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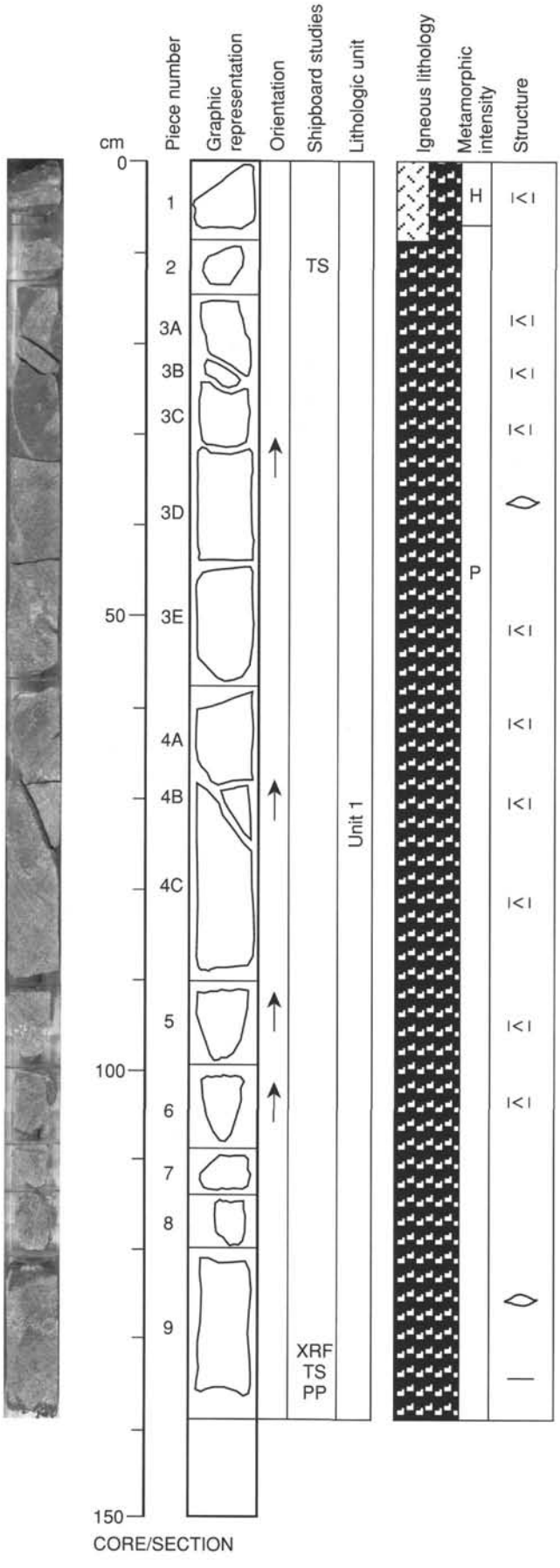

UNIT 1: METATROCTOLITE AND OLIVINE GABBRO

Pieces 1–9

COLOR: Green-gray.

PRIMARY MINERALOGY:

Plagioclase - Mode: 60%–71%.
Crystal Size: 1–7 mm.
Crystal Shape: Anhedral.

Olivine - Mode: 0–30%.
Crystal Size: 1–14 mm.
Crystal Shape: Anhedral.

Clinopyroxene - Mode: 0–40%.
Crystal Size: 1–14 mm.
Crystal Shape: Anhedral.

Comments: This section consists predominantly of metatroctolite (Pieces 2–9). Primary textures and mineralogy have been obscured by complete pseudomorphic replacement of mafic phases. The rocks are fine- to medium-grained and have a mottled green-gray appearance created by clots of fibrous actinolite that are outlined by rims of chlorite. The extensive alteration makes estimation of primary mineral proportions difficult. However, it is assumed that the actinolite and chlorite clots are predominantly after olivine since a few pseudomorphs of poikilitic clinopyroxene by pale brown amphibole(?) can be recognized. Plagioclase is commonly milky white, but may be stained orange-brown where adjacent to altered iron oxide and sulfide minerals. Piece 4A has a weakly developed preferred grain shape orientation and contains numerous thin chlorite veins that are steeply dipping. Piece 1 is a coarse-grained metagabbro and distinct from the other pieces in the section. Plagioclase is less altered (~75%) and recrystallized equant grains are outlined by chlorite, giving the rock a green color. Large clinopyroxene oikocrysts are relatively unaltered and have green cores, but are rimmed by brown clinopyroxene and/or amphibole.

SECONDARY MINERALOGY:

Actinolite.
Mode of Occurrence: After olivine and clinopyroxene.

Chlorite.
Mode of Occurrence: After olivine and clinopyroxene.

Brown amphibole.
Mode of Occurrence: After clinopyroxene.

Clay minerals.
Mode of Occurrence: After plagioclase.

Comments: The section is highly to pervasively altered (70%–90%), except Piece 1 where alteration is estimated at 40%. In Piece 1, olivine is replaced by talc, tremolite, iron oxide minerals, minor smectite and pyrite, and is rimmed by chorite. Plagioclase is slightly altered to secondary plagioclase, and cut by microveinlets of chlorite ± actinolite. Clinopyroxene is rimmed by actinolite and replaced by minor blebs of brown amphibole and fine-grained iron oxide minerals. In Pieces 2–9, the mafic phases are pervasively altered to fine-grained, amoeboid shaped pods with fibrous actinolitic cores and chlorite rims, with a trace of brown amphibole(?) after clinopyroxene. Plagioclase alteration is extensive adjacent to microcracks where it is replaced by actinolite, light green chlorite and, locally, white clay mineral aggregates (Pieces 5, 7, and 8), and is moderately altered away from the veins. Plagioclase grains are commonly enclosed in felted actinolite and chlorite mats, are cut by abundant microveinlets of chlorite and actinolite, and grain boundaries are anhedral. In Piece 5, yellow green pods composed of talc(?) and tremolite after olivine(?) are rimmed by chlorite and brown hornblende.

Veins

In Piece 1, a 1 mm chlorite vein cuts the piece; in Pieces 3A and 3B, a thin (0.1 mm) linear chlorite and amphibole vein is present; in Piece 3C, an irregular 3 mm wide white vein occurs. Minor alteration to secondary plagioclase occurs adjacent to the veinlets. Through Pieces 3B and 3C, a 1 mm wide actinolite and chlorite vein cuts the pieces. Pieces 4 and 5 are cut by fine <1 to 1 mm wide actinolite and chlorite veinlets oriented subhorizontally to subvertically. Piece 9 has a felsic vein (~1 cm wide) at the bottom and a patch (2 x 4 cm) of similar felsic material on the back of the piece. The vein consists of plagioclase and subhedral to euhedral brown amphibole that has been partially replaced by actinolite. Plagioclase may be altered to secondary plagioclase, with minor chlorite, and a trace of epidote. Minor quartz may be present.

ADDITIONAL COMMENTS: Structure

The entire section is composed of altered troctolite with a weakly to moderately

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developed shape preferred orientation of plagioclase grains and evidence for grain-size reduction. The first two unoriented samples do not display this fabric. Pieces 3A to 3C have a subhorizontal foliation, whereas Piece 3D shows a very faint subvertical foliation. This sharp apparent change in the orientation of the mineral fabric may be an artifact of extensive alteration and background pattern although brown amphibole grains seem also to be aligned subvertically. The last piece in the section is lacking any shape preferred orientation. Actinolite and chlorite and actinolite veins cut across the rock in most pieces. There is an actinolite vein with two overlapping segments in Piece 1. Actinolite veins occur in Piece 3; they are up to 2 mm wide and dip moderately to steeply (38° to 72°). They cut across, at least in one case (Piece 3D), the chlorite and actinolite veins. Chlorite and actinolite veins (<1 mm) make conjugate sets (Piece 4A) with subvertical and subhorizontal ones, and subhorizontal ones may be cutting across the subvertical ones although these crosscutting relations are generally difficult to establish. There is one plagioclase vein (magmatic vein ?) in Piece 3D that is nearly 1 cm wide and dips steeply (75°).

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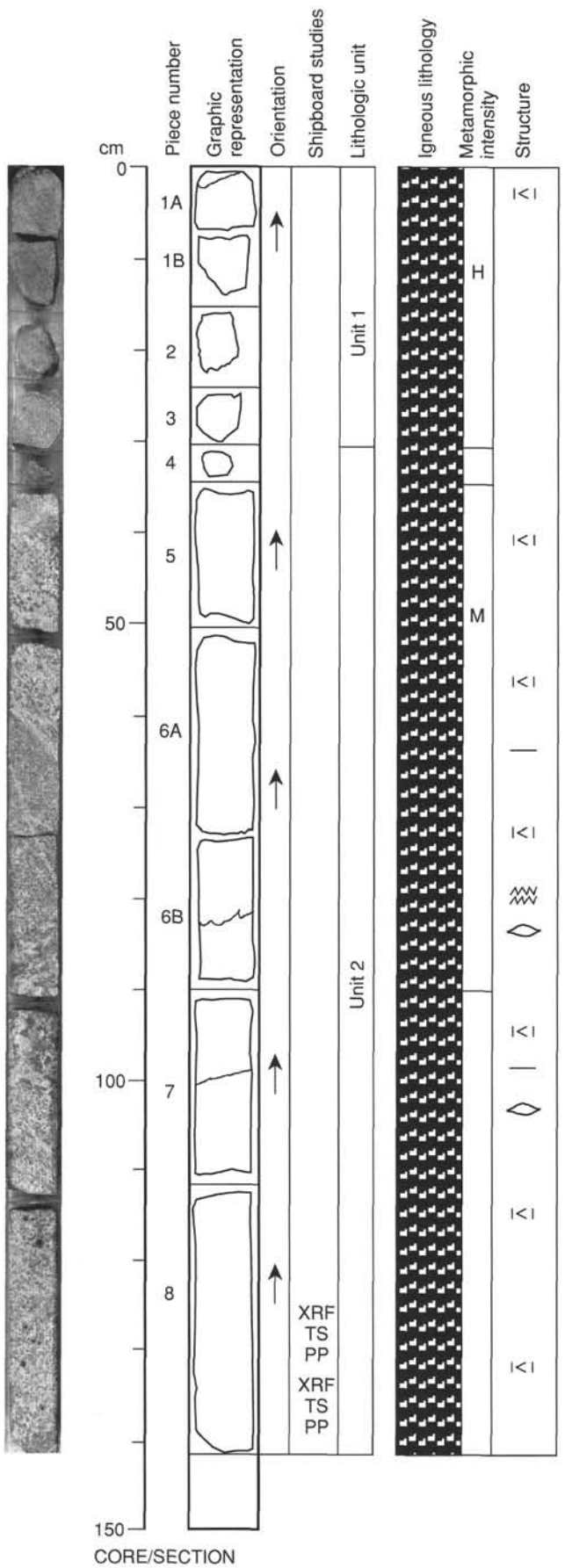

UNIT 1: METATROCTOLITE

Pieces 1A–3

COLOR: Green gray.
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 40%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral.
Comments: Pieces 1–3 are very strongly altered metatroctolite(?). Nearly complete conversion of maific phases to hydrous minerals has taken place.
SECONDARY MINERALOGY:
Brown/green amphibole
Comments: Replacing ferromagnesian phases.
Secondary plagioclase
Comments: Replacing plagioclase.
Comments: Pieces 1–3 contain fine amoeboid shaped pods with complex and variable corona structures after olivine (100% altered). The altered cores generally contain tremolite ± talc and are rimmed by chlorite, with patches of smectite and trace iddingsite. Clinopyroxene is altered to actinolite, chlorite, and fine-grained iron oxide minerals. Plagioclase is variably altered from moderate to pervasive and cut by microveinlets of actinolite and chlorite. The top of Piece 1 is cut by an 8 mm wide vein of chalk white plagioclase, dark green amphibole, actinolite, and chlorite. Plagioclase is altered to epidote and secondary plagioclase. The host rock adjacent to the vein contains abundant brown amphibole.
VEIN/FRACTURE FILLING:
Chlorite.
Size: <1 mm.
Orientation: Filling microcracks.
ADDITIONAL COMMENTS: Structure
A well-developed magmatic (?) fabric is preserved in Piece 1, in spite of the pervasive alteration. It is defined by the common orientation of elongated plagioclase (now chloritized) laths. The fabric appears planar, with a dip of 40°. Pieces 2 and 3 have a similar primary igneous texture but lack of any preferred orientation of ghost plagioclase. A moderately (35°) dipping magmatic vein crosscuts Piece 1.

UNIT 2: TROCTOLITE

Pieces 4–8

COLOR: Green gray/black.
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%–65%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 32%–40%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 1%–3%.
Crystal Size: 2–30 mm.
Crystal Shape: Anhedral.
Comments: The unit boundary was placed between Pieces 3 and 4 in this section, based primarily on the substantial decrease in alteration at this level. It is difficult to distinguish the identity of altered primary phases in the overlying strongly hydrothermally altered rock. This section, below the unit boundary, consists mainly of troctolite. Olivine gabbro occurs from the top 9 cm and bottom 5 cm of Piece 6 and top 8 cm of Piece 8. Olivine gabbro contacts troctolite with a small scale sheared boundary. The olivine gabbro is composed of 70% plagioclase, 17% clinopyroxene, 13% olivine and minor amount of iron oxide minerals. From the bottom 5 cm of Piece 6 to the top 8 cm of Piece 7, the grains are coarser, up to 30 mm in length, than that of top 9 cm of Piece 6 (<10 mm). Troctolite is almost free of clinopyroxene, excepting Piece 8 which contains clinopyroxene oikocrysts enclosing plagioclase and olivine poikilitically. Piece 8 is coarser than the rest of this interval troctolite which is marked by medium grain size.

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SECONDARY MINERALOGY:

Actinolite.

Comments: Replacing clinopyroxene.

Chlorite.

Comments: Replacing clinopyroxene and from olivine breakdown.

Brown amphibole.

Comments: Repalcing clinopyroxene.

Iron oxide minerals

Comments: After olivine.

Comments: Alteration is much lower below Piece 3 in this section, and Pieces 6A and 6B (~40%) are the freshest part of the section. In Pieces 4–8, olivine is altered to talc, iron oxide minerals, smectite, and chlorite. Clinopyroxene is slightly altered to actinolite and discontinuously rimmed by brown hornblende, which also occurs as an interstitial phase. Plagioclase is negligibly altered with minor veinlets of actinolite, chlorite, and trace epidote. Near macroscopic chlorite ± actinolite veins, plagioclase is highly altered developing a thin alteration halo adjacent to veins composed of secondary plagioclase. Rare fine-grained carbonate minerals occur after plagioclase in thin section.

Veins

In Piece 5 abundant thin (<<1 mm wide) chlorite and actinolite veinlets crosscut the sample, in two almost perpendicular directions. In Piece 6A, a 1 mm wide chlorite and actinolite vein crosscuts the contact between coarse- and medium-grained gabbro. Abundant subparallel thin (<<1 mm wide) chlorite actinolite veinlets occur above the 1 mm wide vein. The bottom of the piece is cut by fine <1 mm wide chlorite ± actinolite veinlets with associated 1–2 mm wide alteration halos of secondary plagioclase and chlorite-smectite after olivine. The veinlets continue at the top of Piece 6B. In Piece 8: 2 mm amphibole vein. The bottom of Piece 7 is cut by a similar chlorite actinolite vein, oriented subhorizontally, as is Piece 8 near the top. The veinlet in Piece 8 exhibits a narrow alteration halo similar to that observed in the other pieces.

ADDITIONAL COMMENTS: Structure

An altered subhorizontal irregular magmatic vein crosscuts Piece 5. Thin chlorite veins occur in Pieces 5 to 8. Their dips range from 20° to 65°. They have a high density at the top of Piece 6 only. Pieces 6 and 7 display relatively sharp and gently (20°) dipping grain-size boundaries between coarse- and medium-grained areas (three in Piece 6 and one in Piece 7). In Piece 6, one of these contacts is sheared. The coarse-grained gabbro below has suffered moderate strain parallel to this shear zone. A planar preferred orientation of olivine and plagioclase is well developed in Pieces 6 and 7, with a high dip (50° to 60°).

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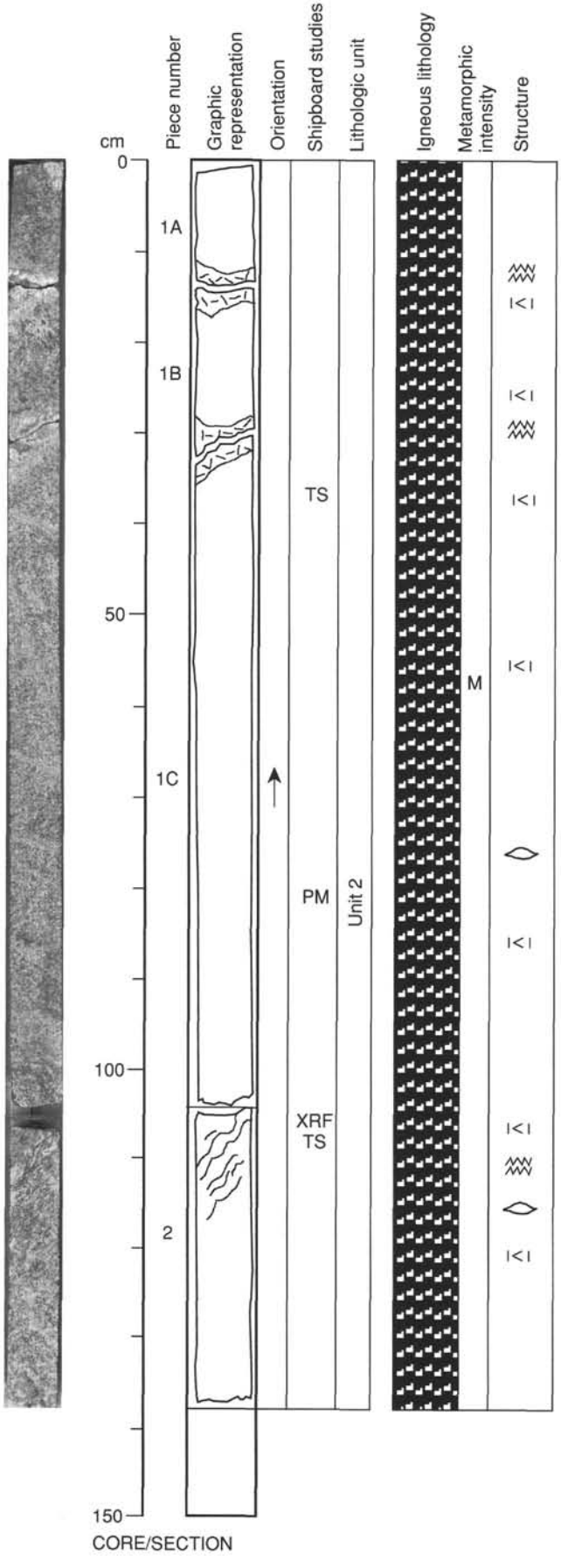
UNIT 2: TROCTOLITE AND OLIVINE GABBRO

Pieces 1A–2



COLOR: Gray and white.

PRIMARY MINERALOGY:

Plagioclase - Mode: 48%–49%.
Crystal Size: 1–12 mm.
Crystal Shape: Anhedral.

Olivine - Mode: 35%–50%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.

Clinopyroxene - Mode: 1%–17%.
Crystal Size: <20 mm.
Crystal Shape: Anhedral.

Comments: This section consists of relatively homogeneous troctolite that is crosscut by (1) magmatic veins, (2) chlorite veins, and (3) an oxide-bearing shear zone. Piece 1 is a relatively long continuous piece of troctolite (104 cm total length) that has broken along two magmatic veins into three subpieces (1A, 1B, and 1C). The veins range from 3 to 4 cm in width and are composed of plagioclase (now totally altered and recrystallized) and clinopyroxene(?) (replaced by a fine-grained, pale-green mineral with a radiating habit, probably actinolite). Iron oxide minerals occur in the veins and in the gabbro adjacent to the veins associated with actinolite and chlorite. Piece 1A has a very weakly developed preferred grain shape fabric. Plagioclase is milky white and largely recrystallized. Poikilitic clinopyroxene is emerald green and partially replaced by brown amphibole. The piece is modally heterogeneous in areas of large clinopyroxene oikocrysts, but otherwise, homogeneous. In Piece 1B poikilitic clinopyroxene is pale brown, although a few have pale green cores; some are partially replaced by brown amphibole. Chlorite and actinolite occur on grain boundaries replacing clinopyroxene and some plagioclase. Piece 1C is a long continuous interval (75 cm) of homogeneous troctolite crosscut by several thin veins that dip at ~25°. It has a very weakly developed preferred grain-shape fabric. The rock contains 1%–2% brown amphibole and very little clinopyroxene (<2%). Some of the brown clinopyroxene/amphibole is poikilitic at the base of the piece. The basal 3–4 cm of Piece 1C may be slightly deformed and related to the more strongly deformed troctolite seen in the top 12 cm of Piece 2. The orientation of the fabric in Piece 2 is ~55°. In the most highly deformed zone, (~3–4 cm wide), there are abundant iron oxide minerals as well as large porphyroclasts (up to 13 mm) of clinopyroxene and plagioclase. Olivine is altered throughout the core to dark granular masses in which individual kernels of relict olivine are surrounded by iron oxide minerals.

