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11. Site 1160[1]

Shipboard Scientific Party[2]

PRINCIPAL RESULTS

Site 1160 is located in eastern Zone A, ~450 km northeast of Site 1159 and ~520 km east of the ~127°E fracture zone that bounds the Australian Antarctic Discordance (AAD). The site is in a perched, sediment-filled basin on the northern side of a 1500-m-high seamount. The seafloor magnetic age is ~22 Ma. This site was drilled with the expectation that it would provide a baseline ~20-Ma Pacific site.

Hole 1160A was spudded in 4625 m water depth and was washed through ~166 m of sediment. A single wash barrel with 1.7 m of variably colored, carbonate-rich clay and silty clay was recovered. The bottom 5 cm of the core catcher contained pieces of lithified carbonate-rich sediment, Mn oxide grains, and palagonitized basaltic glass. Rotary coring continued the hole 5.1 m into volcanic basement, and 0.4 m (8.4%) of aphyric pillow basalt was recovered before the hole was abandoned because of poor drilling conditions.

Hole 1160B, 200 m north of Hole 1160A, was washed through ~160 m of sediment, with no recovery. Rotary drilling continued 45.1 m into volcanic basement, and we recovered 13.0 m (28.8%) of basalt that was divided into seven lithologic units. Three massive flows (Units 2, 4, and 6) are interlayered with four pillow flows (Units 1, 3, 5, and 7). Each massive unit is overlain by a pillow unit of the same lithology. Units 1 and 2 are aphyric basalt. Units 3–6 are plagioclase phyric basalts. Unit 7, the last recovered, is aphyric. The pillow basalts are moderately to highly altered with alteration halos around the outer surfaces of most pieces. Olivine phenocrysts and groundmass are partially to completely replaced by Fe oxyhydroxide and clay. The massive basalts appear to be, at most, only slightly altered in their interiors.

One basaltic glass from Hole 1160A and two from Hole 1160B were analyzed for major and trace elements by shipboard inductively coupled plasma-atomic emission spectrometry (ICP-AES). In addition, nine

[1]Examples of how to reference the whole or part of this volume.
[2]Shipboard Scientific Party addresses.

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whole-rock samples were analyzed by X-ray fluorescence spectrometry (XRF). The two Hole 1160B glasses, together with the whole rocks from the three massive flows, cluster between 8.7 and 9.1 wt% MgO. They are equivalent to the most primitive 0- to 7-Ma Zone A lavas in most aspects of their compositions, with lower Na_2O and Sr and higher CaO/Al_2O_3, suggesting that they were formed by slightly higher extents of melting from a mantle source very similar to that beneath Zone A today. These primitive massive basalts are the first Leg 187 whole rocks that are not significantly depleted in MgO relative to their presumed glass equivalents.

The Ba and Zr contents of the three glasses from both holes lie well within the field of 0- to 7-Ma Pacific-type mid-ocean-ridge basalt (MORB) from Zone A. We conclude that, despite their proximity to a large seamount, basalts from this site are typical MORB derived from Pacific-type mantle.

OPERATIONS

Transit to Site 1160

Site 1160 is 241 nmi east-northeast of Site 1159. Our average speed during the 20-hr transit was >12 kt. At 1600 hr on 21 December, we began a 7-nmi south-to-north single-channel seismic (SCS) and 3.5-kHz survey across the prospectus Global Positioning System (GPS) coordinates. Based on our survey, a positioning beacon was dropped ~0.7 nmi north of the prospectus GPS coordinates in order to avoid rubble that might have shed off a seamount that flanks the southern side of our operations area.

Hole 1160A

Water depth at Site 1160 was determined by the precision depth recorder (PDR) to be 4636.4 m below the rig floor. The nine-collar bottom-hole assembly used on earlier sites was rebuilt, and a new C-7 four-cone rotary bit was made up to a mechanical bit release. We began drilling Hole 1160A by washing down through the sediment column to 166.0 meters below seafloor (mbsf) at an average penetration of 66 m/hr. When the driller noted a sharp decrease in penetration rate, we retrieved the wash barrel and began coring into basement. We advanced Hole 1160A by rotary coring from 166.0 to 171.1 mbsf (Cores 187-1160A-2R and 3R; Table T1) before we decided to abandon the hole because of poor drilling conditions and <10% recovery. A tracer of fluorescent microspheres was deployed on Core 187-1160-2R. The drill string was pulled free of the seafloor at 1045 hr on 22 December.

T1. Coring summary, Site 1160, p. 38.

Hole 1160B

After we offset 200 m farther north, we washed down through sediment at a rate of 43 m/hr to 160.1 mbsf. We rotary cored from 160.1 to 205.2 mbsf, retrieving eight cores (Cores 187-1160B-2R through 9R) with nearly 30% recovery. A tracer of fluorescent microspheres was deployed on Core 187-1160B-2R. Drilling conditions deteriorated while coring the last interval. Since we had achieved our nominal penetration depth and recovered a significant amount of core, we decided to conclude operations at Site 1160. The drill bit cleared the seafloor at 2330 hr on 23 December and the rotary table at 0545 hr on 24 December.

Cautionary Note for Postcruise Sampling

During operations at Site 1160, one of the hoses attached to the new active heave compensation system ruptured, and hydraulic fluid began streaming out of the cover that protects the hoses. This resulted in an intermittent stream of hydraulic fluid that, at times, poured onto the rig floor. This fluid flow was most pronounced when the top drive was high in the derrick (i.e., adding a new length of drill pipe to the string). Because cores are handled on the rig floor immediately after a pipe connection and the core was extracted from the core barrel while a steady rain of hydraulic fluid blanketed the core handling area, some pieces of core may have come in contact with hydraulic fluid. Since all cores were pulled from the core barrel inside a plastic liner that was not split until it was on the catwalk, the bulk of the material we recovered was protected. The only exceptions are the few pieces of core that were in the core catcher, which was removed from the core barrel on the rig floor. These pieces were inspected for evidence of hydraulic fluid, and none was recognized. Nonetheless, samples from the last few centimeters recovered from each core barrel might have been contaminated. As soon as operations were concluded at Site 1160, the hoses were disconnected, so it is unlikely that any material recovered after Site 1160 was affected.

IGNEOUS PETROLOGY

Introduction

Holes 1160A and 1160B were rotary cored into igneous basement from 166.0 to 171.1 mbsf and from 160.1 to 205.2 mbsf, respectively.

Two cores were recovered from Hole 1160A (Cores 187-1160A-2R and 3R), penetrating 5.1 m into basement, with 0.43 m (8.4%) recovered. One lithologic unit of buff to medium gray aphyric pillow-basalt rubble was defined (Table T2).

T2. Site 1160 lithologic units, p. 39.

Nine cores were recovered from Hole 1160B (Cores 187-1160B-1W to 9R), which penetrated an alternating sequence of pillow lavas and massive flows (Table T2) recovering 13.0 m (28.8%) of core. Seven units were defined based on morphology and lithology. Massive flows (Units 2, 4, and 6) are interlayered with pillow flows (Units 1, 3, 5, and 7). Aphyric basalt (Units 1, 2, and 7) alternates with plagioclase ± olivine phyric basalt (Units 3–6).

Hole 1160A

Unit 1

All the basement recovered in Hole 1160A has been assigned to a single lithologic unit, a buff to medium gray aphyric pillow basalt. Less than 1% fresh phenocrysts of plagioclase and olivine as large as 1 mm and 1.5 mm, respectively, are present throughout the unit (e.g., Section 187-1160A-2R-1 [Piece 4]). About 40% of the prismatic plagioclase phenocrysts form glomerocrysts as large as 3 mm in size. In thin section, the microcrystalline groundmass texture ranges from intergranular to intersertal. It consists of 46% prismatic plagioclase (as large as 0.2 mm), 42% granular clinopyroxene (as large as 0.1 mm), and 12% mesostasis (e.g., Section 187-1160A-2R-1 [Piece 5]). Rare, small (<1 mm) vesicles make up <1% of the rock. Three pieces out of 14 include glassy rinds ranging from <1 mm to 2 mm in thickness. These have been partially or entirely replaced by palagonite.

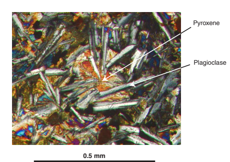
Overall, the unit is slightly to moderately altered (see "Hole 1160A," p. 7, in "Alteration"). The more altered areas of the pieces are generally located on the rims and along fractures (e.g., Section 187-1160A-3R-1 [Piece 1]). In the alteration halos, groundmass replacement by Fe oxyhydroxide and smectite varies between 5% and 15%.

Hole 1160B

Unit 1

The first unit of Hole 1160B is a buff (where altered) to medium gray (where fresh) aphyric pillow basalt. In Section 187-1160B-3R-1, two relatively flat outer surfaces on Piece 5 intersect at an angle of ~130° and can be interpreted as cooling joints. In Section 187-1160B-3R-1, Piece 3 displays radial fractures and an arcuate shape, indicating that it is a pillow-lava fragment. In several pieces, rare olivine microphenocrysts <1 mm in size are totally replaced by Fe oxyhydroxide (e.g., Section 3R-1 [Piece 9]). The microcrystalline groundmass texture varies from intergranular to subophitic on the scale of a single piece (e.g., Section 187-1160B-2R-1 [Piece 3] and Section 3R-1 [Piece 13]) (Fig. F1), with 4% olivine (as large as 0.1 mm), 50% prismatic to tabular plagioclase (as large as 0.4–0.8 mm), 45% clinopyroxene (as large as 0.4–0.6 mm), and 1% opaque minerals (as large as 20–50 µm). Clinopyroxene is anhedral and intergrown with plagioclase.

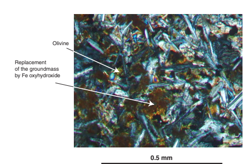
F1. Subophitic texture with clinopyroxene partially enclosing plagioclase laths, p. 14.



Nine pieces out of 39 (23%) retain glassy pillow rinds or chilled margins. Glass thickness ranges from 0.3 to 1 cm. Generally, chilled margins display a millimeter-thick palagonite layer (e.g., Section 187-1160B-3R-1 [Pieces 1 and 3]). In some cases, they also contain a spherulitic zone that is commonly altered to clay and palagonite (e.g., Section 187-1160B-3R-1 [Pieces 2 and 6]). The remaining areas of the rock are usually fresh.

Overall, the unit is moderately (e.g., Section 187-1160B-1W-1 [Pieces 4 to 12]) to highly altered (e.g., Section 3R-1 [Pieces 1 to 9]; see "Hole 1160B," p. 8, in "Alteration"). Spherical vesicles as large as 1 mm constitute <1% of the basalt. For most pieces, alteration is pervasive and is the result of replacement of groundmass olivine by Fe oxyhydroxide ± clays (Fig. F2).

