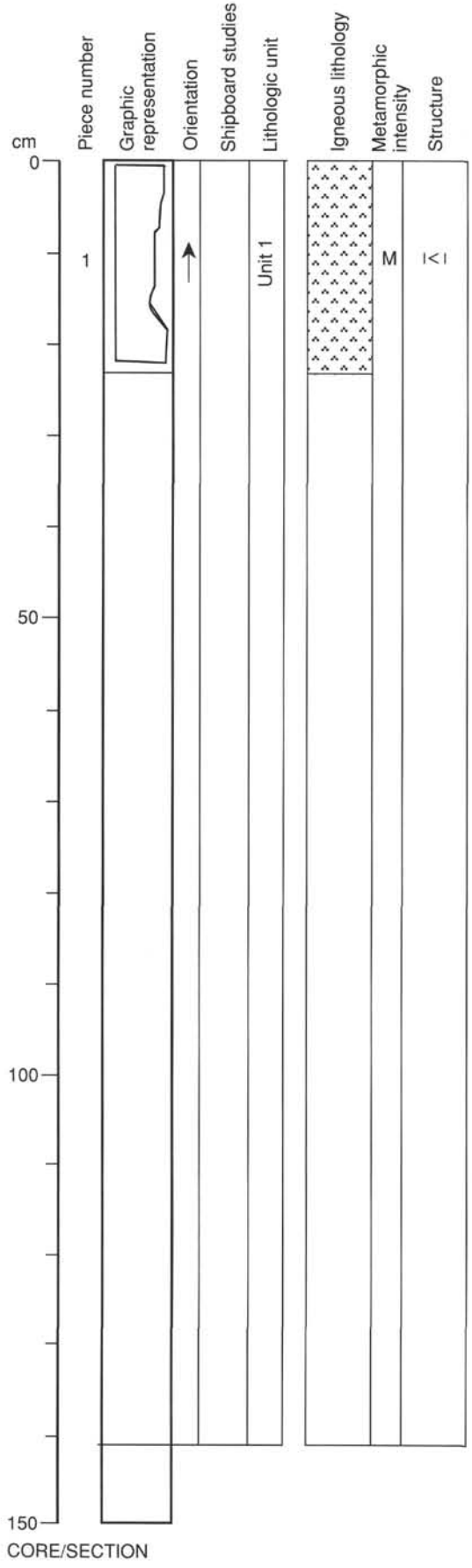
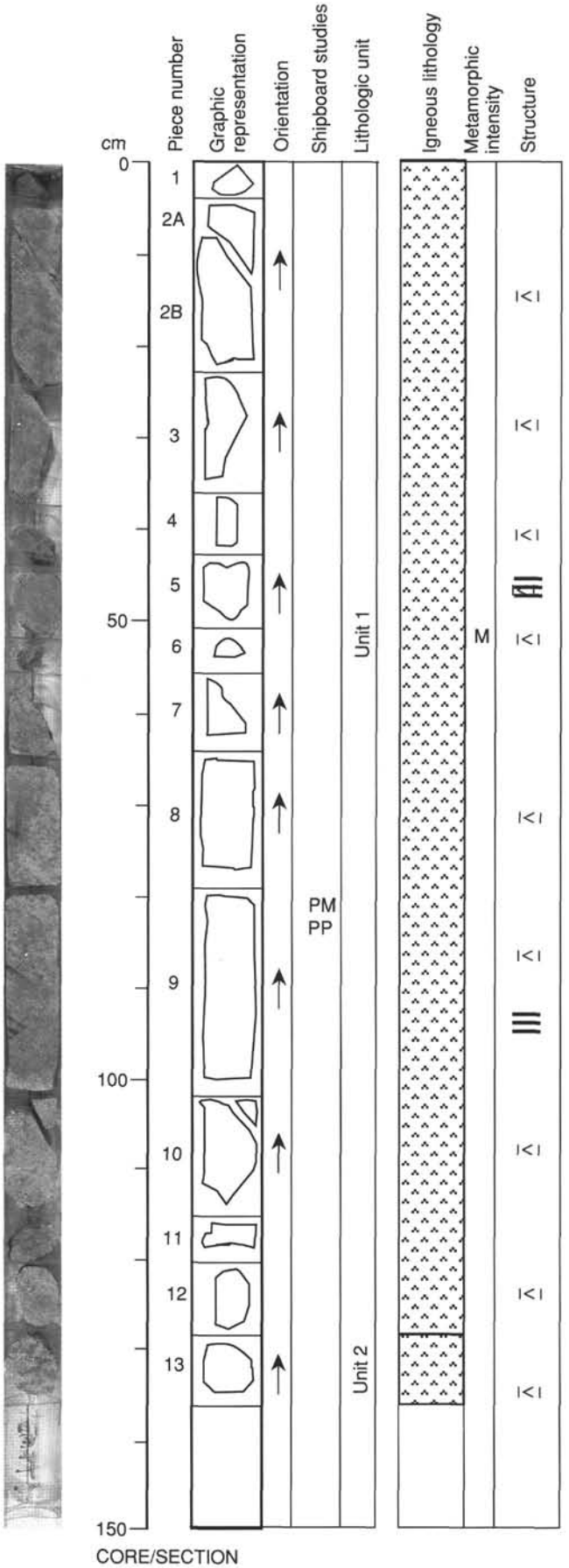


UNIT 1: OLIVINE GABBRO

Piece 1

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: 7%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Clinopyroxene - Mode: 35%.
Crystal Size: 1–12 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Plagioclase - Mode: 58%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Iron oxide minerals - Mode: 0.2%.
Comments: This section consists of one piece of olivine gabbro that has an allotriomorphic granular texture. Clinopyroxene is brown in color, and varies in grain size from medium in the upper half of Piece 1 to coarse in the lower half of the piece, creating a diffuse grain-size layering. Deformation and recrystallization are only weakly developed.
SECONDARY MINERALOGY:
Hornblende.
Total Percent: <0.5
Sulfide minerals.
Total Percent: <0.5
Talc/magnetite.
Total Percent: 0.3
Mode of Occurrence: After olivine.
Actinolite/chlorite.
Total Percent: 1
Mode of Occurrence: After clinopyroxene.
Comments: In the finer grained portion, clinopyroxene is totally replaced by brown amphibole, and olivine is completely altered to talc. Plagioclase is fairly fresh. In the coarse-grained, olivine-rich portion, clinopyroxene is locally finely continuously rimmed by brown amphibole. Sulfide minerals are locally oxidized, and plagioclase is recrystallized. Green amphibole replaces clinopyroxene and plagioclase at bottom of the piece and as patches in the center of the piece.
ADDITIONAL COMMENTS: Structure
No preferred orientation of minerals. A single vein dipping about 20° that is cored by green actinolite and chlorite(?) and has diffuse margins marked by altered plagioclase is 2 cm up from the bottom of the piece.



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UNIT 1: OLIVINE GABBRO-GABBRO

Pieces 1–12

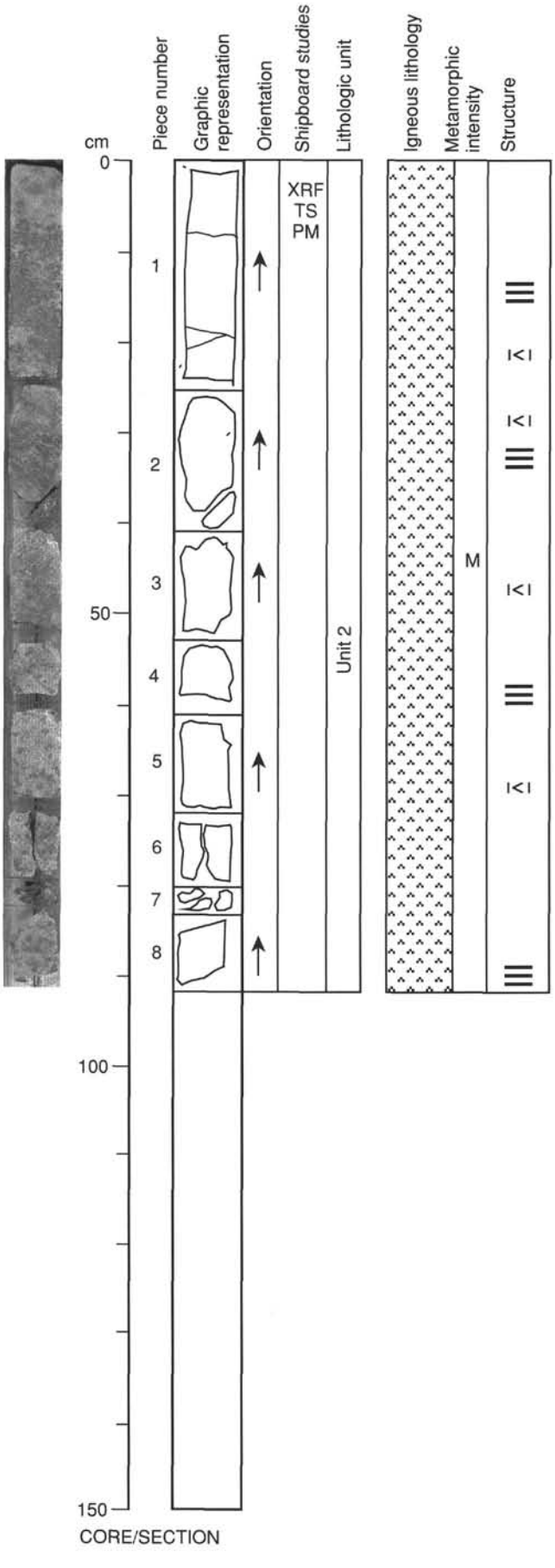
COLOR: Gray.
PRIMARY STRUCTURE: Equigranular igneous texture.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 57%–66%.
Crystal Size: 1–11 mm.
Crystal Shape: Subhedral.
Clinopyroxene - Mode: 27%–35%.
Crystal Size: 1–12 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 3%–10%.
Crystal Size: 1–7 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: 1%.
Crystal Size: <1 mm.
Crystal Shape: Anhedral.
Comments: The section consists predominantly of medium- to coarse-grained olivine gabbro containing 5%–10% olivine, 27%–35% clinopyroxene, and 57%–66% plagioclase (Pieces 2–4 and 6–12). Piece 5 is a gabbro (~3% olivine), but is mineralogically and texturally similar to the olivine gabbro. Piece 1 is a small chip of aphyric diabase that is probably an exotic. In the olivine gabbro, plagioclase forms subhedral grains ranging from 4–10 mm in grain size. Clinopyroxene occcurs as brown interstitial, locally poikilitic crystals ranging from 1 to 12 mm in size. Olivine forms interstitial grains, rarely poikilitic, and ranges from 1–7 mm in size. Minor brown amphibole replaces clinopyroxene rims. All samples contain minor iron oxide minerals. Pieces 9 and 10 include 5 to 8 cm inclusions of medium-grained gabbro; in Piece 10 the inclusion is bounded by chloritic veinlets on two sides. These could have origins as small xenoliths or as patches of melt/dikes.
SECONDARY MINERALOGY:
Brown amphibole.
Total Percent: 2
Comments: After clinopyroxene.
Chlorite/actinolite.
Total Percent: 5
Comments: After clinopyroxene.
Talc/magnetite.
Total Percent: 2
Comments: After olivine.
Comments: Total alteration is ~10%. Piece 1 is a superficially altered basalt; clay minerals are present on open surfaces and in veins. A diffudse rusty alteration halo is on the front of the piece. Pieces 2A is more altered than Piece 2B, but of iron-hydroxide minerals on the outer surface and clay minerals veins impart a diffuse yellow staining on both pieces. At the top of Piece 2B, chlorite rims clinopyroxene, and there are sulfide mineral-filled cracks. In finer grained intervals, green chlorite and actinolite patches replace clinopyroxene. In Pieces 3 and 4, clinopyroxene is more extensively altered to brown amphibole. Pieces are yellow-stained by clay mineral veins. Piece 5–9 are less diffusely stained, and plagioclase is more fresh. In Piece 7, sulfide minerals are strung out along microcracks. In Piece 10A, the contact between the fine- and medium-grained layers is reactivated by two sets of diffusing, parallel actinolite veins. Chlorite replaces clinopyroxene grains around the veins. Piece 11 is very fresh, and clay mineral-filled veins are rare. Rims of green amphibole occur around plagioclase.
Veins
In Piece 2B, a vertical, irregular, white, chlorite and clay mineral-filled vein occurs. At top of Piece 2B, 3 mm wide, composite, parallel actinolite veins occur. In Pieces 11 and 12 clay mineral-filled veins are present. In Piece 12 is a <1 mm wide chlorite vein.
VEIN/FRACTURE FILLING:
Actinolite.
Size: 3 mm.
ADDITIONAL COMMENTS: Structure
Grain-size layering is diffuse, but most evident in Piece 9 in which the layering is subhorizontal, and the grain size grades from coarse at the top to medium at the bottom (18 mm). A mineral-shaped fabric is defined by a preferred orientation of the long axes of anhedral pyroxene grains. Pyroxene generally occurs as single crystals with continuous cleavages and shows no sign of

grain distortion. Plagioclase has subhedral and anhedral shapes and, under the binocular microscope, approximately half of the grains are translucent and show continuous twins (the other half are anhedral, equant, and have a frosty appearence). The lack of pyroxene distortion suggests that fabric was developed in the magmatic state. However, it is impossible to rule out a solid-state origin. The fabric has an obvious planar component, but its development relative to the linear component can not be assessed without oriented cuts in the core. The fabric dips shallowly (<20°). The fabric is penetrative at the piece scale and is best developed in Piece 8, moderately developed in Pieces 2, 5, 9, and 10 and not present in all other pieces. Discrete chlorite- and actinolite-filled veins are present in most pieces (Pieces 2, 3, 5, 6, 9, 10, 12, and 13). They are generally 1 mm thick and dip steeply (>60°), except one vein in Piece 10 that dips 35°. Grain-size varitations (CTV) are found in Pieces 2, 9, and 12. They generally dip <20° and are gradational. The transition occurs over 10–20 mm. However the CTV in Piece 10 contains a sharp boundary and dips 35°. Piece 10 contains a fault with >45 mm offset (CTV in footwall does not appear in hanging wall, sense of shear undetermined). The fault plane is 1 mm wide and contains chlorite and actinolite.

UNIT 2: POIKILITIC OLIVINE GABBRO

Piece 13

COLOR: Gray.
PRIMARY STRUCTURE: Inequigranular igneous texture.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Clinopyroxene - Mode: 10%.
Crystal Size: <1 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 20%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Plagioclase - Mode: 70%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral to subhedral.
Comments: Piece 13 is a poikilitic olivine gabbro consisting of 20% olivine, 10% clinopyroxene, and 70% plagioclase. Clinopyroxene is brown and occurs as very fine-grained (<1 mm) interstitial crystals, that may be poikilitic. Olivine subophitically to poikilitically encloses subhedral to euhedral plagioclase. In between olivine oikocrysts, plagioclase is anhedral and equant to irregular in shape. Sulfide minerals are disseminated throughout the piece. Olivine and plagioclase show a weakly developed grain-shape orientation that is roughly subhorizontal.
SECONDARY MINERALOGY:
Brown amphibole.
Total Percent: Trace.
Mode of Occurrence: Rimming clinopyroxene.
Chlorite.
Mode of Occurrence: Replacing clinopyroxene, and olivine.
Comments: In veins.
Iron oxide minerals
Mode of Occurrence: Replacing olivine.
Comments: Piece 13 is moderately altered, with talc and iron oxide minerals replacing olivine. Chlorite replaces olivine(?) where crosscut by a vein. Brown and green amphibole occur replacing finer grained clinopyroxene and yellow clay mineral microveinlets produce a diffuse patchy replacement after plagioclase.



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UNIT 2: OLIVINE GABBRO

Pieces 1–8

COLOR: Dark gray.
PRIMARY STRUCTURE: Localized magmatic layering.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 65%–72%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral/Subhedral.
Clinopyroxene - Mode: 12%–16%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 12%–22%.
Crystal Size: 1–15 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: <1%.
Crystal Size: <2 mm.
Crystal Shape: Anhedral.
Comments: This section consists of olivine gabbro that is modally homogeneous, but texturally variable. The section is thus notable for being clinopyroxene poor compared to gabbro recovered in previous cores in this hole. The rock is medium grained and has a black and white spotted appearance due to the presence of poikilitic (up to 20 mm) olivine grains that are now partially altered to iron oxide minerals and clay minerals/chlorite?. Plagioclase is subhedral, clinopyroxene is anhedral and interstitial, and olivine is anhedral, occurring both interstitially and poikilitically enclosing plagioclase. Piece 1 is compositionally and texturally layered and Pieces 2–8 are varitextured. Pieces 2–8 contain thin irregular veinlets filled with plagioclase which may be magmatic (trondhjemitic?). Brown hornblende is relatively common (0.5%) in Pieces 2–8 as patches and rims on clinopyroxene.
SECONDARY MINERALOGY:
Green amphibole.
Total Percent: 1
Comments: After clinopyroxene.
Iron hydroxide mine.
Total Percent: 1
Comments: After sulfide minerals.
Brown amphibole.
Total Percent: 1
Comments: After clinopyroxene.
Smectite.
Total Percent: 1
Comments: After olivine.
Comments: Overall alteration downsection is slight. Pieces 1 and 2 are olivine gabbro and are the most altered. Clay mineral veins occur inducing staining of plagioclase, and clinopyroxene is rimmed by brown amphibole. Plagioclase shows limited recrystallization, and olivine is moderately altered to talc. All the other pieces are virtually fresh, exhibiting only moderate alteration of sulfide to hydroxide minerals. Green amphibole replaces olivine. Piece 4 and 5 are similar to Piece 2. Pieces 6A and 6B are a relatively fresh. Piece 6A is fresh and in 6B green amphibole replaces clinopyroxene. Small grains of brown amphibole replace clinopyroxene.
Veins
On the back of Pieces 1 and 2, clay mineral veins induce yellow stains on plagioclase. In Piece 4, a plagioclase and amphibole vein, 0.2–0.4 mm wide is likely of magmatic origin and irregularly diffuse across the piece. In Piece 5, a 2 mm wide plagioclase and amphibole vein cuts across the piece.
VEIN/FRACTURE FILLING:
Clay minerals.
Percent: 1%
Size: <1 mm.
Actinolite.
Percent: 1%
Size: <1 mm.
Altered trondhjemite.
Size: <2 mm.
ADDITIONAL COMMENTS: Structure
Layering is present in Piece 1, which contains a horizontal, 6 cm layer at the top of anorthositic olivine gabbro (75% plagioclase, 20% olivine, 5% clinopyroxene) above 15 cm of diffusely layered olivine gabbro. In Pieces 2 and 4, a

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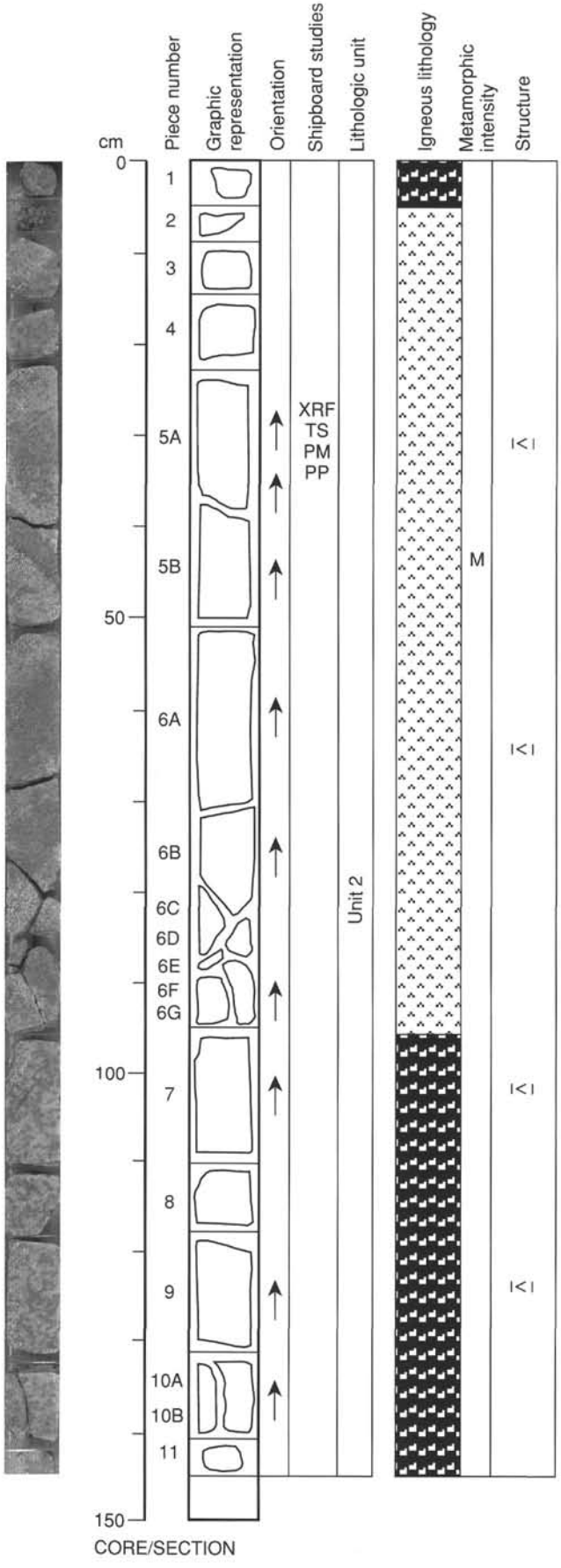
moderate, planar, subvertical, crystal shape fabric is present, likely caused by to solid-state deformation but an unambiguous diagnosis begs detailed thin section studies. Millimeter-sized chlorite, actinolite, and prehnite (?) veins are in Pieces 1, 2, 3, 4, 5, and 8, with a moderate dip (from subhorizontal to 25°, with the exception of a 65° dipping vein in Piece 5).



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UNIT 2: OLIVINE GABBRO, TROCTOLITE AND GABBRO

Pieces 1–11

COLOR: Black and white, and brown and white.
PRIMARY STRUCTURE: Poikilitic, subophitic, and varitextured.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Clinopyroxene - Mode: 0–32%.
Crystal Size: 1–22 mm.
Crystal Shape: Anhedral.
Crystal orientation: ?
Olivine - Mode: 0–40%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral.
Crystal orientation: Magmatic?
Plagioclase - Mode: 48%–70%.
Crystal Size: 1–15. mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Iron oxide minerals - Mode: trace%.
Sulfide minerals. - Mode: trace%.
Crystal Size: 0 mm.
Comments: This section consists of modally and texturally heterogeneous olivine gabbro, gabbro, troctolite, and olivine microgabbro. Pieces 1 and 2 are medium-grained olivine gabbro, verging on troctolite, in which plagioclase comprises 50%, olivine 40%, and clinopyroxene 5% of the mode. Sulfide minerals occur as discrete, small rounded blebs and and as irregular-shaped crystals associated with silvery gray, iron oxide minerals. Clinopyroxene is brown and occurs as very small interstitial grains that are poikilitic. Some of the larger cores are greenish and rimmed by brown clinopyroxene and possibly minor brown amphibole (magmatic?). Plagioclase is colorless and largely unrecrystallized. Olivine has irregular shapes but is not obviously poikilitic; it is partially altered to granular masses, the individual granules of which are separated by netveins of iron oxide minerals Pieces 3 and 4 are olivine gabbro composed of 48% plagioclase, 32% brown clinopyroxene, and 20% olivine. Iron oxide and sulfide minerals occur in trace amounts. The texture is largely medium-grained equigranular, but in a layer or patch approximately 1 cm wide, large clinopyroxene crystals poikilitically enclose tabular plagioclase. Pieces 5 and 6 begin a sequence of rapidly changing mineralogy and grain size. The top 12–13 cm of Piece 5A are medium-grained olivine gabbro with poikilitic clinopyroxene and olivine in which the clinopyroxene is pale brown (70% plagioclase, 25% olivine, and 5% clinopyroxene). Below this is a layer of olivine gabbro (80% plagioclase, 15% clinopyroxene, and 5% olivine) that continues to the bottom of Piece 5A and into the top corner of Piece 5B. The boundary between the two lithologies is oriented at about 50°. The top of Piece 5B then has a 2 cm wide layer of medium-grained troctolite (60% olivine, 40% plagioclase). Olivine in the troctolite may have a preferred grain-shape (magmatic?) orientation. The piece ends with a coarse-grained gabbro (65% plagioclase, 30% clinopyroxene, 5% olivine, and a trace of oxide and sulfide minerals). The grain size coarsens slightly from the top of the gabbro to the bottom of the piece. Piece 6 shows similarly rapid changes in mineralogy and grain size, but in this piece the layers are subvertical. Piece 6A has troctolite on the cut surface (50% plagioclase, 50% olivine) and coarse-grained gabbro on the back surface (60% plagioclase, 40% clinopyroxene). Pieces 6B and 6C have gabbro on the front cut surface (same mineral proportions as in Piece 6A) and microgabbro on the back surface (75% plagioclase, 23% clinopyroxene, 2% olivine). Pieces 6D and 6E are entirely gabbro. Pieces 6F and 6G are possibly a fourth mineral assemblage consisting of medium- to coarse-grained poikilitic olivine gabbro in which the clinopyroxene is pale brown and both clinopyroxene and olivine are poikilitic. In contrast to Pieces 5 and 6, Pieces 7–11 are relatively homogeneous in grain size and mineralogy consisting of 60% plagioclase, 30% olivine, and 10% clinopyroxene. The plagioclase occurs as nearly equant crystals. Clinopyroxene is pale brown, and occurs as small, poikilitic crystals that wrap around the plagioclase, giving the rock a speckled brown/white/black appearance on the cut surface. Primary sulfide minerals occur associated with silvery gray iron oxide minerals Sulfide minerals are also associated with chlorite which may indicate that primary sulfide minerals have been remobilized during alteration.