SECONDARY MINERALOGY:

Smectite.
Comments: Replacing olivine.
Iron oxide minerals
Comments: Replacing olivine.
Chlorite.
Comments: Replacing olivine and rimming brown amphibole.
Brown amphibole.
Comments: Possibly late magmatic, rimming clinopyroxene.
Sulfide minerals
Comments: Replacing clinopyroxene rims.
Tremolite.
Comments: Rarely rimming clinopyroxene.

Comments: Alteration of the section ranges from 20%–40% for Pieces 1A–1C, and increases to more than 50% in Piece 2. Plagioclase alteration is negligible to slight, except adjacent to thin chlorite ± actinolite veinlets, where it is slightly to moderately(?) altered to secondary plagioclase and chlorite. Olivine alteration is moderate (<40% generally) with replacement by talc, smectite, iron oxide minerals, and chlorite. Alteration is pervasive adjacent to magmatic and hydrothermal veins. Green clinopyroxene is discontinuously rimmed by brown amphibole, and locally replaced by actinolite. In the center of Piece 1B, an irregular-shaped pod occurs which is composed of radiating columnar grains of light brown amphbiole up to 5 mm in length, clinopyroxene replaced by actinolite and chlorite, chalky white plagioclase, and minor oxide minerals. At the top of Piece 2 in the highly sheared oxide-rich zone, oxide minerals are rimmed by fine-grained green to brown amphibole and chlorite. Olivine in this zone locally is altered to an orange clay mineral, smectite, tremolite, and chlorite. Plagioclase augen, rimmed by recrystallized

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fine-grained plagioclase, exhibit light brown cores and white rims. Plagioclase grains are cut by fine veinlets of actinolite ± chlorite. Clinopyroxene and orthopyroxene? in this zone exhibit narrow rims of green amphibole. Fine <1 mm wide actinolite ± chlorite veinlets cut the shear zone at about a 45° angle.

Veins

At the bottom of Piece 1A and top of Piece 1B a magmatic felsic vein, 15 to 25 mm wide, occurs which is composed of pale green amphibole after coarse-grained clinopyroxene, brown amphibole, fine-grained, felted mats of actinolite or tremolite (very pale green), plagioclase, magnetite, and apatite or quartz?. The vein margin in Piece 1A is marked by pervasive alteration of the host rock and in Piece 1B the margin is diffuse, with grain size gradually decreasing in size to merge with that of the troctolite. An XRD sample was taken on a green irregular patch from the magmatic vein. A similar vein occurs at the bottom of Piece 1B and the top of Piece 1C, which is 30–40 mm in width. The veins are oriented at ~45°. Piece 1C is cut by numerous ~1 mm wide chlorite and actinolite veins which exhibit associated alteration halos 1–2 mm wide, defined by highly altered plagioclase and olivine. Piece 2 is cut by similar fine veinlets of actinolite and chlorite.

VEIN/FRACTURE FILLING:

Magmatic vein.

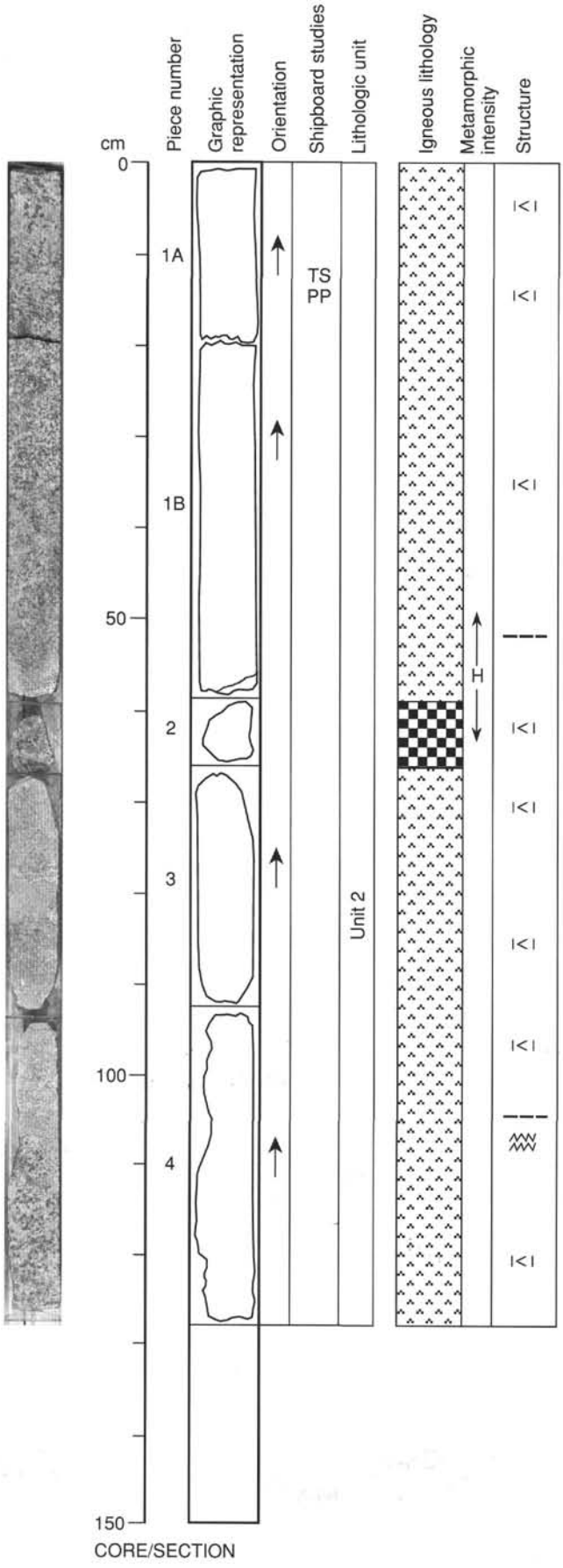
Actinolite.

Size: <1 mm.

Orientation: Pieces 1B, 1C, and 2.

ADDITIONAL COMMENTS: Structure

Primary igneous texture is devoid of any mineral shape preferred orientation but is locally overprinted by plastic deformation. This occurs in Piece 1 between about 60 and 80 cm from the top, where preferred orientation (mostly of olivine) is moderately developed, and in the upper part of Piece 2, where two closely spaced shear zones are observed with development of a gneissic texture. Asymmetric plagioclase and olivine grains suggest a sinistral sense of shearing within this zone. In Piece 2, the preferred orientation decreases progressively in intensity downsection away from the shear zones and disappears at the middle of the piece. Dip of the foliation planes is about 45°. Two magmatic veins (altered coarse-grained gabbro?) crosscut the upper part of Piece 1. These are at least 3 cm thick (these veins are located at the boundaries between subpieces 1A, 1B, and 1C). The margins of these veins are not very straight. The top margin of the upper vein is possibly sheared as suggested by the observed grain-size reduction. The sheared and unsheared margins of these veins are not parallel. The two pieces are crosscut by numerous (more than a dozen) regularly spaced chlorite veins with dips around 45°. These veins are almost perpendicular to the foliation.



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UNIT 2: TROCTOLITE-OLIVINE GABBRO-OXIDE GABBRO

Pieces 1A–4

COLOR: Pale gray/green.
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%.
Crystal Size: 0.2–12 mm.
Crystal Shape: Anhedral/subhedral.
Olivine - Mode: 20%–40%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 3%–40%.
Crystal Size: 1–15 mm.
Crystal Shape: Anhedral/subhedral.
Iron oxide minerals - Mode: <1%–5%.
Crystal Size: <4 mm.
Crystal Shape: Anhedral.
Sulfide minerals - Mode: <1%.
Crystal Size: <1 mm.
Crystal Shape: Anhedral.
Comments: This section consists of medium- to coarse-grained, interlayered olivine gabbro, oxide gabbro, and troctolite. The boundaries between the compositional layers are relatively sharp, possibly sheared (e.g. the bottom of Pieces 1 and 4, and the middle of Piece 4) and may contain clinopyroxene concentrations (middle of Piece 4). Piece 1 is troctolite that is strongly altered below ~30 cm into the piece. The last 1 cm of Piece 1B is coarse-grained gabbro that continues into Piece 2. The modal proportions of plagioclase and olivine in Piece 1 are variable, ranging from 80% plagioclase and 20% olivine at the top of Piece 1B to 60% plagioclase and 40% olivine in the base of Piece 1B. The grain size is also variable, and coarsest at the top of Piece 1A (5–8 mm maximum). About 1% oxide and sulfide minerals are distributed throughout the piece. Large (40 mm) oikocrysts of green-pale brown clinopyroxene, locally altering to brown amphibole, are distributed throughout the section. Pieces 1 and 4 contain irregularly shaped patches rimmed by actinolite, at least some of which is after clinopyroxene, crystalline iron oxide and sulfide minerals (chalcopyrite), and a core of felted tremolite, chlorite, and talc. Piece 2 is 100% altered coarse-grained oxide gabbro containing accessory crystals of a possible carbonate mineral that is clear, soft, but not reactive with HCl. Piece 3 and the top 13 cm of Piece 4 are highly altered troctolite or gabbro in which strong alteration of the mafic phases makes identification of the proportions of olivine vs. clinopyroxene difficult. The base of Piece 4 is fresh troctolite containing 3%–5% fine, poikilitic clinopyroxene and 3% disseminated iron oxide and sulfide minerals.
SECONDARY MINERALOGY:
Actinolite/tremolite
Total Percent: 0–40
Comments: Replaces clinopyroxene.
Chlorite.
Total Percent: <5
Comments: Replaces clinopyroxene/olivine.
Hematite.
Total Percent: Trace.
Comments: Repalcing clinopyroxene.
Comments: Alteration is heterogeneous downsection from 20% at the top of Piece 1 to 50%–60% in the bottom of Piece 1B, and reaching 70%–80% in the bottom of Piece 3. Olivine alteration ranges from 20% to 100% and is variably replaced by talc, tremolite, chlorite, smectite and iron oxide minerals. In highly to pervasively altered zones olivine exhibits moderately to well-developed coronas of tremolite cores and dark green chlorite rims with minor pyrite. Clinopyroxene is altered 50%–100% to actinolite, chlorite, iron oxide minerals and minor brown amphibole, which also occurs as an intersitial phase. Brown amphibole is especially well developed in Piece 2, as are ameoboid-shaped tremolite-chlorite pods after olivine. Piece 2 is a coarse-grained, oxide gabbro which is highly to pervasively altered with coarse-grained clinopyroxene pervasively altered to actinolite and fine-grained iron oxide minerals. Magnetite with inclusions of apatite is rimmed by green amphibole and chlorite. Plagioclase is moderately to highly altered to secondary plagioclase, epidote, and is cut by abundant fine veinlets of actinolite and chlorite.
Veins
Piece 1A is cut by a fine, <1 mm wide, actinolite ± chlorite veinlet, adjacent to which

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olivine is pervasively altered to chlorite. Piece 2 is cut by a 1 mm wide veinlet of epidote and abundant fine veinlets of actinolite and chlorite (<1 mm wide). The epidote veinlet cuts the fine-grained actinolite veins. Piece 3 contains a 5 mm wide vein of intergrown actinolite with minor chlorite (after clinopyroxene?), which exhibits a diffuse margin with white plagioclase. The vein is cut by a fine <1 mm wide epidote veinlet which is oriented vertically and cuts the actinolite vein at a high angle. A subhorizontal chlorite veinlet occurs about 45 mm below the actinolite vein, which pervasively alters adjacent olivine and clinopyroxene. Piece 4 is cut by a diffuse vein (5 mm wide) of actinolite and chlorite (after clinopyroxene?) with diffuse margins and a discontinuous rim of plagioclase, and a fine vein of actinolite and chlorite. The top side of the piece is lined by epidote.

VEIN/FRACTURE FILLING:

Chlorite and actinolite.

Plagioclcase and epidote.

Orientation: Parallel to open fractures.

ADDITIONAL COMMENTS: *Structure*

The primary igneous texture, devoid of any shape preferred orientation, is preserved in all pieces. The only measurable magmatic structures are an igneous contact at the very bottom of Piece 1, which is moderately dipping(20°) and separates medium-grained gabbro (above) from coarse-grained gabbro (below and Piece 2), and a thin subhorizontal coarse-grained interval at the middle of Piece 4. A faint subhorizontal shear zone crosscuts this coarse-grained interval. Veins are moderately abundant and present in all pieces. Most of these veins are chlorite-actinolite veins dipping moderately (<50°). A few veins of possible magmatic origin (made of epidote and plagioclase) occur in Piece 3 and have a subvertical orientation.

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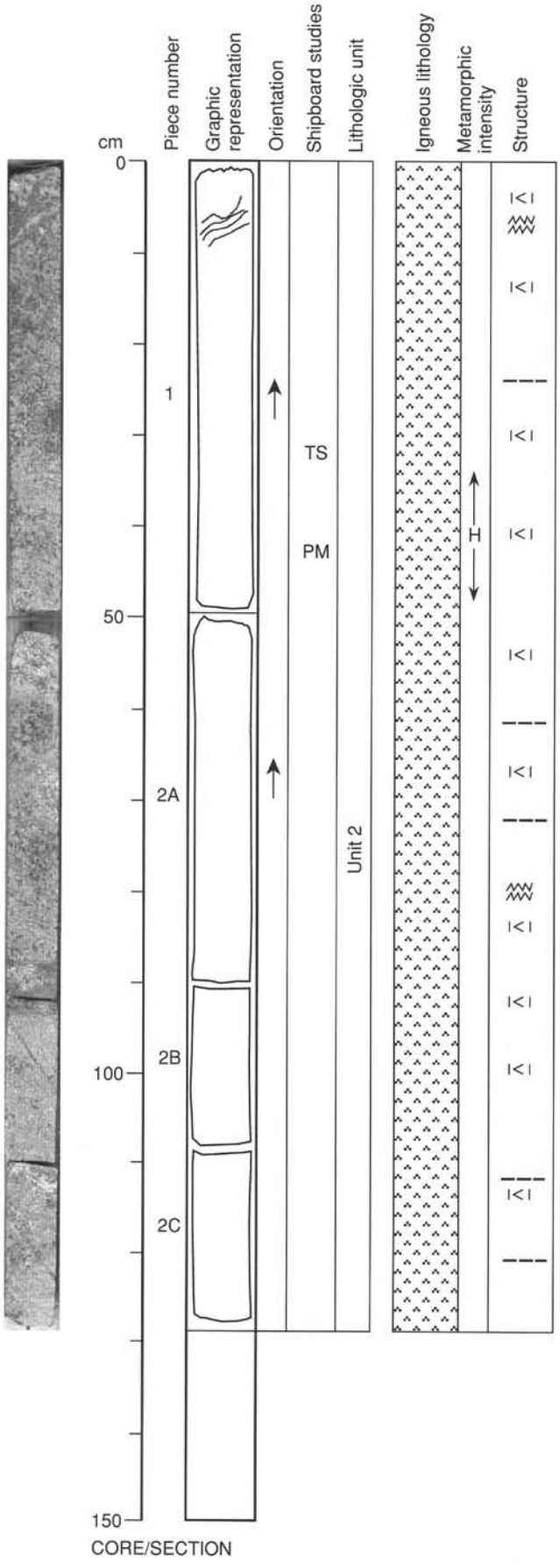

UNIT 2: META-OLIVINE GABBRO

Pieces 1–2C

COLOR: Green-brown.

PRIMARY MINERALOGY:

Plagioclase - Mode: 65%.
- Crystal Size: <10 mm.
- Crystal Shape: Anhedral.
- Crystal orientation: None.

Olivine - Mode: 23%–26%.
- Crystal Size: 5–13 mm.
- Crystal Shape: Anhedral.
- Crystal orientation: None.

Clinopyroxene - Mode: 8%–11%.
- Crystal Size: 17–50 mm.
- Crystal Shape: Anhedral.
- Crystal orientation: None.

Comments: This section consists of generally medium-grained meta-olivine gabbro with occasional coarse-grained zones. The olivine gabbro protolith was composed of 65% plagioclase, 23%–28% olivine, 8%–11% clinopyroxene and minor iron oxide minerals; the distribution of primary olivine and clinopyroxene is slightly heterogeneous. Plagioclase commonly occurs as equant recystallized grains, but occasionally primary lath outlines are preserved. Olivine usually has a highly irregular lobate form and partially encloses plagioclase and green clinopyroxene; it is in turn partially rimmed by pinkish brown clinopyroxene (notably in Piece 1). Clinopyroxene occurs as sparse, angular, intercumulus grains (1–2 mm in size); however, these are frequently orientated in parallel forming large (up to 50 mm) chadacryst-dominated oikocrysts. Clinopyroxene is usually pinkish brown, but larger grains may have greenish beige cores. The inter-relationships between green and brown clinopyroxene, olivine and plagioclase suggest that, like plagioclase, green clinopyroxene crystallized before olivine and that pinkish brown clinopyroxene was the last intercumulus phase. Coarse-grained zones occur in all pieces. They have diffuse, subparallel or diverging boundaries suggesting (if they are related features) that they are lens shaped. They are highly variable in texture, but generally have the appearance of being veins or melt segregations. Five broadly similar subparallel coarse zones occur in Pieces 1, 2A (two), and 2C (two). These consist of large (up to 15 mm) subhedral altered (?clino)pyroxene, smaller euhedral to subhedral plagioclase laths (less elongate than in the olivine gabbro and usually totally recrystallized) and chlorite after interstitial mafic minerals. The 5 cm wide zone at the top of Piece 2A is distinguished from the other zones by having large (5 by 15 mm) euhedral to subhedral stubby plagioclase laths with altered cores and by having only interstitial mafic minerals (now totally replaced by chlorite and ?green amphibole). The zone at the top of Piece 2C has been sheared. A complex 6 cm wide horizontal zone occurs across the base of Piece 2A and the top of Piece 2B. It contains large altered (?clino)pyroxene ± altered olivine + iron oxide minerals + pyrite + chalcopyrite + epidote. A 10 mm wide shear zone at the top of Piece 1 contains lenses of recrystallized plagioclase and chlorite + brown amphibole after mafic minerals.

SECONDARY MINERALOGY:

Talc.

Comments: Replacing olivine.

Chlorite.

Comments: Replacing olivine and clinopyroxene.

Tremolite/actinolite

Comments: Replacing clinopyroxene.

Magnetite.

Comments: After olivine.

Sulfide minerals

Comments: Rimming clinopyroxene.

Plagioclase.

Comments: Replacing plagioclase.

Comments: Alteration in this section is highly variable downsection with pervasively altered zones associated with segregations of evolved melt. Away from these pods and veins total alteration varies from 30% to 60%. Olivine is altered 50% to 100% with variable development of alteration coronas. Secondary phases include variable amounts of tremolite, talc, chlorite, iron oxide minerals, and pyrite. In the most highly altered zones, olivine may be pervasively replaced by smectite, chlorite, and fine-grained pyrite, which

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form irregularly shaped olive green pods (Piece 2A). Clinopyroxene is altered <10% to 100% with alteration phases including actinolite, chlorite, and fine-grained iron oxide minerals. Brown amphibole forms discontinuous rims and blebs after clinopyroxene and occurs rarely as an interstital phase. Plagioclase is slightly to moderately altered to secondary plagioclase, and when adjacent to clinopyroxene is rimmed and cut by actinolite and chlorite. Alteration in segregation pods and veins (20–40 mm wide) in Pieces 1 and 2A–2C, is characterized by pervasive replacement of clinopyroxene by actinolite, with lesser amounts of secondary clinopyroxene and fine-grained iron oxide minerals. Plagioclase in these zones is variably altered to secondary plagioclase, actinolite, chlorite (as veinlets and rimming grains), and minor epidote. In the bottom of Piece 2A, zoned plagioclase grains are pervasively replaced in their cores by pale green yellow epidote, amphibole, and chlorite. These pockets also contain abundant apatite and magnetite. Oxide minerals in these pods are rimmed by dark green amphibole and more rarely chlorite.

