153-921A-1R-1

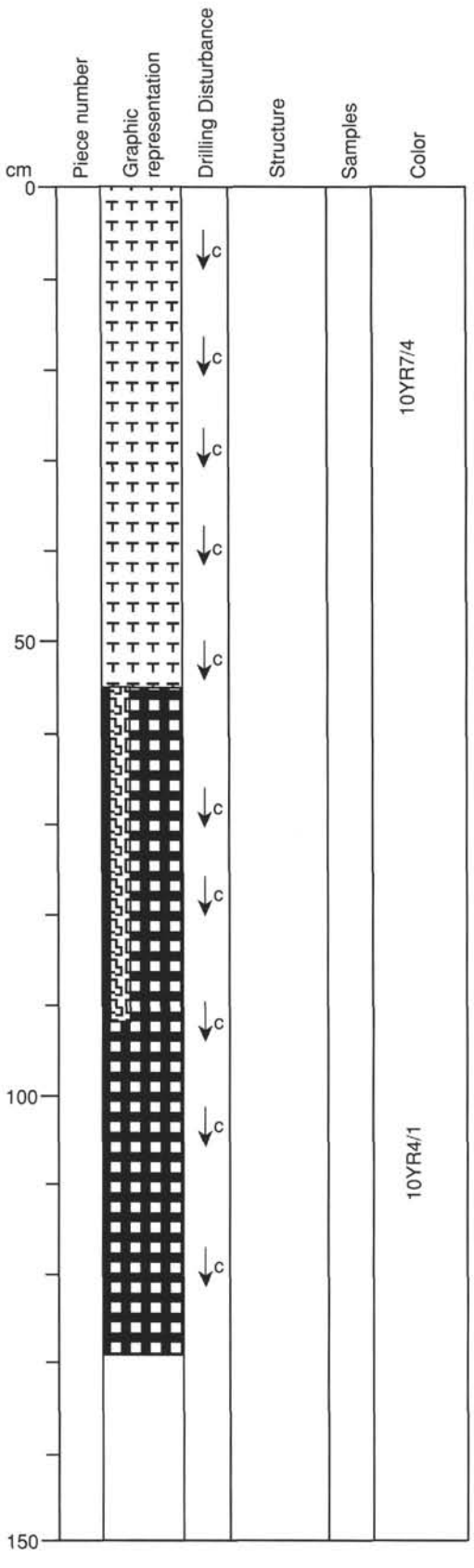
FORAMINIFERAL OOZE, IGNEOUS LITHIC BRECCIA WITH SHELL DEBRIS, and IGNEOUS LITHIC BRECCIA

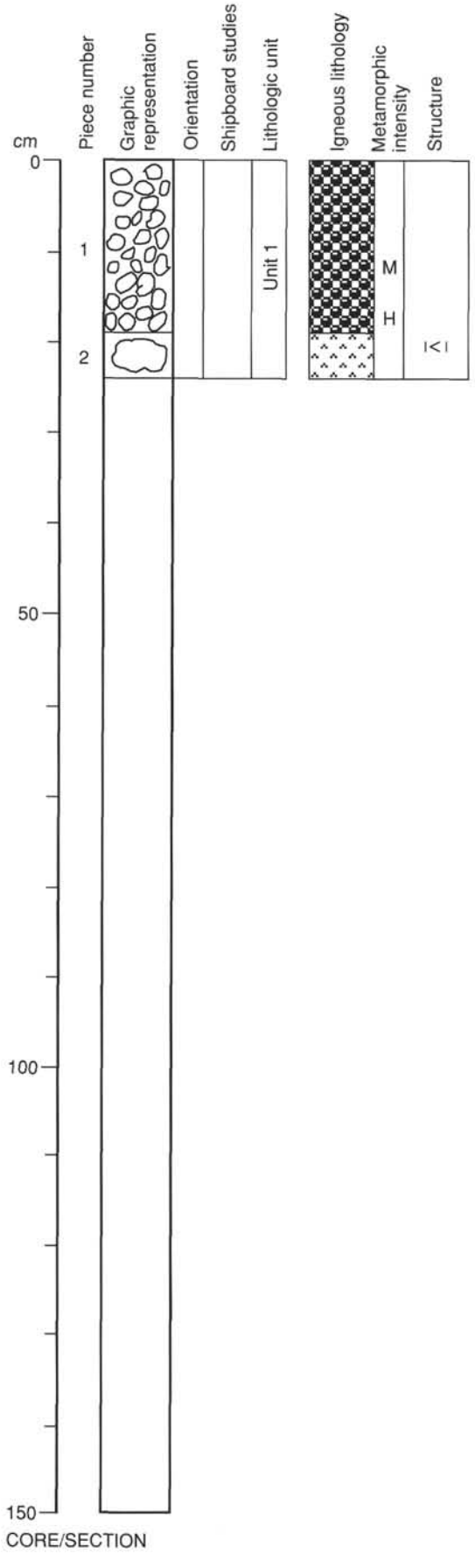
General Description

0–55 cm. Foraminiferal ooze, light brown in color, coarsening downward form a very sticky, clay-rich upper 7 cm to a well-sorted, coarse to very coarse foraminiferal sand, with a minor component of tiny shell fragments, and a very minor component of sand-sized siliciclastic grains. The silicilasic component increases downsection, as grain size increases. There is a complete gradation between this interval and the next lower interval.

55–96 cm. Still coarsening downward, by 55 cm, the siliciclastic component is >50% of the sediment, and quickly increases to account for 70%. Grain size has increased from coarse sand, through very coarse sand and granules, to small pebbles. (1–5 mm) Siliciclastic component is well sorted, and a sediment contains minor foraminifers and a somewhat greater proportion of shell debris, primarily comprising fragmented to nearly complete pterapod and gastropod shells, very minor coral fragments.

96–129 cm. Coarsening downward igneous lithic breccia. Fragments (5–100 mm) of intensely altered, brown basaltic glass, black basalt fragments, green, chloritized metagabbro?, and possibly serpentinized peridotite.





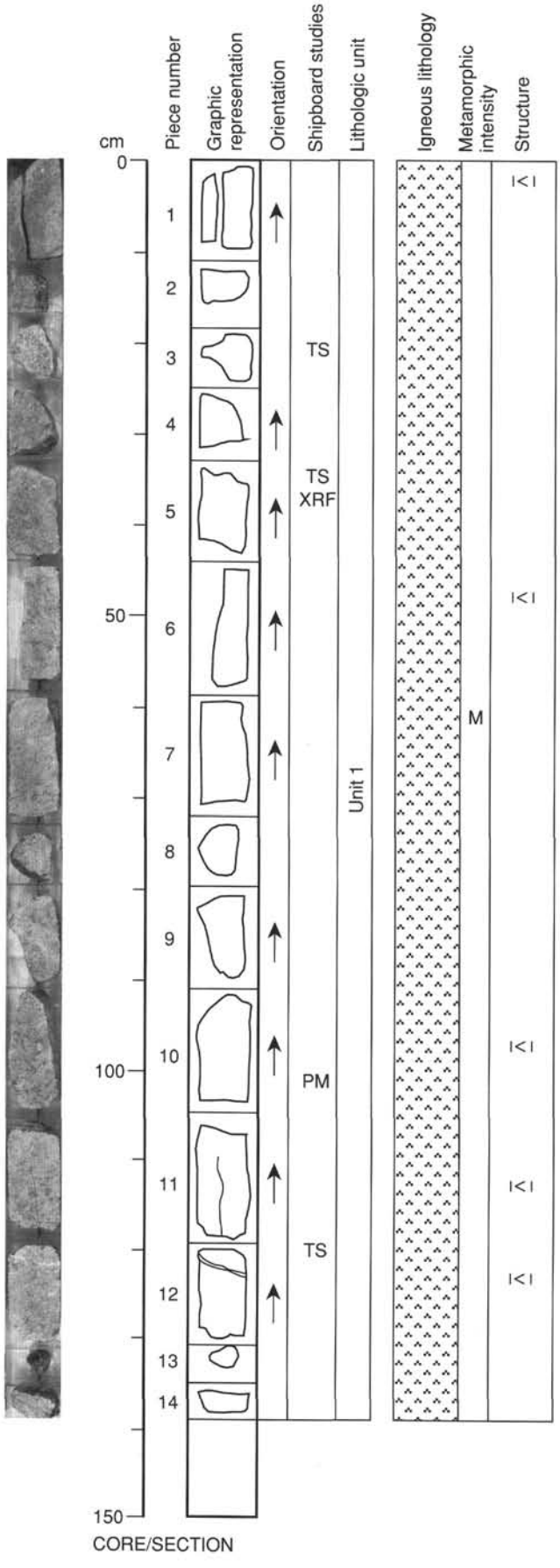
153-921A-1R-2

UNIT 1: COARSE-GRAINED GABBRO

Pieces 1–2

COLOR: Pale green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Clinopyroxene - Mode: 40%.
Crystal Size: 1–10 mm.
Crystal Shape: Subhedral.
Crystal orientation: None.
Plagioclase - Mode: 50%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Iron oxide minerals - Mode: <1%.
Crystal Size: - mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Comments: This section includes some mixed gravels (Piece 1) and one rounded cobble (Piece 2). The clasts are highly altered fine- to coarse-grained gabbroic rocks and diabase that range in size from 5 to 45 mm. The gabbroic clasts predominate, comprising more than 90% of the material recovered. The primary mineralogy of the gabbroic rocks is believed to include olivine, clinopyroxene, and plagioclase. Piece 2 is a coarse-grained olivine gabbro and might have been composed of 40% clinopyroxene, 10% olivine, and 50% plagioclase primarily.
SECONDARY MINERALOGY:
Iron oxide minerals.
Mode of Occurrence: Replacing olivine and clinopyroxene.
Smectite.
Mode of Occurrence: Replacing olivine.
Clay minerals.
Mode of Occurrence: Replacing olivine.
Chlorite.
Mode of Occurrence: Replacing plagioclase. and olivine.
Actinolite.
Texture: Fibrous.
Mode of Occurrence: Replacing clinopyroxene.
Comments: The sample is heterogeneously altered, exhibiting moderate to high intensities of alteration which average ≈40%. Alteration is most intense around the rim of the cobble, where clinopyroxene, plagioclase, and trace olivine are pervasively altered and oxide staining is abundant. Clinopyroxene is moderately to pervasively altered (15%–100%) to actinolite, chlorite and clay minerals with pervasively altered grains forming dark green patches. Plagioclase is moderately to pervasively altered (20%–90%), to secondary plagioclase, with minor chlorite, actinolite(?) and clay minerals. Minor yellow green pods associated with oxide minerals, filled with smectite, and rimmed by chlorite may be pseudomorphs after olivine.
Veins
Plagioclase is cut by microveinlets of actinolite, chlorite, and smectite.
VEIN/FRACTURE FILLING:
Mircroveinlets of actinolite, chlorite, ± smectite.
Size: <<1 mm.
ADDITIONAL COMMENTS: STRUCTURE
No plastic deformation structures. Hairline veins with chlorite filling in Piece 2.

153-921A-2R-1



UNIT 1: GABBRO

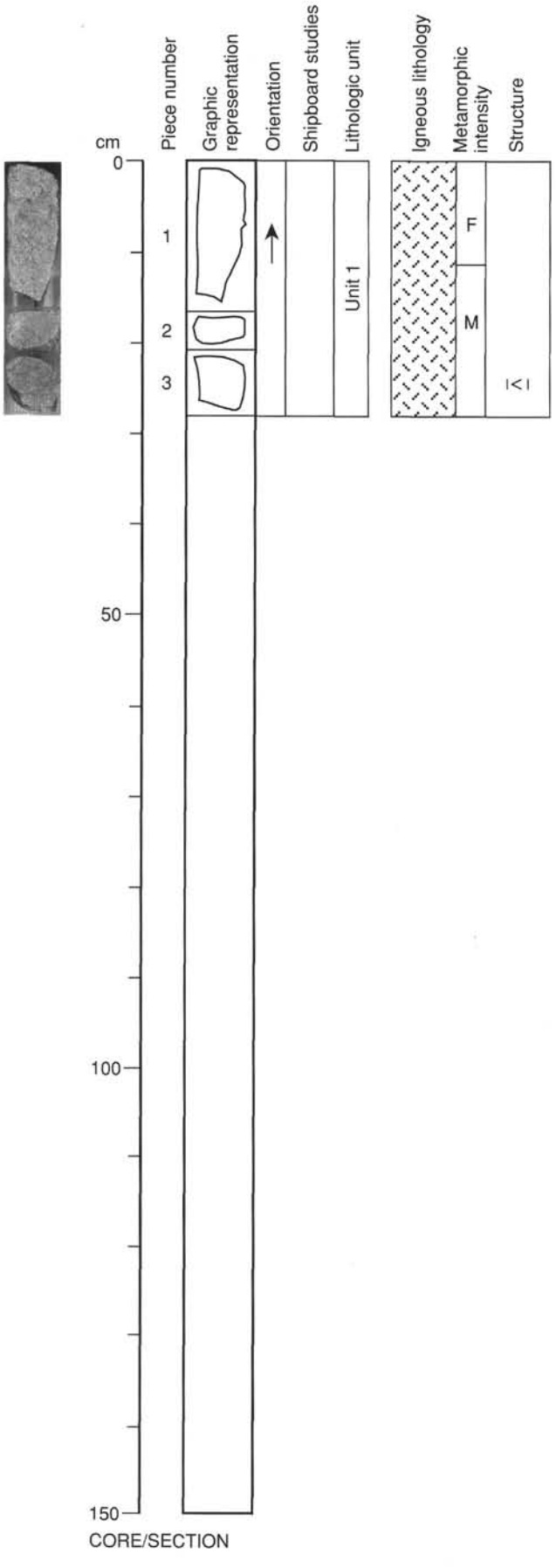
Pieces 1–14

COLOR: Greenish gray/black.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: <1%–20%.
Crystal Size: 0.5–5 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Clinopyroxene - Mode: 17%–45%.
Crystal Size: 1–15 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Plagioclase - Mode: 50%–70%.
Crystal Size: 0.5–10 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Sulfide minerals - Mode: <1%.
Crystal Size: <1 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Comments: This section predominantly consists of olivine gabbro (10%–20% olivine) with variable modes and textures, which is composed of plagioclase, olivine, clinopyroxene, and trace abundances of iron oxide and sulfide minerals. Piece 12 contains less than 1% olivine. The grain size ranges from fine to coarse. Pieces 1 to 3 are fine to medium grained, whereas Pieces 4 to 14 are generally coarse grained and are similar in overall appearance. Piece 5 contains a fine-grained layer about 1 cm thick. Plagioclase abundance is fairly constant throughout the section, whereas the modal olivine to clinopyroxene ratio decreases with increasing depth. Locally, clinopyroxene and olivine subophitically to poikilitically enclose plagioclase but overall the texture is equigranular. The only layering observed is in Piece 5 (described above) and Piece 11, which contains abundant disseminated oxide minerals in a layer ≈3 cm below the top of the piece.
SECONDARY MINERALOGY:
Actinolite.
Mode of Occurrence: Replacing clinopyroxene.
Chlorite.
Mode of Occurrence: Replacing clinopyroxene and olivine.
Amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Clay minerals.
Mode of Occurrence: Replacing olivine.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Comments: The section is heterogeneously altered with oxidation common along piece margins. Total alteration is commonly 25%–30%. Clinopyroxene is moderately to pervasively altered (up to 90%, Piece 3). Chlorite and actinolite (±pyrite) form rims and patches after clinopyroxene and, in the most intensely altered grains, clay minerals are abundant. Plagioclase is moderately altered (<15%–40%) to secondary(?) plagioclase, with minor chlorite and actinolite rimming grain boundaries or concentrated along microfractures. In Pieces 1 and 3, rare, dark-green chlorite ± amphibole ± clay mineral-filled pods may be pseudomorphs after olivine. In Piece 11, plagioclase exhibits light brown cores and pale rims with triple junctions at grain boundaries. Piece 1 contains a 3 cm wide alteration halo in the top part of the piece. Plagioclase is yellowish-orange to green in color, with abundant secondary plagioclase, oxidation staining and minor chlorite and actinolite. Clinopyroxene in this zone is moderately to pervasively altered to chlorite and actinolite. The top of Piece 9 shows extensive alteration, with clinopyroxene replaced by green actinolitic amphibole, with dark, oxide mineral-rich rims. White to light brown patches containing clay and oxide minerals are present around altered clinopyroxene.
Veins
Piece 1 is cut by four, subparallel, <1 mm wide chlorite ± actinolite veinlets. Piece 12 has a 2–3 mm wide, subhorizontal (relative to core axis) vein of plagioclase, actinolite(?), and chlorite.
VEIN/FRACTURE FILLING:

153-921A-2R-1

Plagioclase, quartz, actinolite, and chlorite.
Size: 2–3 mm.
Comments: Vein is approximately horizontal in orientation. Occurs in Piece 12.
Chlorite and actinolite.
Size: <1 mm.
Comments: Occurs in Piece 1.
ADDITIONAL COMMENTS: Structure
Equigranular with primary magmatic texture. Most pieces do not show any preferred grain-shape orientation, except for Piece 11, which exhibits a weakly developed subhorizontal linear fabric. Very few veins crosscut this structurally homogeneous rock: in Piece 12, there is a thin (1 mm) subhorizontal magmatic vein and, in Piece 11, a very thin subvertical hydrothermal vein. A fault surface is exposed in Piece 1, dipping 50°, with subhorizontal striations. Vertical joints occur in Pieces 1 and 6. Piece 8 has an irregular joint.

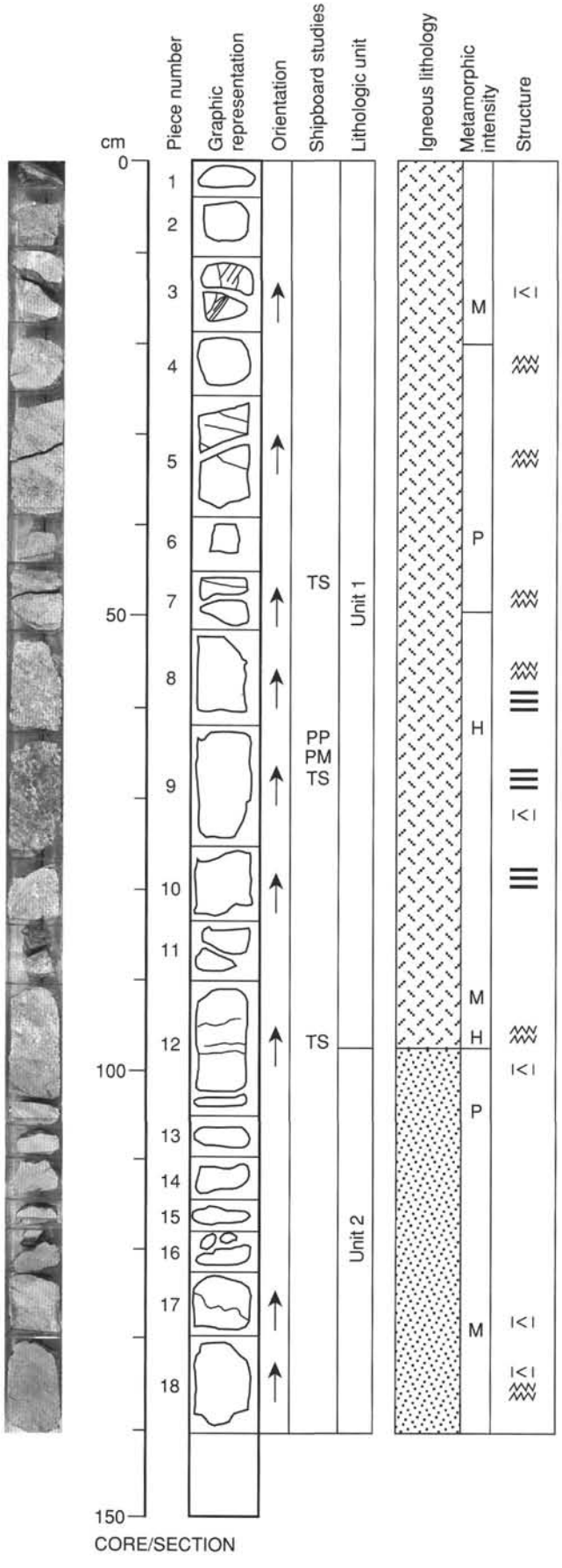
153-921A-2R-2



UNIT 1: GABBRO

Pieces 1–3

COLOR: Gray white.
PRIMARY STRUCTURE: "Magmatic" foliation in Pieces 2 and 3.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%–65%.
Crystal Size: 0.5–18 mm.
Crystal Shape: Subhedral to anhedral.
Clinopyroxene - Mode: 31%–38%.
Crystal Size: 1–18 mm.
Crystal Shape: Subhedral to anhedral.
Olivine - Mode: 1%–3%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: <1%.
Crystal Size: - mm.
Crystal Shape: Anhedral.
Comments: This section predominantly consists of gabbro which is modally homogeneous, but texturally variable. The primary minerals include plagioclase, clinopyroxene, minor olivine and trace abundances of iron oxide and sulfide minerals. The primary minerals are generally very fresh, although olivine in Piece 3 is approximately 75% altered. Grain size decreases downsection from coarse in Piece 1 to medium in Pieces 2 and 3. Locally, clinopyroxene subophitically encloses plagioclase, but overall the texture is equigranular. Pieces 2 and 3 preserve a weak alignment of primary phases. Plagioclase is highly recrystallized and some clinopyroxene crystals are bent and deformed.
SECONDARY MINERALOGY:
Actinolite.
Mode of Occurrence: Replacing clinopyroxene.
Chlorite.
Mode of Occurrence: Replacing clinopyroxene, plagioclase, olivine
Smectite.
Mode of Occurrence: Replacing olivine.
Magnetite.
Mode of Occurrence: Replacing olivine, clinopyroxene.
Sulfide minerals.
Mode of Occurrence: Primary(?)
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Comments: This section of gabbro is slightly altered, ranging from 5%–10% in Pieces 1 and 2, and about 10%–12% in Piece 3. Rare olivine grains are moderately to pervasively altered and commonly form small complex intergrowths of chlorite, smectite, iron oxide minerals, and possibly amphibole. Plagioclase is only slightly altered (<5%), to trace amphibole and chlorite when in contact with clinopyroxene. Coarse plagioclase grains are characterized by having light brown cores and lighter colored rims. Clinopyroxene is commonly rimmed by fine-grained, dark colored actinolite and chlorite and associated with disseminated pyrite. Piece 3 is stained by a small oxidized zone on one side.
Veins
Pieces 1 and 3 are cut by fine (<<1 mm) veinlets of chlorite and actinolite.
VEIN/FRACTURE FILLING:
Chlorite and actinolite.
Size: <1
Comments: Occurs in Pieces 1 and 3.
ADDITIONAL COMMENTS: Structure
Equigranular with primary magmatic texture. Piece 1 shows variations in grain size. A very weakly developed preferred grain shape orientation is seen in Pieces 2 and 3. Piece 3 also has two perpendicular, thin (<1 mm) green chlorite veins cutting it.



153-921B-1W-1

UNIT 1: GNEISSIC GABBRO WITH CATACLASITE

Pieces 1–12

COLOR: Gray/green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 53%–65%.
Crystal Size: 2–12 mm.
Crystal orientation: 45° to core.
Clinopyroxene - Mode: 35%–44%.
Crystal Size: 2–10 mm.
Comments: Pieces 1–12 of this section consist of gabbro and gneissic gabbro displaying a well-defined mineral lineation. Pieces 1–7 are medium grained and Pieces 8–12 are coarse grained. Plagioclase constitutes 53%–65% of gabbro and clinopyroxene 35%–46%. Piece 12 contains minor opaque oxide minerals (2%). An altered, very coarse-grained gabbro vein, 1.5 cm thick, intrudes the gabbro in Piece 3. Piece 4 is highly altered and cut by several thin (≈2–3 mm) cataclastic shear zones.
SECONDARY MINERALOGY:
Iron oxide minerals.
Mode of Occurrence: Interstitial.
Chlorite.
Mode of Occurrence: Replacing clinopyroxene.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Prehnite(?).
Mode of Occurrence: Replacing plagioclase.
Comments: The total alteration typically ranges between 15%–40%. In Piece 5, (altered 90%) remnant angular clasts of altered clinopyroxene to brown amphibole(?) and actinolite are contained within fine-grained, epidote-rich shear zones. Pieces 1–3 are moderately altered gabbro (15%–40%); clinopyroxene is slightly to partially replaced by actinolite, brown amphibole, iron oxide minerals, and possibly chlorite. Plagioclase is relatively fresh, except locally with possible prehnite replacement and minor chlorite and actinolite along grain boundaries. Alteration is most intense near the gabbroic vein in Piece 3. Pieces 4–7 are pervasively altered corresponding with intense deformation in these samples in the form of cataclastic shear zones. Away from the shear zones, plagioclase is whitish in color. Clinopyroxene is locally rimmed by, or shows patches of, chlorite, actinolite, and iron oxide minerals. Within the shear zones, intense grain size reduction makes it difficult to identify alteration products. The shear zones are composed of a very hard, pale green mineral, which is likely to be epidote with intergrowths of actinolite. Within the shear zone is fine-grained brown amphibole, which may be associated with clinopyroxene. Other alteration minerals include chlorite and clay minerals. Rare, fine-grained clear grains may be plagioclase augen. Pieces 9–12 are moderately to highly altered (40%–50%) gabbroic gneiss in which plagioclase is dynamically recrystallized in fine-grained, sugary, whitish aggregates, and are cut by abundant chlorite and actinolite microveinlets which extend from the pyroxene. Clinopyroxene is moderately (15%–20%) altered to brown blebs of amphibole and rimmed by actinolite and chlorite. Piece 12 is heterogeneously altered with the augen gneiss highly to pervasively altered. At the diabase-gabbro contact (Piece 12A), the gabbro is deformed and has a very fine-grained chlorite-rich matrix.
Veins
Piece 3 is cut by a 10 mm wide, pervasively altered, plagioclase-rich vein with minor pale yellow epidote and amphibolitized clinopyroxene; amphibole prisms occur at the selvages. Plagioclase is chalk white. Iron oxide minerals are fresh. The vein is cut by a 1 mm wide shear zone. Pieces 8 and 9 contain microveinlets, <<1 mm wide, which include prehnite(?), chlorite, and possible actinolite veinlets.
VEIN/FRACTURE FILLING:
Actinolite and chlorite.
Size: <<1 mm.
Comments: Veins form less than 1% of rock.
Chlorite and talc.
Size: <<1 mm.

153-921B-1W-1

Comments: Forms less than 1% of the rock.
ADDITIONAL COMMENTS: Structure
A lineation defined by the alignment of the long axes of clinopyroxene grains is well developed in Pieces 9 and 10, where the dip is moderate (about 50°), and more weakly developed in the other pieces from 1 through 12. Brittle shear zones or microfaults are found in Pieces 3, 4, 5, 7, 8, 9, and 12. Typically, they have shallow dips, except in Pieces 8 and 9 where they are subvertical and show west-side down offsets. The shear zones are thin (1–3 mm) except in Piece 5 where a thicker (6 cm) zone was observed and in Piece 12 where a brittle shear zone at the contact with diabase is about 1 cm thick. Pieces 8–12 show a well-defined foliation that appears to sweep into the margin of the cataclasite at a lower angle.
Igneous/Structural Interpretation
The foliation in Pieces 8–12 may represent a subsolidus fabric. This foliation also suggests higher strains adjacent to the margin of the cataclasite. This, and the fact that amphibole clasts are contained in the cataclasite, may suggest that the deformation of the gabbro was at an early, high-temperature stage and that the strain became more localized with time and cooling of the gabbro. It appears that granulite, amphibolite, and greenschist facies assemblages are represented in the assemblages within and adjacent to the shear zone again indicating a progressive down-temperature series of metamorphic and deformation events. Alternatively, high- and low-temperature events may be unrelated. If related, the curvature of the foliation would suggest sinistral shear relative to the archived core face for the higher temperature deformation. There is, however, conflicting evidence of sense of shear in the cataclasite with both sinistral and dextral indicators. The early high-temperature foliation could be related to strain localization along the dike margin shortly after intrusion that continued to lower temperatures. Piece 12 also contains sulfide minerals on either side of the cataclasite. The cataclastic material may be locally fluidized as indications of an intrusive relationship with the gabbro are present.

UNIT 2: SPARSELY PHYRIC DIABASE WITH GABBRO

Pieces 12–18

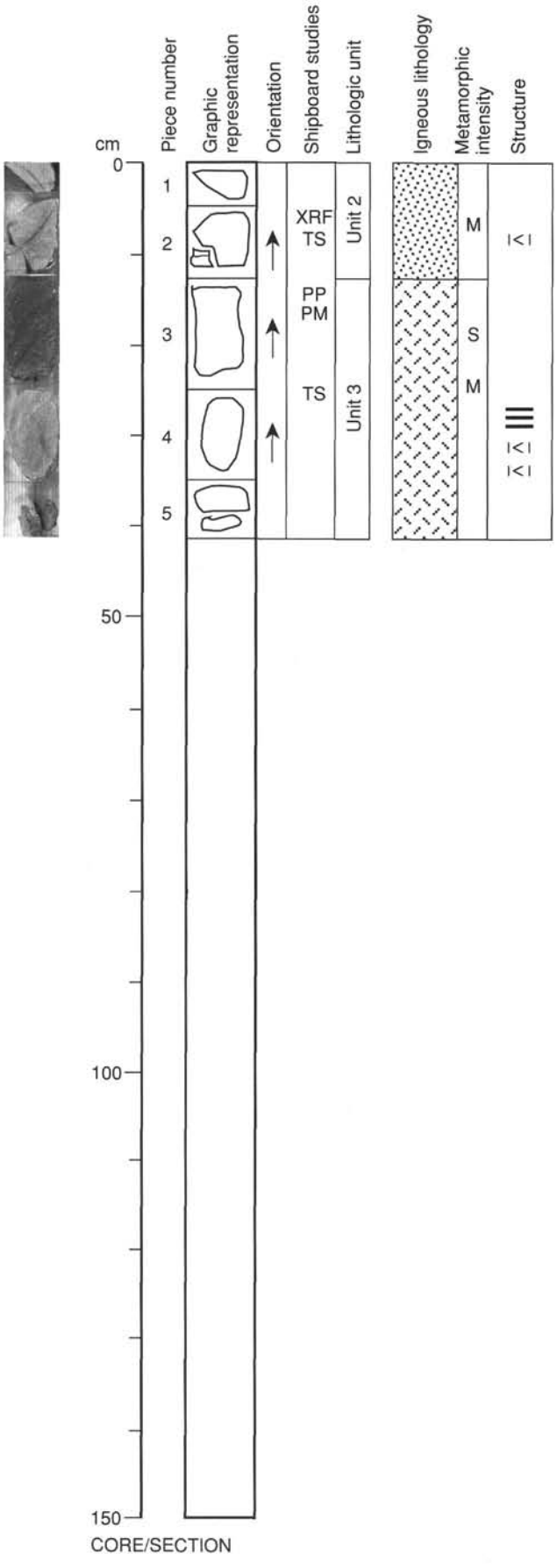
CONTACTS: Diabase strongly chilled against gabbro (Piece 17) or tectonically emplaced (Piece 12)
PHENOCRYSTS:
Olivine - 3%; 1–2 mm; Euhedral.
Plagioclase. - 5%; 2–3 mm; Euhedral.
GROUNDMASS: Fine-grained, aphyric, strongly chilled.
VESICLES: % Size: mm. Shape:
Distribution:
COLOR:
STRUCTURE:
ALTERATION: Olivine phenocrysts are altered to chlorite and pyrite. Plagioclase phenocrysts are altered to prehnite(?) and secondary plagioclase.
VEIN/FRACTURES:
Chlorite.
Size: <<1 mm.
ADDITIONAL COMMENTS: 921B-1W-1 (Unit 2)
Igneous
Pieces 12–19 mark the top of Unit 2, a diabase. The upper contact of the diabase (within Piece 12) is defined by a matrix-poor cataclasite, but preserves a chilled zone within the diabase that is at an angle to the tectonic contact. A second, undulating chilled contact that faces upward (gabbro to the top) is in Piece 17. The diabase is red-gray in color and contains phenocrysts of altered plagioclase and olivine (now chlorite). The diabase varies from aphyric to sparsely phyric.
Metamorphic
Phenocrysts are completely pseudomorphed olivine replaced by chlorite and pyrite, and plagioclase is altered to secondary plagioclase and prehnite(?). Gabbro adjacent to the intrusive contact in Piece 17 is moderately altered (40%) with clinopyroxene altered to amphibole and chlorite, and plagioclase altered to secondary plagioclase.
Veins
Thin (<1 mm), shallowly dipping (≈25°) veins of prehnite(?) is in Pieces 12 and 17.

153-921B-1W-1

Structure

The diabase (Unit 2) first appears in the lower part of Piece 12. This chilled margin contact with the gabbro is sheared and brecciated. The subhorizontal cataclasite (1cm thick) at the contact is similar in characteristics to the other shear zones described above, but matrix poor and rich in angular gabbroic clasts. Another gabbro-diabase contact is irregular though generally of moderate dip (≈50°) in Piece 17.

153-921B-1W-2



UNIT 2: SPARSELY PORPHYRITIC

Pieces 1–2

CONTACTS: None observed.
PHENOCRYSTS:
Olivine - 0.5%–1.0%; 0.5–2.0 mm; Euhedral.
Plagioclase - 0.5%–1.0%; 1–9 mm; Subhedral.
GROUNDMASS: Very fine-grained, intergranular olivine + plagiolcase + clinopyroxene.
VESICLES: % Size: mm. Shape:
Distribution:
COLOR: Gray.
STRUCTURE:
ALTERATION: Olivine replaced by chlorite + smectite + pyrite; plagioclase replaced by secondary plagioclase. Groundmass replaced by chlorite + actinolite.
VEIN/FRACTURES:
Chlorite and actinolite.
Size: <<1 mm.
ADDITIONAL COMMENTS: Igneous
The first two pieces of this section consist of sparsely phyric diabase that is a continuation of the diabase occurring at the bottom of Section 921B-1W-1. Olivine and plagioclase phenocrysts occur in abundances of less than 1%. The groundmass consists of very fine-grained plagioclase, clinopyroxene and olivine and is partially altered.
Metamorphic
Total alteration of the phyric diabase in this section ranges from 20%–30%. Olivine and plagioclase phenocrysts are pervasively replaced. Fine-grained olivine is pseudomorphosed by chlorite and possibly smectite and rimmed by very fine-grained pyrite. Plagioclase phenocrysts are chalk white due to replacement by secondary plagioclase (80%–100%) and are cut by microveinlets of chlorite. Disseminated secondary sulfide minerals occur throughout the groundmass, and as rims and within relict fractures in altered olivine. Alteration of the fine-grained groundmass is difficult to characterize, but is green and probably altered to chlorite with minor actinolite.
Veins
Pieces 1 and 2 are cut by microveinlets of chlorite and possibly actinolite. Piece 2 contains a clay mineral-filled veinlet <1 mm in width.
Structure
This section is largely untectonized with no macroscopic brittle or ductile fabric other than the sparse veining.

UNIT 3: GABBRO

Pieces 3–5

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase. - Mode: 45%–65%.
Crystal Size: <1–10 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 0%–3%.
Crystal Size: 0.5–5 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 34%–53%.
Crystal Size: 1–7 mm.
Crystal Shape: Anhedral.
Comments: Pieces 3, 4, and 5 are gabbroic rocks that are mineralogically and texturally variable. Piece 3 is a coarse-grained gabbro with 50% plagioclase, 47% clinopyroxene, and 3% olivine. Piece 4 is a fine-grained microgabbro with 65% plagioclase, 34% clinopyroxene, and 1% iron oxide minerals. Piece 5 is a coarse-grained gabbro with 53% clinopyroxene, 45% plagioclase, 1% olivine, and 1% iron oxide minerals. Olivine, where preserved, is pale yellow to yellow-green. Plagioclase is partially recrystallized.
Pieces 3 to 5 are slightly to moderately altered (5%–15%). Olivine is pervasively altered, forming fine-grained yellow to olive green pods (Piece 4) with iron oxide minerals rimmed by chlorite. Clinopyroxene is 5%–15% altered with a fine rim of actinolite and chlorite. Plagioclase is fresh to slightly altered to

153-921B-1W-2

trace actinolite and chlorite along grain boundaries when in contact with pyroxene.

Veins

Pieces 3 and 4 are cut by microveinlets of chlorite ± actinolite.

Structure

Piece 4 (not oriented) shows a well-developed, steeply dipping, crystal shape preferred orientation. This fabric is primarily a lineation defined by long axes of pyroxene grains. The tectonic fabric, marked by plagioclase recrystallization, is superimposed on an earlier, magmatic, grain-size layering. The rest of this section is largely untectonized.

SECONDARY MINERALOGY:

Iron oxide minerals.

Mode of Occurrence: Replacing olivine and clinopyroxene.

Smectite.

Mode of Occurrence: Replacing olivine.

Chlorite.

Mode of Occurrence: Replacing clinopyroxene and plagioclase.

