

## 153-924B-2R-1

## UNIT 1: OLIVINE GABBRO

## Pieces 1A-2

**COLOR:** Brown black.

**PRIMARY STRUCTURE:** Igneous compositional layering.

**PRIMARY MINERALOGY:**

Clinopyroxene - Mode: 0-25%.

Crystal Size: 5-25 mm.

Crystal Shape: Anhedral.

Olivine - Mode: 20%-40%.

Crystal Size: 1-25 mm.

Crystal Shape: Anhedral.

Sulfide minerals - Mode: <1%.

Iron oxide minerals - Mode: <1%.

Plagioclase - Mode: 55%-60%.

Crystal Size: 2-5 mm.

Crystal Shape: Subhedral/Euhedral.

**Comments:** Piece 1 of this section consists of banded troctolite, olivine gabbro and gabbro. Medium-grained gabbro forms the top 1 to 2 cm of the piece.

Troctolite forms a 2 to 3 cm wide band that cuts steeply across the core. The troctolite (60% plagioclase, 40% olivine) appears slightly strained (see Structure); olivine is an intercumulus phase but sporadically exhibits a crescumulate texture. A third, 1 to 2 cm wide band cuts the piece parallel to the troctolite layer, consisting of olivine gabbro that contains green poikilitic clinopyroxene (60% cumulus plagioclase, 20% intercumulus olivine, 20% oikocrystic clinopyroxene). The clinopyroxene oikocrysts have thin, brown rims of clinopyroxene, and enclose subhedral plagioclase, and less abundant olivine. The oikocrysts are up to 2 cm in diameter. This rock type forms the bulk of Piece 2, except for a small section of fine-grained olivine gabbro (60% plagioclase, 25% intercumulus olivine, 15% intercumulus clinopyroxene) in the bottom corner of the piece. Traces of disseminated sulfide minerals occur throughout the rocks. Piece 2 is a small piece of highly altered olivine gabbro.

**SECONDARY MINERALOGY:**

Chlorite:

Total Percent: 5

Mode of Occurrence: See Description.

Comments: Reaction rim between olivine and plagioclase.

Talc + oxide minerals:

Total Percent: 20

Mode of Occurrence: Replacing olivine.

Smectite:

Total Percent: 5

Mode of Occurrence: Replacing plagioclase.

Oxide minerals:

Total Percent: Trace.

**Comments:** The section is composed of two pieces showing compositional heterogeneity and grain-size variability. Piece 1A is moderately altered (30%-40%). Olivine is almost completely replaced by talc and oxide minerals. Plagioclase is chloritized at the contact with olivine, or locally replaced by brown smectite. At the bottom of the piece, clinopyroxene and olivine are rimmed by brown amphibole, and more extensive replacement of plagioclase by smectite is common. Irregular, thin (<<1 mm) clay mineral veins occur at the center of the piece. Disseminated sulfide minerals are present. Piece 1B shows grain-size variability. Olivine is altered to talc and oxide minerals and plagioclase is chloritized at the contact; away from mafic phases, plagioclase is replaced by smectite. Thick clay mineral veining occurs at the top and at the bottom of the piece, with irregular distribution and orientation. Chlorite regularly rims clinopyroxene, where smectite overgrowth is more extensive. Piece 2 is more extensively altered, the clinopyroxene is rimmed by chlorite; oxide mineral patches replace olivine. At an edge of the piece, a coating of clay and oxide minerals occurs on open surface. Plagioclase is chloritized.

Veins: At top and bottom of 1B, clay mineral-filled microcracks.

**VEIN/FRACTURE FILLING:**

Clay and secondary iron staining.

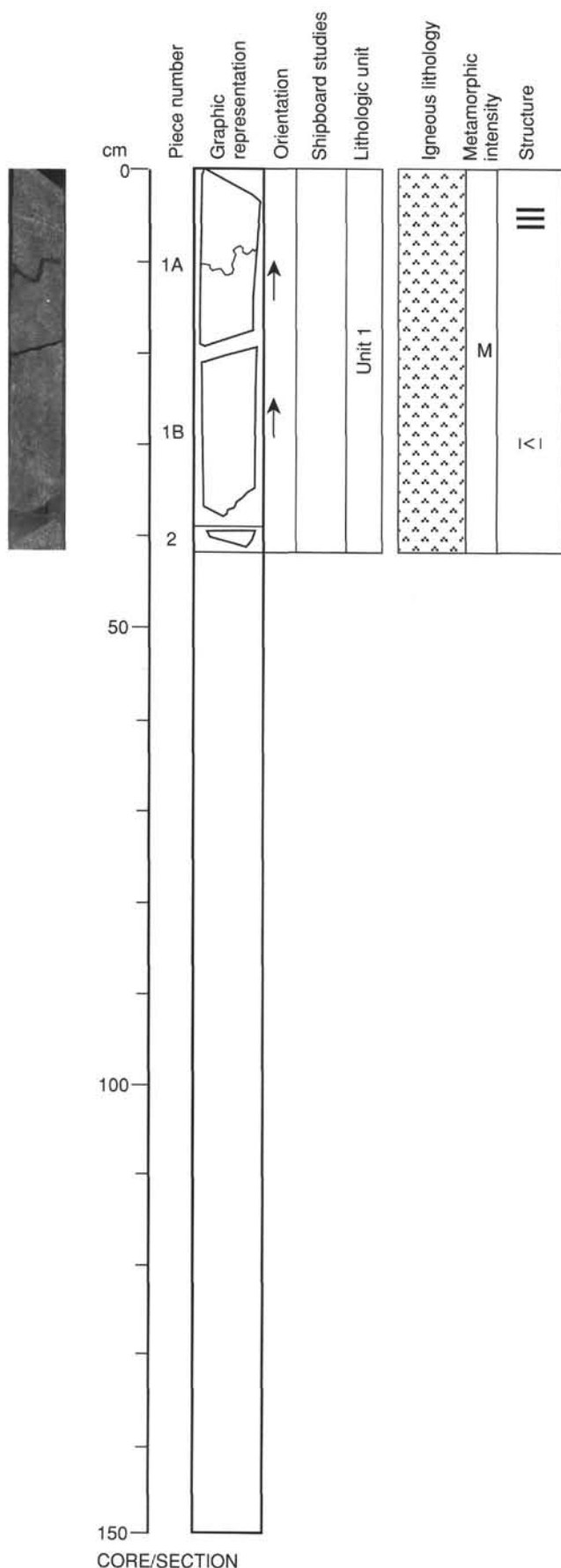
Size: <3 mm.

Orientation: Irregular.

Comments: Open fractures.

**ADDITIONAL COMMENTS:** Layering

A steep dipping, compositional banding consists of 2 to 3 cm wide bands of troctolite



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and texturally variable olivine gabbro.

**Structure:**

Piece 1 is relatively heterogeneous in terms of its structural characteristics. The upper part is olivine-rich gabbro has a well-developed crystal shape preferred orientation likely ascribable to solid-state deformation (flaser texture). The foliation plane is subvertical. The fabric is rather linear with a downdip lineation. The lower part is isotropic. The contact between these two domains is irregular and steep (about 60°). The bottom of Piece 1 and Piece 2 have a moderately developed crystal shape fabric. The contact between the medium- and coarse-grained gabbro is irregular. A few chlorite and actinolite veins crosscut this piece. They are moderately dipping to subvertical. The top of Piece 1 is a vein surface showing a downdip slickenside lineation.

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UNIT 1: OLIVINE GABBRO

Pieces 1–11

**COLOR:** Green-black.  
**PRIMARY STRUCTURE:** Igneous grain-size variation.  
**SECONDARY STRUCTURE:** Crystal-plastic fabric locally developed.

**PRIMARY MINERALOGY:**

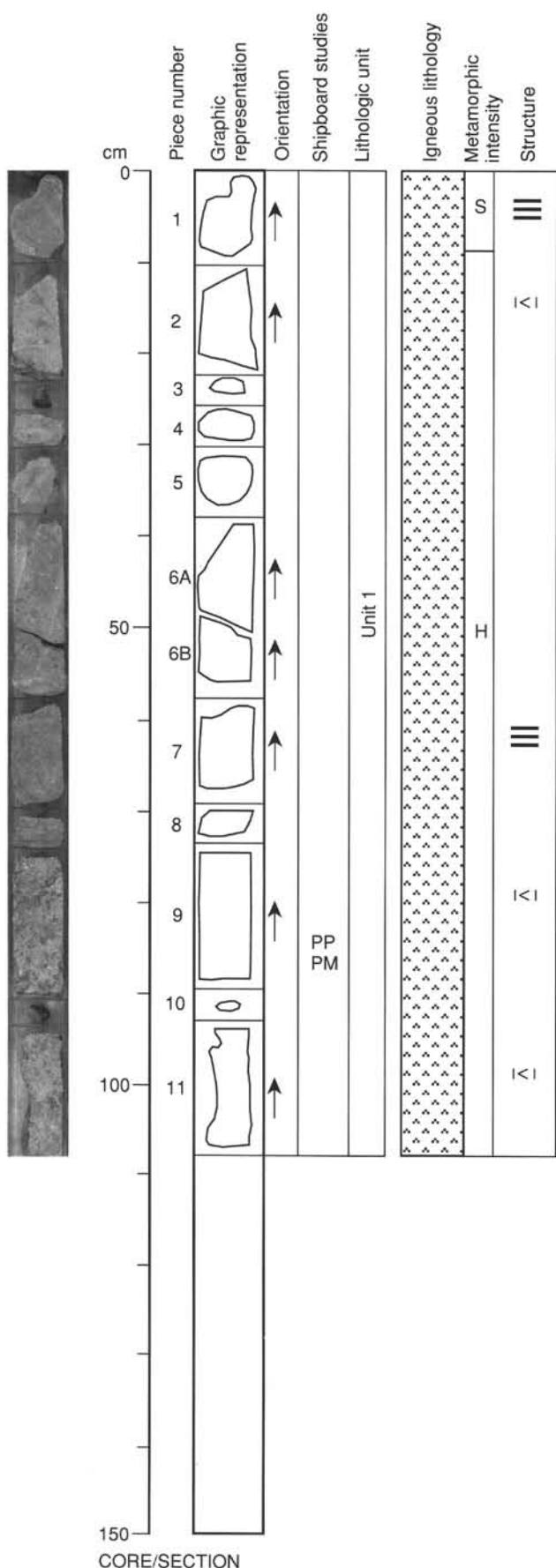
- Olivine - Mode: 15%–20%.  
 Crystal Size: 2–30 mm.  
 Crystal Shape: Anhedral.
- Plagioclase - Mode: 50%–70%.  
 Crystal Size: 2–15 mm.  
 Crystal Shape: Subhedral/anhedral.
- Clinopyroxene - Mode: 15%–30%.  
 Crystal Size: 5–60 mm.  
 Crystal Shape: Anhedral.
- Iron oxide minerals - Mode: <1%.
- Sulfide minerals - Mode: <1%.

Comments: The section consists of medium- to coarse-grained olivine gabbro that is variable in texture and modal proportions of the major phases. The texture varies from coarse-grained, inequigranular to pieces that show a steep-dipping crystal-plastic lineation defined by elongation of clinopyroxene grains (Pieces 1, 6, and 7). The cleavages in some clinopyroxene in the lineated olivine gabbro are bent. Undeformed pieces display a crescumulate to heteradcumulate texture. Olivine has an amoeboid shape and sometimes displays a crescumulate texture (Pieces 2–4 and 8–11). Clinopyroxene poikilolithically to subophitically enclose plagioclase laths, and forms intercumulus crystals up to 30 mm in size.

**SECONDARY MINERALOGY:**

- Chlorite:  
 Total Percent: 10–20  
 Mode of Occurrence: See Description.  
 Comments: Rims and replaces olivine and plagioclase.
- Hydroxide minerals:  
 Total Percent: <1  
 Mode of Occurrence: See Description.  
 Comments: From alteration of sulfide minerals; induces staining.
- Brown amphibole:  
 Total Percent: 5–10  
 Mode of Occurrence: Rims clinopyroxene (Piece 6A)
- Talc + oxide minerals:  
 Total Percent: 40–80  
 Mode of Occurrence: Replacing olivine.