Veins

The shear zone in the top of Piece 1 contains abundant actinolite and chlorite which form thin <<1 mm wide subparallel veinlets in a concentrated zone about 3 mm wide. Fine actinolite ± chlorite veinlets occur throughout this piece. Piece 2A contains 1–2 mm wide actinolite and chlorite veinlets which are oriented at a low angle. Adjacent to these veins, in this piece as well as others, adjacent mafic phases are highly to pervasively altered. In Piece 2B, the top is cut by a fine <1 mm wide veinlet of epidote, and a 1 mm wide, discontinuous vein of olive-green smectite(?). Piece 2C is cut by a 10 mm wide and 20 mm wide set of magmatic veins which contain abundant actinolite after clinopyroxene. The bottom vein exhibits a diffuse boundary with the host rock.

VEIN/FRACTURE FILLING:

Chlorite and actinolite.

Size: <1 mm.

ADDITIONAL COMMENTS: Structure

The rock does not appear to have any preferred orientation resulting from magmatic or penetrative plastic deformation. Textural variations occur in the form of "pods" made of coarse-grained gabbro (Pieces 1, 2A, and 2C). At the top of Piece 2A, coarse euhedral plagioclase crystals show macroscopic evidence of zoning. Three cm-scale and moderately dipping ductile shear zones cut the gabbro at the top of Piece 1, a second at the bottom of Piece 2A, and a third coinciding with a magmatic vein. In this last vein, shear sense indicators (asymmetric chloritized pyroxene crystals) record normal sense movements. Minor shearing also took place along some chlorite veins at the top of Piece 2C. Millimeter-scale green chlorite (+actinolite?) veins are relatively abundant in this section. They are present in all pieces. Spacing between two adjacent veins ranges from of a few centimeters or less in vein "swarms", to a few decimeters. Vein dip ranges from 20° to 60°. Later yellowish, steeply dipping veins cut the green ones at the top of Piece 2B.

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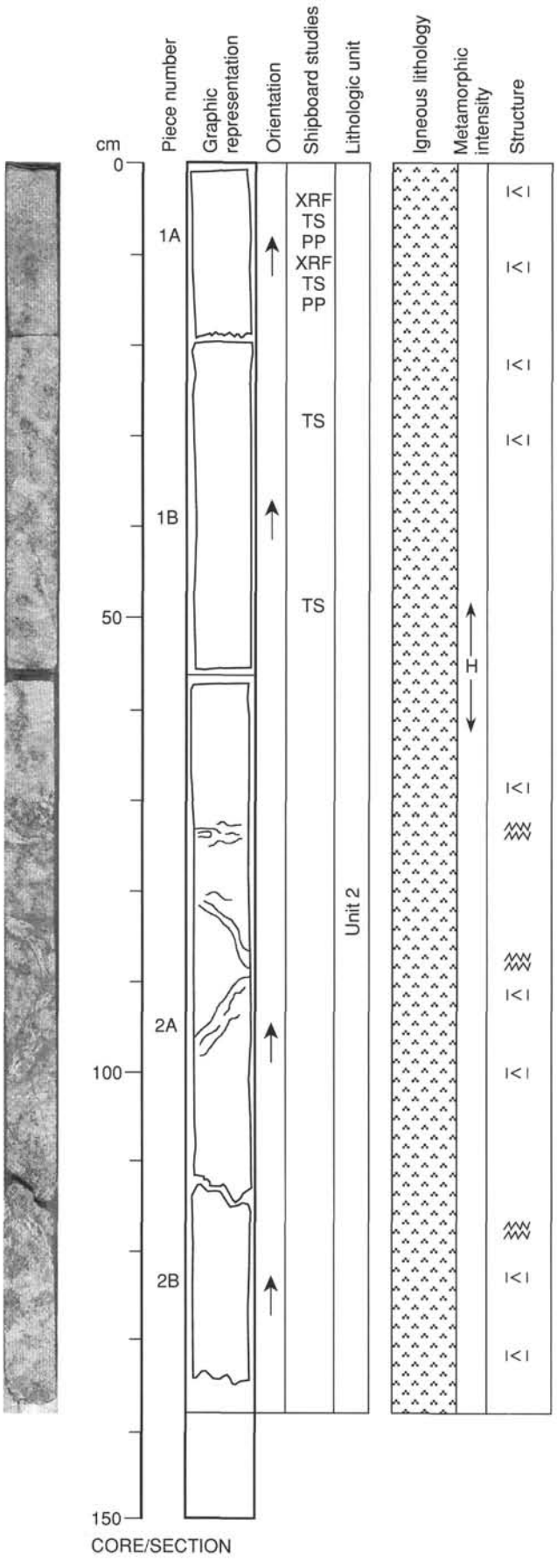

UNIT 2: OLIVINE GABBRO

Pieces 1A–2B

COLOR: Gray.
PRIMARY MINERALOGY:
Plagioclase - Mode: 59%–62%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Clinopyroxene - Mode: 22%–23%.
Crystal Size: 1–6 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Olivine - Mode: 12%–15%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Orthopyroxene. - Mode: 0–25%.
Crystal Size: 3–15 mm.
Crystal Shape: Subhedral to euhedral.
Crystal orientation: None.
Comments: The dominant lithology in this section is a modally and texturally heterogeneous, coarse-grained olivine gabbro with an irregular injection(?) of oxide gabbronorite(?). The olivine gabbro is mostly composed of euhedral to subhedral cumulus plagioclase (2–10 mm in size) and anhedral, intercumulus olivine (1–8 mm) and clinopyroxene (1–6 mm). Clinopyroxene is brown, varies in abundance from 15–30 modal%, and poikilitically to subophitically encloses plagioclase. The modal proportion of olivine ranges from 5%–30%. Plagioclase abundance is relatively uniform (59–62 modal%). Piece 1B contains several large grains of euhedral to subhedral orthopyroxene(?) (up to 10 mm) at the middle of the piece. Minor segregations of iron oxide minerals in this same area are accompanied by magmatic plagioclase + pyroxene veins crosscutting the host olivine gabbro. Pieces 2A and 2B are heterogeneous in their lithology. Olivine gabbro is crosscut by two probable dikes of oxide gabbronorite(?) (1–5 cm thick; 60% plagioclase, 25% orthopyroxene, 10% clinopyroxene, 5% iron oxide minerals) at 13–18 cm and 26–43 cm from the top of Piece 2A, and 0–15 cm from the top of Piece 2B. Orthopyroxene(?) grains are brownish gray and euhedral to subhedral. No olivine was observed. Iron oxide minerals are typically observed as thin segregation veinlets (<5 mm thick) along the border of these dikes.
SECONDARY MINERALOGY:
Talc.
Total Percent: <5
Tremolite/actinolite
Total Percent: <5
Comments: Replacing clinopyroxene.
Brown hornblende .
Total Percent: <2
Chlorite.
Total Percent: <10
Comments: After olivne and clinopyroxene.
Smectite.
Comments: After olivine.
Magnetite.
Total Percent: <5
Comments: After olivine.
Green amphibole.
Comments: Replacing, rimming clinopyroxene.
Comments: Alteration in this section is complex and heterogeneous, with average background alteration varying from 40% to 60%. Olivine alteration characteristically forms complex coronas, which include variable amounts of smectite, talc, iron oxide minerals, tremolite, and well-developed zoned rims of chlorite. In Piece 1, these pods are dominated by tremolite with chlorite rims. In Piece 1B, these coronas are especially well developed giving the rock a spotty appearance. Olivine in this piece is highly to pervasively replaced forming dark blue, black, red, and orange pods, 5 to 7 mm in diameter. Coloration is due to replacement by chlorite, smectite, iddingsite, clay minerals, and a trace of pyrite. These pods rarely rimmed by oxidized zones composed of fine netveins of clay minerals, which gives plagioclase an orange color. Alteration is most intense adjacent to veinlets and veins.

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Clinopyroxene is moderately to highly altered to actinolite, with minor chlorite, iron oxide minerals, and brown hornblende. Brown hornblende also forms as an interstitial phase. In the oxide shear zones in Piece 2A, oxide minerals are enclosed by green amphibole and lesser amounts of chlorite. In these zones, pyroxene porphyroclasts are rimmed by actinolite, with well-developed tails, and minor chlorite. Plagioclase in the shear zones contains light brown cores and white rims, and is crosscut by abundant actinolite ± chlorite veinlets.

Veins

Piece 1A is cut by a high angle, 1 mm wide, white zeolite veinlet and three to four discontinuous veinlets of chlorite, which are subparallel and cross the core at ~45° angle. Piece 1B is cut by multiple actinolite veinlets with variable orientations. An ~3 mm wide tapering actinolite vein occurs about 3 cm from the top of the core. A second 3 mm wide vein, which may be partitially related to shear occurs at the base of the piece forming an actinolite vein network associated with chalk white plagioclase. The adjacent plagioclase is cut by very thin, <<1 mm wide, actinolite veinlets, which are oriented at an angle to the main vein. A fine <<1 mm wide cream-colored zeolite veinlet cuts the plagioclase adjacent to this vein. Piece 2A is heavily veined with actinolite and chlorite. One set of diffuse actinolite veinlets (~1 mm wide) is oriented subhorizontal occurs near the top of the core. At about 12 cm from the top there is a dark green discontinuous, chlorite veinlet ~1 mm wide, which is oriented vertically. Near the actinolite-rich area associated with the oxide-rich shear zone, the core is netveined with abundant very fine actinolite veinlets. A 1 mm wide, actinolite ± chlorite vein, oriented at about 30°, occurs ~4 cm from the base of the piece. Adjacent to this vein, clinopyroxene is pervasively replaced by actinolite. Piece 2B is netveined by very fine actinolite veinlets.

VEIN/FRACTURE FILLING:

Plagioclase.

Size: 2 mm.

Plagioclase, amphibole, ± chlorite.

Size: 0.5 mm.

Plagioclase, amphibole, and clay minerals.

Size: 0.2-0.6 mm.

ADDITIONAL COMMENTS: Structure

The first piece in this section shows a weakly developed foliation. This pervasive, subhorizontal planar fabric is predominantly due to closely spaced microcracks and microveins with coatings of a green mineral (chlorite?). Elongate plagioclase and interstitial altered pyroxene grains may also contribute to the fabric. Piece 2 shows a couple of zones (20 mm thick) of similar subhorizontal microveins in the upper 12 cm of the piece. The rest of the piece is dominated by three thick (5–40 mm) shear zones consisting of elongated, altered pyroxene in a sheared and recrystallized(?) matrix of plagioclase. Oxide and/or sulfide(?) and dark green alteration minerals line the margins of the shear zones. The shear zones are very heterogeneous, with no consistent dip or orientation although the top zone is essentially horizontal and the lowest one steeply dipping. The top zone is cut by dark green, thin (<1 mm) veins. The other shear zones are cut by 2–4 mm wide green veins of chlorite and actinolite(?). Veins in Piece 1 are filled mostly with green chlorite and actinolite(?), except for one thin (<2 mm) white plagioclase vein with diffuse margins. All veins dip moderately to steeply (38°–72°) at a high angle to the microvein fabric and microcracks. A steeply (72°) dipping, long (150 mm) vein near the bottom of the piece consists of several strands of green chlorite ± actinolite adjacent to white plagioclase. Piece 2 has two similarly steeply (75°) dipping veins that cut the shear zones and two thin (<1 mm) green chlorite veins that intersect the lower steep vein at a right angle.

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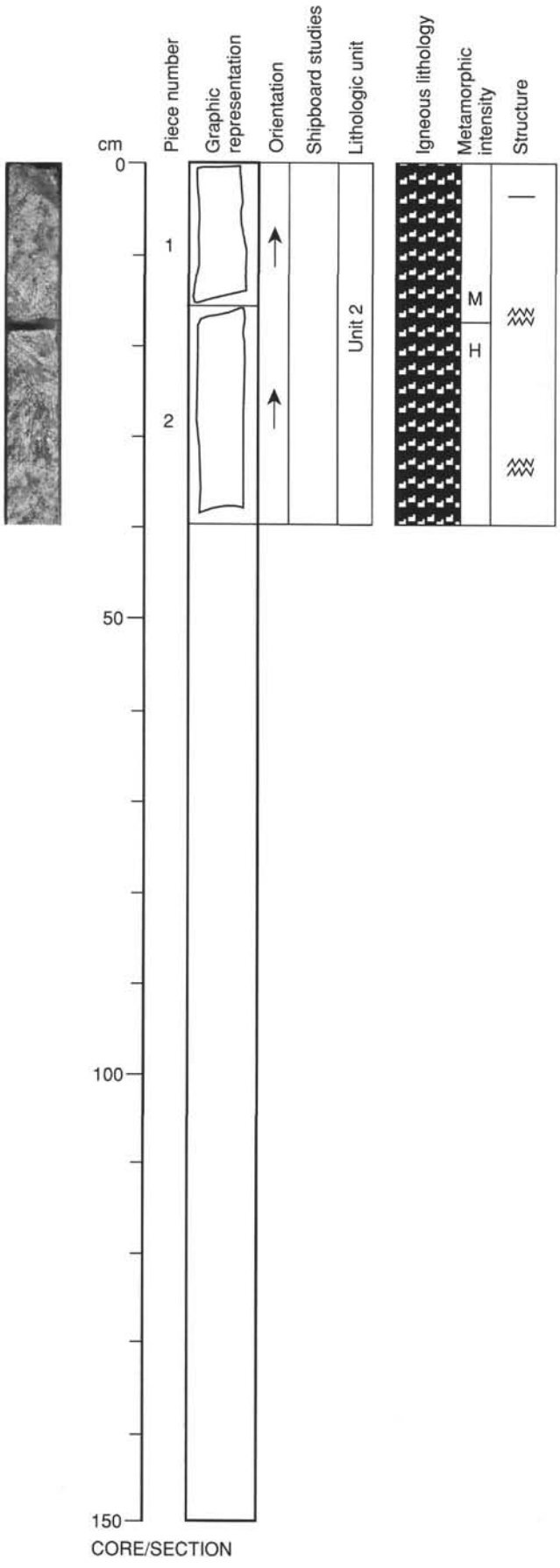

UNIT 2: TROCTOLITE

Pieces 1–2

COLOR: Black and white.
PRIMARY MINERALOGY:
Plagioclase - Mode: 65%.
Crystal Size: 8–20 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 29%–31%.
Crystal Size: 2–11 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 2%–4%.
Crystal Size: 2–8 mm.
Crystal Shape: Anhedral.
Comments: This section consists predominantly of compositionally homogeneous, but texturally variable troctolite interlayered with oxide pyroxenite and oxide-mineral-rich olivine gabbro. In the troctolite, plagioclase was originally euhedral to subhedral, but is now totally recrystallized; small euhedral to subhedral crystals are commonly enclosed in olivine. Clinopyroxene, where present, tends to be poikilitic to subophitic. Larger unaltered crystals have emerald green cores, whereas highly extended, poikilitic to interstitial crystals are typically pale brown. The texture is coarse grained, equigranular, except where poikilitic clinopyroxene occurs. Trace amounts of sulfide and iron oxide minerals occur throughout the section. Olivine is altered to granular dark masses in which individual relict kernels are outlined by iron oxide minerals. Some plagioclase in the troctolite is iron stained. Piece 1 has a very coarse-grained oxide-rich pyroxenite layer in the top 1–2 cm. The contact between the pyroxenite and the troctolite dips at ~40°. It is composed of minor plagioclase (~10%), iron oxide minerals (~10%) and clinopyroxene (80%). The clinopyroxene is altered (~20%) to chlorite and actinolite, and plagioclase is altered to chlorite (~50%), mostly along grain boundaries and cracks. The bottom of the piece contains a 1 to 3 cm wide magmatic vein, composed of blocky crystals of plagioclase that have dark cores and whiter rims and a blocky mafic phase, now totally replaced by actinolite and chlorite. The contact with the troctolite dips at about 40°. Alteration of the troctolite is most intense adjacent to the vein with extensive replacement of the primary phases by actinolite and chlorite. Some olivine has cores are replaced by talc(?) (pearly white and very soft). Away from the vein, altered olivine is orange-brown to red. The troctolite adjacent to the vein has more pyroxene than other intervals of troctolite, but it is difficult to tell whether this was a primary feature or introduced by the vein. The pyroxene adjacent to the vein is partially replaced by brown amphibole. In contrast to Piece 1, the top 8–10 cm of Piece 2 is highly deformed, but the deformation diminishes rapidly beyond 10 cm. The foliation is essentially defined by layers or stringers of brown amphibole, green amphibole, chlorite, iron oxide minerals and elongate olivine, alternating with plagioclase. In the undeformed areas, crystals show no preferred alignment. Iron oxide minerals are concentrated in the deformed zone (~10% in this area) and trace abundances of apatite (clear elongate crystals) are noted near the deformed zone. The ends of the piece are more highly altered than the interior.
SECONDARY MINERALOGY:
Actinolite.
Comments: Replacing clinopyroxene.
Chlorite.
Comments: Replacing olivine.
Iron oxide minerals
Comments: Replacing olivine and clinopyroxene.
Smectite.
Comments: Replacing olivine.
Clay minerals.
Comments: Replacing plagioclase.
Comments: Alteration of this section is moderate (30%) and is dominated by replacment of olivine (50%–100%). Olivine is replaced by variable amounts of fine-grained iron oxide minerals, smectite, iddingsite, orange clay minerals, and tremolite, and is commonly rimmed by chlorite. The most pervasively altered grains are pseudomorphically replaced by smectite, pyrite, and chlorite. Iron oxide minerals, which are abundant at the top and bottom of the core are rimmed by green amphibole. The bottom of the piece is composed of a large felted mat of fine-grained actinolite, which contains inclusions of apatite, magnetite, and rare grains of pale light brown amphibole with a pale green rim. These euhedral amphibole grains reach up

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4 mm in length. The felted area may be a magmatic vein although vein margins are not distinct in hand sample. Plagioclase inclusions in this mat are anhedral with fluted margins which are altered to actinolite and chlorite. Near olivine, plagioclase is netveined by orange clay minerals, giving it an oxidized appearance. In the bottom of Piece 2 in the highly deformed zone, dark elongate composite bands of altered olivine, actinolite, and chlorite, with brown amphibole alternate with more plagioclase-rich bands. Olivine and plagioclase at the base of this piece exhibit intense alteration to orange clay minerals, chlorite, and smectite.

Veins

Microveinlets of actinolite ± chlorite are common throughout the section. Orange fine netveins are locally abundant.

VEIN/FRACTURE FILLING:

Chlorite and amphibole.

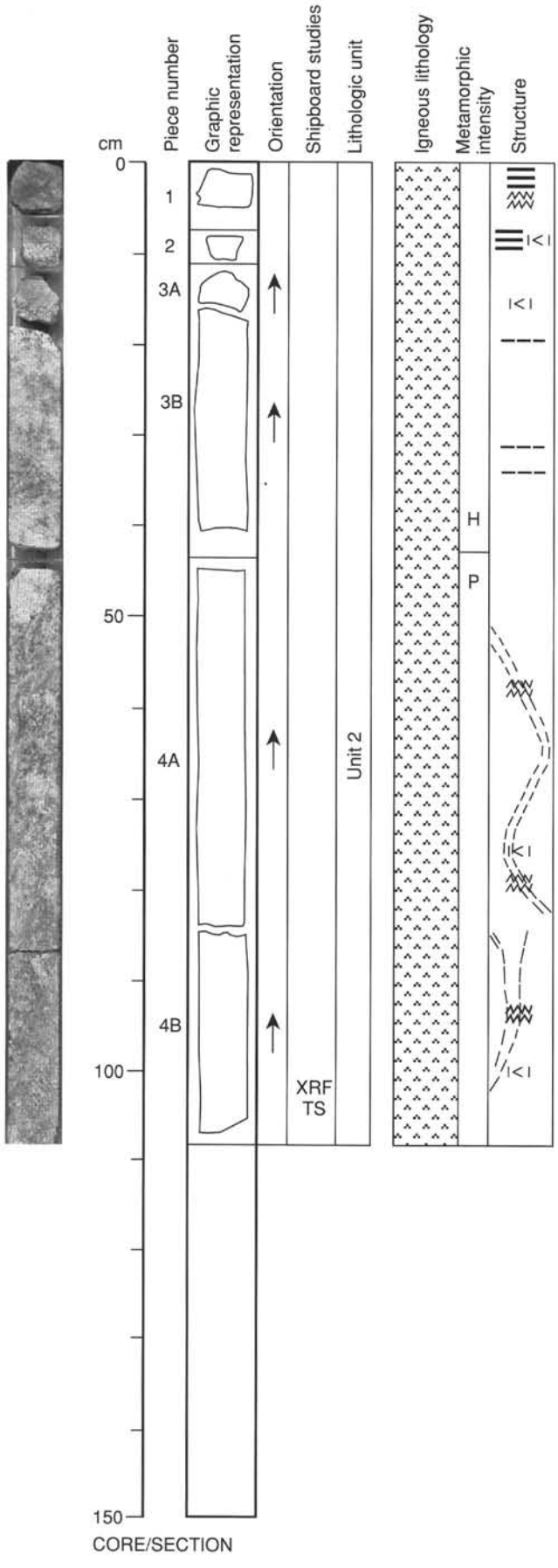
Size: <<1 mm.