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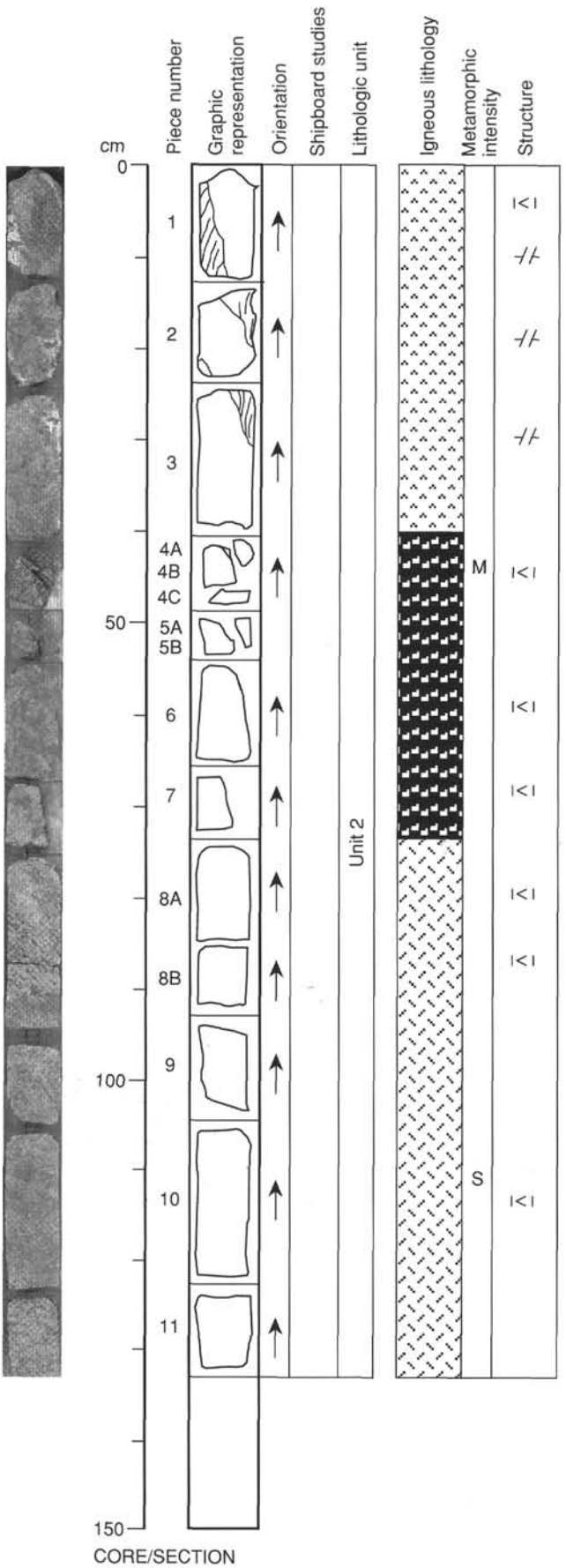
SECONDARY MINERALOGY:
Talc/chlorite/iron oxide minerals
Comments: After olivine.
Clay minerals.
Comments: After plagioclase and olivine.
Brown amphibole.
Comments: Rimming clinopyroxene.
Sulfide minerals.
Comments: The section is variably altered, from very fresh to slightly altered pieces. Pieces 1 and 2 are very fresh. In Pieces 3 and 4 brown amphibole rims clinopyroxene, and total alteration is ~5%. Piece 5A is locally more altered. Olivine alters to talc, chlorite and magnetite, clinopyroxene to brown amphibole. In Piece 5B, brown amphibole locally replaces clinopyroxene. On the break between 5A and 5B, a leucocratic, fine-grained vein occurs. Piece 6A is quite fresh. In Pieces 6B and 8, the alteration is about 15%–20%; olivine alters to talc. On top of Piece 6A, clay minerals or chlorite occur on the open surface. In Piece 7, maximum alteration is about 5%; chlorite patches develop replacing olivine at the intersection with actinolite veinlets. Elsewhere, talc and oxide minerals replace olivine. Brown amphibole occurs rimming clinopyroxene. In Piece 8, the back of the piece has a dense network of very thin clay mineral-filled veins. Chlorite patches develop within plagioclase. In Piece 9, the leucocratic portion has a similar alteration assemblage as in Pieces 6B and 8. Olivine sporadically has an alteration halo of chlorite and oxide minerals. Pieces 10A, 10B, and 11 are fresh.
Veins
In Piece 7 white, clay mineral-filled vein cut across the piece.
VEIN/FRACTURE FILLING:
Clay minerals.
Size: <<1 mm.
Actinolite.
Size: <1 mm.
ADDITIONAL COMMENTS: Structure
Piece 5 has compositional and grain-size layering. A 2 cm thick band of medium-grained olivine gabbro dips 40° about midway down the piece. A 2 cm thick parallel band of darker troctolite is below the first band. These bands have relatively distinct boundaries. Piece 6 has subtle gradational compositional and grain-size changes that do not have planar orientations and are patchy. A thin green actinolite and chlorite vein dipping 65° cuts Piece 5 as well as a couple of plagioclase(?) coated irregular cracks that are subhorizontal. Piece 6 has a thin white plagioclase (?) vein dipping 70° that is cut by an irregular subhorizontal plagioclase (?) coated crack. Short (10–15 mm) thin (<<1 mm) white cracks are also visible in Pieces 7 and 9, most of which are subvertical.



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UNIT 2: OLIVINE GABBRO, OLIVINE MICROGABBRO, TROCTOLITE AND GABBRO

Pieces 1–11

COLOR: Gray, green gray, and black and white.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%–75%.
Crystal Size: 1–16 mm.
Crystal Shape: Euhedral to anhedral.
Clinopyroxene - Mode: 2%–37%.
Crystal Size: 2–25 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 3%–24%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: Tr–4%.
Sulfide minerals. - Mode: Trace%.
Comments: The section is modally and texturally heterogeneous, consisting of olivine gabbro, olivine microgabbro, troctolite, and gabbro. From top to bottom, Piece 1 contains a zone ~2 cm wide of olivine microgabbro (~80% plagioclase, 15% clinopyroxene, and 5% olivine) followed by 5 cm of troctolite (~70% plagioclase, 24% olivine, and 5% clinopyroxene), followed by ~1 cm of microgabbro and a small section of medium-grained gabbro on the bottom corner. This piece is crosscut by a fragment of a vein, ~1.5 cm wide, composed of altered, euhedral plagioclase (up to 1 cm), altered subhedral to euhedral brown amphibole (up to 15 mm), actinolite (after clinopyroxene), iron oxide minerals, and apatite. Plagioclase in the vein is now altered to secondary plagioclase, prehnite(?), and bright yellow epidote. The vein is lined along its edges with olivine altered to chlorite, clinopyroxene altered to actinolite and sulfide minerals. The vein continues into Piece 2 where it becomes diffuse; modes for this gabbro are inferred to have been approximately 75% plagioclase, 17% clinopyroxene, 8% olivine; the rock now contains approximately 4% iron oxide minerals as well as the very coarse-grained vein minerals described above. Piece 3 is an olivine microgabbro (70% plagioclase, 15% clinopyroxene, 14% olivine, and 1% iron oxide minerals) crosscut by the continuation of the felsic vein. Pieces 4, 5, 6, and 7 are relatively homogeneous medium-grained troctolite composed of 75% plagioclase, 23% olivine, and 2% clinopyroxene; they show no obvious grain-size layering or significant modal changes throughout. Clinopyroxene is pale brown and occurs as poikilitic grains. Pieces 8, 9, 10, and 11 are gabbros in which modal mineralogy and grain size vary slightly. Plagioclase ranges from 60%–70%, clinopyroxene from 27%–37% and olivine from 4%–12%. Piece 8A is coarse-grained and has large subhedral clinopyroxene crystals. Most of these crystals enclose plagioclase, but the plagioclase ranges from irregularly shaped anhedral crystals to subhedral laths. The laths frequently occur in the cores of clinopyroxene and appear to bisect the crystals. Piece 8B is similar in mineralogy to 8A, but has a gradational contact between coarse-grained gabbro at the top and medium-grained gabbro at the bottom. Piece 9 is uniformly medium grained, but Piece 10 shows grain-size layering ranging from very coarse grained in the top 7 cm to medium-grained in the bottom 9 cm; the contact is relatively abrupt. Piece 11 is uniformly coarse-grained. Pieces 9, 10, and 11 have a subhorizontal preferred grain-shape fabric that may be primary magmatic. Plagioclase is slightly recrystallized in most pieces. Olivine is variably altered throughout to granular masses of grains separated by oxide mineral netveins.
SECONDARY MINERALOGY:
Brown/green amphibole
Comments: rimming clinopyroxene.
Chlorite/iron oxide minerals.
Comments: Replacing and/or riming olivine
Secondary plagioclase.
Comments: After plagioclase.
Sulfide minerals.
Comments: The section is variably altered. Piece 1 is a variably textured olivine gabbro, crosscut by a leucocratic vein. At the margins of the vein, olivine is pervasively repalced by chlorite. In the leucocratic vein, plagioclase (altered

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to possible albite), sulfide minerals (altered to hydroxide minerals), chlorite, and minor actinolite occur. Abundant oxide minerals and minor sulfide minerals occur at the boundary of the vein. The olivine in the gabbro is altered to talc and chlorite aggregates. Piece 3 is crosscut by a leucocratic vein (1.5 cm) and by a thin (0.5 cm) apophysis. The major vein includes large green amphibole, albite, epidote, and chlorite (talc?), and as secondary phases, quartz, apatite, oxide minerals, and sulfide minerals along clinopyroxene cleavages. In the gabbro, olivine near veins is replaced by chlorite. Talc and oxide minerals partially replace olivine in the rest of the gabbro. Piece 4 is mostly fresh, the outer surface is marked by a plagioclase (likely albite) vein. In Piece 5, chlorite rims olivine, and talc and oxide minerals occur on olivine. Piece 6 is moderately altered; olivine is almost totally replaced by chlorite (as rims), and talc and oxide minerals. In Piece 7, clinopyroxene is partially replaced by brown amphibole, and oxide minerals by hydroxide minerals. The alteration in Piece 8 is about 20%; clinopyroxene is rimmed and locally totally replaced by actinolite. Piece 9 exhibits the same features, and alteration is about 15%. Piece 10 shows grain-size variability, the medium-grained portion is foliated, the total alteration is ~5%, Microveins of actinolite are present all over the piece. Plagioclase is chloritized, chlorite patches replace olivine. The open fracture between the pieces is filled by chlorite and clay minerals.

Veins

In Piece 3, thin actinolite and chlorite veins occur. Piece 5 shows a thin clay mineral vein. In bottom of Piece 9, actinolite-filled microcracks occur.

VEIN/FRACTURE FILLING:

Actinolite.

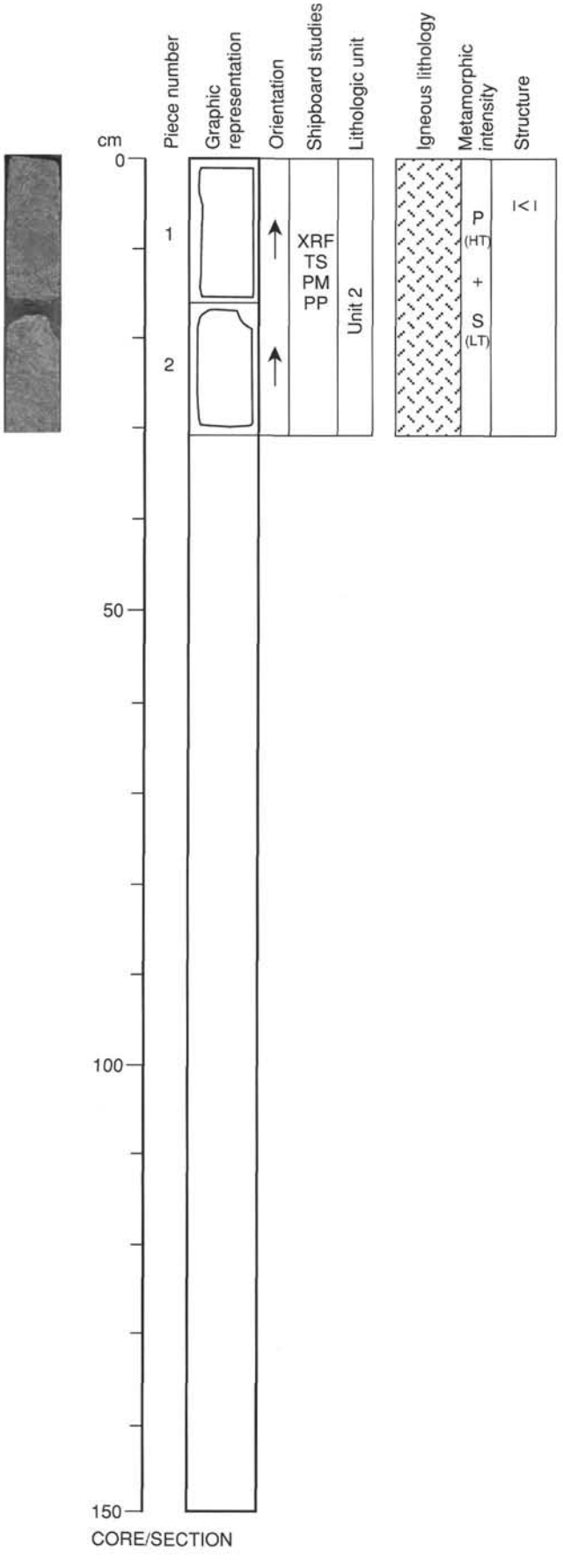
Size: <1 mm.

Clay minerals.

Size: <<1 mm.

ADDITIONAL COMMENTS: Structure

The section consists of medium- to coarse-grained gabbro and troctolite commonly separated by sharp boundaries. The first piece includes several subparallel layers composed of troctolite and microgabbro that have dip angles of 55° to the east (in the core reference frame). A pegmatitic gabbro (vein) intrudes into the gabbro-troctolite layers and truncates them at a high angle. It has a 9 mm wide halo that contains actinolite and plagioclase. The pegmatitic gabbro vein continues down into Pieces 2 and 3 and is cut across by moderately dipping (~58°) chlorite veins. A 3 mm wide secondary pegmatitic vein accompanies the main one in Piece 3. Piece 4 includes a compositional-textural boundary dipping 50°. Pieces 6, 7, and 8 contain subhorizontal and subvertical chlorite veins and grain-size boundaries that are also parallel to chlorite and actinolite veins. There is no mineral shape fabric or preferred orientation in any of the rocks in this section.



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UNIT 2: GABBRO

Pieces 1–2

COLOR: Brown and white.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 55%.
Crystal Size: 2–10 mm.
Crystal Shape: Anhedral to subhedral.
Crystal orientation: Magmatic preferred shape fabric.
Clinopyroxene - Mode: 41%.
Crystal Size: 1–9 mm.
Crystal Shape: Anhedral.
Crystal orientation: Magmatic.
Olivine - Mode: 4%.
Crystal Size: 2–3 mm.
Crystal Shape: Anhedral.
Crystal orientation: Magmatic.
Comments: This section consists of two pieces of coarse-grained gabbro that are relatively homogeneous in both mineral mode and texture. The rock consists of brown clinopyroxene which poikilitically encloses subhedral to anhedral plagioclase. Olivine is present as an interstitial phase. Pyrite is enclosed in the clinopyroxene and in the plagioclase. Both pieces exhibit a preferred grain-shape orientation which is roughly subhorizontal. Piece 2 shows a subtle grain-size layering over the bottom 3–4 cm of the piece decreasing from coarse- (maximum grain size of ~7 mm) to medium-grained (maximum grain size less than 5 mm). Plagioclase is partially recrystallized.
SECONDARY MINERALOGY:
Secondary plagioclase.
Comments: After plagioclase.
Talc plus iron oxide minerals + chlorite.
Comments: After olivine and/or clinopyroxene.
Brown amphibole.
Comments: After clinopyroxene.
Comments: Fine-grained chalky white bands are dynamically recrystallized plagioclase. Apart from the recrystallization, these two pieces are weakly altered (3%). Talc and oxide minerals partially replace olivine. Clinopyroxene exhibits patches and discontinuous rims of brown amphibole. It is more altered at the margins of thin veins (<1 mm wide) of actinolite and chlorite.
Veins
Very thin (<1 mm wide) veins crosscut the gabbro. They are filled with 1) actinolite and chlorite; 2) secondary plagioclase and/or quartz; or 3) white clay minerals.
VEIN/FRACTURE FILLING:
Chlorite, actinolite, and clay minerals.
Size: <1 mm.
Secondary plagioclase and quartz.
Size: <<1 mm.
ADDITIONAL COMMENTS: Structure
Piece 1 has a weakly developed foliation due to the alignment of elongate pyroxene and plagioclase grains that dip 18°. The foliation is subparallel to grain-size banding where several medium- to fine-grained bands about 15 mm thick are repeated several times down the piece. Piece 2 contains similar banding toward the bottom of the piece. A single green actinolite and chlorite vein cuts the upper part of Piece 1 dipping 35°.

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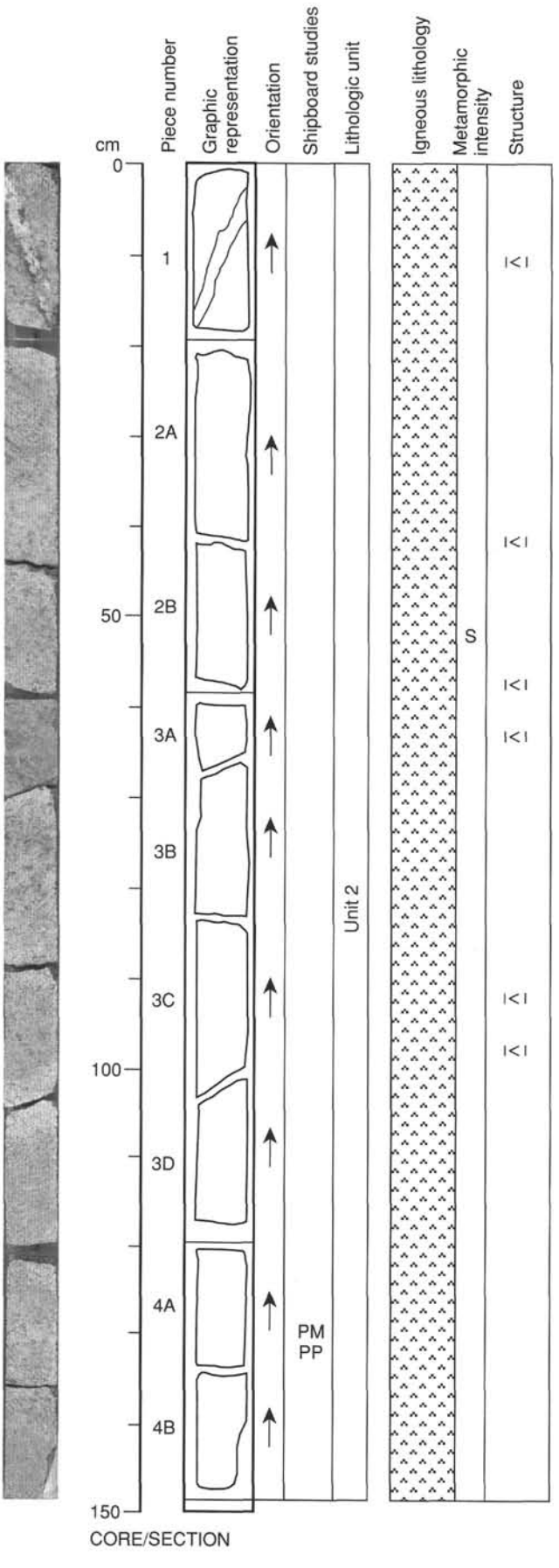

UNIT 2: OLIVINE GABBRO

Pieces 1–4B

COLOR: Gray green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 55%–65%.
Crystal Size: 3–8 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Clinopyroxene - Mode: 25%–34%.
Crystal Size: 3–10 mm.
Crystal Shape: Subhedral.
Crystal orientation: None.
Olivine - Mode: 10%–16%.
Crystal Size: 3–8 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Comments: The section consists of predominantly olivine gabbro with 6%–15% subrounded to irregular olivine, 25%–34% brown cumulus clinopyroxene, and 55%–65% plagioclase. The grain size is nearly constant, but maxima in grain size (8–12 mm) occur in the intervals between 6–20, 75–86, and 117–127 cm, defining a subtle grain-size layering with little change in modal mineralogy. Layer contacts are not discernable and grain-size variation appears completely gradational. Chalcopyrite occurs as interstitial grains throughout the section in each piece. Opaque oxide minerals are in Pieces 1 and 3 (1%–2%). A large (1 cm thick) magmatic vein containing altered plagioclase, altered amphibole, opaque oxide minerals, and abundant apatite also occurs in Piece 1.
SECONDARY MINERALOGY:
Chalcopyrite.
Total Percent: <1
Texture: Interstitial.
Talc/oxide minerals
Comments: After olivine.
Secondary plagioclase.
Clay minerals.
Comments: After plagioclase and olivine.
Actinolite.
Sulfide minerals.
Comments: Overall alteration of this section is slight (generally less than 5%). Locally, the intensity of alteration is greater around a magmatic vein in Piece 1 and along very thin veins (up to 15% in Piece 2B). Plagioclase is fresh and clinopyroxene exhibits small patches or discontinuous rims of brown amphibole, in turn replaced by large green prismatic amphibole in Piece 2B. Olivine is partially replaced by talc and iron oxide minerals. The magmatic vein in Piece 1 is lined on its edges with strongly chloritized olivine, clinopyroxene altered to actinolite, and sulfide minerals (usually chalcopyrite). Along the very thin veins, chlorite and smectite patches replace plagioclase. At the top of the Piece 2, actinolite and chlorite replaces clinopyroxene and epidote replaces plagioclase. Plagioclase is also replaced by a white milky mineral (prehnite?). At the bottom of Piece 3C and top of Piece 3D, a dense network of microcracks is marked by green smectite and chlorite patches. Piece 4A exhibits a clear lineation marked by the elongation of clinopyroxene.
Veins
In the magmatic vein of Piece 1, plagioclase is altered to secondary plagioclase, prehnite, and bright yellow epidote. Iron oxide minerals are fresh. This vein is crosscut by thin, parallel 0.5 mm actinolite-filled veins. Very thin (<1 mm) veinlets crosscut the section. They are filled by white clay minerals or actinolite and chlorite. These veins are surrounded by alteration halos.
VEIN/FRACTURE FILLING:
Chlorite.
Size: <<1 mm.
Clay minerals.
Size: <<1 mm.
ADDITIONAL COMMENTS: Structure
No mineral shape preferred orientation is evident in this section. In Piece 1 a 1.5 cm wide vein of plagioclase and magnetite is cut by thin (<1 mm wide) veins of actinolite. The set of four actinolite veins transects the margins of the

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plagioclase vein at an angle of about 30° and continue across the entire piece. A weak textural banding occurs in Pieces 3 and 4. The approximate dip of the boundaries between coarse- to medium- and fine-grained gabbro varies between 15 and 30°.

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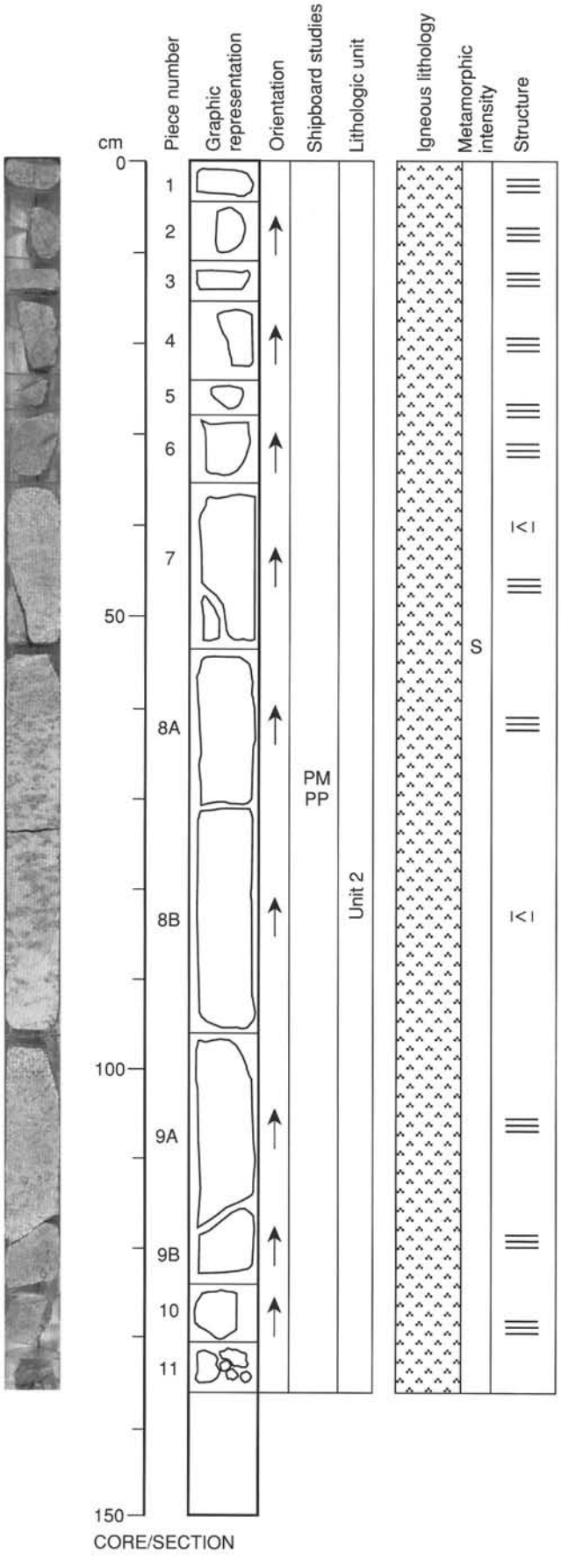
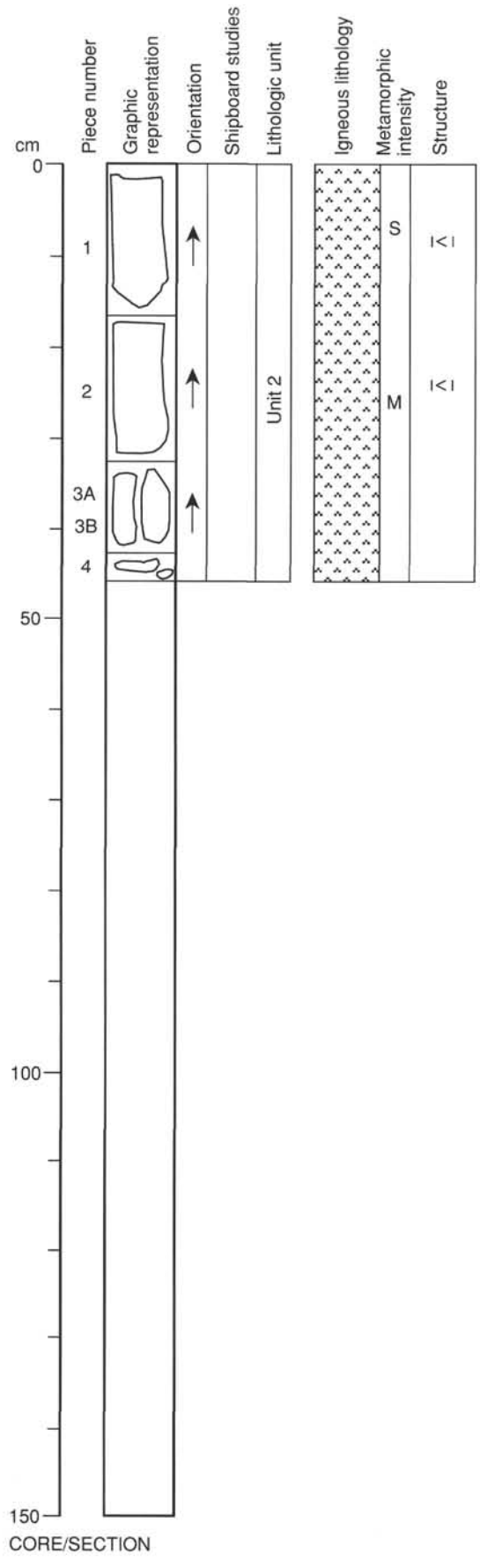