Comments: The section shows variable degrees of alteration, ranging from 5% (Piece 1) to 50%–70% (rest of the section). Piece 1 is a foliated, fine-grained olivine gabbro. The plagioclase is yellow and green and replaced by smectite and chlorite. Vein density is high. The formation of hydroxide minerals induces iron staining. Pieces 2, 4, and 5 is a medium- to coarse-grained gabbro; chlorite and actinolite coronas develop around clinopyroxene and plagioclase. Disseminated sulfide and patches of primary(?) oxide minerals are altered to hydroxide minerals. Microcracks in the clinopyroxene are filled by chlorite and clay minerals. Piece 3 is composed of altered fragments. Piece 5 also has chlorite and actinolite coronas on olivine, which is 70% altered. Pieces 6–11 are 50%–60% altered. In Piece 6A, plagioclase is replaced by smectite and chlorite diffusing along microcracks; disseminated sulfide minerals occur. Minor brown amphibole rims clinopyroxene. At the bottom of the piece, coarse-grained olivine is altered to talc and oxide minerals. Piece 6B is a foliated, fine-grained gabbro; disseminated sulfide minerals occur within mafic phases. Clinopyroxene grains are arranged in elongated trails. Plagioclase is chloritized. Sulfide minerals are strung out along plagioclase boundaries. Smectite replaces plagioclase. Chlorite patches develop on clinopyroxene in the coarser grained intervals. Piece 7 is a foliated olivine gabbro, same as Piece 6, but exhibits more smectite replacing plagioclase, and local total replacement. Piece 8 is foliated olivine gabbro; sulfide minerals are disseminated in plagioclase. Piece 9 is a lineated, very coarse-grained olivine gabbro. Clay mineral veins and clay mineral-filled microcracks cut the plagioclase. Sulfide minerals are dispersed in plagioclase; clinopyroxene is overgrown by actinolite, plagioclase is replaced by chlorite, and olivine is altered to talc and oxide minerals. Piece 10 is composed of altered fragments, where plagioclase is replaced by chlorite and smectite. Sulfide minerals are altered; brown amphibole,



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chlorite, and actinolite rim and replace the clinopyroxene. Olivine is altered to talc and oxide minerals.

## Veins:

In Piece 1 is a 1 mm actinolite vein. The bottom of Piece 6A contains an actinolite vein, and irregular clay and oxide mineral veins. Piece 6B contains clay mineral-filled veins, microcracks filled with chlorite and irregular, diffuse, chlorite-filled veins. Along an edge of Piece 8, there are talc and oxide mineral veins. In Piece 10, diffuse clay veining cuts plagioclase, and actinolite-bearing microcracks are in clinopyroxene.

**VEIN/FRACTURE FILLING:**

## Clay:

Size: <<1 mm.

## Actinolite.

Size: <1 mm.

## Chlorite + clay.

Comments: Filling microcracks in clinopyroxene in Piece 2.

**ADDITIONAL COMMENTS:** Layering

None evident except for variability of texture from piece to piece.

## Structure:

Coarse-grained gabbro (Pieces 2–6 and 8–11) is devoid of any crystal shape preferred orientation. A faint textural variation in Piece 6 makes it possible to define a primary igneous layering dipping 25°. Medium-grained gabbro (Pieces 1 and 7), presents a well-developed crystal shape fabric defined by the elongation of plagioclase and pyroxene. The foliation plane is strongly dipping (about 70°). Very few mm-sized chlorite and actinolite veins crosscut this section (Pieces 2 and 9 and on the back side of Piece 1).

## 153-924B-4W-1

## UNIT 1: OLIVINE GABBRO AND GABBRO

## Pieces 1-5B

**COLOR:** Green-black.**PRIMARY MINERALOGY:**

Plagioclase - Mode: 52%-55%.

Crystal Size: 2-10 mm.

Crystal Shape: Anhedral/subhedral.

Clinopyroxene - Mode: 28%-37%.

Crystal Size: 2-30 mm.

Crystal Shape: Anhedral.

Olivine - Mode: 3%-20%.

Crystal Size: 5-25 mm.

Crystal Shape: Anhedral.

Orthopyroxene - Mode: 0-3%.

Crystal Size: 2-7 mm.

Crystal Shape: Anhedral.

Iron oxide minerals - Mode: &lt;1%.

Crystal Size: &lt;1 mm.

Crystal Shape: Anhedral.

Sulfide minerals - Mode: &lt;1%.

Crystal Size: &lt;1 mm.

Crystal Shape: Anhedral.

Comments: This section consists of highly altered (60%-80%) olivine gabbro and gabbro. Olivine gabbro (Pieces 1-4) shows a very similar style of alteration to that seen in Holes 922A and 922B. Olivine is abundant (~20%) and shows crescumulate texture with plagioclase in olivine gabbro, where the texture is also characterized by the presence of 1-2 cm green poikilitic clinopyroxene grains. Piece 5 is strongly deformed gabbro (3% olivine, 37% clinopyroxene, 55% plagioclase, ?3% orthopyroxene) in which a fabric is defined in the core dipping ~45°. The sheared zone contains both brown and green clinopyroxene, and secondary brown amphibole. A 1.5 cm wide olivine gabbro layer, 9 cm from the top of Piece 5, is subparallel to the shear fabric. Olivine in this piece is relatively fresh when compared with that elsewhere in this section.

**SECONDARY MINERALOGY:**

Actinolite:

Total Percent: 10

Mode of Occurrence: Replacing clinopyroxene.

Brown amphibole:

Total Percent: 3

Mode of Occurrence:

Comments: Rims fresh clinopyroxene and actinolite overgrowth on clinopyroxene.

Chlorite:

Total Percent: 10

Mode of Occurrence: Rims olivine + plagioclase.

Clay:

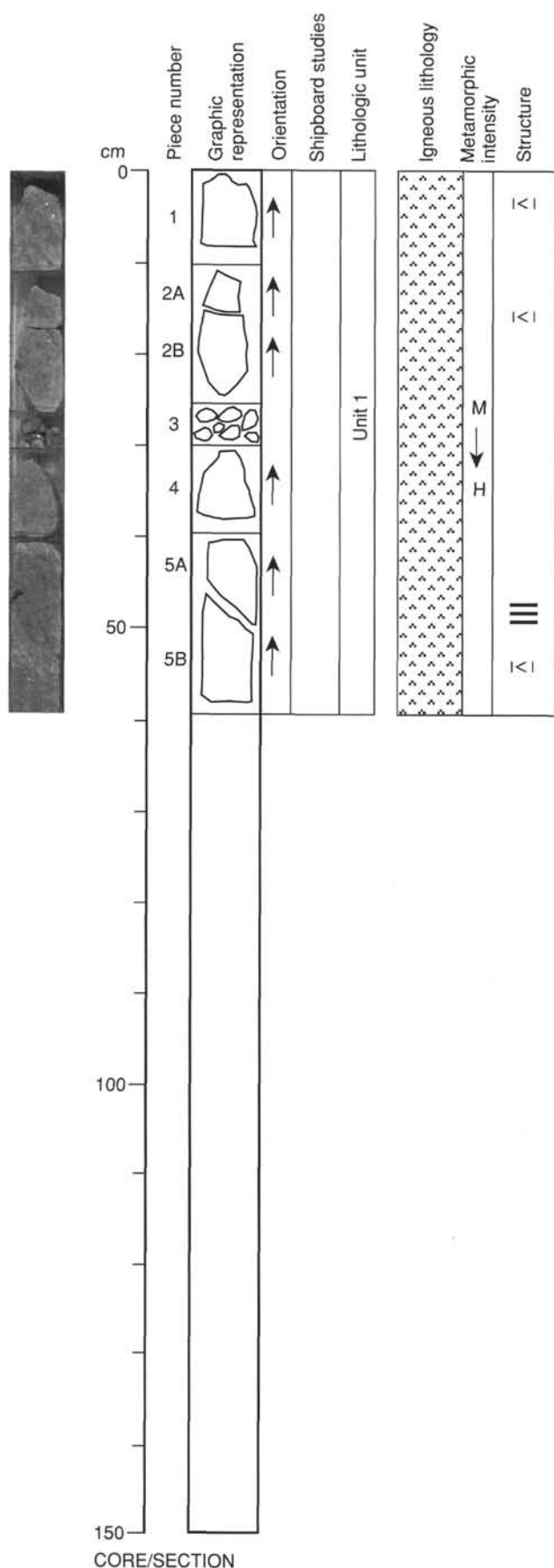
Total Percent: 5

Mode of Occurrence: Replaces plagioclase.

Comments: The total alteration of the section ranges between 50%-55%. Piece 1 is a coarse-grained isotropic olivine gabbro. Clinopyroxene is replaced by pale green actinolite, and is locally rimmed by chlorite. Clinopyroxene is replaced by actinolite and rimmed by brown amphibole. Plagioclase is replaced by chlorite. Smectite filled microcracks crosscut clinopyroxene and plagioclase. Piece 2A is a medium-grained isotropic olivine gabbro. Plagioclase is replaced by clay minerals and chlorite; fibrous actinolite has replaced clinopyroxene. Brown amphibole rims actinolite after clinopyroxene. Piece 3 is rubble. Piece 4 shows coronitic structures of chlorite and actinolite around olivine and plagioclase. Plagioclase is altered to clay in a 1 cm band in the center of the piece, and exhibits a dense, irregular network of microfractures filled with actinolite. In Piece 5A the alteration is moderate (25%-30%); the piece is a foliated coarse-grained metagabbro. Chlorite and actinolite have replaced clinopyroxene. Brown amphibole and actinolite are present in clinopyroxene tails. Plagioclase is altered to clay minerals. Piece 5B is a coarse (8 cm) to medium- (4 cm) grained foliated gabbro. In the coarse-grained interval, olivine shows well-preserved coronitic textures on a cm scale. Olivine cores are rimmed concentrically by tremolite, talc, and chlorite at contacts with plagioclase. In the foliated medium-grained interval, clinopyroxene porphyroclasts are rimmed by actinolite.

Veins:

In Piece 1 smectite filled microcracks crosscut clinopyroxene and plagioclase. Clay



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mineral-filled microveins are in Pieces 2A and 2B. An irregular actinolite filled network cuts the plagioclase in Piece 4. In Piece 5A are clay mineral-filled microfractures.

**VEIN/FRACTURE FILLING:**

Chlorite + clay minerals:

Size: 2–3 mm.

Orientation: In Piece 5: subhorizontal.

Actinolite:

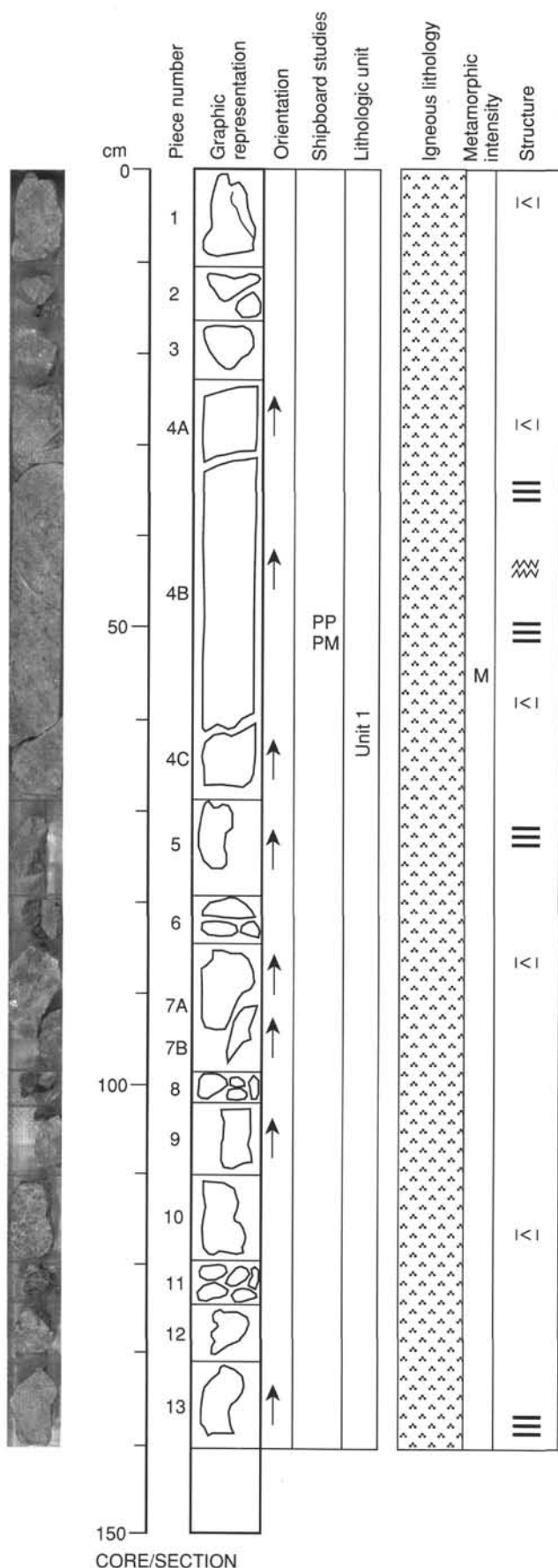
**ADDITIONAL COMMENTS:** Structure

Piece 5 shows moderate development of shape preferred orientation defined by coarse elongate pyroxene. The aligned crystals dip at 50° near the top of the piece. The foliation flattens (to ~35°) near the bottom of the piece. Three thin (~1 mm) dark green subhorizontal veins cut this piece also, with alteration halos a few mm on both sides of the lower two veins. A contact between relatively plagioclase-rich gabbro on the bottom and altered mafic-rich gabbro on top, cuts the middle of Piece 4, dipping 30°. A single near vertical, very thin (<<1 mm), pale green vein cuts Piece 1 and two similar veins cut Piece 2.

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UNIT 1: OLIVINE GABBRO

Pieces 1-13



**COLOR:** Brown-gray-white.

**PRIMARY STRUCTURE:** Igneous texture and grain-size layering.

**PRIMARY MINERALOGY:**

Plagioclase - Mode: 55%-60%.