Secondary plagioclase.

Mode of Occurrence: Replacing plagioclase.

Actinolite.

Mode of Occurrence: Replacing clinopyroxene.

Comments:

VEIN/FRACTURE FILLING:

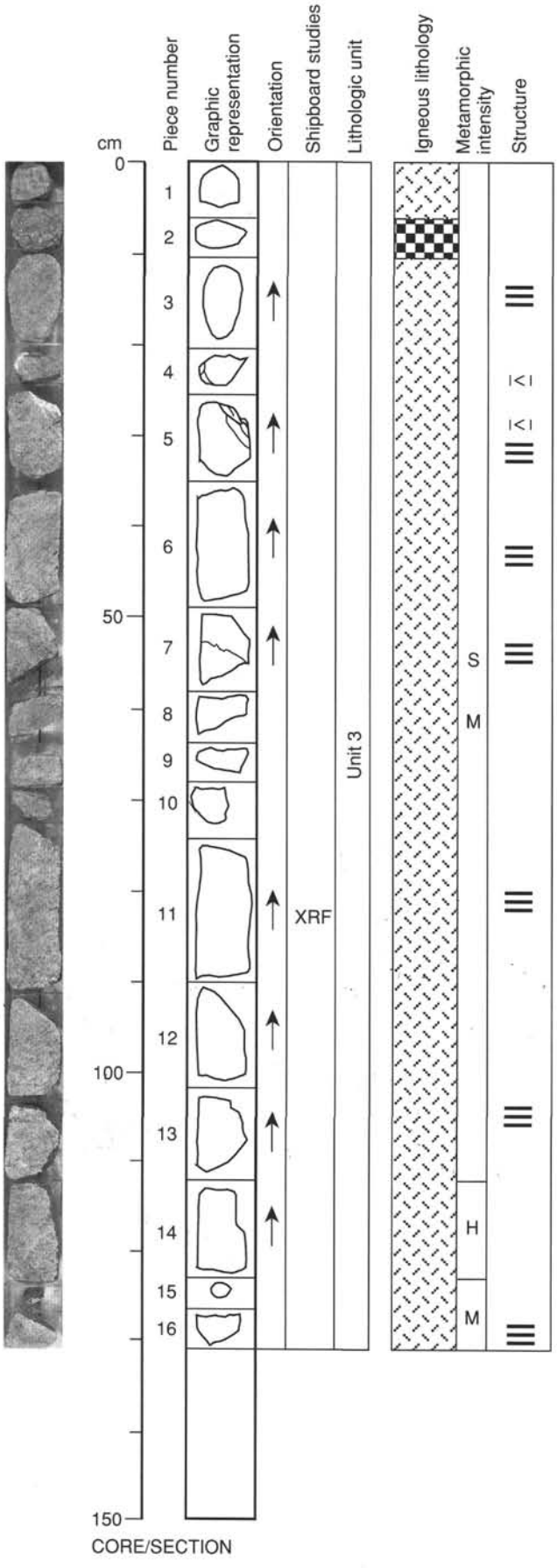
Chlorite and actinolite.

Size: <<1 mm.

Comments: Occurs in Piece 3.

ADDITIONAL COMMENTS: None.

153-921B-2R-1



UNIT 3: GABBRO

Pieces 1–16

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Clinopyroxene - Mode: 38%–53%.
Crystal Size: 1–20 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 1%.
Crystal Size: 0.5–4 mm.
Crystal Shape: Anhedral.
Orthopyroxene - Mode: 0%–3%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral.
Plagioclase - Mode: 40%–60%.
Crystal Size: <1–12 mm.
Crystal Shape: Anhedral.
Comments: This section consists of gabbro (Pieces 1, 3–16), and oxide-gabbro (Piece 2). Aside from Piece 1, the modal mineralogy is relatively homogeneous (≈50%–60% plagioclase; 40%–50% clinopyroxene). Olivine occurs in abundances of less than 2%; sulfide minerals occur in trace amounts throughout. Pieces 2 and 11–15 are significantly more coarse grained (up to 20 mm) than the remaining pieces in the section (up to 7 mm). Gradational, primary magmatic grain-size variations occur in Pieces 7 and 11. Piece 7 varies from medium to fine grained from top to bottom over a piece length of 7 cm. Piece 11 is medium grained in the top 14 cm and coarse grained in the bottom 4 cm. Several other pieces exhibit a preferred alignment of pyroxene crystals (e.g. Pieces 2, 5, 6, 7, 8, 11, 12, and 16). Pieces 4 and 5 contain felsic magmatic (trondhjemite?) veins up to 6 mm in width that are composed of plagioclase and minor actinolite, possibly after clinopyroxene. In Piece 5, two small subparallel veinlets (1 mm wide) splay obliquely off the main vein.
SECONDARY MINERALOGY:
Chlorite.
Mode of Occurrence: Replacing olivine and plagioclase.
Amphibole.
Mode of Occurrence: Replacing olivine.
Smectite.
Mode of Occurrence: Replacing olivine.
Clay minerals.
Mode of Occurrence: Replacing olivine.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene and plagioclase.
Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Pyrite.
Mode of Occurrence: Replacing clinopyroxene.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Comments: Samples from this section are slightly to moderately altered (5%–25%) except for Piece 14 (50%). Oxidation halos are common throughout the section (Pieces 2, 4, 5, 7, 9, 11, 12, 14). These have widths of up to 30 mm that are associated either with piece margins or, more rarely, with plagioclase, actinolite, and chlorite veins (Pieces 4 and 5). Individual pieces exhibit heterogeneous alteration with highest intensity in the oxidized zones. Olivine, throughout the section, is commonly pervasively altered to chlorite, amphibole, and smectite. In oxidized areas, olivine forms orange-red grains with chlorite(?) and clay mineral rims. Clinopyroxene is slightly to moderately altered with rims of actinolite ± chlorite ± pyrite and trace brown amphibole. Plagioclase is extensively recrystallized from Piece 11 through to Piece 13. In the highly recrystallized zones (75%), plagioclase commonly has light brown cores with lighter colored rims and forms irregular shaped plagioclase-rich zones. Plagioclase is up to 45%–50% altered in the oxidized zones to clayey white minerals, but away from these areas it is only slightly altered. Traces of chlorite and amphibole occur along grain boundaries and the microfractures adjacent to pyroxene grains.
Veins
Pieces 4 and 5 are cut by 5–7 mm wide, branching, plagioclase, amphibole, chlorite,

153-921B-2R-1

and magnetite veins that are associated with an oxidized zone. Plagioclase in these veins is chalk white; rare clear grains may be quartz. Fine chlorite and actinolite microveinlets occur throughout the section in trace amounts (<<1 mm in width).

VEIN/FRACTURE FILLING:

Plagioclase, amphibole, chlorite, magneite, quartz.

Size: 5–7 mm.

Comments: Occurs in Pieces 4 and 5.

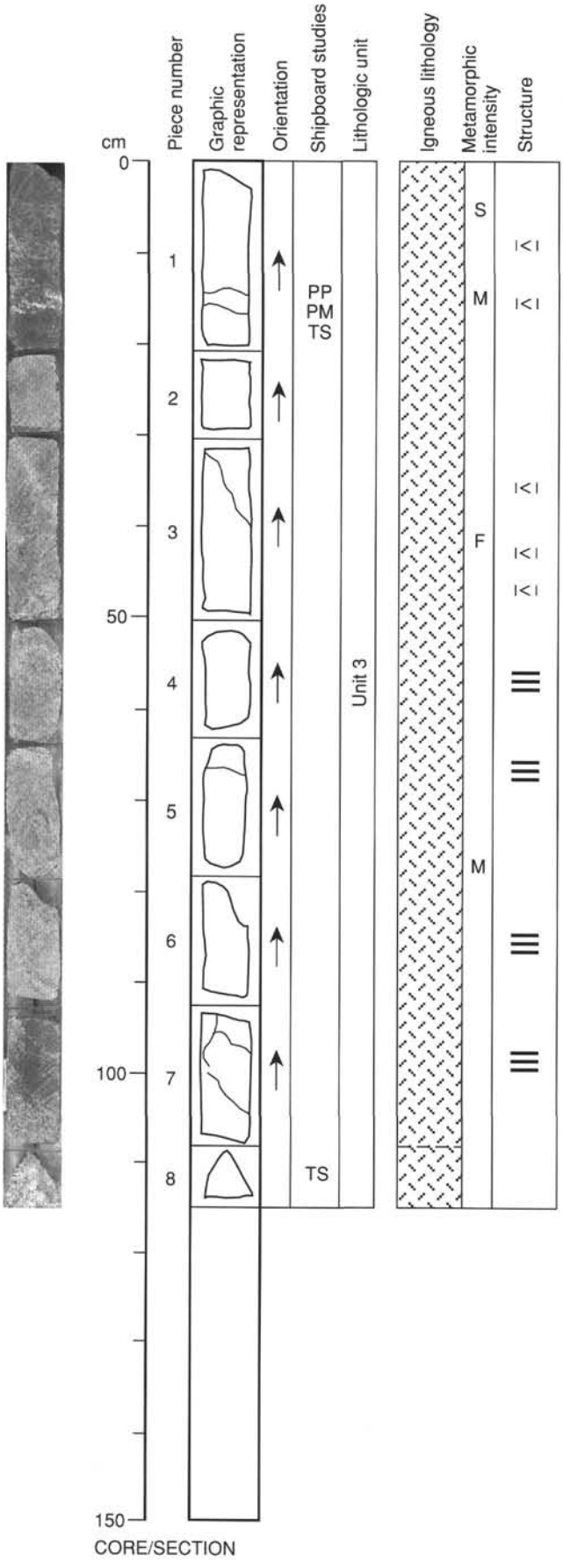
Chlorite and actinolite

Size: <<1 mm.

ADDITIONAL COMMENTS: Structure

Pieces 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, and 16 show a very weakly developed preferred grain-shape orientation due to alignment of the long axes of pyroxene grains. This fabric is primarily a lineation and is strongest in Piece 11 where it dips slightly more than 20°. It is also moderately developed in Pieces 5, 6, and 7 where it dips about 35°.

153-921B-2R-2



UNIT 3: LINEATED GABBRO

Pieces 1–8

COLOR: Gray/brown.
PRIMARY STRUCTURE: Local ?magmatic layering - grain-size variation.
SECONDARY STRUCTURE: Very high grade crystal-plastic fabric.
PRIMARY MINERALOGY:
Plagioclase - Mode: 67%–70%.
Crystal Size: <0.5 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 27%–30%.
Crystal Size: 0.5–6 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 1%–3%.
Crystal Size: <1.5 mm.
Crystal Shape: Anhedral.
Comments: The section consists of fine- to coarse-grained, lineated gabbro with a moderate to well-developed porphyroclastic texture. Clinopyroxene occurs as anhedral, generally equant, relict igneous grains up to 6 mm in size set in a mosaic of fine-grained (<0.5 mm), equant, recrystallized plagioclase displaying a seriate texture. Olivine (<3 mm) occurs both as rounded, anhedral grains and as stringers of finely recrystallized grains aligned with the plastic fabric. Iron oxide minerals are generally rare, but occur (≈5% of the mode) in a coarse-grained pyroxenite pod (1 cm x 3-4 cm) in Piece 7. Grain size varies between pieces, but only in Piece 1 is there evidence of primary igneous layering within a single piece. This piece shows a regular gradation in clinopyroxene grain size from coarse (up to 6 mm) at the base to fine (<2 mm) at the top, over a piece length of 20 cm. There is no variation in the degree of deformation of the pyroxene grains over this interval, so the gradation is interpreted as primary magmatic layering. The grain size of the recrystallized plagioclase matrix is unchanged over this interval, and probably reflects a deformational fabric. Piece 8 is predominantly a strongly altered, coarse-grained, hypidiomorphic granular gabbro that is probably a small magmatic vein crosscutting porphyroclastic gabbro. The vein contains large (3 mm) euhedral apatite(?) grains.
SECONDARY MINERALOGY:
Chlorite.
Total Percent: 5–10
Mode of Occurrence: Replaces olivine/clinopyroxene.
Brown amphibole.
Total Percent: 1
Mode of Occurrence: Associated with clinopyroxene.
Comments: After clinopyroxene.
Sulfide minerals.
Total Percent: <1
Comments: Alteration with chlorite.
Clay minerals.
Total Percent: <1
Mode of Occurrence: Alteration.
Comments: After plagioclase adjacent to some chloritic fractures.
Comments: The total alteration of this section ranges from very low (<5%) to moderate (about 20%). Piece 3 is particularly fresh. In most pieces, alteration of clinopyroxene occurs as minor replacement by brown amphibole, and more commonly by actinolitic amphibole and chlorite (Piece 7). Oxide minerals altered to hydroxide phases induce rusty staining and spotting. Chlorite and sulfide mineral alteration occurs around and on clinopyroxene and olivine, and coats fractures with a randomly oriented crystals. Plagioclase is locally stained by yellow hydroxide minerals adjacent to these fractures (e.g Piece 1). Piece 8 is the most intensely altered. Plagioclase-rich diffuse veins include clinopyroxene grains replaced by brown amphibole patches, actinolite, chlorite, smectite, and oxide minerals. At the clinopyroxene - plagioclase contact epidote, smectite, and sulfide minerals are developed.
Veins
Apart from magmatic veins in Pieces 2 and 6, dark green chlorite and light green, fine-grained, fibrous actinolite veins crosscut the core at a high angle to the gabbro foliation.
VEIN/FRACTURE FILLING:
Chlorite ± actinolite ± sulfide minerals.
Size: <1 mm.

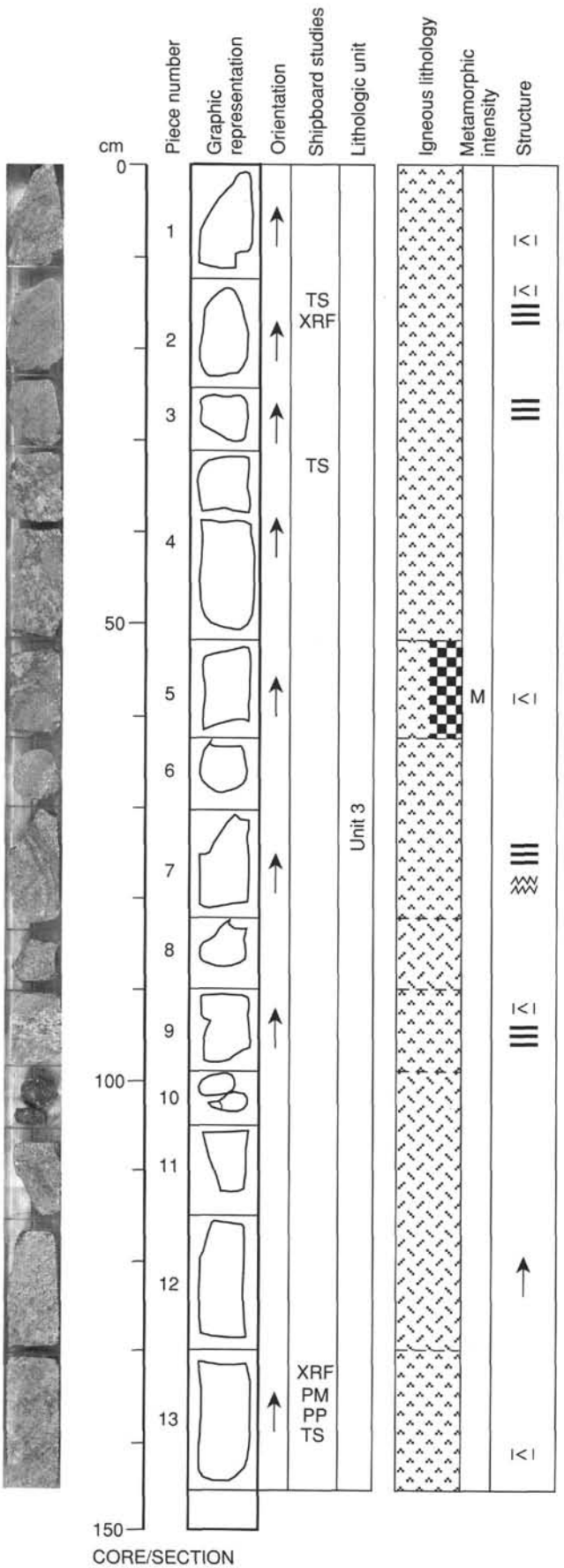
153-921B-2R-2

Comments: Coatings on randomly oriented fractures.

ADDITIONAL COMMENTS: Structure

Pieces 1 to 7 of this section show a well-developed, moderately dipping (about 30°), preferred grain-shape orientation defined by aligned long axes of pyroxene grains. Textural (grain-size) layering is present in Piece 1, the layering being slightly shallower than the grain shape preferred orientation. Pieces 1 and 3 show two veins sets (filled with chlorite and actinolite), locally in en echelon arrays. One vein set is subparallel to the fabric, dipping about 25° and the other is at high angle, dipping 40°–70° in the opposite sense. Piece 8 is coarse-grained, equigranular and devoid of deformation features.

153-921B-3R-1



UNIT 3: GABBRO-OLIVINE GABBRO.

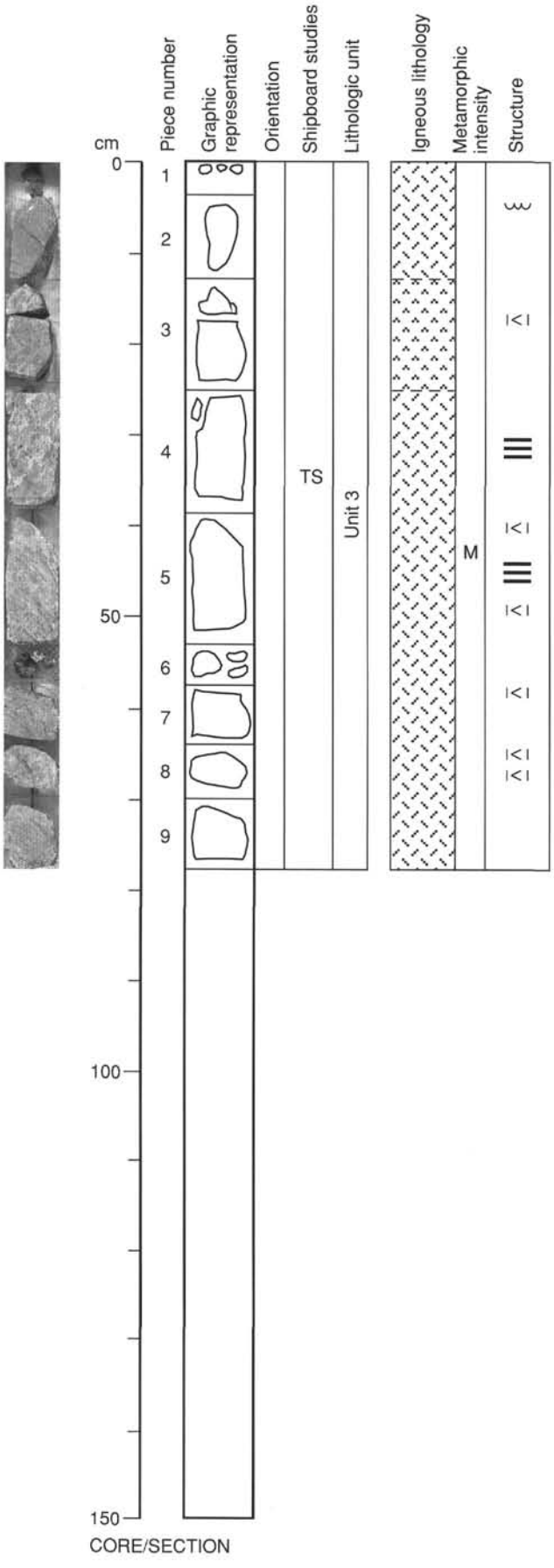
Pieces 1–13

COLOR: Gray
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 55%–65%.
Crystal Size: 1–8 mm.
Crystal Shape: Subhedral.
Crystal orientation: No
Clinopyroxene - Mode: 13%–43%.
Crystal Size: 1–13 mm.
Crystal Shape: Anhedral-subhedral.
Crystal orientation: No
Olivine - Mode: 1%–20%.
Crystal Size: 1-3 mm.
Crystal Shape: Anhedral.
Crystal orientation: No
Iron oxide minerals - Mode: 1%.
Crystal Size: - mm.
Crystal Shape: Anhedral.
Crystal orientation: No.
Comments: This section consists of variably deformed fine- to coarse-grained gabbro and olivine gabbro.Variations in grain size and texture that are probably of magmatic origin exist both between and within pieces. Pieces 1–3 are fine- to medium-grained gabbro in which a weak subhorizontal layering is defined by compositional and grain size variations. A 1 cm wide zone at the base of Piece 3 is coarse grained and may be a continuation of the coarse-grained oxide gabbros seen in Pieces 4–7. In contrast, Piece 9 is olivine gabbro in which the deformational fabric is subhorizontal. Because Piece 8 is small and unoriented, it is unclear whether it is related to the interval above or below it. Pieces 11–13 are coarse-grained gabbro and olivine gabbro that are relatively undeformed and have uniform grain size. Plagioclase content is relatively constant (55%–65%) throughout the section. Clinopyroxene abundance is lower (20%–30%) and olivine abundance higher (15%–20%) in the fine- to medium-grained olivine gabbros than in the coarse-grained gabbros (35%–45% and less than 5%, respectively). The oxide content is generally low (<1%), but reaches 10%–15 % in deformed oxide gabbros in Pieces 3–8.
SECONDARY MINERALOGY:
Sulfide minerals.
Total Percent: <1
Mode of Occurrence: Alteration.
Comments: After olivine/clinopyroxene.
Chlorite.
Total Percent: <5
Mode of Occurrence: Grain boundary cxls.
Comments: After clinopyroxene.
Brown amphibole.
Total Percent: <1
Comments: After clinopyroxene.
Comments: The overall alteration of the section ranges from 7%–15%. Pieces 2, 3, 6, 9, and 15 are relatively fresh. In most pieces, clinopyroxene is weakly replaced by brown amphibole along the cleavage and as rims, and rarely rimmed by actinolitic amphibole. Olivine is replaced by chlorite. Oxidation of iron oxide minerals produces rust stains and spots (Pieces 3, 5, and 7). In Pieces 4A, 7, and 8, plagioclase is altered to clay minerals and stained yellow where in contact with deformation tails in oxide minerals.
Veins
In Piece 6, two 1 mm wide, parallel veins filled by dark green, lamellar chlorite crosscut the piece at a high angle. Microveins filled by actinolite and chlorite are in Piece 9.
VEIN/FRACTURE FILLING:
ADDITIONAL COMMENTS: Structure
There is moderate development of a preferred alignment of the long axes of clinopyroxene and plagioclase, dipping moderately (about 45°) in Piece 3. A 1 cm zone of elongate, very coarse clinopyroxene along the bottom of the piece has a contact that is subparallel to this fabric. A 5 mm thick band (≈30° dip) of elongate and somewhat coarser clinopyroxene and plagioclase cuts

153-921B-3R-1

the grain-size layering in Piece 2. Pieces 4, 5, and 7 contain both coarse-grained, equigranular olivine gabbro and a band of strongly deformed, coarse-grained oxide gabbro (=5 cm wide) in which the fabric is undulating, but generally very steeply dipping. The dip of the foliation is highly variable (from subhorizontal to subvertical). The intimate intermixing relationships between the two lithologies are clearly exposed in Piece 4, where coarse-grained oxide gabbro forms a sinuous, subvertical, dense network of centimeter-thick zones within the finer grained gabbro. Piece 6 is a fine-grained gabbro showing only a weak mineral shape fabric, and appears to have been partially recrystallized. Given the size of the core and the textural characteristics of the two lithologies involved, it is difficult to determine whether they show crosscutting relationships or are interlayered.

153-921B-3R-2



UNIT 3: GABBRO-OLIVINE GABBRO

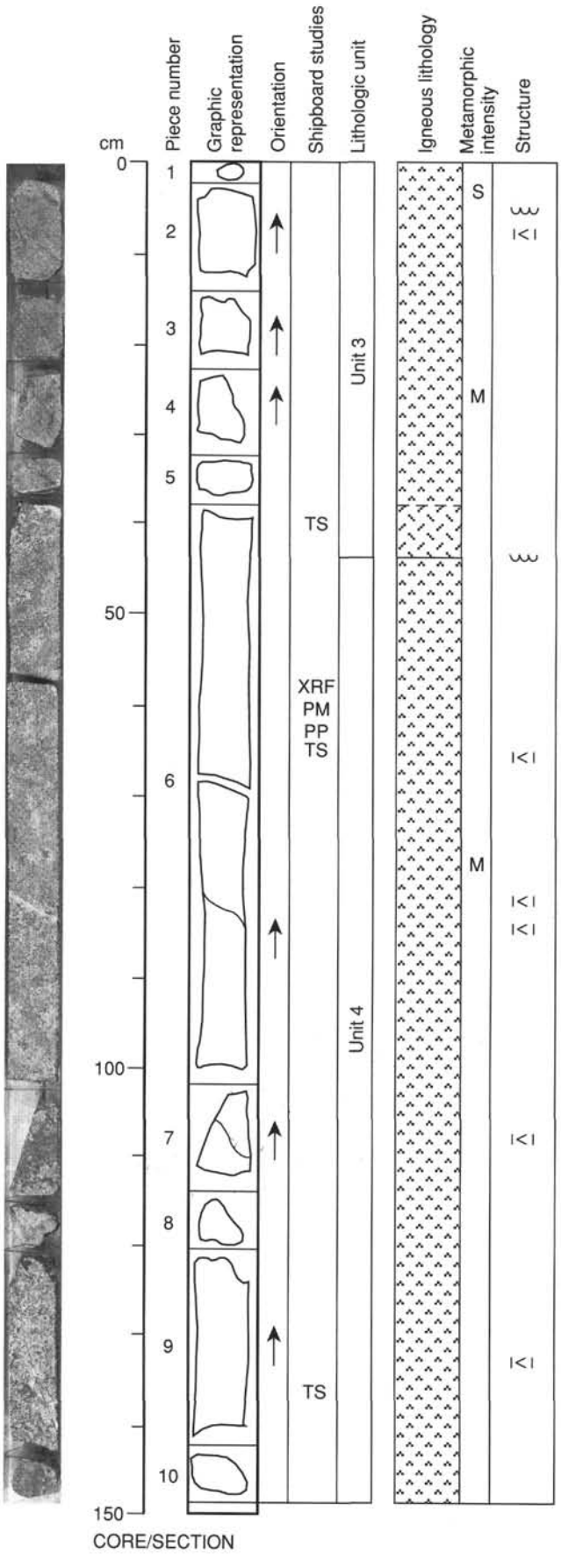
Pieces 1–9

COLOR: Gray.
PRIMARY STRUCTURE: Tectonic/magmatic fabric in Pieces 2–5.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 57%–66%.
Crystal Size: 0.2–5 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 30%–35%.
Crystal Size: .01–8 mm.
Crystal Shape: Anhedral.
Crystal orientation: Tectonic (Pieces 2–5)
Olivine - Mode: 3%–5%.
Crystal Size: <2–5 mm.
Crystal Shape: Anhedral.
Crystal orientation: Tectonic (Pieces 2–5)
Iron oxide - Mode: <1%.
Crystal Size: <1 mm.
Crystal Shape: Anhedral.
Comments: This section consists of gabbroic rocks that are mineralogically similar, but texturally variable. Modal proportions of plagioclase, clinopyroxene, and olivine are relatively constant throughout the section. Texturally the rocks vary from equigranular, weakly foliated microgabbro (Piece 2) to coarse-grained gabbro (Pieces 1, and 6–9) and foliated coarse-grained gabbro/olivine gabbro (Pieces 3–5). Olivine, which is clear to very pale green, generally forms less than 5% of the mode, but is highest in the foliated olivine gabbro of Piece 3. The foliation is defined principally by deformation within the plagioclase. Iron oxide minerals occur in abundances of less than 1%. Pieces 4 and 5 are foliated gabbros that contain relatively coarse (10–15 mm) clinopyroxenes.
SECONDARY MINERALOGY:
Brown amphibole.
Total Percent: <1
Mode of Occurrence: Replacing clinopyroxene
Comments: As blebs within and marginal to clinopyroxene.
Chlorite.
Total Percent: <3
Mode of Occurrence: Replacing olivine.
Comments: Rims and patches after olivine (very dark green) and clinopyroxene.
Sulfide minerals.
Total Percent: <<1
Mode of Occurrence: Disseminated.
Comments: Pyrite and chalcopyrite. As small blebs and coatings with chlorite alteration.
Comments: Alteration of this section ranges between 0 and 7%, and most of the section is remarkably fresh. The most altered rocks (Piece 3A and top of Piece 7) are brown due to clay minerals at the plagioclase - clinopyroxene interface. Actinolite and chlorite rims develop around clinopyroxene. In most pieces, alteration of clinopyroxene occurs as minor replacement by brown amphibole, occasionally partially rimmed by actinolitic amphibole. Oxide minerals altering to hydroxide minerals induce rusty staining and spotting (Pieces 7 and 8). In finer grained pieces, clinopyroxene grains are extensively replaced by brown amphibole. Chlorite ± actinolite is also present as coatings on fracture surfaces in Pieces 3, 5, and 7–9. Piece 7 has a 1 cm wide zone of oxidative alteration along one edge.
Veins
In Piece 2, an epidote bearing vein crosscuts plagioclase grains. In Piece 3B, a dark green, lamellar chlorite vein is present. Actinolite and chlorite veins occur in Piece 9.
VEIN/FRACTURE FILLING:
Chlorite ± actinolite ± sulfide minerals.
Size: <0.2 mm.
Orientation: No preferred.
ADDITIONAL COMMENTS: Structure
The contacts between fine- and coarse-grained areas are gradational. The fine-grained gabbro exhibits a weakly developed, moderately dipping (about 50° in Piece 2), preferred grain-shape orientation. Pieces 4 and 5 show well-developed preferred alignment of the long axes of large (to 1 cm) pyroxene

153-921B-3R-2

grains. The deformation plane is poorly defined. Some grains indicate a dextral shear sense. The plunge of the lineation is subvertical. Vein density is very low in this section. Very thin (<< 1 mm) subhorizontal to shallowly dipping chlorite and actinolite veins are in Pieces 2, 3, 5, and 9. Piece 3 is broken along one of these veins.

153-921B-4R-1



UNIT 3: OLIVINE GABBRO

Pieces 1–6

COLOR: Gray black.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Sulfide minerals - Mode: <1%.
Crystal Shape: Anhedral.
Plagioclase - Mode: 50%–75%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 15%–30%.
Crystal Size: 0.1–8 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 15%–20%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: <1%.
Crystal Shape: Anhedral.
Comments: Pieces 1–5 are olivine gabbro generally consisting of olivine, clinopyroxene, plagioclase, and small amount of iron oxide and sulfide minerals. The top 6 cm of Piece 6 is gabbro, (<1% modal olivine) in contact with the texturally distinct olivine gabbro of Unit 4. Grain size ranges from medium to coarse without systematic variation.
SECONDARY MINERALOGY:
Chlorite.
Mode of Occurrence: Replacing olivine and clinopyroxene.
Smectite.
Mode of Occurrence: Replacing olivine.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene.
Iron oxide minerals.
Mode of Occurrence: Replacing olivine and clinopyroxene.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Talc(?)
Mode of Occurrence: Replacing olivine.
Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Sulfide minerals.
Comments: Occurs on open fractures.
Comments: Penetrative alteration within the gabbro varies irregularly from low to moderate. At the top of Piece 1, a 2 cm thick alteration halo occurs. At the rim of the halo, a brownish patch marks alteration of Fe-oxides and/or olivine; plagioclase is replaced by hydrous oxide minerals. In the center of the halo, clinopyroxene is partly altered to chlorite/actinolite. Plagioclase is chalky white where recrystallized or greenish due alteration to chlorite and actinolite.
Veins
In Piece 3, a plagioclase and actinolite vein (1–3 mm wide) cuts across the piece with a dip of 70°.
VEIN/FRACTURE FILLING:
Plagioclase and actinolite.
Size: <7
ADDITIONAL COMMENTS: Structure
Alignment of elongate clinopyroxene define a weak lineation in Pieces 2 and 3 and a weak foliation in Piece 3 that dips about 45°. In Piece 2 the fabric is more clearly a lineation and dips moderately (≈30°).

UNIT 4: OLIVINE GABBRO

Pieces 6–10

COLOR: Green brown to black.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:

153-921B-4R-1

Plagioclase - Mode: 55%–60%.
Crystal Size: 5–10 mm.
Crystal Shape: Sub-anhedral.
Iron oxide minerals - Mode: 1%.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 10%–20%.
Crystal Size: 2–35 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 20%–35%.
Crystal Size: 1–15 mm.
Crystal Shape: Anhedral.
Sulfide minerals - Mode: 0%–1%.
Crystal Shape: Anhedral.
Comments: Unit 4 is coarse-grained olivine gabbro composed of olivine, clinopyroxene, plagioclase, and small amounts of iron oxide and sulfide minerals. The rocks are distinguished by the relatively high modal abundance of olivine (20%–35%) and the presence of emerald-green clinopyroxene oikocrysts that poikilitically enclose subhedral lath-shaped plagioclase. Green clinopyroxene cores are overgrown by brown clinopyroxene. The average grain size varies irregularly from medium to coarse, but large clinopyroxene oikocrysts are up to 3.5 cm in size. Igneous layering is generally absent in the section. The section has a heterogeneous modal mineralogy due to the disseminated oikocrysts, but the host olivine gabbro is modally homogenous (20%–30%) olivine, 10% clinopyroxene, 60%–70% plagioclase). Coarse (≈10 mm) magnetite grains are present in the top 1 cm of Piece 9.

SECONDARY MINERALOGY:

Actinolite.
Comments: After clinopyroxene.
Brown amphibole.
Comments: After clinopyroxene.
Hydroxide minerals.
Comments: After clinopyroxene.
Sulfide minerals.
Comments: After clinopyroxene.
Smectite.
Comments: After olivine.
Talc.
Comments: After olivine.
Iron oxide minerals.
Comments: After olivine.
Comments: In Piece 6A, the alteration is about 20%–30%, and develops as replacement of actinolite on coarse-grained clinopyroxene. Poikilitic clinopyroxene is altered to brown amphibole and actinolite. Olivine alters to smectite, talc and iron oxide minerals; plagioclase is fresh. In Piece 7, chlorite, smectite, and hydroxide minerals after clinopyroxene develop around veins. In Piece 8, around a leucocratic pod (plagioclase and quartz?), clinopyroxene is altered to green amphibole. In Piece 9, the alteration is marked by the transformation of clinopyroxene to actinolite and chlorite around the vein.

Veins

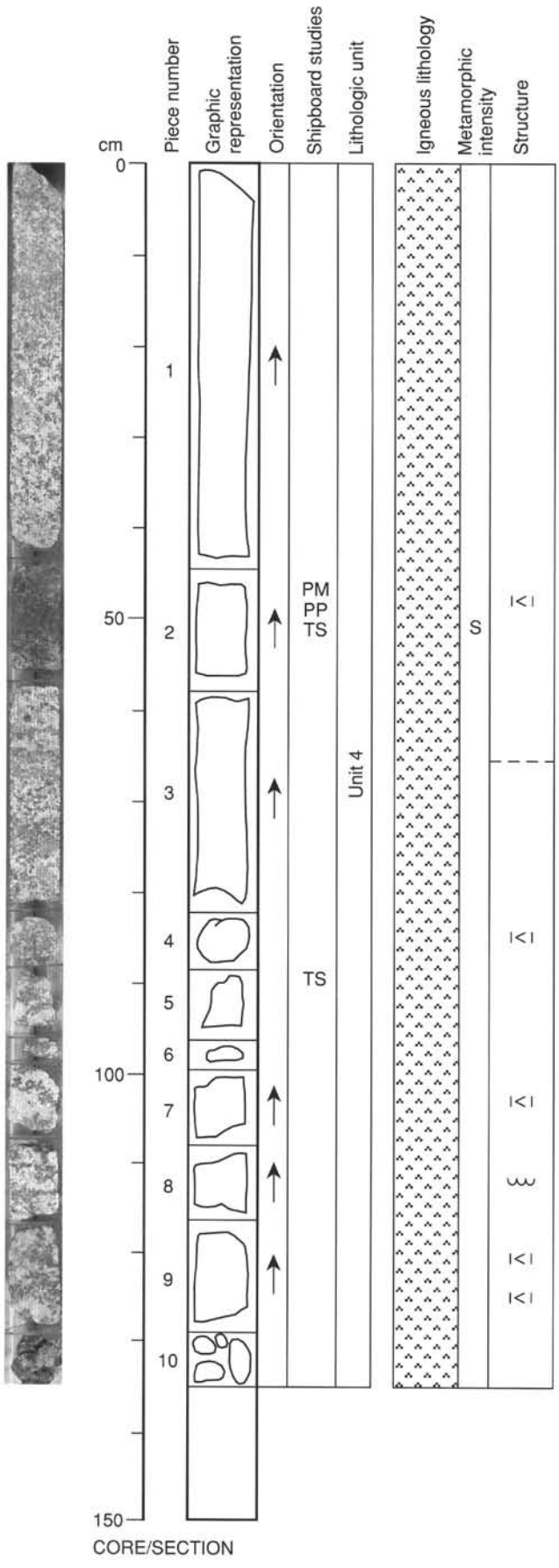
Pieces 7 and 9 contain <2 mm wide, steeply dipping, chlorite and actinolite veins. In Piece 9, steeply dipping plagioclase and actinolite veins (1–3 mm wide) cut across the piece. Piece 6B is cut by a 3 mm wide shallow dipping (20°) plagioclase (magmatic?) veinlet that has a 1–2 mm wide felsic alteration selvage. In Piece 8, sulfide minerals occur on open fractures.