UNIT 2: OLIVINE GABBRO

Pieces 1–11

COLOR: Gray-green.
PRIMARY STRUCTURE: Allotriomorphic granular to poikilitc.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: 15%–20%.
Crystal Size: 1–25. mm.
Crystal Shape: Anhedral.
Crystal orientation: Aligned in Pieces 8 and 9.
Plagioclase - Mode: 60%–65%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Crystal orientation: no.
Clinopyroxene - Mode: 15%–25%.
Crystal Size: 1–12. mm.
Crystal Shape: Anhedral.
Crystal orientation: Aligned in Pieces 8 and 9.
Comments: The section consists of medium-grained olivine gabbro. Pieces 1–7 and 9–11 are modally homogeneous, consisting of 5%–18% olivine, 20%–25% brown cumulus to intercumulus clinopyroxene, and 60%–62% plagioclase. The maximum grain size ranges up to 12 mm (in clinopyroxene), but averages about 5 mm. Piece 8 is a poikilitic olivine gabbro (70% plagioclase, 20% olivine, and 10% clinopyroxene), with large olivine oikocrysts up to 25 mm across that enclose subhedral plagioclase. The oikocrysts define a horizontal foliation in the core. The oikcrysts give the rock a black and white spotted appearance. Outside the oikocrysts, the rock consists of a more plagioclase-rich, fine-grained olivine gabbro (1–2 mm grain size for all phases). Brown clinopyroxene occurs only as very fine-grained interstitial crystals. Chalcopyrite is in Piece 1.
SECONDARY MINERALOGY:
Brown amphibole.
Total Percent: 2
Comments: Rimming and replacing clinopyroxene.
Talc and iron oxide minerals.
Total Percent: 5
Comments: Replacing olivine.
Chlorite.
Total Percent: 3
Comments: Replacing olivine near veins, rimming olivine in contact with plagioclase, replacing plagioclase adjacent to actinolite vein.
Smectite.
Total Percent: Trace.
Comments: Replacing plagioclase.
Comments: The section is slightly altered. Pieces 4 and 6 are a foliated microgabbro, where olivine is altered to talc and oxide minerals, and brown amphibole rims clinopyroxene. Piece 5 is relatively fresh, olivine is altered to green chlorite in patches. Piece 7 is foliated, green chlorite patches mark where olivine is crosscut by thin actinolite veins. Piece 8 shows mottled green patches as chlorite, talc, and oxide minerals replace olivine. Piece 9 is fresh. In Piece 10, plagioclase is locally chloritized; chlorite patches locally completely replace olivine.
Veins
In Piece 7 actinolite microcracks cutting across olivine totally alter to chlorite. In Piece 8B are pale green to white actinolite veinlets.
VEIN/FRACTURE FILLING:
Actinolite.
Size: <<1 to 1 mm.
ADDITIONAL COMMENTS: Structure
Medium-grained gabbro (all pieces except Piece 8) shows a well-developed crystal-shape fabric. Pyroxene and plagioclase have elliptical rather than subhedral shapes and show locally evidence for stretching. The fabric is planar/linear, with well developed foliation and lineation (this can be seen in Piece 2, cut in the foliation plane). Foliation is subhorizontal. Shape fabric intensity is higher at the top of the section (Pieces 1 to 4). Piece 8 is made of olivine-rich gabbro, with large olivine oikocrysts. A compositional variation at the top of the piece is subhorizontal, with an olivine-rich horizon (troctolite?) overlying the troctolitic gabbro. Olivine oikocrysts are slightly flattened parallel to this layering. Plagioclase has mostly a subhedral shape, and shows a moderate preferred subhorizontal orientation. This piece seems largely devoid of plastic deformation. Chlorite and actinolite veins crosscut this section (Pieces 7 and 8), whose dips range from subhorizontal to subvertical.



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UNIT 2: OLIVINE GABBRO

Pieces 1–4

COLOR: Gray.
PRIMARY STRUCTURE: Hypidiomorphic granular.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Iron oxide minerals - Mode: 1%.
Olivine - Mode: 5%–7%.
Crystal Size: 1–6 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 32%–33%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Plagioclase - Mode: 60%–61%.
Crystal Size: 1–11 mm.
Crystal Shape: Subhedral.
Comments: The section consists of coarse-grained olivine gabbro that is modally and texturally homogeneous. The texture is uniformly hypidiomorphic granular in which brown clinopyroxene ranges from subhedral prismatic to anhedral to interstitial and poikilitic. Olivine occurs as anhedral interstitial crystals. Deformation and recrystallization are weak in this section, but some olivines are slightly flattened and elongate and plagioclase is slightly recrystallized.
SECONDARY MINERALOGY:
Chlorite/actinolite.
Total Percent: 1.5
Comments: After olivine and clinopyroxene.
Talc/magnetite.
Total Percent: 0.5
Comments: After olivine.
Sulfide minerals.
Total Percent: <0.5
Brown/grn. amphibole
Total Percent: <0.5
Comments: Replacing and rimming clinopyroxene.
Secondary plagioclase.
Comments: Replacing plagioclase.
Prehnite.
Comments: After plagioclase.
Comments: The section is moderately altered. Piece 1 is very fresh. At the bottom of the piece, olivine is altered to talc. Piece 2 is slightly altered; plagioclase is fresh. Clinopyroxene is crosscut by microcracks, and locally rimmed by brown amphibole. In Piece 3B, the alteration is 20%–30%. In some clinopyroxene grains brown smectite patches are diffused along microcracks.
Veins
In Piece 3B, an actinolite vein occurs. In Piece 4, chlorite patches replace olivine, along microcracks.
VEIN/FRACTURE FILLING:
Chlorite, actinolite, and clay minerals.
Size: <1 mm.
ADDITIONAL COMMENTS: Structure
A very faint subhorizontal mineral shape preferred orientation and sugary plagioclase texture point to a very moderate imprint of solid-state deformation. A few moderately dipping mm-sized chlorite actinolite veins crosscut these gabbros.

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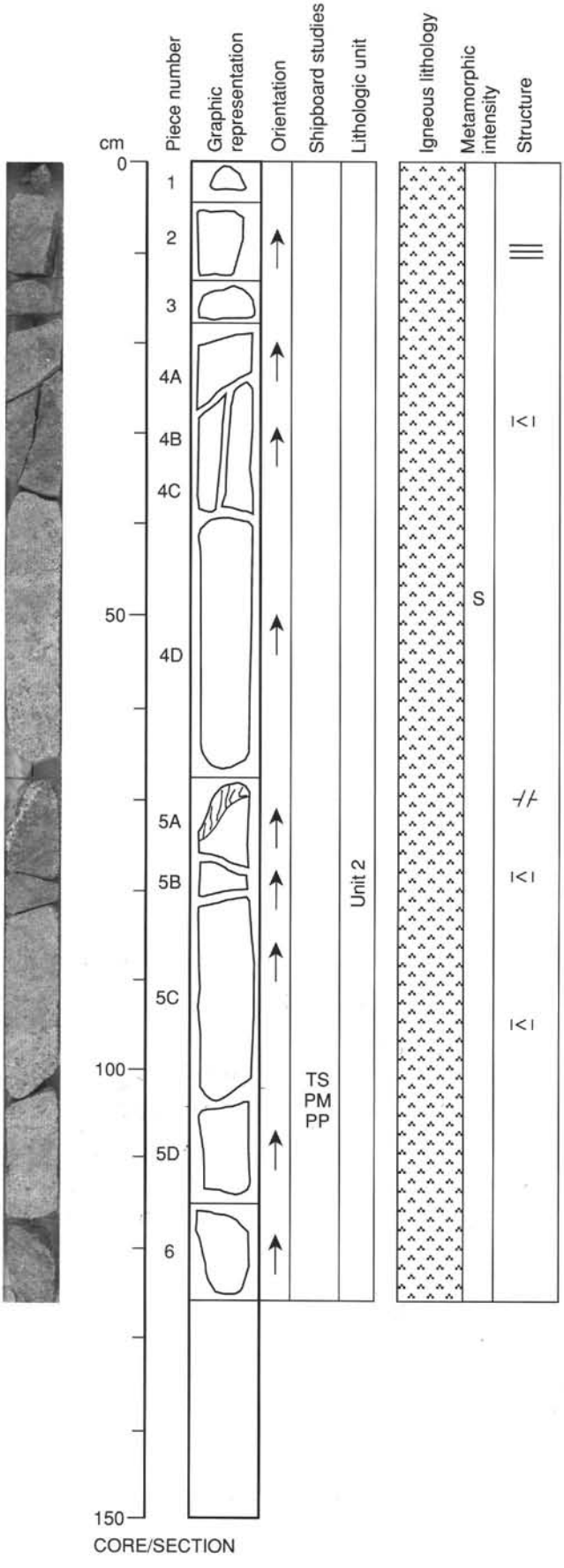

UNIT 2: OLIVINE GABBRO - TRONDHJEMITE

Pieces 1–6

COLOR: Gray.
PRIMARY STRUCTURE: Allotriomorphic to hypidiomorphic granular.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 56%–63%.
Crystal Size: 1–15 mm.
Crystal Shape: Subhedral/anhedral.
Clinopyroxene - Mode: 28%–34%.
Crystal Size: 1–13 mm.
Crystal Shape: Subhedral/anhedral.
Olivine - Mode: 5%–10%.
Crystal Size: 1–12 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: 1%.
Comments: The section consists mostly of medium- to coarse-grained olivine gabbro that is modally homogeneous, but varies in grain size. The primary magmatic lithology is similar to the previous section. The pieces have a nearly uniform texture with small variations from allotriomorphic to hypidiomorphic granular. Brown clinopyroxene is interstitial in Pieces 1–3, showing an anhedral irregular shape, but becomes subhedral prismatic in Pieces 4–6. In Piece 4D, a medium-grained olivine gabbro (2 cm thick) is interlayered with coarse-grained olivine gabbro. At the top of Piece 5A, a trondhjemite dike (~1 cm-thick) composed of 80% plagioclase, 15% brown-green hornblende, and 5% iron oxide minerals sharply cuts the olivine gabbro. Deformation and recrystallization are weak.
SECONDARY MINERALOGY:
Sulfide minerals.
Total Percent: 0.5
Hornblende.
Total Percent: 0.5
Talc/magnetite.
Total Percent: <0.5
Comments: After olivine.
Chlorite/actinolite.
Total Percent: 1.5
Comments: After clinopyroxene.
Comments: Total alteration of this section is low (maximum 15%). It is mainly concentrated around discrete microcracks. Clinopyroxene exhibits patches and rims of brown and light green amphibole. Olivine is partly replaced by talc and oxide minerals. Primary sulfide minerals are locally oxidized. In Pieces 4A, 4B, and 5C, chlorite patches (2 mm) replace plagioclase along the thin veinlets. Clinopyroxene at the margins of these veinlets (top and bottom of Pieces 4A) and of the vein in Piece 5A, is partially to completely replaced by actinolite and chlorite.
Veins
At the bottom of Piece 4D, an 8 mm wide vein is filled by secondary plagioclase or prehnite(?). In Piece 5A, a 1.5 cm thick vein is composed essentially of plagioclase (altered to prehnite?), oxide minerals, and actinolite. Epidote is present on plagioclase (top and bottom of Pieces 4A). Very thin (<1 mm) veinlets filled by green smectite or chlorite, actinolite, and secondary plagioclase(?) are the youngest, cutting the magmatic vein of Piece 5A.
VEIN/FRACTURE FILLING:
Trondhjemite.
Size: 10 mm.
Plagioclase, actinolite, and oxide minerals.
Size: 1.5 mm.
Smectite, chlorite, actinolite, and secondary plagioclase.
Size: <<1 mm.
ADDITIONAL COMMENTS: Structure
A mineral-shape fabric is defined by a preferred orientation of the long axes of anhedral pyroxene grains. Pyroxene generally occurs as single crystals with continuous cleavages and shows no sign of grain distortion. Plagioclase has subhedral and anhedral shapes and, under the binocular microscope, approximately half of the grains are translucent and show continuous twins (the other half are anhedral, equant, and have a frosty appearence). The lack of pyroxene distortion suggests that fabric was developed in the magmatic state. However, it is impossible to rule out a solid-state origin. The fabric has an obvious planar component but its development relative to the linear

component can not be assessed without oriented cuts in the core. The fabric dips shallowly (<20°). The fabric is penetrative at the piece scale and is found in Pieces 4B, 4C, 5C, and 5D. Discrete chlorite- and actinolite-filled veins are in Pieces 2, 4B, 4C, and 5D. They are 1 mm thick and dip steeply (>60°). Grain-size variations (CTV) are in Pieces 5C and 5D. They generally dip <20° and are subparallel to the mineral-shape fabric.

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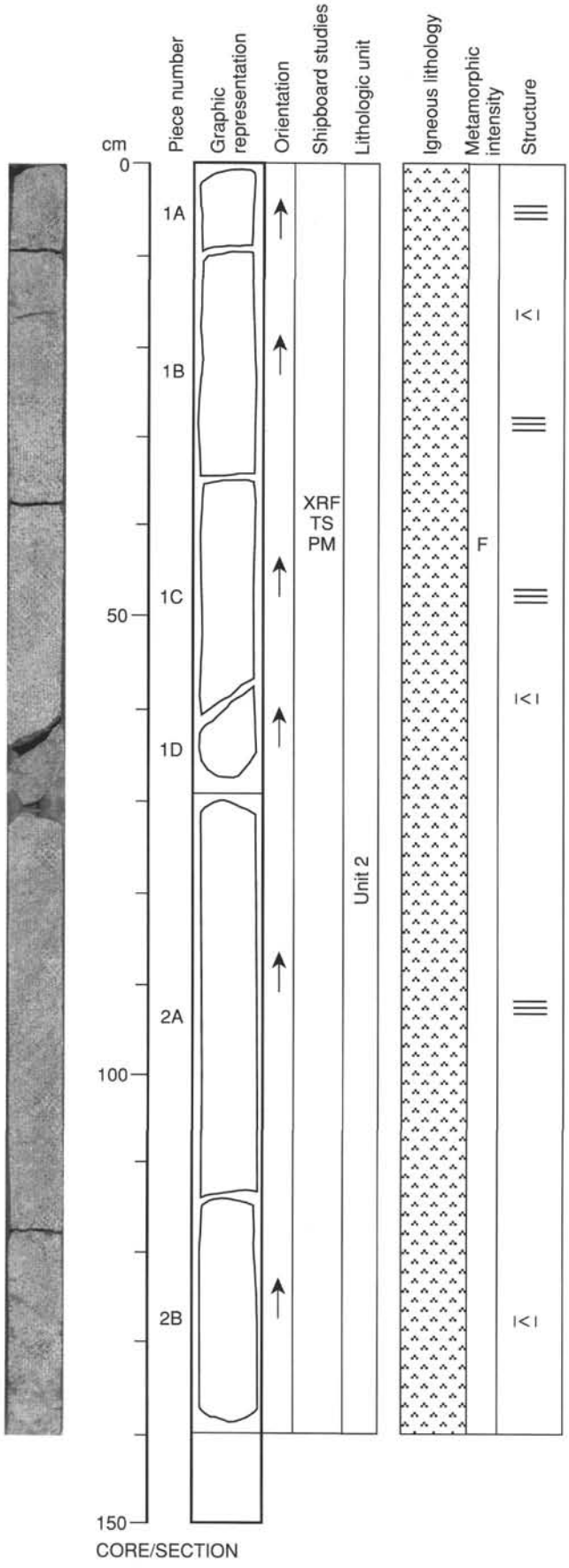

UNIT 2: OLIVINE GABBRO

Pieces 1A–2B

COLOR: Brown and gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase. - Mode: 55%.
Crystal Size: 2–15 mm.
Crystal Shape: Subhedral to anhedral.
Crystal orientation: Magmatic.
Clinopyroxene. - *Mode:* 35%.
Crystal Size: 1–20 mm.
Crystal Shape: Anhedral.
Crystal orientation: Magmatic.
Olivine. - Mode: 10%.
Crystal Size: 2–12 mm.
Iron oxide minerals. - Mode: Trace%.
Comments: The section consists of olivine gabbro that is modally homogeneous, but variable in grain size, resulting in grain-size layering. Clinopyroxene is brown and ranges from subophitic to poikilitic, enclosing anhedral to subhedral plagioclase. Piece 1B shows a well-defined, subhorizontal, grain-shape fabric, probably of magmatic origin since plagioclase does not appear to be recrystallized. The fabric is most clearly defined by elongate clinopyroxene. Grain size increases gradually from top to bottom of Piece 1A, being medium grained for the top 6 cm, then coarse grained for the bottom 3 cm; Pieces 1B to 1D are medium grained throughout, with only very subtle changes in grain size over the length of the pieces. Large clinopyroxene (1cm) occurs infrequently in Piece 1C. Piece 2 also shows grain-size layering and a preferred alignment of the primary minerals. The top 43 cm of Piece 2A are medium grained followed by 3 cm of coarse-grained olivine gabbro (2 cm in the bottom of Piece 2A and 1 cm in the top of Piece 2B). In the coarse-grained area, brown clinopyroxene has a blocky habit. Plagioclase may be slightly recrystallized in the coarser grained areas. In medium-grained areas, clinopyroxene is interstitial to subophitic, more rarely poikiltic. There are two sulfide minerals present, one a brassy yellow and the other a brighter yellow (chalcopyrite and pyrite?); the later is very minor in abundance.
SECONDARY MINERALOGY:
Secondary plagioclase.
Comments: After plagioclase.
Smectite.
Comments: After olivine
Actinolite/chlorite.
Comments: Rimming clinopyroxene.
Oxide minerals.
Comments: After olivine.
Comments: Overall alteration of the section is very slight (<2%). Plagioclase is very fresh. In the coarse-grained part, at the bottom of Piece 2A, thin white chalky bands truncate clinopyroxene and may be composed of small grained recrystallized plagioclase. Near discrete microcracks, rare small green patches chlorite replaces plagioclase in Pieces 1A and 2A. At 15 cm from the top of Piece 2A, a small veinlet (< 1 mm) ends in an irregular white pod where the plagioclase seems to be reolaced by secondary plagioclase. Clinopyroxene remains very fresh. In Piece 1A, a narrow rim of green amphibole (?) is present on some grains. In Piece 1D, some grains are altered to actinolite. Olivine is slightly altered in a granular fashion by netveins of iron oxide minerals plus chlorite plus smectite.
Veins
Discrete thin, <1 mm wide veinlets filled with white minerals cut the gabbro and are marked by green patches of smectite which replace plagioclase.
VEIN/FRACTURE FILLING:
Smectite.
Size: <<1 mm.
ADDITIONAL COMMENTS: Structure
A porphyroclastic shear zone is found at the base of Piece 2B. Its upper boundary is flat and coincides perfectly with a sharp grain-size variation (medium-grained gabbro above pegmatitic gabbro). The shear zone occurs in the pegmatite, and is defined by anastomosing seams of sachroidal plagioclase that wrap around pyroxene porphyroclasts. Grain-size reduction and porphyroclast-tail development are weak in the shear zone. The shear fabric appears to die out in Section 153-923A-10R-3, Piece 1, before the bottom of the pegmatite is

153-923A-10R-2

reached in Section 153-923A-10R-3, Piece 2. A mineral-shape fabric, defined by a preferred orientation of the long axes of anhedral pyroxene grains, is present throughout the section. Pyroxene generally occurs as single crystals with continuous cleavages and shows no sign of grain distortion. Plagioclase has subhedral and anhedral shapes and, under the binocular microscope, approximately half of the grains are translucent and show continuous twins (the other half are anhedral, equant and have a frosty appearence). The fabric seems to be shallowly dipping but is too weak to measure except in Piece 2B where it dips about 10°. Two veins are found in Piece 1. The first is about 1 mm thick and filled with plagioclase. The second is <1 mm thick, filled with plagioclase and has a green alteration halo. Grain-size varitations (CTV) are found in Pieces 2A and 2B. They generally dip <20° and are subparallel to the mineral-shape fabric.

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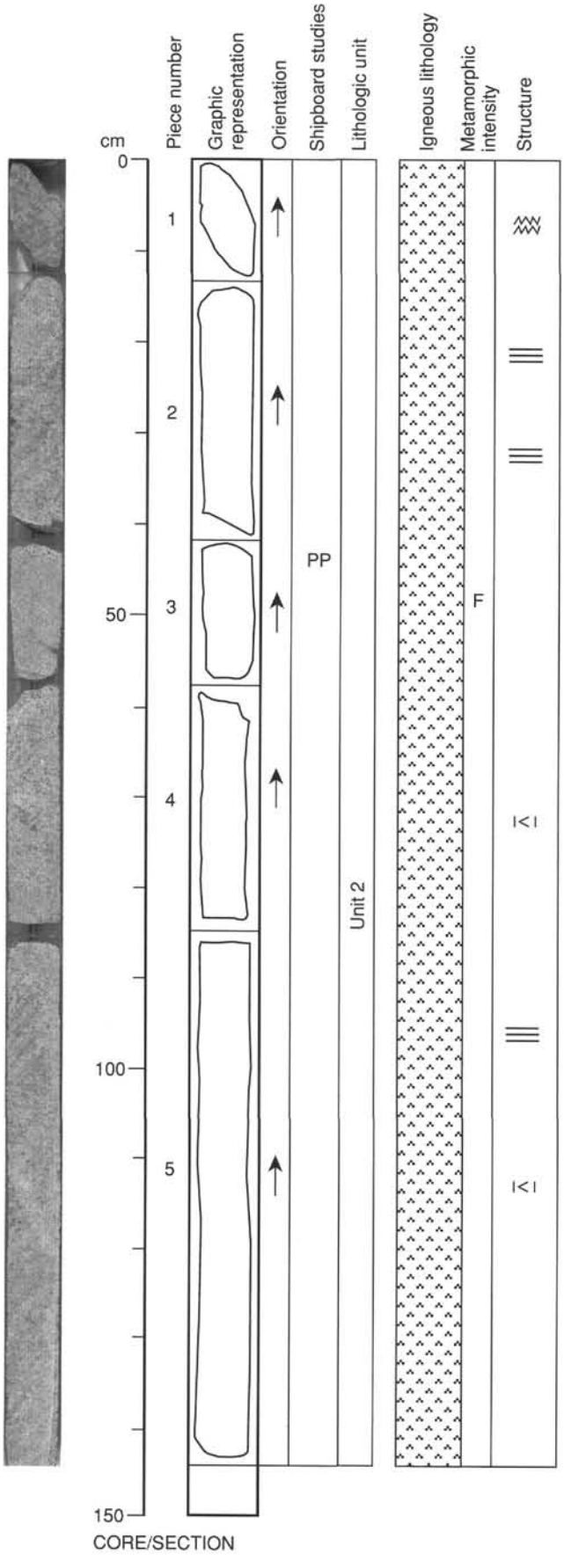

UNIT 2: OLIVINE GABBRO AND GABBRO

Pieces 1–5

COLOR: Brown and gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%–68%.
Crystal Size: 1–20 mm.
Crystal Shape: Subhedral to anhedral.
Crystal orientation: Magmatic.
Clinopyroxene - Mode: 20%–35%.
Crystal Size: 1–12 mm.
Crystal Shape: Anhedral.
Crystal orientation: Magmatic.
Olivine - Mode: 2%–15.%.
Crystal Size: 1–14 mm.
Crystal Shape: Anhedral.
Crystal orientation: Magmatic.
Comments: The section consists of olivine gabbro and gabbro that are modally and texturally heterogeneous. The section shows some grain-size layering; a preferred alignment of grain shapes is well developed in Pieces 1 and 2, but weak to nonexistent in Pieces 3–5. Pieces 1, 2, 4, and 5 are olivine gabbro in which modal plagioclase ranges from 60%–68%, clinopyroxene from 20%–35%, and olivine from 5%–15%. Clinopyroxene ranges from elongate crystals that are almost free of mineral inclusions to poikilitic, where it encloses tabular plagioclase laths, particularly in coarse-grained areas. Piece 2 shows grain-size layering which consists of coarse-grained olivine gabbro over the top 14 cm of the piece that grades into medium-grained gabbro/olivine gabbro toward the bottom. The grain-size variation continues to decrease gradually to the bottom of Piece 3; modal abundance of olivine also decreases toward the bottom of Piece 2 into Piece 3 which is a gabbro (65% plagioclase, 33% clinopyroxene, and 2% olivine). Grain size is relatively uniform in Pieces 4 and 5. Clinopyroxene is commonly zoned, with paler brown cores than rims. Olivine is poikilitic in Piece 5; elsewhere it has a rounded to elongate shape. Iron oxide and sulfide minerals occur in trace amounts throughout.
SECONDARY MINERALOGY:
Sulfide minerals.
Total Percent: Trace.
Chlorite.
Comments: After plagioclase and olivine.
Talc/oxide minerals.
Comments: After olivine.
Actinolite.
Comments: After clinopyroxene, as rims.
Brown amphibole.
Comments: Rimming clinopyroxene.
Iron hydroxide minerals.
Comments: Alteration after sulfide and oxide minerals.
Comments: The section consists of five pieces of fresh olivine gabbro and gabbro, with very slight alteration (2%). Olivine is only partially replaced by talc and oxide minerals. Microcracks occur along clinopyroxene cleavages in localized patches, but no apparent alteration is induced. In Piece 2 locally clinopyroxene is rimmed by actinolite, and chlorite replaces plagioclase. The same alteration assemblage also occurs in the fine-grained portion at the bottom of the piece. Piece 3 is virtually fresh. Piece 4 is fresh, except the center of the piece, where clinopyroxene is locally rimmed by a discontinutous coating of actinolite. Piece 5 shows some localized alteration (max 2%) around the veins at the center of the piece, where clinopyroxene is amphibolitized. Brown amphibole discontinuously rims clinopyroxene. Weak staining due to alteration of sulfide minerals to iron-hydroxide minerals is at the bottom of the piece.
Veins
In Piece 5, a 3 mm wide parallel set of thin actinolite veins crosscuts the piece and intersects a diffuse actinolite vein.
VEIN/FRACTURE FILLING:
Actinolite.
Size: <1 mm.
Orientation: Parallel set.