Crystal Size: 2-15 mm.

Crystal Shape: Anhedral.

Olivine - Mode: 7%-35%.

Crystal Size: 1-30 mm.

Crystal Shape: Anhedral.

Clinopyroxene - Mode: 5%-38%.

Crystal Size: 1-20 mm.

Crystal Shape: Anhedral.

Iron oxide minerals - Mode: <1%.

Comments: Pieces 1-6 are plastically deformed, medium-grained olivine gabbro.

The degree of deformation defined by grain-size varies both from piece to piece and within a single piece. A foliation, dipping approximately 60°, lies parallel to layering defined by the grain-size variation. In Piece 4, more highly deformed zones are located 2, 8, and 15 cm from the top of the piece. A single, foliation-parallel actinolite vein (<1 mm) occurs in the center of this piece. Pieces 7-12 are medium-grained olivine gabbro. This interval has a heteradacumulate to adcumulate texture in which elongate olivine and clinopyroxene grains poikilolithically enclose laths of plagioclase. In olivine-rich pieces (Pieces 10-12), clinopyroxene encloses both plagioclase and equant olivine crystals. Olivine sometimes has a dendritic habit. The olivine abundance increases from 15% to more than 25%, and clinopyroxene decreases from 30% to less than 10% with depth. Piece 13 is a medium-grained, foliated olivine gabbro. Olivine and clinopyroxene are highly elongate. The foliation dips at approximately 45°.

**SECONDARY MINERALOGY:**

Actinolite:

Total Percent: 10 ± 5

Mode of Occurrence: Rims and replacing clinopyroxene.

Chlorite:

Total Percent: 5 ± 3

Mode of Occurrence: Replacing plagioclase.

Secondary plagioclase:

Total Percent: 10 ± 5

Clay:

Total Percent: 5 ± 2

Comments: The section is moderately altered (25%-35%). In Piece 1 (alteration 30%-35%), clinopyroxene is altered to actinolite, and plagioclase is replaced by clay minerals or chlorite. Piece 3 shows moderate alteration (30%); clay minerals replace plagioclase. Actinolite has replaced clinopyroxene. Pieces 4-5 are 25%-30% altered. The joint between Pieces 4A and 4B are overgrown by prehnite and minor epidote. Piece 4A is a foliated metagabbro. Clinopyroxene grains are aligned, and are replaced by actinolite; chlorite has replaced plagioclase. Limited iron staining is present. In Piece 4B, olivine is replaced by chlorite and sulfide minerals. In Pieces 7A, 7B, 9, and 10, chlorite forms after olivine whereas coarse-grained clinopyroxene is relatively fresh. Plagioclase is chloritized and partially replaced by clay minerals. Pieces 12 and 13 are, respectively, coarse- and medium-grained gabbro where alteration ranges from 5% to 20%.

Veins:

Piece 1 is cut by a 1 mm irregular clay mineral vein parallel to a 1 mm actinolite vein. Piece 3, 4A, 4B, and 9 have irregular clay mineral veins. Piece 4B also contains actinolite veins. Piece 7A is cut by a 1 mm irregular vein filled with clay minerals and epidote + prehnite.

**VEIN/FRACTURE FILLING:**

Clay:

Size: <<1 mm.

Orientation: Irregular.

Prehnite + epidote:

Comments: Piece 4A has centimeter-scale globular prehnite and lamellar prismatic epidote on an open fracture.

**ADDITIONAL COMMENTS:** Layering

Layering defined by grain-size variation both between and within pieces on the scale of 2-5 cm.

**153-924B-5R-1****Structure:**

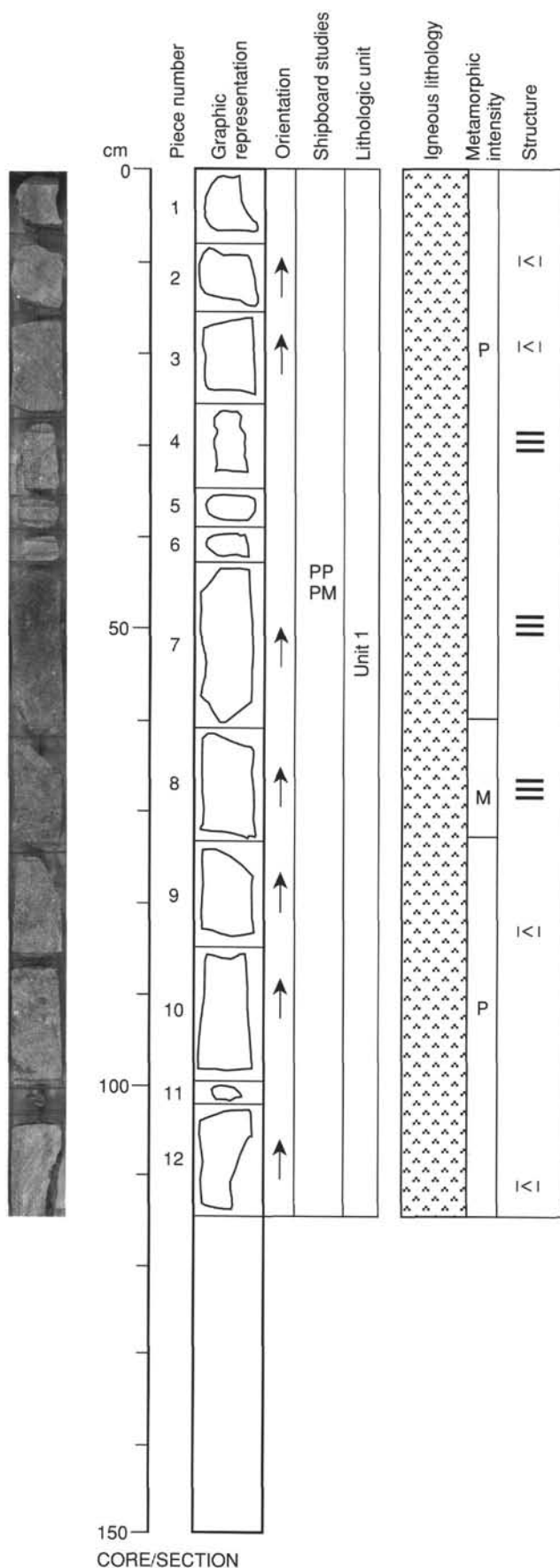
Three pieces (Pieces 4, 7, and 13) have crystal shape preferred orientation. The foliation is clearly developed near the top of Piece 4, dipping about 50° (43° apparent dip on face of archive half) in areas of medium-grained pyroxene-rich gabbro and throughout Piece 13. Piece 7 is coarser and long interstitial olivine and plagioclase grains are the aligned minerals that are subvertical. Piece 4 has compositional layering parallel to the foliation defined by bands about 2–4 cm thick. The deformation fabric is rather linear as it is more obvious on certain portions of the curved backside of the core. Green actinolite ± chlorite veins cut Pieces 1, 4, and 7. The veins are steep (65°–70°) in Pieces 1 and 4, and dip about 35° in Piece 7. The other pieces consist of pebbles or small single pieces with no obvious structural features.



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UNIT 1: META-OLIVINE GABBRO

Pieces 1–12



**COLOR:** Green gray.

**PRIMARY STRUCTURE:** Igneous layering.

**PRIMARY MINERALOGY:**

- Plagioclase - Mode: 47%–52%.  
Crystal Size: 2–10 mm.  
Crystal Shape: Subhedral/anhydral.  
Crystal orientation: None.
- Olivine - Mode: 20%–50%.  
Crystal Size: 3–50 mm.  
Crystal Shape: Anhydral.  
Crystal orientation: None.
- Clinopyroxene - Mode: 3%–30%.  
Crystal Size: 2–25 mm.  
Crystal Shape: Anhydral.  
Crystal orientation: None.
- Iron oxide minerals - Mode: <<1%.
- Sulfide minerals - Mode: <<1%.

**Comments:** This section is essentially composed of highly altered olivine gabbro. Additionally gabbro comprises half of Piece 1 and troctolite comprises the top 10 cm of Piece 7 and Piece 8. Gabbro in Piece 1 is composed of 90% clinopyroxene and 10% plagioclase. The grain size of both minerals is coarse (up to 30 and 15 mm, respectively). The olivine gabbro shows a change in modal olivine content from 20%–25% in Pieces 1 and 9–12, to 40% in Pieces 2–7 and 9. The troctolite (Piece 8) contains 50% olivine. Olivine gabbro and troctolite have crescumulate textures, where olivine pseudomorph exhibit a dendritic habit and enclose plagioclase poikilitically and subophitically. Troctolite displays a particularly beautiful crescumulate texture, where elongated dendritic olivine encloses anhydral plagioclase. Clinopyroxene occurs interstitially in troctolite. The olivine in troctolite are fresh but those in olivine gabbro are altered. This suggests an intrusive origin for the troctolite, but, since the boundary with olivine gabbro is not sharp this variation could be a result of igneous layering.

**SECONDARY MINERALOGY:**

- Chlorite.  
Total Percent: 10–20  
Mode of Occurrence: See Description.  
**Comments:** At contact between olivine and plagioclase.
- Actinolite/tremolite.  
Total Percent: 30–40  
Mode of Occurrence: See Description.  
**Comments:** Replacing and overgrowing clinopyroxene.
- Brown amphibole.  
Total Percent: 2–3  
Mode of Occurrence: See Description.  
**Comments:** Within clinopyroxene grains and as overgrowth.
- Smectite/oxide minerals.  
Total Percent: 10–30  
Mode of Occurrence: See Description.  
**Comments:** Replaces olivine. Smectite alone replaces plagioclase.

**Comments:** Overall alteration of this section is high between 50% (Piece 8) and 80% (bulk of the section). These rocks exhibit a green color resulting from the rims of chlorite and possibly actinolite around olivine, clinopyroxene, and plagioclase. Alteration has enhanced the ameboid-shaped, crescumulate appearance of olivine in Piece 7. Where alteration is high, interstitial and poikilitic clinopyroxene is almost completely replaced by actinolite rimmed by chlorite. In the less altered intervals, brown amphibole along the rims of and as inclusions in clinopyroxene grains (Piece 8). Large oikocrysts of clinopyroxene are light green resulting from their replacement by actinolite. Olivine is altered to oxide-minerals and smectite (Piece 7). Cores of plagioclase are fresh, particularly where fine-grained. They are rimmed by a white green clay mineral and by dark green chlorite. White, soft patches mark the alteration of plagioclase to clay minerals. These white patches are also rimmed by smectite and dark green chlorite.

**Veins:**

Numerous microcracks affect these gabbroic rocks. They are filled by smectite and chlorite.

**VEIN/FRACTURE FILLING:**

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Clay minerals.

Actinolite.

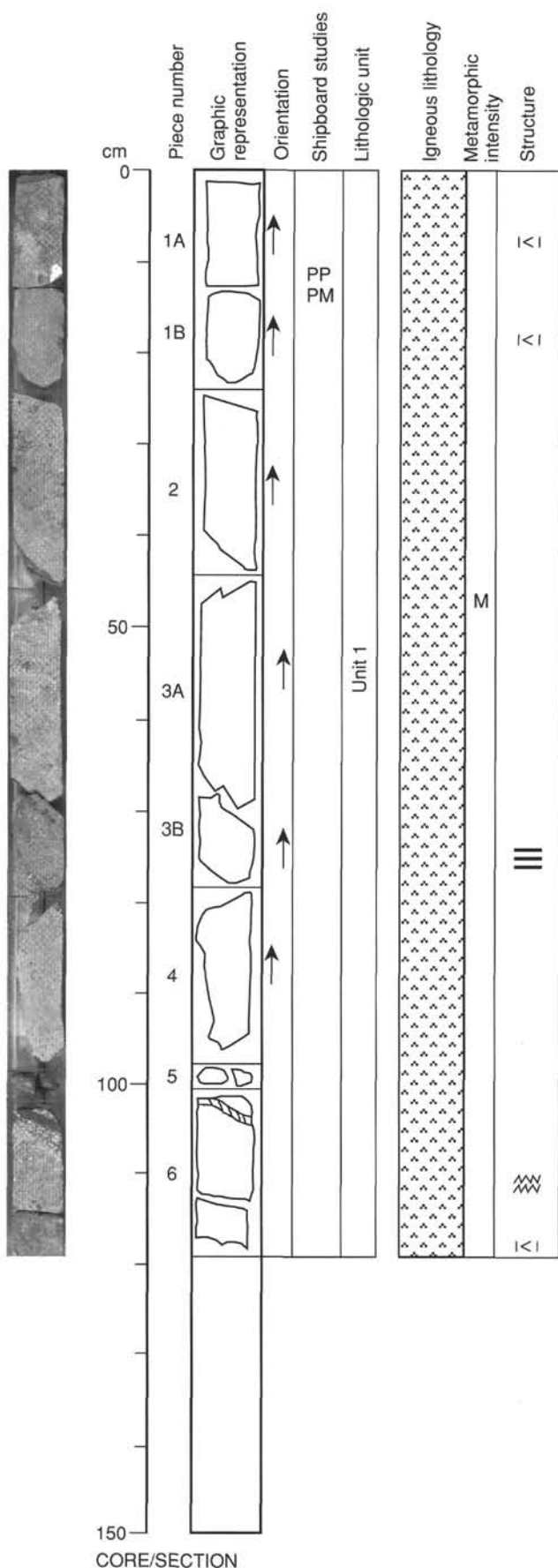
**ADDITIONAL COMMENTS:** Structure

Most pieces (Pieces 1, 4, 7-9, and 12) show a shape preferred orientation of pyroxene. The pyroxene grains show stretched tails in some pieces. The foliation is near vertical ( $80^{\circ}$ - $90^{\circ}$ ) except in Piece 12 where it dips about  $60^{\circ}$ . Thin cream-colored (clay mineral?) veins cut Pieces 2 and 3 at shallow ( $20^{\circ}$ ) dips. Thin ( $<1$  mm) dark mineral-filled vertical cracks cut a large (10 mm) pyroxene crystal in Piece 12.