Orientation: Filling microcracks.

ADDITIONAL COMMENTS: Structure

The top of Piece 1 shows a moderately dipping (40°) igneous contact between coarse-grained pyroxenite above and finer grained, varitextured olivine gabbro that makes up the majority of the piece. In the upper part of Piece 2 (18–30 cm), is a moderately intense shear zone that is approximately 3 cm thick on the 90° side of the cut face and that increases to 9 cm on the 270° side. The shear zone dips approximately 35° to the 270° side but is wavy and becomes less intense and less consistently linear on the 270° side. Elongated or aligned small grains of altered(?) plagioclase, olivine, and pyroxene form thin (~1 mm) parallel layers that define the shear zone. The bottom of the piece has another shear zone, similar in composition and size but less intense. This zone has a subhorizontal to shallow dip toward the 90° side (opposite to the upper shear zone), is less well defined and best observed on the back side of the core.

153-922A-3R-1



UNIT 2: TROCTOLITE, OLIVINE GABBRO AND MINOR OXIDE GABBRO

Pieces 1–4B

COLOR: Gray and white.
PRIMARY STRUCTURE: Steeply to moderately dipping curvi-planar shear zones.
SECONDARY STRUCTURE: Localized crystal-plastic fabric and chlorite/actinolite veining.
PRIMARY MINERALOGY:
Plagioclase - Mode: 58%–71%.
Crystal Size: 0.5–14 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 15%–28%.
Crystal Size: 1–17 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 4%–23%.
Crystal Size: 0.5–30 mm.
Crystal Shape: Anhedral.
Iron oxide minerals. - Mode: 2%–10%.
Crystal Size: 0.5–3 mm.
Crystal Shape: Anhedral.
Comments: The section consists of variably deformed troctolite and olivine gabbro with several iron oxide mineral-bearing gabbro intervals which appear to be intrusive into the host troctolite. Piece 1 has a white and green melt veins which cut the section in Piece 2, at 10–12 cm and in Piece 3, at 18–21 cm. These veins are rich in white plagioclase, are coarser grained and contain abundant iron oxide minerals, relative to their host rocks. Textures, grain sizes and degrees of deformation vary widely and are heterogenously distributed throughout this section. The dominant mineral constituents present in these rocks are olivine and plagioclase. Locally interstitial, often poikilitic clinopyroxene modal abundances reach levels high enough to justify the name olivine gabbro. In Piece 4A, the interval from 57 to 66 cm is particularly olivine rich and the olivine appears to be particularly coarse grained. Just below this olivine-rich interval a large patch (6 cm by 2 cm) of anorthositic material occurs. Patches or vein-like concentrations of pyroxene and oxide minerals are found in Pieces 3B at 34 to 39 cm and in Piece 4A at 80 to 88 cm. The oxide mineral- and clinopyroxene-rich zone in Piece 3B has nonparallel margins and does not appear to be an igneous layer. Sulfide minerals are concentrated in this zone. A subvertical, anastomosing deformation zone occurs in Piece 4A, stretching the entire length of the piece. Similar deformation features are seen in Piece 4B. Primary textural features in parts of these pieces are obscured by these deformation structures with selvages of pristine-textured rock separated by 1–2 cm wide deformed zones.
SECONDARY MINERALOGY:
Sulfide minerals.
Comments: After clinopyroxene.
Chlorite.
Comments: After olivine and clinopyroxene.
Actinolite.
Comments: After clinopyroxene.
Iron oxide minerals.
Comments: After clinopyroxene and olivine.
Sec. plagioclase.
Comments: After plagioclase.
Clay minerals.
Comments: After plagioclase and olivine.
Epidote.
Comments: After plagioclase.
Comments: Pieces 1–3 are highly altered (60%–70%) with alteration dominated by actinolite, secondary clinopyroxene, brown amphibole, and fine-grained iron oxide minerals after clinopyroxene. Pods of actinolite and chlorite that are rimmed by a fine white soft mineral may be pseudomorphs after olivine. Plagioclase in these oxide mineral- and apatite-rich samples is pervasively to highly altered to secondary plagioclase, pale yellow green epidote, ± prehnite(?) and is crosscut by abundant microveinlets of actinolite ± chlorite. Pieces 3–4 are moderately to highly altered. Olivine is altered 20%–100% to variable amounts of iron oxide minerals, smectite, talc, tremolite/cummingtonite, chlorite, and a trace of pyrite. Locally it is replaced by orange clay minerals. In the most pervasively altered grains, smectite and pyrite form

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pseudomorphs after olivine. Clinopyroxene is slightly to moderately altered except adjacent to veins where pervasive replacement by actinolite, fine-grained oxide minerals, and a trace of secondary clinopyroxene occurs. Clinopyroxene is locally rimmed by and contains fine blebs of brown hornblende, which also occurs in trace amounts as an interstitial phase. Pods and stringers of magnetite, which occur throughout the section are rimmed by green amphibole and chlorite. In Piece 3B, a magnetite- and pyrite-rich pod contains abundant apatite and possibly zircon. Plagioclase is negligibly to highly altered to secondary plagioclase, chlorite, and actinolite. It is commonly cut by microveinlets of actinolite ± chlorite and when adjacent to clinopyroxene may be rimmed by these two minerals. In Piece 4, the shear zones are banded by actinolite ± chlorite which wrap olivine, clinopyroxene, and plagioclase grains and which are associated with fine stringers of brown amphibole?

Veins

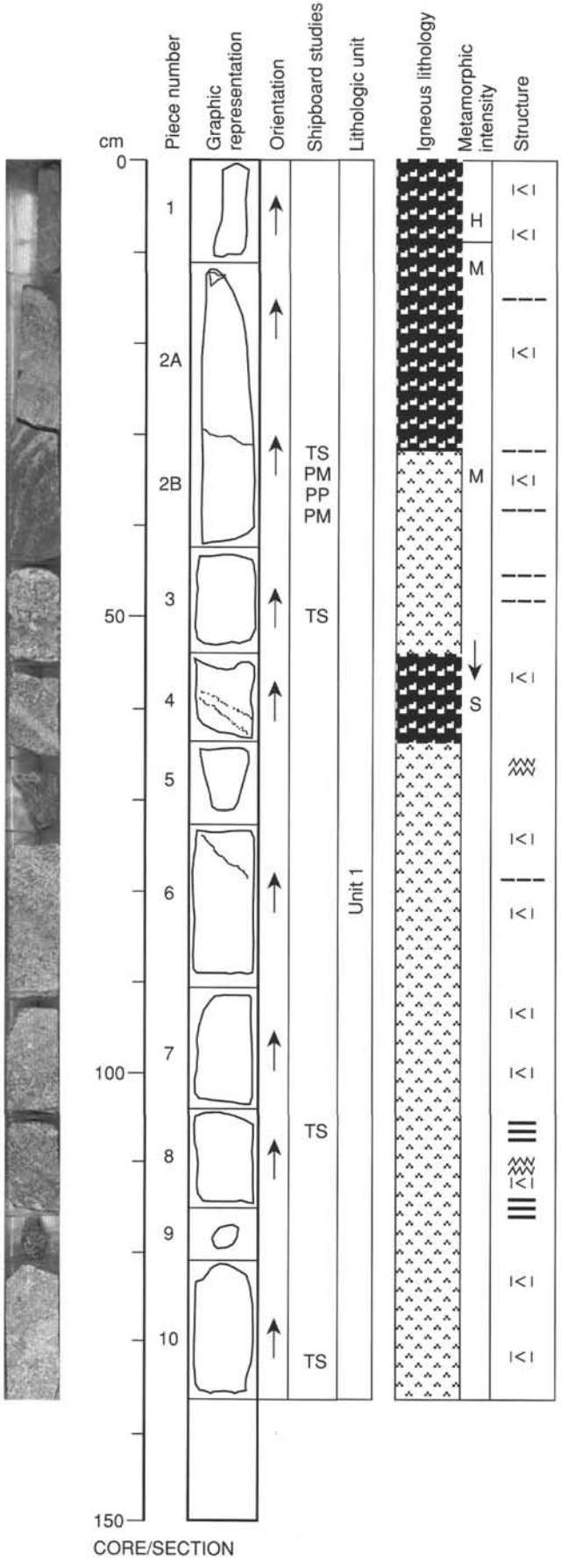
Piece 2 is cut by a 2–4 mm wide epidote veinlet, and abundant fine veinlets of actinolite ± chlorite. Pieces 1–3A are netveined by fine actinolite ± chlorite veinlets <1 mm wide. Piece 3B contains a coarse-grained, 20 mm wide oxide mineral- and apatite-rich band at the top, which may represent an evolved segregation vein. Plagioclase in this vein contains minor epidote and may contain quartz. The piece is crosscut by abundant actinolite ± chlorite veinlets. Piece 4 is netveined by abundant actinolite and chlorite veinlets, which are generally fine, but may reach 2 mm wide.

VEIN/FRACTURE FILLING:

ADDITIONAL COMMENTS: Structure

A shape preferred orientation of plagioclase is evident in Piece 1. This fabric is overprinted by a thin (2 mm) shear zone, lined with chlorite and oxide minerals, evident on the back of the piece. A recrystallized, undeformed patch (1 cm wide) of chlorite, actinolite, and plagioclase lies adjacent to this shear zone. In Piece 2, a medium-grained oxide gabbro is weakly deformed by a plastic fabric deflected into a narrow (2–3 mm) shear zone. In Piece 4A, an overall steeply-dipping (75°–80°), curvi-planar shear zone (1–2 cm) containing oxide gabbro cuts the troctolite (57–63 cm and 80–86 cm). A similar feature is present in Piece 4B (106–110 and 114–118). No mineral shape fabric is present in the troctolite adjacent to these shear zones. In Piece 3 a medium-grained plagioclase-rich vein (18–21 cm) with iron oxide minerals cuts the troctolitic gabbro. A pyroxene- and oxide mineral-rich vein (Piece 3, 35–40 cm) thins from 5 cm to 1 cm toward 270° in the core reference frame. No deformation is evident in either of these veins. Chlorite and amphibole veins (1 mm) cut the shape fabric and shear zone in Piece 1. A 2–3 mm zone of yellow-green alteration (epidote) lies at the diffuse boundary between the oxide gabbro and a strongly altered zone (chlorite and amphibole). Irregular arrays of chlorite and amphibole veins (<1 mm wide) cut both the troctolite and compositional and textural variations in Pieces 3 and 4.

153-922B-1W-1



UNIT 1: TROCTOLITE, OLIVINE GABBRO, MINOR OXIDE GABBRO

Pieces 1–10

COLOR: Gray and white to green and white.

PRIMARY MINERALOGY:

Iron oxide minerals - Mode: 1%–10%.
Crystal Shape: Anhedral.

Clinopyroxene - Mode: 3%–23%.
Crystal Shape: Anhedral.

Plagioclase - Mode: 58%–67%.
Crystal Shape: An to euhedral.

Olivine - Mode: 15%–35%.
Crystal Shape: Anhedral.

Comments: This section consists of metatroctolite in Pieces 1 and 2A, much fresher troctolite in Piece 2B, olivine gabbro, cut by oxide mineral- and plagioclase-rich gabbro in Piece 3, troctolite in Piece 4, olivine gabbro in Pieces 5–9, and meta-olivine gabbro in Piece 10. Piece 7 also includes an oxide mineral-bearing, sheared interval, which dips approximately 50°. Piece 2B shows clear modal layering that dips ~80°. Three pairs of alternating plagioclase-rich and olivine-rich layers occur in this piece. Olivine grains and/or grain clusters are elongated parallel to these layer boundaries. Piece 3 contains three distinctive, euhedral, very coarse-grained, plagioclase-rich bands, separated by two bands of olivine-rich gabbro. The plagioclase-rich bands are also rich in iron titanium oxide minerals, and their upper and lower margins are lined with oxide minerals. The intervening dark olivine gabbro bands are oxide mineral free. Piece 4 is cut by a chlorite and actinolite bearing vein, surrounded by a 1 cm wide alteration halo. This feature superficially resembles layering but is in fact caused by alteration. Apatite occurs in Pieces 3, 7, and 10. Pieces 5 and 8 also have banded features, but these are related to shear zones and are not cumulate layers. Clinopyroxene in the olivine gabbro in Pieces 3 through 10 occurs as fine-grained intergranular crystals. No large clinopyroxene oikiocrysts are observed in this section.

SECONDARY MINERALOGY:

Iron oxide minerals.
Mode of Occurrence: Replacing olivine, clinopyroxene.

Chlorite.
Mode of Occurrence: Replacing clinopyroxene, olivine, plagioclase.

Iddingsite.
Mode of Occurrence: Replacing olivine.

Smectite.
Mode of Occurrence: Replacing olivine.

Hornblende.
Mode of Occurrence: Replacing clinopyroxene.

Actinolite.
Mode of Occurrence: Replacing clinopyroxene.

Tremolite.
Mode of Occurrence: Replacing olivine.

Talc(?)
Total Percent: Trace.
Mode of Occurrence: Replacing olivine.

Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.

Comments: Alteration is heterogeneous downsection with alteration high to moderate (35%–55%) in the top and lower portions of the core (Pieces 1, 2, and 10), whereas the middle section is slightly to moderately altered (5%–25%). Alteration is dominated by secondary minerals after olivine and clinopyroxene. Olivine is pervasively altered (80%–100%) in the top and bottom of the core and is only moderately to slightly altered in the middle section (10%–30%). In the most altered pieces, pervasive replacement by tremolitic amphibole and chlorite, form fine, amoeboid-shaped pods filled with intergrown fibrous actinolite-tremolite, which are rimmed by chlorite. In less altered areas, olivine is replaced by iron oxide minerals, smectite, iddingsite, chlorite, tremolite, and a trace of talc. Trace amounts of brown amphibole form associated with olivine and as fine rims between plagioclase grain boundaries. In the oxide mineral-rich gabbro, green amphibole forms well-developed rims around the oxide minerals. Clinopyroxene is slightly to pervasively altered to actinolite, chlorite, and iron oxide minerals, with a trace of associated pyrite. Plagioclase is slightly to highly altered (<5% to 40%) to secondary plagioclase, with rims of actinolite ± chlorite and minor epidote.

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Chlorite and actinolite microveinlets cutting plagioclase are common.

Veins

Hairline microveinlets of actinolite and chlorite are common thoughout the section (Pieces 1, 2, 5). Piece 4 contains a broad diffuse band, 12 mm wide which is composed of concentrated hairline veinlets of actinolite and chlorite, which have pervasively altered the bounding wall rock to secondary plagioclase, actinolite, and chlorite. Piece 6 is cut by a 1–2 mm wide straight vein of actinolite and chlorite which exhibts a narrow and diffuse alteration halo of secondary plagioclase, and amphibole and chlorite after clinopyroxene. Piece 8 is cut by a brown-green colored composite vein which may contain moderately abundant brown amphibole.

VEIN/FRACTURE FILLING:

Actinolite and chlorite.

Size: 1–12 mm.

Comments: In Piece 4 the vein is 12 mm wide; in Piece 6 the vein is 1–2 mm wide.

Hairline actinolite and chlorite.

Comments: Common throughout.

Brown hornblende.

Comments: Occurs in Piece 8 in a composite vein with plagioclase, actinolite, chlorite at a compositional boundary.

ADDITIONAL COMMENTS: Structure

The most striking features in these rocks are well-developed boundaries marking compositional and/or textural variations. Piece 2B has steeply dipping alternating layers composed of plagioclase and olivine, and there is a weakly developed olivine lineation parallel to these layer boundaries on the curved surface of the core. The layer boundaries become diffuse and subhorizontal to horizontal (~7° to 3°) in Piece 3. In Piece 6, the compositional boundary is also accentuated by the concentration of brown amphibole, particularly on the back surface of the core. The rest of the section is relatively more homogeneous in terms of textural and compositional variations and thus does not display such boundaries. Shear zones are seen in Pieces 5 and 8. In Piece 5, there is a nearly 2 mm wide shear zone that contains asymmetric and elongated plagioclase grains showing a sinistral sense of shearing. Piece 8 includes a strongly developed olivine and plagioclase mineral fabric defining a moderately dipping (39°) foliation plane. The shear zone in this piece dips around 35°, is accompanied by a sheared magnetite layer, and is highly oblique to the brown amphibole vein on the cut face of the core. There are mainly four different kinds of veins in this section. Dark-green, chlorite veins (<1 mm) are most common and occur in most pieces. They commonly form conjugate sets with intervein angles ranging from ~90° to 45°. Their dip angles also change from subhorizontal to subvertical. They cut across the compositional layers and their boundaries and brown amphibole veins. In places where conjugate sets form a mesh network, the rock seems to have microlithons separated by hairline veins (e.g., Piece 10). Brown amphibole veins are found in Pieces 2A and 8. In Piece 2A the vein is 3 mm wide and dips steeply (68°), whereas in Piece 8 it is 2 mm wide and dips moderately (27°). Chlorite and actinolite veins are common, and they may also contain plagioclase as an alteration product forming composite veins. Such a composite vein occurring in Piece 4 is 12 mm wide, dips moderately (40°), and has an actinolite core. Rare plagioclase and brown amphibole veins (Piece 6) rarely appear to truncate the chlorite veins, but their crosscutting relations cannot be well established.