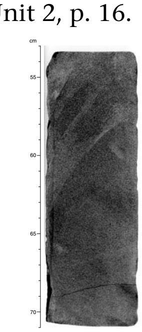
F2. Replacement of groundmass and olivine by Fe oxyhydroxide, p. 15.



Unit 2

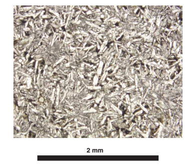
The second unit of Hole 1160B is a medium gray aphyric massive basalt. This unit is interpreted as a massive flow because of the presence of numerous long (as large as 110 cm) continuous core pieces with homogeneous textures (e.g., Section 187-1160B-4R-2 [Piece 1]; Fig. F3). Plagioclase and olivine phenocrysts represent <1% of the rock. Plagioclase as large as 2 mm is prismatic to tabular and subhedral to anhedral. Olivine as large as 1.5 mm is equant and anhedral. About 30% of olivine and plagioclase phenocrysts form glomerocrysts (e.g., Section 187-1160B-4R-1 [Piece 8C]). The groundmass consists of ~2% equant olivine (as large as 0.1 mm), 50% prismatic to tabular plagioclase (as large as 0.8

F3. A long piece of a massive flow with homogeneous intergranular texture, Unit 2, p. 16.



mm), 46% anhedral clinopyroxene (as large as 2.5 mm), and 2% equant anhedral opaque minerals (as large as 75 µm) (Fig. F4). The groundmass texture is fine grained and ranges from intergranular to subophitic. Where the texture is subophitic, clinopyroxene (as long as 1.5 mm) partially encloses plagioclase. In areas where the groundmass is intergranular, granular crystals of pyroxene ranging from 0.1 to 0.3 mm are present in the interstices between plagioclase laths. The rocks are fresh to slightly altered (see "Hole 1160B," p. 8, in "Alteration"). Numerous fractures are lined with chlorite (e.g., Section 187-1160B-4R-1 [Pieces 7 and 8]). However, throughout the unit, alteration halos (1–3 cm wide) are most commonly associated with Fe oxyhydroxide and calcite veins (e.g., Section 187-1160B-4R-2 [Piece 1A]).

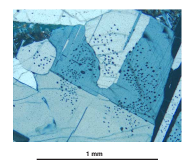
F4. Intergranular groundmass texture with prismatic plagioclase, granular to elongate pyroxene, and anhedral interstitial opaque minerals, p. 17.



Unit 3

The third unit of Hole 1160B is a reddish brown to gray moderately plagioclase phyric pillow basalt. Most of the pieces of this unit are pillow lava debris ranging from 1.5 to 5 cm in size; most surfaces have not been cut by the drill. This unit contains, on average, 4% prismatic to tabular to rounded plagioclase phenocrysts as large as 7 mm that are commonly twinned. Approximately 30% of the plagioclase phenocrysts contain spherical melt inclusions (e.g., Section 187-1160B-4R-2 [Piece 7C]; Fig. F5). Plagioclase phenocrysts from Sections 187-1160B-4R-2 to 5R-1 are light yellow, either throughout the crystal or along crystal edges and faces; this coloration is the result of Fe staining, probably related to alteration of the groundmass (see "Hole 1160B," p. 8, in "Alteration"). Equant olivine as large as 1 mm is only present in Sections 187-1160B-6R-1 to 6R-3, where it represents <1% of the rock. The original grains have been totally replaced by Fe oxyhydroxide. In some pieces (e.g., Section 187-1160B-6R-2 [Piece 1]), as much as 40% of phenocrysts are included in glomerocrysts of plagioclase ± olivine that are as large as 7 mm. The microcrystalline groundmass ranges from intergranular to subophitic. It consists of 9% equant olivine (as large as 0.1 mm), 51% acicular to lath-like plagioclase (as large as 0.4 mm), 38% quench-textured and granular clinopyroxene (as large as 0.3 mm), and 2% equant opaque minerals (as large as 50 µm). Small vesicles <0.65 mm in diameter are present in some sections (e.g., Sections 187-1160B-6R-1 and 4R-2 [Pieces 4–9]).

F5. Spherical melt inclusions in plagioclase phenocrysts, p. 18.



About 8% of the pieces in this unit have glassy chilled margins that range from 0.5 to 1.4 cm in thickness and contain ~2% prismatic to tabular plagioclase phenocrysts. In general, chilled margins consist of three layers: (1) palagonite with a thickness of <1 mm, (2) glass + phenocrysts ranging in thickness from <1 to 10 mm, and, in some cases, (3) a spherulitic zone ranging in thickness from 2 to 3 mm. Some of the glasses have curved margins (e.g., Section 187-1160B-7R-1 [Piece 3]).

Overall, the rocks are moderately (e.g., Section 187-1160B-4R-2 [Pieces 4 to 9]) to highly (e.g., Section 187-1160B-5R-1) altered (see "Hole 1160B," p. 8, in "Alteration"). Throughout the unit, alteration is dominated by pervasive groundmass replacement by Fe oxyhydroxide and clays.

Unit 4

The fourth unit is a buff (where altered) to gray (where fresh), moderately plagioclase phyric basalt except for Section 187-1160B-8R-1 (Piece 1), which is a moderately plagioclase-olivine phyric basalt. Long pieces with uniform texture (e.g., Section 187-1160B-7R-1 [Piece 10]) indicate that this unit is a massive flow.

Unit 4 basalt contains 3% plagioclase phenocrysts and <1% olivine phenocrysts. Plagioclase, as large as 7 mm, is rounded to prismatic and is commonly twinned. A heterogeneous distribution of plagioclase phenocrysts in Pieces 2A and 2C, with more abundant plagioclase at the tops of each piece, may reflect flow banding. Rare equant olivine phenocrysts as large as 0.6 mm are present throughout the unit (e.g., Section 187-1160B-7R-3 [Piece 2E] and Section 8R-1 [Piece 1]). The lower two sections of Unit 4 (Sections 187-1160B-7R-3 and 8R-1) have higher olivine contents (~1%) than the higher sections, suggesting accumulation of olivine at the bottom of the flow.

The groundmass of the massive flow is fine grained and displays an intergranular to subophitic texture (e.g., Section 187-1160B-7R-1 [Piece 10A]). The groundmass consists of 2% equant olivine, 44% plagioclase laths, 51% elongate to granular clinopyroxene, and 3% equant to subspherical opaque minerals. Overall, the unit is fresh to slightly altered (see **"Hole 1160B,"** p. 8, in "Alteration"). Numerous fractures are lined with chlorite (e.g., Section 187-1160B-7R-3 and Section 7R-1 [Piece 10]), like those in Unit 2. Alteration is concentrated along the margins of pieces and in halos around some veins; it consists, predominantly, of replacement of groundmass by Fe oxyhydroxide ± clays (e.g., Section 187-1160B-8R-1 [Piece 1]).

Unit 5

Unit 5 is a grayish brown to light brown, moderately plagioclase-olivine phyric basalt. Some pieces display radial fractures (e.g., Section 187-1160B-8R-1 [Piece 5] and Section 9R-1 [Pieces 1, 2, 3, and 15]), indicating that this unit consists of pillow lavas.

The basalts contain, on average, 3% phenocrysts of plagioclase and olivine, with plagioclase being the more abundant phase. Prismatic to tabular plagioclase is light yellow, either throughout the crystal or along the edges or faces, due to Fe staining (see **"Hole 1160B,"** p. 8, in "Alteration"). Larger rounded plagioclase phenocrysts as large as 4 mm display sieve textures. Equant olivine as large as 0.5 mm is totally replaced by Fe oxyhydroxide. Glomerocrysts of plagioclase and olivine as large as 6 mm are present throughout the unit.

Around 17% of the pieces have chilled margins. Generally, chilled margins consist of three layers: a layer of palagonite with a thickness of 1 mm, a layer of glass and phenocrysts ranging in thickness from 4 to 6 mm, and a layer of spherulites ranging in thickness from 2 to 3 mm.

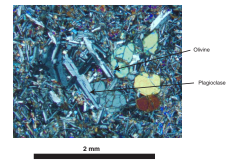
Overall, the unit is moderately to highly altered (see **"Hole 1160B,"** p. 8, in "Alteration").

Alteration is characterized by pervasive and homogeneous replacement of groundmass by Fe oxyhydroxide and brown clays (e.g., Section 187-1160B-9R-1 [Pieces 4, 9, and 10]).

Unit 6

Unit 6 is a massive flow of light gray, moderately plagioclase phyric basalt. Because of the common occurrence of long pieces with no chilled margin, this unit is interpreted to be a massive flow. Plagioclase phenocrysts represent, on average, 2% of the rock. Prismatic to tabular plagioclase as large as 5 mm is commonly twinned and zoned. Approximately 25% of these plagioclase crystals have melt inclusions in their cores (e.g., Section 187-1160B-9R-1 [Piece 21]). In thin section, rare olivine phenocrysts as large 0.8 mm are equant and subhedral. Small prismatic plagioclase crystals (1 mm) usually form single-phase glomerocrysts or mixed-phase glomerocrysts with olivine (Fig. F6).

F6. Glomerocrysts of plagioclase and olivine, p. 19.



In thin section, the fine-grained groundmass texture is intergranular to subophitic. The groundmass consists of 3% equant olivine (as large as 0.1 mm), 47% lath-shaped plagioclase (as large as 0.4 mm), 47% elongate pyroxene (as large as 1.25 mm), and 3% equant opaque mineral (as large as 0.1 mm) (e.g., Section 187-1160B-9R-1 [Piece 21]). Large clinopyroxenes partly or completely enclose plagioclase. Overall, the unit is slightly to moderately altered (see **"Hole 1160B,"** p. 8, in "Alteration"). As in Units 2 and 4, fractures across some pieces are lined with chlorite (e.g., Section 187-1160B-9R-2 [Pieces 1 and 8]). Alteration is limited to halos as wide as a centimeter that are located along the edges of pieces or adjacent to veins.

Unit 7

Unit 7 is a light gray aphyric pillow basalt, although no glassy margins were recovered. In thin section, rare prismatic to tabular plagioclase as large as 1.2 mm makes up <1% of the rock and is commonly twinned. About 50% of the plagioclase phenocrysts form glomerocrysts as large as 3 mm (e.g., Section 187-1160B-9R-3 [Piece 3]). In thin section, the microcrystalline groundmass texture is intersertal and consists of 47% lath-shaped plagioclase (as large as 0.2 mm), 41% granular pyroxene (as large as 0.1 mm), 6% opaque (as large as 0.1 mm), and 5% mesostasis (e.g., Section 187-1160B-9R-3 [Piece 3]).