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UNIT 1: META-OLIVINE GABBRO

Pieces 1A-6



**COLOR:** Green gray.  
**PRIMARY STRUCTURE:** Igneous layering.  
**PRIMARY MINERALOGY:**  
 Plagioclase - Mode: 50%-55%.  
     Crystal Size: 2-20 mm.  
     Crystal Shape: Subhedral/anhydral.  
     Crystal orientation: None.  
 Olivine - Mode: 25%-30%.  
     Crystal Size: 3-20 mm.  
     Crystal Shape: Anhydral.  
     Crystal orientation: None.  
 Clinopyroxene - Mode: 20%.  
     Crystal Size: 3-25 mm.  
     Crystal Shape: Anhydral.  
     Crystal orientation: None.  
 Iron oxide minerals - Mode: <<1%.  
 Sulfide minerals - Mode: <<1%.

**Comments:** This section is composed of highly altered olivine gabbro and a gabbro dike in Piece 1. The gabbroic dike is very coarse grained to pegmatitic. It is composed of 90% clinopyroxene (up to 5 cm in longest axis), 9% plagioclase (up to 2 cm), 1% olivine (up to 1 cm) and abundant iron oxide minerals (<1%). The olivine gabbro is homogeneous, and commonly has dendritic olivine and elongated clinopyroxene which enclose plagioclase laths poikilolithically and subophitically, exhibiting a crescumulate texture. The size of dendritic olivine and elongated clinopyroxene is difficult to measure due to pervasive alteration, but the maximum sizes are greater than 20 mm.

**SECONDARY MINERALOGY:**  
 Actinolite.  
     Total Percent: 10  
     Mode of Occurrence: See Description.  
 Comments: At contact between olivine and plagioclase.  
 Chlorite.  
     Total Percent: 10  
     Mode of Occurrence: See Description.  
 Comments: At contact between olivine and plagioclase and discontinuously rimming clinopyroxene.  
 Comments: The section is composed of moderately altered olivine gabbro (about 20% alteration). Piece 1A is a very fresh olivine gabbro, with interstitial clinopyroxene. Alteration in the olivine gabbro is more pervasive than in the gabbro, as olivine is replaced by clay and oxide minerals. Plagioclase is relatively fresh. Along the margins of clay mineral veins, plagioclase is intensely altered to smectite. In Piece 1B, chlorite locally rims and overgrows olivine and sulfide minerals. Actinolite is widespread at the contact between mafic phases and plagioclase. Chlorite rims around clinopyroxene are discontinuous. Piece 2 is a medium, fine-grained metagabbro.

**Veins**  
 Piece 1A is cut by a 2 mm irregular clay and oxide mineral-filled vein. Piece 1B exhibits an open fracture crosscut by actinolite veins with prehnite and epidote crystals. In Piece 2, a clay mineral vein is on an open surface. An actinolite vein crosscuts Piece 6 at 1 cm below the top with 20° angle relative to horizontal. Along this vein, the host olivine gabbro is more altered in a 2 cm wide halo.

**VEIN/FRACTURE FILLING:**

Actinolite.  
     Size: 1 mm.  
 Clay minerals.  
     Size: <<1 mm.  
     Orientation: Irregular.

**ADDITIONAL COMMENTS:** Structure

A weak shape preferred alignment of altered plagioclase grains defines a foliation in Piece 3B. Apart from this piece, there is no other evidence for crystal-plastic fabric. There are several compositional/textural variations down the section. In Piece 1, a band of clinopyroxene-rich gabbro, 1.5 cm wide, described as a dike in the igneous description, dips at about 55°. In Piece 3A there are two lighter green-yellow bands interlayered with olivine gabbro at 54 cm and 62 cm with a subhorizontal orientation. It is not clear whether the change in color is due solely to alteration or if there is an increase in the clinopyroxene modal

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abundance. In Piece 6, a clear boundary between a plagioclase-rich zone and a finer-grained gabbro below is evident. This compositional variation is located immediately below a 1 cm wide vein with cracked walls over a zone up to 2 cm wide. Plagioclase grains are dissected by dense arrays of subparallel chlorite and actinolite veins (<0.2 mm) that parallel the margins of the main vein. The central vein contains actinolite needles that are oriented obliquely and at a high angle to the vein margins. Yellow clay minerals, chlorite and possibly epidote(?) are also present. Thin veins are present in some pieces. In Piece 1B, there are two subparallel, thin, (<1 mm) veins containing white clay minerals. Other thin veins contain green black chlorite and actinolite. Most of the veins dip between 40° and 60°. In Piece 4 joints have formed along vein surfaces where chlorite and actinolite are still present. Some striations on these surfaces are not mineralized and may be drilling induced.

## 153-924C-2R-2

## UNIT 1: META-OLIVINE GABBRO

## Pieces 1A-11

**COLOR:** Green gray.

**PRIMARY STRUCTURE:** Igneous layering.

**PRIMARY MINERALOGY:**

Plagioclase - Mode: 50%–60%.

Crystal Size: 3–15 mm.

Crystal Shape: Subhedral/anhedral.

Crystal orientation: None.

Olivine - Mode: 10%–40%.

Crystal Size: 2–20 mm.

Crystal Shape: Anhedral.

Crystal orientation: None.

Clinopyroxene - Mode: 1%–30%.

Crystal Size: 1–25 mm.

Crystal Shape: Anhedral.

Crystal orientation: None.

Iron oxide minerals - Mode: <1%.

Sulfide minerals - Mode: <<1%.

**Comments:** This section is predominantly composed of olivine gabbro. Pieces 7 to 10 are more olivine rich. The rocks are commonly highly altered. Olivine pseudomorphs exhibit a dendritic shape, poikilitically and subophitically enclosing plagioclase laths. Clinopyroxene in olivine gabbro (Piece 1–6 and Piece 11), are poikilitic, enclosing plagioclase laths. Clinopyroxene in troctolitic olivine gabbros (Pieces 7–10) tend to occur as small interstitial grains.

**SECONDARY MINERALOGY:**

Brown amphibole.

Total Percent: 5

Mode of Occurrence: See Description.

**Comments:** Overgrows and sometimes discontinuously rims clinopyroxene.

Actinolite.

Total Percent: 30–40

Mode of Occurrence: See Description.

**Comments:** Rims clinopyroxene in composite coronas.

Prehnite(?)

Total Percent: 1

Mode of Occurrence: Replacing plagioclase.

Chlorite.

Total Percent: 30–40

Mode of Occurrence: See Description.

**Comments:** Rims clinopyroxene and actinolite in composite coronas.

Oxide minerals.

Total Percent: 1

Mode of Occurrence: See Description.

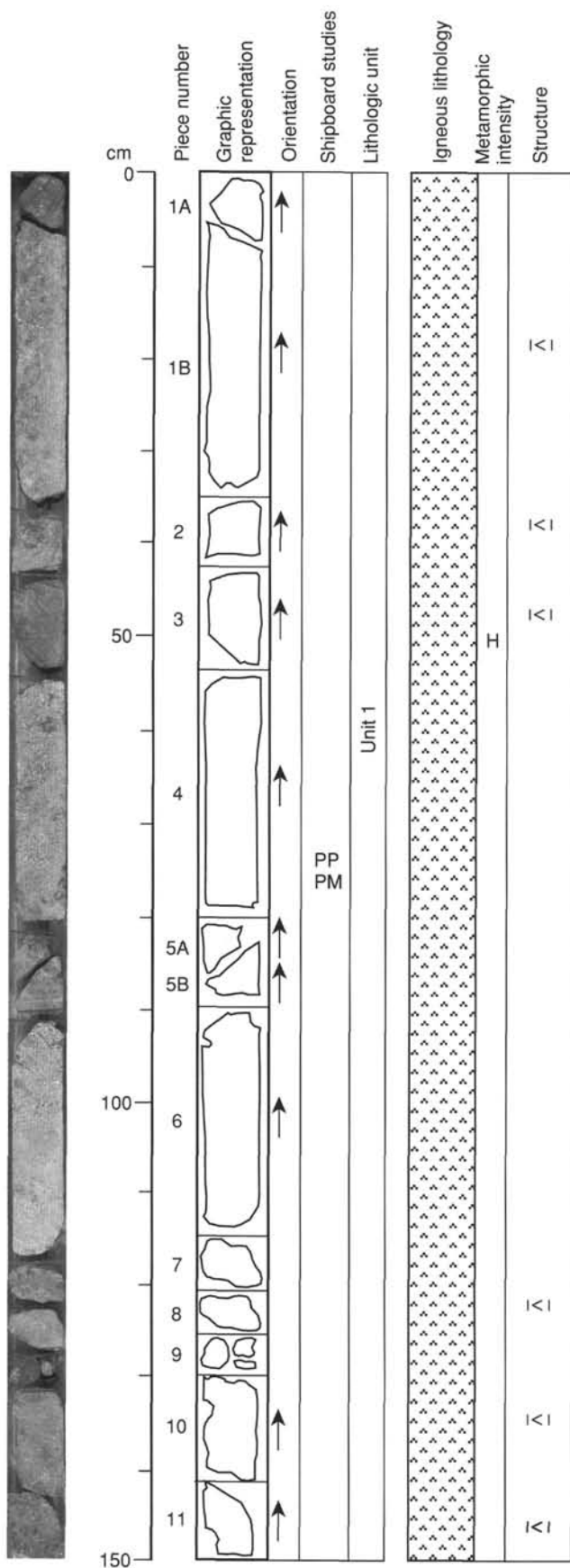
**Comments:** Recrystallized across grains.

Smectite.

Total Percent: 5

Mode of Occurrence: Overgrowing plagioclase.

**Comments:** The section is generally highly altered (50%–70%), and the alteration decreases slightly downsection. The rocks appear spotted due to coronitic alteration of olivine. In Pieces 1 and 2 (60%–70% altered), large clinopyroxene aggregates are replaced by actinolite. Olivine is commonly totally replaced by talc. Plagioclase is chloritized, and altered to prehnite(?); clinopyroxene is irregularly rimmed by brown amphibole. Pieces 3 and 4 are a medium-grained olivine gabbro with coronitic alteration around mafic phases, which imparts a mottled appearance to the rock. Plagioclase is rimmed by minor smectite and chlorite. Zoned rims of chlorite and actinolite surround olivine; clinopyroxene is replaced by actinolite, and locally replaced by brown amphibole. Plagioclase is replaced by smectite. In Pieces 5A and 5B olivine is replaced by tremolite and talc, and rimmed by chlorite. Plagioclase is replaced by smectite. Piece 7 is a foliated metagabbro (alteration ranging about 40%–50%), where the mafic phases are altered, but the plagioclase is almost fresh. Both olivine and clinopyroxene are rimmed by pale green amphibole in turn rimmed by dark green chlorite. Clay minerals are present on plagioclase. Pieces 8 and 9 are similar to Piece 7, with plagioclase slightly fresher in Piece 8. Piece 10 is weakly foliated; plagioclase is moderately overgrown by smectite; clinopyroxene (and amphibole alteration) exhibit a continuous chlorite rim at the contact with plagioclase. Piece 11 is more altered, marked by the presence of clay



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mineral and chlorite veins. Plagioclase is replaced by chlorite and minor smectite.

## Veins

On the back of Piece 1A is a dense network of parallel clay mineral veins. Piece 2B contains chlorite- and actinolite-filled microcracks. The are clay mineral and chlorite veins in Piece 10.

**ADDITIONAL COMMENTS:** Structure

There are several pieces in this section that preserve a weak shape preferred orientation of plagioclase grains and partially altered pyroxene and pyroxene pseudomorphs but the fabric is too weak to be measured reliably (Pieces 7, 8, 10, and 11). Much of the fabric is obscured by high alteration. In addition, there are several bands defined by textural and alteration variations. In Piece 1, there is a diffuse margin between coarse- and fine-grained gabbro, located on the right hand side of oriented core pieces. The contact is overall steeply dipping but is irregular. At the base of Piece 2, there is a slight reduction in grain size in the lowermost centimeter. In Piece 6, there is a band about 6 cm wide that appears darker and has a finer grain size than the adjacent regions which contain coarse-grained, altered clinopyroxene grains. Thin (0.1–1 mm) veins containing pale green, fine-grained minerals (possibly clay minerals) dip between 40° and 60°, and cross the entire core in Pieces 3, 6, 10, and 11. No structures are evident in Piece 4. A joint surface is present in Piece 5, dipping 70°.