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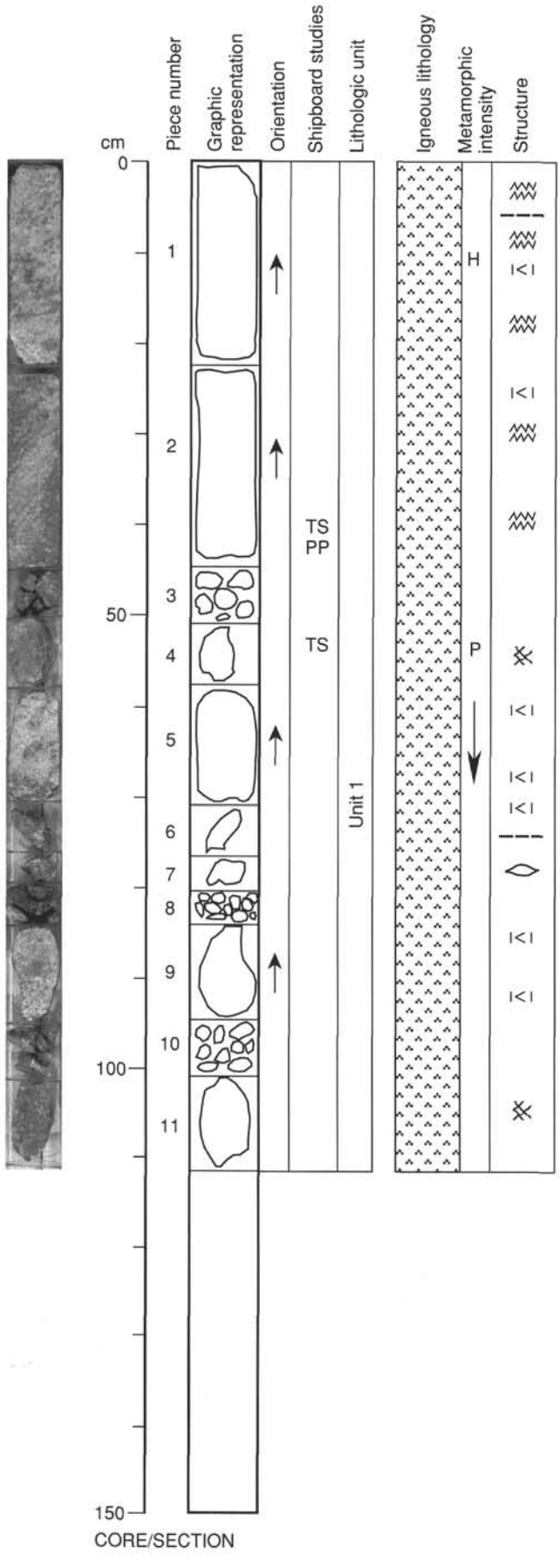

UNIT 1: OLIVINE GABBRO, OXIDE GABBRONORITE, OXIDE OLIVINE GABBRO

Pieces 1–11

COLOR: Green gray.
PRIMARY MINERALOGY:
Olivine - Mode: 4%–20%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Orthopyroxene. - Mode: 0–6%.
Crystal Size: 1–6 mm.
Crystal Shape: Euhedral.
Crystal orientation: No preferred orientation.
Clinopyroxene - Mode: 17%–36%.
Crystal Size: 1–17 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Plagioclase - Mode: 50%–61%.
Crystal Size: 1–18 mm.
Crystal Shape: Subhedral.
Crystal orientation: No preferred orientation.
Comments: This section is composed of texturally and modally heterogeneous, coarse-grained olivine gabbro and a highly deformed iron oxide mineral-bearing gabbro that appears to have intruded into the olivine gabbro. The coarse-grained olivine gabbro (Pieces 1–5 and 9) is mostly composed of euhedral to subhedral plagioclase (1–18 mm in size) and anhedral, interstitial olivine (1–8 mm) and clinopyroxene (1–17 mm). Clinopyroxene varies in abundance from 8–15 modal%, and poikilitically to subophitically encloses plagioclase. The modal proportions of olivine and plagioclase are relatively uniform, ranging from 12%–5%, and 54%–60%, respectively. Olivine gabbro in Pieces 1 and 2 contains shear bands (0.5–2.0 cm thick), showing a mylonitic texture and made of plagioclase, olivine, clinopyroxene, and orthopyroxene porphyroclasts and very fine-grained recrystallized matrix, associated with thin seams of recrystallized clinopyroxene and hornblende aggregations with common iron oxide minerals. Characteristically, euhedral to subhedral orthopyroxene is observed as porphyroclasts in the gabbronorite shear bands. The coarse- to very coarse-grained iron oxide mineral-bearing gabbronorite and olivine gabbro (Pieces 6–8, and 10–11) are composed mostly of euhedral to subhedral, prismatic plagioclase (1–16 mm), anhedral olivine (1–7 mm), clinopyroxene (1–17 mm), and iron oxide minerals. Pieces 6 and 8 contains euhedral prismatic grains of orthopyroxene (2–6 mm). Piece 6 contains iron oxide mineral aggregation seams and recrystallized clinopyroxene and hornblende aggregation seams. The modal abundance of olivine ranges from 7%–16%. Clinopyroxene ranges in abundance from 17–30%, and plagioclase 50%–61%. Piece 10 is texturally heterogeneous oxide olivine gabbro with a shear band, perpendicular to the core, containing thin, irregularly shaped aggregations of iron oxide minerals.
SECONDARY MINERALOGY:
Sulfide minerals
Total Percent: Trace–0.5%
Actinolite.
Total Percent: <5
Mode of Occurrence: Replacing orthopyroxene and clinopyroxene.
Chlorite.
Total Percent: <5
Mode of Occurrence: Replacing clinopyroxene.
Talc.
Total Percent: <5
Mode of Occurrence: Replacing orthopyroxene and olivine.
Magnetite.
Mode of Occurrence: Replacing orthopyroxene and olivine.
Smectite.
Total Percent: <5
Mode of Occurrence: Replacing plagioclase.
Hornblende.
Total Percent: 0.5-1
Mode of Occurrence: Replacing clinopyroxene.
Secondary plagioclase.

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Mode of Occurrence: Replacing plagioclase.

Comments: Alteration is heterogeneous downsection, though it is commonly moderate to high (40%). Olivine is highly to pervasively altered and exhibits well-developed alteration halos composed of variable amounts of talc, tremolite, iron oxide minerals, chlorite, and interlayed chlorite-smectite. In pervasively altered areas and in Piece 4, olivine alteration includes abundant smectite, minor iddingsite, and an orange clay mineral. Locally olivine is completely replaced by tremolite-actinolite and rimmed by dark green chlorite forming well-developed halos (Piece 2). Heterogeneous alteration of olivine gives the section a spotted appearance. In plagioclase, clay minerals form fine netveins which locally gives plagioclase an orange color (Piece 4, 5, and 11). Clinopyroxene is slightly to pervasively altered to actinolite, with lesser amounts of fine-grained iron oxide minerals and minor chlorite. In pervasively altered patches, actinolite after clinopyroxene forms fine, felted green mats which enclose altered plagioclase grains. Actinolite after clinopyroxene in Piece 1 forms rare, coarse-grained irregularly shaped mats. In coarse-grained, oxide-rich patches such as at the bottom of Piece 5, secondary clinopyroxene partially replaces clinopyroxene. In shear zones, such as at the top of Piece 1 and near the top of Piece 2, fine-grained oxide stringers are rimmed by thin <1 mm wide bands of green to brown amphibole and chlorite. The bands form a fine anastomosing network which wraps elongate relict and recrystallized plagioclase grains, which are chalky white. Plagioclase alteration is highly variable from slight to pervasive. In highly altered areas adjacent to veins and in Piece 4, plagioclase is highly replaced to secondary plagioclase, chlorite, trace carbonate, and crosscut by abundant microveinlets of actinolite and chlorite.

Veins

Piece 1 contains a thin (<1 mm) actinolite bearing vein. Piece 2 has abundant microveinlets (<1 mm wide) of actinolite and chlorite, which commonly cut plagioclase. Piece 3 is rubble of coarse-grained olivine gabbro, crosscut by chlorite veins. Piece 4 is cut by a network of chlorite, and actinolite and chlorite veins, and a fine network of irregular, orange-brown clay mineral veins associated with olivine alteration. Piece 5 contains an actinolite vein, <1 mm wide, on the top left of the piece. Piece 8 is rubble with locally more developed microcracks.

VEIN/FRACTURE FILLING:

Clay minerals.

Size: <<1 mm.

ADDITIONAL COMMENTS: Structure

In general, the section is characterized by a coarse-grained gabbro with localized shear zones, locally developed mineral shape fabric, and some veins. Olivine gabbro in Pieces 1 and 2 contains shear bands (0.5–2.0 cm thick), showing a mylonitic texture and made of plagioclase, olivine, clinopyroxene, and orthopyroxene porphyroclasts and very fine-grained recrystallized matrix, associated with thin seams of recrystallized clinopyroxene and hornblende aggregations and with common iron oxide minerals. Characteristically, euhedral to subhedral orthopyroxene if observed as porphyroclasts in the gabbronoritic shear bands. Piece 1 has three discrete shear zones. The first one near the top dips gently (30° to 16°), is 1 mm wide, and cuts across the plagioclase concentration in the piece. The second shear zone has a changing width along its trace (4 to 12 mm) and is marked by deformed olivine grains. The domain between the two shear zones shows strong mineral fabric and elongation of olivine and plagioclase grains. The foliation plane dips gently (16° to 2°). The third shear zone in this piece is anastomozing and dips moderately (44°). The shear zones in Piece 2 are similarly branching and are associated with subdomains of elongated plagioclase and amphibole grains. Pieces 6, 7, 8, and 10 display mineral shape fabric defined by elongated plagioclase, olivine, and/or brown amphibole grains (all unoriented pieces). Veins are limited to <1–1 mm chlorite and actinolite veins, and their dips range from gentle (13°) to steep (70°).

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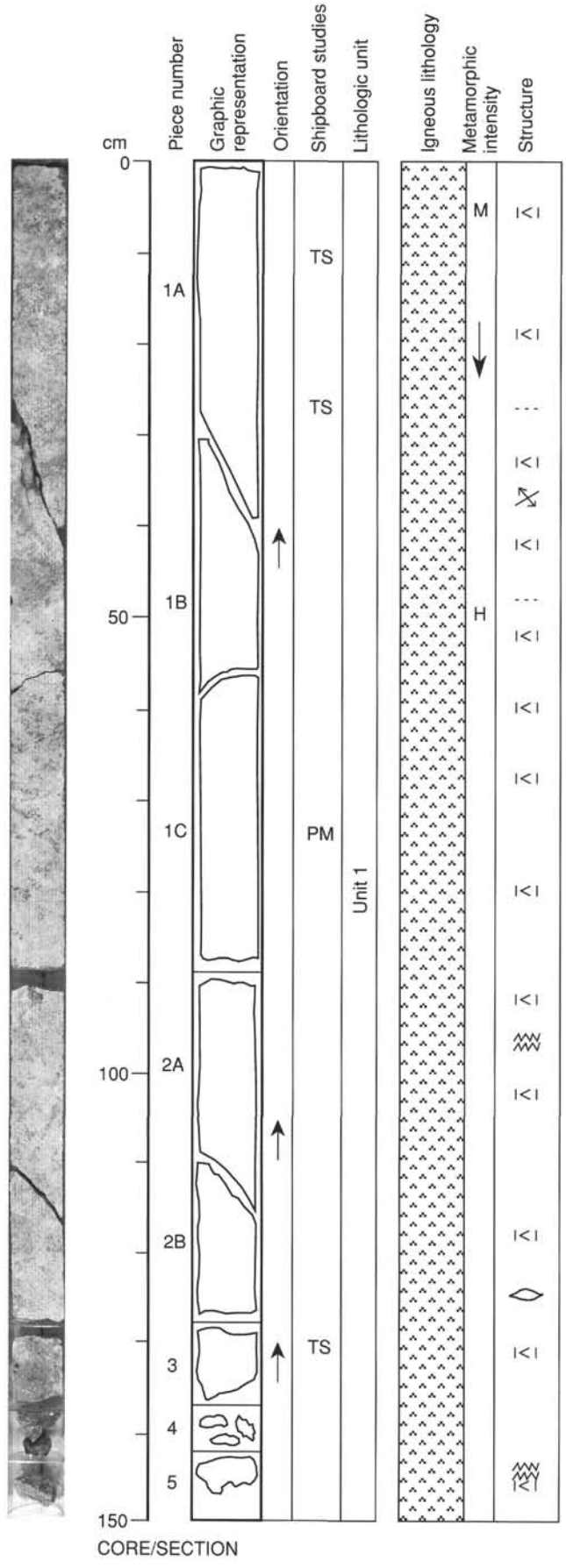

UNIT 1: OLIVINE GABBRO AND TROCTOLITE

Pieces 1A–5

COLOR: Green and white to gray and white.

PRIMARY MINERALOGY:

Plagioclase - Mode: 55%–66%.
- Crystal Size: 1–30 mm.
- Crystal Shape: Subhedral.
- Crystal orientation: Magmatic alignment.

Olivine - Mode: 12%–28%.
- Crystal Size: 1–15 mm.
- Crystal Shape: Anhedral.
- Crystal orientation: Magmatic alignment.

Clinopyroxene - Mode: 4%–25%.
- Crystal Size: 1–40 mm.
- Crystal Shape: Anhedral.
- Crystal orientation: Magmatic alignment.

Iron oxide minerals - Mode: 1%–2%.
- Crystal Shape: Anhedral.

Comments: This section includes troctolite, olivine gabbro, and meta-olivine gabbro. Piece 1A diplays well-developed crescumulate textures in the interval between 15 and 20 cm. A diffuse layer boundary dipping at approximately 30° is decorated along its upper margin with large (30 mm) radiating plagioclase grains. Microscopic inspection of the core cut face reveals dendritic olivine crystals that are up to 15 cm in length, with thin (~0.5–1 mm) widths and delicate branching shapes. Piece 1B is more altered and deformed than Piece 1A, so that fine igneous textures are not so well preserved. The central portion of Piece 1B is oxide gabbro that intrudes the brecciated, netveined troctolitic protolith. In the lower portion of Piece 1B, plagioclase exhibits a well-developed magmatic fabric, with elongate plagioclase laths aligned, such that the fabric dips at ~20–25°. In Piece 1C, radiating plagioclase crystals are developed at 70 cm. A shear zone in the upper portion of Piece 2A separates anorthositic, deformed olivine gabbro from relatively undeformed olivine gabbro. A small patch of apatite-rich material with oxide and sulfide minerals occurs in this shear zone at the top of Piece 2A. In this lower portion of Piece 2A, olivine is generally distributed in patches, which are surrounded by regions that are composed of plagioclase with a fine-grained intergranular clinopyroxene. Similar textures, with patchy distribution of olivine- and clinopyroxene-bearing regions is seen in Pieces 2B and 3. Magmatic fabrics, with aligned elongate plagioclase crystals occur in the lower part of Piece 2B and in Piece 3. Pieces 4 and 5 are quite small, 2–3 cm pieces of olivine gabbro.

SECONDARY MINERALOGY:

Actinolite.
- Mode of Occurrence: Replacing clinopyroxene.

Chlorite.
- Mode of Occurrence: Replacing clinopyroxene and plagioclase.

Iddingsite.
- Mode of Occurrence: Replacing olivine.

Smectite.
- Mode of Occurrence: Replacing olivine.

Iron oxide minerals
- Mode of Occurrence: Replacing olivine and clinopyroxene.

Pyrite.
- Mode of Occurrence: Replacing clinopyroxene and olivine.

Tremolite.

Clay minerals.
- Mode of Occurrence: Replacing olivine.

Secondary plagioclase.
- Mode of Occurrence: Replacing plagioclase.

Comments: The core is moderately to highly altered with alteration increasing downsection (10% to 55%). Alteration in the top part of the core is heterogeneous, with large, highly altered oxidized pods in troctolitic Pieces 1A-C. The oxidation and enhanced alteration is locally associated with an oxide mineral-rich area in which oxide minerals are rimmed by green amphibole, plagioclase is orange and olivine is locally altered to orange clay minerals/smectite. In general, olivine is moderately to pervasively altered and exhibits complex alteration halos of intermixed and variable amounts of iddingsite, iron oxide minerals, pyrite, olive green smectite, tremolite, a trace of talc, and chlorite. In some zones, coronas are very well developed with fibrous tremolite ± talc in the cores of pods which exhibit dark chlorite rims.

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In Piece 2B, these coronas form elongate ellipses and are associated with a shear zone. In pervasively altered zones, smectite after olivine forms fine olive green pods. Clinopyroxene is heterogeneously altered (15%–50%), to fibrous actinolite, chlorite, and pyrite. Alteration is most intense along microfractures, where amphibole forms fibrous green patches. Plagioclase alteration is variable from 5%–40%, with alteration intensity generally less in the top part of the core. Alteration minerals include minor secondary plagioclase, and actinolite and chlorite along grain boundaries and as microveinlets which commonly cut plagioclase. Piece 2A contains a small oxide mineral- and apatite-rich pod which is enclosed in amphibolitzed clinopyroxene and secondary clinopyroxene(?). Plagioclase at the outer margins of this pod, contains fine-grained epidote.

Veins

Actinolite ± chlorite veinlets are commoon throughout the section, but are especially abundant in Piece 3. Piece 1 is cut by <1 mm wide orange to green veinlets of smectite(?) and clay minerals. The bottom of Piece 1A and top of Piece 1B is an epidote, plagioclase, ± quartz(?), and magnetite-rich pod or vein. In Piece 1B, this vein extends as a fine veinlet vertically down the piece and changes mineralogy to a clay mineral/smectite-rich assemblage. The bottom of Piece B is cut by a 2–3 mm wide actinolite vein.

VEIN/FRACTURE FILLING:

Actinolite and chlorite.

Size: <<1–~1 mm.

Comments: Hairline veinlets <<1 mm crosscut plagioclase; veinlets <1 mm in size are common throughout the section.

Smectite and clay minerals.

Size: <1 mm.

Comments: Occurs in Piece 1.

Epidote, plagioclase?, quartz, and magnetite.

Comments: Occurs on a broken surface of Piece 1.

Actinolite.

Size: 2–3 mm.

Comments: Occurs in Piece 1B.

ADDITIONAL COMMENTS: Structure

The section displays no mineral shape fabric and/or preferred orientation of the constituent minerals. A compositional boundary dipping 37° to the 090° (in the core reference frame) separates the plagioclase-rich layer below from the olivine-rich layer above. A small oxide gabbro body seems to be intrusive into the troctolite and across the layer boundary. In Piece 2A a steeply dipping (60°) shear zone separates the anorthositic gabbro from the olivine gabbro. A small patch of oxide mineral-, sulfide mineral-, and apatite-rich material occurs in this shear zone at the top of Piece 2A. In general, the actinolite and chlorite veins dip moderately to steeply (25° to 75°). An epidote and plagioclase, ± quartz vein dipping 70° to the 270° cuts across a network of actinolite and chlorite veins, and the rock is jointed along this vein plane. In Piece 5 an actinolite-containing, 3 mm wide shear zone truncates two actinolite and chlorite veins (unoriented sample).

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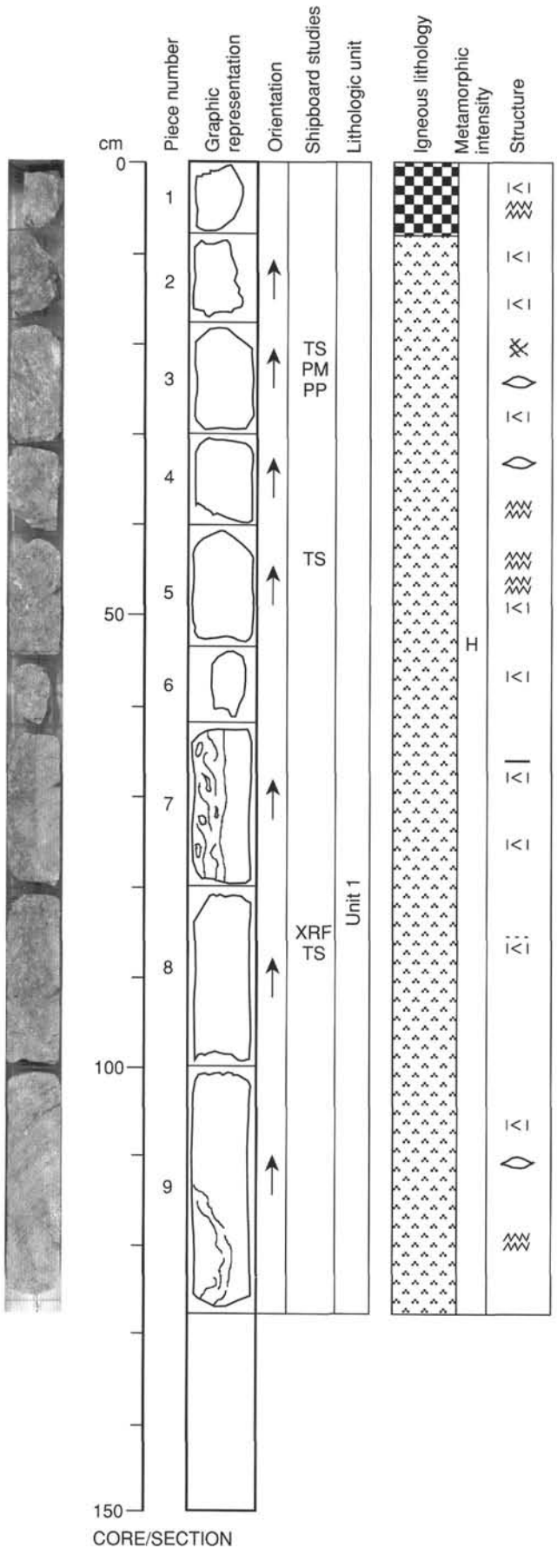