VEIN/FRACTURE FILLING:

ADDITIONAL COMMENTS: Structure

The contact between gabbro and troctolite/olivine gabbro containing large poikilitic clinopyroxenes in Piece 6 dips about 35°. Aligned long axes of large clinopyroxene grains adjacent to the contact indicates possible shearing. This foliation in the gabbro is subparallel to the contact grading to slightly steeper 1 cm above the contact.

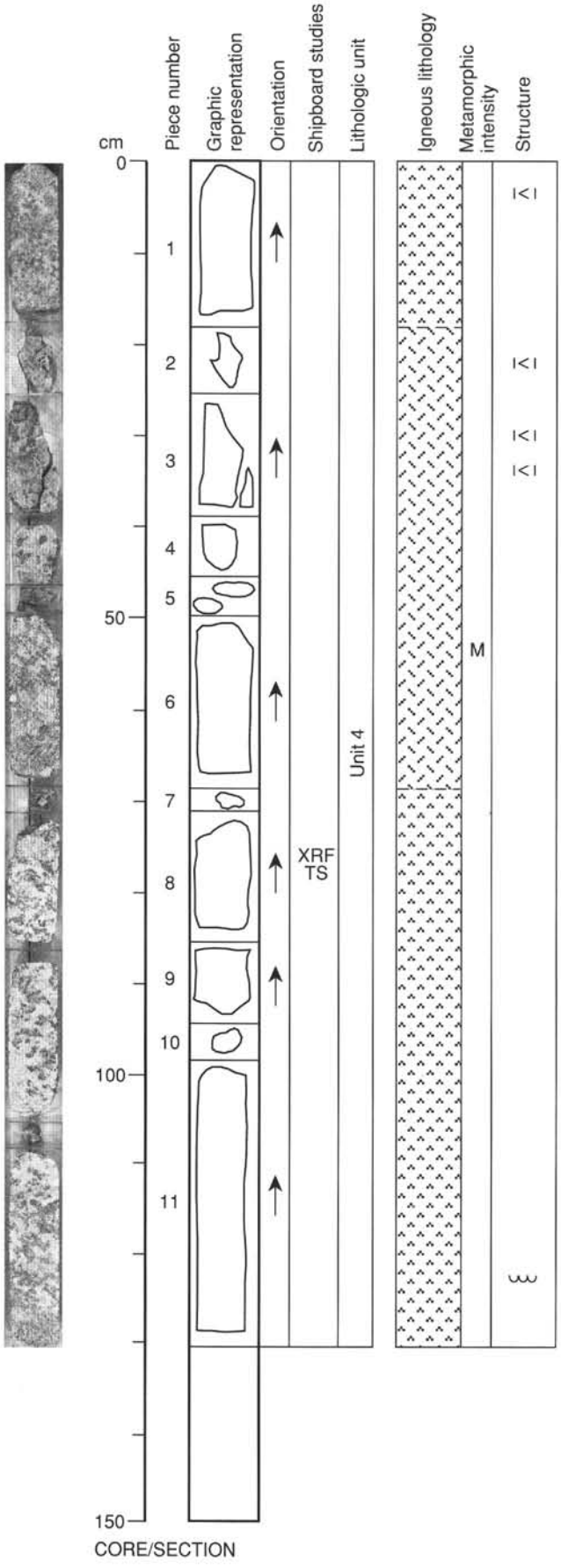
153-921B-4R-2



UNIT 4: OLIVINE GABBRO AND GABBRO

Pieces 1–10

COLOR: Gray and white.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 55%–70%.
Crystal Size: 0.5–13. mm.
Crystal Shape: Anhedral to subhedral.
Crystal orientation: No preferred orientaion.
Clinopyroxene - Mode: 10%–25%.
Crystal Size: 5–50 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Olivine - Mode: 15%–30%.
Crystal Size: 0.5–10.0. mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Comments: Poikilitic olivine gabbro is characteristic of this section. The olivine and plagioclase matrix is medium to coarse grained. Extremely coarse-grained clinopyroxene oikocrysts (up to 5 cm) enclose tabular or lath-shaped plagioclase grains. Modal olivine abundances vary inversely with the clinopyroxene abundances. Clinopyroxene is emerald green in some rocks, but is gray or brown in others. Variations in the modal proportions of matrix and oikocryst phases produce a heterogeneous textural and compositional layering on the scale of 2–10 cm.
SECONDARY MINERALOGY:
Iron oxide minerals.
Mode of Occurrence: After olivine.
Smectite.
Mode of Occurrence: After olivine.
Chlorite.
Mode of Occurrence: After olivine and clinopyroxene.
Talc.
Mode of Occurrence: After olivine.
Actinolite.
Mode of Occurrence: After olivine and clinopyroxene.
Comments: Alteration of the olivine gabbro is slight in most of the section (3%–10%), but increases in Pieces 9 and 10 to moderate (20%). Within Pieces 1, 2, 3, and 4, alteration varies from negligible to extensive replacement of coarse-grained clinopyroxene by bright green amphibole. In Piece 5 and 6, olivine is replaced by smectite and oxide-minerals or chlorite and oxide minerals, and clinopyroxene by chlorite. In Piece 9, clinopyroxene is replaced by green and lesser brown amphibole, with abundant chlorite-filled fractures. Fresh olivine is only locally preserved. Altered olivine is characterized by net veins of smectite, iron oxide minerals, and lesser amounts of talc and chlorite which separate clear olivine kernels. Alteration is most intense where grains are cut by chlorite and actinolite and smectite and chlorite veinlets. Plagioclase alteration is low, with a trace of alteration to chlorite and actinolite along microcracks. Orange-brown staining from iron hydroxide minerals occurs on plagioclase.
Veins
Piece 2 is cut by a microveinlet of talc(?) and chlorite <1 mm in width.
In Piece 9, microveinlets of chlorite and possibly actinolite and smectite and chorite vein 2 <1 mm wide are present, dipping between 45° (upper vein) and subvertical (lower vein).
VEIN/FRACTURE FILLING:
Chlorite and actinolite.
Size: <<1 mm.
Smectite and chlorite.
Size: <<1 mm.
ADDITIONAL COMMENTS: Structure
Structure
This section is almost devoid of any preferred grain shape orientation, except in Piece 3 where it is weakly developed and dips 30°. A rough compositional and grain-size layering is present in Piece 3 and parallel to the crystal shape preferred orientation.



153-921B-4R-3

UNIT 4: GABBRO AND OLIVINE GABBRO

Pieces 1–11

COLOR: Gray-green.
PRIMARY STRUCTURE: Meso- to heteradcumulate.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagiclase - Mode: 53%–60%.
Crystal Size: 1 to 4 mm.
Crystal Shape: Euhedral.
Crystal orientation: No
Clinopyroxene - Mode: 10%–45%.
Crystal Size: 2–40 mm.
Crystal Shape: Anhedral.
Crystal orientation: No
Olivine - Mode: 15%–30%.
Crystal Size: 2–25 mm.
Crystal Shape: Anhedral.
Crystal orientation: No
Orthopyroxene - Mode: 3%.
Crystal Size: 20–30 mm.
Crystal Shape: Anhedral.
Crystal orientation: No
Oxide minerals - Mode: 0.5%–2%.
Crystal Size: 0.5–2 mm.
Crystal Shape: Euhedral.
Crystal orientation: No
Sulfide minerals - Mode: <1%.
Crystal Size: 0.2–0.5 mm.
Crystal Shape: Euhedral.
Crystal orientation: No
Comments: This section is composed of gabbro and olivine gabbro in which variations in grain size and modal content of intercumulus olivine and clinopyroxene together with variations in the texture produce a diffuse layering. The layering occurs on the scale of a few centimeters (Pieces 6, 8, 9, and 11). Equant to tabular, subhedral plagioclase (1–4 mm) occurs as a cumulus phase. Anhedral clinopyroxene (2–40 mm) and olivine (2–25 mm) occur poikilitically enclosing plagioclase and as irregularly shaped interstitial crystals. Clinopyroxene is light green and rimmed by dark brown clinopyroxene. Iron oxide and sulfide minerals occur at the rims of pyroxene (Piece 2) and alter to produce iron staining of adjacent plagioclase (Pieces 1 and 2). Fresh olivine is yellow, but brown tinged where altered (a mixture of talc or serpentine and oxide or hydroxide minerals; Pieces 8, 10, and 11).
SECONDARY MINERALOGY:
Brown amphibole.
Total Percent: 1
Mode of Occurrence: Replacing clinopyroxene.
Comments:
Actinolite.
Total Percent: 1
Mode of Occurrence: Replacing clinopyroxene.
Chlorite.
Total Percent: 1
Mode of Occurrence: Replacing clinopyroxene and olivine.
Talc.
Total Percent: 0.5
Mode of Occurrence: After olivine.
Comments: Apart from Pieces 5 and 7, which are altered rubble, the pieces have generally low to moderate (10%–15 %) alteration. Pieces 2 and 3 (bottom) are the most altered. Olivine is altered to talc, smectite, and oxide minerals (Piece 2) and clinopyroxene is altered to chlorite and actinolite. In Piece 9, olivine is altered to orange-green smectite(?) with continuous dark rims of chlorite and possibly smectite. Plagioclase alteration is low, except in Pieces 2 and 3, where it exhibits a chalky alteration and brown staining.
Veins
Pieces 1, 2, and 3 are cut by irregular veinlets (<< 1 mm wide) of talc(?) and chlorite that are generally steeply dipping. Piece 1 is cut by a chlorite veinlet , <1 mm wide, that dips about 50°.
VEIN/FRACTURE FILLING:
ADDITIONAL COMMENTS: Structure
The pieces in this section are devoid of any preferred grain-shape orientation. Weak compositional and grain-size variations locally define a diffuse subhorizontal layering (Piece 6). Hydrothermal vein density is low throughout this section.

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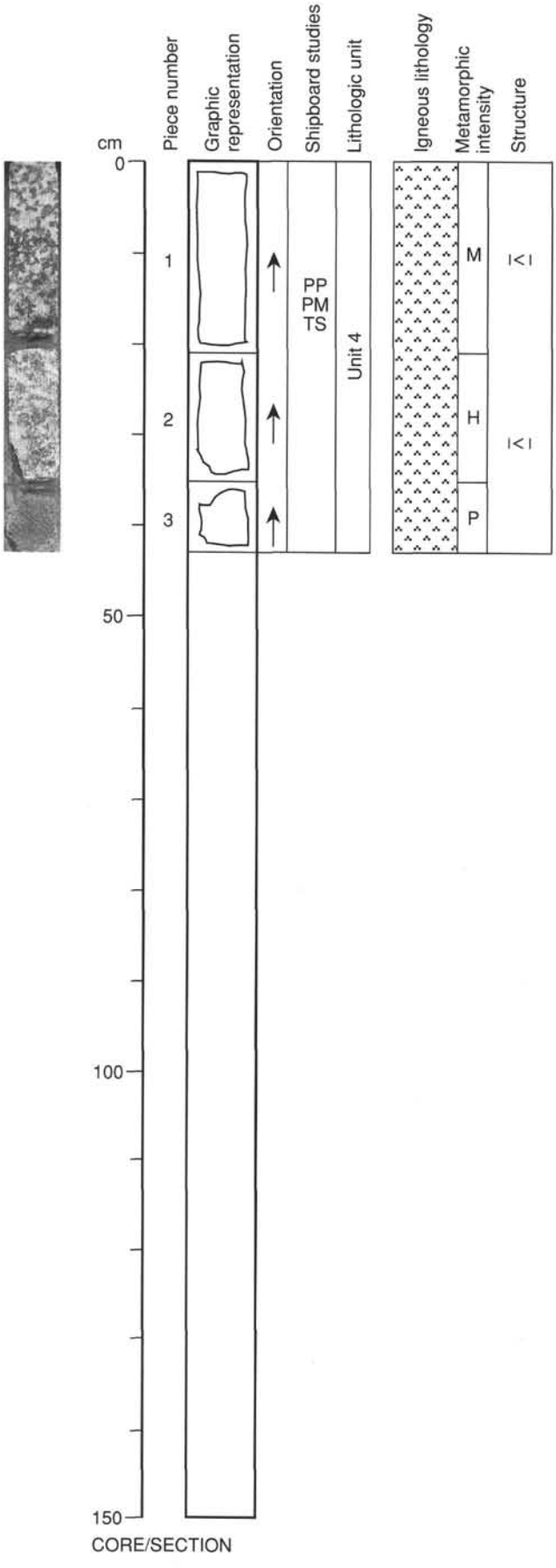
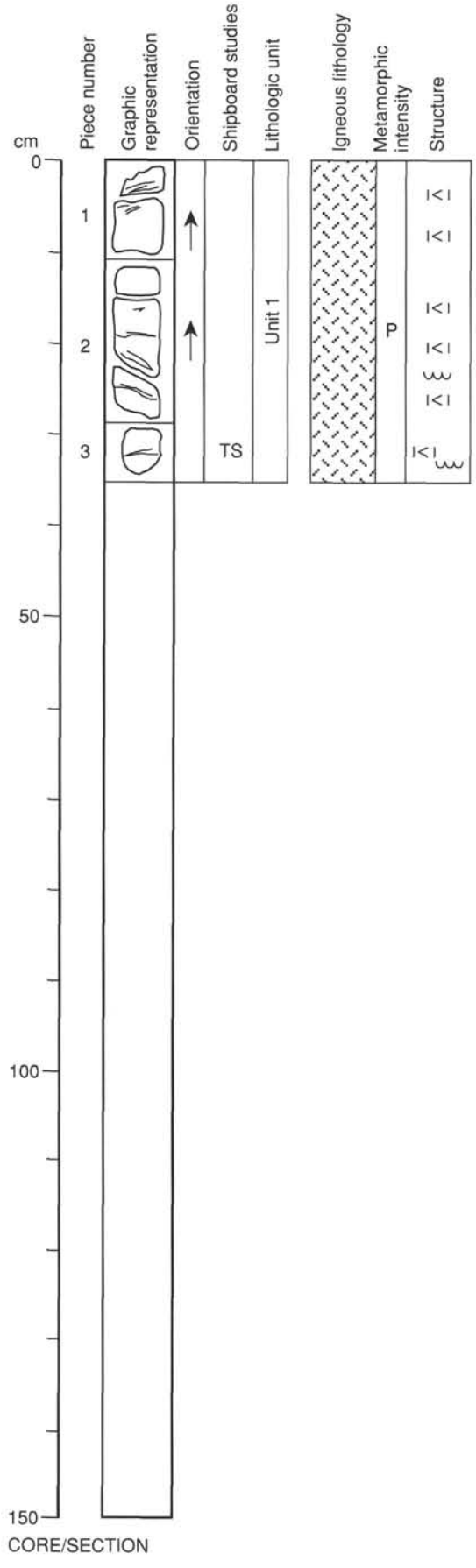


UNIT 4: OLIVINE GABBRO

Pieces 1–3

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: 10%–35%.
Clinopyroxene - Mode: 15%–38%.
Crystal Size: <7 mm.
Crystal Shape: Anhedral.
Crystal orientation: No.
Orthopyroxene - Mode: 0%–0.5%.
Crystal Size: <0.5 mm.
Crystal Shape: Anhedral.
Crystal orientation: No.
Plagioclase - Mode: 49%–55%.
Crystal Size: <5 mm.
Crystal Shape: Euhedral.
Crystal orientation: No.
Iron oxide minerals - Mode: <0.5%.
Comments: The section contains three pieces of olivine gabbro that are modally and texturally different from each other. Pieces 1 and 2 are fresh, coarse-grained gabbros with cumulus plagioclase and intercumulus olivine and clinopyroxene. Piece 1 contains 55% plagioclase, 29% olivine, and 15% clinopyroxene; orthopyroxene is possibly present as rims on olivine. Piece 2 has 40% plagioclase, 35% olivine, and 15% clinopyroxene, and includes an enclave of fine-grained leucogabbro (3 x 5 cm) composed of 60% plagioclase and 40% oikocrystic green clinopyroxene. On the working half, the inclusion is cut by a relatively large (2 x 30 mm) poikilitic green clinopyroxene that encloses plagioclase. Piece 3 is a medium-grained olivine gabbro with relatively uniform texture and grain size. It is composed of subhedral cumulus plagioclase (51%) and anhedral interstitial olivine (10%) and clinopyroxene (38%).
SECONDARY MINERALOGY:
Sulfide minerals.
Total Percent: <1
Brown hornblende.
Total Percent: <2
Mode of Occurence: After clinopyroxene.
Chlorite.
Total Percent: 1-5
Mode of Occurence: After olivine.
Talc.
Total Percent: <2
Mode of Occurence: After olivine.
Comments: Alteration in this section is slight, with an average alteration of ≈10%. Pieces 1 and 2 are characterized by slight to moderate alteration of olivine (10%–40%) which is yellow tinged due to replacement of smectite with abundant iron oxide minerals. Olivine grains exhibit discontinuous dark green black rims of chlorite ± oxide minerals. Locally, clinopyroxene is slightly to moderately altered to amphibole, and to chlorite adjacent to veinlets. Plagioclase is slightly altered to minor chlorite and possibly actinolite near veinlets. In Piece 3, alteration is less intense, and fresh clinopyroxene is preserved.
Veins
Piece 1 contains a vein of chlorite which is < 1 mm wide and dips 60°.
VEIN/FRACTURE FILLING:
ADDITIONAL COMMENTS: Structure
Pieces 1 and 2 of this section are devoid of any preferred grain-shape orientation. Piece 3 is a medium-grained gabbro displaying a very faint grain shape preferred orientation, possibly of magmatic origin.



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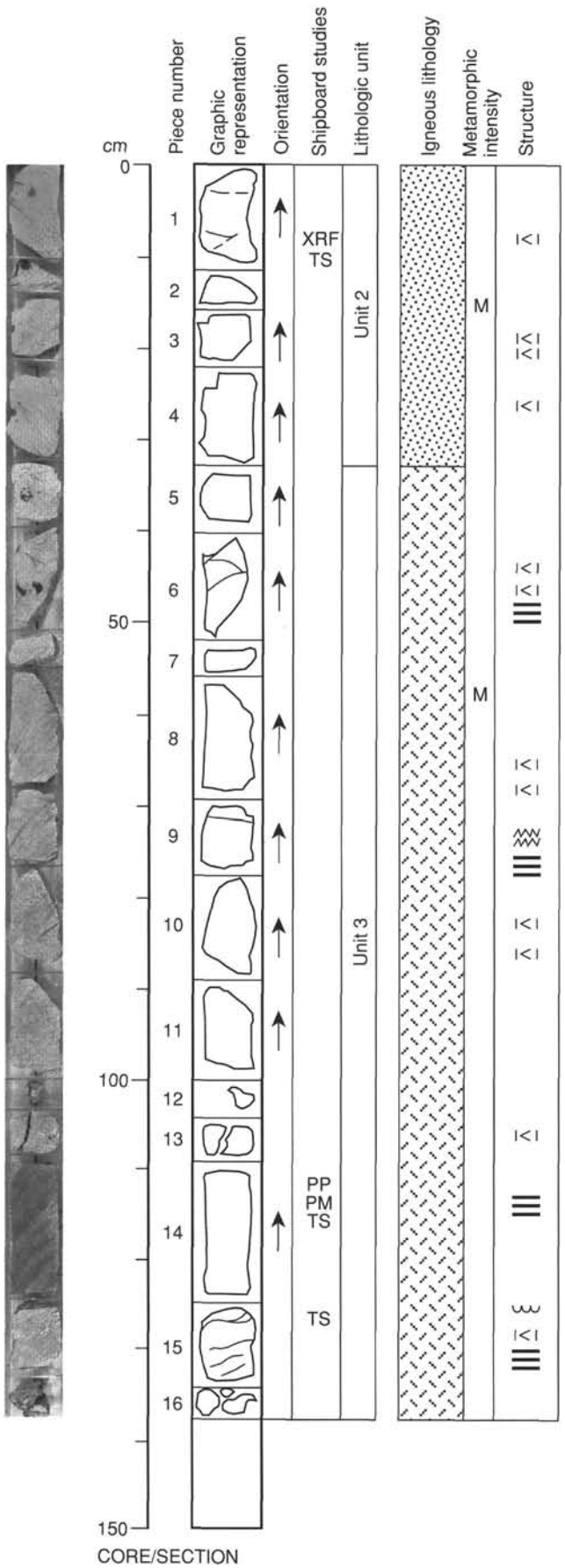
UNIT 1: METAGABBRO

Pieces 1–3

COLOR: Buff.
PRIMARY STRUCTURE: Medium-grained equigranular.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: 0.1%.
Crystal Size: 1 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 35%–40%.
Crystal Shape: Anhedral.
Plagioclase - Mode: 60%–65%.
Crystal Size: 1–3 mm.
Crystal Shape: Subhedral.
Iron oxide minerals - Mode: 0.1%.
Comments: This section is a highly altered, medium-grained, equigranular metagabbro. The metagabbro protolith is relatively uniform in grain size and modal mineralogy. Plagioclase is largely recrystallized and cloudy white. Pale gray/brown/green clinopyroxene occurs as oikocrysts up to 6 cm in size that poikilitically enclose plagioclase. Olivine and primary iron oxide minerals are rare. Sulfide minerals occur in association with the breakdown of olivine and clinopyroxene. The gabbro is crosscut by several subhorizontal, pale green veins that have a felty appearance and are probably fine-grained actinolite and epidote; small clear epidote crystals occur interstitially between plagioclase grains near the veins. Numerous thin veins typically occur together in zones 3–5 mm wide, but one zone 10 mm across occurs in Piece 2. They enclose lenses of small equant clinopyroxene and plagioclase grains, indicating that they may have been shear zones.
SECONDARY MINERALOGY:
Green amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Iron oxide minerals.
Mode of Occurrence: Replacing olivine.
Sulfide minerals.
Mode of Occurrence: Replacing olivine and clinopyroxene.
Chlorite.
Mode of Occurrence: Replacing olivine, clinopyroxene, plagioclase.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Comments: Pieces 1–3 are pervasively altered (85%–90%), and associated with intensely deformed, closely spaced, cataclastic shear zones. The mm-sized shear zones, characterized by a light pale green to cream color, are composed of very fine-grained matrix of prehnite(?), clasts of pyroxene, plagioclase, oxide minerals, chlorite, and epidote. Clinopyroxene is variably altered to actinolite, chlorite, and lesser clay minerals. Small plagioclase grains are relatively fresh. Diffuse microfractures are filled by dark green chlorite, and locally develop small alteration patches.
Veins
In Piece 3, at least four veins,1 mm wide, cut across the piece with a subhorizontal dip and spaced one to several centimeters apart.
VEIN/FRACTURE FILLING:
Actinolite.
Comments: Occurs in shear zones that form 5%–10% of the rock.
Chlorite and brown amphibole.
Size: <1
ADDITIONAL COMMENTS: Structure
This section is devoid of any grain-shape preferred orientation. It is cut by closely spaced cataclastic shear zones. Each shear zone, defined by a high concentration of anastomosing submillimeter thick veinlets, is a few cm thick, but most of the shear is concentrated along submillimeter horizons rich in epidote, actinolite, and chlorite. The shear zone orientation is subhorizontal.



153-921C-2R-1

UNIT 2: SPARSELY PHYRIC DIABASE.

Pieces 1–4

CONTACTS: None preserved or inferred.
PHENOCRYSTS:
Olivine - 1%; 0.5–2 mm; Resorbed.
Plagioclase - 3%; 0.5–5 mm; Euhedral-subhedral.
GROUNDMASS: Intergrown plagioclase laths (?50% altered) and intergranular clinopyroxene (50% altered) ± olivine (100% altered to chlorite).
VESICLES: % Size: mm. Shape:
Distribution:
COLOR: Gray.
STRUCTURE:
ALTERATION: The diabase groundmass alteration is difficult to determine due to its fine grain size, but it is approximately 30%. Clinopyroxene and/or olivine phenocrysts are altered to chlorite and tremolite; plagioclase phenocrysts appear to be fresh. The groundmass is dotted with green aggregates (possibly amphibole ± chlorite and oxide minerals). Secondary pyrite is disseminated throughout the groundmass and along fractures within the altered olivine.
VEIN/FRACTURES:
Chlorite and clay minerals.
Size: <1 mm.
Orientation: None preferred.
ADDITIONAL COMMENTS: Igneous
The first four pieces of this section consist of a fine-grained, porphyritic diabase. Resorbed phenocrysts of olivine (<2 mm) and plagioclase (<5 mm) are set in an intergranular groundmass of plagioclase laths (<1 mm) and anhedral clinopyroxene. Chlorite alteration of the groundmass is probably after olivine. There is no significant variation in grain size or phenocryst abundance within or between pieces and no contacts with the over- or underlying gabbro were recovered.
Veins
A smectite vein (<1 mm wide) is in Pieces 1–4. Plagioclase is more intensely altered around the vein.
Structure:
Pieces 1 to 4 comprise diabase, transected by sparse, <1 mm veins of clay minerals and chlorite(?). No other fabric is evident in these pieces.

UNIT 3: ALTERED FOLIATED GABBRO.

Pieces 5–16

COLOR: Gray/green.
PRIMARY STRUCTURE: High-temperature crystal-plastic fabric.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 70%.
Crystal Size: 0.1–3 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Clinopyroxene - Mode: 25%–30%.
Crystal Size: 0.2–8 mm.
Crystal Shape: Anhedral.
Crystal orientation: None.
Olivine - Mode: 1%.
Crystal Size: 0.5–3 mm.
Crystal Shape: Amhedral.
Crystal orientation: None.
Comments: Pieces 5–16 of this section are predominantly gabbro and metagabbro in which the modal proportions of plagioclase and clinopyroxene are relatively uniform (≈70% and ≈30%, respectively). These rocks are variably altered and deformed. Piece 5 is an equigranular metagabbro (>50% total alteration), whereas Pieces 6–7 are deformed metagabbro. Below Piece 7, alteration diminishes slightly, but the gabbros remain deformed, having a porphyroclastic texture. The lobate grain shape and bimodal grain-size distribution of clinopyroxene in Pieces 8–14 suggests that some of the clinopyroxene may have been intercumulus. Olivine may be present in small quantities, but the degree of alteration makes a positive identification difficult.

153-921C-2R-1

Piece 15 appears compositionally layered, but this may be due to variable recrystallization of plagioclase over the length of the piece. Piece 16 is a small chip of coarse-grained metagabbro that is highly altered to chlorite and possibly cataclastically deformed.

SECONDARY MINERALOGY:

Chlorite.

Total Percent: <10

Comments: Replaces olivine and clinopyroxene.

Epidote.

Total Percent: <20

Comments: Replaces plagiclase.

Pyrite.

Total Percent: <1

Comments: Blebs with chlorite.

Comments: Total alteration in Pieces 5–7 ranges from 60%–70%. Clinopyroxene is moderately to highly altered (up to 100%) to chlorite and actinolite. Intense alteration occurs where chlorite and actinolite filled microcracks crosscut the core. Olivine is locally replaced by brown green smectite and an iron oxide mineral; it is generally rimmed by dark green chlorite (Piece 7). Plagioclase is altered to very fine-grained secondary plagioclase. In contact with clinopyroxene, plagioclase contains minor amounts of chlorite and actinolite. Pieces 8–16 are generally moderately altered (=40%) with alteration dominated by chlorite and actinolite after clinopyroxene, and a trace of brown amphibole. Plagioclase is extensively recrystallized in very fine-grained textures and moderately altered to secondary plagioclase. Rare fine-grained black pods may be talc and oxide mineral pseudomorphs after olivine. Alteration intensity near the shear zone in Piece 9 is difficult to determine due to the fine grain size.

Veins

Pieces 1–4 have very thin (max 0.5 cm) subhorizontal white veins. Pieces 6, 8, 10, and 15 contain veinlets of chlorite and actinolite 1 mm wide. Piece 8 contains a smectite(?)/ clay mineral veinlet <1 mm wide.

VEIN/FRACTURE FILLING:

Chlorite, clay minerals, magnetite, ± pyrite.

Orientation: None preferred.

ADDITIONAL COMMENTS: Structure

A weak lineation and foliation are evident in Piece 6, defined by the shape preferred orientation of pyroxene. This fabric is cut by <1 mm veins of chlorite and clay minerals. A weak to moderate preferred orientation of plagiolase crystals of likely magmatic origin is also present in Pieces 8, 14, and 15. A cm-wide shear zone, dipping at about 60°, is present at the top of Piece 9. It is unclear as to whether this cuts the weak pyroxene lineation and foliation (dip about 40°). Piece 10 is undeformed except for clay mineral-filled veins. The base of Piece 11 looks as though it has split along a clay and iron oxide mineral vein. Several of the pieces have similar joint-controlled tops and bases (e.g., Piece 13). A textural, and possibly compositional variation is located at the center and the top of Piece 15, characterized by coarser, elongated clinopyroxene grains. Sparse, <1 mm veins of chlorite and clay minerals cut this fabric.

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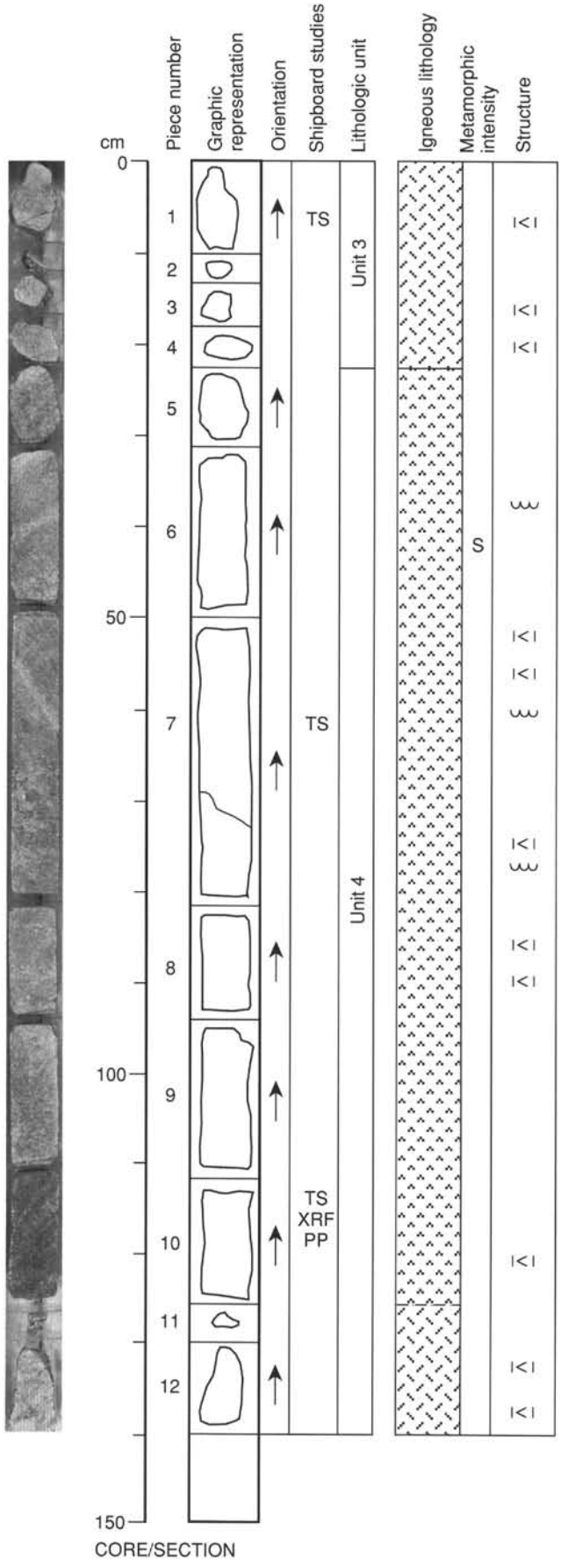

UNIT 3: GABBRO

Pieces 1–4

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 57%–59%.
Crystal Size: 1–6 mm.
Crystal Shape: Subhedral.
Clinopyroxene - Mode: 40%–42%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Iron oxide minerals. - Mode: <1%.
Crystal Size: <2 mm.
Crystal Shape: Anhedral.
Comments: This section consists of gabbro (Pieces 1–4) and olivine gabbro (Pieces 5–12). Plagioclase contents are similar throughout the section (≈60%), but pyroxene decreases from ≈40% at the top of the section to ≈25% toward the bottom. Olivine is absent in Pieces 1–4, but increases from 7% in Piece 5 to 15% in Pieces 8–10. Grain size varies both between pieces and within a piece. Pieces 1, 3, and 4 have relatively uniform fine- to medium-grained, equigranular textures. Pieces 5 to 10 have inequigranular textures and exhibit gradational changes in grain size downsection that are probably original magmatic layering. In this interval, grain-size alternates on a scale of 3 to 10 cm between layers with crystals 3–5 mm in size, to layers where crystals reach 13 mm. The most prominent variation occurs in the middle of Piece 7 where the clinopyroxene grain size reaches 10–12 mm. The coarsest average grain sizes are in Pieces 7, 10, and 12 (7–8 mm). Piece 12 also contains a diffuse contact between olivine gabbro and leucogabbro/trondhjemite in the bottom 5 cm of the piece. Pyroxene in the gabbroic portion of the piece is more strongly altered (20%) than in most of the gabbro in this section, but still appears to be bright green in color. The leucogabbro is medium grained (1–2 mm grain size) and composed predominantly of chalky white plagioclase. It is largely devoid of mafic phases (<5% of the mode).
SECONDARY MINERALOGY:
Sulfide minerals.
Chlorite.
Total Percent: <15
Comments: After clinopyroxene.
Secondary plagioclase.
Total Percent: <20
Comments: Replacing plagioclase.
Comments: Alteration decreases downsection. In Pieces 1–4, alteration reaches as high as 40%. Actinolite replaces clinopyroxene. In Pieces 1–7, clinopyroxene alters to brown amphibole. In Pieces 5–9, alteration is very low (up to 10%), brown amphibole only locally develops on clinopyroxene. In Piece 5, a white fibrous mineral replacinging clinopyroxene has been determined as Mg-hornblende by XRD. Plagioclase shows limited chalky alteration and olivine is generally fresh. Iron oxide minerals altering to hydroxide minerals produce rusty staining and spotting, mainly on plagioclase grains (Pieces 7 and 10). In Piece 10–12, clinopyroxene is altered to actinolite; plagioclase is moderately replaced by clayey aggregates and olivine is locally altered to talc and oxide minerals. In Piece 12, clinopyroxene and olivine are more extensively altered.
Veins
In Pieces 3 and 4, thin actinolite veins with plagioclase-rich selvages cut across the core. Pieces 7 and 8 contain chlorite-filled, irregular, diffuse veins about 4 mm in width. In Piece 11, a 1 mm wide white clinochlore vein cuts the sample.
VEIN/FRACTURE FILLING:
Chlorite.
Percent: <5%
Size: <3
Orientation: None preferred.
ADDITIONAL COMMENTS: Structure
Medium- to coarse-grained gabbro with gradational boundaries between areas of different grain size. The gabbro is weakly lineated in Pieces 1 and 3, defined by alignment of long axes of clinopyroxene grains. Thin hairline veins of

chlorite and/or actinolite(?) and altered plagioclase margins are found in most pieces. These veins are usually subhorizontal with dips of up to 20° except in Piece 7. Piece 7 contains two veins, a steep (60° dip) chlorite ± actinolite vein with associated white alteration that appears to cut a chlorite ± actinolite vein that dips about 40°. The width of the white-colored alteration that develops on the margins of the veins varies from <<1 mm to 5 mm (Piece 8).

UNIT 4: OLIVINE GABBRO.

Pieces 5–12

COLOR: Gray/brown.
PRIMARY STRUCTURE: Igneous texture, hypidiomorphic granular.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 54%–59%.
Crystal Size: 1–10 mm.
Crystal Shape: Subhedral.
Clinopyroxene - Mode: 25%–38%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 7%–15%.
Crystal Size: <3 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: <1%.
Crystal Size: <1 mm.
Crystal Shape: Anhedral.
Comments:
SECONDARY MINERALOGY:
Chlorite.
Total Percent: 5–10
Comments: After clinopyroxene.
Brown amphibole.
Total Percent: <1
Comments: After clinopyroxene.
Smectite/magnetite.
Total Percent: <5
Comments: After olivine.
Sulfide minerals.
Total Percent: <1
Mode of Occurrence: Disseminated.
Clay.
Total Percent: <5
Comments: After plagioclase.
Comments:
VEIN/FRACTURE FILLING:
Actinolite/chlorite.
Size: <4
Clinochlore.
Size: <1
ADDITIONAL COMMENTS: None.