153-924C-3R-1

UNIT 1: OLIVINE GABBRO AND TROCTOLITE

Pieces 1-10

**COLOR:** Green and white, and gray and white.  
**PRIMARY STRUCTURE:** Modal layering, crescumulate layering.

**PRIMARY MINERALOGY:**

- Plagioclase - Mode: 58%–65%.  
 Crystal Size: 1–15 mm.  
 Crystal Shape: Subhedral/anhydral.
- Olivine - Mode: 18%–30%.  
 Crystal Size: 1–20 mm.  
 Crystal Shape: Anhydral.
- Clinopyroxene - Mode: 4%–25%.  
 Crystal Size: 1–30 mm.  
 Crystal Shape: Anhydral.
- Iron oxide minerals - Mode: ~1%.  
 Crystal Size: <2 mm.  
 Crystal Shape: Anhydral.

**Comments:** This section consists of poikilitic olivine gabbro and troctolite. Large (up to 30 mm) oikocrysts of clinopyroxene occur in every large piece. Troctolite occurs where clinopyroxene oikocrysts are rare or absent. Plagioclase generally forms an interlocking framework of subhedral grains. Olivine is usually elongate, quasi-dendritic, and lobate. The only clear example of layering occurs in Piece 7, in which a prominent 2–3 cm thick layer of anorthositic troctolite dips approximately 20°. Generally the distribution of olivine, plagioclase, and poikilitic pyroxene is heterogeneous throughout the section. Clinopyroxene oikocrysts are generally green or gray. Brown clinopyroxene appears to rim green oikocrysts in Piece 5. Oikocrysts generally enclose plagioclase chadacrysts. Olivine grain shapes appear to be crescumulate. Interdigitating margins between elongate, amoeboid olivine and elongate plagioclase are recognized throughout this section

**SECONDARY MINERALOGY:**

- Tremolite.  
 Total Percent: 5–6  
 Texture: Radiating, fibrous.  
 Mode of Occurrence: After olivine.
- Chlorite.  
 Total Percent: 40–60  
 Mode of Occurrence: After olivine and plagioclase.
- Comments:** Rimming tremolite in composite coronas around olivine.
- Actinolite.  
 Total Percent: 30–50  
 Mode of Occurrence: After clinopyroxene.
- Brown amphibole.  
 Total Percent: 5  
 Mode of Occurrence: After clinopyroxene.
- Clay minerals.  
 Total Percent: 10

**Comments:** Alteration is heterogeneous in this section. Pieces 2, 9, and 10 are extensively altered (up to 90%). Pieces 1, 3, 4, 5, 6, 7, and 8 are less altered (between 40% and 70%). In the most altered pieces, clinopyroxene is completely replaced by actinolite and rimmed by chlorite. Olivine is partially or completely replaced by smectite (brown) and/or chlorite associated with oxide minerals. Plagioclase contains microcracks filled with chlorite which also occurs as rims. Locally, the plagioclase is totally replaced by a white clayey soft material, always surrounded by green rims. The most extensively altered intervals are characterized by coronas around clinopyroxene and olivine and, to a lesser extent, plagioclase. Pieces 3–8 are less altered. Brown amphibole patches and rims are present on clinopyroxene. Olivine is relatively fresh. In Piece 7, large poikilitic pyroxene is altered to actinolite.

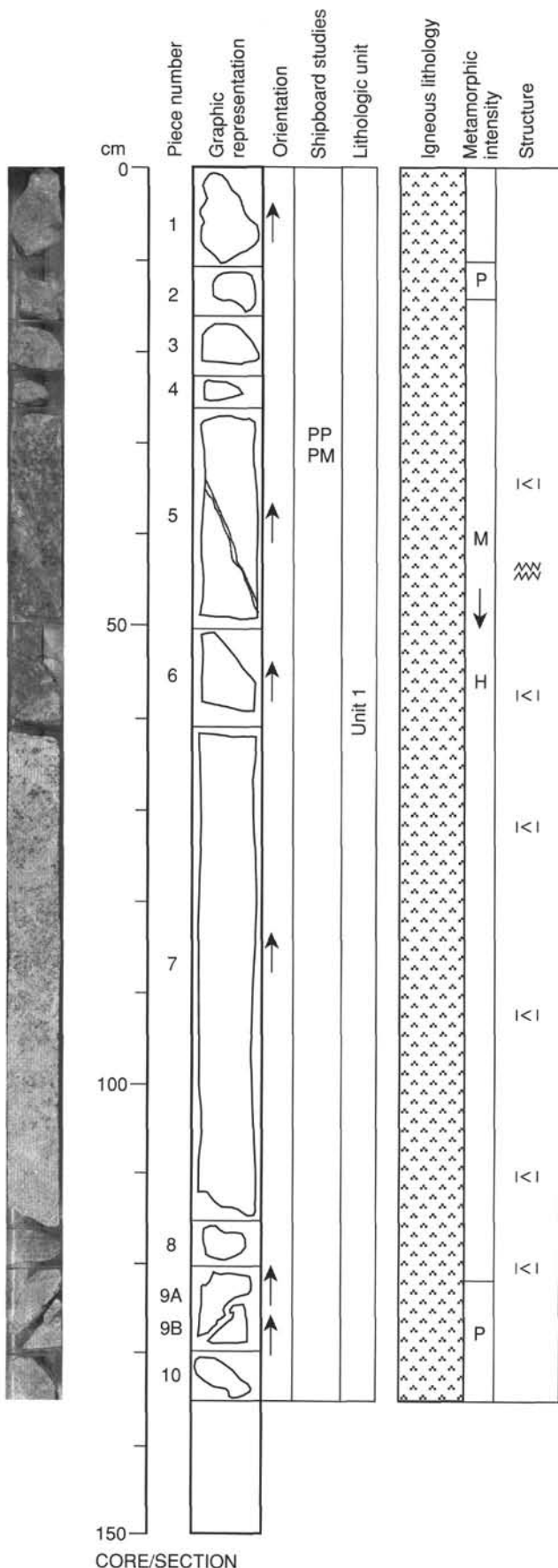
**VEIN/FRACTURE FILLING:**

- Actinolite.  
 Size: <1 mm.
- Chlorite.
- Comments:** Filling microcracks in clinopyroxene.

**ADDITIONAL COMMENTS:** Layering

Crescumulate textures are common and modal layering occurs but is not abundant. Structure

Primary igneous structure is not overprinted by solid state deformation. Igneous texture is rather isotropic, with the exception of Piece 5, where large olivine crystals are slightly elongated and aligned and define a faint subvertical



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foliation. Variations in modal olivine content in Piece 7 define a weak and irregular subhorizontal igneous layering. Millimeter-sized chlorite and actinolite veins crosscut Pieces 5, 7, and 8. Their dip ranges from subhorizontal to subvertical, with a preferred dip around 60°. A 60° dipping vein in Piece 6 is sheared.



153-924C-3R-2

UNIT 1: OLIVINE GABBRO

Pieces 1-7

**COLOR:** Green gray.  
**PRIMARY STRUCTURE:** Igneous layering.

**PRIMARY MINERALOGY:**

Plagioclase - Mode: 30%–60%.  
 Crystal Size: 1–8 mm.  
 Crystal Shape: Euhedral/anhedral.  
 Crystal orientation: None.  
 Olivine - Mode: 20%–35%.  
 Crystal Size: 3–40 mm.  
 Crystal Shape: Anhedral.  
 Crystal orientation: None.  
 Clinopyroxene - Mode: 20%–35%.  
 Crystal Size: 3–30 mm.  
 Crystal Shape: Anhedral.  
 Crystal orientation: None.

Iron oxide minerals - Mode: <<1%.  
 Sulfide minerals - Mode: <<1%.

**Comments:** This section consists of olivine gabbro. In Pieces 1–3, plagioclase content is low (~30%) and usually occurs as euhedral to subhedral laths enclosed in elongated olivine and clinopyroxene. Olivine and clinopyroxene are elongated and enclose plagioclase laths poikilitically, showing heteradcumate texture. The grain sizes of olivine and clinopyroxene are up to 40 and 30 mm, respectively. Olivine and clinopyroxene in Pieces 4–7 are highly altered (more than 80%) and it is difficult to distinguish the texture, however, olivine pseudomorphs show elongated dendritic shapes and appear to define a crescumulate texture. Accompanying the textural change, plagioclase is more abundant (more than 50%) than in Pieces 1-3. Also, clinopyroxene grain size decreases from 30 mm to less than 20 mm and appears to be interstitial in Pieces 4–7.

**SECONDARY MINERALOGY:**

Smectite.  
 Total Percent: 10  
 Mode of Occurrence: Overgrows plagioclase.  
 Talc/oxide minerals.  
 Total Percent: 40  
 Mode of Occurrence: Replaces olivine.  
 Chlorite.  
 Total Percent: 20  
 Mode of Occurrence: Rims talc/oxide minerals.  
 Brown amphibole.  
 Total Percent: 5  
 Mode of Occurrence: See Description.

**Comments:** Discontinuous rims on clinopyroxene.

**Comments:** This section is moderately to highly altered (40% to 80%). Alteration is moderate in Piece 1 (50%), higher in Pieces 2–3 (60%–70%) and intense in Pieces 4–6 (80%). In Piece 1, clinopyroxene is partly altered along margins to actinolite overgrown by chlorite. Olivine is slightly to moderately altered to talc and oxide minerals, and is commonly rimmed by chlorite. Plagioclase is altered to chlorite along grain boundaries. White soft, clayey patches are also present in plagioclase. In Pieces 2 and 3, olivine has a brown color marking replacement by smectite and oxide minerals. Chlorite encloses the altered primary phases. Large poikilitic pyroxene is replaced by actinolite, and rimmed by brown amphibole. In Piece 6, white clay minerals are rimmed by green smectite and chlorite. Oxide and hydroxide minerals occur on clinopyroxene replacing oxide and/or sulfide minerals.

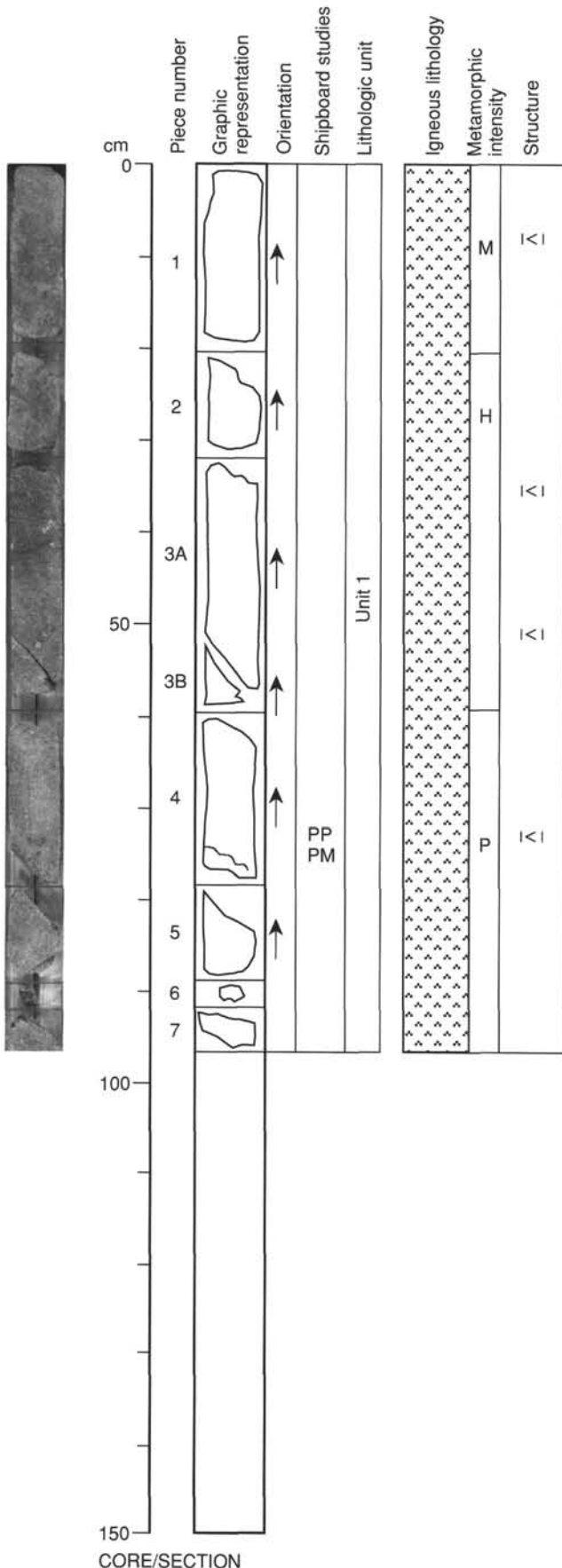
**VEIN/FRACTURE FILLING:**

Clay minerals.  
 Size: << 1 mm.  
 Orientation: Irregular.