UNIT 1: OLIVINE GABBRONORITE WITH OLIVINE GABBRO

Pieces 1–9

COLOR: Green gray to black.
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%–70%.
Crystal Size: 2–23 mm.
Crystal Shape: Anhedral to subhedral.
Crystal orientation: Tectonic alignment.
Orthopyroxene. - Mode: 10%–15%.
Crystal Size: 2–33 mm.
Crystal Shape: Subhedral.
Crystal orientation: Tectonic alignment.
Clinopyroxene - Mode: 10%–15%.
Crystal Size: 1–12 mm.
Crystal Shape: Anhedral.
Crystal orientation: Tectonic alignment locally.
Olivine - Mode: 5%–10%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred alignment.
Comments: This section is composed of olivine gabbronorite and olivine gabbro. Piece 1 is sheared oxide gabbro and Pieces 2, 3, 6, and 9 are sheared gabbronorite. The olivine gabbronorite is coarser than the olivine gabbro, and huge, elongated and bent orthopyroxene(?) porphyroclasts, up to 33 mm in length, can be found in Piece 8. The contact can be seen in Pieces 5, 7, and 8. The contact planes are irregular and the shear orientation is different piece by piece. In Piece 5, the central part is olivine gabbronorite sandwiched by the olivine gabbro with the irregular boundary crosscuting the piece at about 40° with respect to the piece axis. Piece 7 is divided into olivine gabbronorite on the left half and olivine gabbro on the right half of piece. In Piece 8, the irregular boundary is found on the right side. In Piece 4, an olivine gabbro block is included in olivine gabbronorite. Olivine gabbro is commonly highly altered. These might be suggest that the gabbronorite intruded into olivine gabbro. Near the boundary, a concentration of iron oxide minerals and apatite is present in all the gabbronorite, and apatite is also in the host olivine gabbro near the contact.
SECONDARY MINERALOGY:
Talc?
Total Percent: Trace.
Mode of Occurrence: Replacing olivine.
Smectite.
Mode of Occurrence: Replacing olivine.
Iron oxide minerals
Mode of Occurrence: Replacing olivine and clinopyroxene.
Tremolite.
Mode of Occurrence: Replacing olivine.
Chlorite.
Mode of Occurrence: Replacing olivine, clinopyroxene, plagioclase.
Pyrite.
Mode of Occurrence: Replacing olivine and clinopyroxene.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene and plagioclase.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Epidote.
Mode of Occurrence: Replacing plagioclase.
Secondary clinopyroxene.
Mode of Occurrence: Replacing clinopyroxene.
Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Comments: Alteration is heterogeneous downsection but is generally high (50%–60%) due to abundant actinolite veining and intense deformation, with alteration intensity increasing downhole. Olivine alteration is heterogeneous (30%–100%), but commonly it is pervasively altered. Secondary minerals form well-developed zoned, amoeboid-shaped pods with cores of fibrous tremolite, and a dark green-black rim of chlorite ± actinolite. Grains pervasively replaced by smectite and iron oxide minerals are olive green. Complex and heterogeneous coronas are common and include variable amounts of smectite, iddingsite, chlorite, iron oxide minerals, and pyrite. In

shear zones, the pods from ellipses. Clinopyroxene is commonly moderately altered (20%–30%), but adjacent to veinlets pervasive replacement by actinolite and fine-grained iron oxide minerals is common. Replacement by brown amphibole is generally minor. In highly deformed areas, clinopyroxene augen exhibit well-developed narrow rims of actinolite with minor chorite(?) along tails. Porphyroclasts are locally bent and broken in these zones with fibrous amphibole rimming grain boundaries. Secondary clinopyroxene is present locally. Pervasively altered grains form interconnecting fibrous pods/patches of actinolite. Orthopyroxene(?) is rarely be altered to tremolite. In oxide mineral-rich zones, magnetite is rimmed by amphibole ± chlorite. Plagioclase is moderately to highly altered (10%–50%) away from veins, and pervasively replaced adjacent to veins. Alteration phases include secondary plagioclase, abundant actinolite and chlorite rimming grain boundaries and along microcracks, and a trace of epidote. Plagioclase commonly exhibits pale brown cores and white rims. Actinolite is abundant at shear zone boundaries.

Veins

Netveins of actinolite with minor chlorite are common throughout the section.

VEIN/FRACTURE FILLING:

Actinolite and chlorite netveins.

Comments: Abundant throughout the section.

ADDITIONAL COMMENTS: Structure

Most pieces in this section have a preferred alignment of long axes of pyroxene grains, plagioclase stringers and oxide mineral veinlets, particularly Pieces 3, 7, 8, and 9. In highly deformed areas, clinopyroxene augen exhibit well-developed narrow rims of actinolite with minor chlorite along tails. Porphyroclasts are locally bent and broken in these zones with fibrous amphibole rimming grain boundaries. In Pieces 7 and 8, the fabric is subvertical and dominant on the coarse-grained part of the section. These pieces also have an igneous contact with a finer grained gabbro that is also subvertical (vertical in Piece 7). The contact has a subparallel 2–3 mm thick chlorite and actinolite vein. The elongate fabric in Piece 9 dips less steeply (~30°) except between the two shear zones in the lower part of the piece where they have dips of ~60°. Piece 9 has a grain size intermediate between the coarse-grained and fine-grained parts of Piece 7. This crystal aligned fabric in Pieces 7 and 8 is hard to discern because of extensive microvein development and alteration with a horizontal orientation that is especially predominant in the finer grained gabbro. Shear zones with highly elongate plagioclase, pyroxene and oxide mineral areas cut Pieces 1, 4, 5, and 9. Two shear zones intersect in Pieces 1 and 9. The zones dip at about 60° and vertical in Piece 9. Almost all pieces have substantial amounts of, if not pervasive, microveins with chlorite and actinolite coatings that are generally horizontal. A few other thin (<1 mm) actinolite and chlorite veins dip moderately except for the vertical vein near the contact in Piece 7.

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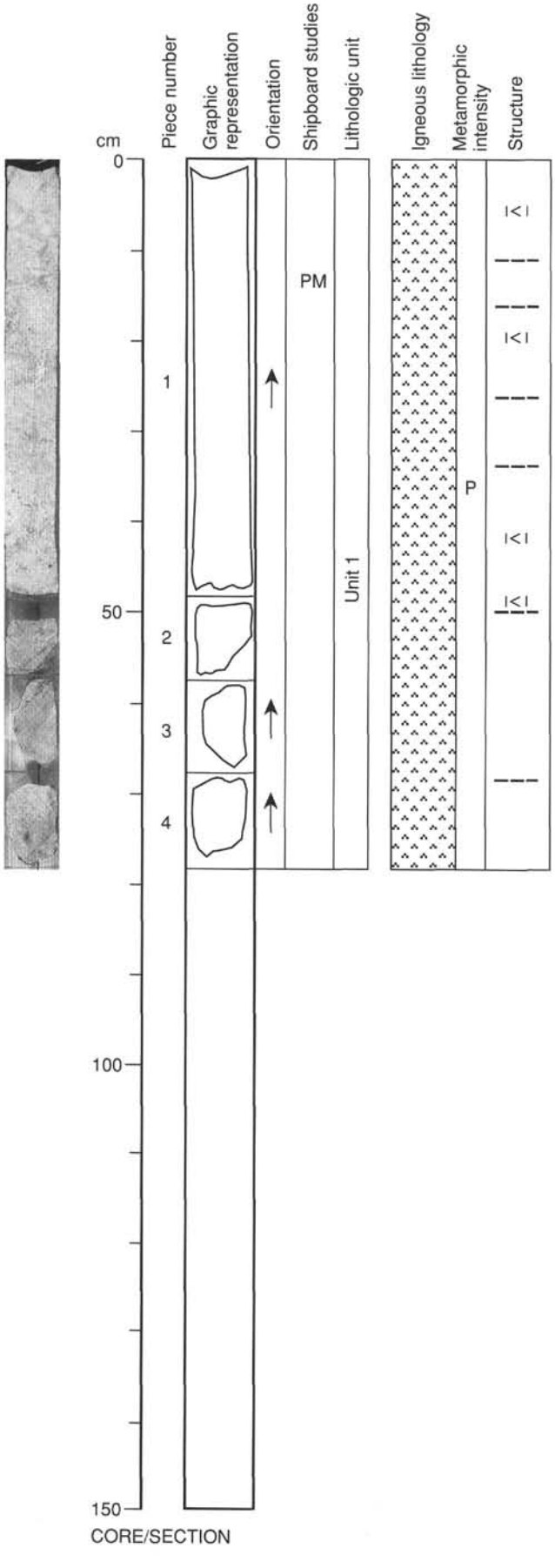
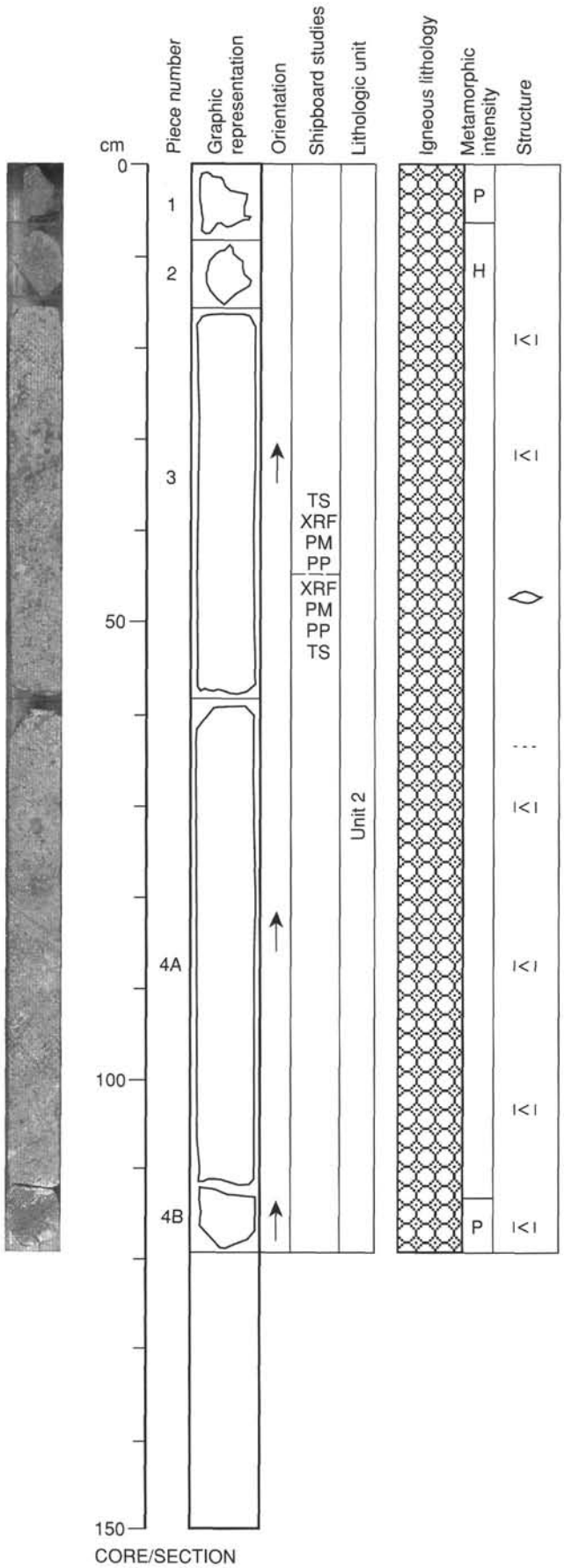


UNIT 1: OLIVINE GABBRO

Pieces 1–4

COLOR: Green and white.
PRIMARY MINERALOGY:
Plagioclase - Mode: 53%–62%.
Crystal Size: 1–12 mm.
Crystal Shape: Anhedral to subhedral.
Crystal orientation: No preferred orientation.
Clinopyroxene - Mode: 25%–38%.
Crystal Size: 1–14 mm.
Crystal Shape: Anhedral to subhedral.
Crystal orientation: No preferred orientation.
Olivine - Mode: 9%–15%.
Crystal Size: 1–6 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Iron oxide minerals - Mode: 1%–2%.
Crystal Size: 1–3 mm.
Crystal Shape: Anhedral.
Comments: This section consists of olivine gabbro and meta-olivine gabbro. Alteration is generally high throughout the section, making positive identification of the protolith and primary mode quite difficult in hand specimen. Mega-netveins separate zones of olivine gabbro. Large (18 cm) subhedral clinopyroxene grains in Piece 4 are not poikilitic.
SECONDARY MINERALOGY:
Actinolite.
Mode of Occurrence: Replacing clinopyroxene.
Chlorite.
Mode of Occurrence: Replacing clinopyroxene.
Iddingsite.
Mode of Occurrence: Replacing olivine.
Talc.
Mode of Occurrence: Replacing olivine.
Magnetite.
Mode of Occurrence: Replacing olivine.
Smectite.
Mode of Occurrence: Replacing olivine.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Comments: This section is highly to pevasively altered (40%–80%) with well-developed coronas after clinopyroxene and olivine. Olivine is completely pseudomorphed by tremolite, chlorite, with lesser amounts of talc, iron oxide minerals, and a trace of carbonate minerals forming amoeboid-shaped pods which contain cores and dark green chlorite rims. Some olivine grains are completely replaced by mixed smectite and chlorite with minor iddingsite and pyrite. Clinopyroxene is moderately to highly replaced to actinolite, secondary clinopyroxene, fine-grained iron oxide minerals, and blebs and fine discontinuous rims of brown amphibole. Plagioclase is slightly to highly altered to secondary plagioclase, a trace of carbonate minerals (associated with olivine alteration?), and cut and rimmed by abundant actinolite ± chlorite.
Veins
Piece 1 is cut by a 2–3 mm wide, subvertical, actinolite with minor chlorite vein. Adjacent and cut clinopyroxene is pervasively replaced by actinolite. Fine microveinlets of actinolite ± chlorite are common. The side of Piece 4 is cut by an oxide mineral- and apatite-rich vein(?) with clinopyroxene replaced by actinolite, plagioclase with brown cores and white rims, minor epidote, and abundant microveins of actinolite. A similar coarse-grained 20 mm wide band occurs near the top of Piece 1. Boundaries of the compositionally evolved band are diffuse with the enclosing host rock.
ADDITIONAL COMMENTS: Structure
The section is composed of a coarse-grained rock with a weak to nonexistent mineral fabric. Compositional-textural variation bondaries are common in Pieces 1 and 4 and generally separate plagioclase-rich and plagioclase-poor domains. These boundaries commonly coincide with multiple and irregular branches of chlorite and actinolite veins (best examples are in Piece 1). The similar geometry and mineral composition of the veins suggest a common generation of their development. Dip angles range from subhorizontal (6°) to steep (80°) on the cut face.



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UNIT 2: OLIVINE GABBRO

Pieces 1–4B

COLOR: Green gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 61%–64%.
Crystal Size: 1–22 mm.
Crystal Shape: Euhedral to subhedral.
Crystal orientation: No preferred orientation.
Clinopyroxene - Mode: 14%–32%.
Crystal Size: 1–38 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Olivine - Mode: 5%–20%.
Crystal Size: 1–12 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Iron oxide minerals - Mode: 1%–2%.
Comments: This section consists mostly of modally heterogeneous, medium- to coarse-grained olivine gabbro with thin layers of anorthositic gabbro.The medium- to coarse-grained olivine gabbro is composed of euhedral to subhedral plagioclase (1–22 mm in size) and anhedral, interstitial olivine (1–12 mm) and clinopyroxene (1–38 mm). The modal proportion of olivine and clinopyroxene shows a wide range from 5%–20%, and 14%–32%, respectively. Plagioclase is relatively uniform in modal proportion, ranging from 61%–64%. Very large, interstitial, and poikilitic grains of clinopyroxene are present (25–38 mm), commonly rimmed by brown hornblende. At the bottom of Piece 4A and at both the top and the bottom of Piece 4B, the olivine gabbro becomes rich in euhedral to subhedral plagioclase (anorthositic gabbro layer, 2–3 cm thick).
SECONDARY MINERALOGY:
Sulfide minerals
Total Percent: Trace.
Hornblende.
Total Percent: 1
Comments: Rims on clinopyroxene.
Talc.
Total Percent: 13
Mode of Occurrence: Replacing olivine.
Magnetite.
Total Percent: 2
Mode of Occurrence: Replacing olivine.
Actinolite.
Total Percent: <14
Mode of Occurrence: Replacing clinopyroxene, olivine, plagioclase.
Tremolite.
Total Percent: <2
Mode of Occurrence: Replacing clinopyroxene, olivine, plagioclase.
Chlorite.
Total Percent: <5
Mode of Occurrence: Replacing clinopyroxene, olivine, plagioclase.
Smectite.
Total Percent: <3
Mode of Occurrence: Replacing clinopyroxene, olivine, plagioclase.
Comments: Alteration in this section is heterogeneous ranging from 40%–60% in Pieces 1 and 2, 20%–30 % in Pieces 3 and 4A, and up to 60%–70% in Piece 4B. Tremolite, talc, iron oxide minerals, and actinolite form amoeboid shaped alteration pods after olivine and clinopyroxene, respectively, with dark green chlorite rims. Other alteration minerals after olivine include dark olive green smectite, interlayered smectite, chlorite, and pyrite (alteration ranges from 50%–100%). The pods commonly enclose variably altered plagioclase which is crosscut by fine microveinlets of actinolite and chlorite. Clinopyroxene is moderately to highly altered (40%–75%) to fine felted actinolitic mats with *fine-grained iron oxide minerals, and minor blebs and rims of brown* hornblende, which also occurs as a rare interstitial phase. Coarse-grained clinopyroxene which occurs throughout the section in pods and patches and which is associated with oxide mineral- and apatite-rich zones is slightly altered to actinolite and rimmed by hornblende. Plagioclase is slightly to

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pervasively altered with intensely altered areas associated with oxide mineral-rich patches and veins. Plagioclase in these areas is chalk white and altered to secodnary plagioclase, epidote, prehnite, and cut by actinolite ± chlorite veinlets.

Veins

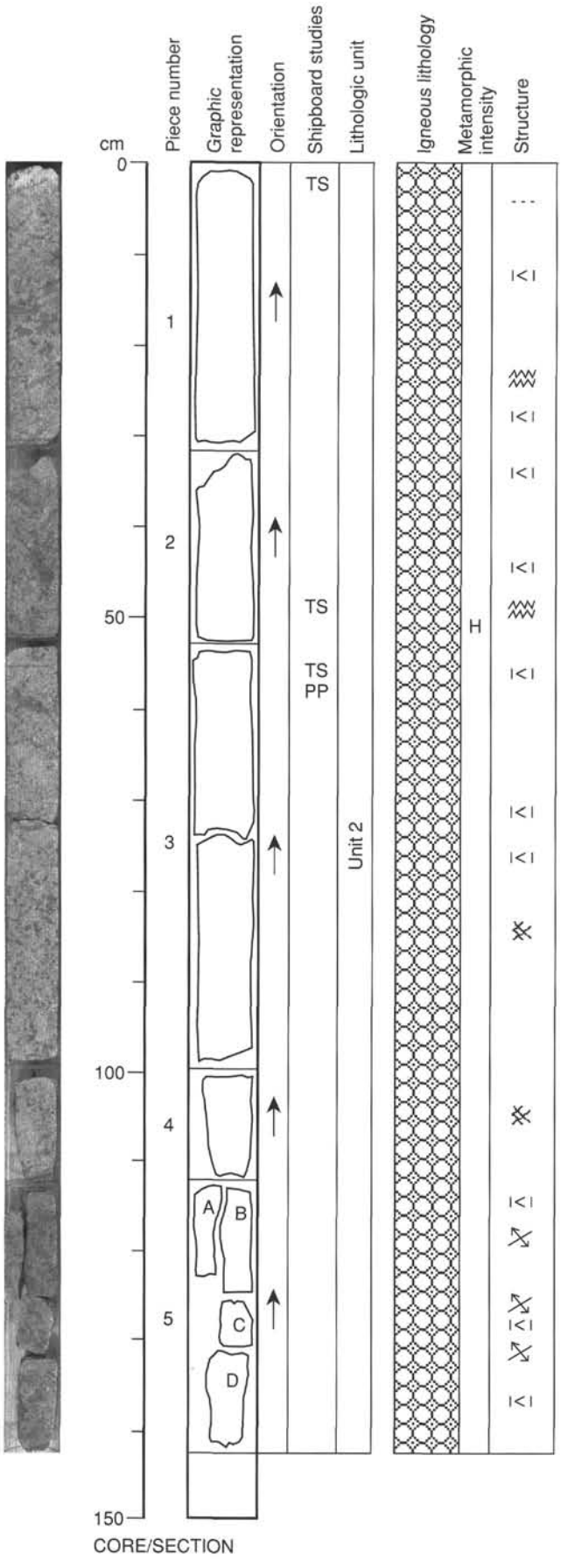
Piece 2 is cut by abundant microveinlets of actinolite ± chlorite (<<1 mm wide). Piece 3 is cut by a fine chlorite veinlet, <1 mm wide, and oriented at ~30°. Piece 4 A is cut by a composite, 3 mm wide, diffuse, actinolite and chlorite vein which is associated with oxide minerals and brown amphibole along the rim. A 5 mm wide irregular shaped diffuse magmatic vein of actinolite after clinopyroxene and pervasively altered plagioclase occurs at the base of the piece. Fine <1 mm wide actinolite ± chlorite veinlets are common throughout this piece. Piece 4B contains evolved magmatic pods (veins?- only one contact is exposed) which include altered clinopyroxene, plagioclase with associated epidote, and oxide minerals.