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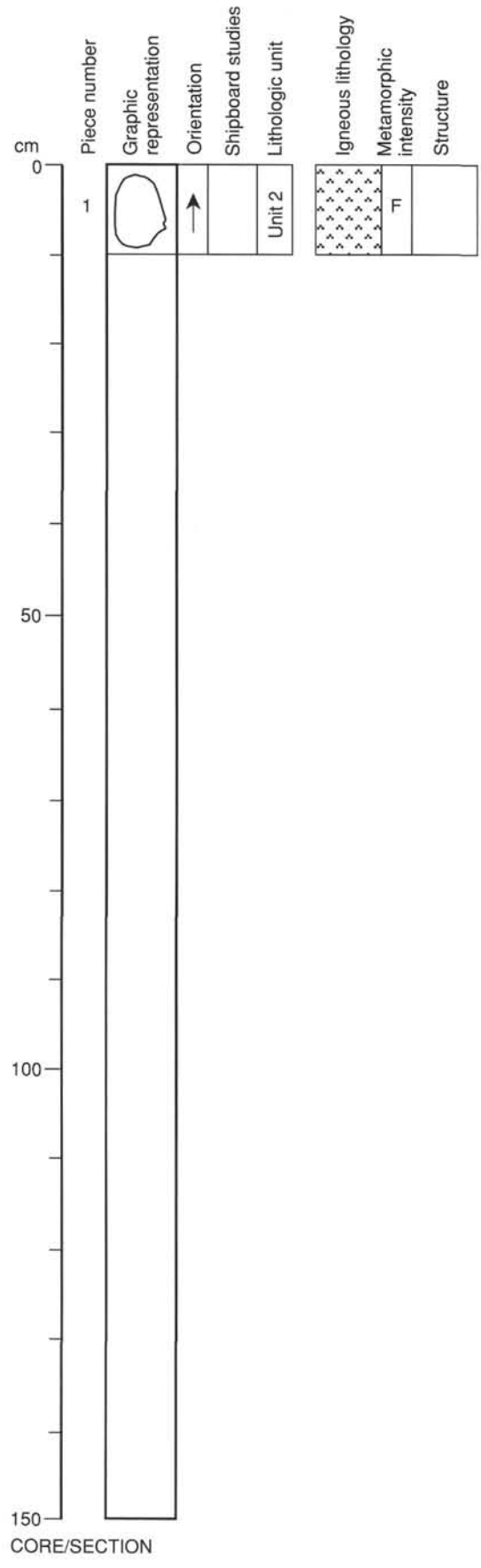
ADDITIONAL COMMENTS: Structure

The porphyroclastic shear zone, found at the base of Section 153-923A-10R-2, Piece 2B, continues into 153-923A-10R-3, Piece 1. The shear zone occurs in the pegmatite, and is defined by anastomosing seams of saccharoidal plagioclase that wrap around pyroxene porphyroclasts. Grain-size reduction and porphyroclast-tail development are weak in the shear zone. The lower boundary is diffuse but shearing appears to stop in Piece 1 before the bottom of the coarse-grained gabbro is reached in Piece 2. A mineral-shape fabric, defined by a preferred orientation of the long axes of anhedral pyroxene grains, is present in Pieces 2, 4, and 5. Pyroxene generally occurs as single crystals with continuous cleavages and shows no sign of grain distortion. Plagioclase has subhedral and anhedral shapes and, under the binocular microscope, approximately half of the grains are translucent and show continuous twins (the other half are anhedral, equant and have a frosty appearence). The lack of pyroxene distortion suggests that fabric was developed in the magmatic state. The fabric seems to be shallowly dipping but is too weak to measure except in Piece 2 where it dips about 3°. In Piece 5, a parallel set of two steep (65°) actnolitic veins appears to crosscut a shallow (10°) diffuse actinolitic vein. Another steep actinolitic vein occurs in Piece 4. All veins are about 1 mm thick. A grain-size varitation (CTV) is found in Pieces 2. It dips 3° and coarse-grained gabbro overlies medium-grained gabbro.

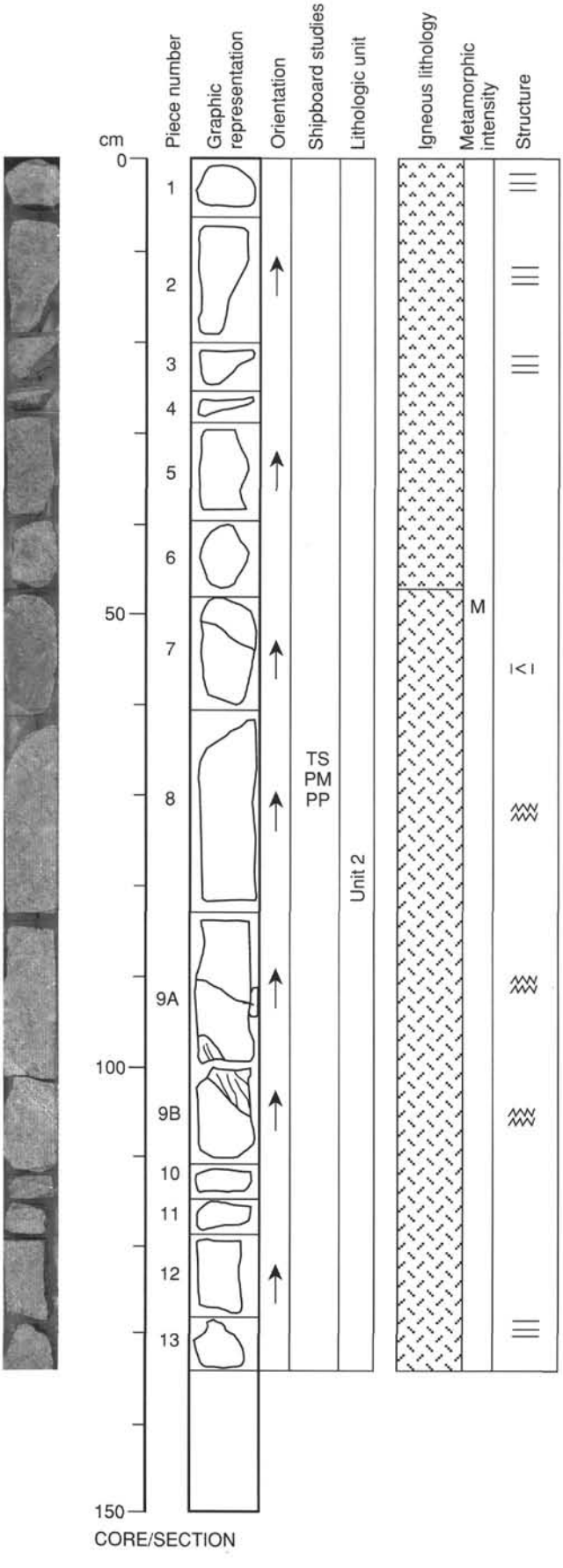
153-923A-10R-4



UNIT 2: OLIVINE GABBRO

Piece 1

COLOR: Brown and gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%.
Crystal Size: 1–7 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 32%.
Crystal Size: 1–6 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 8%.
Crystal Size: 1–4 mm.
Crystal Shape: Anhedral.
Comments: The section consists of one piece of olivine gabbro that is similar in appearance to those in Sections 153-923A-10R-2 and 153-923A-10R-3. The piece is relatively homogeneous throughout and shows no grain-size layering or preferred orientation grain-shape fabric. Clinopyroxene is pale brown and poikilitically encloses tabular plagioclase laths. Plagioclase also occurs as anhedral equant crystals. Iron oxide minerals and iron oxide minerals occur interstitially in trace amounts.
SECONDARY MINERALOGY:
Sulfide minerals.
Total Percent: Trace.
Chlorite.
Comments: After olivine.
Comments: The piece of olivine gabbro is very fresh; on the right side of the piece chlorite completely replaces some grains of olivine. Inside chlorite, iron oxide minerals mark the fractures in olivine grains.
Veins
No veins are present.
ADDITIONAL COMMENTS: Structure
The section consists of one piece of olivine gabbro that contains no mineral-shape fabric, no faults, and no veins.



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UNIT 2: OLIVINE GABBRO, GNEISSIC GABBRO AND GABBRO

Pieces 1–13

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 55%–72%.
Crystal Size: 0.1–7 mm.
Crystal Shape: Anhedral.
Crystal orientation: Pieces 7, 8, 9; foliated.
Clinopyroxene - Mode: 25%–38%.
Crystal Size: 0.1–17 mm.
Crystal Shape: Anhedral.
Crystal orientation: Pieces 7, 8, 9; foliated.
Olivine - Mode: 13%–60%.
Crystal Size: 1.5–4 mm.
Crystal Shape: Anhedral.
Crystal orientation: Pieces 7, 8, 9; foliated.
Comments: This section consists of coarse-grained olivine gabbro, fine- to medium-grained gneissic gabbro (granulite facies), and coarse-grained gabbro. Pieces 1–6 are coarse-grained olivine gabbro with low modal olivine (5%–8%) and 28%–38% modal clinopyroxene. A contact between coarse-grained gabbro and a gneissic gabbro occurs in Piece 7. The grain-size reduction that occurs is from 4 mm to an average of 0.7 mm, with individual grains as fine as 0.1 mm. The grain-size reduction corresponds to an increase in modal plagioclase and the dissappearance of modal olivine into the ductile shear zone, suggesting a possible compositional control on rheology and deformation. Clinopyroxene displays a strong lineation in the downdip direction defined by recrystallized aggregates and elongated porphyroclasts. Clinopyroxene has locally recrystallized along augen-like tails and forms aggregates locally isolated in a plagioclase matrix probably as a consequence of grain boundary sliding. Plagioclase is recrystallized to a fine-grain size as well. Piece 8 is a continuation of this gneissic gabbro, as is Piece 9, where the lower contact of the ductile shear zone is present and the transition between deformed and mildly deformed or undeformed gabbro takes place. Here, as in the upper contact it is also inclined at approximately 30° to the core. The lineation continues to plunge downdip at the edge of the shear zone where the grain size becomes somewhat coarser. Below a gradational contact where grain sizes increase to 4–6 mm, the deformation is weakly developed. Pieces 11 and 12 are coarse-grained olivine-free gabbros that appear undeformed and lack any strong fabric development. The mineralogy of the shear zone is plagioclase and clinopyroxene. Plagioclase content reaches 72% in Piece 8. The intensity of the fabric can vary on a fine scale as well (cm scale) through the shear zone as a function of modal plagioclase/clinopyroxene, with elongation and recrystallization increasing in regions of low modal pyroxene and high modal plagioclase. Piece 13 is a coarse-grained, olivine-free gabbro and contains a weakly developed foliation. The grain size is at maximum for this section ranging up 17 mm. The pyroxene modal abundance is also at a maximum for the section in Piece 13 (~45%). Clinopyroxene in the shear zone is recrystallized, but generally unaltered to lower temperature assemblages, although locally some marginal replacement by brown amphibole is present. The generally anhydrous mineralogy of the shear zones indicate either granulite facies or upper amphibolite facies (anhydrous conditions) conditions prevailed during dynamic recrystallization and deformation. Sulfide minerals are abundant throughout the section and appear to be chalcopyrite (or pyrrotite).
SECONDARY MINERALOGY:
Sulfide minerals.
Total Percent: <1
Texture: Anhedral.
Chlorite.
Total Percent: <1
Comments: Replacing olivine.
Talc/iron oxide minerals.
Total Percent: 4
Comments: Replacing olivine.
Actinolite.
Total Percent: <1

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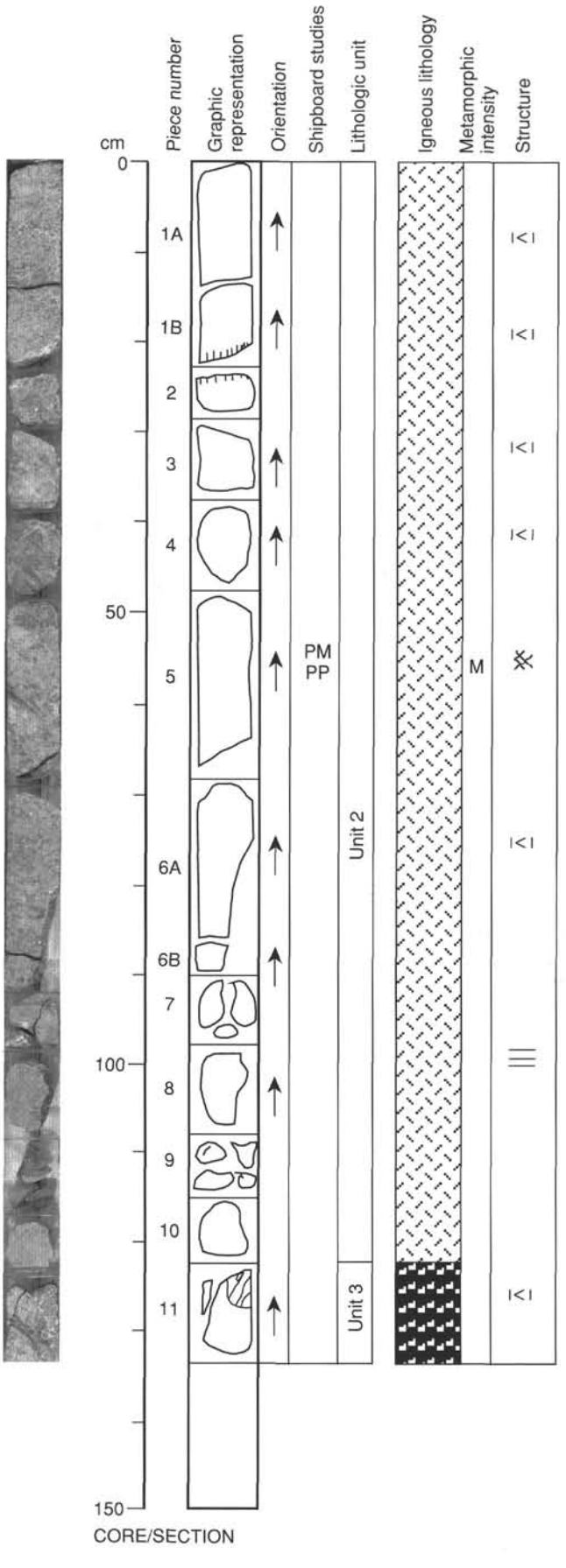
Comments: Rimming clinopyroxene.
Brown amphibole.
Total Percent: <1
Comments: Replacing clinopyroxene.
Secondary plagioclase.
Total Percent: 5
Comments: Replacing plagioclase.
Smectite.
Total Percent: <1
Comments: Replacing plagioclase.
Comments: The metamorphic overprint on the section is variable. Pieces 1–6 are fairly fresh and show only moderate hydrothermal alteration (10%–15%, max 20% in Piece 4), expressed as alteration of olivine to chlorite (+/- tremolite) and talc (back of Piece 1). Plagioclase is fresh, and clinopyroxene is only partially rimmed by actinolite. In Piece 3, sulfide minerals occur along thin stringers. Plagioclase is stained and partially altered to clay minerals. In Piece 4 olivine is totally replaced by talc plus iron oxide minerals. Actinolite partially replaces clinopyroxene. The main metamorphic overprint is a shear zone. Piece 6 is foliated and marks the top of shear zone. Piece 7 is a foliated olivine gabbro, with a sharp contact along the mylonitic foliation between medium- and fine-grained gabbro. The shear zone results in grain-size reduction of clinopyroxene and plagioclase grains, with strong flattening and recrystallization along the tails of microporphyroclasts. Olivine is totally altered to talc and iron oxide minerals, and inclusions of primary sulfide minerals are remobilized as stringers. The deformation preserves primary coarse-grained bandings within the pieces. In Piece 8, the top is a very fine-grained gabbro; grain-size reduction results in the recrystallization of very fine brown amphibole. The rest of the piece is fairly fresh, except a vein in the center of the piece around which clinopyroxene is altered to actinolite and minor smectite replaces plagioclase. The top of Piece 9A is a sheared gabbro, where clinopyroxene and plagioclase are recrystallized with grain-size reduction, and brown amphibole occurs in the tails of elongated clinopyroxene. At the bottom of the piece, a large (4 cm) undeformed clinopyroxene is replaced by brown amphibole patches. At the bottom of Piece 9A and in Piece 9B brown amphibole is recrystallized in the tails of elongated clinopyroxene. In the center of Piece 9B, at the selvage of the shear zone, microcracks are marked by green patches, a result of clinopyroxene alteration to chlorite and actinolite. At the bottom of Piece 9B, a clay mineral-filled vein is lined with chlorite patches replacing plagioclase. In Pieces 10–13, the minerals are fresh, except along microveinlets, where chlorite patches occur along the margins and clinopyroxene is altered to actinolite.
Veins
Subhorizontal, <1 mm wide, composite chlorite (margins) and clay mineral (cores) veins develop in Pieces 8–13.

VEIN/FRACTURE FILLING:
Chlorite and clay minerals.
Size: <1 mm.

ADDITIONAL COMMENTS: Structure
Pieces 1–6 and 10–12 of this section are made of medium-grained gabbro with preserved primary igneous textures showing no, or a very weak (Piece 1–3), grain-shape preferred orientation. Solid-state deformation structures are well developed in Pieces 7, 8, 9, and 13. It is defined by very strong mineral-shape fabrics and by a concordant grain size (Pieces 7–8) and compositional layering. Layering and foliation dip is 35°. The deformation textures range from elongated porphyroclastic to mylonitic. Recrystallization tails are well developed around pyroxene porphyroclasts. Piece 8 contains two thin ultramylonitic shear zones, discordant to the main foliation. These dip 60° and normal shear sense can be deduced by drag of earlier fabric. A 1 cm thick mylonitic shear zone marks the boundary between the deformed gabbro and the underlying undeformed gabbro. This shear zone dips 50° and normal shear sense can be deduced from drag of earlier foliation and asymmetrical development of tails around clinopyroxene porphyroclasts. Very few actinolite and chlorite veins are found in this section.



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UNIT 2: GABBRO, TROCTOLITE AND MICROGABBRO

Pieces 1A–10

COLOR: Brown and gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 55%–70%.
Crystal Size: 1–20. mm.
Crystal Shape: Anhedral to subhedral.
Clinopyroxene - Mode: 26%–42%.
Crystal Size: 1–21. mm.
Crystal Shape: Anhedral.
Olivine - Mode: 3%–4.%.
Crystal Size: 1–10. mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: Trace%.
Comments: This section is modally and texturally heterogeneous consisting of gabbro (Pieces 1, 2, 3, 5, and 6), gabbro and troctolite (Piece 4), and microgabbro (Pieces 7–10). Pieces 1, 2, 3, 5, and 6 are similar to one another, being coarse-grained gabbro composed of 55%–62% plagioclase, 35%–42% clinopyroxene, and 3% olivine with only trace amounts of iron oxide and sulfide minerals. Piece 8 shows a subhorizontal preferred grain-shape orientation that may be magmatic in origin, but other pieces lack this fabric. Clinopyroxene is brown and ranges from large, chadacryst-free crystals (Pieces 1, 5, and 6) to poikilitic (Pieces 2 and 3). Piece 4 begins in coarse-grained gabbro similar to Pieces 1–3, but the bottom of the piece is troctolite (70% plagioclase, 26% olivine, 4% clinopyroxene); the boundary between these two lithologies is sharp. Pieces 7, 8, 9, and 10 are microgabbro (grain size averages less than 1 mm) and consist of 70% plagioclase, % clinopyroxene, and 4% olivine; all pieces are similar in modal proportions of phases and grain size. Piece 7 contains several fragments of a felsic vein, now composed of secondary plagioclase or prehnite and a fibrous actinolite amphibole.
SECONDARY MINERALOGY:
Talc/iron oxide minerals
Mode of Occurrence: After olivine.
Sulfide minerals.
Total Percent: Trace.
Actinolite.
Mode of Occurrence: After clinopyroxene
Brown amphibole.
Mode of Occurrence: After clinopyroxene.
Chlorite.
Comments: After olivine, clinopyroxene, and plagioclase.
Comments: The section is moderately altered. Pieces 1A and 1B are moderately altered gabbro; the pieces are separated by a joint. Piece 1A is an isotropic gabbro (alteration about 20%). Plagioclase is stained, and contains disseminated sulfide minerals. Clinopyroxene has alteration halos, and plagiolcase is quite fresh but is, in places, altered to chalky secondary plagioclase. In Piece 1B, the alteration is ~50%. Mafic phases are largely replaced, olivine to talc and iron oxide minerals, clinopyroxene by actinolite and brown amphibole rims. Disseminated sulfide minerals are common. At the top of the piece, chlorite replaces olivine, so that the piece is marked by green patches. The joint between Pieces 1A and 1B is coated with chlorite and epidote. Piece 2 is a coarse-grained gabbro, crosscut by irregular clay mineral veins. Along the margins of the veins, chlorite totally replaces olivine. Sulfide minerals are remobilized along the margins of grains. In the rest of the piece, olivine is largely replaced by talc plus iron oxide minerals. On an open surface, a coating of a white mineral, possibly albite, occurs. Actinolite replaces plagioclase around clinopyroxene. Thin actinolite veins cut across the back of the piece. In Pieces 3 and 4, the alteration is pervasive, a large clinopyroxene grain at the top of the piece is fractured along cleavages and replaced by amphibole. Olivine is replaced along fractures by smectite plus talc and magnetite. Plagioclase is chloritized. Piece 5 is a coarse-grained gabbro, highly altered by a network of actinolite and clay mineral veins which wraps around and crosscuts the grains. Pieces 6A and 6B are strongly altered; mafic phases are largely replaced; olivine alters to talc and oxide minerals. Sulfide minerals are segregated at the boundaries between plagioclase and talc after olivine. Rims of chlorite occurs on plagioclase at

the bottom of the piece. Piece 7B, 7C, and 7D are a microgabbro, with an apophysis of a felsic vein. The inner part of the vein is filled by fibrous, radiating actinolite, after clinopyroxene, and the outer part is mostly albite. Piece 8–10 show the contact between a fine-grained and a medium-grained gabbro. The alteration is moderate to high in these pieces. Plagioclase is chloritized. Aragonite is on open surfaces. Minor epidote replaces plagioclase.

Veins

Piece 1A has a 2 mm wide actinolite vein. In the back of Piece 1B, a composite, subhorizontal, chlorite and actinolite vein cuts the piece. In Piece 4, at the back of the piece, a fracture surface is coated by aragonite and sulfide minerals. A <1 mm clay mineral-filled fracture cuts the top of the piece. In Piece 5, the back is crosscut by a diffusing irregular net of clay mineral and actinolite veins. Chlorite coats the bottom of the piece.

VEIN/FRACTURE FILLING:

Actinolite.

Clay minerals.

ADDITIONAL COMMENTS: Structure

The only piece with a foliation is Piece 8 which has medium- to fine-grained pyroxene aligned and dipping 12°. The top and 270° side of this piece are medium to coarse grained while the rest is fine grained. Piece 11 has a subvertical contact midcore between an altered olivine-rich section and a fresher section with more plagioclase and pyroxene in it. Felsic, possibly magmatic veins cut Pieces 1, 2, and 7. The vein between Pieces 1 and 2 appears to dip about 25°. Chlorite and actinolite veins cut Pieces 1, 3, 4, 5, and 6. These are subhorizontal to shallowly dipping in Pieces 1, 3, 5, and 6.

UNIT 3: POIKILITC OLIVINE GABBRO

Piece 11

COLOR: Gray, green and white.

PRIMARY STRUCTURE:

SECONDARY STRUCTURE:

PRIMARY MINERALOGY:

Plagioclase - Mode: 50%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.

Olivine - Mode: 40%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.

Clinopyroxene - Mode: 10%.
Crystal Size: 1–15 mm.
Crystal Shape: Anhedral.

Comments: Piece 11 is compositionally heterogeneous olivine gabbro. The upper corner of the core face is troctolite that is highly altered and oxidized, composed of appproximately 60% olivine and 40% plagioclase. The remainder of the piece is poikilitic olivine gabbro (70% plagioclase, 25% olivine, and 5% clinopyroxene) in which the clinopyroxene is dark green and poikilitically encloses plagioclase; clinopyroxene is zoned from green cores to brown rims. The rock contains trace abundances of sulfide minerals.

SECONDARY MINERALOGY:

Serpentine/talc/oxide minerals

Comments: After olivine.

Chlorite.

Comments: After olivine and plagioclase.

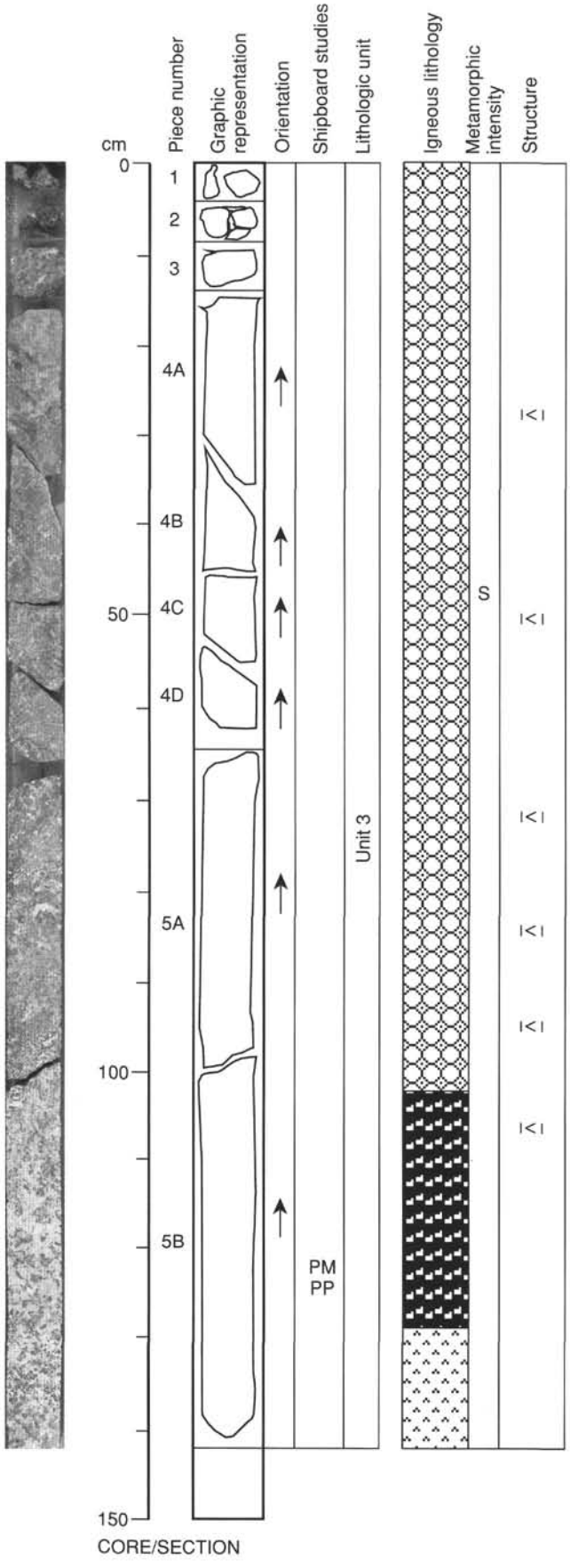
Comments: The left portion of the piece is more altered; olivine and plagioclase alter respectively to (serpentine?), talc, oxide minerals, and chlorite. In the top right portion of the piece plagioclase is fresh, whereas serpentine, magnetite, and locally massive green chlorite replace olivine.