**Comments:** Clay mineral-filled veins (<1 mm) are present in Pieces 2, 3, and 5.

**ADDITIONAL COMMENTS:** Structure

Primary igneous texture is not overprinted by plastic deformation structures. No compositional or textural layering, nor measurable magmatic fabric is seen in this section. Elongated dendritic shape of some olivine crystals results



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likely from crystal growth processes. The margins of a cataclastic zone are at the bottom of Piece 4 and at the top of Piece 5. They are characterized by a high density of subparallel microcracks extending a few mm away from the bottom and top of Pieces 4 and 5, respectively. The dip of this cataclastic zone is 50°. A swarm of mm-sized white clay mineral veins occurs at the top of Piece 3, the average dip of these veins is 45°. Mm-sized chlorite and actinolite veins are found in Pieces 1, 3, and 4.

153-924C-4R-1

UNIT 1: META-OLIVINE GABBRO

Pieces 1-10

**COLOR:** Green brown.  
**PRIMARY STRUCTURE:** Igneous layering.  
**PRIMARY MINERALOGY:**

Plagioclase - Mode: 45%-50%.  
 Crystal Size: 1-10 mm.  
 Crystal Shape: Subhedral.  
 Crystal orientation: None.  
 Olivine - Mode: 20%-30%.  
 Crystal Size: 2-20 mm.  
 Crystal Shape: Anhedral.  
 Crystal orientation: None.  
 Clinopyroxene - Mode: 20%-25%.  
 Crystal Size: 2-20 mm.  
 Crystal Shape: Anhedral.  
 Crystal orientation: None.  
 Iron oxide minerals - Mode: <<1%.  
 Sulfide minerals - Mode: <<1%.

**Comments:** This section is composed of highly altered olivine gabbro, similar to the core recovered from the bottom of Section 153-924C-3R-2. Olivine pseudomorphs commonly show elongated and dendritic texture, enclosing plagioclase subophitically. This gabbro appears to have a crescumulate texture. Most of the clinopyroxene contains poikilitic and subophitic plagioclase inclusions.

**SECONDARY MINERALOGY:**

Actinolite.  
 Total Percent: 10-20  
 Mode of Occurrence: See Description.  
**Comments:** Replaces and overgrows clinopyroxene.  
 Actinolite.  
 Total Percent: 5-10  
 Mode of Occurrence: See Description.  
**Comments:** Replaces and overgrows clinopyroxene.  
 Brown amphibole.  
 Total Percent: 5  
 Mode of Occurrence: Rims clinopyroxene.  
 Talc/oxide minerals.  
 Total Percent: 15-20  
 Mode of Occurrence: Replacing olivine.  
 Chlorite.  
 Total Percent: 10-15  
 Mode of Occurrence: See Description.  
**Comments:** Rims mafic phases at contact with plagioclase.  
**Comments:** Alteration in this section is high (about 70%). Clinopyroxene is partly to totally replaced by actinolite. Clay minerals partially replace plagioclase. In Piece 6, amphibole replaces deformed clinopyroxene. Brown amphibole rims clinopyroxene. Olivine is partly replaced by talc and oxide minerals. White to yellow clayey patches develop on plagioclase and on clinopyroxene (Piece 5). All of these altered minerals are enclosed by dark green chlorite rims.

**Veins**

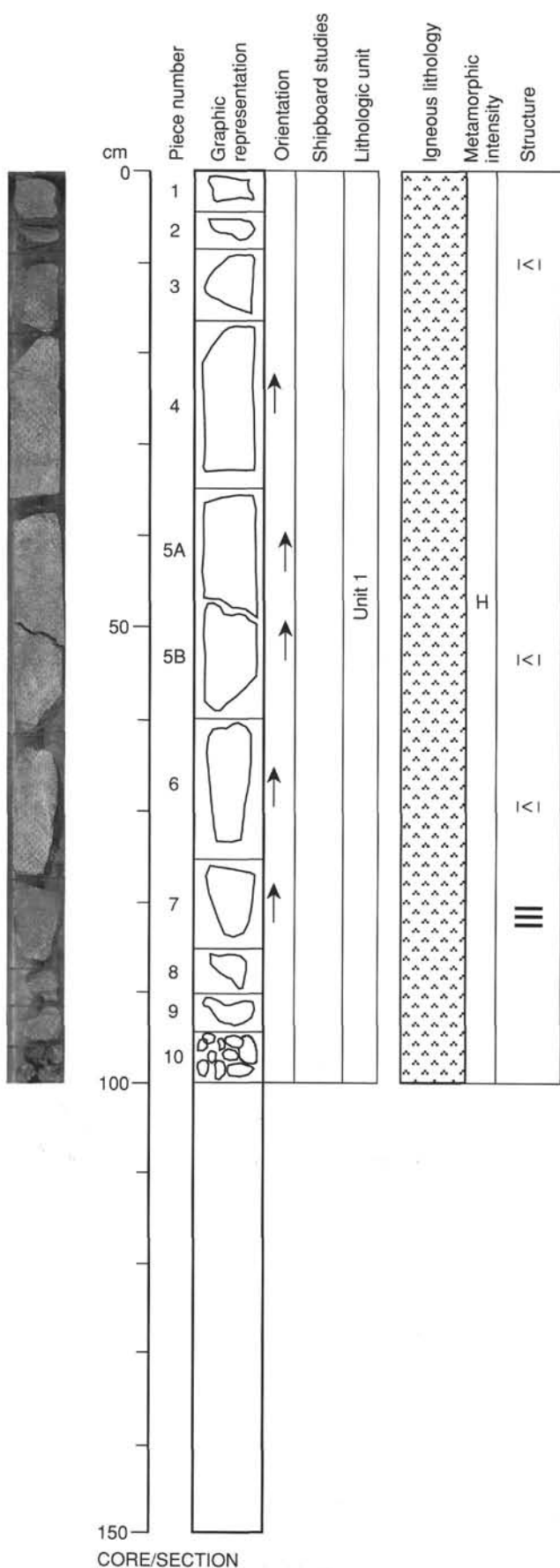
Clay mineral-filled microcracks are in Piece 1. In Piece 6A, a linear array of clinopyroxene is crosscut by actinolite and clay mineral veins.

**VEIN/FRACTURE FILLING:**

Clay minerals.  
 Actinolite.

**ADDITIONAL COMMENTS: Structure**

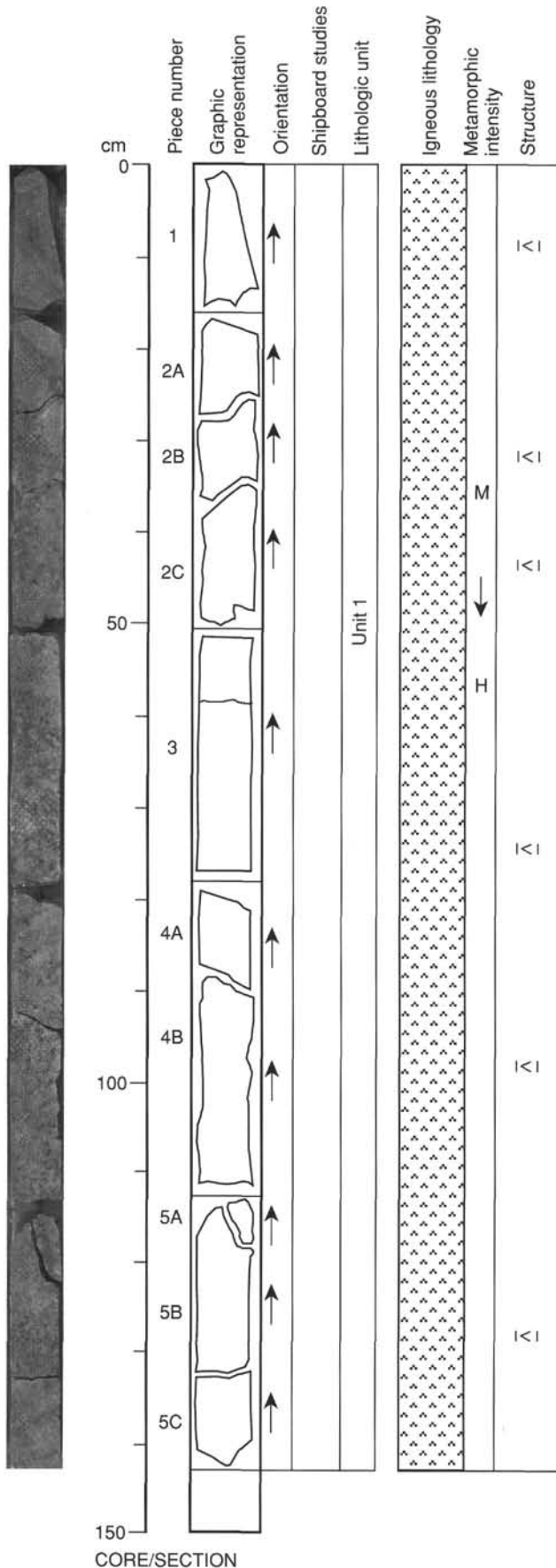
Primary igneous texture is isotropic. In Piece 4, a faint compositional layering can be identified, with a subhorizontal orientation. In Piece 6, clinopyroxene crystals have a slightly elongated fabric, resulting likely from crystal-plastic deformation. The fabric is very linear with a highly dipping orientation (75°). Very few veins are observed in this section, one in Piece 3, is filled with white clay minerals, another one in Piece 6, dips 40° and is filled with green chlorite and actinolite. These veins are ±1 mm thick.



CORE/SECTION

UNIT 1: OLIVINE GABBRO AND TROCTOLITE

Pieces 1-5C



**COLOR:** Gray, green, and white.

**PRIMARY STRUCTURE:** Grain-size layering.

**PRIMARY MINERALOGY:**

Plagioclase - Mode: 62%-68%.

Crystal Size: 1-20 mm.  
Crystal Shape: Subhedral.  
Crystal orientation: None.

Olivine - Mode: 20%-30%.

Crystal Size: 1-30 mm.  
Crystal Shape: Anhedral.  
Crystal orientation: None.

Clinopyroxene - Mode: 3%-18%.

Crystal Size: 1-22 mm.  
Crystal Shape: Anhedral.  
Crystal orientation: None.

Iron oxide minerals - Mode: ~1%.

**Comments:** This section consists of olivine gabbro and troctolite. Clinopyroxene appears to be poikilitic throughout these rocks. No clear examples of cumulus clinopyroxene were recognized. Poikilitic and interstitial clinopyroxene is observed in Pieces 2-5. An unusual, large gray clot of subophitic clinopyroxene occurs near the top of Piece 3. This clot is found in a portion of the piece that is olivine poor. Plagioclase is generally lath shaped and subhedral to euhedral throughout the section. Extreme grain-size ranges for plagioclase and olivine are in Piece 3. Near the base of Piece 3, olivine and plagioclase grains are approximately 30 mm long and randomly (or radially?) oriented. The grain size for both these minerals increases downsection in this piece. An interesting layer/boundary occurs at the interval from 55-60 cm. This boundary dips approximately 15°. The rock above this boundary is olivine poor.

**SECONDARY MINERALOGY:**

Tremolite.

Total Percent: 2-5  
Mode of Occurrence: Overgrows plagioclase.

Chlorite.

Total Percent: 5-10  
Mode of Occurrence: See Description.

**Comments:** Rims olivine at contact with plagioclase.

Iddingsite.

Total Percent: <<1  
Mode of Occurrence: After olivine.

**Comments:** Occurs in Piece 1.

Sulfide minerals.

Total Percent: <1

Actinolite.

Total Percent: 10-15  
Mode of Occurrence: Replacing clinopyroxene.

Talc/oxide minerals.

Total Percent: 30-40  
Mode of Occurrence: Replacing olivine.

Smectite.

Total Percent: 10-15  
Mode of Occurrence: Overgrows plagioclase.

**Comments:** Alteration is moderate to high throughout this section (50%-70%). Piece 1 is the most altered; clinopyroxene is replaced by actinolite-tremolite or clay minerals. In less altered pieces, clinopyroxene is only partly replaced and rimmed by brown amphibole. Coronas with tremolite-actinolite or white to brownish clay cores, green smectite and chlorite rims after olivine and clinopyroxene are in Piece 1. However, relatively fresh olivine can also be found in this section (Piece 2A, more or less vertically oriented elongated olivine grains). Fresher olivine is net veined with kernels of fresh material surrounded by small veinlets. Oxide minerals and talc(?) fill the vein networks in fresher olivine. Iddingsite after olivine occurs in Piece 1. Piece 1 also contains yellowish clay minerals (smectite) after olivine, that are rimmed by chlorite. Chlorite alteration and rims are abundant.

Veins

Piece 1 contains chlorite and clay mineral-filled veinlets. Pieces 2C and 5B have abundant clay mineral alteration.

**153-924C-5R-1****VEIN/FRACTURE FILLING:**

Chlorite.

Orientation: Irregular.

Clay minerals

**ADDITIONAL COMMENTS:** Layering

Modal and grain-size layering occur in Piece 3.

Structure

This section is completely devoid of crystal-plastic fabric. The magmatic fabric is rather isotropic except in Piece 3 where perfectly euhedral plagioclase laths have a moderately developed shape preferred orientation. The magmatic fabric plane dips moderately (20°). At the base of Piece 3, the contact between the coarse-grained olivine gabbro and pegmatitic gabbro is irregular. White clay veins are abundant in this piece, forming swarms of mm-sized irregular veinlets with an echelon offsets.