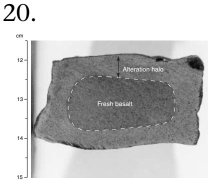
Overall, the unit is slightly altered (see **"Hole 1160B,"** p. 8, in "Alteration"). Alteration tends to be concentrated in alteration halos (as wide as 1 cm) where groundmass is partially replaced by smectite. Small (<0.2 mm) spherical vesicles represent <1% of the rock. Where located in the alteration halos, they are filled with dark green smectite or yellow clays.

ALTERATION

Hole 1160A

Basalt from Hole 1160A is slightly to moderately altered by low-temperature reactions. The uncut surfaces are weathered to a buff color, suggesting that a rubble deposit was encountered. Patchy coatings of yellowish white clay are <0.3 mm thick and usually associated with ~0.2-mm spots of Mn oxide on the uncut surfaces of some pieces (e.g., Section 2R-1 [Pieces 3 and 6]). More commonly, spots (0.2–0.5 mm) of Mn oxide alone are present on the uncut surfaces of pieces. The degree of alteration is highest within concentric oxidation halos extending 1–10 mm inward from the piece margins (Fig. F7). Within these halos, the degree of alteration increases toward the piece margin and is characterized by 5%–15% groundmass replacement by Fe oxyhydroxide and smectite (Fig. F8). Veins are not present, but rare open fractures are 1 mm wide, lined with Mn oxide and Fe oxyhydroxide, and surrounded by 1- to 9-mm alteration halos. Even within single pieces, minor vesicles (<1%, ~0.1 mm) range from unfilled to lined to partially filled to completely filled with light green clay, yellow clay, Mn oxide, Fe oxyhydroxide, cryptocrystalline bluish silica, or crystalline quartz. Sparse, fresh glass rinds range from <<1 mm (Section 187-1160A-2R-1 [Piece 2])

F7. Alteration halo in aphyric basalt, p. 20.



F8. Boundary between unaltered and altered groundmass, p. 21.

to 1.5–2.5 mm in thickness (Section 187-1160A-3R-1 [Pieces 2 and 5]). Orange-brown palagonite layers (0.5 mm thick) entirely cover the fresh glass or dissect the fresh glass along minute (~0.3 mm) cracks.

Hole 1160B

Based on significant differences in the degree of alteration and vein mineralization, two facies of alteration are recognized in the seven lithologic units from this hole.

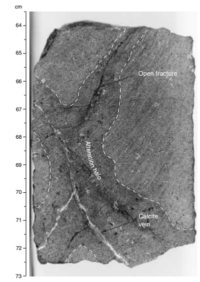
Facies I

Unit 1, Sections 187-1160B-2W-1 through 4R-1; Unit 3, Sections 4R-2 through 7R-1; and Unit 5, Sections 8R-1 through 9R-1

This facies is characterized by moderate to high degrees of low-temperature alteration that dominates the pillow basalt units recovered from Hole 1160B (see **"Igneous Petrology,"** p. 3). These units are moderately to highly affected by low-temperature alteration, except for fresh glass from quenched pillow margins and a significantly less altered area within Section 187-1160B-4R-2 (Piece 7C). Patchy coatings or spots of Mn oxide, white clay, Fe stains, and calcite (in places Fe stained) are present on the uncut surfaces throughout. Uncut, weathered outer surfaces on most 1- to 4-cm-sized pieces in Section 187-1160B-6R-1 indicate that at least some sections consist of rubble rather than an in situ pillow lava pile. In Units 1 and 5, all fractures are open, usually 0.1–0.4 mm wide and 1–3 cm long, and commonly lined with Mn oxide and/or Fe oxyhydroxide; most are free of alteration halos. In Unit 3, sparry calcite-filled veins 0.1–1 mm wide sometimes surrounded by 5- to 20-mm-wide alteration halos are present (Fig. F9). Within the alteration halos, the groundmass is mostly replaced by Fe oxyhydroxide and clay, resulting in a reddish brown color. The walls of the veins are commonly lined with Mn oxide and, in places, with Fe oxyhydroxide. A single 3-mm-thick vein of Fe-stained cryptocrystalline silica is present in Section 187-1160B-6R-1 (Piece 19A) (Fig. F10). In the same section, irregular calcite patches up to 5 mm across, some of which are associated with calcite veins, may represent groundmass replacement and/or vug fillings (Fig. F11).

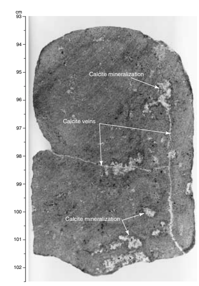
The most distinctive alteration feature in this facies, however, is the pervasive groundmass replacement by Fe oxyhydroxide and smectite, giving the basalts a light to medium red-brown appearance and causing their overall moderately to highly altered condition. Olivine (80%–100%), clinopyroxene (15% in Fig. F12; elsewhere as much as 30%), and mesostasis (20%–30%) appear to be most affected, whereas groundmass plagioclase remains relatively fresh throughout. The percentage of groundmass replacement ranges from 10% to 20% in Unit 1 to 20%–50% in Unit 3. The outer zones of some pieces are highly (80%–95%) altered, resulting in up to 1.5-cm-wide, light brown halos (e.g., Section 187-1160B-8R-1 [Pieces 6 and 7]) that grade into a patchy orange-brown to grayish brown replacement textures toward the centers of pieces (Fig. F13). The grayish brown areas appear to contain more smectite and less Fe oxyhydroxide. Plagioclase phenocrysts in Units 3 and 5 are mostly fresh throughout, but many are Fe stained, resulting in a yellowish green color throughout the crystal or along crystal edges and faces. Some plagioclase phenocrysts of Unit 5 in the vicinity of Mn oxide–lined microcracks appear black but are transparent under the binocular microscope, suggesting that the discoloration stems from the Mn oxide

F9. Alteration halo in the basalt of Unit 3, p. 22.

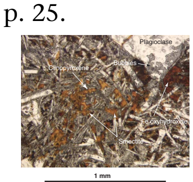


F10. Small, Fe-stained silica vein in basalt from Unit 3, p. 23.

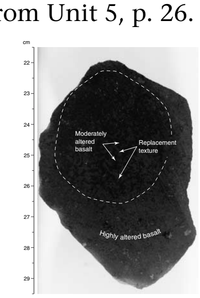
F11. Patches of calcite mineralization, p. 24.



F12. Smectite and Fe oxyhydroxide replacing groundmass clinopyroxene, p. 25.



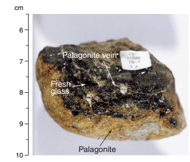
F13. Highly altered basalt fragment from Unit 5, p. 26.



that possibly lines crystal faces. Olivine phenocrysts in Units 3 (<1%) and 5 (1%–2%) are totally (90%–100%) altered throughout.

Basalt chilled margins containing fresh glass in 3- to 14-mm-wide zones are present in all three units (see **"Igneous Petrology,"** p. 3), with the outermost glass rim commonly covered with the thickest (0.3–1 mm) layer of orange-brown palagonite (Fig. **F14**). Smaller palagonite-filled veins (<0.5 mm) are mostly aligned subparallel to the quenched margin or dissect the fresh glass subperpendicular to the quenched margin, thereby splitting the glass zone into alteration cells. Plagioclase phenocrysts associated with the glass zones in Units 3 and 5 are fresh throughout. Some palagonite veins in Unit 5 are associated with cryptocrystalline silica and Mn oxide. In all three units, the zone of discrete spherulites is 1–3 mm wide and altered to Fe oxyhydroxide and clay.

F14. Quenched margin of a pillow lava, p. 27.

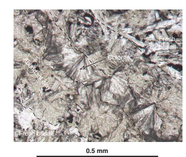


Facies II

Unit 2, Sections 187-1160B-4R-1 through 4R-2; Unit 4, Sections 187-1160B-7R-1 through 8R-1; Unit 6, Sections 187-1160B-9R-1 through 9R-2; and Unit 7, Sections 187-1160B-9R-2 through 9R-3

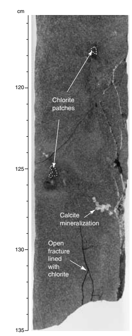
Alteration Facies II, which occurs exclusively in the massive basalts of this hole (see **"Igneous Petrology,"** p. 3), is characterized by fresh to slightly altered rocks with chlorite-bearing fractures and veins. The low degree of alteration in the massive basalts (Fig. **F3**) contrasts with the more severe alteration seen in the pillow basalts of Units 1, 3, and 5 of this hole. An exception is the massive basalt of Unit 4, which is slightly to moderately altered in Sections 187-1160B-7R-2 and 8R-1 (Piece 1). As with Facies I, alteration occurred at low temperature.

F15. Chlorite-filled fracture, p. 28.



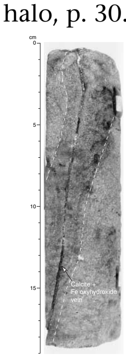
The massive basalts are cut by numerous randomly oriented fractures or very thin veins (<<0.5 mm). The fracture surfaces are covered with (1) pale green chlorite ± silica (Fig. **F15**), chlorite ± calcite, or (2) chlorite + clay + Fe oxyhydroxide. Chlorite was not observed at any previous Leg 187 site. In most places there are no substantial alteration halos associated with the chlorite-lined fractures or small veins. An exception occurs in Unit 6 in Section 9R-2, where a narrow (0.5 cm) zoned alteration halo has developed around a chlorite vein (<<0.5 mm). Closest to the vein the groundmass of the halo appears virtually unaltered, but the outer edge of the halo is darker, separating the halo from the fresh basalt. This halo differs macroscopically from alteration halos associated with calcite veins seen so far in this leg, but the origin of these color differences is unclear. Patches of chlorite + white clay are present in the vicinity of chlorite-bearing fractures and veins in Section 187-1160B-4R-1 (Piece 8) (Fig. **F16**) and in Section 9R-2 (Pieces 1 and 3–7). In some places where it is associated with chlorite, calcite is present as radiaxial clusters of elongate crystals as long as 5 mm. Minute fractures lined with Mn oxide in Section 187-1160B-7R-2 of Unit 4 lack alteration halos and are closely associated with calcite-filled veins. Fractures lined with cryptocrystalline silica are present only in Section 187-1160B-9R-1 (Piece 21).