VEIN/FRACTURE FILLING:

Chlorite and actinolite.

ADDITIONAL COMMENTS: Structure

Chlorite and actinolite veins in Piece 11 dip 70°.



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UNIT 3: POIKILITIC OLIVINE GABBRO

Pieces 1–5B

COLOR: Black, green, and white.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 35%–40%.
Crystal Size: <25 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 5%–25.%.
Crystal Size: 2–70 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 40%–50%.
Crystal Size: 1–16. mm.
Crystal Shape: Anhedral.
iron oxide minerals - Mode: Trace%.
Comments: This section consists of coarse-grained poikilitic olivine gabbro that is extremely heterogeneous, both modally and texturally. Pieces 1 and 2 are small pebbles that are composed largely of single clinopyroxene crystals similar to the large poikilitic clinopyroxene crystals observed in the underlying olivine gabbro. Piece 3 is a pyroxene-poor olivine gabbro (35% plagioclase, 55% olivine, and 5% clinopyroxene). Clinopyroxene is zoned from green cores to brown rims. It subophitically to poikilitically encloses plagioclase and some olivine; larger cores are chadacryst-free. Pieces 4 and 5 are remarkably heterogeneous with regard to the modal proportions of primary mineral phases, but that variation is not distributed in simple layers. Instead it appears rather chaotic. Note that the details of the following description are only accurate for the back surface of the archive portion of the core. Modal variations are so rapid that the cut surface of the core differs from the back surface and both differ from the working half. One side of Piece 4A is medium-grained troctolite; two large clinopyroxene crystals occur near the top of the piece. Clinopyroxene has green cores and is zoned to brown rims; the cores are chadacryst free. Surrounding large clinopyroxene crystals is a 0.5 cm wide band that is largely olivine-free, i.e. anorthositic. One clinopyroxene crystal appears to be continuous diagonally across the core for a maximum dimension of ~70 mm. Below this is a large patch (~3.5 cm diameter) that is anorthositic. This continues downward in Piece 4A into a coarse-grained olivine layer (80% olivine and 20% plagioclase). The bottom corner of Piece 4A is fine-grained troctolite in which the clinopyroxene is brown rather than green. Piece 4B is essentially a feldspathic wehrlite on one side and an olivine gabbro on the other; the wehrlite is composed of 50% olivine, 45% clinopyroxene, and 5% plagioclase. The olivine gabbro has an equigranular texture and is 70% plagioclase, 25% olivine gabbro, and 5% brown clinopyroxene. Piece 4C is heterogeneous poikiltic olivine gabbro (70% plagioclase, 20% clinopyroxene, and 10% olivine) that tends to be more coarse grained at the bottom than at the top. It contains both brown and green clinopyroxene as separate crystals. Piece 4D is similar to Piece 4C (70% plagioclase, 15% clinopyroxene, and 15% olivine) and also shows a gradual increase in grain size from top to bottom of the piece. Piece 5 is a coarse-grained olivine gabbro that is plagioclase poor. The modal proportions of primary phases vary significantly. At the top of Piece 5A, plagioclase is 5%, olivine 50%, and clinopyroxene 45% of the mode. Olivine appears flattened at the top of Piece 5A as if it is structurally deformed. Modal proportions change to approximately 20% plagioclase, 50% olivine, and 30% clinopyroxene downsection. This continues into the top of Piece 5B which is olivine gabbro (30% plagioclase, 40% olivine, and 30% clinopyroxene), but becomes troctolite over the bottom 30 cm of the piece (70% plagioclase, 27% olivine, and 3% clinopyroxene). The clinopyroxene changes from predominantly green at the top of Piece 5A to brown at the top of Piece 5B. At the top of Piece 5B it has a crescumulate texture. Trace abundances of interstitial sulfide minerals occur throughout the section.
SECONDARY MINERALOGY:
Sulfide minerals.
Total Percent: Trace.
Chlorite/smectite/magnetite.
Comments: Replacing olivine.
Brown amphibole.
Comments: Replacing clinopyroxene.
Actinolite.
Comments: Replacing clinopyroxene.

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Iron-hydroxoide minerals.

Comments: Alteration of iron oxide and sulfide minerals.

Comments: Overall alteration in this section is slight to moderate (<15%), apart from the Pieces 1 and 2 which are rubble (composed mainly of monomineralic clinopyroxene including patches of chlorite and green to brown smectite) and Piece 5C which is affected by numerous discrete cracks. Plagioclase remains fresh throughout the section. Olivine is variably altered (from 10% to 40%). It is replaced by talc and iron oxide minerals (Pieces 4A, 4B, 4C) and by smectite and oxide minerals (Pieces 3, 4D, 5A, 5B, and 5C). The largest crystals seem to be the more altered (Pieces 4D and 5A). Large clinopyroxene in Pieces 3, 4A, 4B, 4C, and 5B exhibit patches and rims of brown amphiboles. In the finer grained part of Piece 4D and the top of Piece 5A, clinopyroxene is partially replaced by actinolite, and in Piece 5C, pervasively replaced by a dark green actinolite and chlorite assemblage. Green smectite or chlorite patches replace clinopyroxene near thin veinlets. Oxide minerals are altered to hydroxide minerals.

Veins

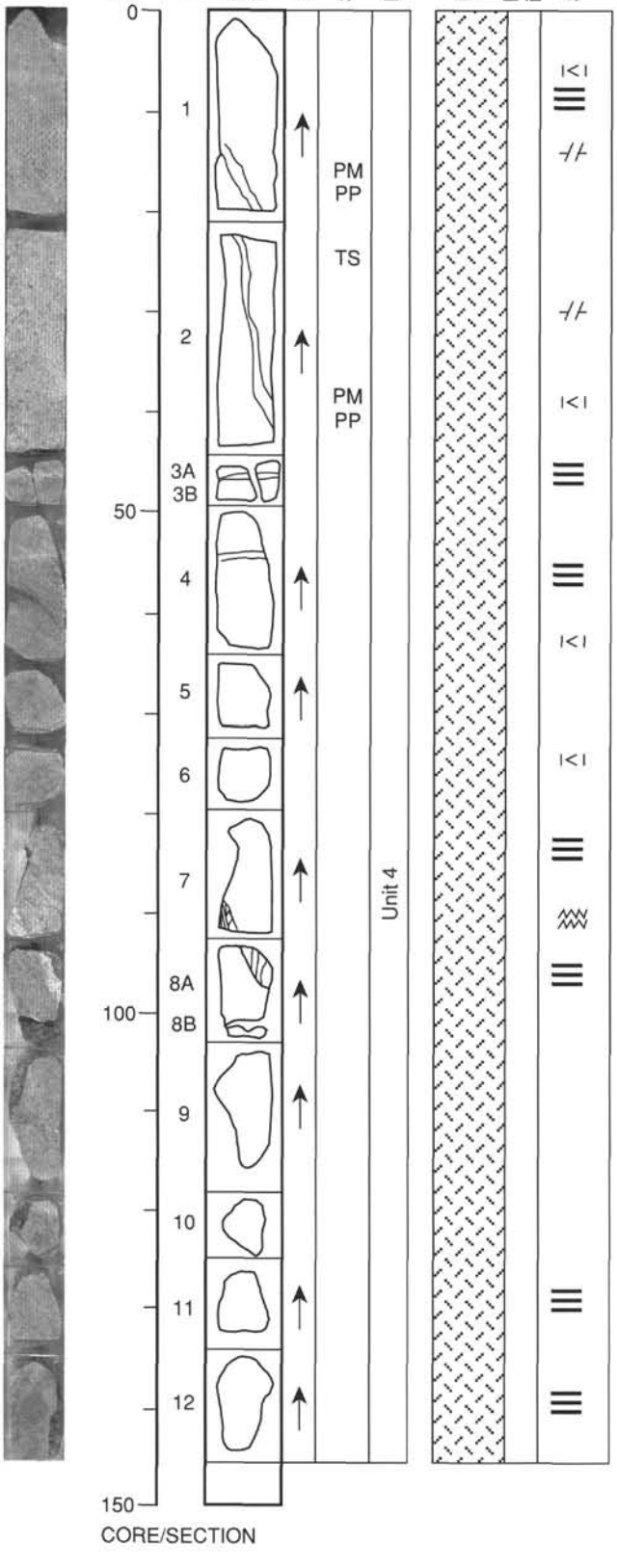
Rare thin (<1 mm) veins are filled with smectite and chlorite in Pieces 1 and 5A. In Piece 5C, the vein density is high. Veins in Piece 5 dip from 30° to 70°. One vein in Piece 4 is horizontal, while another green actinolite and chlorite vein dips 60°.

VEIN/FRACTURE FILLING:

Smectite and chlorite.

ADDITIONAL COMMENTS: Structure

Pieces 4 and 5 display heterogenous compositional changes throughout but the best defined contact is near the top of Piece 5 where the contact between very coarse-grained gabbro and a fine- to medium-grained olivine-rich gabbro dips 60° and is sharply defined. Several bands of compositional changes occur along this piece including a horizontal band at the bottom of clinopyroxene rich rock.



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UNIT 4: GABBRO - OLIVINE GABBRO

Pieces 1–12

COLOR: Dark gray/gray.
PRIMARY STRUCTURE: Igneous hypidiomorphic to allotriomorphic granular.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 57%–66%.
Crystal Size: 1–11 mm.
Crystal Shape: Sub/anhedral.
Clinopyroxene - Mode: 30%–38%.
Crystal Size: 1–15 mm.
Crystal Shape: Anhedral/subhedral.
Olivine - Mode: 2%–7%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: 0–1%.
Comments: Medium- to coarse-grained gabbro and olivine gabbro dominate in this section. The rocks are modally and texturally heterogeneous in both primary and secondary lithology. The texture of the gabbro (Pieces 1 and 3–8) and the olivine gabbro (Pieces 2 and 9–12) is allotriomorphic to hypidiomorphic granular, comprising anhedral to subhedral grains of olivine (1–10 mm), clinopyroxene (1–15 mm), and plagioclase (1–11 mm). The texture becomes more anhedral, equigranular downward in the core toward the olivine gabbro. The modal abundance of olivine ranges from 2% in gabbro to 7% in olivine gabbro. The modal abundance of clinopyroxene and plagioclase varies throughout the section from 30%–38% and from 58%–66%, respectively. Fine-grained, olivine-free gabbro (5–7 mm thick) crosscuts the medium- to coarse-grained, olivine-bearing gabbro of Piece 1. At the margin of Piece 10, a 1.5-cm-thick, fine-grained, olivine-free gabbro is in sharp contact with coarse-grained olivine gabbro. Thin trondhjemite veins are present in Pieces 3 (2–3 mm thick), 4 (3 mm thick), 7 (8–10 mm thick), and 8A (1.5 cm thick). They are composed mostly of plagioclase and brown-green hornblende with minor amounts of iron oxide minerals and apatite.
SECONDARY MINERALOGY:
Brown hornblende.
Total Percent: <1
Comments: After clinopyroxene.
Sulfide minerals.
Total Percent: <0.5
Mode of Occurrence: Disseminated.
Talc/magnetite.
Total Percent: <1
Comments: After olivine.
Chlorite/actinolite.
Total Percent: <6
Comments: After clinopyroxene.
Comments: Alteration in this section is variable from very fresh to moderately altered (up to 30%) gabbro. Apart from the olivine which can be pervasively altered to talc and oxide minerals, alteration of the other phases is along hydrothermal veinlets or magmatic veins cutting the rocks. The alteration is also more intense in the sheared zone. Alteration around the veins consists of a partial replacement of clinopyroxene by actinolite and/or chlorite and smectite and chlorite patches replacing plagioclase (Pieces 1–7). The plagioclase is sporadically stained by brown iron hydroxide minerals or partially replaced by secondary plagioclase (Piece 4, 6, and 7) and/or quartz at the selvages of these veins. Epidote is present near open cracks in Pieces 5 and 6. In Pieces 9–12, the veinlets are more discrete and this type of alteration is more pervasive. In Piece 8A, clinopyroxene at the selvage of the vein is completely replaced by actinolite. A mesh of ilmenite laths in a green brown clayey (?) mat occurs at the margin of the vein. In the shear zone (Pieces 7 and 8A), elongated patches of chlorite and actionolite replace clinopyroxene and are parallel to the mylonitic foliation.
Veins
Pieces 7 and 8A contain 1 to 1.5 cm wide veins filled with plagioclase altered to secondary plagioclase and containing disseminated grains of epidote, quartz, green amphibole, massive oxide minerals, ilmenite laths, and prehnite (?) in the center of the veins. Late thin (<1 mm) veinlets filled with secondary plagioclase ± quartz at the margin and green smectite at the core are in in Pieces 1, 3A, and 3B (abutting a 5 mm irregular quartz-bearing pod). Chlorite and actinolite veins are in Pieces 2 and 4, and veins filled with

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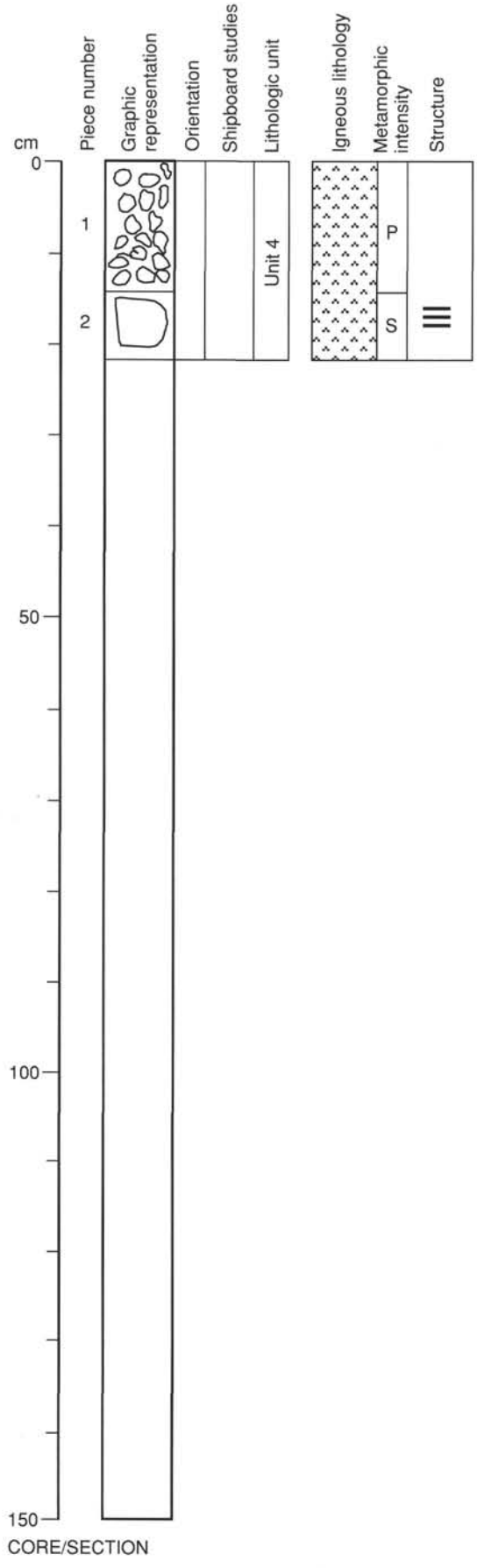
smectite, chlorite, and a white clay mineral (?) are in Pieces 5–7 and 9–12).

ADDITIONAL COMMENTS: Structure

Primary igneous texture is variably overprinted by plastic deformation. A well-developed grain shape preferred orientation, dipping 20°–40° is in the fine-grained intervals (Pieces 1, 3, 4–6, 11, and 12). Plastic deformation overprint is more heterogeneously partitioned in medium-grained intervals. Pieces 2, 9, and 10 have no evident crystal shape fabric, while Pieces 7 and 8 show a well-developed elongate porphyroclastic texture, concordant with the foliation in the fine-grained intervals. A contact between fine- and medium-grained gabbro is exposed in Piece 4 and dips 60°. It is discordant to the plastic strain fabric, although at the very contact, the foliation rotates into parallelism with the contact. Two 8 mm thick magmatic veins of fine-grained gabbro crosscut Pieces 1 and 2. Vein margins are generally clear cut, but locally diffuse. A similar fine-grained gabbro vein is in the small unoriented Piece 10. In Piece 1, these microgabbro veins are concordant to the mineral shape fabric; in Piece 2, their dip is 60°. A coarse-grained, altered magmatic vein is in Pieces 8 and 9. A few chlorite and actinolite (some of them with an alteration halo) crosscut this section (Pieces 1–4, 6, and 8). Their dip ranges from 10° to 70°.



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UNIT 4: GABBRO - OLIVINE GABBRO

Pieces 1–2

COLOR: Gray.
PRIMARY STRUCTURE: Equigranular igneous texture.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 65%–67%.
Crystal Size: 1–6 mm.
Crystal Shape: Subhedral/anhedral.
Clinopyroxene - Mode: 30%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 3%–5%.
Crystal Size: 1–3 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: <1%.
Crystal Size: <1 mm.
Crystal Shape: Anhedral.
Comments: The section consists of a collection of fresh gabbroic rubble (Piece 1) and a small piece of olivine gabbro (Piece 2). Samples from both pieces are equigranular, medium-grained in texture, with 3%–5% olivine. Iron oxide and sulfide minerals are rare.
SECONDARY MINERALOGY:
Brown hornblende.
Total Percent: 1–3
Comments: After clinopyroxene.
Talc/magnetite.
Total Percent: 1
Comments: After olivine.
Comments: The section is formed by two pieces. Piece 1 is rubble of microgabbro, and is relatively fresh. Piece 2 is relatively fresh, with brown amphibole rimming clinopyroxene; staining of plagioclase by iron hydroxide mineral alteration occurs. Secondary plagioclase and/or chlorite replaces plagioclase.
VEIN/FRACTURE FILLING:
Chlorite.
Percent: Trace.
Orientation: Thin coating.
ADDITIONAL COMMENTS: Structure
Piece 1 of this section is made of 34 fragments of medium-grained gabbro ranging in size from 5 mm to 40 mm. Piece 2 (not oriented) is a medium-grained gabbro showing a moderately developed crystal shape fabric.

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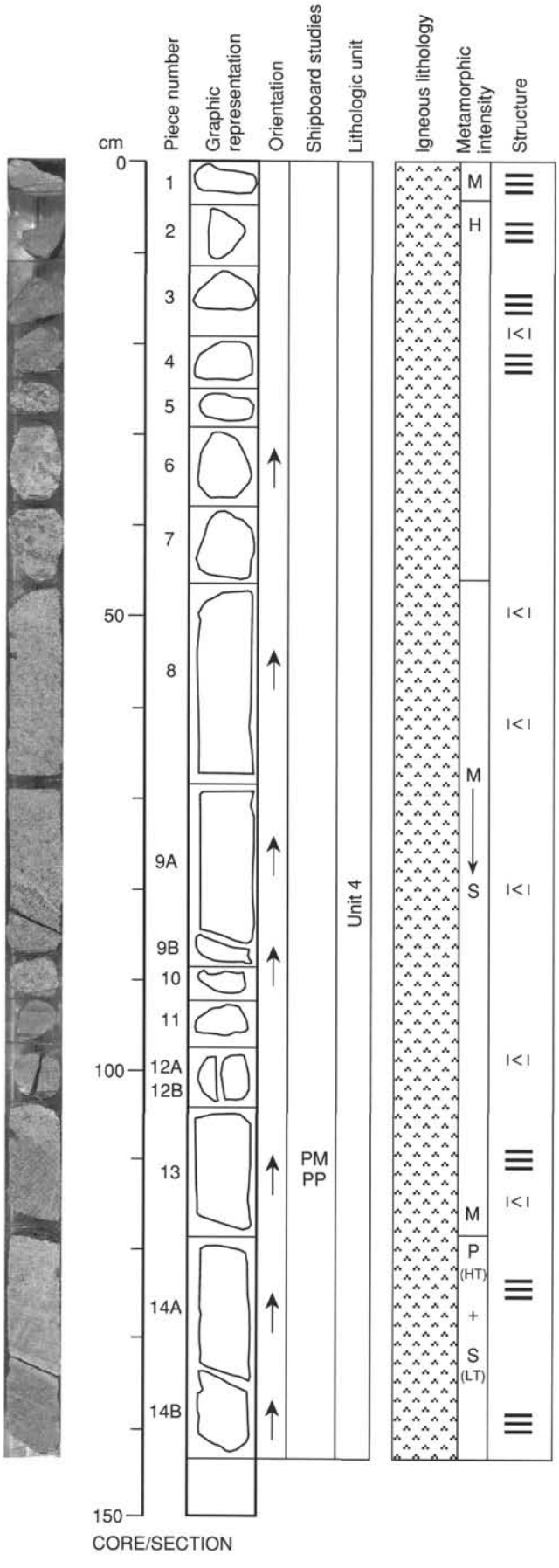


UNIT 4: GABBRO - OLIVINE GABBRO - TROCTOLITE - GNEISSIC OLIVINE GABBRO

Pieces 1–14B

COLOR: Gray/brown.
PRIMARY STRUCTURE: Diffuse igneous layering.
SECONDARY STRUCTURE: Heteregeneous tectonic and mylonitic overprint
PRIMARY MINERALOGY:
Plagioclase - Mode: 67%–77%.
Crystal Size: 0.1–10 mm.
Crystal Shape: Anhedral/subhedral.
Clinopyroxene - Mode: 3%–30%.
Crystal Size: 0.1–6 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 0–30%.
Crystal Size: 0.1–8 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: Trace.
Crystal Shape: Anhedal.
Comments: The section is heterogeneous in terms of the rock types present, their composition, and the textural range. Pieces 1 to 4 are fine- to medium-grained gabbro containing 70% subhedral plagioclase, 30% interstitial brown clinopyroxene, and 0–5% olivine (Piece 4 contains 5% olivine). Piece 1 is strongly foliated and altered around chlorite and clay mineral-filled fractures, and Piece 4 is a fine-grained gneiss in which all phases are strongly altered. These pieces are small rounded cobbles (<6 cm), and may have fallen in from the top of the hole. Pieces 5–7 are undeformed, coarse-grained troctolite in which coarse olivine (20%–30%) is interstitial, and probably poikilitic, to subhedral plagioclase laths. Poikilitic green clinopyroxene is more abundant (3%) toward the bottom of Piece 7, and the very base of the piece is a coarse-grained layer of olivine and poikilitic clinopyroxene. Pieces 8–13 are olivine gabbro that is variously altered in Pieces 8–10. Pieces 11 and 12 contain diffuse subhorizontal grain-size layering that alternates on the scale of 1 to 5 cm between various grades of medium grained. A 5 cm thick coarse-grained layer dipping about 30° occurs 10 cm into Piece 9. Shear fabric increases toward Piece 13 where there is a 20 cm thick mylonite in which extensive shearing and recrystallization of olivine gabbro occurs. There is a normal sense of shear. An augen on the back of the working half consists of a green poikilitic clinopyroxene subophitically enclosing plagioclase, a mineral association that is entirely exotic to the host olivine gabbro.
SECONDARY MINERALOGY:
Sulfide minerals.
Total Percent: Trace
Clay/chlorite.
Total Percent: 0–10
Comments: After clinopyroxene around veins.
Brown hornblende.
Total Percent: <3
Comments: After clinopyroxene and rimming olivine in troctolite.
Talc/smectite/magnetite.
Total Percent: <5
Comments: After olivine.
Comments: The section shows variable alteration from moderate to high. Piece 1 is a foliated microgabbro; alteration is ~50%–60%. Olivine is altered to talc and oxide minerals. Locally patches of dark green chlorite completely replaces olivine at the intesection with actinolite veins. In Pieces 2–4, alteration is ~70%–80%; olivine is largely replaced by talc and oxide minerals; plagioclase is chloritized, and oxide minerals are disseminnated on the outer surfaces. In Piece 3, plagioclase is pervasively replaced by chlorite. Pieces 5–7 are moderately altered. In Piece 6, olivine alters to talc and oxide minerals, rimmed by chlorite (at the contact with plagioclase). Sulfide minerals occur included in plagioclase. In plagioclase, there is alteration to chlorite along microcracks. Local staining of plagioclase is due to alteration of iron hydroxide minerals. Piece 7 is more leucocratic and slightly coarser, but alteration is similar to the previous pieces. Olivine is completely replaced by chlorite where crosscut by thin actinolite veins, marked by green patches. Plagioclase is partially chloritized, along actinolite-bearing microcracks. In Piece 9, alteration is ~10%–20%. Clinopyroxene is discontinuously rimmed by brown and green amphibole, and plagioclase is locally replaced by

chlorite. On the open surface between Pieces 9A and 9B is a green clay mineral vein. Piece 9B is a coarser grained olivine gabbro than Piece 9A, with the same extent of alteration. Olivine is altered to talc and oxide minerals. In Piece 10 the alteration is moderate. Olivine is altered to talc and iron oxide minerals and clinopyroxene is rimmed by green actinolite. Iron staining is present on plagioclase. Pieces 11, 12A, and 12B are moderately altered. Clay minerals replace plagioclase and olivine. Piece 14A is 1) isotropic for 5 cm from the top, 2) sheared and very fine grained for 1 cm, 3) 1.5 cm foliated medium grained, 4) coarse-grained sheared gabbro. The macroscopic metamorphic features are elongation and recrystallization of clinopyroxene and plagioclase. In 1) olivine is altered to talc; plagioclase is replaced by chlorite, clinopyroxene is rimmed by brown amphibole. Between 2) and 3) grains of clinopyroxene are rimmed by actinolite, and secondary plagioclase is present. The most outstanding features are around the largest grains. In 3) clinopyroxene is fresh, but secondary plagioclase is present; in 4) clinopyroxene porphyroclasts are rotated, and brown amphibole and actinolite occur in the pressure shadows. Grain-size reduction occurs in plagioclase and brown amphibole marks the foliation. Piece 14B is similar to Piece 14A, showing 1) 4 cm of strongly foliated metagabbro, and 2) 4 cm of foliated metagabbro. In 1) striped textures are present, clinopyroxene porphyroclasts are flattened defining a schistosity, and strong grain-size reduction is recorded in plagioclase. In 2) brown amphibole rims clinopyroxene and is in pressure shadows, and strong grain-size reduction is recorded in plagioclase.