**UNIT 1: OLIVINE GABBRO**

**Pieces 1-2**

**COLOR:** Gray.

**PRIMARY STRUCTURE:** Olivine-crescumulus plagioclase-heteradcumulate.

**SECONDARY STRUCTURE:** Coronitic alteration texture.

**PRIMARY MINERALOGY:**

Plagioclase - Mode: 67%-70%.

Crystal Size: 1-10 mm.

Crystal Shape: Subhedral.

Crystal orientation: None.

Olivine - Mode: 23%-25%.

Crystal Size: 3-20 mm.

Crystal Shape: Anhedral.

Crystal orientation: None.

Clinopyroxene - Mode: 6%-7%.

Crystal Size: 2-8 mm.

Crystal Shape: Anhedral.

Crystal orientation: None.

Iron oxide minerals - Mode: 1%.

Comments: This section is composed of two pieces of coarse-grained olivine gabbro.

Both Pieces 1-2 contain sparsely distributed black spots (3-15 mm) that are anhedral grains of poikilitic to crescumulate olivine. This interval has an olivine-spotted plagioclase heteradcumulate texture, composed of anhedral olivine (23%-25%), euhedral to subhedral cumulus plagioclase (67%-70%) and anhedral intercumulus clinopyroxene (6%-7%). Piece 2 contains a wehrlitic layer of olivine adcumulate (1-3 cm thick), which consists of 70% euhedral olivine, 5% euhedral to subhedral plagioclase, and 25% interstitial clinopyroxene.

**SECONDARY MINERALOGY:**

Actinolite.

Total Percent: 3-4

Mode of Occurrence: Replacing clinopyroxene.

Smectite.

Total Percent: 3-4

Mode of Occurrence: Replacing olivine.

Oxide minerals.

Total Percent: 4-5

Mode of Occurrence: Replacing olivine.

Chlorite.

Total Percent: 4-5

Mode of Occurrence: Replacing all phases.

Talc.

Total Percent: 5-6

Mode of Occurrence: Replacing olivine.

Clay minerals.

Total Percent: 1-2

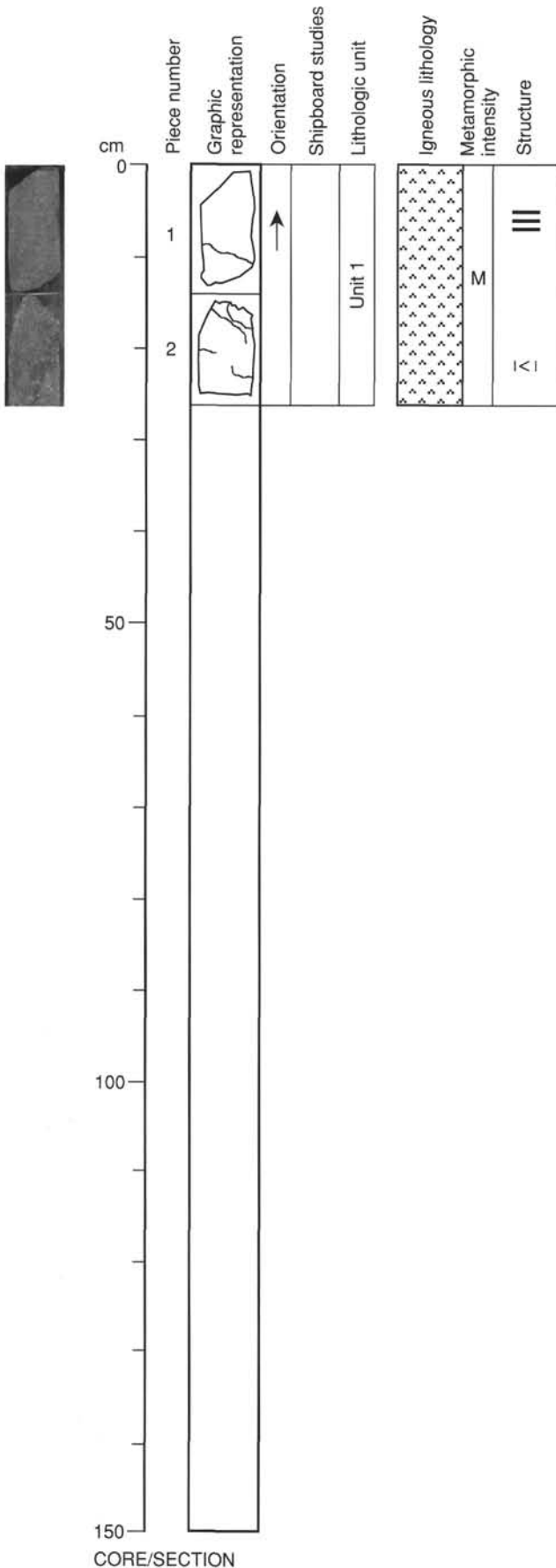
Mode of Occurrence: Replacing plagioclase.

Comments: This olivine gabbro is moderately altered, ~30%. Plagioclase is fresh.

Clinopyroxene is only partly replaced by actinolite, and olivine by smectite and oxide minerals. All the minerals are surrounded by either smectite or chlorite.

**ADDITIONAL COMMENTS:** Structure

In Piece 1, a well-developed preferred orientation and elongation of pyroxene and olivine is likely of crystal-plastic origin. It dips 40°. Piece 2 has preserved its primary igneous texture; euhedral plagioclase laths are embedded in large cm-sized olivine and clinopyroxene oikocrysts. A few mm-sized white clay mineral veins crosscut both Pieces 1 and 2. They form swarms of rather irregular veinlets, with a dip varying from subvertical to subhorizontal.

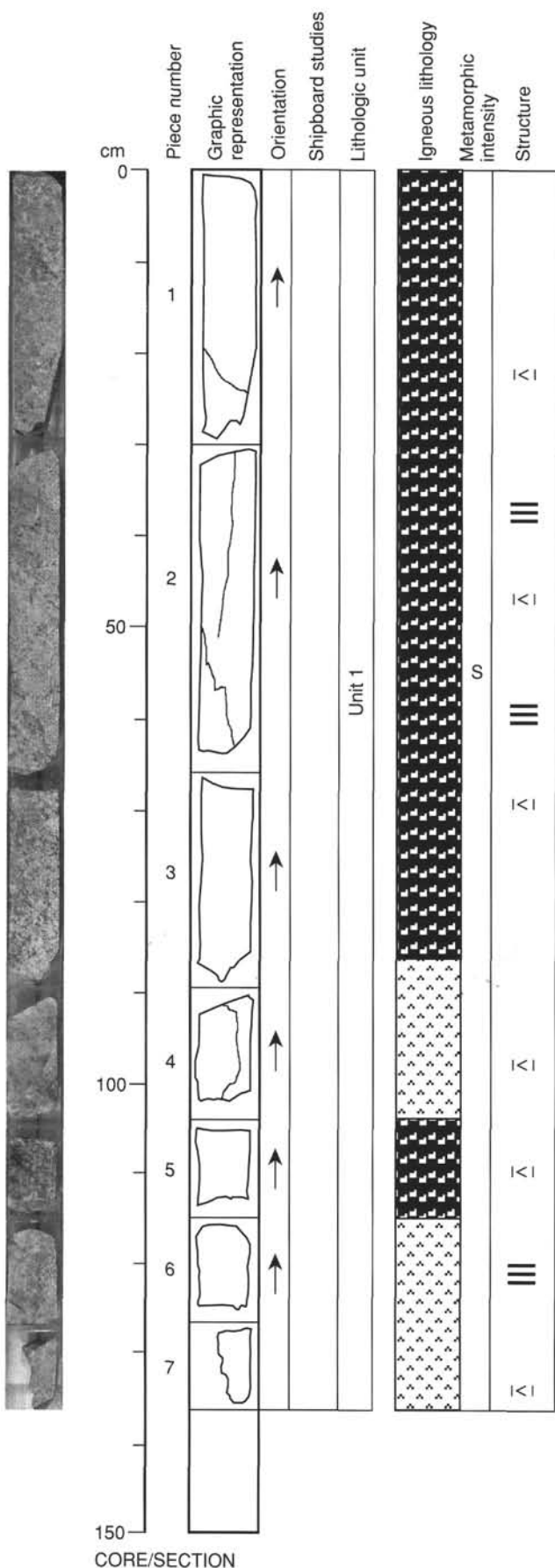


CORE/SECTION

153-924C-6R-1

UNIT 1: TROCTOLITE AND OLIVINE GABBRO

Pieces 1-7



**COLOR:** Gray/green gray.

**PRIMARY STRUCTURE:** Olivine-plagioclase adcumulate/olivine-crescumulus plagioclase-heteradcumulate.

**PRIMARY MINERALOGY:**

Plagioclase - Mode: 62%-76%.

Crystal Size: 1-15 mm.  
Crystal Shape: Subhedral.  
Crystal orientation: None.

Olivine - Mode: 18%-35%.

Crystal Size: 2-25 mm.  
Crystal Shape: Euhedral-anhedral.  
Crystal orientation: None.

Clinopyroxene - Mode: 2%-8%.

Crystal Size: 1-18 mm.  
Crystal Shape: Anhedral.  
Crystal orientation: None.

**Comments:** This section is composed of coarse-grained troctolite and olivine gabbro.

Pieces 1-3 and 5-6 are coarse-grained troctolite, which is composed of euhedral to anhedral grains (2-25 mm) of cumulus olivine (10%-35%), euhedral to subhedral grains (1-15 mm) of cumulus plagioclase (62%-74%), and anhedral irregular grains (1-8 mm) of clinopyroxene (2%-4%). The troctolite in this section are characterized by abundant euhedral cumulus olivine. Piece 2 exhibits a compositional layering of medium-grained olivine-rich troctolite (5 cm thick) and coarse-grained troctolite (major portion) at the top of the piece, at 45° oblique to the piece. Pieces 4 and 7 are coarse-grained olivine gabbro with olivine-crescumulus heteradcumulate texture, which consist of anhedral olivine (18%-25%), anhedral clinopyroxene (5%-8%), and subhedral to anhedral plagioclase (65%-76%). Both Piece 6 (troctolite) and Piece 7 (olivine gabbro) are rich in plagioclase (74%-76%).

**SECONDARY MINERALOGY:**

Actinolite.

Total Percent: 3-4

Mode of Occurrence: Replacing clinopyroxene + olivine.

Smectite.

Total Percent: 2-3

Mode of Occurrence: Replacing clinopyroxene + olivine.

Oxide minerals.

Total Percent: 2-4

Mode of Occurrence: Replacing clinopyroxene + olivine.

Talc.

Total Percent: 2-4

Mode of Occurrence: Replacing clinopyroxene + olivine.

Chlorite.

Total Percent: 4

Mode of Occurrence: Replacing clinopyroxene + olivine.

Clay minerals.

Total Percent: 2

Mode of Occurrence: Replacing plagioclase.

**Comments:** Alteration of this section is moderate (15%). Olivine in the troctolite is slightly altered to talc and oxide minerals. Chlorite replaces olivine and clinopyroxene and partially rims plagioclase. Large clinopyroxene oikocrysts are partially altered to actinolite. Plagioclase is negligibly altered.

**ADDITIONAL COMMENTS:** Structure

Piece 1 has no apparent layering or fabric in it. An irregular, 1 mm wide vein filled with plagioclase(?), chlorite, and iron oxide minerals dips steeply (72°) to 270°. Piece 2 displays a grain-size/compositional boundary in the upper part that is parallel to the orientation of plastic fabric in the rock. This plastic fabric is defined by preferred alignment of the elongated plagioclase and olivine grains and dips steeply (57°) to 270°. Downward in the piece, the intensity of this plastic fabric decreases midway through and then increases again in the very last part. Three subparallel, irregular veins filled with chlorite and iron oxide minerals ± talc cut across the fabric obliquely and have nearly subvertical dips. Piece 3 shows no shape preferred orientation and/or veins. Piece 4 displays a subvertical (72°) clay-filled vein. Piece 5 has a faint, subhorizontal fabric defined by preferred alignment of olivine grains. A subhorizontal chlorite and clay mineral vein cuts across the fabric obliquely. Piece 6 has a plastic fabric that dips steeply (73°) to 090°; it is defined by

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elongated plagioclase and olivine grains. There is no vein in this piece. Piece 7 has no shape fabric. A 1 mm wide and moderately dipping fault transects the upper part of the piece, and the fault plane contains oblique actinolite/tremolite fibers, which suggest down to  $090^\circ$ , normal sense of shearing. It is cut across by two, nearly orthogonal veinlets composed of clay minerals and probably some epidote. At the bottom of the piece, a 5 mm wide shear zone, dipping steeply ( $53^\circ$ ) to  $090^\circ$  includes fine-grained, mylonitic material and is cut across by a 1 mm wide actinolite vein that represents the oldest vein generation in this piece.