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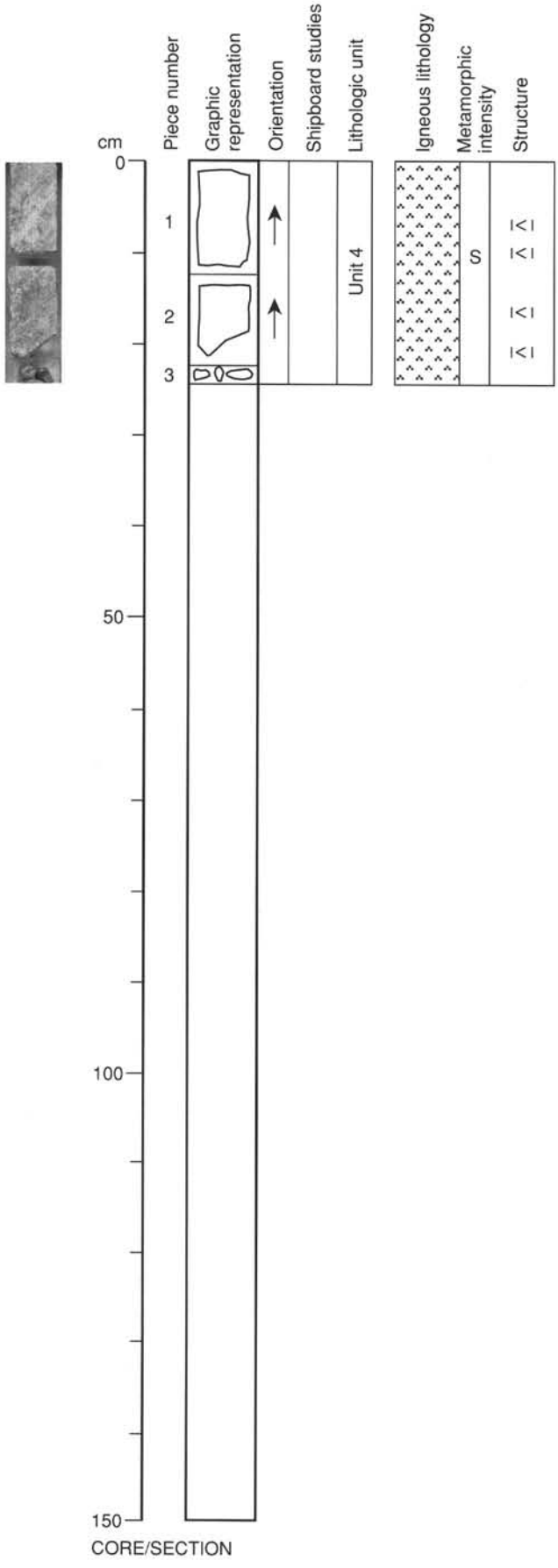
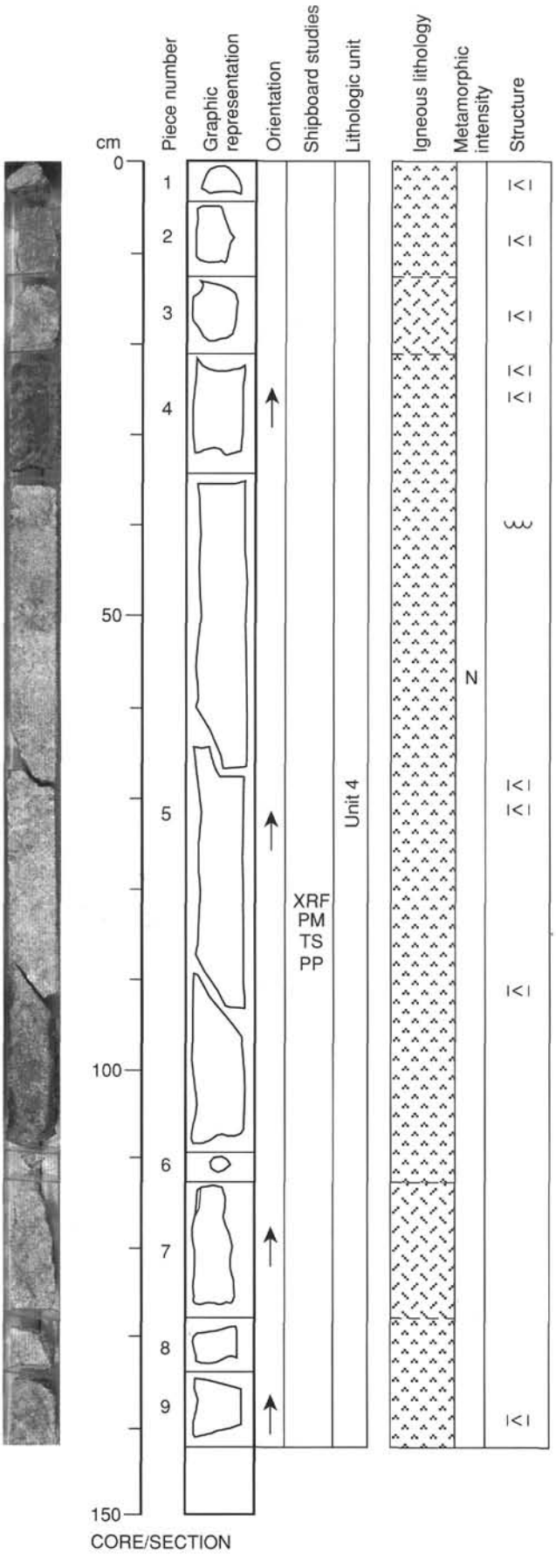


UNIT 4: OLIVINE GABBRO

Pieces 1–3

COLOR: Gray-green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: 14%–15%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 20%–33%.
Crystal Size: 2–10 mm.
Crystal Shape: Subhedral.
Plagioclase - Mode: 53%–55%.
Crystal Size: 3–9 mm.
Crystal Shape: Anhedral.
Comments: This section consists of medium- to coarse-grained olivine gabbro with a variable grain size and modal mineralogy. Piece 1 shows a sharp contact between a medium-grained, clinopyroxene-poor olivine gabbro at the top and a medium- to coarse-grained olivine gabbro containing 20% poikilitic clinopyroxene at the base. Piece 2 is very heterogeneous in its grain size and mineral distribution, and contains emerald green, poikilitic clinopyroxene rimmed by brown clinopyroxene. Piece 3 is highly altered olivine gabbro rubble.
SECONDARY MINERALOGY:
Brown amphibole.
Mode of Occurrence: After clinopyroxene.
Actinolite.
Mode of Occurrence: After clinopyroxene.
Talc.
Mode of Occurrence: After olivine.
Iron oxide minerals.
Mode of Occurrence: After olivine.
Comments: In Piece 1, clinopyroxene is partially replaced by brown amphibole along cleavages and as alteration rims, and by actinolite. Olivine is relatively fresh, and locally alters to talc and iron oxide minerals, which oxidize to produce yellow spotting and staining.
Vein
In Piece 1, a very thin vein, composed of actinolite and chlorite is present and has a dip of 67°. Another white plagioclase(?) vein dips about 60°. Two veins of similarly steep dip also cut Piece 2.
VEIN/FRACTURE FILLING:
Actinolite, chlorite, and ± plagioclase.
Plagioclase(?)
ADDITIONAL COMMENTS: Structure
The section consists of medium- to coarse-grained olivine gabbro with two different vein generations. The rock has no preferred orientation of the constituent minerals. A compositional and textural change in Pieces 1 and 2 has an irregular boundary. The contact between clinopyroxene-poor and clinopyroxene-rich olivine gabbro in Piece 1 dips at about 50°.



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UNIT 4: GABBRO AND OLIVINE GABBRO

Pieces 1–9

COLOR: Gray-green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: 4%–8%.
Crystal Size: 2–7 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 38%–42%.
Crystal Size: 2–8 mm.
Crystal Shape: Anhedral.
Plagioclase - Mode: 54%–62%.
Crystal Size: 2–10 mm.
Crystal Shape: Subhedral.
Comments: The section consists of finely interlayered gabbro and olivine gabbro. Pieces 1, 2, 4, 5, 6, 8, and 9 are olivine gabbro and Pieces 3 and 7 are gabbro. Modal olivine varies from 0%–8%, plagioclase from 54%–62%, and clinopyroxene from 38%–42%. The grain size varies from medium to coarse. Clinopyroxene forms large (up to 60 mm) apple green oikocrysts and is partially rimmed by brown clinopyroxene. Disseminated sulfide minerals are in Pieces 3 and 4. A pegmatitic clinopyroxenite that occurs at the bottom of Piece 4 (<5 mm) and the top of Piece 5 (30 mm) is probably contiguous.
SECONDARY MINERALOGY:
Sulfide minerals.
Chlorite.
Mode of Occurrence: After olivine and clinopyroxene.
Comments: In patches, between clinopyroxene and plagioclase. Rimming olivine.
Actinolite.
Mode of Occurrence: After clinopyroxene.
Comments: Along veins and fractures.
Smectite.
Mode of Occurrence: After olivine.
Brown amphibole.
Mode of Occurrence: After clinopyroxene.
Comments: Overgrowths and as pseudomorphs.
Talc.
Mode of Occurrence: After olivine.
Comments: Alteration in this section is slight and irregular. In Piece 1, alteration is only observed along a vein, where patches of green chlorite after clinopyroxene and between clinopyroxene and plagioclase are present. Actinolite replaces clinopyroxene along the margins of fractures and veins (e.g. Piece 3). Piece 7 is the most pervasively altered (up to 10%), showing brown alteration patches of smectite. Patches of green chlorite and actinolite after clinopyroxene are also present. In other pieces, alteration is less than 5%. In the freshest intervals, brown amphibole occurs as overgrowths around coarse clinopyroxene. Olivine is slightly altered to talc and chlorite.
Veins
Actinolite ± chlorite veins occur in Pieces 1–5 and 9.
VEIN/FRACTURE FILLING:
Actinolite and chlorite.
ADDITIONAL COMMENTS: Structure
There is no preferred orientation of the constituent minerals. In Piece 5B, a steeply dipping (75°) fracture is marked by alteration of mafic phases cut by the fractures, as well as oxide and sulfide minerals.

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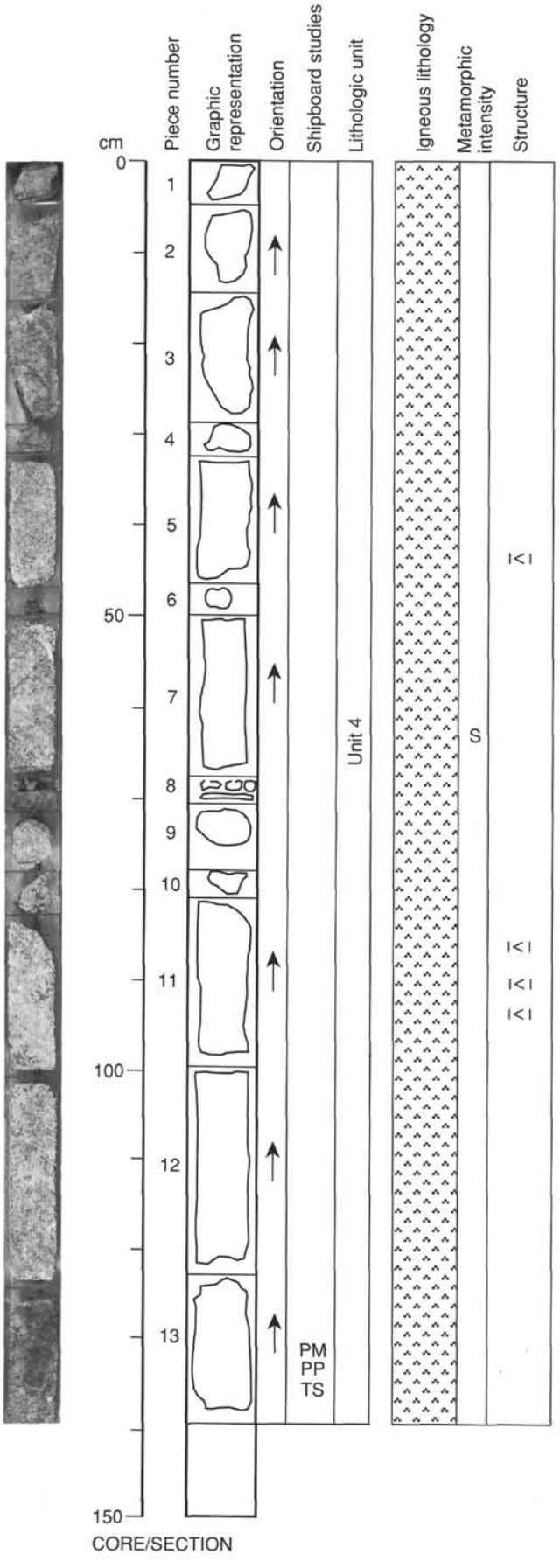
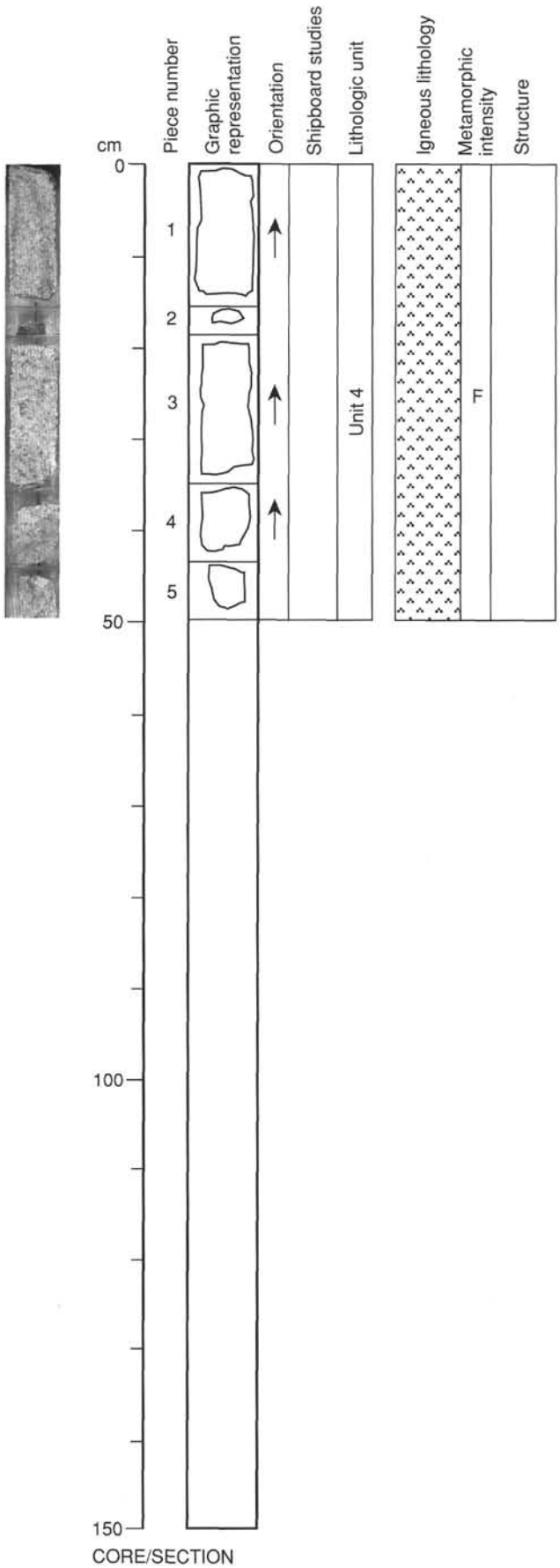


UNIT 4: OLIVINE GABBRO

Pieces 1–13

COLOR: Gray, green, and white.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: 15%–20%.
Crystal Size: 2–5 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 15%–25%.
Crystal Size: 3–22 mm.
Crystal Shape: Anhedral.
Plagioclase - Mode: 55%–65%.
Crystal Size: 2–10 mm.
Crystal Shape: Anhedral.
Comments: The section consists of olivine gabbro which is both texturally and modally homogeneous. Olivine crystals, originally 4–5 mm in size, now consist of very fine-grained granules outlined by thin coatings of chlorite, smectite, and possibly iron oxide minerals(?). Clinopyroxene has emerald green cores and rims of brown clinopyroxene and possibly brown amphibole at the outermost edges. Clinopyroxene, and perhaps minor olivine, has irregular dendritic shapes as a result of poikilitically enclosing plagioclase. Subhedral to anhedral plagioclase crystals are ≈10 mm in size. Iron oxide and sulfide minerals occur in minor and trace amounts, respectively. Average grain size, independent of the poikilitic/oikocrystic textures of the mafic phases, is medium to coarse.
SECONDARY MINERALOGY:
Actinolite.
Mode of Occurrence: After clinopyroxene.
Comments: Along veins and as rims.
Chlorite.
Mode of Occurrence: After clinopyroxene and olivine.
Brown amphibole.
Mode of Occurrence: After clinopyroxene.
Comments: Rims.
Comments: The overall alteration of the section is slight. Alteration is most evident around cracks and fractures (Piece 5). Clinopyroxene is altered to actinolite and chlorite along rims and at vein selvages. Away from the cracks, alteration is slight (<5%). Brown amphibole occurs as patches and rims replacing and surrounding clinopyroxene. Minor staining due to oxidation of iron oxide minerals occurs in Piece 3–12.
Veins
Piece 5 contains a diffuse chlorite vein in the lower corner as well as oxidation on thin fractures. In general, the alteration is localized. In Piece 10, clay minerals are present on open surfaces.
VEIN/FRACTURE FILLING:
Chlorite.
Clay minerals.
ADDITIONAL COMMENTS: Structure
No preferred shape or crystallographic fabrics were seen in this section. Thin (<1 mm) chlorite- and amphibole-filled veins were found in Pieces 5 (dip of 60°) and 11 (dips of 45°–50°).

153-921C-3R-3



UNIT 4: OLIVINE GABBRO

Pieces 1–5

COLOR: Gray, green and white.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Clinopyroxene - Mode: 16%–25%.
Crystal Size: 3–7 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 14%–15%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral.
Plagioclase - Mode: 60%–70%.
Crystal Size: 1–6 mm.
Crystal Shape: Anhedral.
Comments: This section consists of relatively fresh olivine gabbro which is homogeneous, both texturally and modally. The main distinguishing feature is the presence of emerald green, poikilitic clinopyroxene rimmed by brown clinopyroxene and possibly brown amphibole at the outermost edges. Variable alteration is observed between pieces (see metamorphic comments). Olivine crystals, originally 1–5 mm in size, now consist of very fine-grained granules outlined by thin coatings of chlorite, smectite, and iron oxide minerals(?). Clinopyroxene and olivine have irregular, dendritic shapes due to their poikilitic habit, enclosing plagioclase. The outlines of original plagioclase crystals are preserved in these poikilitic crystals and suggest a subhedral crystal shape; plagioclase now occurs as equant, anhedral grains due to recrystallization. Iron oxide and sulfide minerals occur in minor and trace amounts, respectively. Original grain sizes are difficult to estimate accurately due to the degree of recrystallization of the plagioclase and the poikilitic/oikocrystic textures of the mafic phases, but in general the rocks are medium to coarse grained.
SECONDARY MINERALOGY:
Brown amphibole.
Mode of Occurrence: After clinopyroxene.
Actinolite.
Mode of Occurrence: After clinopyroxene.
Comments: Near veins.
Comments: Slightly altered (<5%). Brown amphibole partially replaces clinopyroxene in Pieces 1 and 4. Olivine is generally fresh and only locally altered. In Piece 3 alteration of clinopyroxene to actinolite occurs around the vein.
Veins
In Piece 3, a thin actinolite and chlorite vein cuts across the core.
VEIN/FRACTURE FILLING:
Actinolite and chlorite.
ADDITIONAL COMMENTS: Structure
No preferred shape fabrics has been seen in this section. One green chlorite vein occurs in Piece 3. It is <1 mm wide and dips about 50°.

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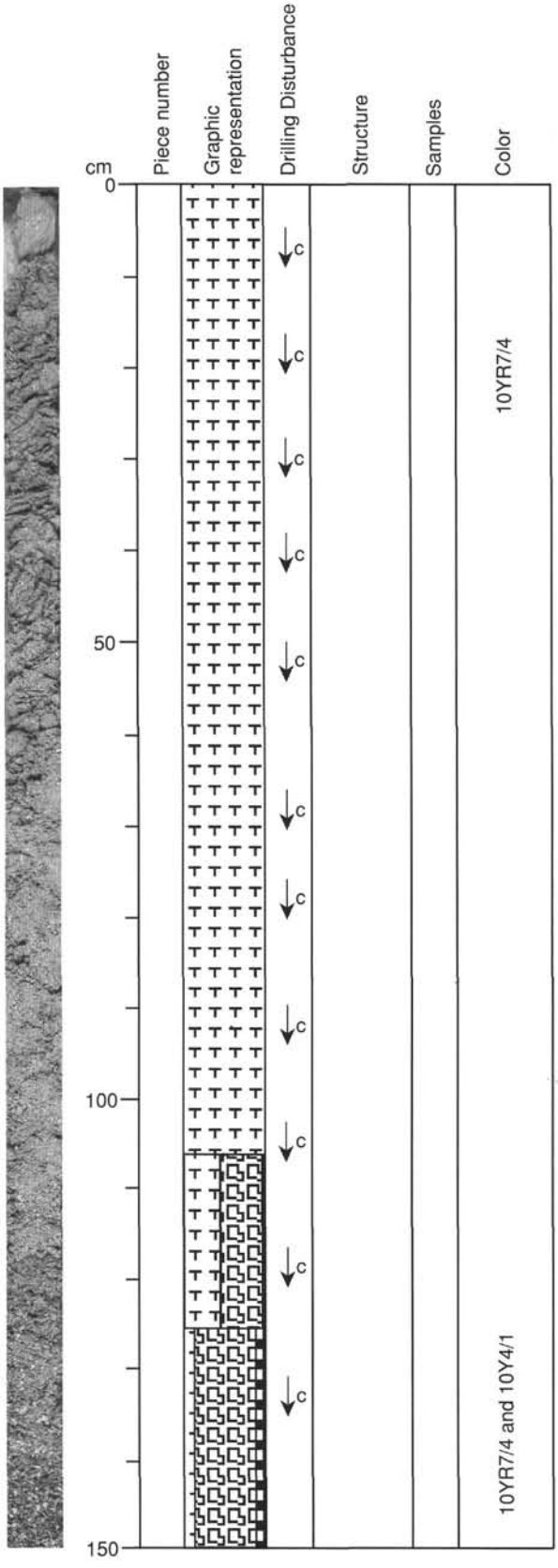


FORAMINIFERAL OOZE, SHELL DEBRIS, AND SILICICLASTIC SAND

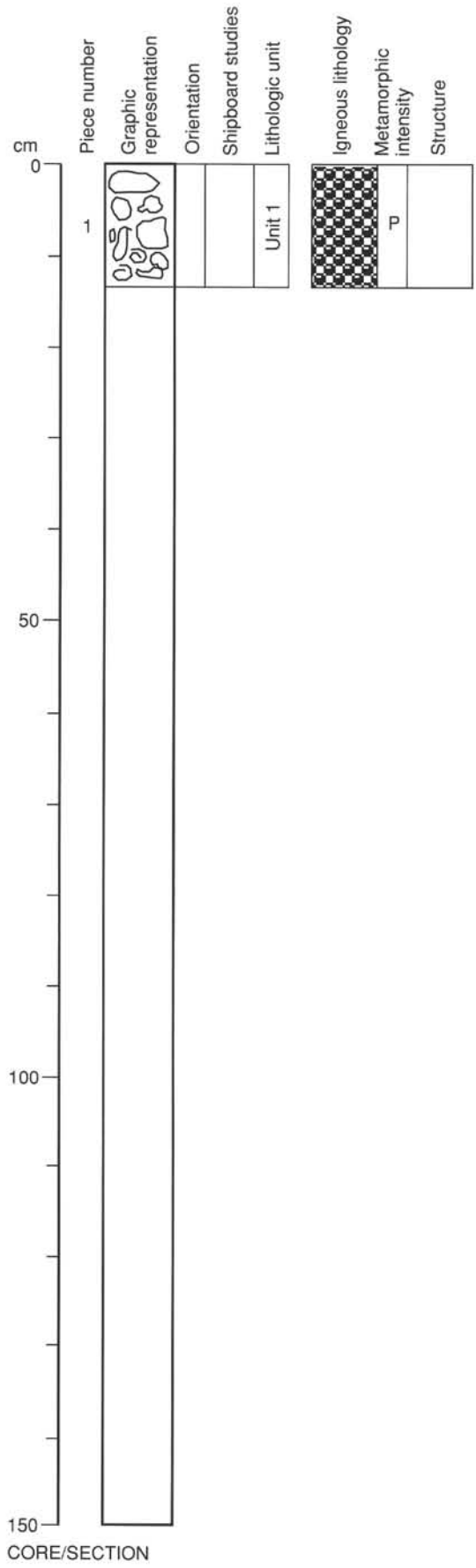
General Description

0–7 cm Foraminiferal ooze, light brown in color, comprised of a very sticky, clay-rich foraminiferal sand, with a very minor component of tiny shell fragments. This mud was forcibly extracted from the core barrel, and now forms a hard-packed lump.

7–107 cm. Foraminiferal ooze, light brown in color, comprised of predominantly foraminiferal sand, with a minor component of shell debris, and a lesser amount of clay. Although poorly sorted, this sand generally coarsens downward, as the fraction of shell debris increases, and the clay fraction decreases.

107–132 cm. There is a rather sharp boundary with the sediment below 107 cm. containing a distinctly higher fraction of shell debris (30%–40%). There is also a minor component of sand to very coarse sand-sized grains of siliciclastic material. This siliciclastic component increases downsection.

132–150 cm. 70% shell debris, 10% foraminiferal sand, and 20% coarse to very coarse sand-sized siliciclastic sediment. The sediment continues to coarsen downsection, with a marked increase in shell debris and siliciclastic components. Shell debris includes fragments to nearly complete pterapod and lesser gastropod shell. Larger grains of the siliciclastic component appear to be fragments of basalt (black), metamorphosed gabbro (green), and some mineral fragment (plagioclase and pyroxene).

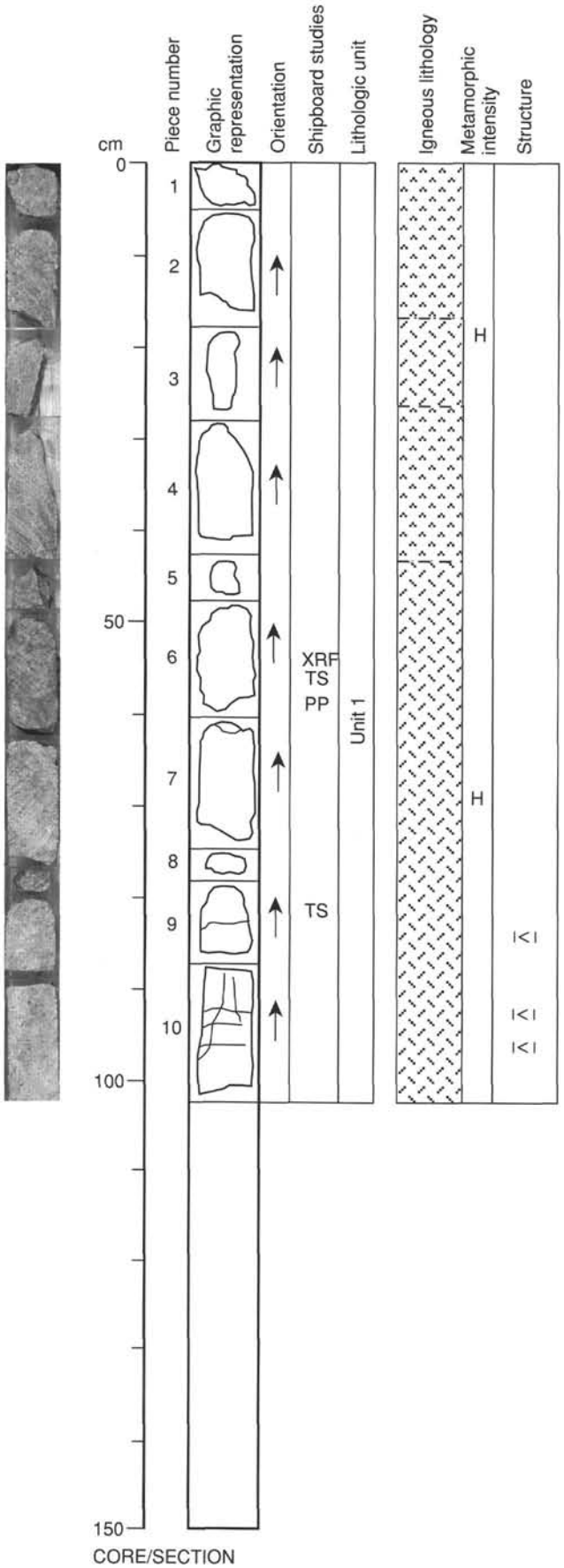


153-921D-1R-2

UNIT 1: RUBBLE

Pieces 1

COLOR: Gray, white, buff, and black.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Comments: The section consists of polygenetic gravels ranging from 1 to 5 cm in size. Most clasts are fine grained and either white, gray, buff, or black. Black clasts are heavily coated by MnO. The origin of many of the clasts is difficult to determine due to the extensive degree of alteration, but included are altered basalt, gabbro, cataclasite(?), and partially lithified silty sediments (probably a mix of pelagic and volcanic sources).
SECONDARY MINERALOGY:
Comments: Altered fragments of microgabbro and basalt.
VEIN/FRACTURE FILLING:
ADDITIONAL COMMENTS: Structure
No structures were noted.

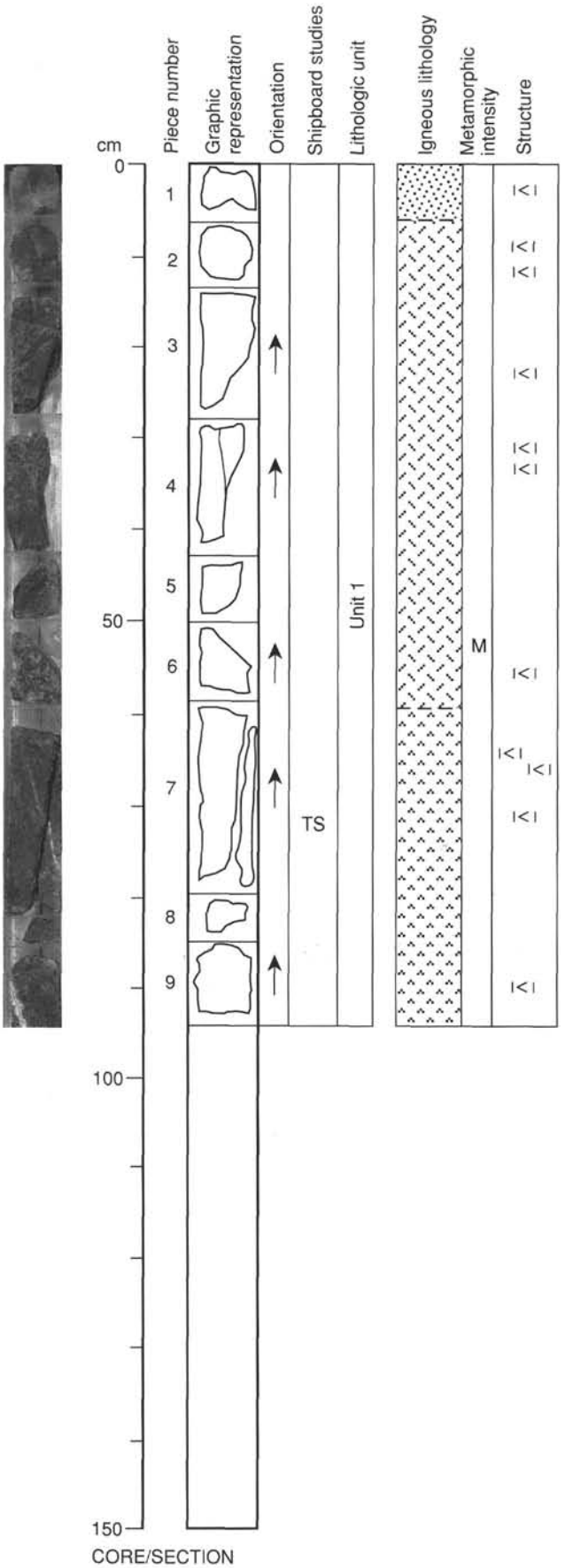


153-921D-2R-1

UNIT 1: OLIVINE GABBRO AND GABBRO

Pieces 1–10

COLOR: White, gray, and gray-green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: 2%–8%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 35%–45%.
Crystal Size: 1–20 mm.
Crystal Shape: Anhedral.
Plagioclase - Mode: 55%–62%.
Crystal Size: 0.5–16 mm.
Crystal Shape: Subhedral.
Comments: This section consists of coarse-grained olivine gabbro (Pieces 1–4) and medium-grained gabbro (Pieces 5–10). Piece 4 is layered, where abrupt variations in grain sizes, on the scale of 1–3 cm, of plagioclase and clinopyroxene is evident. Clinopyroxene occurs both as large oikocrysts (up to 20 mm), enclosing subhedral, elongate plagioclase laths in the olivine gabbro, and as a discrete cumulus phase in both olivine gabbro and gabbro. Iron oxide minerals are rare in the olivine gabbro but are a common accessory phase in the gabbro. A small xenolith of fine-grained gabbro occurs in Piece 6. The contact of the xenolith and host rock is marked by large (up to 15 mm) subhedral clinopyroxene grains.
SECONDARY MINERALOGY:
Actinolite.
Mode of Occurrence: After clinopyroxene.
Chlorite.
Mode of Occurrence: After clinopyroxene.
Brown amphibole.
Mode of Occurrence: After clinopyroxene.
Comments: As rims.
Green amphibole.
Mode of Occurrence: After clinopyroxene
Comments: In more pervasively altered pieces.
Clay minerals.
Mode of Occurrence: After plagioclase.
Hydroxide minerals.
Comments: Picked out by rusty spotting.
Serpentine.
Mode of Occurrence: After olivine.
Iron oxide minerals.
Mode of Occurrence: After olivine.
Talc.
Mode of Occurrence: After olivine.
Comments: The alteration of the upper part of the section is slight (about 5%), but increases downsection to 30% (Pieces 9 and 10). Clinopyroxene is replaced by actinolite and minor chlorite. Clinopyroxene contains blebs of brown amphibole (Pieces 2–6), and minor alteration rims. As the alteration intensity increases downsection, clinopyroxene becomes pervasively replaced by fibrous green amphibole. Plagioclase is generally fresh. Local rust spotting by hydroxide minerals occurs on plagioclase. In the olivine gabbro (Pieces 1 to 4), olivine shows only minor replacement by a mesh of iron oxide minerals and talc.
Veins
In Piece 2, a thin (<1 mm) vertical chlorite vein is present. In Piece 9, a similar thin chlorite vein cuts subhorizontally across the core. In Pieces 7 and 10, 1 mm wide chlorite and actinolite veins cut the core. The topmost vein in Piece 7 is 2 mm wide and dips 30°, 10 cm lower in the core, thin chlorite and actinolite veins are parallel to the upper vein. Piece 10 contains vertical and horizontal vein sets in which the horizontal veins cut vertical veins. The vertical veins are composed of strands of very thin (<<1 mm) chlorite and actinolite in en echelon arrangement that form a zone 2–3 mm across close to the 090° side of the core. A 1 mm thick horizontal vein cuts the vertical strand.
VEIN/FRACTURE FILLING:
Chlorite.
Chlorite and actinolite.
ADDITIONAL COMMENTS: Structure
No deformational fabrics are seen in Pieces 1–4. A very subtle, subhorizontal shape preferred alignment of the long axes of pyroxene grains is found in Pieces 5–10. Intragranular microcracking occurs in Pieces 5–10.