Veins

In Piece 1, white clay mineral and actinolite microveins crosscut the foliation at high angle. Pale yellow clay mineral veins are subparallel to the foliation. In Piece 3 yellow-brown clay mineral veins occur at the bottom of the piece. In Piece 4 subhorizontal <<1mm clay mineral veins occur irregularly. In the back of the piece, an actinolite vein is <<1 mm. Piece 5 is cut by irregular clay mineral, and hydroxide and oxide mineral veinlets. In Piece 8, irregular very thin yellow clay and oxide mineral veins crosscut the piece. In Pieces 12A and 12B, chlorite-filled microcracks occur, and on one edge is a felsic vein lined with oxide minerals. The plagioclase and actinolite felsic vein is crosscut by actinolite and clay mineral veins. Piece 13 is a medium coarse- (top) to fine-grained (bottom) foliated olivine gabbro. At the top of the piece, chlorite veinlets crosscut olivine and plagioclase, marked by diffuse chlorite patches. The rest of the piece is similar to Pieces 11 and 12 in terms of alteration. In Piece 14A, subvertical, green actinolite veins crosscut the piece.

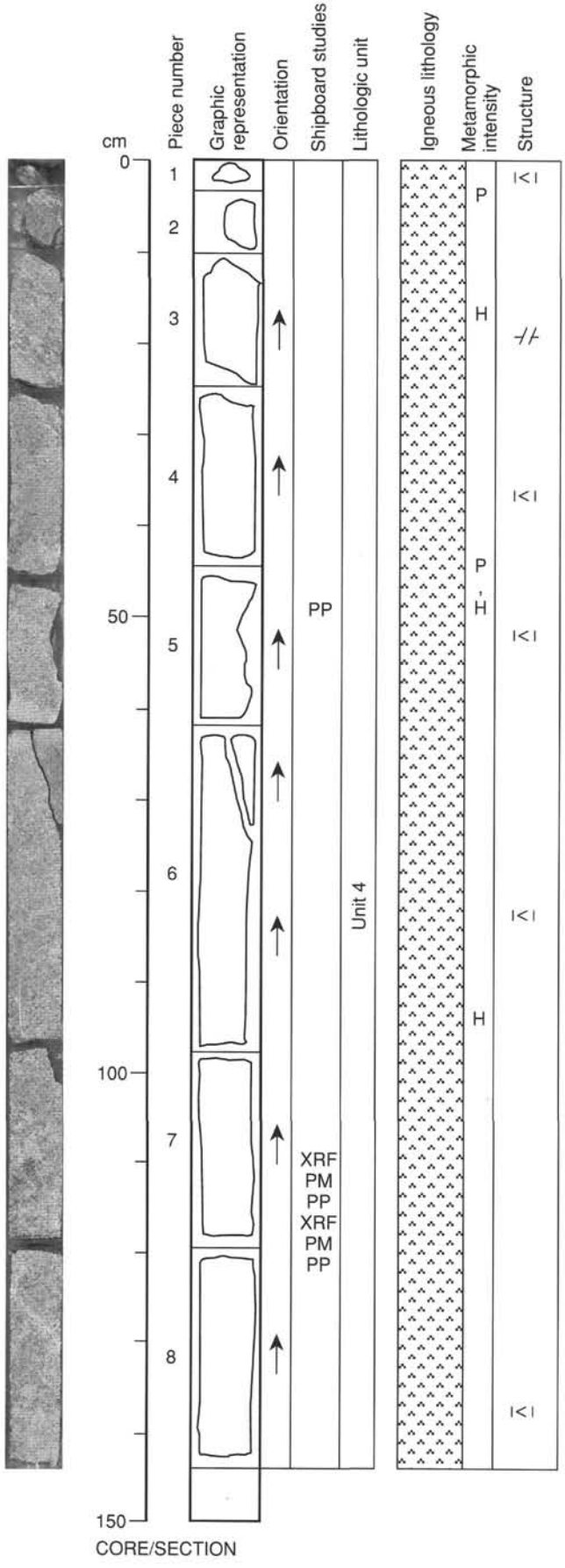
VEIN/FRACTURE FILLING:

Clay/chlorite.

Size: <3 mm.

ADDITIONAL COMMENTS: Structure

Two distinct preferred mineral-shape fabrics occur in this section. The first is interpreted to be magmatic in origin and it is defined by a preferred orientation of the long axes of anhedral pyroxene and subhedral plagioclase grains. It is present in Pieces 8, 9, and 13. Pyroxene generally occurs as single crystals with continuous cleavages and shows no sign of grain distortion. Plagioclase has subhedral and anhedral shapes and, under the binocular microscope, approximately half of the grains are translucent and show continuous twins (the other half are anhedral, equant, and have a frosty appearence). The lack of pyroxene distortion suggests that fabric was developed in the magmatic state. The fabric seems to be shallowly dipping but is too weak to measure except in Piece 13 where it dips about 3°. The second mineral-shape fabric is clearly solid-state and is found in Pieces 1–4, 13, and 14. This fabric is characterized by pyroxene porphyroclasts with long (3–10 mm), recrystallized tails. Plagioclase occurs as a saccharoidal neoblast mosaic. The fabric ranges in intensity from protomylonitic (e.g. Piece 13) to ultramylonitic (e.g. Piece 14) and occurs in a spectacular decimetric shear zone found in Piece 14. The mineral-shape fabrics with a preferred orientation only occur in the olivine gabbro. Long axes of all crystals in the troctolite (Pieces 5–7) are randomly oriented. Discrete chlorite- and actinolite-filled veins are in Pieces 4, 8, 9, 12, and 13. They are <1 to 1 mm thick and dip between 25 and 60°. Grain-size varitations (CTV) are found in Pieces 9 and 14. They generally dip <20° and are subparallel to the mineral-shape fabric.



153-923A-13R-2

UNIT 4: GNEISSIC OLIVINE GABBRO - OLIVINE GABBRO.

Pieces 1–8

COLOR: Gray.
PRIMARY STRUCTURE: Igneous heteradcumulate texture.
SECONDARY STRUCTURE: Gneissic fabric in the top of the section.
PRIMARY MINERALOGY:
Plagioclase - Mode: 58%–70%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral/subhedral.
Clinopyroxene - Mode: 7%–33%.
Crystal Size: 1–13 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 7%–32%.
Crystal Size: 1–12 mm.
Crystal Shape: Anhedral.
Comments: This section is composed of medium- to coarse-grained gneissic olivine gabbro (Pieces 1–4) and coarse-grained olivine gabbro (Pieces 5–8). Pieces 1 and 2 are medium-grained gneissic olivine gabbro, containing aggregations of recrystallized olivine associated with porphyroclasts of primary brown clinopyroxene, and plagioclase within augens, and shows a strongly elongated, augen gneiss texture. Piece 3 and the top of Piece 4 are coarse-grained olivine gabbro characterized by a porphyroclastic texture of large porphyroclasts of primary clinopyroxene in a fine-grained matrix of recrystallized plagioclase, clinopyroxene and brown hornblende. In Piece 3, a mylonitic layer (<5 mm thick) of fine-grained gabbro is present, nearly parallel to the foliation. The intensity of deformation decreases downward at the top of Piece 4. The main portion of Piece 4 is undeformed. Pieces 5–8 are composed predominantly of texturally and modally uniform, coarse-grained olivine gabbro. The rock consists of euhedral cumulus (1–15 mm) plagioclase (60%–67%) and anhedral, intercumulus grains (1–13 mm) of olivine (22%–32%) and clinopyroxene (7%–10%). The clinopyroxene is brown, often green in the center, and commonly rimmed by brown hornblende. Piece 5 contains a green clinopyroxenite dikelet (1.5 cm thick), in which the clinopyroxene grains are connected to interstitial clinopyroxene. At the top of Piece 6, plagioclase-rich (leucocratic) pyroxene gabbro (2 cm thick) is interlayered with olivine gabbro. In Piece 4, trondhjemite veins (>1.5 cm thick) contain subhedral, brown-green hornblende and large grains of zoned plagioclase, with minor amounts of iron oxide minerals and apatite. A thin trondhjemitic vein (3–5 mm) cuts olivine gabbro in Piece 8.
SECONDARY MINERALOGY:
Brown hronblende.
Total Percent: 0.5–1
Comments: After clinopyroxene.
Sulfide minerals.
Total Percent: 0–1
Mode of Occurrence: Disseminated.
Talc/magnetite.
Total Percent: <1.5
Comments: After olivine.
Chlorite/actinolite.
Total Percent: <2
Comments: After clinopyroxene.
Comments: The section shows variable, but generally high to pervasive alteration. Piece 1 is completely altered. Olivine is replaced by chlorite and oxide minerals are segregated long the grain margins. Plagioclase is chloritized or recrystallized to secondary plagioclase. Piece 2 is altered ~80%–90%. A leucocratic vein occurs at the top of the piece. Olivine is altered to talc and iron oxide minerals, and oxide stringers mark the schistosity. Clinopyroxene is flattened defining a foliation, altered to green amphibole and locally rimmed by brown amphibole. Plagioclase is recrystallized to secondary plagioclase. Piece 3 is altered 70%–80%. It shows alignment of clinopyroxene, rimmed or replaced by actinolite or brown amphibole. Plagioclase is chalky white, replaced by secondary plagioclase or chlorite. Piece 4 is a foliated metagabbro. At the top of the piece, the gabbro is coarse grained, and more strongly foliated. The center and the bottom of the piece is fine grained and deformation is less pervasive. Clinopyroxene is elongated and rimmed by actinolite. Olivine is altered to talc and iron oxide minerals, plagioclase is recrystallized to secondary plagioclase. Clinopyroxene is only aligned and not strongly flattened and rotated. At the center to the bottom of

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the piece the gabbro is more olivine rich (alteration pervasive). Olivine is extensively altered; bright green pyroxene is rimmed by brown amphibole. Plagioclase is chalky white and partially recrystallized. Piece 5 is moderately altered (up to 40%), mainly affecting olivine, so that the piece is mottled looking. Green clinopyroxene in large patches and in a clinopyroxenite dikelet is rimmed by brown amphibole. Olivine is altered to talc and iron oxide minerals. Plagioclase is locally chloritized. In Piece 6 (alteration 40%–50%), at top of the piece, a clinopyroxene rich dikelet is altered to brown amphibole rims and locally chlorite. Olivine is altered to talc and iron oxide minerals. Plagioclase is locally altered to chlorite. Piece 7 is similar to 6, but coarser grained. Clinopyroxene occurs as large crystals, totally replaced by actinolite and chlorite. Chlorite and minor smectite replace plagioclase. Sulfide minerals are dispersed in plagioclase, and rimmed by chlorite. In Piece 8 (alteration of the gabbro 10%) a 2 mm wide trondjemitic vein occurs.

Veins

In Piece 1 actinolite microveins cut the piece parallel to the foliation. In Piece 2, actinolite veins crosscut clinopyroxene, inducing alteration. In Piece 5, a <1 mm actinolite vein cut across. In Piece 8, a 2 mm wide trondjemitic vein occurs, inducing alteration. In the vein, actinolite at the center and plagioclase (possibly albitized?) at the selvages occur.

VEIN/FRACTURE FILLING:

Actinolite.

Trondhjemite.

ADDITIONAL COMMENTS: Structure

A porphyroclastic ductile fabric is found in Pieces 1–4. This fabric is characterized by pyroxene porphyroclasts with long (3–10 mm), recrystallized tails. Plagioclase occurs as a saccharoidal neoblast mosaic. The porphyroclastic fabric varies in intensity with the most strongly deformed rock in Pieces 1–3. In Piece 4, the fabric is weakly developed in the top of the piece and it is discordantly cut by a more olivine-rich green pyroxene gabbro, which makes up the rest of the piece. The rest of the section (Pieces 5–8) is composed of undeformed troctolitic gabbro that has a random shape fabric. Discrete chlorite- and actinolite-filled veins are in Pieces 1, 2, 4, 5, and 8. They are <1 to 1 mm thick and dip between 15° and 60°. The chlorite-actinolite vein in Piece 8 has a 4 mm thick alteration halo. Compositional and textural varitations (CTV) are found in Pieces 9 and 14 They generally dip <20° and are subparallel to the mineral-shape fabric.

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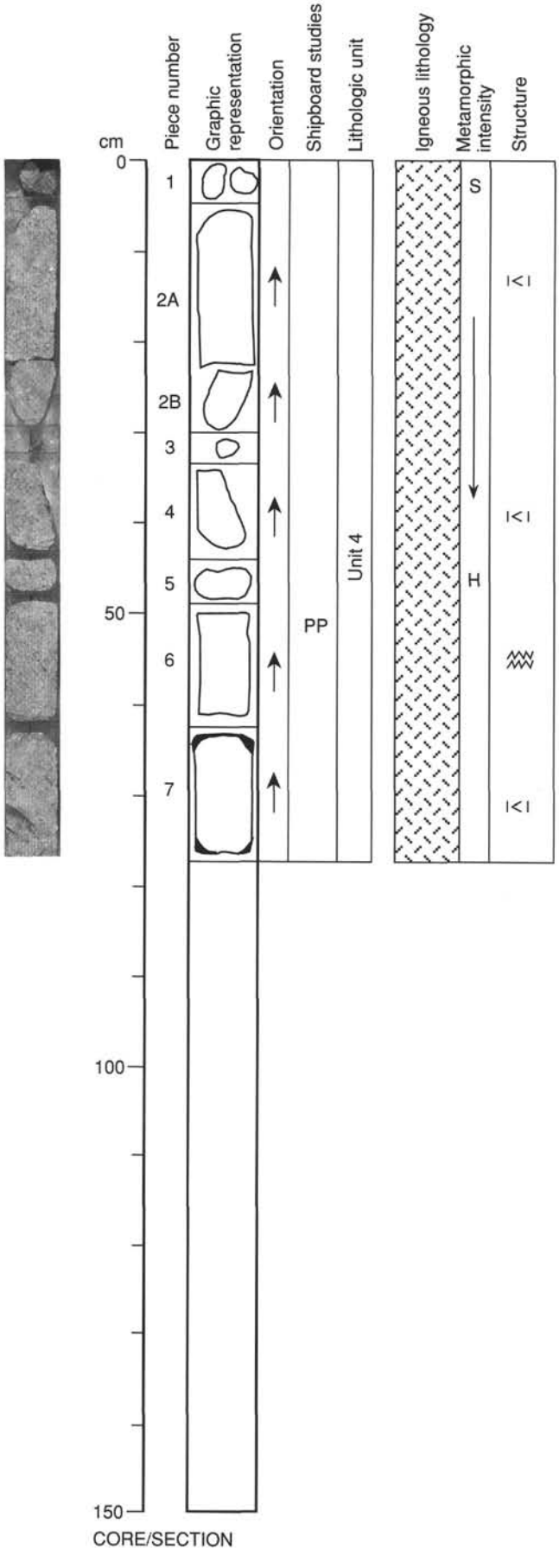

UNIT 4: GABBRO - OLIVINE GABBRO

Pieces 1–7

COLOR: Gray.
PRIMARY STRUCTURE: Igneous-hypidiomorphic equigranular.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 50%–72%.
Crystal Size: 0.1–15 mm.
Crystal Shape: Anhedral/Subhedral.
Clinopyroxene - Mode: 20%–50%.
Crystal Size: 0.2–50 mm.
Crystal Shape: Anhedral/subhedral.
Olivine - Mode: 3%–10%.
Crystal Size: 0.1–6 mm.
Crystal Shape: Anhedral.
Comments: This section is coarse-grained gabbro at the top grading down through coarse-grained olivine gabbro to very coarse-grained gabbro at the base. Alteration is most intense in Piece 4. Pieces 1 to 4 are variable in grain size and display a very poor, shallow-dipping (<20°) magmatic layering. Piece 2B and the basal 1 cm of Piece 4 are fine-grained, sheared gabbro that may have originally been small (1–2 cm) veins of microgabbro. Piece 5 is a small piece of coarse-grained olivine gabbro that is cut by a shear zone on one upper corner. Piece 6 is pegmatitic gabbro (grain size of clinopyroxene up to 50 mm) that is cut by a 45°-dipping shear zone. The shear zone shows a gradation in intensity toward the lower boundary. Piece 7 is very coarse-grained gabbro with pods/intrusions? (one in the archive half, two in the working half) of fine- to medium-grained gabbro; grain size in the pod decreases toward the contact in one area, but variations are not systematic elsewhere. Plagioclase laths in the very coarse-grained gabbro are extensively recrystallized. The contact between the pods and the coarse-grained gabbro varies from sharp to diffuse. The absence of clinopyroxene within the recrystallized plagioclase suggests that no melt has been intruded into the host gabbro, although fluid may have crossed the boundary and promoted recrystallization.
SECONDARY MINERALOGY:
Brown amphibole.
Total Percent: <1
Comments: After clinopyroxene and olivine.
Smectite/talc/magnetite.
Total Percent: 0–5
Comments: After olivine.
Green chlorite/clay.
Total Percent: 0–5
Comments: After clinopyroxene.
Sulfide minerals.
Total Percent: <1
Mode of Occurrence: Disseminated.
Comments: The alteration varies in the section from slight to moderate. In Piece 1 (alteration 10%) clinopyroxene is partially rimmed by brown amphibole. Iron oxide minerals are disseminated in olivine along the fractures, and the host olivine is altered to chlorite. Pieces 2A and 2B (5%–10% altered) have actinolite-filled microcracks. Piece 3 is a fragment, similar to Piece 2. Piece 4 is more altered (up to 40%). Olivine is altered to chlorite and sulfide minerals. Plagioclase is recrystallized, clinopyroxene is altered to actinolite, and sporadically rimmed by brown amphibole. Piece 5 is a foliated gabbro, showing flattening and elongation of clinopyroxene; olivine is altered to talc. In Piece 6 brown amphibole rims clinopyroxene; pale green tremolite replaces clinopyroxene. Fracture surfaces are coated with green clay minerals or fine-grained chlorite. Piece 7 is a very coarse-grained to coarse-grained gabbro; alteration is as high as 45%–50%. Large clinopyroxenes are fractured and altered to clay minerals and actinolite.
Veins
Actinolite-filled microcracks occur in Pieces 2A and 2B. Piece 4 has a multistranded dark green actinolite/ plagioclase(?) vein cutting the lower part of it with attendent alteration of pyroxene crystals that it cuts. In Piece 7 a diffuse network of actinolite/clay veinlets develop, wrapping and crosscutting the large clinopyroxene grains. An dark green actinolite/chlorite vein cuts the piece subhorizontally near the bottom.
VEIN/FRACTURE FILLING:
Green chlorite/clay.

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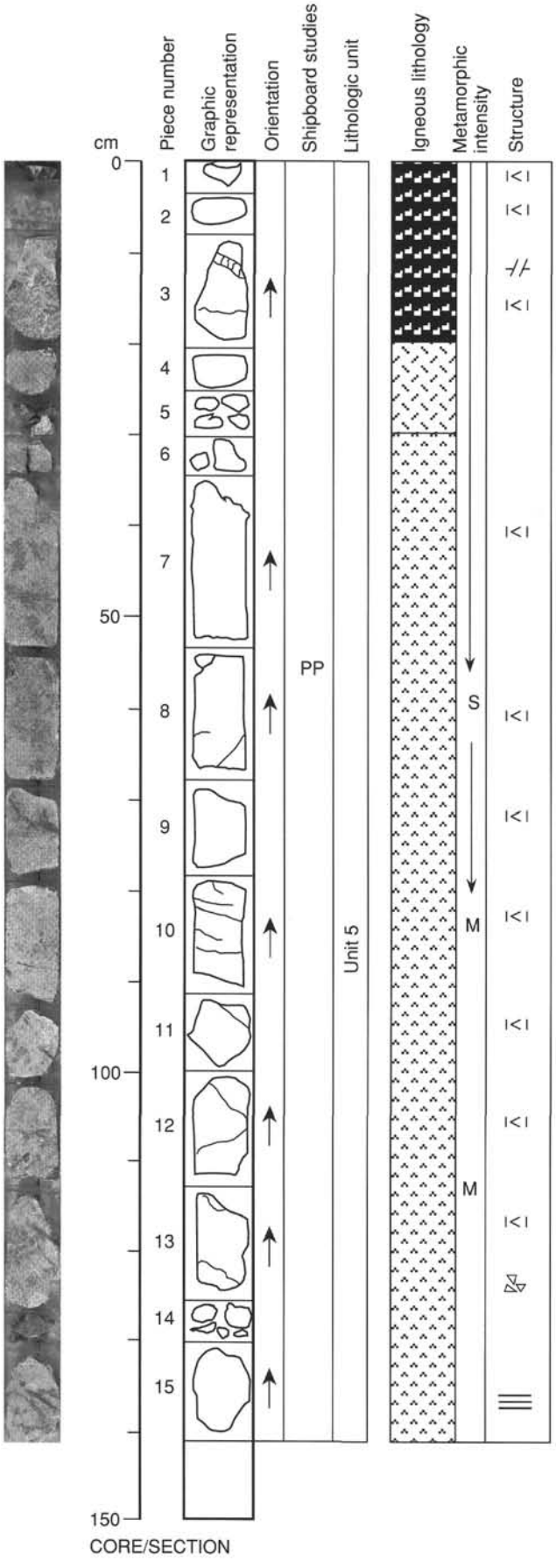
Percent: 0.1%–3%
Orientation: None preferred.

Actinolite.

ADDITIONAL COMMENTS: Structure

This section displays compositional and grain-size changes that are banded in Pieces 2, 4, and 6. A 1.5 cm thick, fine-grained band in Piece 6 also shows alignment of small altered pyroxene that defines a fabric that is probably more a lineation than foliation because the alignment is more obvious on portions of the curved surface than the cut face of the core. This band has irregular edges but dips approximately 45°. The upper corner of this piece also shows a preferred mineral alignment dipping slightly steeper (60°). Piece 5 is a small piece of coarse-grained olivine gabbro that is cut by shear zone. Piece 7 has the "magmatic breccia" texture where fractured pyroxene crystals are embedded in a fine-grained "recrystallized" plagioclase matrix. This piece also has an irregular patch of fine-grained altered amphibolite(?) gabbro on the side.



153-923A-14R-1

UNIT 5: TROCTOLITE, OLIVINE GABRRO AND GABBRO

Pieces 1–15

COLOR: Gray and brown gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%–65%.
Crystal Size: 2–15 mm.
Crystal Shape: Subhedral.
Crystal orientation: None.
Olivine - Mode: 3%–32%.
Crystal Size: 1–25 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Clinopyroxene - Mode: 3%–30%.
Crystal Size: 1–60 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Iron oxide minerals - Mode: Trace%.
Comments: This section is composed of coarse-grained troctolite and olivine gabbro with a lithology similar to that of Core 153-923A-13R-2. Olivine and clinopyroxene poikilitically enclose plagioclase laths. Pieces 1, 2, and the top 5 cm of Piece 3 are troctolite containing less than 5% clinopyroxene. However, emerald green oikocrystic clinopyroxene occurs in Piece 2, which is similar to that in Piece 5 in Core 153-923A-13R-2. In Piece 3, a plagioclase vein 1 cm in width crosscuts the troctolite. At the contact with troctolite in Piece 3, the olivine gabbro contains characteristic emerald green clinopyroxene which encloses equant olivine crystals poikilitically. Pieces 4 and 5 modally qualify as gabbro, but they are small pieces and the estimated modes may not be representative; mineralogical similarities suggest that they are of the same lithology as other olivine gabbro intervals in this section. There is a sheared olivine gabbro in Piece 6, making it unclear whether the olivine gabbro in Pieces 7 through 15 are a continuation of the olivine gabbro in Pieces 3, 4, and 5. From Piece 7 to 15, the olivine gabbro has close-packed oikocrystic olivine and clinopyroxene which enclose lath-shaped plagioclase grains. The oikocrystic crystals are commonly large (>20 mm) and heterogeneously distributed, creating a heterogeneous banding. The olivine gabbro shows systematic compositional variation in the ratio of clinopyroxene to olivine. This ratio increases gradually with depth and the maximum grain size of clinopyroxene oikocrysts increases from 20 mm in Pieces 7 and 8 to 60 mm in Piece 15.
SECONDARY MINERALOGY:
Sulfide minerals.
Total Percent: Trace.
Serpentine/talc/magnetite
Total Percent: 5
Comments: Replacing olivine.
Chlorite/actinolite
Total Percent: 5
Comments: Replacing plagioclase.
Actinolite.
Total Percent: <1
Comments: Rimming and replacing clinopyroxene.
Comments: Alteration in this section ranges from virtually absent to slight. Piece 1 is a fresh. Piece 2 is altered up to 2%. Olivine partially alters to talc and iron oxide minerals. Piece 3 is a relatively fresh troctolite, with a plagioclase vein at the top of the piece. Olivine is altered to talc, clay minerals, and oxide minerals. An actinolite vein crosscuts the piece. Plagioclase is generally fresh, but it can be locally chloritized or albitized. In Piece 4, at an edge of the piece, a trondjemitic vein occurs; within the vein is a fibrous radiating green amphibole and plagioclase may be albitized. The piece is quite fresh (maximum 5% alteration). Clinopyroxene is rimmed by amphibole and chlorite. Pieces 5 and 6 are fragments of the same. Piece 7 is an olivine gabbro (max 5% alteration), with patchy dark gray alteration. Olivine is quite fresh, and rimmed by chlorite. The alteration of olivine results in mottled green patches. In Piece 10 alteration ranges between 15%–20%. Clinopyroxene has a pinkish luster. Diffuse actinolite- and chlorite-filled microcracks cut across plagioclase. Olivine and clinopyroxene are crosscut by actinolite veins and altered to chlorite. Far from the veins, olivine is altered to talc and iron oxide minerals. In Piece 11 alteration is ~10%–20%. Olivine

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is altered to talc and iron oxide minerals, and locally to chlorite where crosscut by veins; plagioclase is fresh, only locally chloritized. Pieces 12–15 are 15%–25% altered. Clinopyroxene is rimmed by brown amphibole. Olivine is replaced by chlorite.

Veins

In Piece 1, white clay mineral veins occur. In Piece 3, around thin actinolite veins, chlorite replaces olivine. In Piece 7–8 clay mineral veins are present. In Piece 9, there is a <1 mm actinolite vein in the back of the piece. In Piece 10, two joints are coated by green clay minerals/chlorite(?); in the same piece two sets of gently dipping actinolite veins crosscut each other.