F16. Fresh massive basalt crosscut by chlorite-lined fractures and thin calcite veins, p. 29.



Veins filled with sparry calcite + Fe oxyhydroxide ± Mn oxide are usually 0.2–2 mm wide and generally surrounded by 1- to 4-cm-wide alteration halos (Fig. **F17**), except for a calcite vein in Section 187-1160B-7R-2 (Piece 7C) (Unit 4) that has no alteration halo. Clinopyroxene and mesostasis are the most commonly replaced groundmass phases (by Fe oxyhydroxide and smectite), whereas groundmass plagioclase is fresh throughout. Alteration related to calcite + Fe oxyhydroxide–bearing veins is most abundant in Sections 187-1160B-7R-2 and 8R-1, corre-

F17. Calcite vein surrounded by an alteration halo, p. 30.

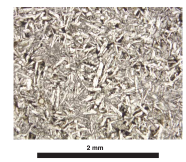


sponding to the most altered sections of Unit 4. Notably, the outer edge of the alteration halo is characterized by a greater abundance of Fe oxyhydroxides than areas closer to the vein. The inner walls of the calcite veins are commonly lined with Mn oxide.

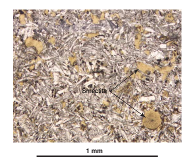
In Section 187-1160B-4R-2 (Pieces 1G and 1H), an Fe oxyhydroxide + calcite vein terminates in a chlorite-lined vein/fracture. A similar spatial sequence in vein mineralogy is observed for Unit 4 in Section 187-1160B-7R-1 (Piece 10) where, in addition to numerous chlorite-lined fractures, the center of a 5-mm-wide vein in Piece 10F is filled by sparry calcite, lined by Fe oxyhydroxide/Mn oxide, and surrounded by chlorite toward the wall rock.

Except for alteration halos, the groundmass is exceptionally fresh throughout all units of this alteration facies (Fig. **F18**). Plagioclase phenocrysts are fresh throughout; rare olivine phenocrysts at the base of Unit 4 (Section 187-1160B-7R-3) and olivine microphenocrysts of Unit 7 are totally altered to Fe oxyhydroxide and clay. Rare botryoidal, radiaxial, or dogtooth calcite mineralization is present in Sections 187-1160B-4R-1 (Piece 8) and 7R-2 (Piece 2) (Fig. **F16**). Vesicles are only present in Unit 7 (<1%, 0.2 mm); they are filled with yellow and dark green smectite within 3- to 10-mm-wide alteration halos (Fig. **F19**) that are aligned subparallel to the piece margins. Within these halos, as much as 15% of the groundmass is replaced by smectite (Fig. **F19**).

F18. Unaltered groundmass of massive basalt in Unit 2, p. 31.



F19. Smectite replacing groundmass and filling vesicles, p. 32.



MICROBIOLOGY

At Site 1160, four rock samples were collected as soon as the core liners were split to characterize the microbial community inhabiting this environment (Table **T3**). Three are pillow basalt fragments composed of partially altered glass rinds and crystalline basalt interiors (Samples 187-1160B-1W-1 [Piece 3A, 16–18 cm], 4R-1 [Piece 2, 5–10 cm], and 8R-1, 0–87 cm), and one is crystalline basalt (Sample 187-1160B-6R-1 [Piece 18, 102–105 cm]). To sterilize them, the outer surfaces of the rocks were quickly flamed with an acetylene torch, and enrichment cultures and samples for DNA analysis and electron microscope studies were prepared (see **"Igneous Rocks,"** p. 7, in "Microbiology" in the "Explanatory Notes" chapter).

T3. Rock samples for cultures, DNA analysis, SEM/TEM, and contamination studies, p. 40.

STRUCTURAL GEOLOGY

Hole 1160A

Rare fractures and a single vein were observed in basalts from Hole 1160A. Fracture + vein density (effectively fracture density since there is only one vein) for Hole 1160A is 20.8/m.

Hole 1160B

The fracture + vein density in basalts from Hole 1160B ranges from 3.5 to 34.7/m and averages 19.1/m. The vein density ranges from 0 to 17.9/m and averages 7.5/m.

In basalts from Hole 1160B, seven lithologic units were defined based on macroscopic features (see **"Hole 1160B,"** p. 4, in "Igneous Petrology"). The fracture density for all units is roughly similar (~16 to 18/m), but no veins were identified in the three pillow lava units (Units 1, 5, and 7).

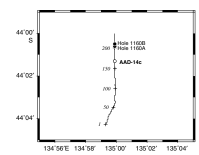
SITE GEOPHYSICS

Site 1160 was located based on 1996 SCS site survey data and confirmed by a short 3.5-kHz PDR and SCS presite survey from the *JOIDES Resolution* (JR). Onboard instrumentation included a precision echo sounder, gyrocompass, seismic system, and GPS receivers.

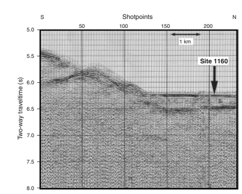
Seismic Reflection Profiling

Site selection for Site 1160 was based on a SCS survey conducted during the *R/V Melville* cruise Boomerang 5 in 1996. A 1.5-hr SCS and 3.5-kHz PDR survey was conducted on approach to Site 1160 (JR SCS line S8; Fig. **F20**) to ensure the correct site location by comparison of the GPS-navigated SCS data with the 1996 SCS image and to verify sediment thickness. Survey line S8 crossed the prospectus site AAD-14c from south to north. The ship's average speed was 4.7 kt. The water gun was triggered at a shot interval of 12 s, equivalent to ~29 m at 4.7 kt. Data acquisition and processing parameters are described in **"Underway Geophysics,"** p. 10, in the "Explanatory Notes" chapter. We marked the position of Hole 1160A in 4625 m water depth near seismic shotpoint 206 of line S8, ~1.3 km north of prospectus site AAD-14c (Fig. **F21**). Hole 1160B is 200 m north of Hole 1160A.

F20. Track chart of the JR SCS survey line S8, p. 33.



F21. SCS profile line S8, p. 34.



The sediment cover (Fig. **F21**) appears to extend from 6.24 to 6.48 s in two-way traveltime, equivalent to at least 240 m of sediment, and there are several distinct reflectors within this interval. However, both Holes 1160A and 1160B were drilled through only 166 and 160.1 m of sediment, respectively, before basement was reached, obviously thinner than we estimated from the SCS profile. One possible explanation is that the sediment is much more unconsolidated than that encountered so far, delaying the two-way traveltime of the basement signal. Alternatively, and perhaps more likely, the basin may be partially filled by horizontal flows with interflow rubble and/or pillow zones. This explanation would be consistent with the actual recovery in 46 m of penetration of three massive flows, ranging between 2 and 3 m thick, separated by broken pillow material.

SEDIMENTS

A single wash barrel was recovered from Hole 1160A (Core 187-1160A-1W; 0.0–166.0 mbsf). This core contains carbonate-rich clay and silty clay of varying color. Intervals range from 1 to 20 cm thick and vary from white silty clay, with a chalky texture, to dark brown clay, with rare light gray silty clay layers. From 0 to 45 cm in Section 187-1160A-1W-1 is a severely drilling disturbed interval. Below that, drilling disturbance is manifested by the bending of contacts downsection along core margins and by the smearing of intervals along the inside of the core liner. Nearly all contacts between intervals are sharp but irregular, some over as much as a centimeter. There are rare diffuse contacts, but these may be artifacts of rotary coring. All intervals effervesce in dilute HCl (~5%–10%). The bottom 5 cm of the core-catcher section contains lithified, subangular to subrounded, 1- to 4-cm-sized pieces of carbonate-rich sediment, with abundant millimeter-sized Mn oxide grains and one piece of palagonitized basaltic glass with adhered lithified sediment.

GEOCHEMISTRY

Introduction

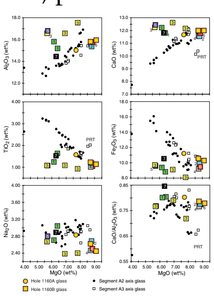
Basalt was recovered at Site 1160 from two holes that penetrated ~22-Ma crust near the base of a large seamount within Zone A. This site is the farthest east of all Leg 187 sites and was selected to provide a baseline Pacific-type sample for this region at 22 Ma. One glass from Hole 1160A and two glasses and one whole-rock sample from Hole 1160B were analyzed for major and trace elements by ICP-AES. Nine whole-rock samples from Hole 1160B were analyzed for major and trace elements by XRF (Table T4). The highly altered nature of the whole-rock samples from Hole 1160A precluded XRF analysis. Hole 1160B whole-rock XRF powders were not analyzed by ICP-AES.

T4. Compositions of basalts from Site 1160, p. 41.

Hole 1160A

A single lithologic unit of slightly to moderately altered aphyric pillow basalt rubble was recovered from Hole 1160A (see **"Hole 1160A,"** p. 3, in "Igneous Petrology"). The single glass sample analyzed from this hole is identical in composition to younger Southeast Indian Ridge (SEIR) glasses with comparable MgO contents (7.7 wt%) from Segments A2 and A3 (Figs. F22, F23).

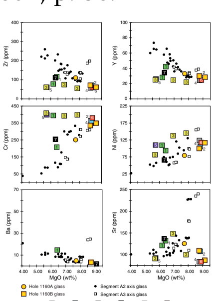
F22. Major element variations vs. MgO for basalts from Holes 1160A and 1160B, p. 35.



Hole 1160B

From Hole 1160B seven lithologic units of aphyric and moderately plagioclase ± olivine phyric basalt were defined in an alternating sequence of pillow basalt and massive flows. As a group, Hole 1160B lavas range from high-MgO (~9.0 wt%) primitive basalt glass and massive flow whole rocks to low-MgO (~5.5 wt%) pillow basalt whole rocks. Glasses from Units 1 and 5 have ~3.5 wt% higher MgO contents than their whole-rock counterparts. Whole rocks from Units 1, 3, 5, and 7 (i.e., the pillow lavas) have the lowest MgO contents. CaO, TiO_2, Zr, Y, and Cr contents show little variation with respect to MgO content, and variations of Al_2O_3, Na_2O, and CaO/Al_2O_3 are unsystematic. The evolved whole-rock compositions cannot be explained by simple magmatic processes, and we believe that they represent alteration effects. Massive flow whole rocks from Units 2, 4, and 6 are very fresh and overlap the Hole 1160B glass data. These fresh whole-rock and glass samples have high MgO contents that cluster at the least-fractionated end of the Zone A compositional range.

F23. Trace element variations vs. MgO for basalts from Holes 1160A and 1160B, p. 36.