153-921D-3R-1

UNIT 1: OLIVINE GABBRO WITH METADIABASE

Pieces 1–9

COLOR: Green brown to black.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Sulfide minerals - Mode: <1%.
Crystal Shape: Anhedral.
Olivine - Mode: 5%–17%.
Crystal Size: 0.5–8 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: <1%.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 25%–40%.
Crystal Size: 1–13 mm.
Crystal Shape: Anhedral.
Plagioclase - Mode: 55%–60%.
Crystal Size: 1–3 mm.
Crystal Shape: Anhedral.
Comments: The section predominantly consists of gabbro (Pieces 2–6) and olivine gabbro (Pieces 7–9), except for Piece 1 which is a totally altered aphyric diabase. The diabase is fine grained, and may either be a small dike or a clast that has fallen into the hole during drilling. The groundmass texture suggests that it was composed of plagioclase, olivine, clinopyroxene, and iron oxide minerals. All gabbro pieces contains similar modal abundances of plagioclase (45% of the mode) throughout the section, but varying proportions of the mafic phases. Pieces 2–6 contain no olivine, whereas Pieces 7–9 contain ≈15% olivine. Large (>12 mm) brown clinopyroxene crystals poikilitically enclose subhedral plagioclase laths in Piece 9. Grain-size layering is present in Pieces 3–7. In Pieces 3–5, fine- to coarse-grained gabbro is horizontally layered on a cm scale. Piece 3 contains a 1 cm wide, oxide-rich gabbro layer. In Piece 4, the top 7 cm is coarse-grained whereas the bottom 4 cm is medium grained. Piece 6 is dominantly coarse grained, and Piece 7 (21 cm) shows diffuse grading from coarse grained gabbro at the top and base through medium grained in the center. Piece 2 contains a 10 mm wide, irregular, coarse-grained (5–7 mm) vein(?) of gabbro. The change in grain size is abrupt, such that an origin for the layering either during crystallization or by intrusion is difficult to assess at the scale of the piece.
SECONDARY MINERALOGY:
Brown amphibole.
Mode of Occurrence: After clinopyroxene.
Comments: In gabbro.
Green amphibole.
Mode of Occurrence: After clinopyroxene.
Comments: In gabbro.
Smectite.
Mode of Occurrence: After olivine.
Comments: Clay minerals in diabase, after plagioclase in gabbro.
Hematite.
Mode of Occurrence: After olivine.
Comments: In diabase.
Actinolite.
Mode of Occurrence: After cllinopyroxene.
Comments: Near veins.
Comments: The overall alteration of the section is moderate to high. Alteration of the diabase is pervasive; clinopyroxene is replaced by chlorite, and olivine is altered to smectite and iddingsite. In the gabbro, unaltered zones show very well-preserved primary mineralogy. Clinopyroxene contains brown amphibole (all pieces), and rarely green amphibole. Near veins, clinopyroxene is altered to actinolite. Piece 2, 3, and 5 are irregularly altered; clinopyroxene is altered to actinolite or light green tremolite. Locally, plagioclase is finely recrystallized. Near the most altered plagioclase grains, clinopyroxene is replaced by brown smectite aggregates. In Pieces 6 and 9, the alteration is more intense, apparently due to the presence of veins, and is characterized by green patches. Piece 7 is the freshest sample, except for localized zones around veins. Disseminated sulfide minerals associated with altered clinopyroxene occur in most pieces.

153-921D-3R-1

Veins

A thin chlorite vein occurs in Pieces 3 and 4. Actinolite veins occur in Pieces 6 and 7. Pieces 7A and 7B are fractured along a subvertical aragonite and actinolite vein. 1–2 cm wide composite plagioclase and actinolite-cored veins cut Pieces 7 and 9.

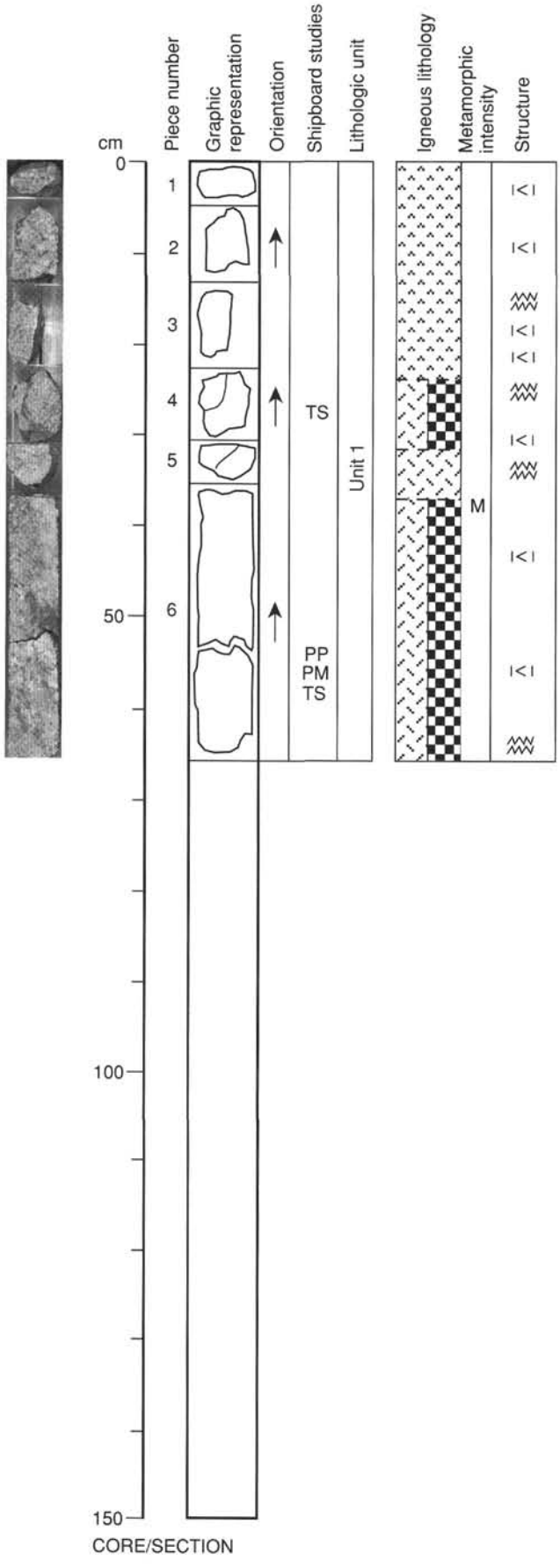
VEIN/FRACTURE FILLING:

Chlorite.

Actinolite.

ADDITIONAL COMMENTS: Structure

A very subtle grain-size layering that is subhorizontal (≤30°), with a spacing of 1 to several cm occurs in Pieces 3–7. One or more thin hairline veins with chlorite and actinolite(?) filling are found in almost all pieces. The dips of these veins range from steep (70°) in Pieces 3 and 4 to moderate (30°–45°) in Piece 6. Piece 7 is broken along a vein that has chlorite and aragonite fill. A steep (70°), white plagioclase(?) vein with dip of opposite sense is cut by the vein along which the piece is broken.

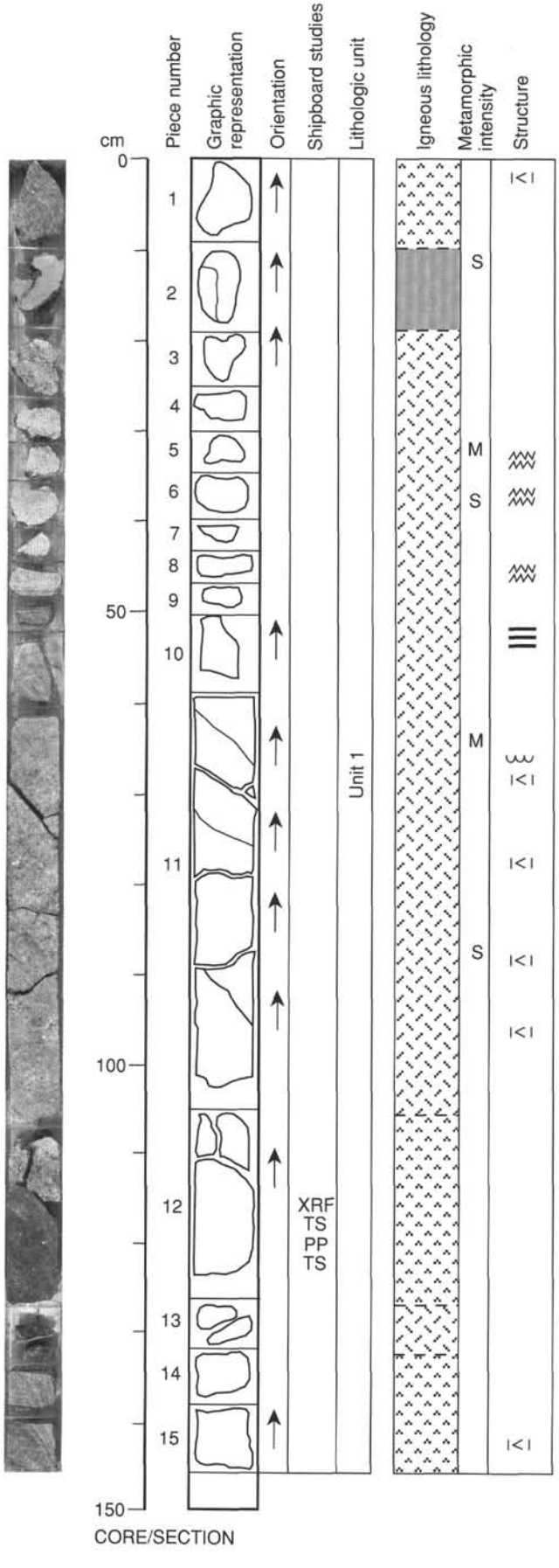


153-921D-4R-1

UNIT 1: GABBRO, OXIDE GABBRO, AND OLIVINE GABBRO

Pieces 1–6

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 53%–60%.
Crystal Size: 3–13 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 15%–44%.
Crystal Size: 2–18 mm.
Crystal Shape: Subhedral.
Olivine - Mode: 0%–25%.
Crystal Size: 3–6 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: 2%.
Crystal Shape: Anhedral.
Comments: The section is composed of olivine gabbro, gabbro, and oxide gabbro. Pieces 1 and 2 are medium- to coarse-grained olivine gabbro containing 15%–22% olivine, 15%–22% clinopyroxene, and 58%–60% plagioclase. Alteration approaches 25% in both pieces with brown amphibole and actinolite replacing pyroxene and serpentine and chlorite replacing olivine. Piece 6 contains a layer contact between medium-grained oxide gabbro below and coarse-grained gabbro to oxide gabbro above. The coarse-grained layer contains subhedral clinopyroxene as the primocryst phase, and plagioclase and iron oxide minerals as interstitial phases. The contact is oxide rich, sheared, and marked by brittle structures and sulfide mineral veins.
SECONDARY MINERALOGY:
Sulfide minerals.
Comments: Disseminated and in veins.
Brown amphibole.
Comments: After clinopyroxene.
Actinolite.
Comments: After clinopyroxene.
Smectite.
Comments: After plagioclase.
Comments: Alteration of this section is heterogeneous, from slight to high. In Piece 1, clinopyroxene with brown amphibole is surrounded by green actinolite rims. Alteration of oxide minerals causes staining on plagioclase. Piece 2 is fresh except for clinopyroxene with brown amphibole, and diffuse alteration along microcracks where clinopyroxene is altered to actinolite and chlorite. Plagioclase locally alters around veins to brown smectite. Piece 3 is very altered, and crosscut by a thin vein around which alteration is patchy. Plagioclase has chlorite alteration rims and brown patches are altered to smectite and stained by hydroxide minerals. Pieces 4 and 5 exhibit somewhat more intense alteration, mainly on small clinopyroxene grains. Clinopyroxene, along contacts with plagioclase are altered to green chlorite and actinolite patches. Disseminated sulfide minerals occur in Piece 5. In Pieces 6A and 6B, plagioclase is altered to chlorite and to actinote and chlorite at the boundary between clinopyoxene and plagioclase. Thin green chlorite microcracks occur within plagioclase. Iron oxide minerals altering to hydroxide minerals produce rust stains (Pieces 1 and 3).
Veins
In Pieces 3 and 4, clay mineral veins occur through the sample. Actinolite veins occur in Pieces 2 (<1 mm) and 5 (≈3 mm).
VEIN/FRACTURE FILLING:
Chlorite.
Actinolite.
ADDITIONAL COMMENTS: Structure
Brittle shear zones are evident along the margins of Pieces 3 through 6. These shear zones consist of an anastomosing set of fractures and veins, in which plagioclase and pyroxene are deformed into elongate grains. Thin veins with iron staining and filled with clay minerals are seen in Pieces 1, 2, 4, and 5. The contact between coarse- and medium-grained gabbro (Piece 6) is sheared with brittle structures and sulfide veins along the contact. The contact is dipping at about 50°. Some plastic deformation and grain-size reduction may also have occured in, and near, the shear zones (especially Piece 6).



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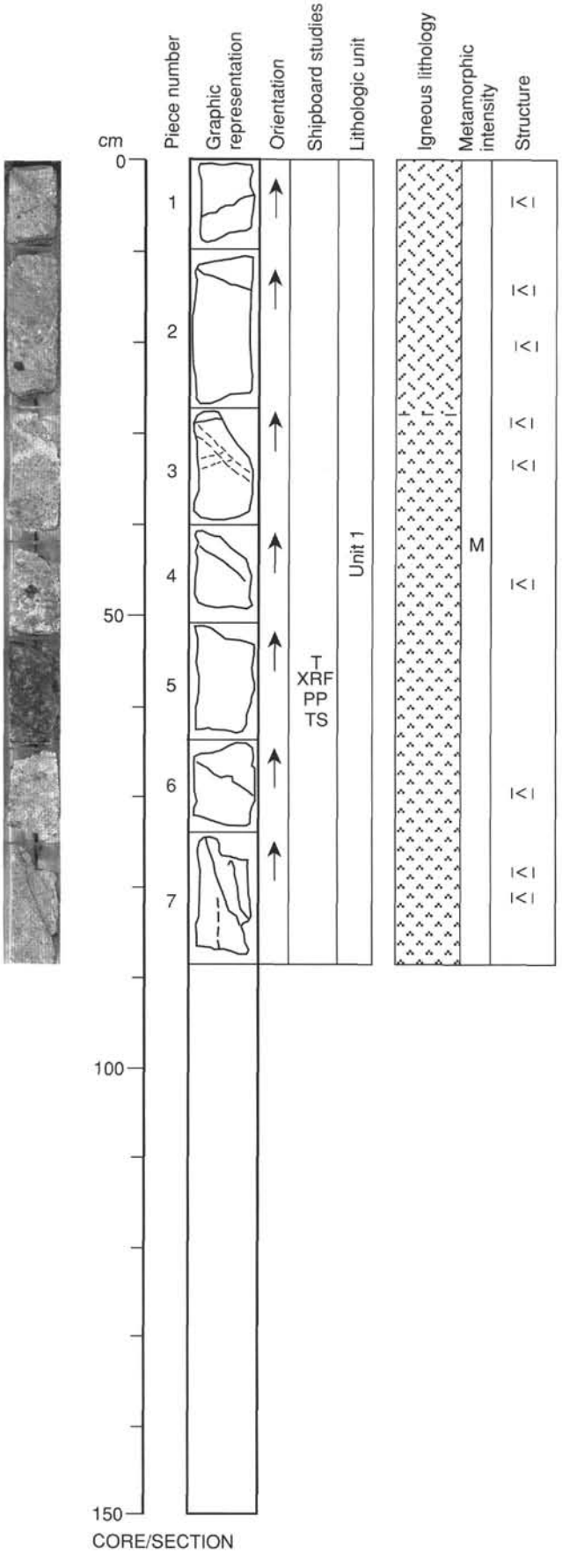
UNIT 1: GABBRO AND OLIVINE GABBRO

Pieces 1–15

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 50%–60%.
Crystal Size: 1–10 mm.
Crystal Shape: Subhedral.
Clinopyroxene - Mode: 35%–45%.
Crystal Size: 1–18 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 0%–8%.
Comments: This section consists of texturally and modally variable gabbro and olivine gabbro, except for Piece 2 which is a totally altered, aphyric diabase. The diabase is very fine grained and originally contained intergranular plagioclase and clinopyroxene with minor iron oxide minerals. It may either be a small dike or a clast that has fallen into the hole during drilling, although the fine grain size of the diabase is consistent with it being a small dike within the cored interval. The medium- to coarse-grained gabbro (Pieces 3–11, and 13) is modally uniform, consisting of subhedral to anhedral plagioclase (50–60 modal%) and interstitial clinopyroxene (40–45 modal%) with minor iron oxide minerals (up to 1 modal%). Medium-grained gabbro grades into coarse-grained gabbro in Piece 11A. Brown hornblende (less than 2 modal%) is commonly asscciated with clinopyroxene. Olivine gabbro (Pieces 1, 12, 14, and 15) contains olivine (3–8 modal%), clinopyroxene (35–42 modal%) and plagioclase (50–56 modal%). Olivine and clinopyroxene commonly appear as intercumulus phases. Some olivine gabbro displays subophitic textures (Pieces 1 and 12).
SECONDARY MINERALOGY:
Chlorite.
Mode of Occurrence: Replacing clinopyroxene.
Iron oxideIron oxide minerals.
Mode of Occurrence: Replacing olivine.
Brown amphibole.
Actinolite.
Comments: The overall alteration of this section is variable. Piece 1 is <10% altered. Pieces 2 and 3 are up to 20% altered. Alteration of Pieces 4 to 11 is slight (<10%). Pieces 12A and 12B are up to 30% altered . From Piece 12C to 15, the alteration is <5%. Piece 1 is a relatively fresh olivine gabbro with only minor replacement of olivine by talc and iron oxide minerals, clinopyroxene, only partially rimmed by actinolite and chlorite, and minor replacement by brown amphibole. Limited staining by hydroxide minerals occurs on plagioclase. In Piece 2, the diabase is highly altered; the green color suggests the groundmass has been altered to chlorite. Piece 3 is altered in mottled green patches; actinolite and chlorite are after clinopyroxene and in diffuse patches adjacent to plagioclase. The bottom of the Piece 3 is spotted due to oxidation of smectite and hydroxide minerals at the contact between clinopyroxene and plagioclase, and a "Y" shaped chlorite-bearing vein has altered the adjacent phases. In Pieces 4 to 10 the rock is quite fresh, apart from zones where clinopyroxene is altered to actinolite and chlorite. In Piece 5, brown amphibole rims clinopyroxene. In Piece 11, the gabbro is relatively fresh; clinopyroxene is mainly altered near veins and has an actinolite rim surrounded by irregular patches of chlorite. In Pieces 12A and 12B along microfractures, clinopyroxene alters to actinote and chlorite. Pieces 12C, 13, 14, and 15 are fresh, away from the rare microveins.
Veins
Pieces 6, 8 and 15 are crosscut by very thin clayey veins. In Piece 3, a"Y" shaped, chlorite-bearing vein crosscuts the core. In Pieces 12A, 12B, 12C, and 15, very thin actinolite and chlorite veins with irregular orientations cut across the core. Piece 11 is crosscut by several dark green chlorite and actinolite veins, dipping 45°, and a single brown-green vein near the top of the piece.
VEIN/FRACTURE FILLING:
ADDITIONAL COMMENTS: Structure
A magmatic, preferred, subhorizontal alignment of the long axes of clinopyroxenes can be observed in Pieces 6 and 10. Thin (<3 mm) brittle shear zones cross Pieces 5, 6, 7, and 8 (all unoriented). Piece 11 is banded and has a gradational boundary from a medium-grained top to a coarse-grained bottom about 6 cm from the top with a subhorizontal orientation to the banding. Piece 12 has significant microcracking and very thin (<1 mm) veins.



153-921D-5R-2

UNIT 1: GABBRO AND OLIVINE GABBRO

Pieces 1–7

COLOR: Gray to green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 52%–57%.
Crystal Size: 1–5 mm.
Crystal Shape: Euhedral.
Clinopyroxene - Mode: 5%–67%.
Crystal Size: 3–17 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 10%–30%.
Crystal Size: 2–7 mm.
Crystal Shape: Anhedral.
Iron oxide minerals. - Mode: %.
Comments: The section is composed of gabbro and olivine gabbro. Pieces 1 and 2 are relatively clinopyroxene-rich gabbro in which large brown clinopyroxene poikilitically encloses subhedral plagioclase laths. Piece 2 shows gradational grain-size variations, ranging from medium to coarse, on the scale of cm over the length of the piece. Pieces 3–7 are medium- to coarse-grained isotropic olivine gabbro that show no apparent layering or deformational fabric. They are composed of olivine (10%–30%), clinopyroxene (5%–35%), and plagioclase (53%–57%). The clinopyroxene is typically dark green brown and poikilitically encloses lath-shaped plagioclase. Two samples contain poikilitic clinopyroxene crystals (10 mm in size) that have a white micaceous luster on cleavage faces and may be orthopyroxene. Pyroxene and olivine grains vary slightly in grain size between pieces, whereas plagioclase grain size remains relatively constant. Plagioclase is partially recrystallized throughout the section.
SECONDARY MINERALOGY:
Chlorite.
Mode of Occurrence: Replacing clinopyroxene.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene.
Comments: Alteration in this section is <15%. Pervasive alteration affects mainly olivine crystals which are partly altered to smectite, talc, and iron oxide minerals (Piece 5 and 7). Clinopyroxene exhibits patchy alteration and rims of brown amphibole, variably altered to actinolite and chlorite (Piece 1). Plagioclase is generally fresh, except for staining due to hydroxide minerals (Pieces 2, 3, 5, and 6), or spotty alteration to chlorite where in contact with clinopyroxene (Piece 2). Alteration is more intense near veinlets. In Piece 4, a finer grained portion at top of the section shows more intense alteration.
Veins
The veinlets (<1 mm) are filled mainly with chlorite and actinolite. In Piece 1, clinopyroxene and plagioclase are altered along an actinolite and chlorite vein. In Piece 3, a "Y" shaped chlorite-bearing vein occurs altering mafic phases to chlorite.
VEIN/FRACTURE FILLING:
Actinolite and chlorite.
Size: <1
Orientation: Within fracture.
Unidentified white minerals.
ADDITIONAL COMMENTS: Structure
There is a weak grain-size variation in Pieces 2 and 4 defining a roughly subhorizontal layering. In Pieces 1 and 2, smaller clinopyroxene crystals have more equant to slightly elongate shapes that define a weakly developed preferred orientation. The aligned grains dip approximately 20° in the fine-grained bands in Piece 2. Two leucocratic veins, cored by green chlorite and actinolite, a few cm thick, are in the top of Piece 3. Dips on the chlorite and actinolite veins vary from 20°–30° in Pieces 1, 2, 3, and 4, to 70°–90° in Piece 6.

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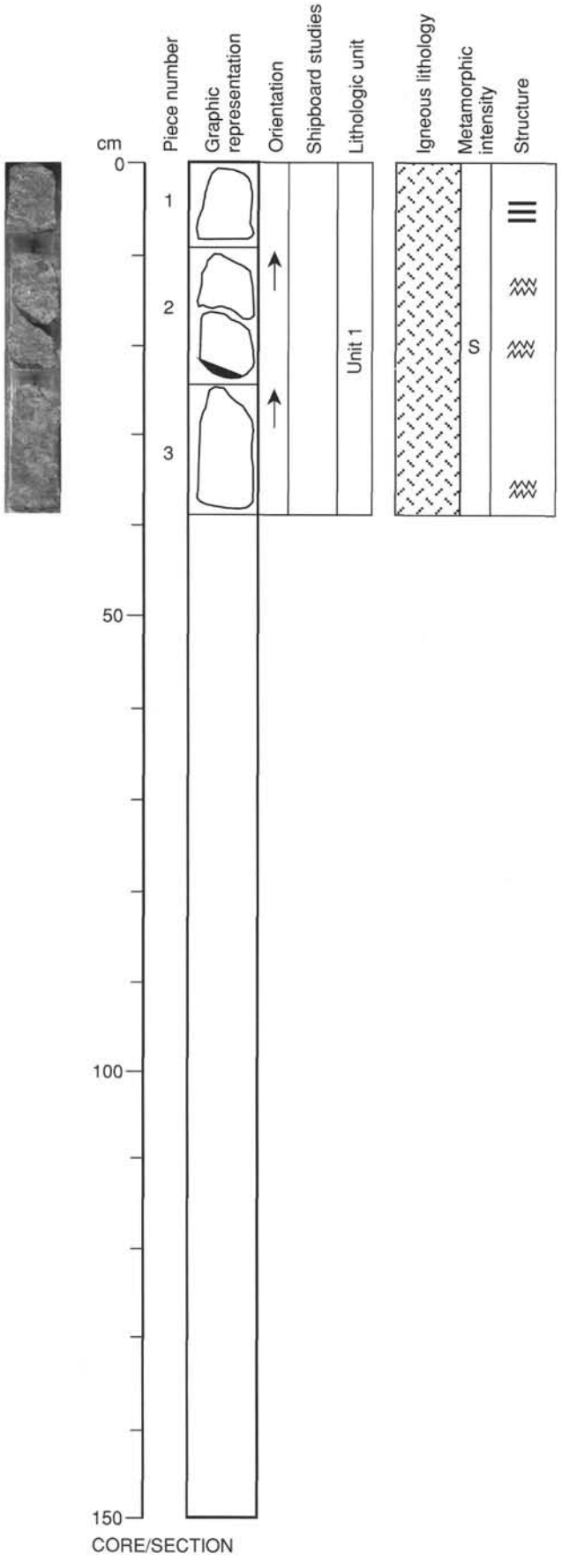
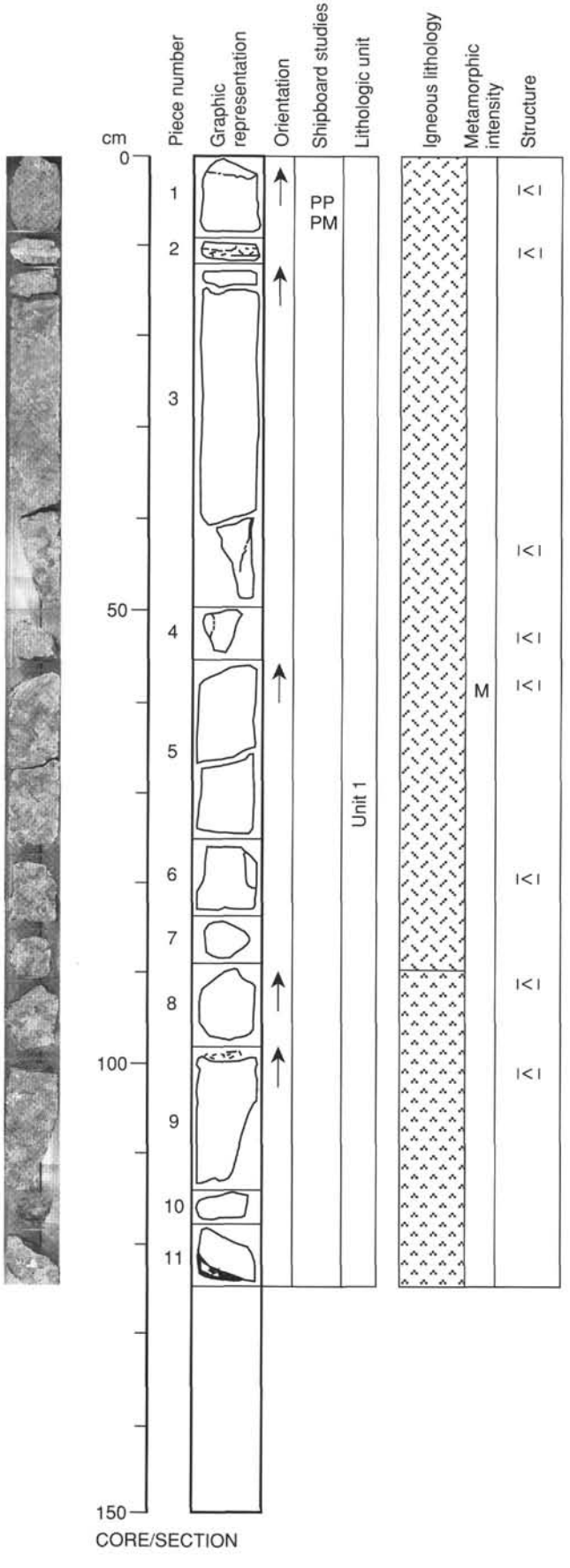


UNIT 1: GABBRO

Pieces 1–3

COLOR: Pink gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%–65%.
Crystal Size: 10–15 mm.
Crystal Shape: Subhedral.
Clinopyroxene - Mode: 34%–38%.
Crystal Size: 26–55 mm.
Crystal Shape: Anhedral.
Crystal orientation: Weak magmatic(?)
Olivine - Mode: 1%–2%.
Crystal Size: 5–15 mm.
Crystal Shape: Anhedral.
Crystal orientation: Weak magmatic(?)
Comments: This section is composed of a poikilitic, pink gray gabbro which varies from medium to coarse grained downsection, but is modally homogeneous. Plagioclase is the predominant mineral phase; it occurs as equant grains and laths, the latter becoming more common downsection. Although on average the rocks are medium to coarse grained equigranular, pink brown clinopyroxene oikocrysts reach 55 mm in size and enclose subhedral plagioclase laths. Olivine tends to occur as elongate, lobate interstitial grains. Both olivine and clinopyroxene show a weakly developed, preferred direction of elongation. The gabbro is relatively fresh with only olivine showing significant alteration.
SECONDARY MINERALOGY:
Sulfide minerals.
Mode of Occurrence: Replacing olivine and clinopyroxene.
Talc.
Mode of Occurrence: Replacing olivine.
Iron oxide minerals.
Mode of Occurrence: Replacing olivine.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene.
Chlorite.
Comments: Alteration is slight throughout the section. Clinopyroxene is in part replaced by brown amphibole; minor alteration to actinoite occurs as rims. Locally olivine is pervasively altered to magnetite, talc, and oxide and sulfide minerals. Altered plagioclase is very fine grained. Rare sulfide minerals occur as disseminated grains or within clinopyroxene; their alteration to hydroxides results in yellow-orange staining on plagioclase. Smaller clinopyroxene grains tend to be more pervasively altered (Piece 1).
Veins
No veins are visible.
VEIN/FRACTURE FILLING:
Chlorite.
Size: 1
Orientation: Subhorizontal.
ADDITIONAL COMMENTS: Structure
The igneous texture is weakly but pervasively overprinted by plastic deformation defined by the elongation of large clinopyroxene crystals. Several cm-thick shear zones defined by plagioclase-rich layers in which the plagioclase is recrystallized in long stringers surrounding plagioclase and pyroxene fragments, cut Pieces 2 and 3. Shear zones are subhorizontal. Two thin (<<1 mm), actinolite and chlorite veins horizontally cut the 2 cm thick shear zone in the bottom of Piece 3. There is one similar subhorizontal vein in Piece 1.



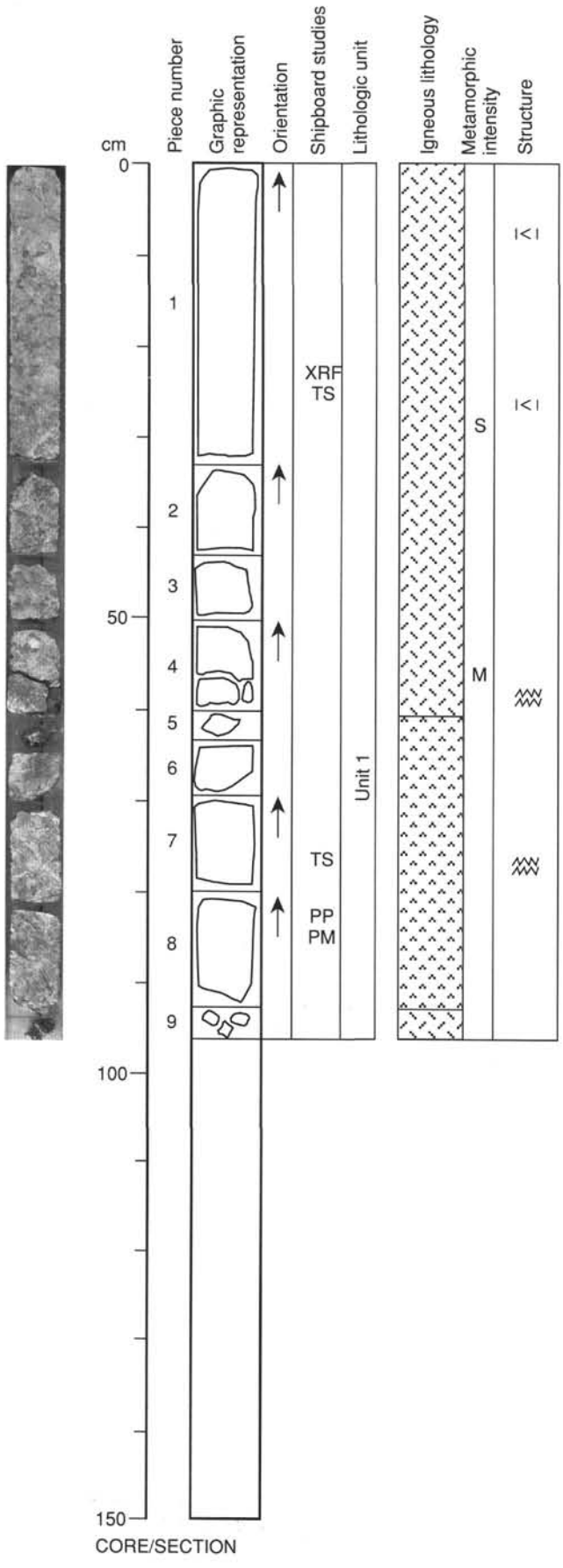
153-921E-2R-1

UNIT 1: GABBRO AND OLIVINE GABBRO

Pieces 1–11

COLOR: Pink brown and gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 54%–60%.
Crystal Size: 2–28 mm.
Crystal Shape: Euhedral.
Clinopyroxene - Mode: 32%–40%.
Crystal Size: 2–32 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 2%–7%.
Crystal Size: 1–7 mm.
Crystal Shape: Anhedral.
Comments: This section is composed of very coarse-grained pink gray gabbro (Pieces 1–8) and olivine gabbro (Pieces 9–11). Plagioclase modal abundance is relatively constant throughout the section, occuring as euhedral to subhedral prismatic crystals (1–20 mm) weakly recrystallized into a fine-grained, granuloblastic aggregate. Clinopyroxene occurs as very coarse, anhedral, irregularly shaped, often deformed, pink brown crystals (2–32 mm). Olivine occurs as anhedral, irregularly shaped grains (1–7 mm) and is slightly more abundant in Pieces 9–11 (≈7%) than in Pieces 1–8 (2%–4%). Piece 2 contains a 1 cm thick vein consisting of plagioclase with minor actinolite and iron oxide minerals. This vein is probably magmatic and may have crystallized from differentiated liquid extracted from the intercumulus areas.
SECONDARY MINERALOGY:
Iron oxide minerals.
Total Percent: 1
Mode of Occurrence: Replacing clinopyroxene.
Comments: Replacing at rims.
Sulfide minerals.
Total Percent: <1
Comments: Occurs in association with iron oxides along rims of clinopyroxene.
Magnetite.
Total Percent: <1
Chlorite.
Total Percent: <5
Secondary plagioclase.
Total Percent: <2
Comments: The gabbro is slightly and irregularly altered. Clinopyroxene is either fresh, rimmed by brown amphibole (Pieces 3), or locally completely altered to actinolite and chlorite aggregates mainly at the contact with plagioclase (Piece 4, and bottom of Piece 5). Plagioclase is very fine grained and exhibits a chalky color and stained due to hydration of iron oxide minerals (Piece 5). Sulfide minerals occur in patches (Piece 11). Near fractures, usually filled with chlorite and actinolite, the degree of alteration increases with complete replacement of clinopyroxene actinolite (Piece 3A).
Veins
In Piece 5, an en echelon vein with chlorite filling cuts across the piece.
A few thin (<1 mm) subvertical chlorite veins cut Pieces 3 and 9.
VEIN/FRACTURE FILLING:
ADDITIONAL COMMENTS: Structure
No evidence for plastic deformation. Veins are uncommon in this section with the exception of unoriented Piece 2 where a magmatic vein of plagioclase and green amphibole makes up about 30% of the piece.