153-924C-7R-1

UNIT 1: META-OLIVINE GABBRO AND TROCTOLITE

Pieces 1-15

**COLOR:** Green gray/gray.

**PRIMARY STRUCTURE:** Olivine adcumulate/olivine-crescumulus plagioclase-heteradcumulate.

**PRIMARY MINERALOGY:**

Plagioclase - Mode: 58%-69%.

Crystal Size: 1-15 mm.  
Crystal Shape: Subhedral.  
Crystal orientation: None.

Olivine - Mode: 20%-38%.

Crystal Size: 1-20 mm.  
Crystal Shape: Anhedral.  
Crystal orientation: None.

Clinopyroxene - Mode: 3%-15%.

Crystal Size: 1-8 mm.  
Crystal Shape: Anhedral.  
Crystal orientation: None.

Iron oxide minerals - Mode: 1%.

Comments: This section consists of highly altered, medium- to coarse-grained olivine gabbro and troctolite. Pieces 1 and 5-11 are coarse-grained meta-olivine gabbro, which were composed originally of 25% olivine, 5%-15% clinopyroxene, and 59%-64% plagioclase. All the pieces are strongly altered. In Pieces 5-11 no primary olivine was observed. Pieces 2-4 and 12-13 are highly to moderately altered, medium- to coarse-grained troctolite and metatroctolite, of which original modal composition are 20%-38% olivine, 3%-4% clinopyroxene, and 58%-76% plagioclase. Piece 2 metatroctolite exhibits a magmatic layering formed by modal compositional heterogeneity in olivine.

**SECONDARY MINERALOGY:**

Talc/oxide minerals.

Total Percent: 40-60  
Mode of Occurrence: Replacing olivine.

Smectite.

Total Percent: 10-20  
Mode of Occurrence: Replacing clinopyroxene.

Chlorite/sulfides.

Total Percent: 2  
Mode of Occurrence: Replacing olivine.

Chlorite.

Total Percent: 20-30  
Mode of Occurrence: See Description.

Comments: Rims all phases. Overgrows plagioclase.

Actinolite.

Total Percent: 15-20  
Mode of Occurrence: Overgrows clinopyroxene.

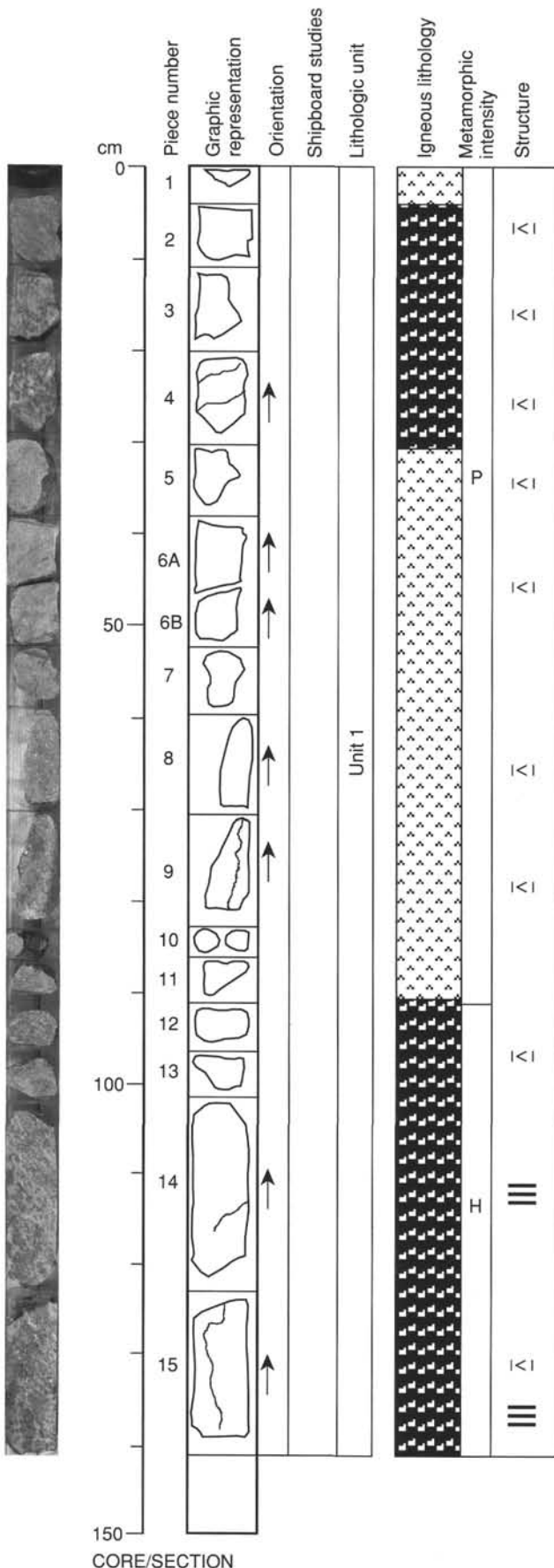
Clay minerals.

Total Percent: 10-20  
Mode of Occurrence: Overgrows plagioclase.

Comments: Alteration downsection is high to pervasive (60%-100%). Grain-size variability appears to correlate with alteration intensity. From Pieces 1-11 alteration is pervasive (80%-100%), and in Pieces 12 to 15 it is high (60%-80%). In Piece 1, olivine is altered to talc and oxide minerals; plagioclase is cut by smectite veins, and variably replaced. In Piece 2, olivine is altered by talc and oxide minerals, chlorite replaces olivine and plagioclase, resulting in green patches; clinopyroxene is altered to actinolite. Chlorite and sulfide minerals after olivine are locally flattened and recrystallized where cut by cracks. Piece 4 exhibits extensive chlorite (and oxide and/or sulfide minerals) replacement of olivine. Yellow smectite replaces plagioclase. Piece 5 is a weakly foliated medium- to fine-grained gabbro. Actinolite replaces clinopyroxene. The plagioclase is chalky white. In Piece 6A, plagioclase is chalky, crosscut by a vein network of clay minerals and actinolite. Pieces 6-7 is a deformed gabbro, crosscut by actinolite veins at the center of the piece. Clinopyroxene is highly replaced by actinolite. Piece 12 is a troctolitic gabbro, in which olivine is totally altered; plagioclase shows chloritic reactions rim with olivine.

Veins

In Piece 2 are clay and oxide mineral veins. Piece 3 has actinolite microveins at the bottom of piece. Clay microfractures across olivine and plagioclase. In Piece 4 clay mineral and actinolite parallel veins cut the piece and have a steep dip.



CORE/SECTION

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Thin prehnite(?) veins are in Piece 5. In Piece 15 is an irregular 1 mm actinolite vein with an alteration halo, mainly resulting in diffuse secondary plagioclase after plagioclase.

**VEIN/FRACTURE FILLING:**

Actinolite.

Size: <<1 mm.

Comments: In microcracks in grains.

Clay minerals and actinolite.

Size: <<1 mm.

Comments: In steeply dipping parallel microveins.

Prehnite(?)

Size: <<1 mm.

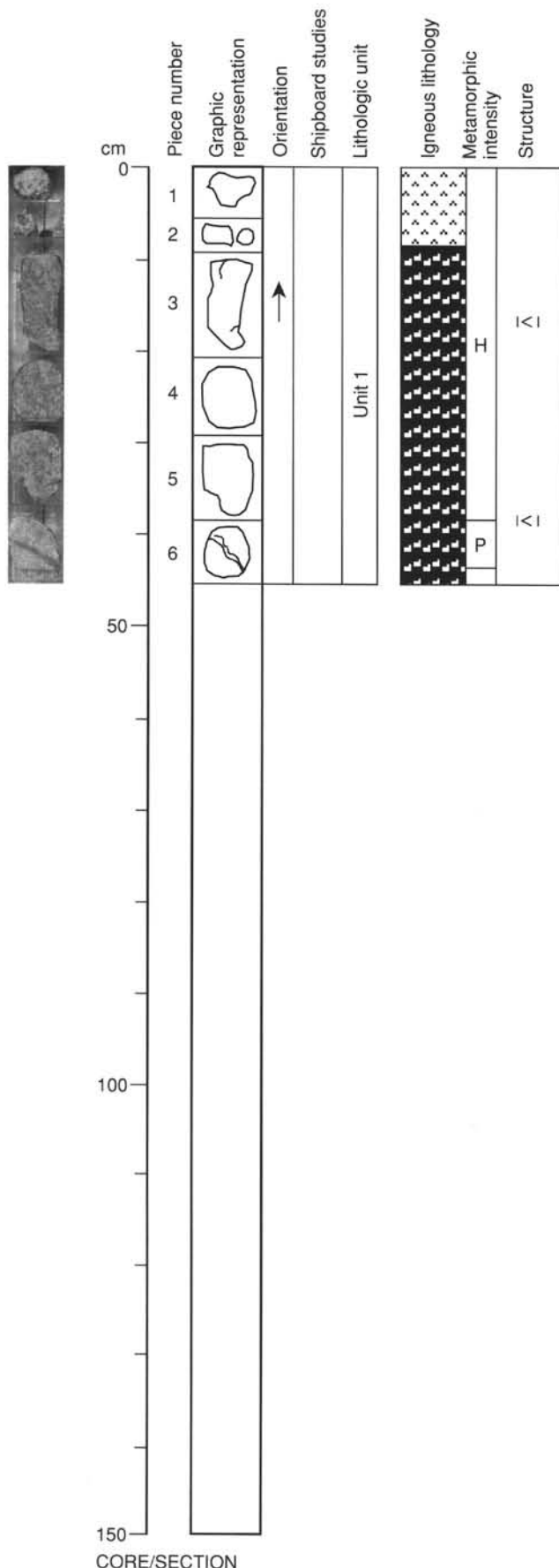
**ADDITIONAL COMMENTS:** Structure

Elongation and preferred shape orientation of olivine and pyroxene, reflecting likely an imprint of crystal-plastic deformation, is visible in Pieces 2 and 13–15. It is well developed in Pieces 14 and 15, dipping 50° to 60°. Magmatic veins are present in Piece 3 and mainly in Piece 15 (two 5 mm thick parallel medium-grained gabbro veins). Their dip is 65°. Mm-wide hydrothermal veins include chlorite and actinolite veins (Pieces 3–6, and 15). They are crosscut by white clay mineral veins, which occur in Pieces 5, 6, 8, and 14. Their dip ranges from 30° to subvertical.

153-924C-7R-2

**UNIT 1: OLIVINE GABBRO, TROCTOLITE AND META-OLIVINE GABBRO**

**Pieces 1-6**



**COLOR:** Gray/green gray.

**PRIMARY STRUCTURE:** Olivine-plagioclase adcumulate, olivine-crescumulus plagioclase-heteradcumulate.

**PRIMARY MINERALOGY:**

Plagioclase - Mode: 57%-64%.

Crystal Size: 1-12 mm.  
Crystal Shape: Subhedral.  
Crystal orientation: None.

Olivine - Mode: 8%-38%.

Crystal Size: 2-25 mm.  
Crystal Shape: Anhedral-subhedral.  
Crystal orientation: None.

Clinopyroxene - Mode: 4%-25%.

Crystal Size: 1-10 mm.  
Crystal Shape: Anhedral.  
Crystal orientation: None.

Iron oxide minerals - Mode: 1%.

**Comments:** This section is composed of highly to moderately altered, coarse-grained olivine gabbro and troctolite. Pieces 1-2 are small fragments of coarse-grained olivine gabbro with crescumulus to poikilitic olivine spots. Pieces 3-5 are highly altered troctolite with a heterogeneous abundance of modal olivine (28%-38%). The olivine exhibits euhedral cumulus to crescumulus relations to the other coexisting phases. Piece 6 is meta-olivine gabbro, of which mafic minerals are all altered.

**SECONDARY MINERALOGY:**

Chlorite.

Total Percent: 10-15  
Mode of Occurrence: Replacing plagioclase.

**Comments:** Also rims olivine.

Talc/oxide minerals.

Total Percent: 40-50  
Mode of Occurrence: Replacing olivine.

Act/smectite/clays.

Total Percent: 5-10  
Mode of Occurrence: See Description.

**Comments:** Developing into all phases adjacent to veins.

**Comments:** The section consists of highly altered troctolitic gabbro. Pieces 1-5 exhibit 60%-70% alteration. Chlorite is altered to talc and oxide minerals, rimmed by chlorite. Piece 6 is more pervasively altered (90%-100%); at the center of the piece, a 1 cm thick zone of dense veins filled with actinolite and clay minerals occurs.

**VEIN/FRACTURE FILLING:**

Actinolite and clay minerals.

Size: <<1 mm.  
Orientation: Subhorizontal in Piece 6

**ADDITIONAL COMMENTS:** Structure

No shape preferred orientation in any of the pieces. Piece 3 has a gradational boundary between an area of highly altered olivine and less altered area on the top of the piece. Two thin (<1 mm) short (<20 mm) white veins possibly filled with plagioclase or clay minerals cut Piece 3 also. A green actinolite and clay mineral vein cuts unoriented Piece 6. Adjacent and parallel to the main vein (1 mm thick) is a dense array of green coated microveins that decrease rapidly in intensity away from the main vein. An approximately 1 cm thick (each side) alteration halo surrounds the vein also.