VEIN/FRACTURE FILLING:

Actinolite.

ADDITIONAL COMMENTS: Structure

Primary igneous structures include a weakly developed preferred orientation of euhedral plagioclase laths and grain-size variations. The magmatic foliation has a dip of 15° in the lower half of Piece 3. The gradational boundary between the coarse- and medium-grained gabbro, seen at the top of Piece 4, is weakly sheared along a gently dipping plane (20°). The primary igneous texture is overprinted by a plastic fabric in Pieces 1 and 4 as indicated by the preferred orientation of anhedral and elongated plagioclase crystals. Magmatic and hydrothermal veins occur in Pieces 3 and 4. At the bottom of Piece 4, cm-scale, altered magmatic veins occur and contain plagioclase and pyroxene. They are irregularly oriented, with dips ranging from 0° to 55°. Hydrothermal veins containing actinolite/chlorite occur in Pieces 3 and 4. Their dips cluster around 30° and they are commonly slightly sheared along their boundaries. A composite magmatic vein (MVa in log) occurs in the bottom of Piece 4 (100–110 cm below the top of section) and shows a 12 mm apparent-shear offset of a chlorite and actinolite vein (V4b in log). This relationship is exposed on the back side of the archive half.



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UNIT 2: OLIVINE GABBRO

Pieces 1–5

COLOR: Green gray.
PRIMARY MINERALOGY:
Plagioclase - Mode: 52%–62%.
Crystal Size: 1–32 mm.
Crystal Shape: Euhedral to subhedral
Crystal orientation: No preferred orientation.
Clinopyroxene - Mode: 14%–30%.
Crystal Size: 2–200 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Olivine - Mode: 15%–23%.
Crystal Size: 1–17 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Iron oxide minerals - Mode: 1%.
Comments: This section comprises texturally and modally variable, coarse- to very coarse-grained olivine gabbro. The olivine gabbro of Pieces 1 and 2 has a heteradcumulate texture, composed of euhedral, prismatic grains of cumulus plagioclase (1–32 mm) and anhedral, intercumulus olivine (1–17 mm) and clinopyroxene (2–200 mm). Piece 1 contains a pegmatitic single grain of interstitial, poikilitic clinopyroxene, 20 cm in size, in the lower half of the piece. Pieces 2 and 4 olivine gabbro are interstitially filled by large clinopyroxene. At the top of the Piece 1 a thin layer of anorthositic gabbro (3 cm thick) grades rapidly into the olivine gabbro.
SECONDARY MINERALOGY:
Hornblende.
Total Percent: <1
Comments: Rims on clinopyroxene.
Sulfide minerals.
Total Percent: Trace.
Talc.
Total Percent: <10
Mode of Occurrence: Replacing olivine.
Magnetite.
Mode of Occurrence: Replacing olivine.
Actinolite.
Total Percent: 15
Mode of Occurrence: Replacing clinopyroxene, olivine, plagioclase.
Tremolite.
Mode of Occurrence: Replacing clinopyroxene, olivine, plagioclase.
Chlorite.
Mode of Occurrence: Replacing clinopyroxene, olivine, plagioclase.
Smectite.
Mode of Occurrence: Replacing clinopyroxene, olivine, plagioclase.
Comments: Alteration in this section is moderate, varying from 20%–30%. Olivine is heterogeneously altered averaging ~35%–40% throughout most of the section, except in Piece 5 in which it is altered 60%–80%. Alteration coronas after olivine are complex and variable with cores of smectite ± pyrite ± iddingsite, enclosed in fibrous intergrowths of talc and tremolite, which are rimmed by dark green chlorite. Where pervasively replaced by smectite, a trace of pyrite and iddingsite pseudomorphs occur as dark olive green pods. Rare pods contain yellow green cores of smectite(?), rimmed by chlorite. Clinopyroxene is altered 25% to 60% to actinolite, fine-grained iron oxide minerals, brown hornblende as blebs and rims, and minor chlorite. Hornblende forms a rare interstitial phase. Plagioclase is generally slightly to moderately altered (5%–15%) to secondary plagioclase, and chlorite and actinolite when adjacent to clinopyroxene. It is commonly crosscut by abundant netveins of actinolite ± chlorite. In rare, coarse-grained intervals of clinopyroxene and associated oxide minerals, pyrite, and apatite, clinopyroxene is only slightly altered to actinolite and secondary clinopyroxene (Piece 3A, ~1 cm wide vein at the end of Piece 3B).
Veins
Very fine netveins of actinolite ± chlorite are common throughout the core. Piece 1 at the top is bounded by a 20–30 mm wide felsic band of chalk white plagioclase with a trace of epidote(?), magnetite, apatite, and minor clinopyroxene which is pervasively altered to fine-grained, felted mats of actinolite. Piece 2 at the top is cut by 3–4 subparallel chlorite and actinolite

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veinlets (1–2 mm wide), which are oriented at ~45°. Piece 3A, near the top, is cut by a subhorizontal 2 mm wide actinolite ± chlorite vein. Piece 5 is cut near the top by a fine actinolite ± chlorite veinlet.

VEIN/FRACTURE FILLING:

MnO.

Orientation: On open surfaces.

Prehnite.

Clay minerals.

Iron oxide minerals.

ADDITIONAL COMMENTS: Structure

Unlike Section 11, 153-922B-3R-1, this section contains no mesoscopic mineral fabric. However, several discrete shear zones reactivate green chlorite and actinolite filled veins. These shear zones have horizontal <15° and steep 70° dips and range in width from 2–10 mm as seen in Pieces 1, 3A, and 3B. Apparent offset on the shear zone at 23–26 cm below section top is about 2.5 cm (1/2 diameter of core) because it contains coarse-grained gabbro in the hanging wall of the working half that is only present in the footwall of the archive half. This shear zone is 7 mm thick. Several discrete green chlorite and actinolite veins (<1–2 mm thick) are found in Pieces 1, 3, 4, and 5. A set of evenly distributed thin (<<1 mm) discontinuous (20 mm long) veins is found in Pieces 1, 3, 4, and 5. The typical spacing between veins is 5 mm.

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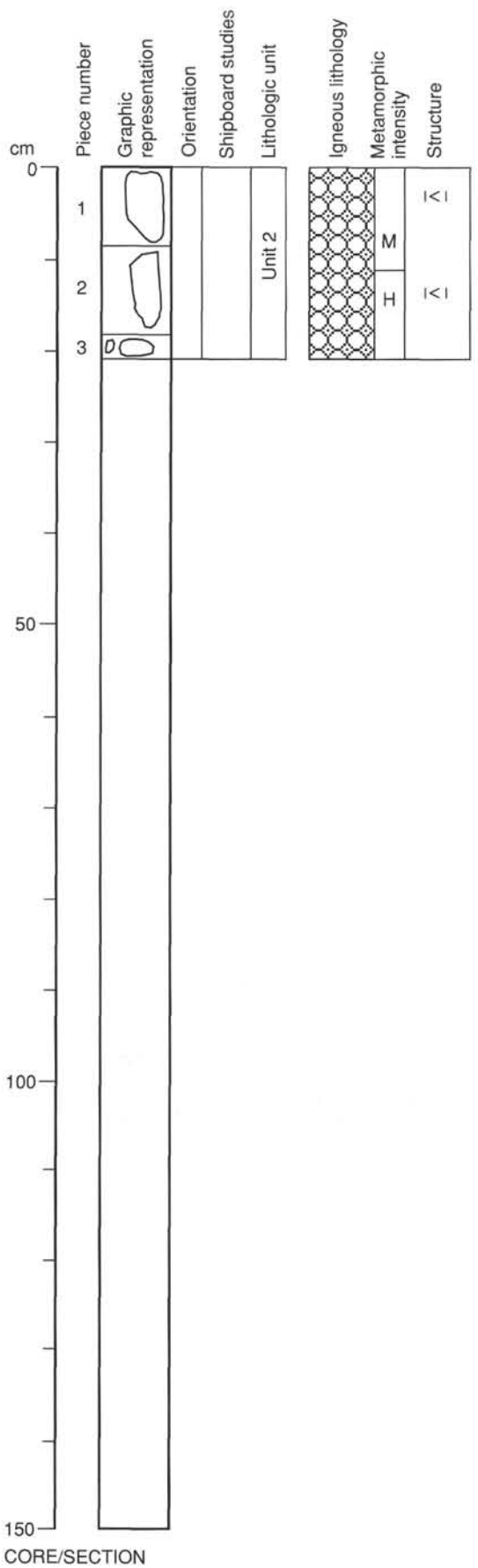

UNIT 2: OLIVINE GABBRO

Pieces 1–3

COLOR: Green gray.
PRIMARY MINERALOGY:
Plagioclase - Mode: 63%.
Crystal Size: 1–13 mm.
Crystal Shape: Subhedral.
Crystal orientation: No preferred orientation.
Olivine - Mode: 15%–28%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Clinopyroxene - Mode: 8%–21%.
Crystal Size: 3–18 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Iron oxide minerals - Mode: 1%.
Comments: This section is strongly altered coarse-grained olivine gabbro, composed of subhedral plagioclase (1–13 mm), anhedral olivine (1–10 mm), and clinopyroxene (2–20 mm). Modal proportion of olivine varies from 15% to 28%, and clinopyroxene from 8%–21%.
SECONDARY MINERALOGY:
Hornblende.
Total Percent: 0.5
Sulfide minerals.
Total Percent: Trace.
Talc.
Total Percent: 10
Mode of Occurrence: Replacing olivine.
Magnetite.
Mode of Occurrence: Replacing olivine.
Actinolite.
Total Percent: 14
Mode of Occurrence: Replacing clinopyroxene, olivine, plagioclase.
Tremolite.
Mode of Occurrence: Replacing clinopyroxene, olivine, plagioclase.
Chlorite.
Mode of Occurrence: Replacing clinopyroxene, olivine, plagioclase.
Smectite.
Mode of Occurrence: Replacing clinopyroxene, olivine, plagioclase.
Comments: Alteration in this section is moderate, varying from 20%–40%. Olivine is heterogeneously altered averaging ~40–100% with coronas after olivine common. Coronas are complex and variable composed of fibrous intergrowths of talc and tremolite, smectite, iddingsite, and trace pyrite, which are rimmed by dark green chlorite. Clinopyroxene is altered 25% to 70% to actinolite, fine-grained iron oxide minerals, brown hornblende as blebs and rims, and minor chlorite. Plagioclase is generally slightly to moderately altered (5%–20%) to secondary plagioclase, chlorite and actinolite when adjacent to clinopyroxene. It is commonly crosscut by abundant net veins of actinolite ± chlorite.
Veins
Veinlets of actinolite ± chlorite (<<1mm wide) are common in Piece 1.
VEIN/FRACTURE FILLING:
Clay minerals.
Size: <<1
ADDITIONAL COMMENTS: Structure
The three small pieces in this section all contain the distributed vein set that is characterized by thin (<<1 mm) discontinuous (20 mm long) veins with a typical spacing of 5 mm.

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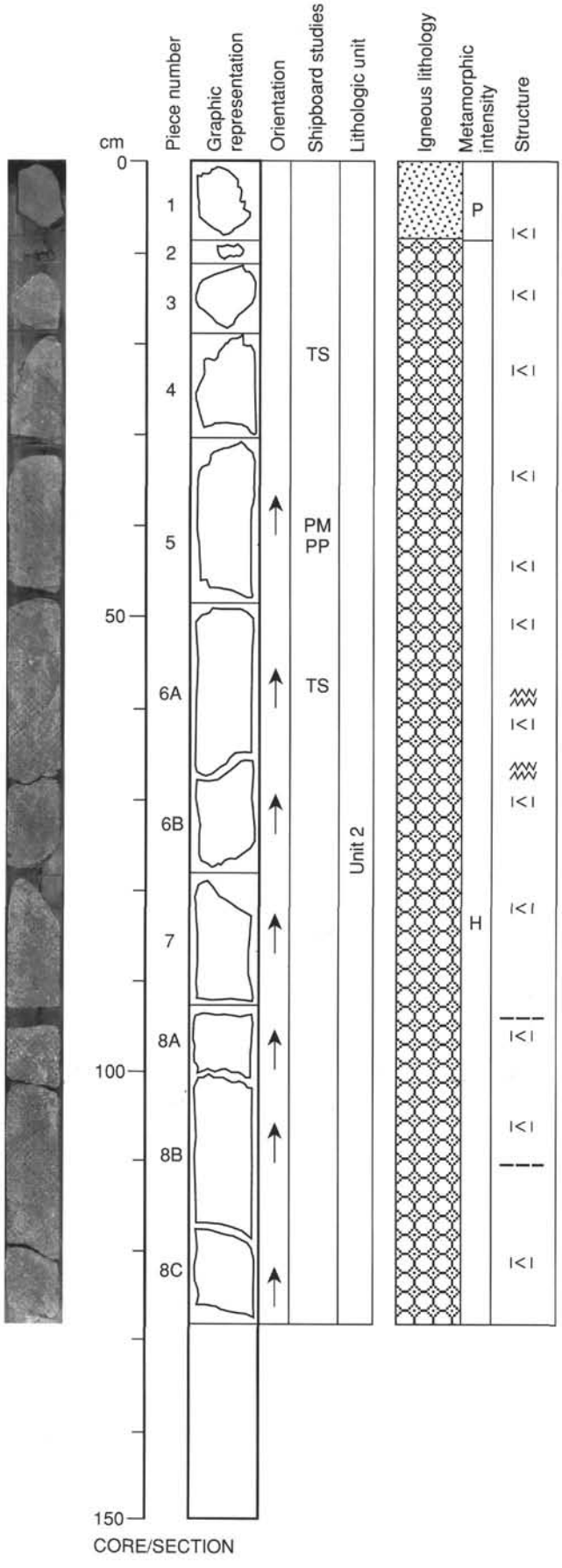

UNIT 2: OLIVINE METAGABBRO

Pieces 1–8C

COLOR: Gray green.

PRIMARY MINERALOGY:

Plagioclase - Mode: 55%–64%.
Crystal Size: 4–10 mm.
Crystal Shape: Subhedral.

Clinopyroxene - Mode: 18%–40%.
Crystal Size: 4–40 mm.
Crystal Shape: Anhedral.

Olivine - Mode: 5%–20%.
Crystal Size: 2–8 mm.
Crystal Shape: Anhedral.

Apatite. - Mode: 0–15%.
Crystal Size: 1–2 mm.
Crystal Shape: Euhedral.

Comments: The section consists of one piece of aphyric diabase (Piece 1) and olivine metagabbro (Pieces 2–8). The contact between the diabase and the gabbro is not exposed. The diabase is highly altered (~60%), but primary mineralogy (plagioclase, clinopyroxene, and olivine) is preserved. The diabase is aphyric with lath-shaped slender and radiating plagioclase enclosed in clinopyroxene in subophitic to ophitic relationship. Olivine occurs as discrete rounded grains in intergranular positions. Pieces 2–8 are dominantly meta-olivine gabbro. Alteration is generally between 50% and 65% with plagioclase being the freshest, followed by clinopyroxene. Olivine is highly altered. Where olivine is partially preserved it is usually associated with partial replacement by iddingsite. Olivine is generally subrounded and sometimes enclosed within clinopyroxene, where it is best preserved. It forms between 5%–20% of individual pieces through the section and varies on the scale of cm. Clinopyroxene is usually intergranular to plagioclase, but in places form discrete large subhedral grains 20 mm across with an elongate or blocky appearance (Piece 7). Elongate clinopyroxene often shows magmatic growth twins {100}, obvious in hand specimen (Piece 7). Clinopyroxene is replaced by actinolite, but is well preserved in most samples as relict cores. Opaque oxide minerals occupy interstitial regions between plagioclase. Plagioclase is partially altered to secondary plagioclase. Piece 8B contains >40 mm clinopyroxene grains at the base. It is not poikilitic, and is free of inclusions. It is intergrown on its edge with euhedral-subhedral plagioclase, much smaller in grain size (5–8 mm). The top of Piece 8B and the base of piece 8A contains an intrusive coarse grained vein-like clot that contains euhedral blocky plagioclase at its center enclosed in intergranular clinopyroxene. On the margin of the clot (base of Piece 8A) there is a zone of clinopyroxene (now altered to actinolite) that is rimmed by hornblende and is asociated with discrete grains of euhedral to subhedral prismatic hornblende. This zone apears to have solidified on the edge of the intrusive. The intrusive has abundant apatite (in places making up 10%–15% of the clot at top of Piece 8B). A thin vein cuts obliquely across the top of Piece 8B and appears to link with the larger clot above. The vein is very narrow and is easily seen as a line of smaller apatite and pyroxene/amphibole with minor amounts of plagioclase. The apatite appears to be interstitial to clinopyroxene and forms a trail extending to the clot seen above. Two coarser grained gabbroic veins cut across Piece 6A, one is subhorizontal, one is inclined.

SECONDARY MINERALOGY:

Actinolite.
Mode of Occurrence: Replacing clinopyroxene.

Chlorite.
Mode of Occurrence: Replacing clinopyroxene and orthopyroxene.

Tremolite.
Mode of Occurrence: Replacing olivine.

Talc?
Mode of Occurrence: Replacing olivine.

Second. plagioclase.
Mode of Occurrence: Replacing plagioclase.

Clay minerals.
Mode of Occurrence: Replacing plagioclase.

Smectite.
Mode of Occurrence: Replacing olivine.

Iddingsite.

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Mode of Occurrence: Replacing olivine.

Pyrite.

Mode of Occurrence: Replacing olivine.

Comments: The diabase in Piece 1 is highly altered (60%–70%), and green due to replacement of mafic phases by actinolite and chlorite. Rare pseudomorphs after olivine form irregular shaped rounded pods with cores of tremolite ± talc and chloritic rims. Plagioclase is highly altered to secondary plagioclase, clay minerals ± actinolite and chlorite. Mesostasis is likely replaced by abundant chlorite, actinolite, and clay minerals. Alteration is high throughout the rest of the section (Pieces 2–8, 50%–65%), with well-developed amoeboid-shaped pods of tremolite, rimmed by dark green chlorite common. Olivine alteration is complex and heterogeneous with variable amounts of smectite, iddingsite, chlorite, iron oxide minerals, pyrite, clay minerals and minor talc (85%–100%). Rare, yellow green pods of clay and serpentine(?) replace olivine. Clinopyroxene, when pervasivley altered, forms green fibrous actinolitic patches with radiating microveinlets of actinolite into adjacent plagioclase. Other minerals after actinolite include fine-grained iron oxide minerals, a trace of brown hornblende, and pyrite. Fine cream-colored patches of clay minerals, rarely completely pseudomorph orthopyroxene. Plagioclase is highly altered (50%) to secondary plagioclase, and clay minerals, and is rimmed and crosscut by actinolite ± chlorite intergrowths and veinlets, respectively. Plagioclase commonly exhibits light brown cores and white rims. Pieces 8A and 8B contains a clinopyroxene- and hornblende-rich tapering vein. Clinopyroxene in this zone is highly to pervasively replaced by actinolite, brown amphibole, and actinolite replaces brown-black amphibole.

Veins

Netveinlets of actinolite ± chlorite are common throughout the section (<<1 mm in width) Piece 6A is cut by a 2–3 mm wide diffuse vein of actinolite(?) and zeolite rimmed by chalky white plagioclase. Pieces 8A and 8B contain a clinopyroxene-, brown-black hornblende-, apatite-bearing vein with euhedral olive green to black amphibole up to 11 mm long. Piece 8C is cut by 2, <1 mm wide actinolite veinlets.

VEIN/FRACTURE FILLING:

Actinolite and chlorite.

Size: <<1 mm.

Comments: Common throughout.

Actinolite and zeolite (rimmed by chalkly white plagioclase)

Size: 2–3 mm.

Comments: Occurs in Piece 6A.

Clinopyroxene and brown-black hornblende, apatite, and actinolite.

Size: Up to 20 mm.

Comments: Occurs in Pieces 8A and 8B. Width of vein tapers.

Actinolite.

Size: <1 mm.

Comments: Occurs in Piece 8C.