153-921E-2R-2



UNIT 1: PEGMATITIC GABBRO

Pieces 1–9

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: 1%–10%.
Crystal Size: 2–7 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 40%–85%.
Crystal Size: 6%–33 mm.
Crystal Shape: Anhedral.
Plagioclase - Mode: 14%–48%.
Crystal Size: 4–15 mm.
Crystal Shape: Anhedral.
Iron oxide minerals.
Total Percent: 1–2
Texture: Intergranular.
Mode of Occurrence: Space filling.
Comments: The section contains very coarse-grained to pegmatitic gabbro (Pieces 1–4), pegmatitic olivine gabbro (Pieces 5–7), and olivine gabbro (Piece 8). Piece 9 consists of several single, large, clinopyroxene crystals. The predominant characteristic of the section is the very coarse to pegmatitic grain size. Modal variations occur rapidly through the section with clinopyroxene varying between 80%–40%, olivine 0%–10%, plagioclase 14%–48%, and oxide minerals 1%–2%. The general appearance of these variations is enhanced by deformation and recrystallization of plagioclase. Subhedral, pink brown clinopyroxene is the primocryst phase in most samples with plagioclase, olivine, and iron oxide and sulfide minerals the interstitial phases. A ≈2 cm thick, subhorizontal mylonite containing altered plagioclase and clinopyroxene, abundant iron oxide minerals and euhedral apatite occurs in Piece 4. The enrichment of iron oxide minerals in this interval may indicate that the zone was originally a magmatic vein. Plagioclase in the adjacent gabbro is elongate and oriented parallel to the margin of the mylonite, and inclusions of pyroxene similar to that in the host gabbro are isolated within the mylonite. A similar shear zone occurs in Piece 7.
SECONDARY MINERALOGY:
Sulfide minerals.
Total Percent: <1
Texture: Intergranular.
Mode of Occurrence: Space filling.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene and plagioclase.
Chlorite.
Mode of Occurrence: Replacing clinopyroxene, plagioclase.
Smectite.
Mode of Occurrence: Replacing clinopyroxene, plagioclase, olivine.
Talc(?)
Mode of Occurrence: Replacing olivine.
Hematite.
Mode of Occurrence: Replacing magnetite.
Comments: In shear zone.
Clay minerals.
Mode of Occurrence: Replacing olivine and plagioclase.
Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Comments: Total alteration in this section is slight to moderate (10%–20%) with narrow rims of actinolite and chlorite after clinopyroxene (5%–10% altered) common. Rare inclusions within clinopyroxene are probably brown amphibole. Plagioclase is locally altered to secondary plagioclase adjacent to the shear zone in Piece 4, and chalky white plagioclase occurs adjacent to chlorite and actinolite veinlets in Pieces 1 and 2. Throughout the rest of the section, plagioclase is slightly to moderately altered (<10% in the upper part of the section). Magnetite and pyrite ± chalcopyrite grains are narrowly rimmed by chlorite and amphibole, which is brown to green. In Piece 1, the top part of the sample is oxidized, plagioclase is orange tinged, and there is

153-921E-2R-2

slight development of clay minerals. Rare rounded pods of olivine(?) are altered to an orange clay mineral, which is rimmed by dark green chlorite and iron oxide minerals, or are cut by the oxide minerals. Alteration, although still slight, increases toward the shear zone in Piece 4. The margin of the shear zone is discontinuously rimmed by actinolite ± chlorite, and oxide minerals at the outer margins are oxidized to hematite. Below the shear zone alteration increases to 20% with further development of actinolitic ± chlorite-rich rims and patches after clinopyroxene. These patches reach 5 mm in width and overprint relict plagioclase. Altered plagioclase is chalky white, and the intensity of alteration appears to increase with the increase in deformation. Plagioclase in the lower section is slightly altered to chlorite and actinolite, and is cut by microveinlets with chlorite and actinolite filling. Rare rounded and irregular pods of talc rimmed by chlorite may be pseudomorphic after olivine (Piece 7).

Veins

Chlorite and actinolite veins occur in Pieces 1 and 2 and have altered, chalk white plagioclase rims <1 to 2 mm wide. In Piece 2, microveinlets of oxide minerals occur associated with the shear zone.

VEIN/FRACTURE FILLING:

Chlorite, actinolite, ± plagioclase.

Size: 1–2

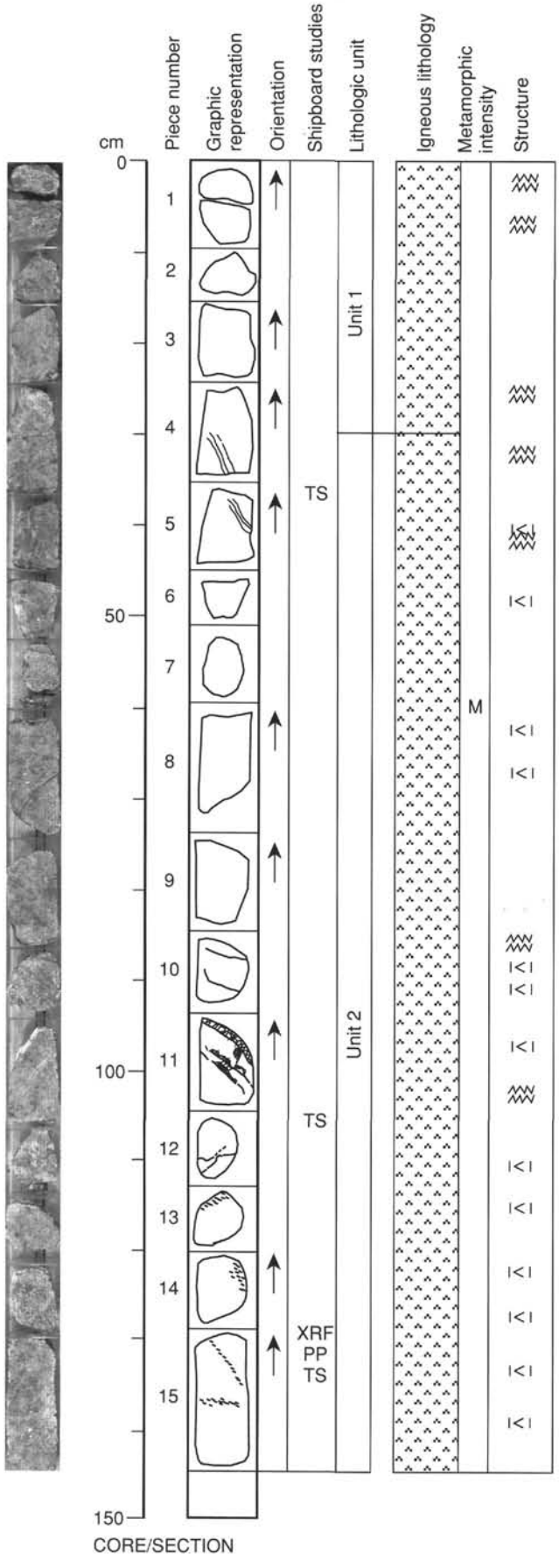
Iron oxide minerals.

Comments: Occurs as microveinlets in shear zone in Piece 2.

ADDITIONAL COMMENTS: Structure

The primary igneous texture is locally overprinted by plastic deformation defined by the elongation of clinopyroxene and stringers of plagioclase crystals, as in a cm-thick shear zone in Piece 7. The crystal-plastic fabric progressively decreases in intensity away from the shear zone. Plagioclase is recrystallized along this shear zone which is dipping 50°. The gabbro is cut by a 1 cm thick mylonitic zone (Piece 4), possibly along the trace of a previous dike. Elongate plagioclase appears to be plastically deformed and elongated parallel to the margin of the oxide mineral-rich zone. The boundaries with the country rock are generally sharp. The mylonitic zone is within a plagioclase-rich zone within an otherwise pyroxene-rich sample.

153-921E-3R-1



UNIT 1: OLIVINE GABBRO

Pieces 1–4

COLOR: Green brown.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 50%–60%.
Crystal Size: 2–25 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 44%–49%.
Crystal Size: 1–45 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 1%–2%.
Crystal Size: 2–15 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: <1%.
Crystal Shape: Anhedral.
Sulfide minerals - Mode: <1%.
Crystal Shape: Anhedral.
Comments: Pieces 1–4 are very coarse-grained to pegmatitic gabbro similar to that described in Section 921E-2R-2. They mainly consist of anhedral clinopyroxene and plagioclase ranging in size from 25–45 mm. Olivine, and iron oxide and sulfide minerals are present in minor amounts as interstitial phases.
Unit 1/2 Boundary
The boundary between pegmatitic gabbro in Unit 1 and olivine gabbro of Unit 2 has been placed along a 1 cm thick shear zone within Piece 4, although the contact extends into Piece 5. The shear zone contains oxide gabbro and is inclined at approximately 30° to the core. Piece 5 is olivine gabbro cut by oxide gabbro consisting of 35% plagioclase, 25% clinopyroxene and 40% iron oxide minerals occurring as subvertical stringers. Piece 6 is olivine gabbro with an oxide-rich zone forming the top 1 cm of the piece. Coarse-grained gabbro of Unit 1 is deformed and sheared at the boundary with Unit 2. Pieces 1, 4, 5, and 6 are also relatively rich in plagioclase.
SECONDARY MINERALOGY:
Smectite.
Mode of Occurrence: Replacing olivine.
Iron oxide minerals.
Mode of Occurrence: Replacing olivine.
Talc.
Total Percent: Trace.
Mode of Occurrence: Replacing olivine.
Chlorite.
Mode of Occurrence: Replacing olivine, clinopyroxene, plagioclase.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene and plagioclase.
Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Clay minerals.
Mode of Occurrence: Replacing olivine and plagioclase.
Pyrite.
Mode of Occurrence: Replacing clinopyroxene.
Comments: Total alteration in this unit is slight to moderate (10%–20%) with narrow rims of actinolite ± chlorite after clinopyroxene (5%–10% altered). Rare brown patches within clinopyroxene are probably brown amphibole. Plagioclase is slightly altered (about 5%). Altered plagioclase is chalky white and is finer grained (Piece 1B) corresponding to an increase in deformation along a shear zone. Locally, plagioclase (Piece 2) is orange with slight alteration to clay minerals. In other pieces, a dense network of microcracks within the plagioclase imparts a gray color. In Piece 4, near a shear zone, olivine is altered to smectite and iron oxide minerals, and clinopyroxene is rimmed by chlorite and actinolite.
Veins
A dark green thin (<1 mm) actinolite and chlorite vein cuts the shear zone in Piece 4 and is steeper than the shear zone.
VEIN/FRACTURE FILLING:
Actinolite and chlorite
Size: <<1
Comments: Common in most samples as microveinlets cutting plagioclase.

Plagioclase, actinolite, chlorite, ±quartz, apatite, and magnetite.
Size: <4 mm.

ADDITIONAL COMMENTS: Structure

The primary igneous texture is locally overprinted by plastic shear zones defined by the elongation of clinopyroxene and plagioclase crystals. These shear zones are found in Pieces 1 and 4. The shear zones are locally associated with compositional variations (i.e. oxide-rich gabbro in Piece 5). The dip of these shear zones is subhorizontal at the top of Piece 1, moderately dipping (35°) in the bottom of Piece 1 and steeply dipping (≈60°) in Piece 4.

UNIT 2: OLIVINE GABBRO

Pieces 4–15

COLOR: Green brown/black.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:

Plagioclase - Mode: 60%.
Crystal Size: 3–16 mm.
Crystal Shape: Subhedral to anhedral.

Clinopyroxene - Mode: 23%–30%.
Crystal Size: 14–20 mm.
Crystal Shape: Anhedral.

Olivine - Mode: 10%–17%.
Crystal Size: 1–13 mm.
Crystal Shape: Anhedral.

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

Sulfide minerals. - Mode: <1%.
Crystal Shape: Anhedral.

Comments: Pieces 5 to 15 are texturally and modally homogeneous olivine gabbro. They are coarse-grained with an average grain size of ≈7mm, significantly less than that of the very coarse-grained gabbros of Unit 1. Olivine appears to be a cumulus phase, as do clinopyroxene and plagioclase. The texture is generally allotriomorphic granular, although Pieces 14 and 15 contain subhedral, tabular plagioclase crystals. Piece 6 contains a 1 cm wide patch of felsic material (trondhjemite?) that is best exposed on the outer surface of the core.

SECONDARY MINERALOGY:

Smectite.
Mode of Occurrence: Replacing olivine.

Iron oxide minerals.
Mode of Occurrence: Replacing olivine.

Talc.
Total Percent: Trace.
Mode of Occurrence: Replacing olivine.

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

Actinolite.
Mode of Occurrence: Replacing clinopyroxene and plagioclase.

Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.

Clay minerals.
Mode of Occurrence: Replacing olivine and plagioclase.

Pyrite.
Mode of Occurrence: Replacing clinopyroxene.

Comments: Alteration is generally slight to moderate (10%–15%), but Pieces 11 and 14 are highly altered (50%). Clinopyroxene is slightly to moderately altered (<10%–15%) and exhibits moderately to well developed dark green rims of actinolite with minor chlorite, iron oxide minerals, brown amphibole as discontinuous rims and as blebs, and a trace of pyrite. In more intensely altered zones, pyroxene appears patchy due to replacement along grain boundaries. In the most intensely altered areas, clinopyroxene is pseudomorphed by amphibole and chlorite, forming fibrous green pods. Plagioclase alteration is heterogeneous and is most intense where associated with veinlets and pods of actinolite and chlorite (Pieces 6, 10, 11, 12, 13, 14, and 15) and adjacent to deformed zones. In these zones, plagioclase is chalk white to orange, due to oxidation staining. When adjacent to pyroxene, plagioclase is rarely cut and grain boundaries are rimmed by actinolite ± chlorite veinlets. Olivine alteration is extremely

153-921E-3R-1

heterogeneous, ranging from 20% (Piece 10) to 100%, and is commonly marked by chlorite, clay minerals, net-veined iron oxide minerals, and talc. Small, irregular, rounded pods with talc cores and dark green chlorite rims may be pseudomorphs after olivine. Magnetite, pyrite, and chalcopyrite are commonly rimmed by brown to green amphibole and chlorite. Pieces 6, 10, 11, 12,13, 14, and 15 contain pods and veinlets of plagioclase, which is pervasively altered to secondary plagioclase and minor clay minerals, actinolite and chlorite after clinopyroxene and apatite and/or quartz. Alteration of host material adjacent to these zones is intense (80%–100%) with secondary plagioclase, actinolite, and chlorite common and traces of epidote (Piece 10).

Veins

Actinolite ± chlorite microveinlets are common in most samples.

Plagioclase (chalky white), actinolite and chlorite (after clinopyroxene), ± quartz ± apatite ± magnetite veins occur in Pieces 11, 12, and15. Vein widths are up to 4 mm.

VEIN/FRACTURE FILLING:

Actinolite and chlorite.

Size: <1

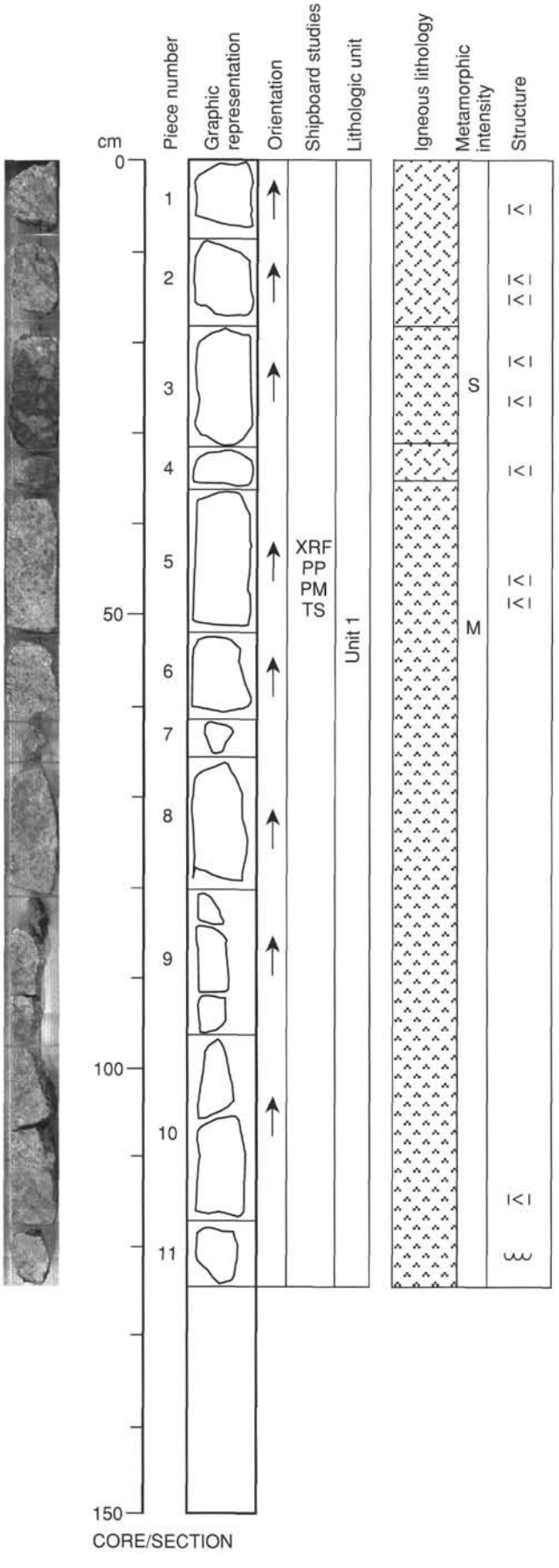
Comments: Occurs as microveinlets cutting plagioclase in most pieces.

Plagioclase, actinolite, chlorite, ± quartz, apatite, and magnetite.

Size: <4

ADDITIONAL COMMENTS: Structure

The primary igneous texture is locally overprinted by plastic shear zones defined by the elongation of clinopyroxene and plagioclase crystals. These shear zones are found in Pieces 5, 6, and 10. In Piece 5, the shear zone is subvertical. In Piece 6 the shear zone is 5 mm thick zone dipping 45° along the bottom edge. In Piece 10, it is a subhorizontal, relatively diffuse zone of elongate grains. Two magmatic veins (plagioclase + actinolite) are in Piece 11. One is 5 mm thick along the upper edge, is parallel to a double vein in the center of the piece that is 3 mm thick (each branch), cuts large pyroxene grains, and dips about 50°. Another irregular vein is in Piece 12 and three more are in Piece 15. One of the 2 mm thick veins in Piece 15 dips 60° and is cut by a thin (<1 mm) actinolite and chlorite vein dipping in the opposite sense about 50°. The other magmatic veins intersect on the 90° side of the piece and are more irregular and diffuse.



153-921E-4R-1

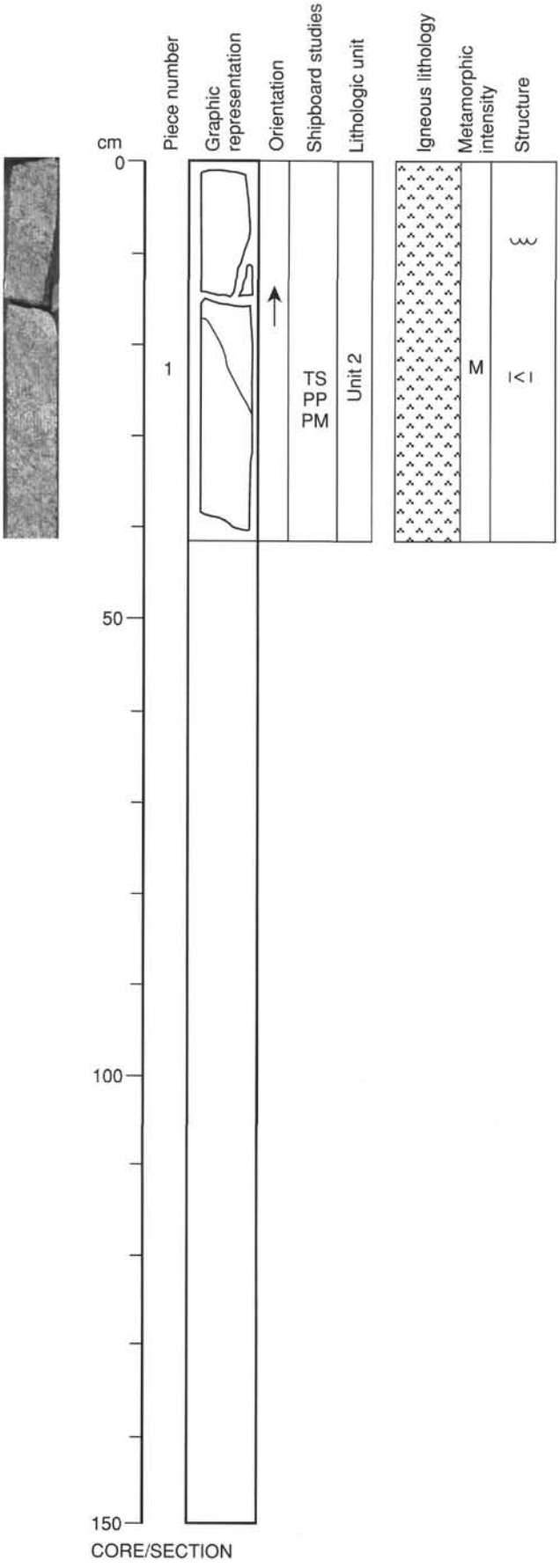
UNIT 2: GABBRO AND OLIVINE GABBRO

Pieces 1–11

COLOR: Gray to white.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Olivine - Mode: 0%–18%.
Crystal Size: 1–6 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Clinopyroxene - Mode: 20%–41%.
Crystal Size: 1–20 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Plagioclase - Mode: 56%–70%.
Crystal Size: 0.5–16 mm.
Crystal Shape: Sub-Anhedral.
Crystal orientation: No preferred orientation.
Comments: This section consists of gabbro (Pieces 1, 2, and 4) and olivine gabbro (Pieces 3 and 5–11). Clinopyroxene and plagioclase are cumulus phases throughout the section; olivine is a cumulus phase except in Piece 1. The texture is hypidiomorphic equigranular except in Pieces 3, 4, and 11 where the texture is poikilitic inequigranular. Gabbro in these pieces consists of large clinopyroxene oikocrysts enclosing lath-shaped plagioclase. No preferred orientation of mineral grains was noted in hand specimen. Diffuse interlayering of coarse- and medium-grained gabbro on the scale of 1–5 cm is present in Pieces 8 and 10. The layer boundaries are relatively abrupt, and dip steeply (≈70°) with respect to the core. The layering is better represented in the working halves of the core.
SECONDARY MINERALOGY:
Iron oxide minerals.
Mode of Occurrence: Replacing olivine and clinopyroxene.
Talc(?)
Mode of Occurrence: Replacing olivine.
Clay minerals.
Mode of Occurrence: Replacing olivine.
Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene.
Chlorite.
Mode of Occurrence: Replacing olivine and clinopyroxene.
Comments: Alteration is irregular, slight to moderate (< 10% to 30%) with oxidation zones common in Pieces 1, 2, 3, and 5. Olivine alteration is heterogeneous (5%–100%). In less altered pieces, it is only slightly altered to iron oxide minerals and talc. Clinopyroxene is slightly to moderately altered (5%–40%), but adjacent to veinlets alteration is commonly pervasive. Secondary minerals include minor brown amphibole, actinolite with the minor chlorite which forms alteration rims, and iron oxide minerals with very rare pyrite. Plagioclase is slightly to moderately altered, with most intense alteration associated with veinlets and oxidized zones. In these areas, it is yellow to green and is altered to secondary plagioclase and minor chlorite with some actinolite. Piece 1 is highly altered with extensive replacement by chlorite and actinolite associated with a veinlet. Plagioclase is stained by hydroxide minerals. Piece 3 contains an irregularly shaped, iron-stained, oxidation halo within which plagioclase is altered to chlorite(?), imparting a pale green color to the plagioclase. In Piece 4, clinopyroxene is replaced by actinolite and rimmed by chlorite. Olivine is altered to smectite and hydroxide minerals. Pieces 6, 7, and 8 are fresh. Piece 10 has stained plagioclase and patches of amphibole.
Veins
In Piece 2, actinolite and chlorite microveinlets cut plagioclase (<<1 mm in width).
VEIN/FRACTURE FILLING:
Actinolite and chlorite microveinlets.
Size: <1 mm.
Comments: Cuts plagioclase.
ADDITIONAL COMMENTS: Structure
Piece 8 has a coarse-grained central section 8 cm thick with approximately subhorizontal gradational boundaries. Piece 10 has a 1 cm thick, horizontal,

153-921E-4R-1

fine-grained band cutting it that shows subtle grain alignment and may be a weak shear zone. Piece 11 grades to a darker, finer grained material at the bottom of the piece. Thin (<1–2 mm) dark green, moderately dipping (≈35°) chlorite veins are in Pieces 1 and 2. Piece 5 contains a steeply dipping (60°) chlorite vein.



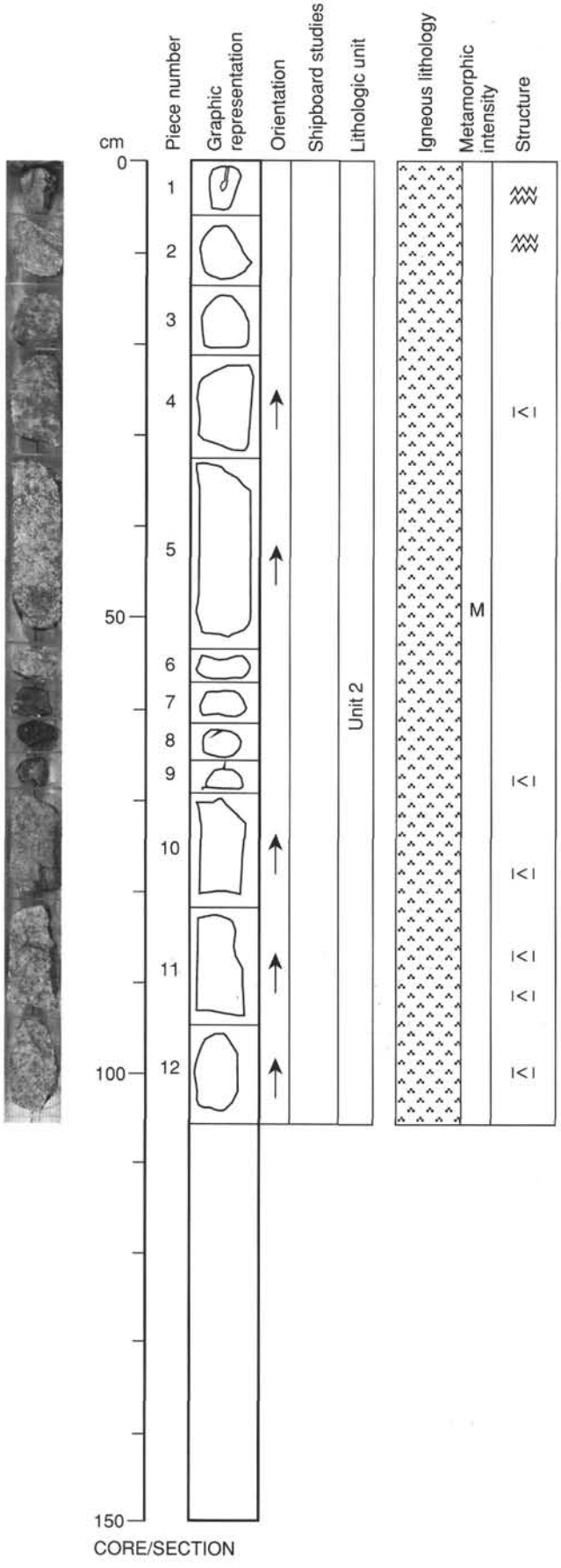
153-921E-4R-2

UNIT 2: OLIVINE GABBRO

Pieces 1

COLOR: Gray/green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 55%–60%.
Crystal Size: 2–5 mm.
Crystal Shape: Euhedral/anhedral.
Clinopyroxene - Mode: 2%–15%.
Crystal Size: 2–15 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 5%–10%.
Crystal Size: 2–10 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: <1%.
Crystal Size: <3 mm.
Crystal Shape: Anhedral.
Comments: This section consists of medium- to coarse-grained olivine gabbro that is modally homogeneous and relatively fresh (<5% total alteration). Plagioclase occurs as a cumulus phase, whereas olivine and most clinopyroxene appear to be interstitial; some clinopyroxene may have originated as a cumulus phase. Layering, defined by grain-size variations, is observed in Pieces 1A and 1B. Within a given interval, grain size is generally constant (with one exception noted below), and the contacts between intervals of different grain size are gradational over a distance of a few cm. The layering dips at an angle of approximately 30°. The top 6 cm of Piece 1A is coarse grained, followed downward by 7 cm that is medium to fine grained. A small wedge of medium- to coarse-grained olivine gabbro is at the bottom of Piece 1A which continues into Piece 1B for a length of 5 cm. Below this is a 10.5 cm section of coarse-grained olivine gabbro (maximum grain size ≈15 mm) that decreases in grain size downward to a maximum of 7 mm. Plagioclase occurs as large, prismatic crystals, but is also present as fine-grained, anhedral aggregates that may be recrystallized zones. A few grains of sulfide minerals are enclosed within plagioclase in Piece 1B.
SECONDARY MINERALOGY:
Iron oxide minerals.
Total Percent: <1
Mode of Occurrence: Replacing olivine.
Talc.
Total Percent: <1
Mode of Occurrence: Replacing olivine.
Chlorite.
Total Percent: 2–5
Mode of Occurrence: Replacing olivine/clinopyroxene.
Actinolite.
Total Percent: 2
Mode of Occurrence: Replacing clinopyroxene.
Brown amphibole.
Total Percent: <1
Pyrite.
Total Percent: <1
Comments: Occurs disseminated with chlorite.
Comments: Alteration is slight to moderate (10 %). The bottom of Piece 1A contains very fresh olivine, clinopyroxene, and plagioclase, with very local orange staining of plagioclase. The top of the piece is moderately altered. Clinopyroxene alters to actinolite and olivine alters to smectite and iron oxide minerals. Altered plagioclase is chalky white. Piece 1B is remarkably fresh, with very local replacement of plagioclase rims by actinolite. At the margins of a vein, clinopyroxene is altered to actinolite and chlorite.
Veins
Piece 1B is cut by a 1 mm wide actinolite and chlorite vein.
VEIN/FRACTURE FILLING:
Actinolite and chlorite.
Size: 1
Orientation: Steep dip.
ADDITIONAL COMMENTS: Structure
A single chlorite and actinolite vein in Piece 1B is steeply dipping (60°) and cuts a 15 cm thick, fine-grained layer. The finer grained layer has a gradational top that dips ≈40° and a bottom that dips 45° to the opposite side.

153-921E-5R-1



UNIT 2: OLIVINE GABBRO

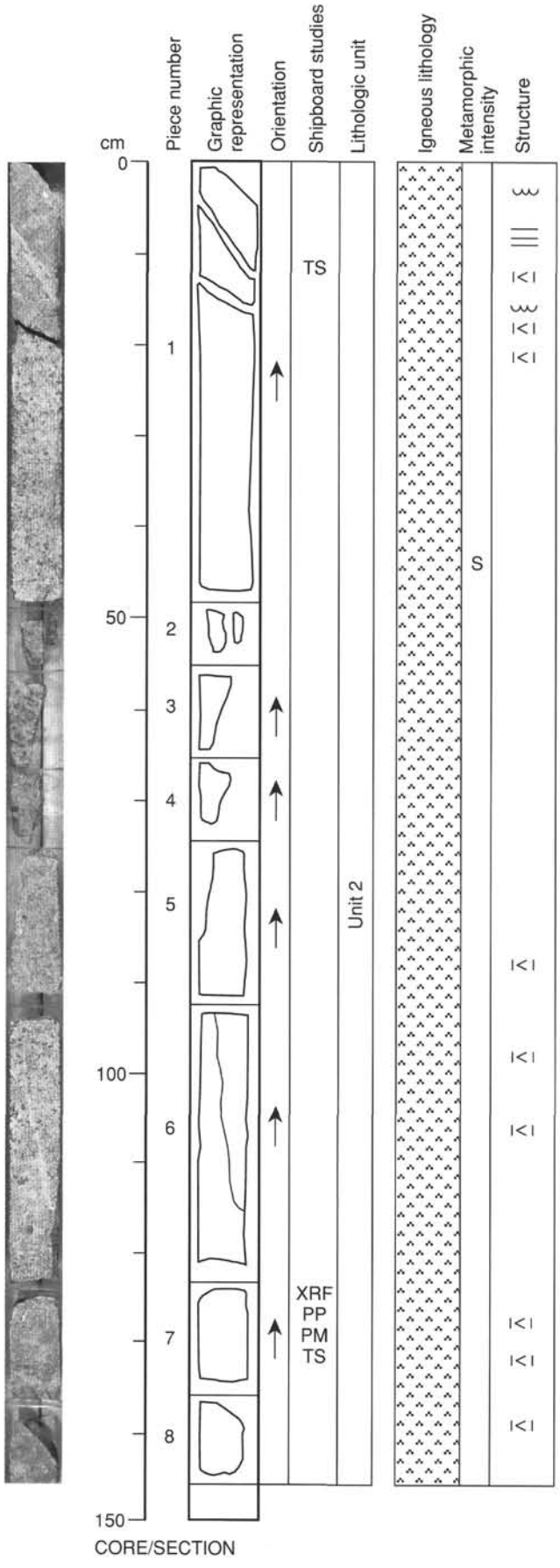
Pieces 1–12

COLOR: Speckled white/brown/black.
PRIMARY STRUCTURE: Medium-grained poikilitic.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%–70%.
Crystal Size: 5–15 mm.
Crystal Shape: Subhedral.
Olivine - Mode: 13%–24%.
Crystal Size: 7–20 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 10%–19%.
Crystal Size: 10–27 mm.
Crystal Shape: Anhedral.
Oxide minerals - Mode: <1%–10%.
Crystal Shape: Anhedral.
Comments: The dominant lithology of this section is a medium-grained poikilitic olivine gabbro (Pieces 3–5 and 10–12). Four small pieces of iron-stained gabbro occur in the middle of the section (Pieces 6–9) and a larger, fresher piece of gabbro occurs near the top (Piece 2). The gabbro (Pieces 2 and 6–9) contains 60%–65% plagioclase, 27%–38% clinopyroxene, and 2%–4% olivine. Piece 1 is an oxide-gabbro, containing approximately 10% iron oxide minerals that occur interstitially and in long (20 mm) thin layers. The piece is crosscut by a diffuse vein or layer containing abundant oxide minerals (10%) in thin layers that parallel the vein margins. The olivine-gabbro (Pieces 3–5 and 10–12) contains 60%–70% plagioclase, 13%–24% olivine, 10%–19% clinopyroxene and minor amounts of oxide minerals. Plagioclase occurs as equant grains and laths; the latter are prominant only in Piece 5. Clinopyroxene appears to have a bimodal size distribution. Small (≈2mm) widely dispersed (late?) interstitial clinopyroxenes are pink brown and occasionally have light green, fresh cores. Larger grains (maximum grain size: 10–27 mm) are a similar pink brown, but their cores often have a pale pearly luster on cleavage planes. Olivine is altered in nearly all pieces, but in Piece 3 small, fresh olivine grains occur interstitially and on the rims of larger, altered olivines.
SECONDARY MINERALOGY:
Magnetite.
Total Percent: 4–8
Comments: After olivine.
Talc.
Total Percent: 4–8
Comments: After olivine.
Sulfide minerals.
Total Percent: <<1
Comments: After olivine/clinopyroxene.
Green amphibole ± chlorite.
Total Percent: <1–8
Comments: After clinopyroxene.
Comments: Overall alteration is between 10% and 30%. Olivine alteration is variable within the same piece (relatively fresh in Pieces 2, 3, and 11), and occurs as replacement by talc and oxide minerals, and locally as thin rims of green chlorite marked by recrystalized plagioclase and flattened clinopyroxene. Plagioclase is chalky and stained orange. In all pieces, the coarsest clinopyroxene crystals show lesser replacement by brown amphibole than finer grained crystals; clinopyroxene is locally replaced by actinolite and chlorite. Plagioclase is generally fresh, except for limited iron staining, and alteration to chlorite near veins. At the top of Piece 11, plagioclase is altered to chlorite and actinolite, particularly along thin, discrete, parallel chlorite and actinolite veins.
Veins
In Pieces 4, 11, and 12, very thin chlorite and actinolite veins crosscut the core.
VEIN/FRACTURE FILLING:
Quartz(?), feldspar, oxide minerals.
Size: 5
Orientation: Diffuse margins.
ADDITIONAL COMMENTS: Structure
There is no distinct preferred mineral shape fabric in this section. Piece 1 has a shear

153-921E-5R-1

zone that makes up approximately half of its volume (15 mm wide), consisting of elongate plagioclase and oxide minerals (magnetite?) surrounding altered pyroxene crystals. (Note: this zone is described as a vein in the Igneous section above). Piece 2 has a semibrittle, 1 mm wide, shear zone composed of a veinlike network of plagioclase surrounding angular pyroxene grains. A thin (<<1 mm) green chlorite vein with a gentle dip (<25°) appears in each of Pieces 4, 7, and 11. A few thin (<<1 mm) and short (<20 mm) cracks with no filling, and of varying orientations appear in Pieces 10, 11, and 12.