Temporal Variations

We see no compositional traits in Site 1160 basalts that would indicate significant temporal variability in ridge crest processes in this region. The similarities of Site 1160 glasses and unaltered massive whole rocks to the compositions and trends in Segments A2 and A3 are remarkable, given that these samples are from the flank of a large seamount. The high-MgO-content samples from Hole 1160B are as primitive as high-MgO Zone-A propagating rift tip lavas, but they do not have the enriched Na_2O, Ba, and Sr contents or low CaO/Al_2O_3 of the latter. The lower Na_2O, Ba, and Sr and high CaO/Al_2O_3 suggest a higher degree of melting, and the majority of Zone A–type lavas could have parental magmas with similar composition.

Mantle Domain

Basalts from Site 1160 are clearly derived from a Pacific-type mantle source. The glasses have Zr/Ba ratios >23 and low Ba contents, placing them well within the Pacific-type field defined by dredged Zone A glasses (Fig. **F24A**). The primitive Site 1160 lavas also overlap the high-MgO end of the Na_2O/TiO_2 vs. MgO trend shown by Segment A2 and A3 lavas, consistent with a Pacific-type mantle source (Fig. **F24B**).

F24. Variations of Zr/Ba vs. Ba and Na_2O/TiO_2 vs. MgO for Holes 1160A and 1160B basaltic glass and whole-rock samples, p. 37.

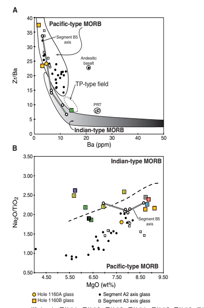


Figure F1. Photomicrograph, with crossed polars, of Sample 187-1160B-3R-1, 63–66 cm (see "Site 1160 Thin Sections," p. 22), showing subophitic texture with clinopyroxene partially enclosing plagioclase laths in Hole 1160B, Unit 1.

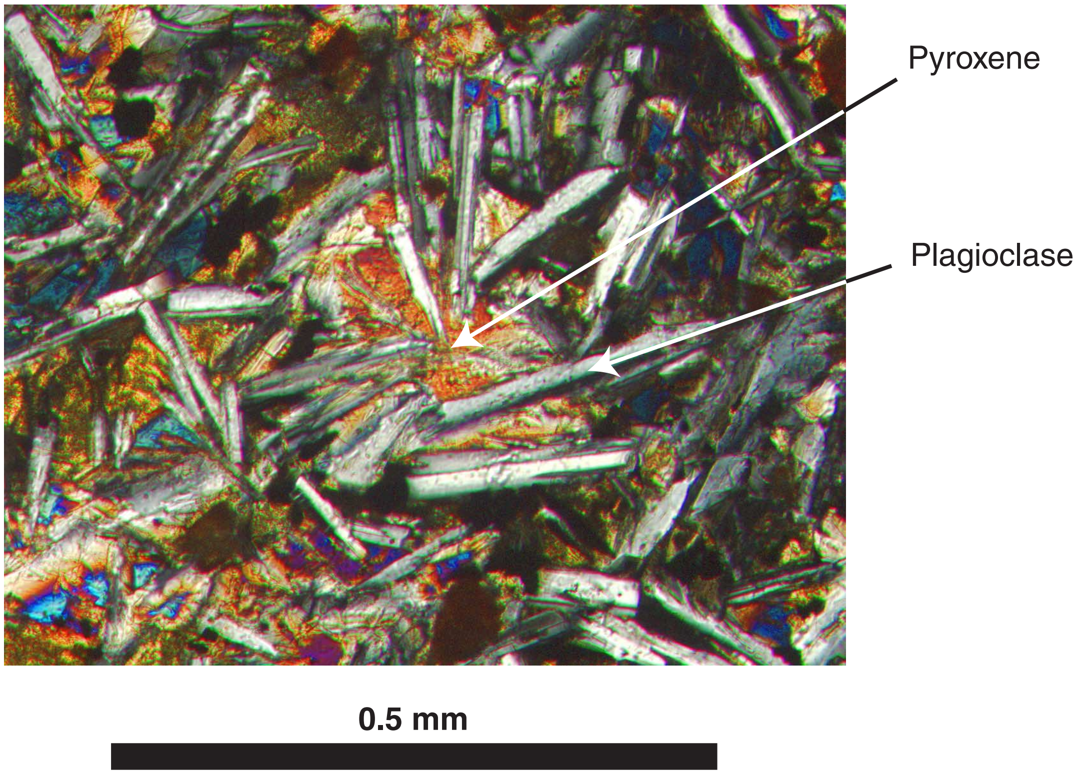


Figure F2. Photomicrograph, with crossed polars, of Sample 187-1160B-3R-1, 63–66 cm, (see **"Site 1160 Thin Sections,"** p. 22), showing replacement of the groundmass and olivine by Fe oxyhydroxide in Hole 1160B, Unit 1.

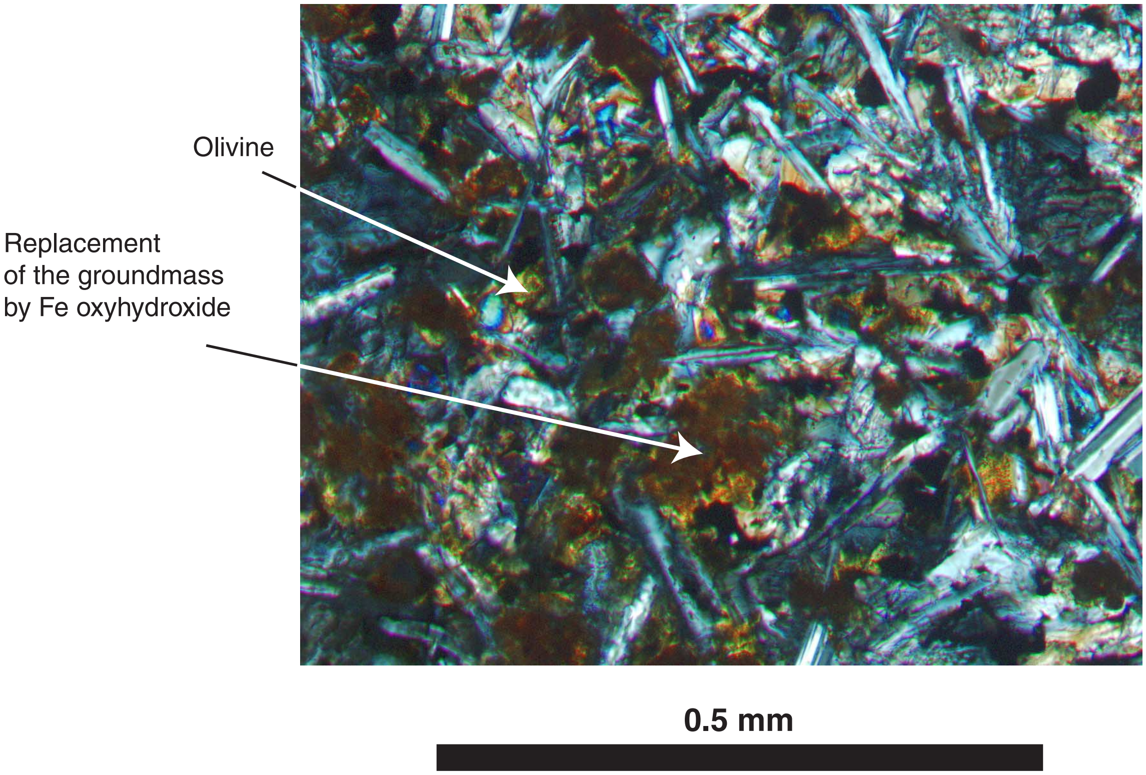


Figure F3. Photograph of Section 187-1160B-4R-2, 54–70 cm (Piece 1), showing a long piece of a massive flow (a continuous core of fresh massive basalt) with homogeneous intergranular texture of Hole 1160B, Unit 2. The open fracture at 69 cm is lined with chlorite, a typical feature of alteration Facies II.

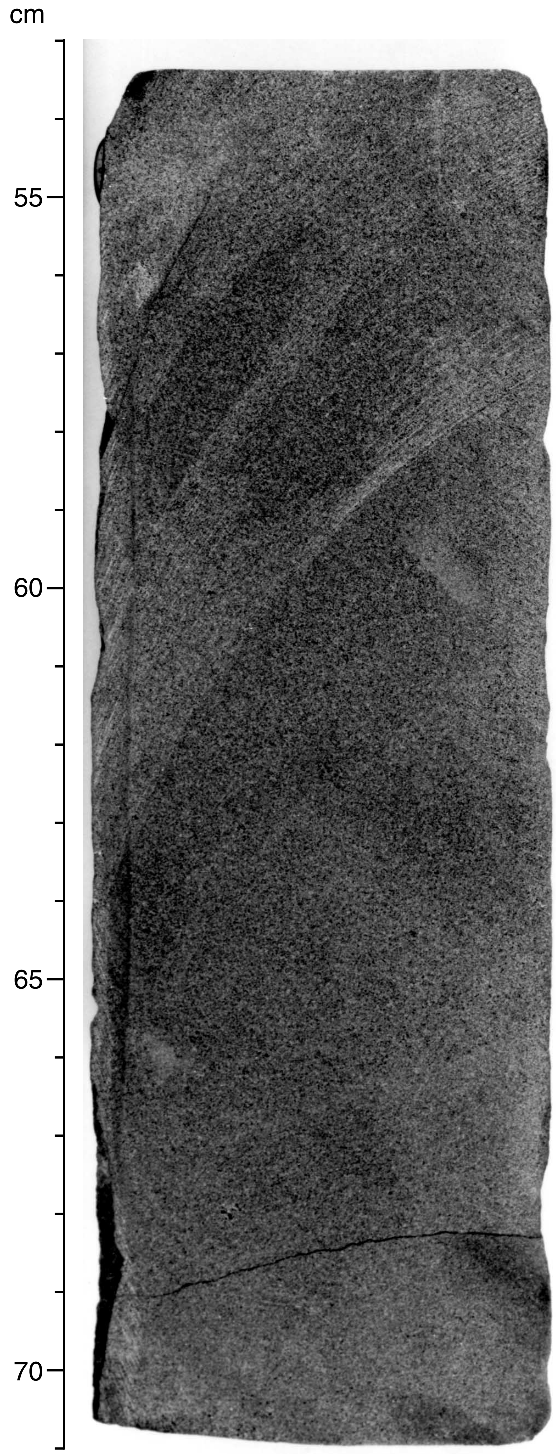


Figure F4. Photomicrograph in plane-polarized light of Sample 187-1160B-4R-1, 59–62 cm (see "Site 1160 Thin Sections," p. 23), showing intergranular groundmass texture of Unit 2, with prismatic to tabular plagioclase, granular to elongate pyroxene, and anhedral interstitial opaque minerals.