VEIN/FRACTURE FILLING:

Clay minerals.

Size: <<1 mm.

Orientation: Irregular.

Actinolite.

Size: <1 mm.

Orientation: Sets, subhorizontal.

ADDITIONAL COMMENTS: Structure

Primary igneous texture is well preserved throughout the section. Grain-size variations are very irregular and do not define any clear layering. No preferred orientation of primary igneous crystals has been found. Local development of sugary textures in plagioclase suggests solid-state recrystallization so that a very weak imprint of plastic deformation can not be ruled out. A cm-sized, fine-grained gabbroic vein crosscuts Pieces 2 and 3, dipping 50°. In piece 2, it shows diffuse contacts with the host gabbro. Two subhorizontal sheared chlorite-actinolite veins crosscut Piece 10, with the development of slickenfibers on its surface. Chlorite and actinolite veins are distributed throughout the section. Their dips range from horizontal to 50°.

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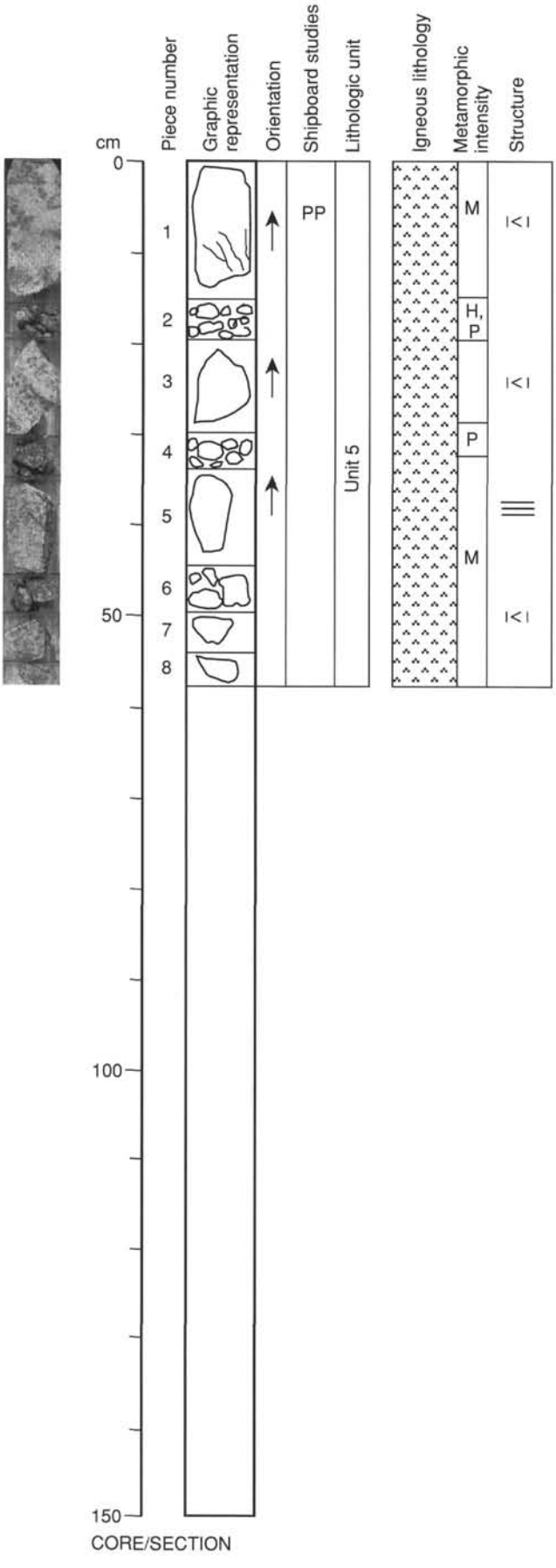
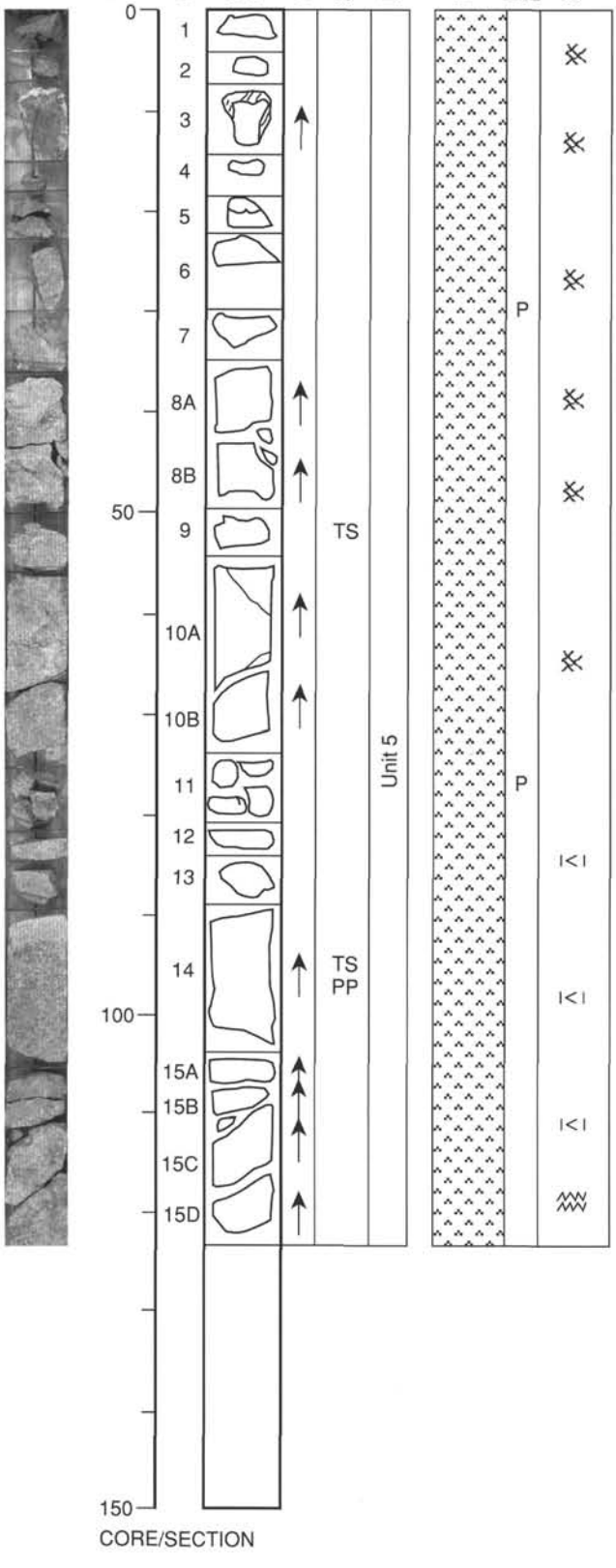


UNIT 5: OLIVINE GABBRO

Pieces 1–8

COLOR: Gray/white.
PRIMARY STRUCTURE: Heteradcumulate texture.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 65%.
Crystal Size: 3–6 mm.
Crystal Shape: Subhedral.
Olivine - Mode: 20%.
Crystal Size: 2–20 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 15%.
Crystal Size: 0.5–4 mm.
Crystal Shape: Anhedral.
Comments: This section consists of coarse-grained olivine gabbro that is modally homogeneous. Subhedral plagioclase laths typically form radiating aggregates. Olivine occurs as interstitial grains with lobate limbs that approach a crescumulate texture in form. Green to brown intercumulus clinopyroxene fills the angular interstitial pores between plagioclase. Rare *fine-grained oxide and sulfide minerals are disseminated along grain* boundaries. The overall texture is patchy/spotted due to the irregular distribution of partially altered olivine grains.
SECONDARY MINERALOGY:
Talc/magnetite.
Total Percent: 10
Comments: After olivine.
Chlorite.
Total Percent: 2
Comments: After clinopyroxene.
Comments: The section is moderately altered. Piece 1 is 10% altered, with gray alteration patches marking replacement of olivine by talc and iron oxide minerals. Piece 3, 5, 7, and 8 are a gray and spotted, where olivine crosscut by actinolite veins is altered to chlorite. Pieces 1 and 3 are cut by steep-dipping fractures that are weakly chloritized.
Veins
In Piece 1 are clay mineral-filled microfractures. In Piece 3, two <1 mm actinolite and chlorite veins crosscut the piece.
VEIN/FRACTURE FILLING:
Chlorite/clay.
Size: <3 mm.
Orientation: Steep, Pieces 1 and 3.
ADDITIONAL COMMENTS: Structure
Perfectly preserved primary igneous tecture. Plagioclase occurs as coarse-grained radiating laths. Clinopyroxene forms pluri-centimetric poikilitic crystals and olivine forms coarse patches slightly flattened in a horizontal plane. A few mm-sized chlorite and actinolite veins crosscut the core, in Pieces 3 and 7. A vertical joint is in Piece 5.



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UNIT 5: OLIVINE GABBRO, METAGABBRO, MICROGABBRO, AND META-OLIVINE GABBRO

Pieces 1–15D

COLOR: Green-gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 65%–75%.
Crystal Size: 1–19 mm.
Crystal Shape: Subhedral to anhedral.
Crystal orientation: Piece 15 only.
Clinopyroxene - Mode: 15%–35%.
Crystal Size: 1–15 mm.
Crystal Shape: Anhedral.
Crystal orientation: Piece 15 only.
Olivine - Mode: 0–10%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Crystal orientation: Piece 15 only.
Iron oxide minerals - Mode: Trace%.
Comments: This section consists of olivine gabbro and gabbro that are variably altered and deformed. Pieces 1, 2, 4, and 5 are small pebbles that are heavily altered (30%–40% total alteration), so modal and grain-size estimates are difficult to do with certainty. Piece 1 is a microgabbro consisting of approximately 65% plagioclase and 35% clinopyroxene. Piece 2 is a medium-grained olivine gabbro (40%–50% altered) in which the clinopyroxene appears to define a preferred grain-shape orientation. Given the size of the piece and the amount of alteration it is difficult to determine whether this is a tectonic or magmatic fabric. Pieces 5 are medium- to coarse-grained gabbro/metagabbro (40%–60% total alteration) composed of approximately 65% plagioclase and 35% clinopyroxene. Pieces 6–13 are olivine metagabbro that is very consistent in texture, style of alteration, and modal mineralogy (75% plagioclase, 15% clinopyroxene, and 10% olivine). This interval is highly altered to secondary plagioclase (after plagioclase) and chlorite (after plagioclase and olivine) giving them a very pale minty green and white color. The olivine is totally altered, but was originally dendritic/poikilitic. Clinopyroxene is largely fresh and has a poikilitic habit; both olivine and clinopyroxene enclose subhedral to anhedral plagioclase crystals. Some of the larger clinopyroxene cores are green, but most clinopyroxene is brown. The top 2 cm of Piece 14 are similar in mineralogy and style of alteration to Pieces 6–13, but the remainder of the piece is relatively fresh. It consists of 65% plagioclase, 25% clinopyroxene, and 10% olivine. Olivine adjacent to the altered zone is decorated with sulfide minerals. Both olivine and clinopyroxene are dendritic/poikilitic, enclosing and wrapping around tabular plagioclase laths. Toward the bottom of the piece, olivine is much less altered (~15%) and is pale yellow. Piece 15 is again heavily altered to chlorite, and the protolith for Pieces 15A and 15B appears to be similar to Piece 14. Clinopyroxene in Pieces 15A and 15B is poikilitic and cores are rarely pale green; most are pale brown. Pieces 15C and 15D are porphyroclastic in addition to being heavily altered. Clinopyroxene porphyroclasts range up to 12 mm in size and are partially replaced along grain boundaries to brown amphibole. Olivine is totally replaced by chlorite and plagioclase is highly recrystallized.
SECONDARY MINERALOGY:
Talc/oxide minerals.
Comments: Replacing olivine.
Chlorite.
Comments: Replacing olivine, plagioclase, clinopyroxene.
Secondary plagioclase.
Comments: After plagioclase.
Smectite.
Comments: After plagioclase.
Serpentine/iron oxide minerals
Comments: After olivine.
Actinolite.
Comments: Replacing clinopyroxene.
Comments: The section is pervasively altered, ranging about 80%–90%. In Pieces 1–2, olivine is altered to talc and iron oxide minerals, and plagioclase is replaced secondary plagioclase. In Piece 3 (80%–90% alteration),

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clinopyroxene is rimmed by chlorite, plagioclase is replaced by chlorite. Olivine is altered to chlorite. On fracture surfaces are plagioclase, epidote(?), and oxide mineral veins. In Piece 3, the outer surface of the working half of the core has bulbous prehnite growing on epidote. In Piece 4 (90% altered) plagioclase and olivine are is chloritized. In Piece 6 chlorite and brown amphibole grows on clinopyroxene. Piece 7 is highly altered and has abundant actinolite and chlorite veins. Pieces 8A and 8B are the same as Piece 7; in Piece 8A the center of the piece is devoid of veins. Piece 9, is the same as Piece 8, but has less dense actinolite vein network. Piece 14 is crosscut by actinolite veins. Olivine is altered to serpentine and oxide minerals. Plagioclase is chloritized.

Veins

In Piece 1 there are actinolite microveins. In Piece 6–7 actinolite veins are present. In Piece 8B one major oblique <1 mm actinolite vein and minor actinolitie abnd chlorite veins are present. Piece 9, is the same as Piece 8, but shows less dense actinolite vein network. In Piece 10A the veining is diffuse, and a composite chlorite and albite vein is present. In Piece 10B, a 2 mm green amphibole and albite irregular diffuse vein is crosscut by actinolite vein. In Piece 15, a dense parallel set of actinolite microveins occurs; the same alteration features occur at the bottom of the piece, in the more flattened gabbro.

VEIN/FRACTURE FILLING:

Epidote, plagioclase, oxide minerals.

Orientation: On fracture surface.

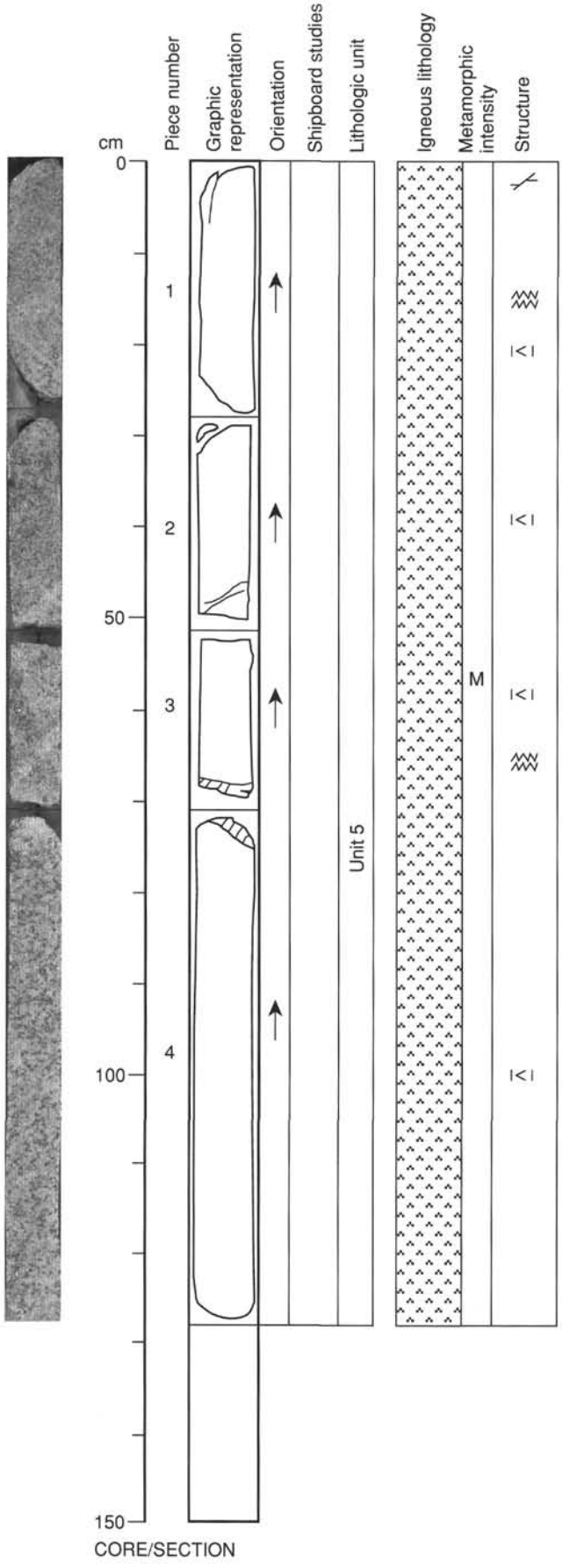
Actinolite and chlorite.

Size: <1 mm.

Orientation: Very dense veining.

ADDITIONAL COMMENTS: Structure

Primary igneous texture is variably overprinted by deformation. Pieces 1 and 2, are two small fragments showing a well-developed plastic mineral shape preferred orientation. In Pieces 3 to 13 the primary igneous texture is still present but extensively overprinted by a brittle deformation event: chlorite and actinolite veins forms swarms fracturing the host rock. The dominant vein orientation is subhorizontal to 20°. In Piece 8, a subhorizontal slickenside lineation is present on a fracture parallel to a chlorite vein dipping 50°. The fractured and altered zone ends at the top of Piece 14. A small recurrence of altered gabbro is at the top of Piece 15. The base of Piece 15 is made of highly deformed gabbro; elongated porphyroclastic textures are present on a total thickness of about 15 cm, down to the bottom of the section. The plastic foliation dip is 55°.



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UNIT 5: OLIVINE GABBRO

Pieces 1–4

COLOR: White and gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 65%–70%.
Crystal Size: 2–12 mm.
Crystal Shape: Subhedral to anhedral.
Crystal orientation: None.
Olivine - Mode: 20%.
Crystal Size: 2–13 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Clinopyroxene - Mode: 10%–15%.
Crystal Size: 2–25 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Iron oxide minerals - Mode: <1%.
Comments: The section consists of coarse-grained olivine gabbro showing subtle, but systematic, variations in modal mineralogy. Modal proportions change from approximately 60% plagioclase, 25% olivine and 15% clinopyroxene in the top of Piece 1 to approximately 75% plagioclase, 15% olivine and 10% clinopyroxene at the bottom of Piece 4. The variation is gradational over the entire length of the section. The crystal habit of clinopyroxene also varies downsection from prismatic/interstitial grains at the top to exclusively poikilitic at the bottom. Both olivine and clinopyroxene enclose plagioclase laths poikilitically and subophitically, indicating their intercumulus origin. The cores of poikilitic clinopyroxene are commonly greenish and the interstitial clinopyroxene is brownish. The top 4 cm of Piece 1 is sheared and contains large, blocky clinopyroxene porphyroclasts (up to 10 cm). The deformation continues weakly over most of Piece 1, but diminishes downsection from there. In Pieces 1, 2, and 3, very thin actinolite and chlorite veins, less than 1 mm thick, crosscut the core.
SECONDARY MINERALOGY:
Sulfide minerals.
Total Percent: Trace.
Chlorite.
Total Percent: 2
Comments: Replacing olivine.
Brown amphibole.
Total Percent: 2
Comments: After clinopyroxene.
Smectite/sec. plagioclase
Total Percent: 8
Comments: After plagioclase.
Comments: The alteration in the section is moderate, ranging about 10%–30%. Piece 1 is 15% altered. At the top of the piece actinolite veins highlight chlorite replacement of olivine. Clinopyroxene is relatively fresh. In Piece 2 alteration is about 10% (plagioclase is modally more abundant). At the bottom of the piece, a 0.5 cm trondjemite vein occurs. The vein is zoned: the inner part is green amphibole, and the outer part is plagioclase, possibly albite. In the gabbro, brown amphibole is a minor replacement phase on clinopyroxene. In Piece 3, the alteration ranges between 10%–15%, and a 0.5 cm wide trondjemite vein occurs. In the gabbro, chlorite replaces on plagioclase; chlorite replaces olivine.
VEIN/FRACTURE FILLING:
Magmatic.
Actinolite.
Size: <1 mm.
ADDITIONAL COMMENTS: Structure
Most of this section has preserved its primary isotropic igneous texture. Localized zones of moderately developed mineral preferred orientation, 1 cm to a several cm in thickness, are present in Pieces 1 and 3. The transition between the undeformed interval and these zones of localized and moderate solid-state deformation is gradational. In Piece 1, a grain-size variation allows definition of a primary igneous layering. Primary igneous layering and plastic deformation dip by 40°. A few mm-sized green chlorite-actinolite veins crosscut the igneous and plastic structures, in all the four pieces of this section. Their dip is relatively constant around 40°.

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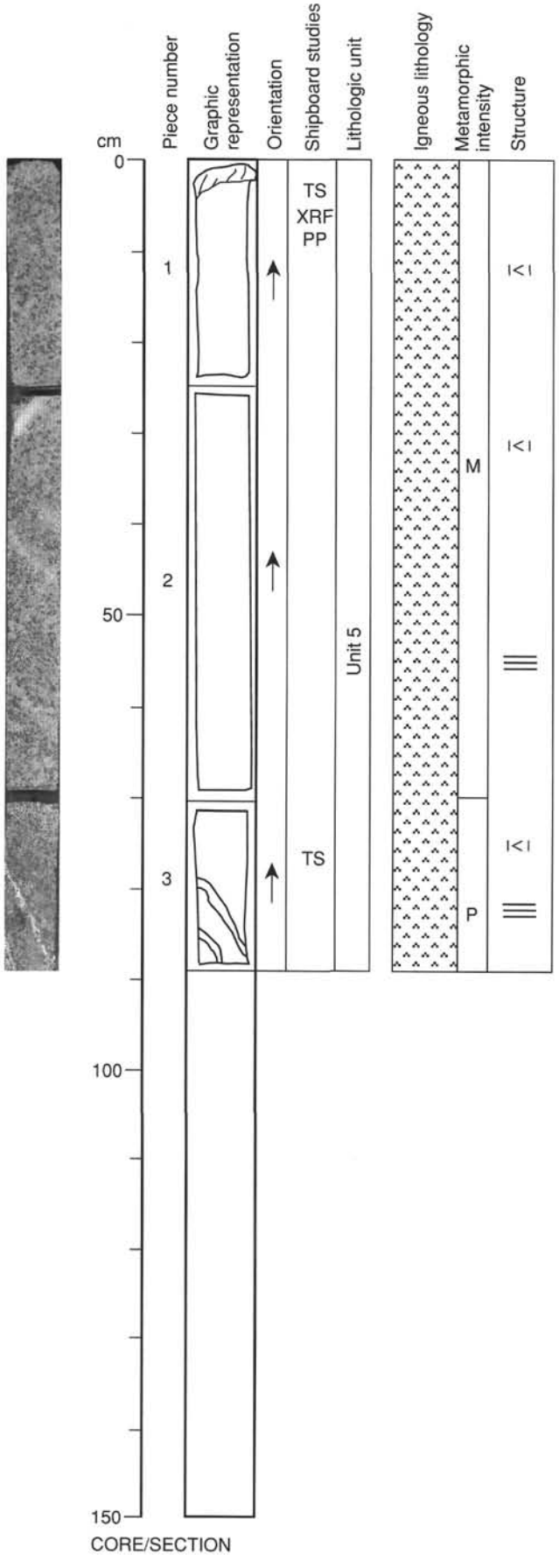

UNIT 5: OLIVINE GABBRO

Pieces 1–3

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%.
Crystal Size: 2–10 mm.
Crystal Shape: Subhedral.
Crystal orientation: None.
Olivine - Mode: 20%.
Crystal Size: 3–20 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Clinopyroxene - Mode: 20%.
Crystal Size: 5–20 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Iron oxide minerals - Mode: <1%.
Comments: The section consists of coarse-grained olivine gabbro with a lithology quite similar to the previous section. Olivine and clinopyroxene, 10–20 mm in size, enclose plagioclase laths poikilitically and subophitically. Those are sparsely distributed throughout the core. The poikilitic clinopyroxene is greenish and the interstitial clinopyroxene is brownish. In Pieces 1 and 2, very thin actinolite and chlorite veins, less than 1 mm wide, crosscut the core. In Piece 3, two trondhjemite veins, 1 to 2 cm in width, crosscut the piece. It contains abundant euhedral apatite crystals, and is relatively enriched in iron oxide and sulfide minerals relative to the host rock.
SECONDARY MINERALOGY:
Sulfide minerals.
Total Percent: Trace.
Chlorite.
Comments: Rimming and replacing olivine in patches.
Smectite/Secondary plagioclase.
Comments: Replacing plagioclase.
Brown/green amphibole
Comments: Replacing clinopyroxene.
Talc.
Comments: Minor replacement of olivine, bottom of Piece 3.
Comments: The alteration is variable along the section: it is moderate in Pieces 1 and 2, and locally high to pervasive in Piece 3. Pieces 1 and 2 are mottled green due to olivine alteration to chlorite. Piece 3 is cut by a magmatic vein (1–2 cm wide) from the center to the bottom of the piece, with a symmetric 3 cm wide alteration halo. In the vein, clinopyroxene is rimmed by chlorite, and is more or less extensively replaced by actinolite, plagioclase is replaced by secondary plagioclase. In the alteration halo, alteration is ~90%–95%. Green and brown amphibole occur in the alteration halo. Chlorite replaces olivine in patches. Actinolite replaces mafic phases. Near the veins at the bottom, olivine is also replaced by talc plus magnetite.
VEIN/FRACTURE FILLING:
Magmatic.
Size: 1–2 mm.
Orientation: Oblique.
Actinolite.
Orientation: Parallel to magmatic vein.
ADDITIONAL COMMENTS: Structure
Pieces 1 and 2 show a plastic fabric consisting of steeply dipping (50°–70°) aligned elongate olivine grains in a plagioclase matrix. The alignment becomes less organized downward through a gradational composition change to more pyroxene-rich rock in Piece 3. In Piece 2 the foliation is largely restricted to a band about 4 cm wide, but is pervasive in Piece 3. A magmatic vein about 1 cm wide and dipping 70° in Piece 3 is cut by thin (<1 mm) actinolite and chlorite(?) veins that dip 30°–40°. Other actinolite and chlorite veins in Pieces 1 and 2 have dips ranging from horizontal to 70°. Intersecting veins show no clear crosscutting relationships.