153-921E-5R-2



UNIT 2: OLIVINE GABBRO - TROCTOLITE

Pieces 1–8

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 61%–68%.
Crystal Size: 1–15 mm.
Crystal Shape: Subhedral/anhedral.
Clinopyroxene%– - Mode: 7%–30%.
Crystal Size: 2–12 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 8%–25%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: <0.5%.
Comments: The section consists of modally and texturally heterogeneous, coarse-grained olivine gabbro and medium- to coarse-grained troctolite. Both olivine gabbro and troctolite contain subhedral plagioclase (1–15 mm in size) and anhedral, irregularly shaped interstitial olivine (1–10 mm) and clinopyroxene (2–30 mm). Clinopyroxene is brown and varies in abundance from <<1% in troctolite to 30% in olivine gabbro. It poikilitically to subophitically encloses plagioclase. The modal proportion of olivine ranges from 7% in olivine gabbro to 30% in troctolite. Plagioclase abundance is relatively uniform (61–68 modal%), but highest in the troctolite (70 modal%). Primary iron oxide minerals are rare or absent in both rock types. Piece 1A exhibits grain-size and compositional layering, the boundaries between layers dipping at about 30°. This piece is composed of predominantly medium-grained troctolite (10–13 cm) containing 70% plagioclase and 30% olivine with a 1 cm wide layer of coarse-grained olivine gabbro at the bottom, and possibly at the top; it is crosscut by a 1 cm wide magmatic vein in the middle of the piece that dips at approximately 50°. Pieces 1B to 6 are, on average, more coarse-grained than Piece 1A and are relatively homogeneous in modal proportions of phases and textural characteristics. Piece 1B contains a diffuse vein of fine-grained material which crosscuts the core at a similar angle to the magmatic vein in Piece 1A. Pieces 7 and 8 are troctolite (35% olivine and 65% plagioclase) interlayered with thin bands or pockets (<1 cm wide) of medium- to coarse-grained olivine gabbro (10% olivine, 25% clinopyroxene, and 65% plagioclase).
SECONDARY MINERALOGY:
Chlorite.
Total Percent: <5
Comments: After clinopyroxene and olivine.
Secondary plagioclase.
Comments: After plagioclase.
Magnetite.
Total Percent: <0.5
Comments: Alteration of the olivine gabbro and troctolite is slight (5%–15%) with the most intense alteration associated with the presence of veinlets filled either by chlorite and/or actinolite or brown oxidized clay minerals. Altered plagioclase is chalky white and is altered to a white clayey mineral at the selvages of veins, with light green chlorite where adjacent to clinopyroxene. Clinopyroxene is slightly altered to amphibole, with only light brown rims or in small patches. When close to a vein clinopyroxene is altered to actinolite. Olivine is slightly altered (never >10%) to talc, and clay and oxide minerals. Piece 1A contains an oxidized zone.
Veins
A thin en echelon vein (4 mm thick) crosscuts Piece 1. Along margins it is composed mostly of plagioclase in small recrystallized grains; at the center, brown amphibole (replacing clinopyroxene?) is partly (or completely) altered to actinolite, with white selvages of small, white, chalky plagioclase grains with local clayey alteration, and small clinopyroxene grains, altered to brown amphibole and actinolite. Pieces 1B, 3, 4, 6, and 7 are crosscut by <1 mm veins containing either chlorite and/or actinolite, and clay minerals (reactivated?). A 1 mm wide vein filled with white, chalky plagioclase and actinolite and very finely recrystallized or altered clay minerals(?) and actinolite occurs in Piece 6.
VEIN/FRACTURE FILLING:
Secondary plagiclase and actinolite.

153-921E-5R-2

Size: 5 mm.

Orientation: Cuts Piece 1A ≈30°

Secondary plagioclase.

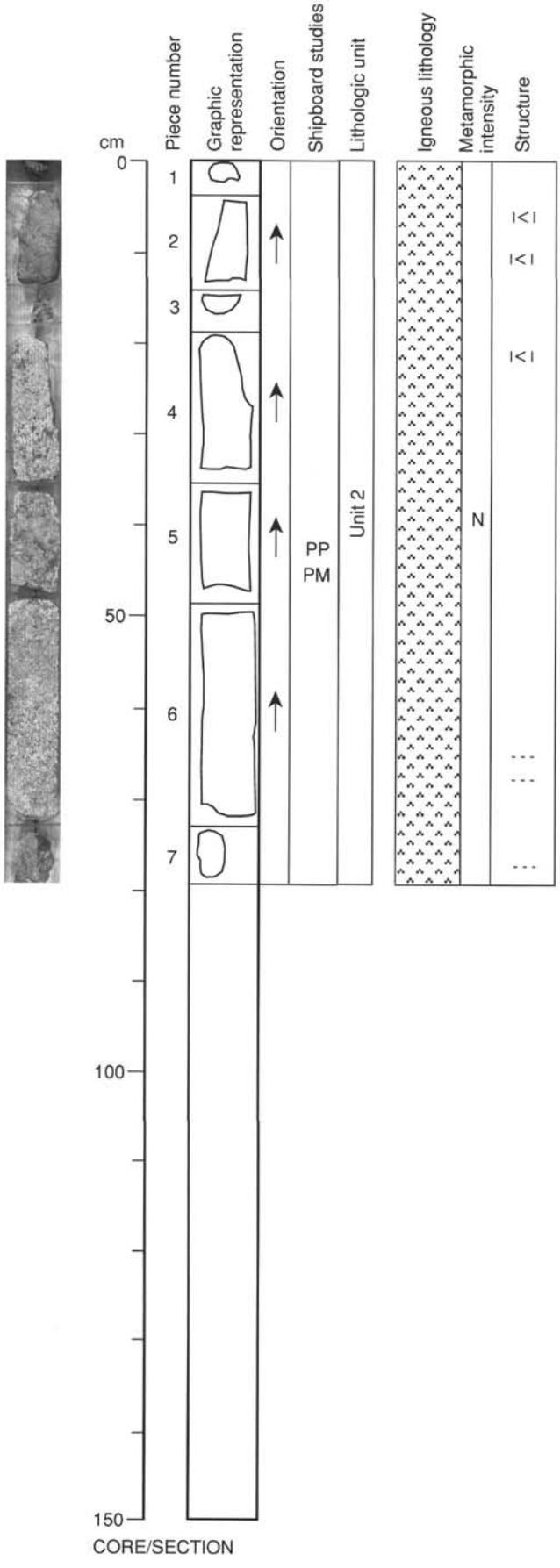
Size: <2 mm.

Orientation: Cut along Pieces 5 and 6

ADDITIONAL COMMENTS: Structure

In general, there is no preferred shape fabric developed in this rock, however, Piece 1 contains a faint alignment of olivine grains, forming an ill-defined lineation, close to the vein. It plunges moderately (36°). The vein, composed mainly of chlorite and actinolite, has a 2 mm wide halo on each side, and it displays en echelon, overlapping segments (possible microfaulting ?). Piece 1B contains a planar, subhorizontal vein filled with chlorite and actinolite. Two igneous contacts in Piece 1 separate olivine gabbro at the top and bottom of the piece from troctolite. There is a change in grain size from Piece 2 (medium) to 3 (coarse), and Pieces 2, 3, and 4 have no mesoscopic structural features in them. Piece 5 has a subvertical vein filled with plagioclase and chlorite that appears to continue into Piece 6. This vein in Piece 6 is cut across by a moderately dipping actinolite and chlorite vein. Piece 7 displays a textural change that is manifested in the development of a sinusoidal, light-colored band in the lower part separating olivine gabbro from oikocrystic olivine gabbro at the very bottom of the piece. Both Pieces 7 and 8 contain moderately to steeply dipping chlorite and actinolite ± smectite veins.

153-921E-5R-3



UNIT 2: OLIVINE GABBRO - GABBRO.

Pieces 1–7

COLOR: Gray.

PRIMARY STRUCTURE: No magmatic or subsolidus foliations or mineral lineations are evident.

SECONDARY STRUCTURE: Veins.

PRIMARY MINERALOGY:

Olivine - Mode: 5%–20%.
Crystal Size: 2–7 mm.
Crystal Shape: Anhedral.

Clinopyroxene - Mode: 25%–50%.
Crystal Size: 2–15 mm.
Crystal Shape: Anhedral/subhedral.

Plagioclase - Mode: 50%–60%.
Crystal Size: 1–10 mm.
Crystal Shape: Euhedral.

Comments: The section consists of gabbro and olivine gabbro which are modally and texturally heterogeneous. Olivine varies considerably in modal abundance from 0%–5% in Pieces 1–2 to 12%–20% in Pieces 4–7. Clinopyroxene is brown and shows an antithetic variation in modal abundance (25%–50%) to olivine. Olivine and clinopyroxene occur as interstitial phases in association with subhedral plagioclase. Grain size varies between pieces, but unambiguous layering within a single piece was not observed. Pieces 1, 3, 4, and 5 are coarse grained. Piece 5 contains the largest crystals (up to 12 mm) and has the most equigranular texture given that the section is dominated by an inequigranular, poikilitic texture. Piece 2 is medium to coarse grained and Pieces 6 and 7 are fine to medium grained.

SECONDARY MINERALOGY:

Brown amphibole.
Total Percent: <1

Comments: Rims on clinopyroxene.

Comments: This section is comprised of slight to negligibly altered gabbro (max 5%). In Piece 2, green chlorite fills cracks in plagioclases, near a <1 mm wide vein. Clinopyroxene in Piece 1 exhibits the most extensive alteration (50%). Plagioclase is fresh. Clinopyroxene shows minor alteration to brown amphibole and actinolite as patches and rims (Piece 4). Olivine is generally very fresh and locally replaced by talc, clay, and oxide minerals.

Veins

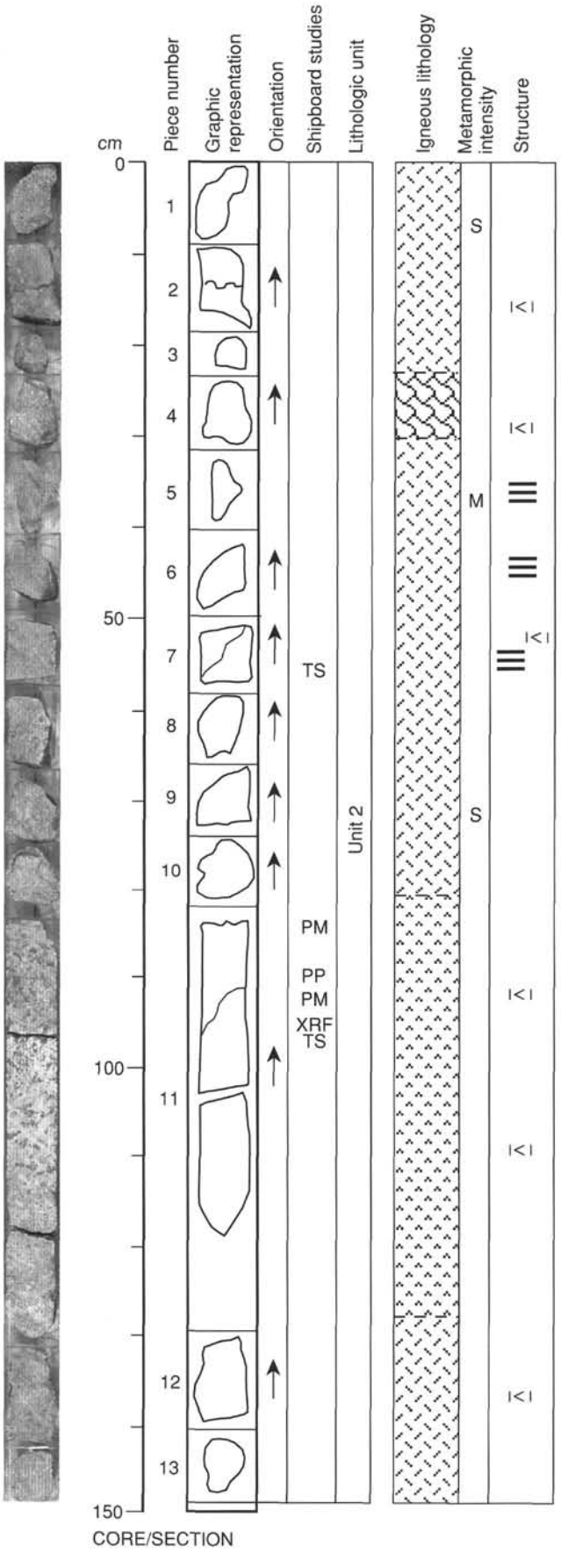
In Piece 2, a <1 mm wide vein is filled with actinolite and a hard white mineral (probably recrystallized feldspar).

VEIN/FRACTURE FILLING:

Chlorite ± ?feldspar.
Size: <1

ADDITIONAL COMMENTS: Structure

No mineral shape fabric is evident in this section. At the base of Piece 6, an irregular, diffuse boundary delineates a lens-shaped zone of finer grain size (1–2 mm) within a medium-grained gabbro. Two chlorite and actinolite veins (<< 1 mm), are present in Piece 2. Both veins dip at about 20°. Piece 4 is cut by a plagioclase vein (<< 1 mm), dipping at about 60°. Coarser (>2 mm) plagioclase at the base of Piece 7 (unoriented) may represent an irregular vein or a compositional variation in the host rock. Intracrystalline fractures are present in the coarse plagioclase and pyroxene crystals in Piece 5. Pieces 1 and 3 are small pieces (≈3 cm) of coarse-grained, undeformed gabbro.



153-921E-6R-1

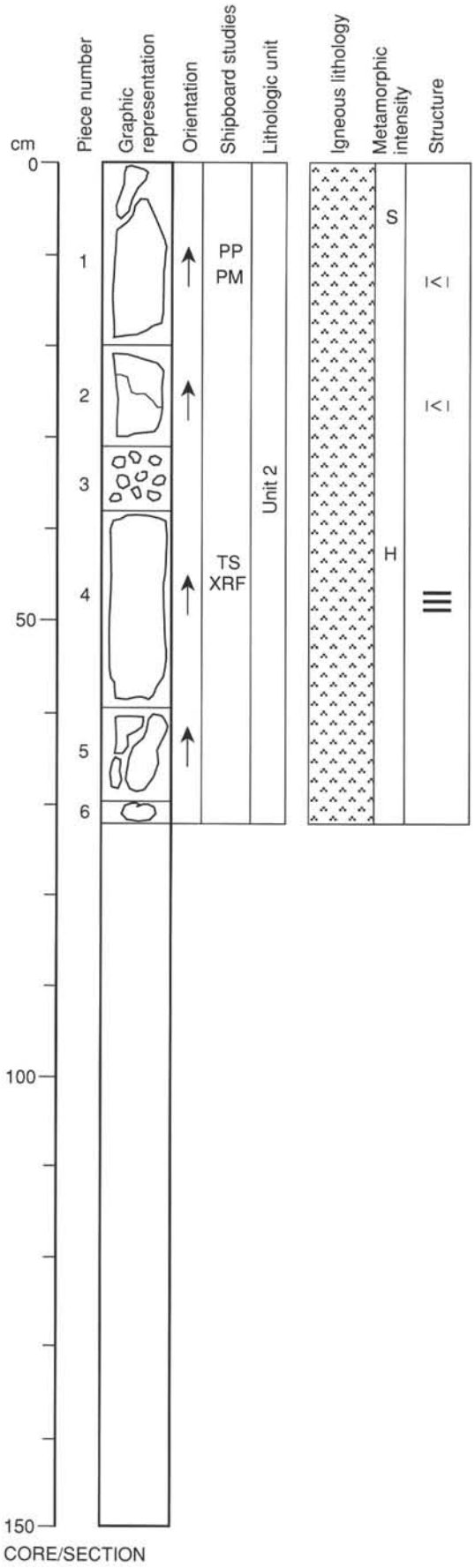
UNIT 2: GABBRO-OLIVINE GABBRO

Pieces 1–13

COLOR: Dark gray/green
PRIMARY STRUCTURE: Mesocumulate to heteradcumulate.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 40%–58%.
Crystal Size: 2–20 mm.
Crystal Shape: Euhedral.
Clinopyroxene - Mode: 15%–60%.
Crystal Size: 2–10 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 3%–25%.
Crystal Size: 3–15 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: 1%–2%.
Crystal Size: 1–3 mm.
Crystal Shape: Euhedral.
Sulfide minerals. - Mode: <1-1%.
Comments: This section is characterized by an increase in grain size with depth. Pieces 1–10 are fine- to medium-grained gabbro (average ≈3mm) which, in places, display a steeply dipping layering (Pieces 3, 6, 7 and 8). Pieces 11–13 are coarse- to very coarse-grained (<25 mm) gabbro in which variations in grain size define a diffuse subhorizontal layering. Piece 11A and the top 12 cm of Piece 11B are very coarse grained and homogeneous in both grain size and modal mineralogy. The lower 9 cm of Piece 11B and all of 11C are generally medium to coarse grained, but contain thin layers or pockets of very coarse-grained olivine gabbro. Brown clinopyroxene forms approximately 45% of the mode in most pieces, but reaches 60% in Piece 4. With the exception of Piece 11, the modal content of olivine is low (<5%), and it is heterogenously distributed within most pieces such that some layers are olivine free. In contrast, Piece 11 contains 15% clinopyroxene and 25% olivine. Euhedral to subhedral plagioclase and clinopyroxene are cumulus phases, whereas anhedral olivine and clinopyroxene are interstitial phases. iron oxide and sulfide minerals are present in the pyroxene-rich layers (<2%). Anhedral poikilitic clinopyroxene and olivine enclose plagioclase, the clinopyroxene sporadically occurrs as very thin rims surrounding feldspar (Piece 11).
Locally, clinopyroxene encloses interstitial olivine. At the bottom of Piece 11B, plagioclase laths are randomly oriented and slightly radiating. Some have pointed terminations and contain cores of clinopyroxene.
SECONDARY MINERALOGY:
Actinolite.
Total Percent: 10
Comments: Replacing clinopyroxene.
Chlorite.
Comments: In most pieces alteration is variable from slight to moderate (5%–35%) and most intense when associated with veinlets. Pieces 3 and 4 are the most altered (up to 25%); in the other pieces alteration is restricted to the vein margins. Pieces 3 and 4 are iron stained along one side. On the other edge of the piece, clinopyroxene is rimmed by green actinolite and chlorite which fills the interstices between plagioclase crystals. Plagioclase is only slightly altered to a white clay mineral and, adjacent to clinopyroxene is altered to actinolite and chlorite. Plagioclase is commonly pervasively altered near veins, marked by a white halo. Clinopyroxene is generally slightly altered, with small patches or rims of brown amphibole and actinolite common. In Piece 4, clinopyroxene is partially rimmed by fibrous actinolite, chlorite, and iron oxide minerals with a trace of pyrite. Along an edge of the piece, a diffuse brown zone is filled with smectite and the clinopyroxene is altered to a brown material along the vein.
Veins
Pieces 1, 2, 4, 5, 11, and 12 are crosscut by <1 mm wide veins containing either chlorite and/or actinolite or brown oxidized clay minerals, marked by green and white alteration halos.
VEIN/FRACTURE FILLING:
Chlorite and actinolite.
Size: <1
ADDITIONAL COMMENTS: Structure
This section is almost devoid of any crystal shape preferred orientation, except in

153-921E-6R-1

Pieces 5, 6, and 7 where a very weak preferred alignment of plagioclase is developed. A foliation plane can be defined with a subvertical orientation. As the shape fabric is more developed on vertical than on horizontal surfaces, the crystal shape fabric is rather linear with a subvertical plunge. In Piece 11, a coarser grained horizon defines a rough subhorizontal layering. Straight, mm-sized chlorite veins are widespread throughout the section (observed in Pieces 1, 2, 4, 5, 11, and 12), but not abundant, and have a consistent dip around 45°.



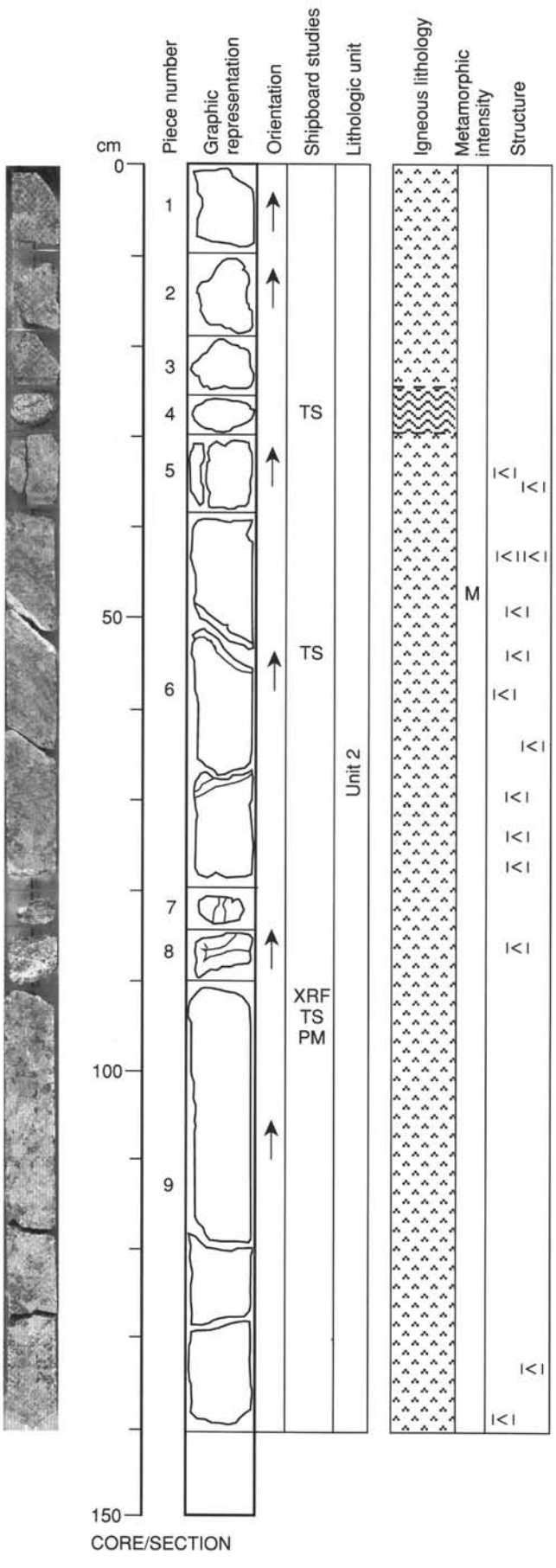
153-921E-6R-2

UNIT 2: OLIVINE GABBRO.

Pieces 1–6

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 63%–66%.
Crystal Size: 1–15 mm.
Crystal Shape: Euhedral/subhedral.
Clinopyroxene - Mode: 27%–30%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 6–10%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: <1%.
Comments: This section consists of very fresh, medium- to coarse-grained olivine gabbro that exhibits grain-size layering. Pieces 1, 2, and 4 are composed of medium-grained olivine gabbro interlayered with coarser grained olivine gabbro. These intervals exhibit a weakly developed preferred orientation of crystals parallel to layering. In Pieces 1 and 2, the layering is oriented subvertically whereas in Piece 4, the layering dips approximately 30° relative to the core axis and shows a near rhythmic alternation in grain size on a scale of 1–3 cm. Piece 5 is uniformly coarse grained. Both medium-grained and coarse-grained olivine gabbro contain euhedral to subhedral plagioclase (1–15 mm in size) and anhedral, irregularly shaped, interstitial olivine (1–8 mm) and clinopyroxene (1–10 mm). Clinopyroxene is brown in most pieces, but has green brown cores with darker brown rims in Piece 5. The primary lithology is fairly uniform in modal composition. Primary iron oxide minerals are absent from all except Piece 5.
SECONDARY MINERALOGY:
Chlorite.
Total Percent: <7
Comments: After olivine/clinopyroxene.
Actinolite.
Total Percent: <1
Comments: After olivine.
Magnetite.
Total Percent: <1
Comments: After olivine.
Comments: Alteration in this section is slight to moderate (5%–15%) with the most intense alteration associated with veinlets. Altered plagioclase has a white chalky color and at vein margins is replaced very locally by white clay minerals. Where adjacent to clinopyroxene, plagioclase is altered to light green chlorite (Piece 2). Clinopyroxene is slightly altered, with brown rims or small patches of brown amphibole and actinolite. In Pieces 4 and 5, adjacent to veins, clinopyroxene is partially to completely replaced by fibrous actinolite, chlorite, and iron oxide minerals with a trace of pyrite.
Veins
Veins in Piece 1 are horizontal, 3 mm wide, and contain chalky, fine-grained plagioclase and clinopyroxene locally altered to actinolite. In Piece 5, thin veinlets are filled with clay and hydroxide minerals. Pieces 1, 2, 4, 5, 11, and 12 are crosscut by mm-sized veins containing either chlorite and/or actinolite or brown, oxidized clay minerals. These veins commonly have green and white alteration halos.
VEIN/FRACTURE FILLING:
ADDITIONAL COMMENTS: Structure
Piece 3 is made of fragments of coarse-grained gabbro. This section is almost devoid of any crystal shape preferred orientation, except in medium-grained pieces (Pieces1 and 2), where clinopyroxene has a very weak, subvertical preferred alignment. The fabric is so poorly developed that it is difficult to determine if it is planar or linear. Veins are not abundant in this section (present in Pieces 1, 2, 4, 5, 11, and12). Plagioclase veins (mm-sized) are in Pieces 1 and 2.

153-921E-7R-1



UNIT 2: OLIVINE GABBRO

Pieces 1–9

COLOR: Gray, white, brown and green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 50%–80%.
Crystal Size: 1–10 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Clinopyroxene - Mode: 18%–26%.
Crystal Size: 1–30 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Olivine - Mode: 2%–30%.
Crystal Size: 1–20 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Iron oxide minerals - Mode: <1%.
Crystal Size: <1 mm.
Crystal Shape: Anhedral.
Sulfide minerals. - Mode: <<1%.
Crystal Size: <<1 mm.
Crystal Shape: Anhedral.
Comments: This section predominantly consists of coarse-grained olivine gabbro crosscut by white magmatic veins. With the exception of Piece 4, modal proportions of plagioclase are uniform throughout the section. Typical modal proportions of olivine and clinopyroxene vary slightly relative to one another, with Pieces 1–3 containing more olivine (27%–30%) than Pieces 5–9 (18%–20%). Grain size is also uniform throughout the section, although Piece 3 (unoriented) contains a gradational contact between a 3 cm wide, fine-grained olivine gabbro and medium- to coarse-grained olivine gabbro. The fine-grained olivine gabbro contains ≈40% olivine and 10% clinopyroxene whereas the coarser grained area is composed of 35% clinopyroxene and 15% olivine. Piece 9 contains large poikilitic clinopyroxene and olivine (up to 3 cm) not seen in the other pieces in the section. Clinopyroxene typically has green cores overgrown by brown clinopyroxene. Plagioclase is moderately to highly recrystallized. Minor amounts of iron oxide and sulfide minerals occur throughout the section. One of the more distinctive features of this section of core is the common occurrence of altered, white magmatic veins (1–20 mm wide). In Piece 6, these veins have relatively sharp contacts with the olivine gabbro and are thickest at the breaks between Subpieces 6A, 6B and 6C. Pieces 7 and 8 are intruded by more diffuse areas of these magmatic veins. In contrast to the other pieces of this section, Piece 4 is low in modal olivine (≈2%) and high in modal plagioclase (80%); it may also be a magmatic vein but the small piece size and high degree of alteration make this difficult to assess.
SECONDARY MINERALOGY:
Iron oxide minerals.
Mode of Occurrence: Replacing olivine.
Comments: Netveined.
Smectite.
Mode of Occurrence: Replacing olivine.
Talc.
Total Percent: Trace.
Mode of Occurrence: Replacing olivine.
Chlorite.
Mode of Occurrence: Replacing olivine, clinopyroxene, plagioclase.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene and plagioclase.
Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Clay minerals.
Mode of Occurrence: Replacing olivine and plagioclase.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Epidote.
Mode of Occurrence: Replacing plagioclase.
Comments: Alteration in this section is generally very slight (< 10%), though localized

153-921E-7R-1

halos along veins are highly to pervasively altered. Within the gabbroic host rock, alteration is dominated by slight alteration of olivine to talc and hydroxide minerals. Alteration of clinopyroxene is negligible to slight away from veins and pervasive adjacent to them. Brown amphibole blebs are common; intensely altered grains near the veinlets are replaced by actinolite, rimmed by chlorite and iron oxide minerals (Piece 9). Plagioclase is only slightly altered, except near veins where it becomes chalky in color. Sulfide minerals are present in altered olivine and clinopyroxene. Piece 4 is a pervasively altered plagioclase-rich rock in which primary plagioclase is chalky. Quartz may be present. Relict clinopyroxene grains are highly to pervasively altered to chlorite, actinolite, and iron oxide minerals.

Veins

Pieces 6A, and 6C, 7, and 8 are cut by plagioclase-rich veins which are commonly oxidized and are composed of plagioclase, quartz(?), clinopyroxene, magnetite, and a trace of pyrite. These veins commonly occur along the top and bottom edges of pieces and so complete veins are not observed. Rare pods of chlorite and amphibole associated with vein margins may be replaced olivine. Piece 9C is cut by a 5 mm wide zoned vein in which the core is composed of actinolite ± chlorite and is symmetrically rimmed by a chlorite-rich zone. Vein boundaries rarely contain discontinuous lenses of brown clay minerals. The adjacent host rock is pervasively altered to chlorite, actinolite, clay minerals, and secondary plagioclase.

VEIN/FRACTURE FILLING:

Plagioclase, quartz, magnetite, epidote, and altered clinopyroxene.

Size: <10

Comments: Occurs in Pieces 6, 7, and 8.

Actinolite, chlorite, and clay minerals.

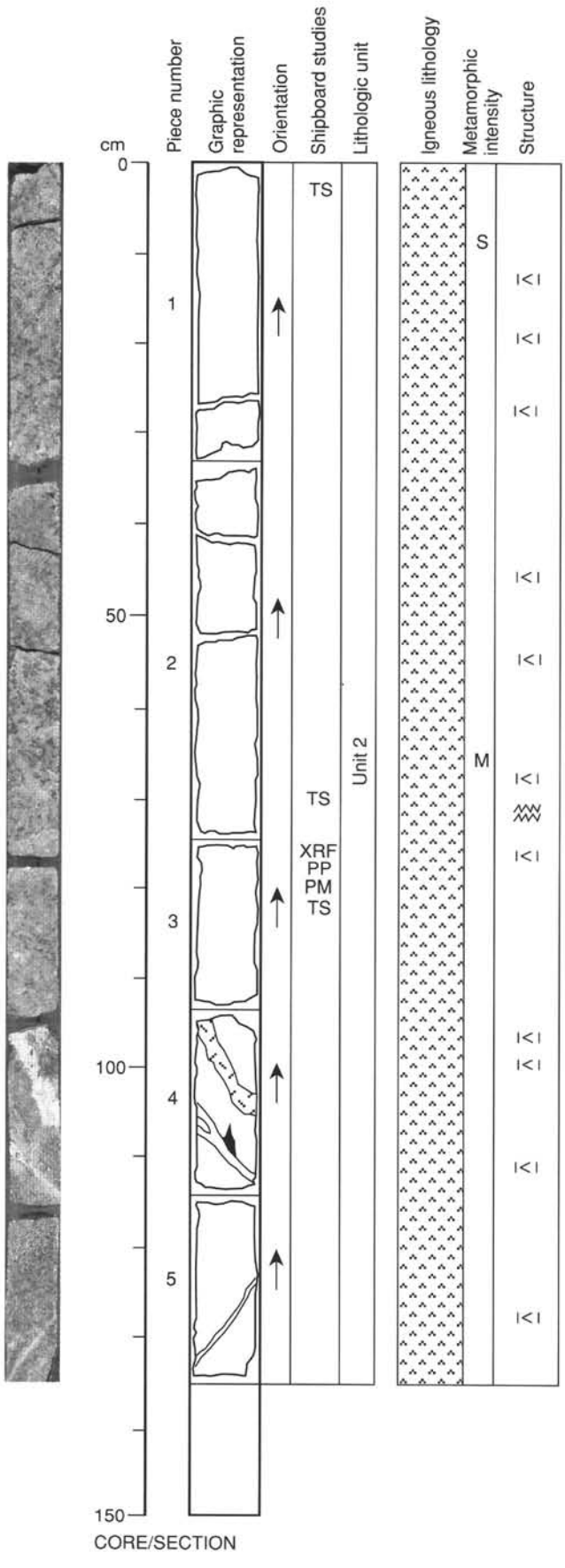
Size: 5

Comments: Occurs in Piece 9C.

ADDITIONAL COMMENTS: Structure

No grain shape preferred orientation has been observed. There are variations in grain size within Pieces 1 to 3, but these do not define any measurable layering. In Pieces 6 to 8, the gabbro is intruded by leucocratic magmatic veins. These veins are 1 to 2 cm thick and their dip is around 45°. In Piece 6, the veins have well-defined (sharp) contact relationships with the country rock, whereas in Piece 8, they have more irregular margins which mimic the grain boundaries in their coarse-grained host. A few mm-sized chlorite veins crosscut this section, in Pieces 5, 6, 8, and 9. Their dips range from subhorizontal to 70°.

153-921E-7R-2



UNIT 2: OLIVINE GABBRO, OXIDE GABBRO, TROCTOLITE, AND OIKOCRYSTIC GABBRO

Pieces 1–5

COLOR: Gray.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 53%–56%.
Crystal Size: 3–15 mm.
Crystal Shape: Subhedral.
Clinopyroxene - Mode: 24%–39%.
Crystal Size: 2–20 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 8%–20%.
Crystal Size: 3%–15 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: 0%–50%.
Crystal Shape: Anhedral.
Sulfide minerals - Mode: 0%–1%.
Crystal Shape: Anhedral.
Comments: The section consists of heterogeneous olivine gabbro which comprises olivine gabbro, oxide gabbro, oikocrystic olivine gabbro and troctolite with veins of trondhjemite and diorite. Pieces 1–3 consist of coarse-grained olivine gabbro with pyroxene grain sizes between 5–20 mm. Average modal olivine for these pieces is 8%–16%, but varies considerably due to the presence of very coarse, cumulus to oikocrystic apple green clinopyroxene that commonly has brown rims. Piece 4 is distinctive, consisting of 5 cm of oxide gabbro (50% oxide minerals, 25% plagioclase, 25% pyroxene, accessory sulfide minerals) and 10 cm of oikocrystic olivine gabbro with large clinopyroxene oikocrysts (10 mm) enclosing plagioclase. The clinopyroxene has dark green cores and is rimmed by brown clinopyroxene. This piece is cut by two veins that appear to have a connecting channel (partly hidden within the interior of the piece). The upper vein is trondhjemitic, composed of altered plagioclase (≈88 %), quartz (3%) and amphibole (now altered to chlorite and talc). The lower vein is silicic (diorite?) and contains altered plagioclase and bladed to prismatic, euhedral, brown amphibole that appears magmatic in origin, and elongated crystals of amphibole. Quartz was not identified in this vein. The association of high concentrations of oxide minerals and trondhjemites is repeated at several places higher in the hole. Piece 5 consists of oikocrystic olivine gabbro with large pyroxene oikocryts (10 mm) enclosing plagioclase. Zones in which oikocrysts are absent are troctolitic.
SECONDARY MINERALOGY:
Iron oxide minerals.
Mode of Occurrence: Replacing olivine.
Talc.
Mode of Occurrence: Replacing olivine.
Chlorite.
Mode of Occurrence: Replacing olivine, plagioclase, clinopyroxene.
Smectite.
Mode of Occurrence: Replacing olivine.
Pyrite.
Mode of Occurrence: Replacing olivine.
Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Comments: Alteration of the olivine gabbro is slight to moderate (5%–15%) with the most intense alteration associated with alteration halos rimming trondhjemitic to dioritic veins. In Piece 4 alteration is as high as 50%. Olivine alteration is generally slight to locally high. Secondary minerals after olivine include iron oxide minerals, talc and, in more pervasively altered grains, dark green rims of smectite ± chlorite and sulfide minerals. Clinopyroxene is slightly altered, locally replaced by brown patches and rims in the freshest pieces (Piece 2B). Near the veins, clinopyroxene is partially to completely replaced by fibrous actinolite, chlorite, and iron oxide minerals with a trace of pyrite (Piece 4). Plagioclase is generally fresh in Piece 5A.

153-921E-7R-2

Veins

Fine veinlets of actinolite and chlorite cut Piece 2C and 2B. Microfractures filled with actinolite and chlorite extend from clinopyroxene and radiate across adjacent plagioclase grains. Piece 4 is cut by a 25 mm wide trondhjemitic vein in which the plagioclase is chalk white in color and altered to prehnite and epidote. A light, brown gray mineral (tremolite?) is in the center of the vein. Actinolite and chlorite form fine intergrown patches which are commonly associated with vein margins and replace amphibole or clinopyroxene. A subparallel dioritic vein in Piece 4 contains plagioclase, and radiating sprays of green amphibole, which overgrows the fine-grained chalky plagioclase. Moderately well-developed alteration halos (5–10 mm in width) which rim the vein are composed of variable amounts of actinolite and chlorite after clinopyroxene, secondary plagioclase, and chlorite. At the margins of the vein, iron oxide minerals in the gabbro are enclosed by chlorite and actinolite. Part of the vein includes actinolite replaced by chlorite-filled microveinlets in plagioclase. Piece 5A is cut by a 5 mm wide vein composed of plagioclase ± quartz(?) with chlorite, actinolite, epidote, and orange-colored clay minerals. There is an associated narrow alteration halo in which clinopyroxene is altered to chlorite and actinolite, and plagioclase is replaced by secondary plagioclase and minor actinolite.

VEIN/FRACTURE FILLING:

Trondhjemitic and dioritic magmatic veins.

Size: Up to 20 mm.

Actinolite and chlorite microveinlets.

Comments: Cutting plagioclase.

Chlorite and zeolites.

Size: <1 mm.