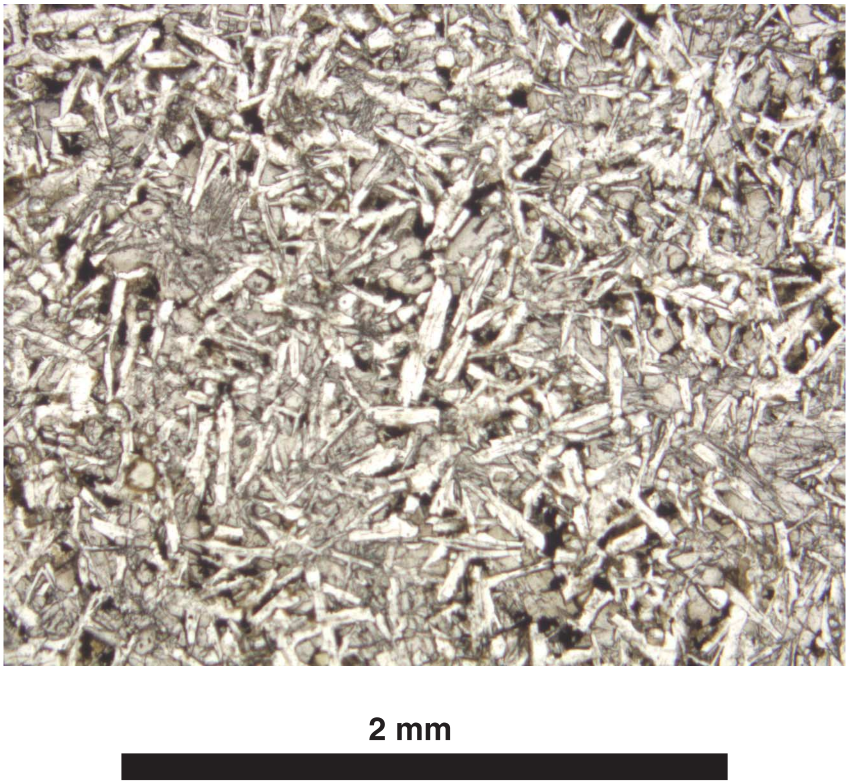


Figure F5. Photomicrograph, with crossed polars, of Sample 187-1160B-4R-2, 122–126 cm (see **"Site 1160 Thin Sections,"** p. 24), showing spherical melt inclusions in plagioclase phenocrysts in Hole 1160B, Unit 3.

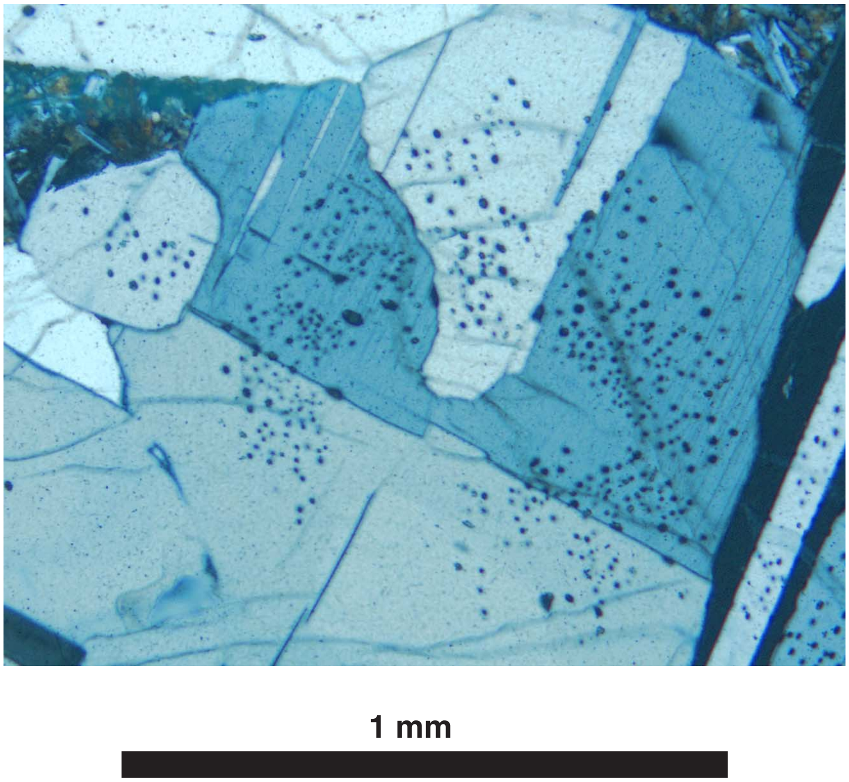


Figure F6. Photomicrograph, with crossed polars, of Sample 187-1160B-9R-1, 125–129 cm (see "Site 1160 Thin Sections," p. 29), showing glomerocrysts of plagioclase and olivine in Unit 6.

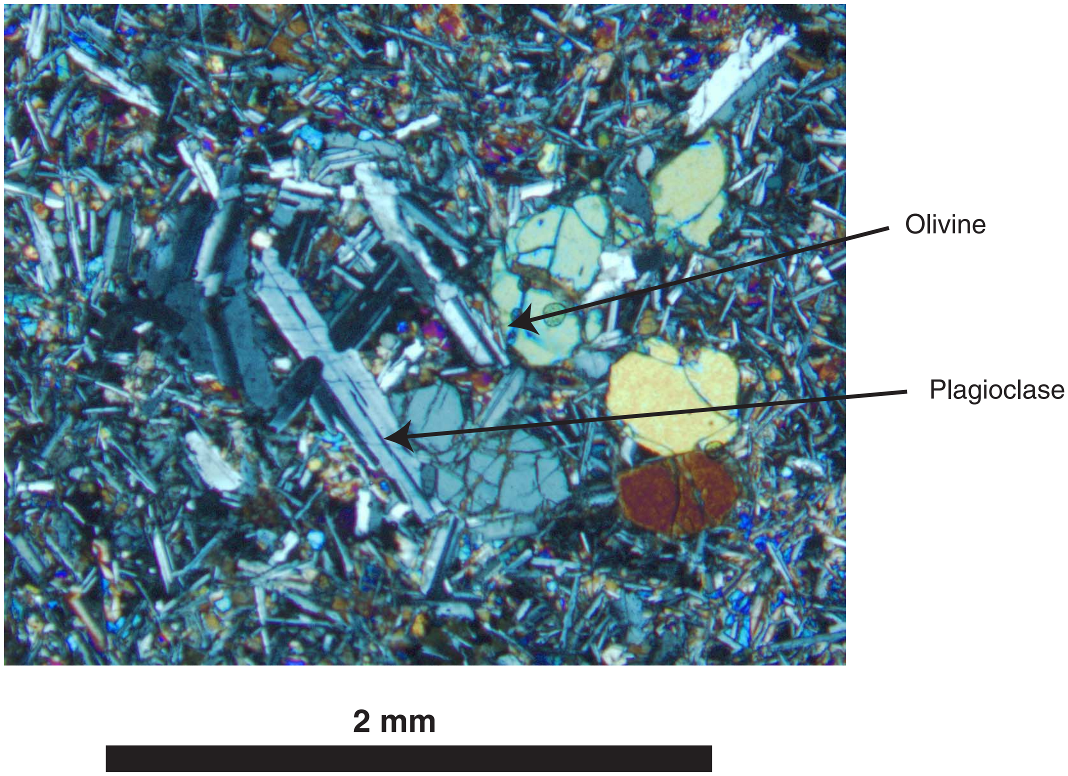


Figure F7. Photograph of interval 187-1160A-3R-1, 10–16 cm, showing a 0.5- to 0.8-cm-wide alteration halo aligned subparallel to the piece margins in an aphyric basalt.

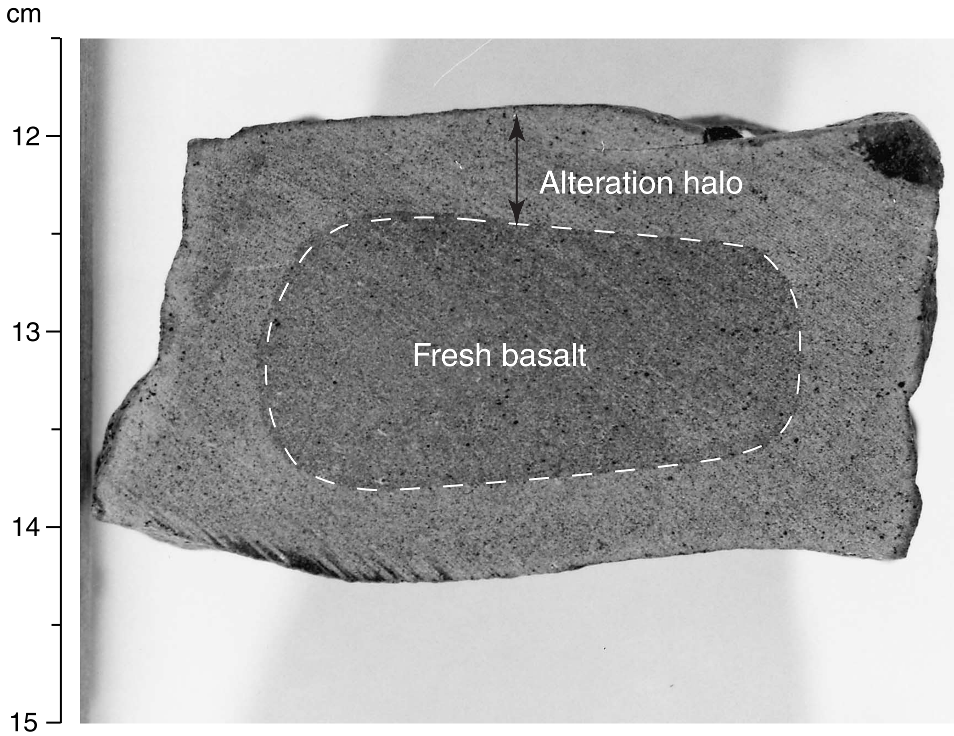


Figure F8. Photomicrograph in plane-polarized light of Sample 187-1160A-2R-1, 16–17 cm (see "Site 1160 Thin Sections," p. 20), showing the boundary between unaltered groundmass with unfilled vesicles (right) and altered groundmass with ~5% smectite replacement and smectite-filled vesicles.