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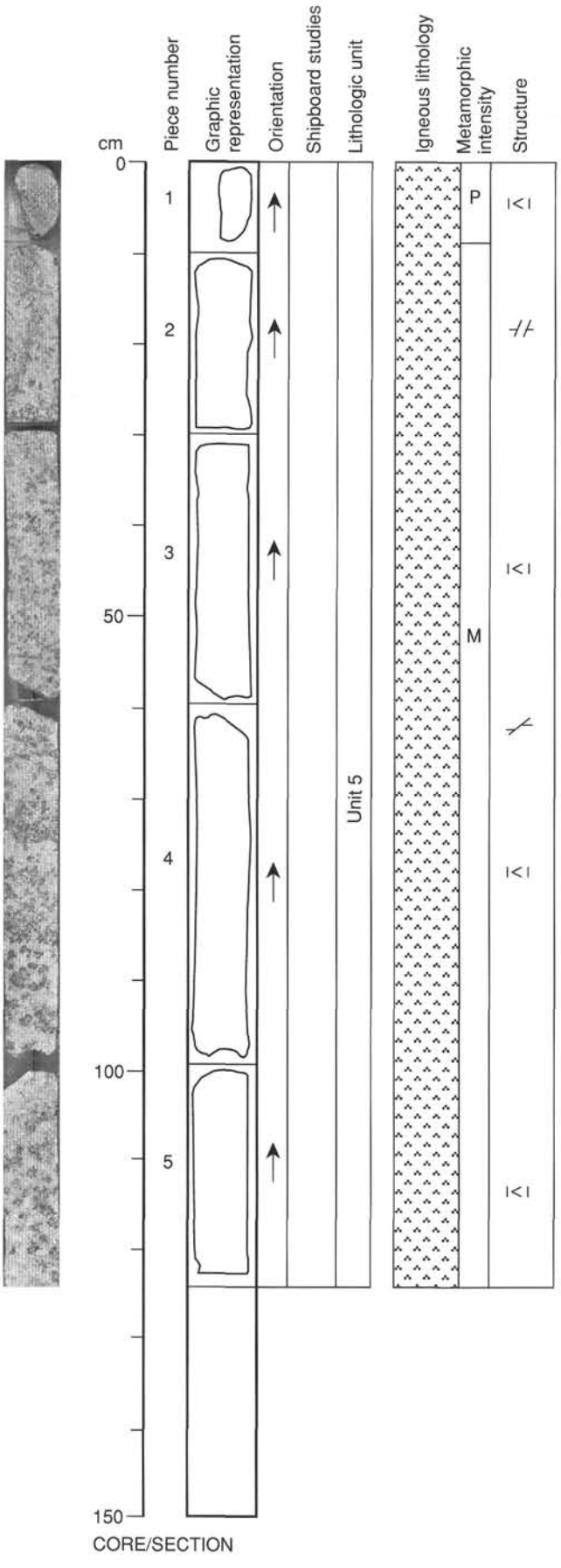

UNIT 5: OLIVINE GABBRO

Pieces 1–5

COLOR: Light gray with black spots.
PRIMARY STRUCTURE: Heteradcumulate.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: 15%–18%.
Crystal Size: 1–40 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Clinopyroxene - Mode: 10%–16%.
Crystal Size: 1–35 mm.
Crystal Shape: Anhedral.
Plagioclase - Mode: 65%–71%.
Crystal Size: 1–16 mm.
Crystal Shape: Euhedral.
Iron oxide minerals - Mode: 1%.
Comments: This section consists predominantly of coarse-grained olivine gabbro that is uniform in texture and modal composition (Pieces 1–5). Euhedral plagioclase occurs as a cumulus phase (1–16 mm), whereas anhedral olivine (1–40 mm) and clinopyroxene (1–35 mm) are intercumulus. The rock has a black and white spotted appearance due to the distribution of olivine, now partially altered to iron oxide minerals and chlorite(?), within plagioclase-rich rocks. The maximum grain size increases downward and reaches 40 mm in Piece 4. The intercumulus clinopyroxene (10%–16%) is dominantly green with brownish rims and is commonly rimmed by brown hornblende. Piece 1 is crosscut by a highly altered trondhjemite vein (5 mm wide); the margins of the vein are diffuse.
SECONDARY MINERALOGY:
Hornblende.
Total Percent: 0.5–1
Mode of Occurence: After clinopyroxene.
Sulfide minerals.
Total Percent: <0.5
Talc.
Magnetite.
Chlorite.
Smectite.
Mode of Occurence: After olivine.
Comments: The section is variably, but highly altered (50%–90%). Piece 1 (80%–90% altered) is crosscut by a trondjemite vein. Around the vein, olivine is pervasively altered to chlorite; far from the vein, it is replaced by talc and iron oxide minerals. Plagioclase is replaced by chlorite and smectite. Piece 2 is highly altered (up to 50%–60%). Olivine alters to talc, iron oxide minerals, and minor chlorite. Plagioclase is replaced by smectite. Piece 3 is similar to Piece 2. At the top and at the bottom are diffuse actinolite veins. Chlorite rims olivine, and olivine cores are replaced by talc and oxide minerals. Thin (<<1 mm) actinolite veins occur at the top of the piece.
ADDITIONAL COMMENTS: Structure
This section shows only local alignment of elongate grains in altered Pieces 1 and 2. Piece 2 has a subvertical one cm-wide band of olivine with microveining alteration parallel to the length of the band. The back side of the piece shows local development on small elongate pyroxene with tails in vertical orientation. Dark green veins of actinolite, chlorite(?), and smectite(?), several with white altered plagioclase halos cut the core pieces at variable angles, dipping 0 to 70°.

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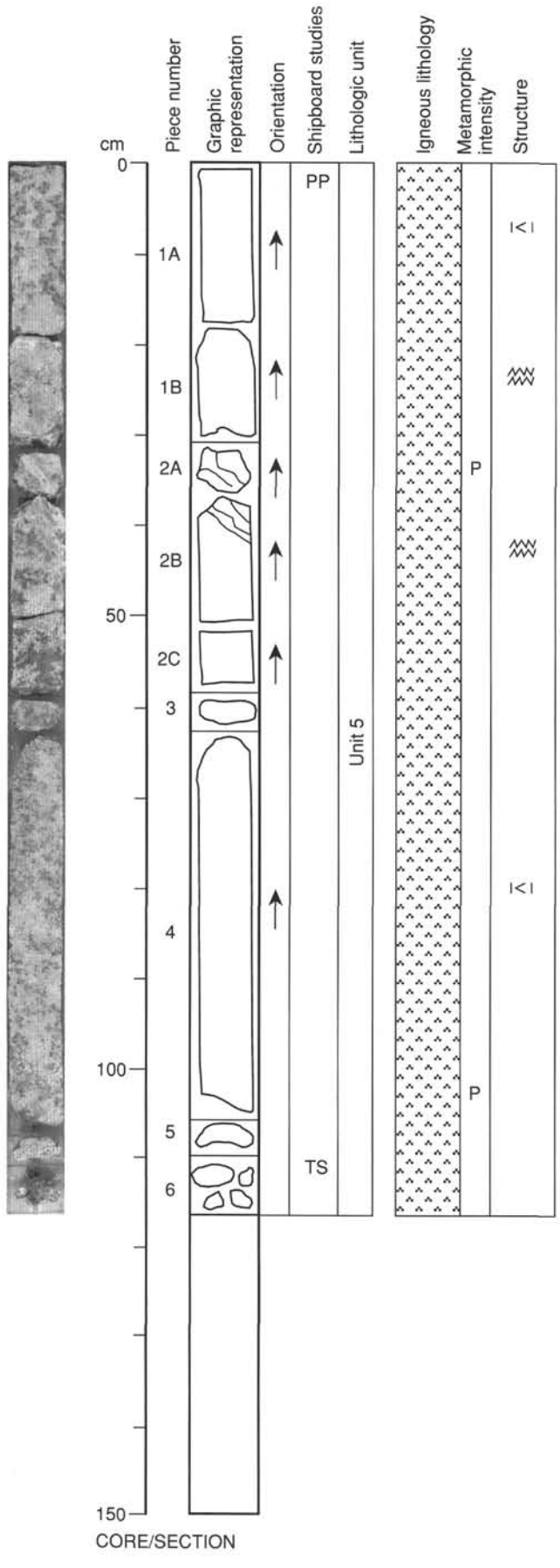

UNIT 5: OLIVINE GABBRO - METAGABBRO

Pieces 1A–6

COLOR: Light gray with black spots.
PRIMARY STRUCTURE: Heteradcumulate.
SECONDARY STRUCTURE: Porphyroclastic.
PRIMARY MINERALOGY:
Olivine - Mode: 22%–25%.
Crystal Size: 3–32 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Clinopyroxene - Mode: 10%–35%.
Crystal Size: 1–50 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Plagioclase - Mode: 61%–67%.
Crystal Size: 1–16 mm.
Crystal Shape: Euhedral/Anhedral.
Crystal orientation: None/tectonic
Iron oxide minerals - Mode: %.
Comments: This section is composed of coarse-grained olivine gabbro (Pieces 1–4) and metagabbro (Pieces 5–6). The olivine gabbro is modally uniform, and texturally similar to the previous section (923A-16R-1). The olivine gabbro contains euhedral cumulus plagioclase (1–16 mm) and anhedral intercumulus olivine (3–32 mm) and clinopyroxene (2–50 mm). Intercumulus clinopyroxene is typically green, with only minor rimming by brown clinopyroxene and/or brown hornblende. Maximum grain size reaches 50 mm in Piece 2C. Piece 1B has a coarse-grained gabbronorite layer(?) (>2.5 cm) at the bottom of the piece, consisting of euhedral to subhedral prismatic grains of orthopyroxene, anhedral plagioclase and clinopyroxene, with minor amounts of iron oxide minerals (approximately 50% plagioclase and 50% pyroxene). In Pieces 2A and 2B, the gabbronorite crosscuts the olivine gabbro at high angle, showing a strongly foliated, pyroxene-augen gneissic texture, the matrix of which is composed mostly of fine-grained recrystallized plagioclase, pyroxene, olivine and iron oxide minerals. Pieces 5–6 are highly altered metagabbro, which is primarily composed of 32%–35% clinopyroxene, 64%–67% plagioclase, and 1% iron oxide minerals.
SECONDARY MINERALOGY:
Hornblende.
Total Percent: 0.5–1
Sulfide minerals.
Total Percent: 0.5–1
Talc.
Magnetite.
Mode of Occurence: After olivine.
Chlorite.
Actinolite.
Mode of Occurence: After clinopyroxene.
Smectite.
Mode of Occurence: After olivine.
Comments: The section is variably, but pervasively altered. Piece 1 (alteration 85%–90%) is similar to the last pieces of gabbro in Section 153-923A-16R-1, and in Piece 1B exhibits grain-size variation. There is diffuse chloritization of olivine. The bottom of the piece is 100% altered. In Pieces 2A and 2B, a shear zone is present. In the shear zone in Piece 2B, clinopyroxene is flattened and elongationed, plagioclase is recrystallized around the clinopyroxene porphyroclasts. In Piece 2C, the gabbro is up to 90% altered. Clinopyroxene is replaced by actinolite. Piece 3 is 90% altered. Olivine is altered to chlorite, talc and iron oxide minerals, and plagioclase is replaced by secondary plagioclase.
Veins
In Piece 1B, there are actinolite veins at the bottom of the piece. In Piece 2, actinolite veins <1 mm, and clay mineral veins are present. In Piece 2B actinolite veins are parallel to the foliation. Clay mineral microveins cut across the piece.
ADDITIONAL COMMENTS: Structure
No preferred orientation of mineral shapes. Ductilely deformed rock occurs in shear zones in Pieces 1–2. The shear zones have very sharp boundaries and and are compositionally different (less olivine and brown pyroxene, neither of

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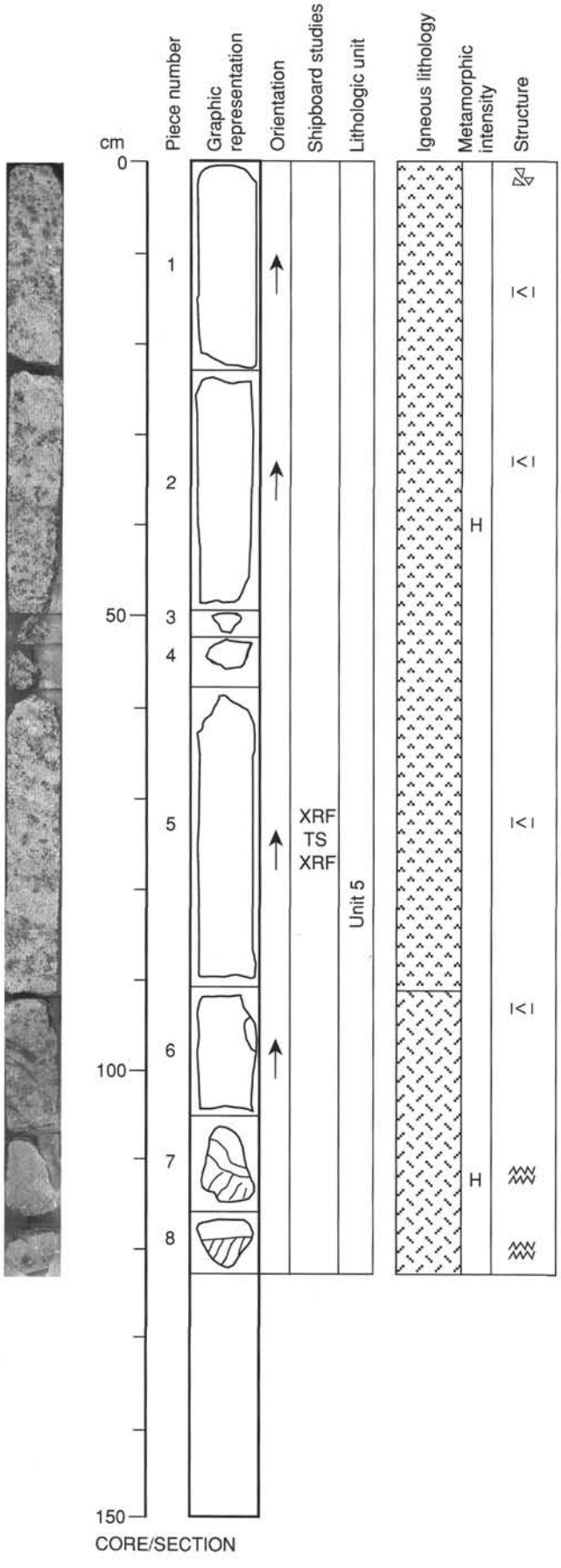
which are oikocrystic) from the wall rock. The deformational fabric in the shear zones is porphyroclastic and both zones show a normal sense of shear. Pyroxene contains dynamically rcrystallized tails and plagioclase is strongly recrystallized. Chlorite and actinolite veins occur in Pieces 1–2 and 4–6. Chlorite and actinolite veins crosscut the shear zone in Piece 2 and earlier white plagioclase-filled veins in Piece 2. All veins are up to 1 mm thick with variable dips (10°–70°). Pieces 5–6 are strongly altered and contain numerous fractures and veins.



153-923A-16R-3

UNIT 5: OLIVINE GABBRO AND GABBRO

Pieces 1–8

COLOR: Light gray with black spots.
PRIMARY STRUCTURE: Plagioclase heteradcumulate.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: 2%–23%.
Crystal Size: 3–48 mm.
Crystal Shape: Anhedral.
Crystal orientation: no
Clinopyroxene - Mode: 10%–52%.
Crystal Size: 1–55 mm.
Crystal Shape: Anhedral.
Crystal orientation: no
Plagioclase - Mode: 43%–71%.
Crystal Size: 1–20 mm.
Crystal Shape: Euhedral.
Crystal orientation: None.
Iron oxide minerals - Mode: 1%–3%.
Comments: This section is composed of coarse- to very coarse-grained olivine gabbro (Pieces 1–5), coarse-grained gabbro with microgabbro (Pieces 6) and microgabbro (Pieces 7 and 8). The olivine gabbro contains 18%–23% olivine, 10%–17% clinopyroxene, 64%–68% plagioclase, and 1% iron oxide minerals It contains euhedral cumulus plagioclase (2–20 mm) and anhedral intercumulus olivine (4–48 mm) and clinopyroxene (2–55 mm). In Piece 5 the grain size of intercumulus olivine and clinopyroxene exceeds 45 mm (maximum dimension). This piece shows a planar development of intercumulus phases, with alternating oikocrysts of clinopyroxene and intercumulus olivine producing a modal layering that varies in thickness from 1 to 5 cm. No magmatic orientation is in the cumulus phase (plagioclase). Piece 6 is coarse-grained gabbro, consisting of euhedral cumulus olivine (2%) and plagioclase (43%) and intercumulus clinopyroxene (52%) and iron oxide minerals (3%). Piece 7 consists of olivine-free microgabbro (composed of 28% clinopyroxene, 71% plagioclase, and 1% iron oxide minerals) in the top 5 cm and ~3 cm of very coarse-grained gabbro at the bottom. It is unclear whether the contact is intrusive or tectonic. The pyroxene-rich layer shows plagioclase recrystallization. Piece 8 is small and unoriented, but contains a 3 cm wide fragment of a layer/vein that is similar mineralogically and texturally to the layer/vein described in Piece 7, suggesting that the layer/vein may indicate the top side of the piece.
SECONDARY MINERALOGY:
Hornblende.
Total Percent: 0.5
Sulfide minerals.
Total Percent: <0.5
Talc.
Mode of Occurence: After olivine.
Magnetite.
Mode of Occurence: After olivine.
Chlorite.
Smectite.
Mode of Occurence: After olivine.
Actinolite.
Mode of Occurence: After clinopyroxene.
Comments: The section is variably, but on the whole, pervasively altered (70%–100%). Piece 1–5 (alteration 80%–90%) are highly altered and crosscut by clay mineral veins. Olivine alters to talc and iron oxide minerals. Piece 6 exhibits variable alteration (80% at the top, 100% at the bottom), with olivine altered to talc, and iron oxide minerals; clinopyroxene has a pinkish luster. Piece 7 exhibits grain-size variability: finer grained at the top, coarser grained at the bottom; at the contact is a plagioclase and green amphibole vein. Fine-grained intervals are moderately altered, whereas the coarser grained intervals are pervasively altered (90%–100%). Piece 8 is a coarse-grained gabbro in contact with microgabbro, with pervasive alteration. Clinopyroxene is altered to actinolite with chlorite rims; plagioclase is altered to smectite. The microgabbro is chloritized.
Veins
In Pieces 1–5, white clay mineral microveins cut the pieces. In Piece 7, clay minerals and actinolite veins are developed irregularly.

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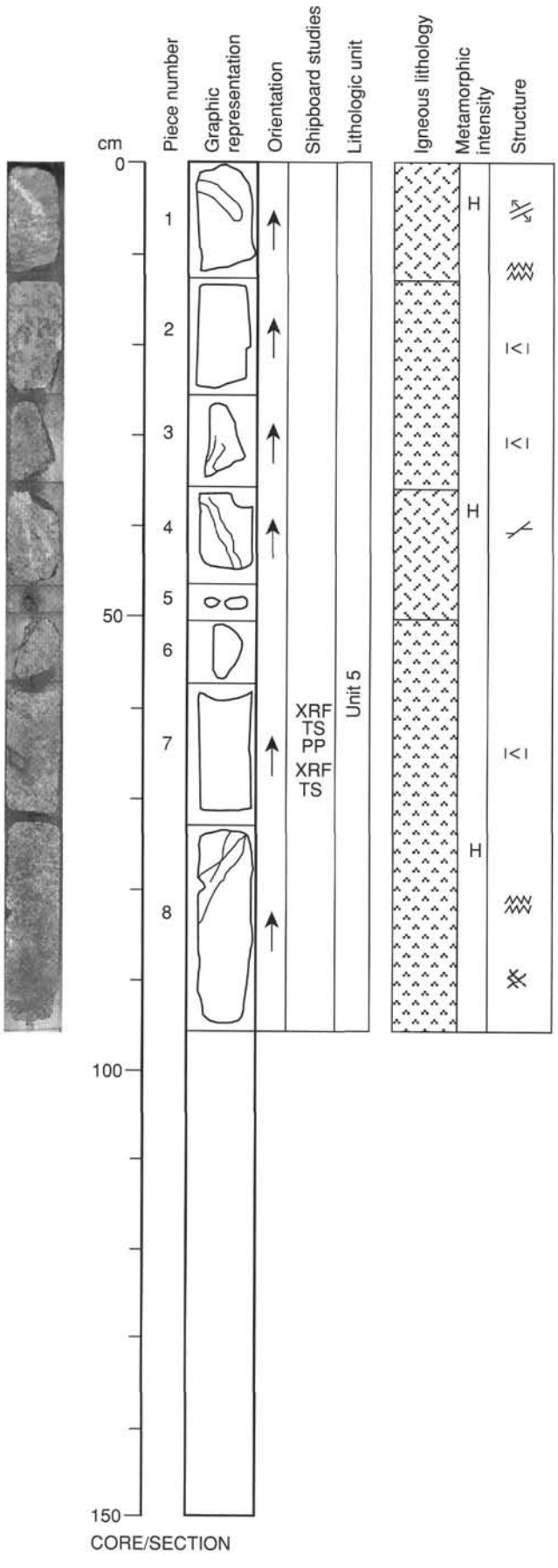
ADDITIONAL COMMENTS: Structure

The section is predominantly composed of coarse-grained poikilitic olivine gabbro that shows no preferred orientation of mineral shapes. Ductilely deformed rock occurs in shear zones in Pieces 7–8 at the contact of fine-grained granoblastic gabbro and pegmatitic gabbro. Near the shear zone, the fine-grained gabbro is weakly deformed but pyroxene in the pegmetitic gabbro is angular and appears cataclastic. The shear zone shows normal shear sense. Chlorite and actinolite veins occur in Pieces 1–5. All veins are ≤1 mm thick with variable dips (10°–70°).



153-923A-16R-4

UNIT 5: GABBRO-OLIVINE GABBRO, GNEISSIC OLIVINE GABBRO

Pieces 1–8

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: 0–20%.
Crystal Size: 1–18 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Clinopyroxene - Mode: 2%–45%.
Crystal Size: 2–45 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Plagioclase - Mode: 43%–68%.
Crystal Size: 1–16 mm.
Crystal Shape: Euhedral to subhedral.
Crystal orientation: None.
Iron oxide minerals - Mode: 1%–2%.
Comments: This section consists of coarse-grained gabbro (Pieces 1, 4–5), coarse-grained olivine gabbro (Pieces 2–3 and 6–7), and gneissic olivine gabbro (Piece 8) that is extremely heterogeneous, both modally and texturally. Piece 1 is gabbro with a coarse-grained hypidiomorphic texture, which is cut by highly altered trondhjemitic vein (1.2–1.5 cm thick). Pieces 2–3 are coarse-grained olivine gabbro consisting largely of euhedral cumulus plagioclase (63%–68%) and anhedral intercumulus olivine (12%–20%) and clinopyroxene (11%–24%). Clinopyroxene is predominantly zoned from green cores to brown rims, coated by brown hornblende. Pieces 4 and 5 are olivine-free and pyroxene-rich gabbro (55% clinopyroxene, 43% plagioclase, and 2% iron oxide minerals). Clinopyroxene is characteristically brown and subhedral prismatic in grain shape. In Piece 4, a trondhjemite vein (3–5 mm thick) cuts the gabbro. Pieces 6 and 7 are coarse-grained olivine gabbro with hypidiomorphic granular texture. Piece 8 is strongly deformed gneissic olivine gabbro, which is composed of porphyroclastic clinopyroxene (27%), aggregates of recrystallized olivine(12%) in augen, and a fine-grained matrix of recrystallized plagioclase (60%). A trondhjemite vein (5–7 mm thick) in Piece 8 cuts the gneissic olivine gabbro, perpendicular to the foliation, and branches into several thin veinlets (less than 5 mm) of actinolite and chlorite.
SECONDARY MINERALOGY:
Hornblende.
Total Percent: 0.5
Sulfide minerals.
Total Percent: 0.5
Talc.
Mode of Occurence: After olivine.
Magnetite.
Mode of Occurence: After olivine.
Chlorite.
Smectite.
Mode of Occurence: After olivine.
Actinolite.
Mode of Occurence: After clinopyroxene.
Comments: The section is variably altered between 10%–80%. Alteration in the trondhjemite vein in Piece 1 is pervasive (70%–80%). Plagioclase (replaced by secondary plagioclase) and a mafic phase (replaced by chlorite) occur in the vein. On the curved face of the piece, the vein shows talc and radiating green amphibole within plagioclase. Talc and chlorite diffusely replace around the vein. In the gabbro, clinopyroxene is quite fresh, rimmed by chlorite (back of the piece). Pieces 2–3 which show a higher modal abundance of olivine, are altered to about 10%–20%. Olivine is altered to serpentine and oxide minerals. Plagioclase is chloritized, clinopyroxene is quite fresh. Piece 4 is crosscut by a trondhjemite vein, which is relatively altered (60%–70%). The vein is zoned, with a chloritized mafic phase at the center, and plagioclase (altered to secondary plagioclase) at the margins. In the host gabbro, clinopyoxene is rimmed or partially replaced by actinolite. Piece 5 is 100% altered fragments. In Piece 6 alteration is about 50%–60%, the clinopyroxene is fresh, and the plagioclase partially altered to chlorite. Piece 7 is altered 40%–50%, clinopyroxene is altered to chlorite around the

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vein. Piece 8 is a foliated gabbro, the grain size is coarser at the top, and finer at the bottom, and a trondhjemite vein (apatite and oxide mineral bearing) cuts the piece. In the vein, green amphibole and secondary plagioclase occur. In the host gabbro, clinopyroxene is rimmed by brown amphibole and/or actinolite. Clinopyroxene grains are flattened and aligned.

ADDITIONAL COMMENTS: Structure

The rock in this section is composed of medium- to coarse-grained gabbro with locally well-displayed grain-size boundaries (Pieces 7 and 8). The first piece contains a 9 mm wide, gently dipping (11°) shear zone with elongated plagioclase grains in a fine-grained matrix. Grain-size reduction across the shear zone is very strong. An actinolite vein with a plagioclase mantle (alteration halo) occupies the upper central part of the piece. Piece 2 is a coarse-grained gabbro with a gently dipping (11°) actinolite and chlorite vein. Piece 3 has three subparallel chlorite veins that are subvertical. Piece 4 contains a subvertical magmatic vein with apophyses injecting between the clinopyroxene grains. This vein is cut across and offset by a subhorizontal fault dipping 7° toward 270° on the cut face. The fault plane is reactivated and filled with plagioclase. The separation as measured on the cut face is 11 mm and shows a reverse component. On the upper surface of the core piece the fault displays a dextral sense of movement as deduced from the separation of the magmatic vein. Piece 6 has a single, <1 mm wide chlorite vein. Piece 7 includes subhorizontal grain-size boundaries and a moderately dipping chlorite vein. In Piece 8, a subvertical (68°) fault zone, which is 7 mm wide, is occupied by anastomosing strands of chlorite veins. The subhorizontal plastic fabric defined by elongated plagioclase and clinopyroxene grains in the footwall shows downward drag approaching the fault zone suggesting a normal sense of movement along the fault.