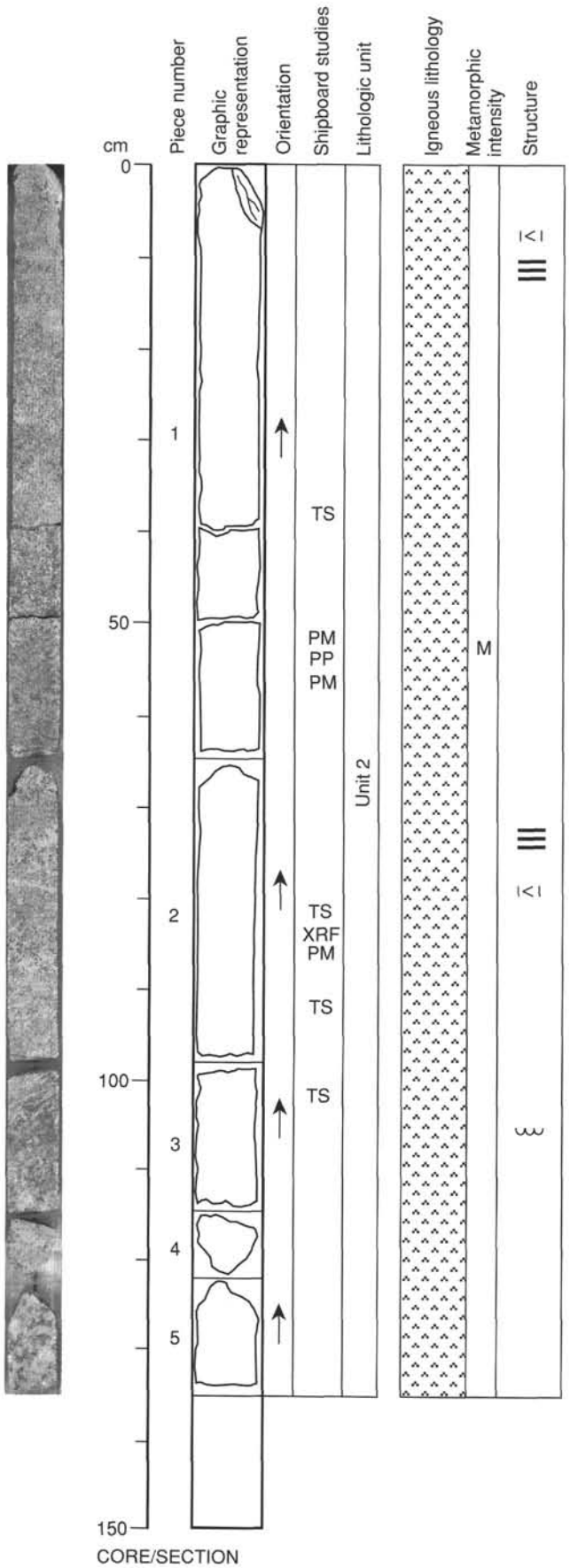
Actinolite and chlorite.

Size: <1 mm.

ADDITIONAL COMMENTS: Structure

Pieces 1 to 3 of this section are devoid of grain shape preferred orientation (similar to Piece 9 of Section 1 of this core). In Pieces 4 and 5, the gabbro is medium grained and a clear mineral shape fabric is observed due to alignment of elongate clinopyroxene. In Piece 5, the planar fabric is moderately dipping (30°) and parallel to compositional layering defined by variations in modal olivine and pyroxene content. A brittle-ductile shear zone cuts the coarse-grained gabbro at the very bottom of Piece 2. It is 1 cm thick and shallowly dipping (about 15°). The top boundary is sharp and defined by a brittle fault plane. Within the shear zone plagioclase is dynamically recrystallized and pyroxene shows both cataclastic deformation and recrystallized tails. Leucocratic magmatic veins are abundant in Piece 4 and present in Piece 5. They either occur as narrow (<1 cm) dikelets displaying sharp contacts with the country rock (Pieces 4 and 5), or, as thicker (a few cm), anastomosing veins having more irregular margins which locally mimic the grain boundaries in their coarse-grained host (Piece 4) . A few mm-sized chlorite veins cut Pieces 1 to 4. Their dips range from subvertical to subhorizontal.

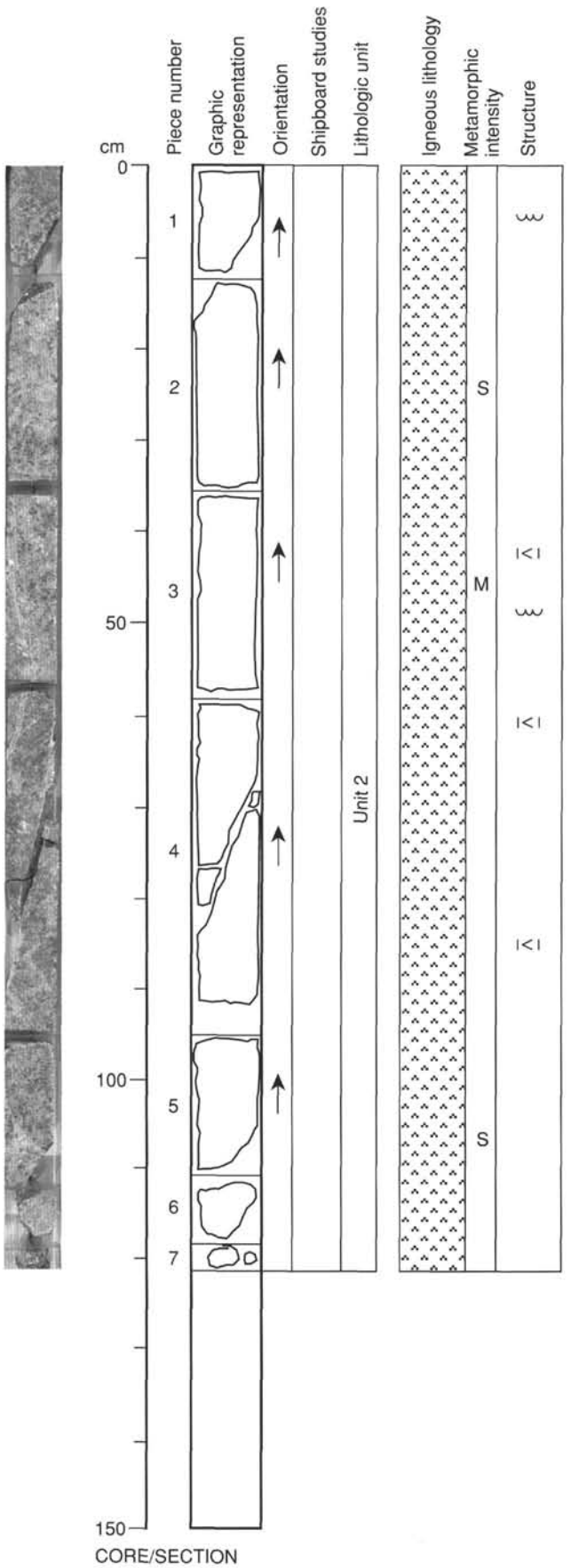
153-921E-7R-3



UNIT 2: OIKOCRYSTIC OLIVINE GABBRO

Pieces 1–5

COLOR: Green brown to black.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 65%–70%.
Crystal Size: 1–10 mm.
Crystal Shape: Subhedral.
Clinopyroxene - Mode: 15%–20%.
Crystal Size: 1–30 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 15%–20%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: <1%.
Sulfide minerals - Mode: <<1%.
Comments: This section predominantly consists of oikocrystic olivine gabbro. The rocks are medium grained, with two generations of clinopyroxene distinguished by their brown and green colors. The oikocrysts are green, range from 10–30 mm in size, and enclose euhedral to subhedral plagioclase laths. The gabbro shows compositional and grain size layering on the scale of 2–5 cm caused by the nonuniform distribution of cumulus phases and oikocrysts. Troctolite "layers" are thus areas in which oikocrysts are not present. Intergranular olivine and clinopyroxene are typically anhedral. Sulfide minerals are rare. Piece 2 contains a 1–2 mm wide magmatic vein composed of plagioclase, minor amphibole and iron oxide minerals.
SECONDARY MINERALOGY:
Iron oxide minerals.
Mode of Occurrence: Replacing olivine.
Smectite.
Mode of Occurrence: Replacing olivine.
Talc.
Mode of Occurrence: Replacing olivine.
Chlorite.
Mode of Occurrence: Replacing olivine and plagioclase.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene.
Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Clay minerals.
Mode of Occurrence: Replacing plagioclase.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Comments: Alteration of this section is generally slight to moderate (<10% to 15%), Pieces 4 and 5 exhibit higher degrees of alteration. Secondary minerals after olivine include talc, iron oxide minerals, brown smectite, and chlorite. Clinopyroxene is negligibly to moderately altered to trace blebs of brown amphibole, actinolite, and chlorite. These two pieces contain very light green clinopyroxene. Locally, plagioclase is stained brown by hydroxide minerals. Plagioclase generally is negligibly to slightly altered. Plagioclase in Piece 4 is oxidized and yellow in color.
Vein
Fine fractures in Piece 2 result in a 1 mm wide band of alteration in which the matrix plagioclase is whiter than the surrounding matrix plagioclase.
VEIN/FRACTURE FILLING:
ADDITIONAL COMMENTS: Structure
This section has a variably developed grain shape preferred orientation. In Pieces 1 and 2, it is defined by olivine and is weakly developed. The lower part of Piece 3 shows a weak mineral lineation defined by long axes of olivine and pyroxene grains. The fabric is generally too weak to orient but, in Pieces 1 and 2, it dips about 30° toward 180° (core coordinates). Pieces 4 and 5 show no mineral shape fabric. The igneous layering is irregular, poorly defined and was not measured. A shallowly-dipping textural variation is in Piece 3 with medium-grained olivine gabbro above poikilitic olivine gabbro. Piece 1 also contains two chlorite veins: one dips steeply (70°) and the other is shallowly (15°) dipping. Piece 2 contains a white magmatic vein of plagioclase that is 2 mm thick, dips 20° and has diffuse boundaries.



153-921E-7R-4

UNIT 2: OLIVINE GABBRO AND TROCTOLITE

Pieces 1–7

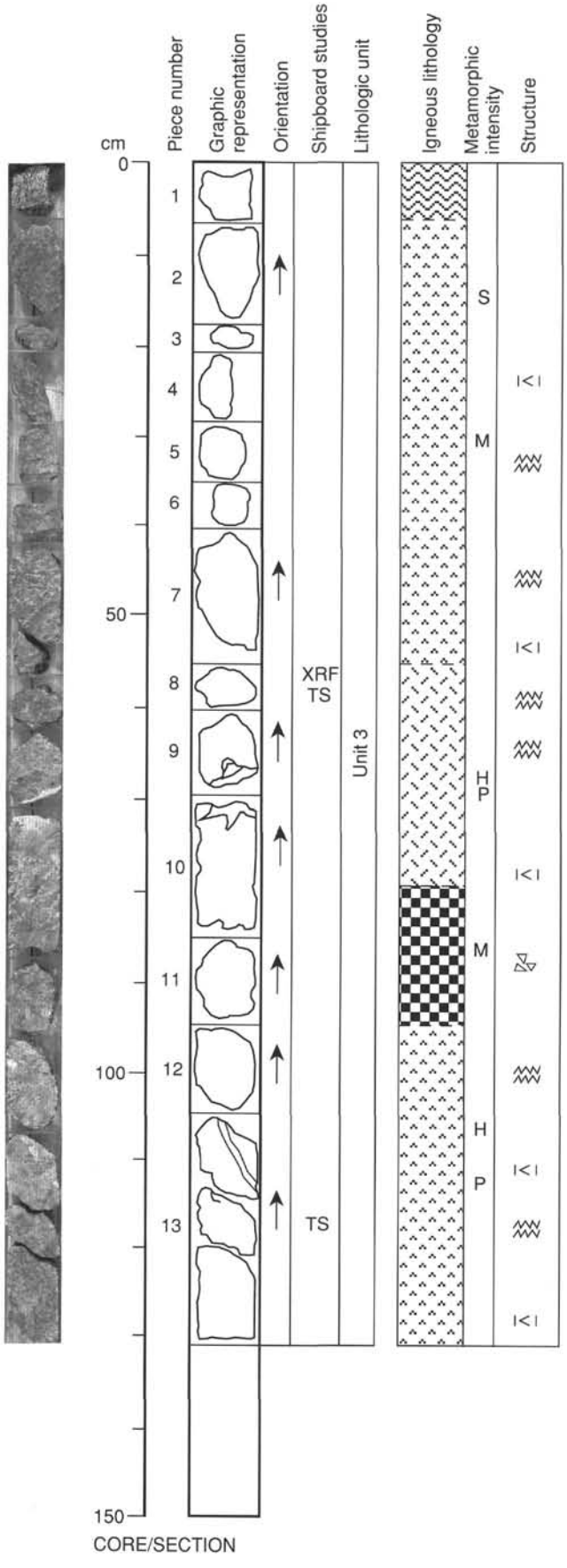
COLOR: White, gray, and green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%–70%.
Crystal Size: 1–13 mm.
Crystal Shape: Subhedral.
Crystal orientation: No preferred orientation.
Clinopyroxene - Mode: 2%–25%.
Crystal Size: 1–25 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Olivine - Mode: 15%–28%.
Crystal Size: 1–14 mm.
Crystal Shape: Anhedral.
Crystal orientation: No preferred orientation.
Sulfide minerals - Mode: Trace%.
Crystal Size: <<1 mm.
Crystal Shape: Anhedral.
Comments: The section consists of interlayered coarse-grained, olivine gabbro and medium-grained troctolite. Pieces 1, 2, 5, 6, and 7 are relatively homogeneous coarse-grained olivine gabbros that are similar in both grain size and mode. Cores of clinopyroxene crystals are emerald green in color; some are rimmed by brown clinopyroxene, but many in this section show minimal overgrowths. Olivine and clinopyroxene poikilitically to subophitically enclose subhedral plagioclase. Pieces 3, 5, and 6 contain rare large (2–3 cm) clinopyroxene crystals that are subophitic to poikilitic. Plagioclase is partially recrystallized throughout the section. Pieces 3 and 4 show modal and grain-size layering. The top 10.5 cm of Piece 3 is coarse-grained olivine gabbro (65% plagioclase, 19% olivine, 16% clinopyroxene) that is followed by 9 cm of troctolite (70% plagioclase, 28% olivine and 2% clinopyroxene). The boundary between the two is gradational and dips about 35°. The layering continues into Piece 4 with 8 cm of troctolite similar to that in the base of Piece 3 followed by 2 cm of olivine gabbro. Below this is a 9 cm interval of intermixed troctolite and olivine gabbro and the basal 7 cm of the piece is coarse-grained olivine gabbro.
SECONDARY MINERALOGY:
Iron oxide minerals.
Mode of Occurrence: Replacing olivine.
Smectite.
Mode of Occurrence: Replacing olivine.
Talc.
Total Percent: Trace.
Mode of Occurrence: Replacing olivine.
Chlorite.
Mode of Occurrence: Replacing olivine, plagioclase, clinopyroxene
Actinolite.
Mode of Occurrence: Replacing clinopyroxene and plagioclase.
Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Comments: Alteration of this section is generally slight to moderate (<10%–30%). Olivine is moderately to highly altered. Secondary minerals after olivine include iron oxide minerals and talc (Piece 4). Clinopyroxene is negligibly to moderately altered to trace blebs of brown amphibole. Alteration is most intense adjacent to veins, where clinopyroxene is replaced by actinolite and chlorite. Plagioclase is negligibly altered, and alteration is associated with veinlets. In Pieces 3 and 4, at the margins of the veinlets, plagioclase is chalk white and is altered to chlorite. The bottom of Piece 1 and top of Piece 2 have complementary sloping surfaces that have zones of iron staining and oxidation (≈1 cm wide), suggesting the two pieces may have been abutted along a fracture.
Veins
Pieces 3 and 4 are cut by thin, <1 mm wide, actinolite and chlorite veinlets which exhibit alteration halos 3 mm wide away from the veinlets.
VEIN/FRACTURE FILLING:
Actinolite and chlorite
Size: <<1 mm.

153-921E-7R-4

Comments: Occurs in Pieces 3 and 4 and has a ~3 mm alteration halo of chalk white plagioclase + actinolite(?) + chlorite after clinopyroxene.

ADDITIONAL COMMENTS: Structure

Rocks in this section shows no mineral fabrics except the troctolite in the lower portion of Piece 3 which contains a weak shape preferred orientation defined by long axes of olivine grains. The olivine in the troctolite is anhedral and occupies interstices between euhedral to subhedral plagioclase laths. Microscopic examination suggests the fabric is controlled by cumulus plagioclase laths with a preferred orientation. Olivine shows no obvious internal deformation. A steep (77°–85°) strand (1–3 closely spaced veins) of chlorite veins is found throughout the entire length (≈20 cm) of Piece 3 and appears to continue into Piece 4.



153-921E-8R-1

UNIT 3: OLIVINE GABBRO AND FOLIATED GABBRO WITH QUARTZ DIORITE

Pieces 1–13

COLOR: White, gray, and green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE: Veins and melt channels.
PRIMARY MINERALOGY:
Plagioclase - Mode: 39%–60%.
Crystal Size: 0.5–7 mm.
Crystal Shape: Sub-Anhedral.
Clinopyroxene - Mode: 22%–55%.
Crystal Size: 1–30 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 5%–25%.
Crystal Size: 1–5 mm.
Crystal Shape: Anhedral.
Iron oxide minerals - Mode: 1%–10%.
Crystal Shape: Anhedral.
Sulfide minerals - Mode: <1%.
Crystal Shape: Anhedral.
Comments: The top piece in this section is quartz diorite containing plagioclase, quartz, biotite, hornblende, actinolite, epidote, iron oxide minerals and possibly apatite. The remaining pieces in the section are modally and texturally heterogeneous gabbroic rocks, some of which have a brecciated appearance of clinopyroxene fragments in a feldspathic matrix. The matrix is fine-grained in Pieces 2–11. Piece 2 is a medium-grained olivine gabbro (25% olivine, 18% clinopyroxene, and 45% plagioclase). Pieces 3 through 7 are medium- to coarse-grained olivine gabbro (8%–15% olivine, 28%–45% clinopyroxene, 40%–57% plagioclase) that show a preferred orientation of clinopyroxene crystal shapes. Pieces 8–11 are strongly deformed gabbro (45%–55% clinopyroxene, 39%–55% plagioclase) and oxide gabbro (35%–42% clinopyroxene, 55%–58% recrystallized plagioclase, and 5%–10% iron oxide minerals). Piece 10 grades from gabbro into oxide gabbro near its base and Piece 11 is composed solely of oxide gabbro. Piece 12 is undeformed olivine gabbro (5% olivine, 42% clinopyroxene, and 53% plagioclase), and Piece 13 grades from olivine gabbro at the top to clinopyroxene-bearing troctolite toward the bottom. Poikilitic, emerald green clinopyroxene (up to 50 mm) encloses plagioclase in Pieces 2, 12, and 13. Elsewhere, green clinopyroxene cores are rimmed by brown clinopyroxene. The principal cumulus phases are olivine, plagioclase and clinopyroxene (Pieces 2–6), plagioclase and clinopyroxene (Pieces 7, 8, 9, and 10), plagioclase, clinopyroxene and iron oxide minerals (Pieces 10 and 11), plagioclase, olivine and clinopyroxene (Pieces 12 and 13), and plagioclase and olivine (the lower portion of Piece 13). Felsic dikelets occur in Pieces 9, 10, 12, and 13.
SECONDARY MINERALOGY:
Iron oxide minerals.
Mode of Occurrence: Replacing olivine and clinopyroxene.
Smectite.
Mode of Occurrence: Replacing olivine.
Chlorite.
Mode of Occurrence: Replacing olivine.
Comments: Also replacing clinopyroxene, plagioclase and iron oxide minerals.
Brown amphibole.
Mode of Occurrence: Replacing clinopyroxene.
Actinolite.
Mode of Occurrence: Replacing clinopyroxene.
Clay minerals.
Mode of Occurrence: Replacing olivine.
Talc.
Total Percent: Trace.
Mode of Occurrence: Replacing olivine.
Secondary plagioclase.
Mode of Occurrence: Replacing plagioclase.
Epidote.
Mode of Occurrence: Replacing plagioclase.
Comments: Alteration is heterogeneous throughout the section and is most intense around felsic veins and thin actinolite-chlorite veinlets. Away from the veins, background alteration of the gabbroic rocks is slight to moderate (5%–30%),

153-921E-8R-1

and near veins it is high to pervasive (60%–85%). In less altered areas, olivine is totally altered to iron oxide minerals, clay minerals and/or a trace amount of talc. Clinopyroxene is slightly to moderately altered away from veins and pervasively altered near the veins. In Piece 10, near the felsic veins, clinopyroxene alters up to 3 cm away from the vein to a white blue amphibole. Adjacent to thin green veins, clinopyroxene pods exhibit actinolite cores and chlorite rims. Intergrown actinolite and chlorite form well developed alteration rims around clinopyroxene in deformed pieces. Alteration minerals include brown amphibole and iron oxide minerals. Plagioclase is generally chalky white in the deformed gabbro. Pyrite is common throughout the section. The quartz diorite sample (Piece 1) is moderately altered to secondary plagioclase, trace epidote, actinolite, and minor chlorite. Chlorite is common after green amphibole and as rims around oxide minerals and biotite. Iron oxide grains are commonly oxidized. In Piece 12, pervasive alteration affects the clinopyroxene mainly as replacement by actinolite, and oxide minerals near thin oxidized cracks.

Veins

Pieces 1, 2, and 7 are cut by irregular actinolite and chlorite veinlets <1 mm in width). Pieces 9, 10, and 13 are cut by 3–5 mm wide felsic veins composed of plagioclase, quartz, a trace of epidote, actinolite, and chlorite. The veins exhibit alteration halos in the host rock in which plagioclase has been replaced by secondary plagioclase, chlorite, and clinopyroxene is altered to actinolite and chlorite.

VEIN/FRACTURE FILLING:

Actinolite and chlorite veinlets

Size: <1

Comments: Occurs in Pieces 1, 2, and 7.

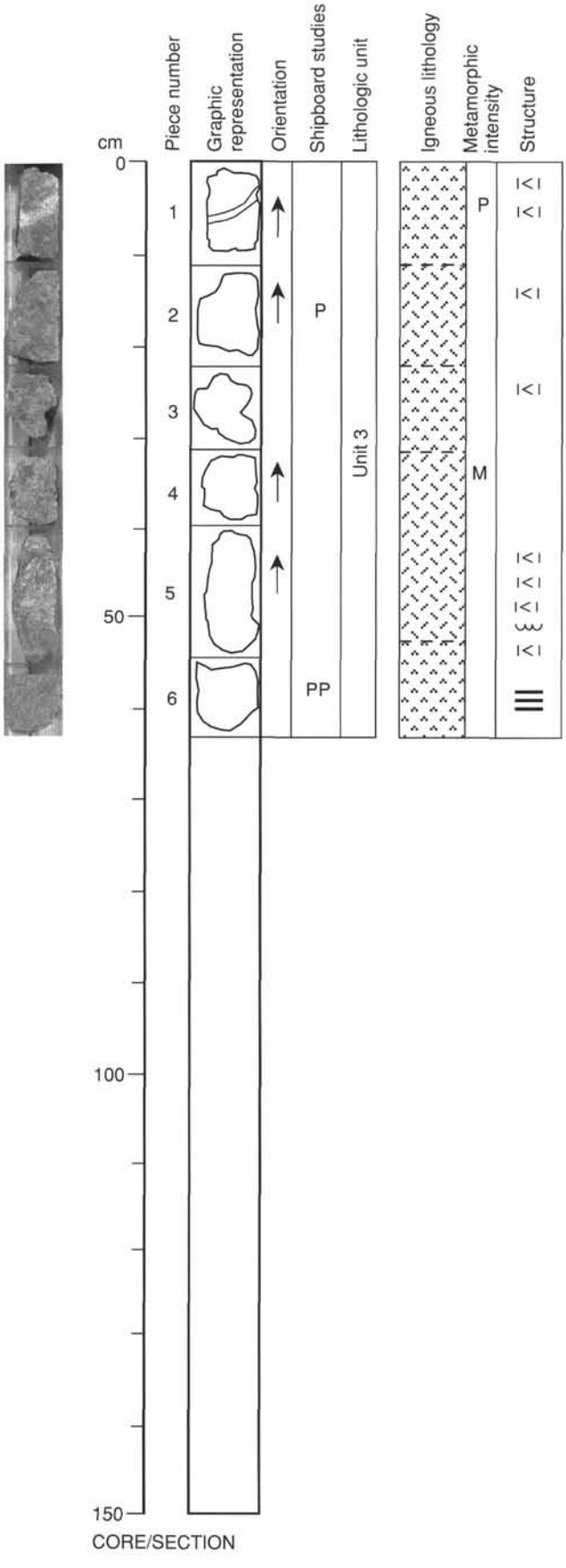
Quartz, plagioclase, actinolite, ± epidote and chlorite.

Size: 3–5

Comments: Occurs in Piece 9, 10, and 13. Has alteration halos.

ADDITIONAL COMMENTS: Structure

The top piece, composed of quartz diorite, and the following two pieces of olivine gabbro have no apparent crystal shape preferred orientation. Piece 4 shows a weakly developed alignment of elongate pyroxene grains. The mineral lineation has a plunge around 45°–50° to the long axis of the saw-cut plane (unoriented sample). This mineral shape fabric is truncated along the edge of the piece by an actinolite and chlorite vein. Pieces 5 through 11 show a characteristic brecciated texture with angular and irregular fragments of mafic minerals (mainly clinopyroxene) embedded in a plagioclase-rich fine-grained matrix. In Pieces 5, 7, 9, and 10, this brecciated texture is accompanied by mm-scale brittle shear zones with mafic minerals aligned subparallel to them. The shear zones dip gently to moderately. Mafic fragments in the brecciated texture range in size from several cm to 1 mm, and locally they display jig-saw puzzle fit along their edges within the plagioclase matrix. Thin (<2 mm), actinolite and chlorite veins occur subparallel and/or oblique to these shear zones (e.g., in Pieces 5, 7, 9, and 10). When they intersect, the veins crosscut the shear zones. Felsic melt channels occur in Pieces 9, 10 and 13 that truncate the actinolite and chlorite veins. Piece 12 contains a steeply dipping vein (70°) that shows brittle shearing and cataclasis within and along its edges. Piece 13 has steeply dipping melt channels and subhorizontal actinolite and chlorite veins. Cracks, related to the actinolite and chlorite veins crosscut the magmatic vein, although the presence of actinolite and chlorite is not observed in the vein. This could lead to the misleading interpretation that the magmatic vein crosscuts the hydrothermal veins.



153-921E-8R-2

UNIT 3: OLIVINE GABBRO - GABBRO

Pieces 1–6

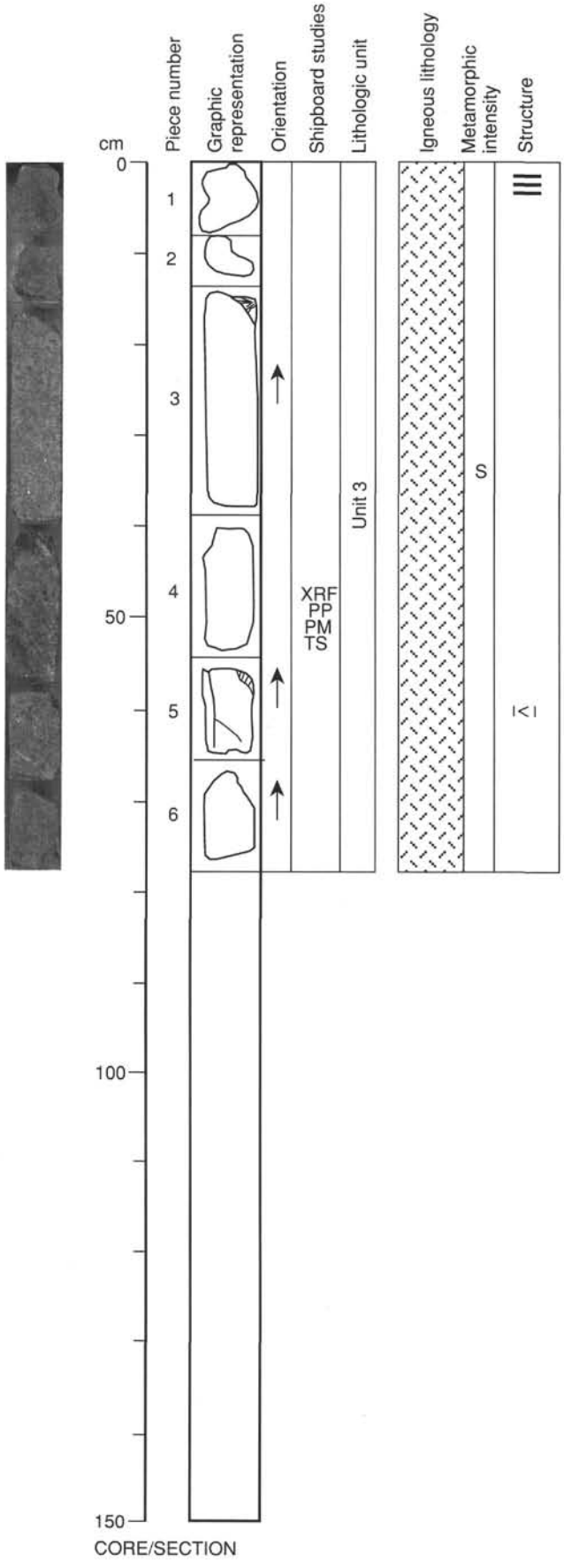
COLOR: Gray/green.
PRIMARY STRUCTURE:
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 60%–63%.
Crystal Size: 2–15 mm.
Crystal Shape: Subhedral/anhedral.
Clinopyroxene - Mode: 14%–36%.
Crystal Size: 1–20 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 1%–25%.
Crystal Size: 1–8 mm.
Crystal Shape: Anhedral.
Opaque oxides - Mode: <1%.
Crystal Size: <2 mm.
Crystal Shape: Anhedral.
Comments: The section consists of modally and texturally heterogeneous olivine gabbro (Pieces 1, 3, and 6) and gabbro (Pieces 2, 4, and 5). Olivine gabbro contains 10%–25% olivine, 14%–20% clinopyroxene, and 60% plagioclase. The gabbro has similar abundances of plagioclase to the olivine gabbro, but clinopyroxene ranges from 30%–36% and olivine from 1%–4% of the mode. Pieces 1–4 are coarse grained and equigranular. Clinopyroxene is dark green in color and rimmed by brown clinopyroxene. Both clinopyroxene and olivine are interstitial phases. Piece 4 shows localized recrystallization of plagioclase. Piece 5 is a poikilitic gabbro in which the original shape of oikocrysts of clinopyroxene is preserved, but in which plagioclase is dynamically recrystallized. Larger clinopyroxene crystals are straw brown and show some subgrain development. Piece 6 is fine grained and has a porphyroclastic texture in which strongly recrystallized plagioclase (grain sizes <0.1 mm) and clinopyroxene (<0.5 mm) form a matrix for rare straw brown clinopyroxene porphyroclasts (up to 3 mm). Olivine typically occurs as elongate stringers associated with the edges of clinopyroxene porphyroclasts. Iron oxide minerals are present as an accessory phase throughout the section. Piece 1 contains a ≈1 cm wide vein of plagioclase (trondhjemite?).
SECONDARY MINERALOGY:
Actinolite.
Total Percent: <5
Comments: After olivine.
Chlorite.
Total Percent: <5
Comments: After clinopyroxene/olivine.
Pyrite.
Total Percent: <1
Comments: With chlorite after olivine.
Comments: Alteration is high in and around the felsic vein in Piece 1. Above the felsic vein, plagioclase is recrystallized and mafic minerals are altered to actinolite and chlorite or green clay minerals. A set of anastomosing veinlets filled with chlorite or green smectite occurs parallel to the vein. At the bottom of the piece, alteration extends up to 1.5 cm from the vein, with partial replacement of the clinopyroxene by actinolite and chlorite. The plagioclase is stained brown by hydroxide minerals. Away from the vein, background alteration of the gabbroic rocks is slight (5%–15%). Secondary minerals after olivine include iron oxide minerals and smectite. Clinopyroxene is slightly altered and is rimmed by brown amphibole. Plagioclase is fresh. Clinopyroxene Piece 2 and the iron oxide minerals around it are intensely altered, and plagioclase is stained by brown hydroxide minerals.
Veins
The felsic vein includes an intergranular mafic mineral (altered to brown amphibole), actinolite, chlorite, and clay minerals, most abundant at the margins of the vein. Plagioclase is translucent to opaque (chalky white in color). Plagioclase grain boundaries are coated by late pale blue fibrous clay minerals. Pieces 2, 3, and 5 contain <1 mm-sized actinolite and chlorite filled veinlets.
VEIN/FRACTURE FILLING:
Plagioclase (magmatic).
Size: ≈10 mm.
Orientation: ≈50°, patchy distribution.

153-921E-8R-2

ADDITIONAL COMMENTS: Structure

A weak preferred orientation of pyroxene and plagioclase grains is obseved in Piece 6. No brittle shear zones or faults were observed. Piece 1 contains a 10 mm wide vein of felsic composition dipping approximately 30° and a thin (<1 mm), short (12 mm), near vertically orientated, green chlorite-filled vein. Piece 5 contains several green, thin (<1 mm) veins of mostly subhorizontal orientation. One vein is essentially vertical. No clear crosscutting relationship was evident. A sharp, subhorizontal igneous contact separates darker, finer grained oxide(?) gabbro from coarser, relatively plagioclase-rich gabbro in the upper 3/4 of the piece.

153-921E-9R-1



UNIT 3: GABBRO

Pieces 1–6

COLOR: Green/gray/white.
PRIMARY STRUCTURE: Medium-coarse grained.
SECONDARY STRUCTURE:
PRIMARY MINERALOGY:
Plagioclase - Mode: 65%–70%.
Crystal Size: 5–9 mm.
Crystal Shape: Anhedral.
Clinopyroxene - Mode: 27%–34%.
Crystal Size: 5–20 mm.
Crystal Shape: Anhedral.
Olivine - Mode: 1%–3%.
Crystal Size: 3–10 mm.
Crystal Shape: Anhedral.
Oxide minerals - Mode: <<1%.
Comments: This section is composed of medium- to coarse-grained gabbro that is compositionally homogeneous, but texturally heterogeneous. Pieces 1, 2, and 6 are medium grained and similar in appearance to each other. Pieces 3–5 are coarse grained, and again similar to each other. Plagioclase is partially recrystallized throughout, particularly in the coarser grained pieces; outlines of subhedral laths are identifiable only in Pieces 1 and 6. The coarser grained pieces also contain slightly less olivine and less fine-grained (1–2 mm) interstitial clinopyroxene. Small patches are present (notably in Pieces 1 and 4) where the finer interstitial clinopyroxene is granular in appearance, suggesting that, like the plagioclase, it has been recrystallized. The clinopyroxene in the coarse-grained gabbros is typically brown in color, whereas it may have green cores and brown rims in the medium-grained gabbros. A small proportion of the pyroxene in Pieces 2, 3, and 6 is dark brown to black; it is unclear whether this phase is brown amphibole after clinopyroxene or orthopyroxene. Piece 5 is crosscut by several 1–2 mm wide plagioclase-rich veinlets or segregations which are intermittantly cored by chlorite. A relatively clinopyroxene-rich area of the piece is bounded by these veinlets and contains dark pink gray plagioclase. It may have undergone localized loss of a felsic melt fraction to the veinlets. Patchy replacement of clinopyroxene by green amphibole occurs on either side of these veinlets.
SECONDARY MINERALOGY:
Sulfide minerals.
Total Percent: <<1
Comments: After olivine/clinopyroxene.
Chlorite.
Total Percent: <<1
Comments: After olivine/clinopyroxene.
Green amphibole.
Total Percent: 1
Comments: After clinopyroxene.
Magnetite.
Total Percent: 2
Comments: After olivine.
Talc.
Comments: After olivine.
Comments: Alteration in this section is slight. Clinopyroxene is altered to actinolite + chlorite along fractures (Pieces 1 and 5). Away from the <1 mm wide veins, clinopyroxene shows minor alteration to brown amphibole, and rarely to actinolite. Olivine is locally replaced by talc and iron oxide minerals. Minor pyrite and chalcopyrite are present along clinopyroxene grain boundaries.
Veins
In Piece 1, a thin fracture is filled with a coating of blue green clay minerals. In Piece 5, a <1 mm wide veinlet contains actinolite ± chlorite ± a white, fibrous clay mineral. The vein filling minerals are not deformed, whereas at the margins of the veinlet plagioclase shows grain-size reduction.
VEIN/FRACTURE FILLING:
ADDITIONAL COMMENTS: Structure
A shape preferred orientation of pyroxene crystals defines a very weak foliation in Piece 1. The foliation is oriented subparallel to the cut face of the piece. On the back of Piece 3 there is a very weak elongation of pyroxene in a steeply dipping (80°–90°) zone about 2 cm wide. The back of Piece 4 also has zones (1–5 cm) where a very weak shape fabric is evident but no reliable measurement could be taken. The only veins in this section are found in Piece 5. Four chlorite, plagioclase, and actinolite(?) veins (1–3 mm), dipping at about 45°–50° intersect a thin (1 mm) subvertical vein.