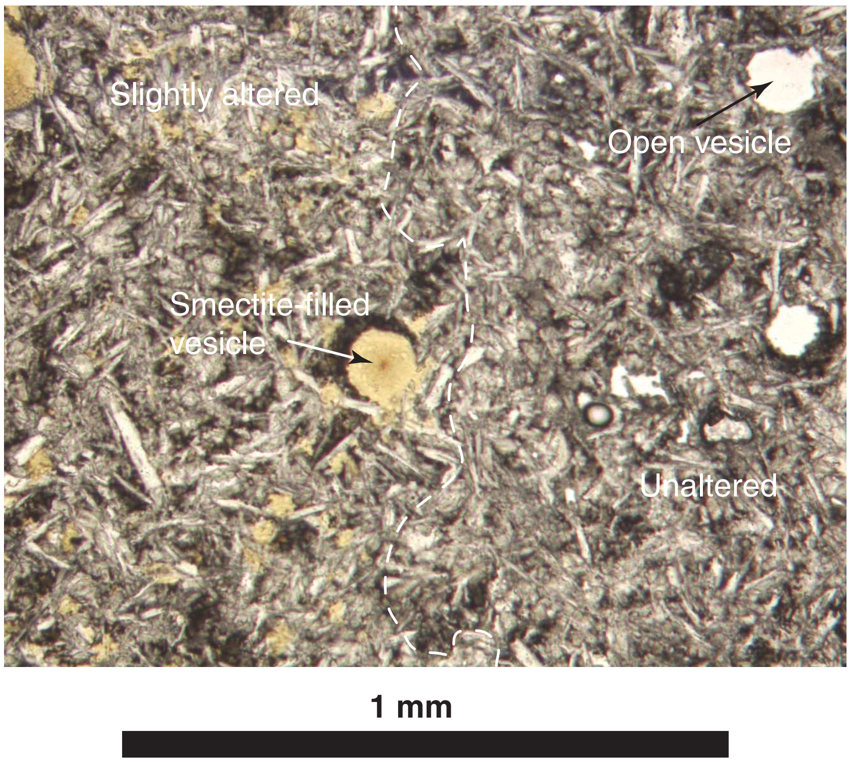


Figure F9. Photograph of interval 187-1160B-6R-1, 64–72 cm, showing basalt of Unit 3 within which an alteration halo is associated with calcite veins and Mn oxide–lined open fractures (alteration Facies I).

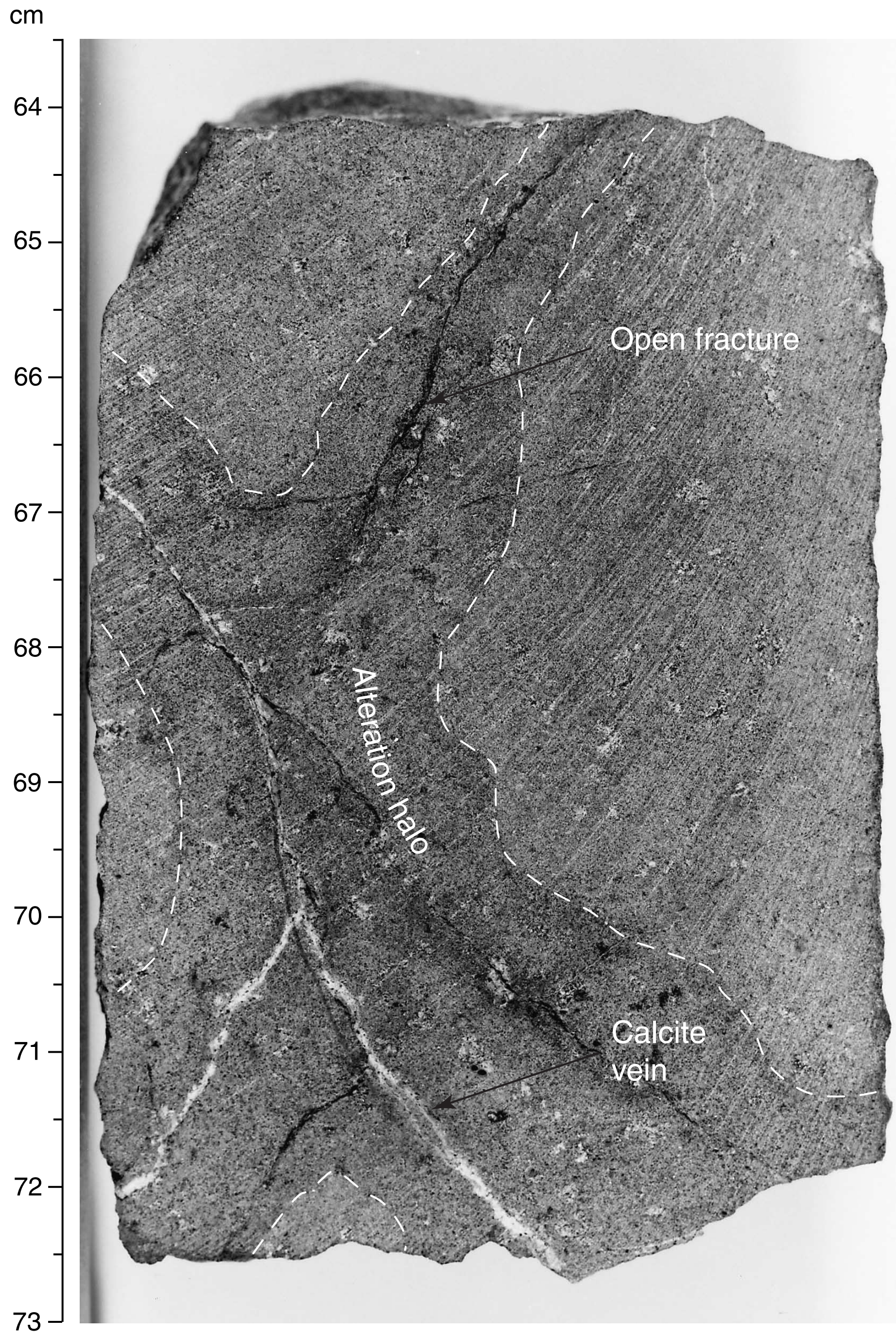


Figure F10. Photograph of interval 187-1160B-5R-1, 42–50 cm, showing a small, 2-cm-long Fe-stained silica vein in basalt from Unit 3 (alteration Facies I).

Figure F11. Photograph of interval 187-1160B-6R-1, 93–102 cm, showing patches of calcite mineralization, some of which are associated with calcite veins (alteration Facies I, Unit 3).

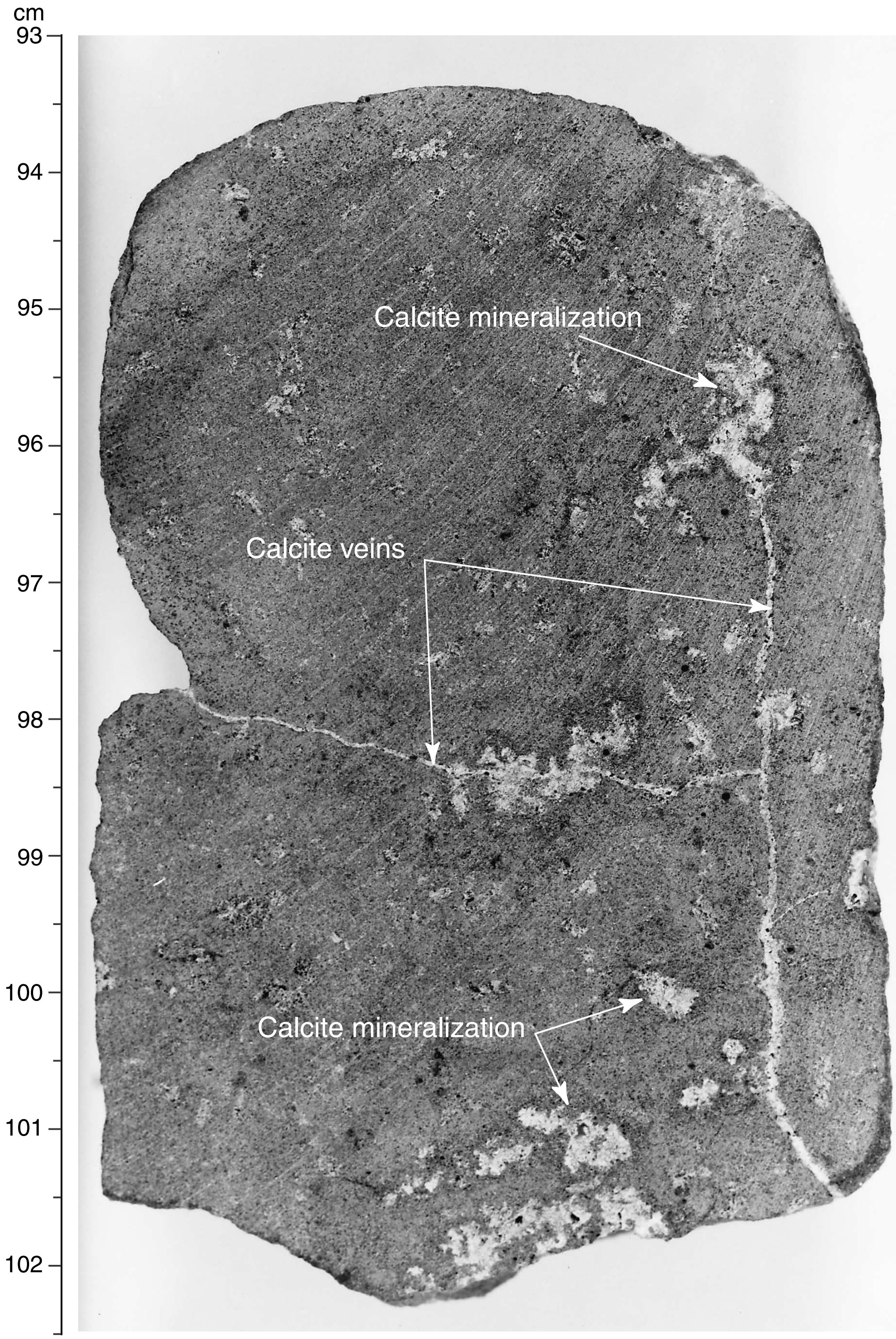


Figure F12. Photomicrograph in plane-polarized light of Sample 187-1160B-6R-1, 106–110 cm (see "Site 1160 Thin Sections," p. 25), showing smectite and Fe oxyhydroxide replacing groundmass clinopyroxene. Note the Fe staining of the plagioclase phenocryst along a microcrack (alteration Facies I, Unit 3). Also note that bubbles are defects in the section.