ADDITIONAL COMMENTS: Structure

No penetrative mineral shape fabrics were observed in this section except for a weak local alignment of subhedral plagioclase. However, Piece 6 contains a steep (70°) brittle-ductile shear zone. Its thickness varies from 3–25 mm. Three main types of veins occur in the section. The first is a group of evenly distributed thin (<<1 mm) discontinuous (about 15 mm long) veins filled with actinolite and chlorite (V5 in structure log). These veins are dipping shallowly (10°–25°) and are found in Pieces 2, 3, 4, 5, 6, 7, and 8. The next set (V4 in structure log) includes discrete actinolite and chlorite veins that are about 1 mm thick and generally >7 cm long. These veins dip more steeply (25°–50°) than the V5 set and are found in Pieces 3, 4, 5, 6, 7, and 8. The last set includes discrete veins that have strong white halos and are cored by green actinolite. The boundaries of both the core and the halo are very diffuse. One of these veins is found in Piece 6 and it dips about 8°. The apatite-bearing clinopyroxene and amphibole vein in Pieces 8A and 8B is highly irregular in orientation and thickness.

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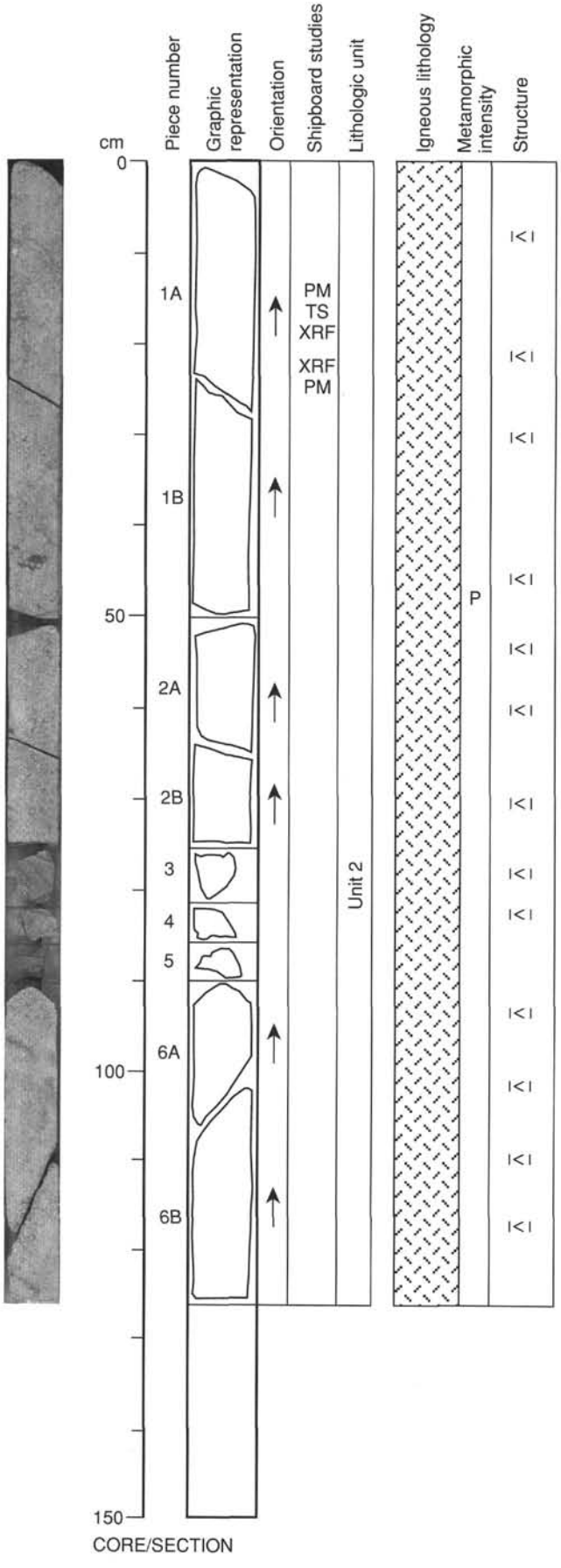

UNIT 2: OLIVINE METAGABBRO

Pieces 1A–6B

COLOR: Green gray.

PRIMARY MINERALOGY:

Plagioclase - Mode: 60%.
- Crystal Size: 2–15 mm.
- Crystal Shape: Subhedral to anhedral.
- Crystal orientation: No preferred orientation.

Clinopyroxene - Mode: 28%–30%.
- Crystal Size: 1–50 mm.
- Crystal Shape: Anhedral.
- Crystal orientation: No preferred orientation.

Olivine - Mode: 10%–12%.
- Crystal Size: 1–12 mm.
- Crystal Shape: Anhedral.
- Crystal orientation: No preferred orientation.

Comments: This section is composed of olivine gabbro that sometimes contains huge clinopyroxene oikocrysts. The rock is commonly homogeneous, though it contains a coarse gabbroic band, 2–3 cm width, and an actinolite vein at the top of Piece 6. The average grain size is ranges from 5 to 7 mm. The oikocrysts are up to 50 mm in longest axis, enclosing euhedral plagioclase and olivine grains. The coarse gabbroic band in Piece 6 is depleted in olivine relative to the host olivine gabbro. Large euhedral plagioclase (>7 mm) are poikilitically enclosed by clinopyroxene. Along the actinolite vein, the host olivine gabbro is relatively enriched in plagioclase.

SECONDARY MINERALOGY:

Smectite.
- Mode of Occurrence: Replacing olivine.

Iron oxide minerals.
- Mode of Occurrence: Replacing olivine and clinopyroxene.

Tremolite/actinolite.
- Mode of Occurrence: Replacing olivine, clinopyroxene, plagioclase.

Talc.
- Mode of Occurrence: Replacing olivine.

Iddingsite.
- Mode of Occurrence: Replacing olivine.

Pyrite.
- Mode of Occurrence: Replacing olivine.

Chlorite.
- Mode of Occurrence: Replacing olivine, clinopyroxene, plagioclase.

Actinolite.
- Mode of Occurrence: Replacing clinopyroxene.

Secondary plagioclase.
- Mode of Occurrence: Replacing plagioclase.

Comments: Alteration in this section is high to pervasive (70%–90%), with pervasive alteration of olivine and clinopyroxene common. Olivine is generally altered at least 80%, with most grains pervasively replaced by variable amounts of smectite, iron oxide minerals, tremolite/actinolite, and chlorite, with talc, iddingsite, and pyrite less common. In Piece 1, olivine is pseudomorphed by a yellow green soft mineral (clay or serpentine(?)), which is rimmed by chlorite. These minerals typically form amoeboid shaped coronas after olivine with tremolitic cores and dark green chlorite rims common. Rare grains are narrowly rimmed by brown amphibole. Clinopyroxene is highly to pervasively replaced (70%–100%) by actinolite, iron oxide minerals, and rare secondary clinopyroxene and brown amphibole blebs. Intergrown actinolite and chlorite forms fibrous patches and microveinlets which cut plagioclase. Plagioclase is highly altered (60%) to secondary plagioclase, and clay minerals, and is both rimmed and cut by actinolite and chlorite at grains boundaries and as veinlets. Very fine oxide mineral stringers occur throughout the core which are rimmed by an orange clay mineral(?).

Veins

Microveinlets (<<1 mm) of actinolite and chlorite are common, especially in Piece 3. Piece 4 contains a 10 mm wide actinolite vein with fine-grained apatite near vein margins, rare oxide minerals, and that exhibits feathery edges. The vein is bounded by a 1–2 mm wide zone of chalk white plagioclase. The vein is cut at a high angle by a fine veinlet (~1 mm wide) of chlorite and actinolite. Coarse-grained clinopyroxene near this vein is highly altered to actinolite, clay minerals and brown hornblende.

VEIN/FRACTURE FILLING:

Actinolite and chlorite.

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Size: <<1 mm.

Actinolite, apatite, magnetite, and plagioclase.

Size: 10–12 mm.

Comments: Actinolite occurs replacing clinopyroxene. Vein occurs in Piece 4.

Chlorite.

Size: ~1 mm.

Comments: Crosscuts the actinolite + apatite + magnetite + plagioclase vein in Piece 4.

ADDITIONAL COMMENTS: Structure

No penetrative mineral shape fabrics were observed except for a weak local alignment of subhedral plagioclase. Three main types of veins occur in the section. The first is a group of evenly distributed thin (<<1 mm) discontinuous (about 15 mm long) veins filled with actinolite and chlorite (V5 in structure log). These veins are shallowly dipping 30°–35° and are found in Pieces 1, 2, 3, 4, and 5. The next set (V4 in structure log) includes discrete actinolite and chlorite veins that are about 1 mm thick and generally >7 cm long. These veins have a steeper orientation (25°–50°) than the V5 set and are found in Pieces 1, 2, and 6. The last set includes discrete veins that have strong white halos and are cored by green actinolite. The boundaries of both the core and the halo are very diffuse. One of these veins is found in Piece 6, it dips about 30° and it is crosscut by discrete V4 veins. A coarse-grained magmatic vein occurs in Piece 6. It has very diffuse boundaries, is 15 mm thick and dips about 60°.

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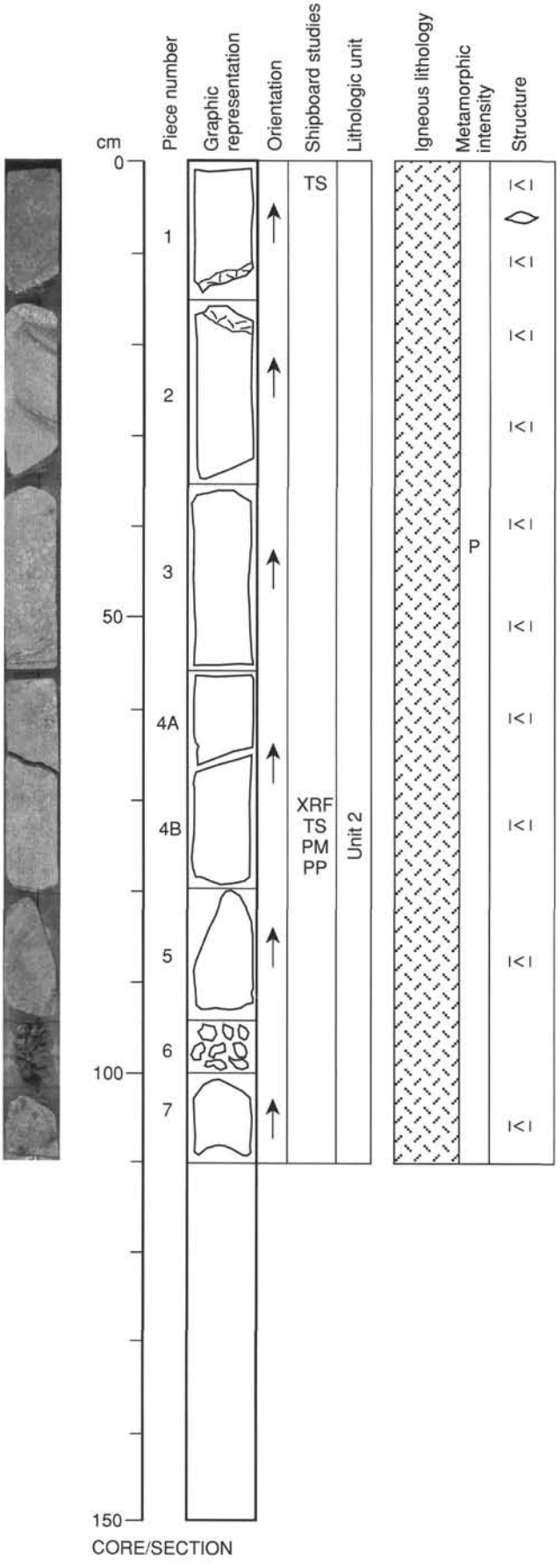


UNIT 2: METAGABBRO

Pieces 1–7

COLOR: Gray green.

PRIMARY MINERALOGY:

Plagioclase - Mode: 57%–68%.
- Crystal Size: 4–15 mm.
- Crystal Shape: Subhedral to anhedral.
- Crystal orientation: No preferred orientation.

Clinopyroxene - Mode: 32%–40%.
- Crystal Size: 3–10 mm.
- Crystal Shape: Anhedral.
- Crystal orientation: No preferred orientation.

Olivine - Mode: 1%–3%.
- Crystal Size: 2–4 mm.
- Crystal Shape: Anhedral.
- Crystal orientation: No preferred orientation.

Comments: The section consists of varitextured coarse metagabbro. Only several grains of altered olivine are seen throughout the section, except Piece 1 which contains 3 modal%. In places plagioclase is the primocryst phase (e.g., Piece 3; in others prismatic twinned clinopyroxene dominates as the primocryst phase and plagioclase is space filling (Pieces 4, 5, and 7). Iron oxide minerals are present throughout the section, except in Piece 7. They are >1% only in Piece 4. Coarse-grained plagioclase-rich veins, 1–2 cm thick cut across the base of Piece 1 and the top of Piece 2. They contain subhedral blocky plagioclase with space filling clinopyroxene. An altered clinopyroxenite vein (now actinolite) is rimmed by a margin of brown amphibole forming a coronal-like rim on the edge of the vein.

SECONDARY MINERALOGY:

Tremolite.

Comments: Coronas around olivine adjacent to clinopyroxene.

Actinolite.

Comments: Coronas around olivine adjacent to clinopyroxene.

Chlorite.

Comments: After olivine.

Clay minerals.

Comments: After olivine and plagioclase.

Secondary plagioclase.

Comments: ?After plagioclase.

Comments: Alteration continues to be high to pervasive as with Core 153-922B-4R-2. Olivine is pervasively altered, with well-developed coronas common and defined by tremolitic-actinolitc cores and dark green chlorite rims. Iddingsite is absent in this section, in contrast to the other three sections in Core 153-922B-4R. Rare pods contain a light yellow-white core which may be clay minerals. Clinopyroxene is highly to pervasively replaced by actinolite, chlorite, iron oxide minerals and in pervasively altered pods by clay minerals. Plagioclase is moderately to highly altered to secondary plagioclase, actinolite, chlorite and less commonly clay minerals. Coarse-grained pods throughout the section are commonly highly to pervasively altered, with a secondary mineralogy similar to that in the finer grained zones. Rare fine stringers of iron oxide minerals are altered to orange clay minerals(?). Piece 1 (working half) contains a coarse-grained pod of pervasively altered clinopyroxene, plagioclase, and olivine with abundant actinolite, chlorite, and secondary plagioclase.

Veins

The top of Piece 1 is cut by a subparallel vein network of 0.8 mm wide chlorite, zeolite, and clay mineral? veinlets. The bottom of the piece is bounded by a 7 mm wide band of chalk white plagioclase and patches of clinopyroxene pervasively replaced by actinolite. This vein continues into the top of Piece 2 and is composed of a 20 mm wide vein. Massive actinolite after clinopyroxene forms the core of the vein which is bounded on its side by fine-grained chlorite and intergown actinolite and by chalk white plagioclase. This vein is similar to one in the bottom of Piece 3 which contains an embayed core of gray green actinolite with euhedral sprays of green black amphibole overgrowing the actinolite. Dark green chlorite and mustard yellow clay minerals(?) rim the actinolitic core. Piece 3 is also cut by 2, <<1 mm wide, actinolite veinlets, which are subparallel.

VEIN/FRACTURE FILLING:

Chlorite, zeolites, and clay minerals.
- Size: 0.8 mm.

Actinolite.

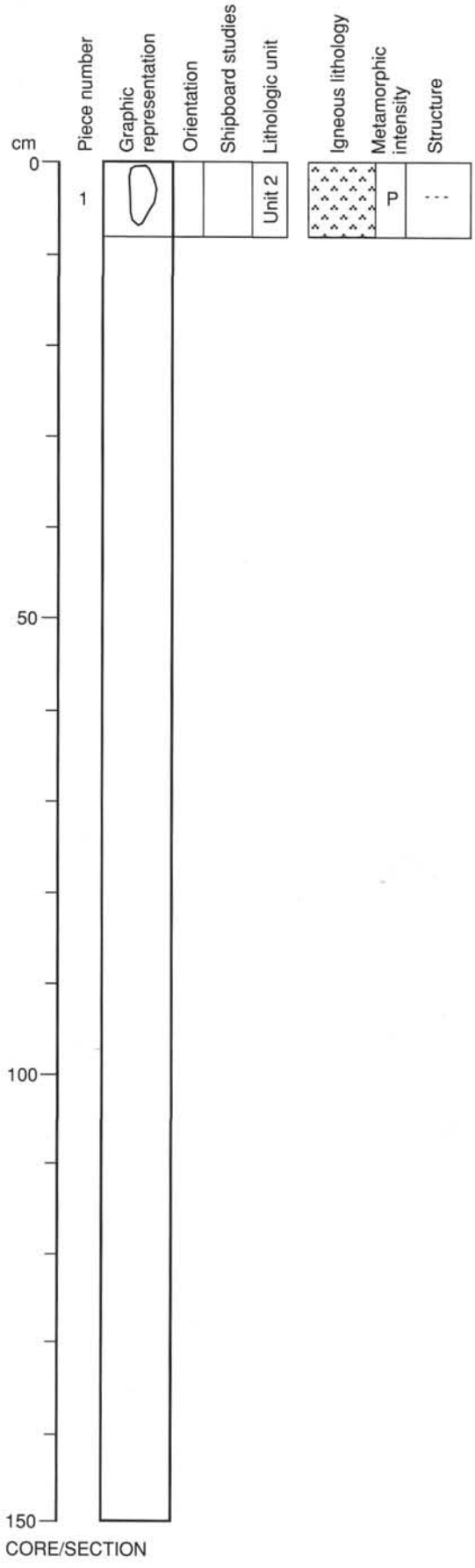
153-922B-4R-3

Size: <<1 mm.

ADDITIONAL COMMENTS: Structure

A shape fabric defined by elongated pyroxene is seen in Piece 1. The pyroxene grains have tails and deformed shapes. Three main types of veins occur in the section. The first is a group of evenly distributed thin (<<1 mm) discontinuous (about 15 mm long) veins filled with actinolite and chlorite (V5 in structure log). These veins are shallowly dipping 15°–25° and are found in Pieces 1, 2, 3, 4, 5, 6, and 7. An examination of thin sections may show that this vein set has wall-parallel shear. Pieces 1 and 2 are the most likely candidates for showing the shear. The next set (V4 in structure log) includes discrete actinolite and chlorite veins that are about 1 mm thick and generally >7 cm long. These veins dip 20°–60° and are found in Pieces 3, 4, 5, 6, 7, and 8. The last set includes discrete veins that have strong white halos and are cored by green actinolite. The boundaries of both the core and the halo are very diffuse. These veins are found in Pieces 1, 3, and 7 and they dip 5°–20°.

153-922B-5R-1



UNIT 2: OLIVINE METAGABBRO

Pieces 1

COLOR: Green black.
PRIMARY MINERALOGY:
Plagioclase - Mode: 65%.
Crystal Size: 2–20 mm.
Crystal Shape: Subhedral.
Crystal orientation: No preferred orientation.
Clinopyroxene - Mode: 20%.
Crystal Size: 2–20 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Olivine - Mode: 15%.
Crystal Size: 3–10 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Comments: This section consists of only one small sample of olivine gabbro. It is highly altered and difficult to know its igneous texture. Olivine is totally altered and show elongated shape. Huge tabular plagioclase crystals, up to 20 mm, are common. Clinopyroxenes having same lattce orientation fill the interstice of plagioclase huge grains.
SECONDARY MINERALOGY:
Smectite.
Mode of Occurrence: Replacing olivine.
Iddingsite.
Mode of Occurrence: Replacing olivine.
Chlorite.
Mode of Occurrence: Replacing olivine, clinopyroxene, plagioclase.
Pyrite.
Mode of Occurrence: Replacing olivine.
Tremolite/actinolite
Mode of Occurrence: Replacing olivine.
Second. plagioclase.
Mode of Occurrence: Replacing plagioclase.
Comments: Sample is pervasively altered (80%–90%). Olivine exhibits complex patchy alteration to smectite (olive green to yellow green), iddingsite, chlorite, pyrite, and tremolite-actinolite giving the grains a mottled appearance. Clinopyroxene is highly to pervasively altered to actinolite and chlorite forming fibrous intergrowths with gray green, amphibole-rich cores and dark green-black, chlorite-rich rims. Plagioclase is highly altered and has a pale green coloration due to crosscutting veinlets of actinolite and chlorite. Actinolite and chlorite also rim grain boundaries when plagioclase grains are adjacent to clinopyroxene.
VEIN/FRACTURE FILLING:
Actinolite and chlorite.
Comments: Occurs as microveinlets crosscutting plagioclase.
ADDITIONAL COMMENTS: None.