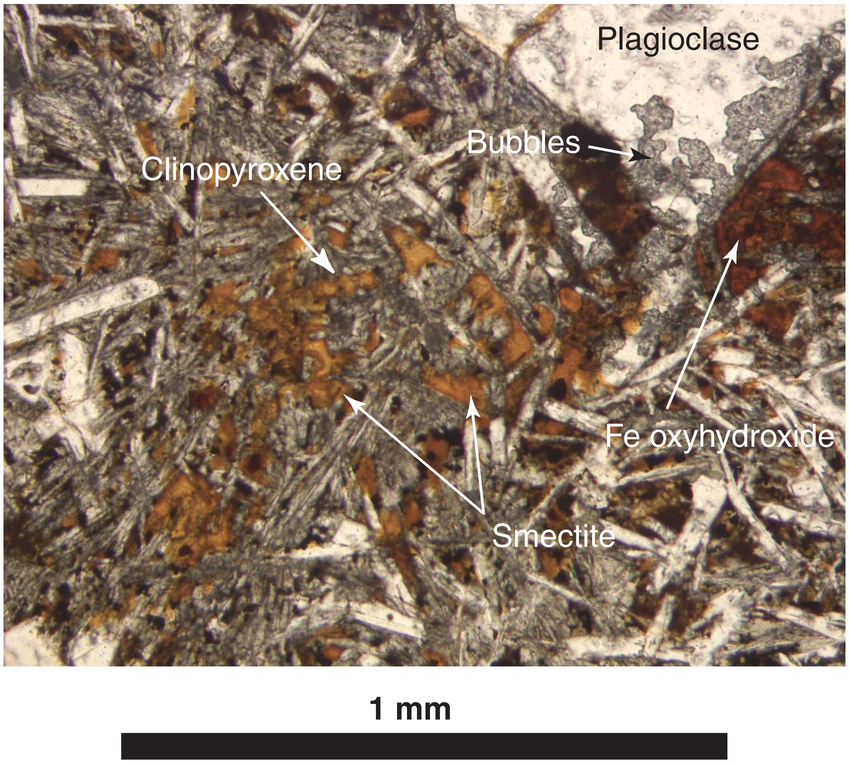


Figure F13. Photograph of interval 187-1160B-8R-1, 22–29 cm, showing a highly altered basalt fragment from Unit 5 (alteration Facies I). The alteration halo grades from a homogeneous buff color in the outer margins to a mottled orange-brown to grayish brown replacement texture toward the center of the piece.

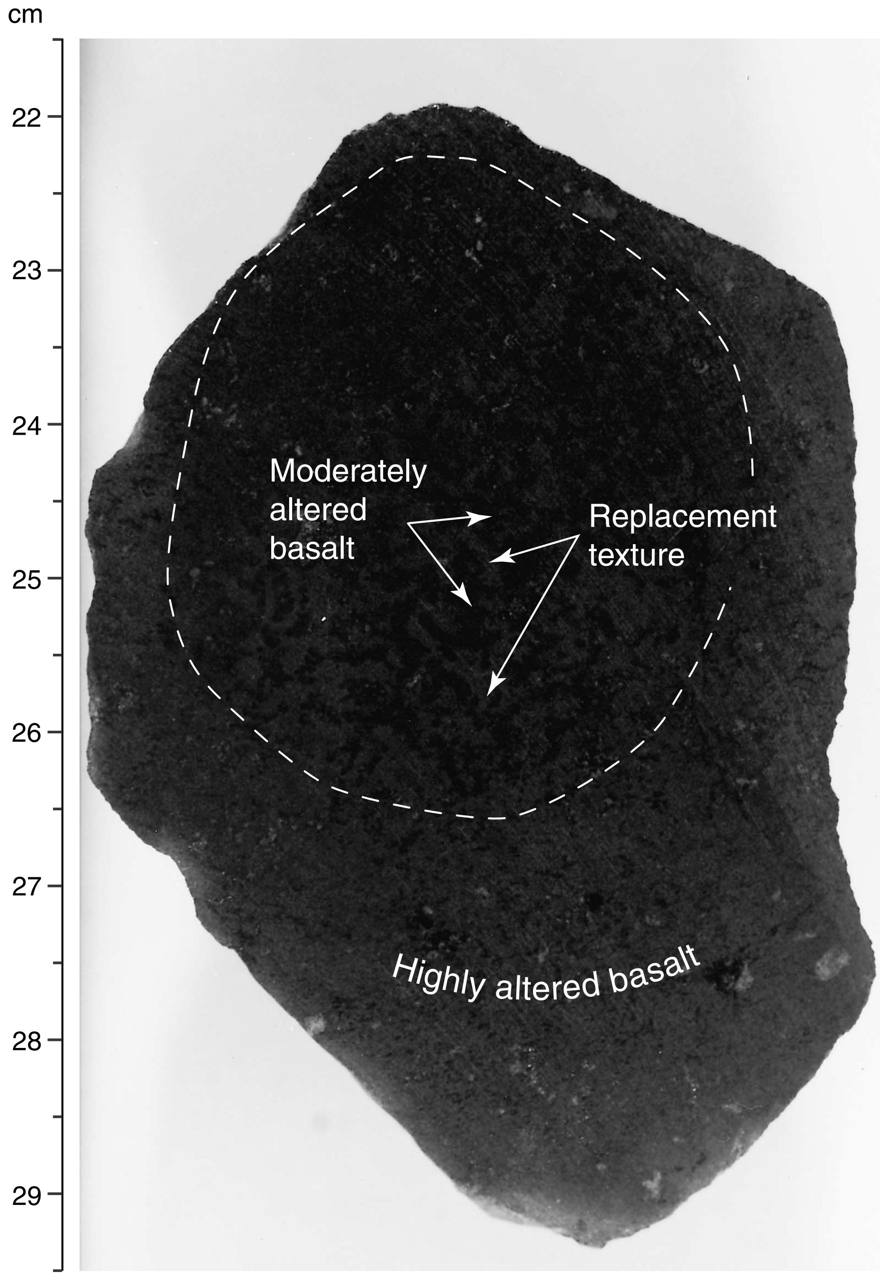


Figure F14. Photograph of interval 187-1160B-7R-1, 5–11 cm (alteration Facies I, Unit 3), showing the quenched margin of a pillow lava, consisting of fresh glass that is covered by a millimeter-thick palagonite layer. Note that the fresh glass is dissected by thin palagonite veins aligned subparallel to the curved glass margin.

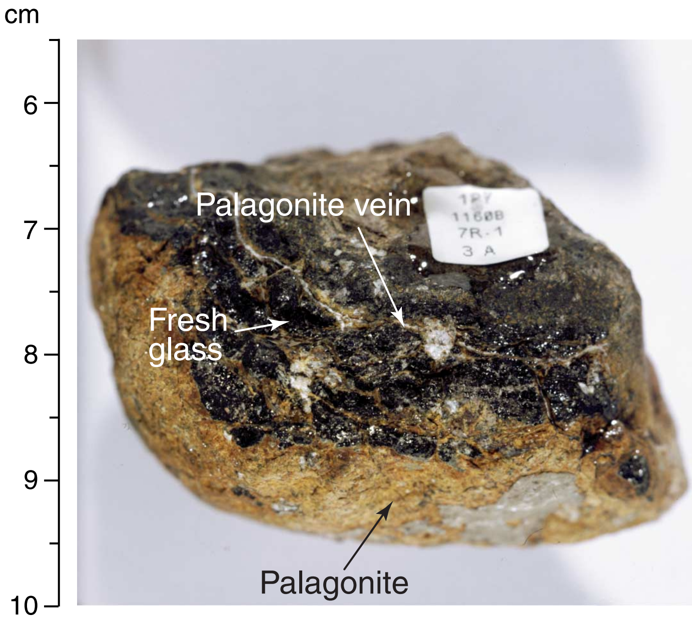


Figure F15. Photomicrograph in plane-polarized light of Sample 187-1160B-7R-1, 53–56 cm (see "Site 1160 Thin Sections," p. 27), showing a chlorite-filled fracture surrounded by a green-tan discoloration halo that contains clay (alteration Facies II, Unit 4).

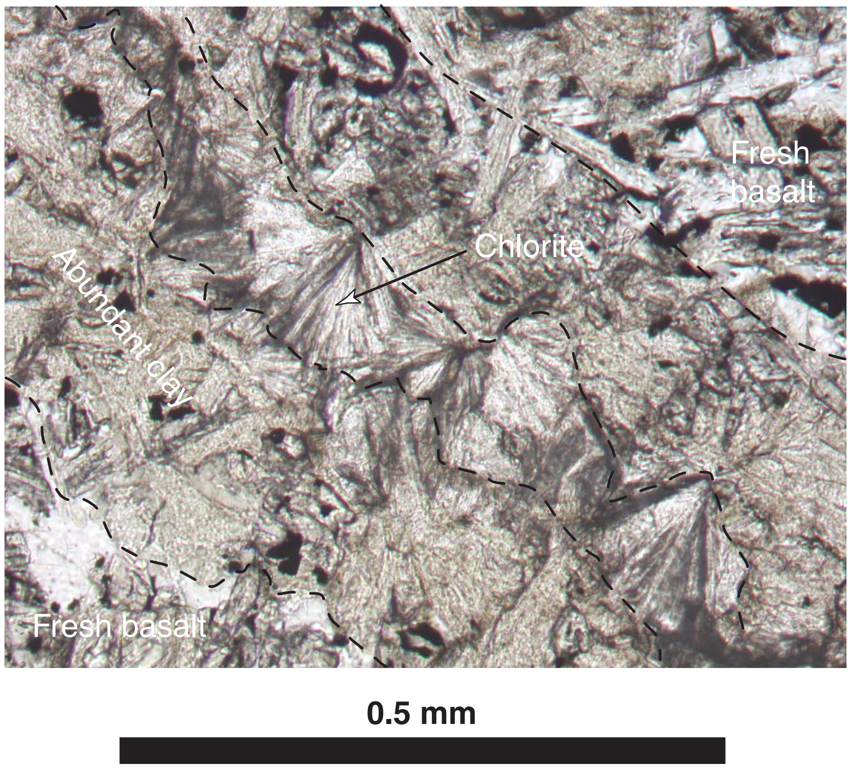


Figure F16. Photograph of interval 187-1160B-4R-1, 116–135 cm, showing fresh massive basalt crosscut by chlorite-lined fractures and thin calcite veins and with minor patchy calcite and chlorite mineralization (1–15 mm) (alteration Facies II, Unit 2).

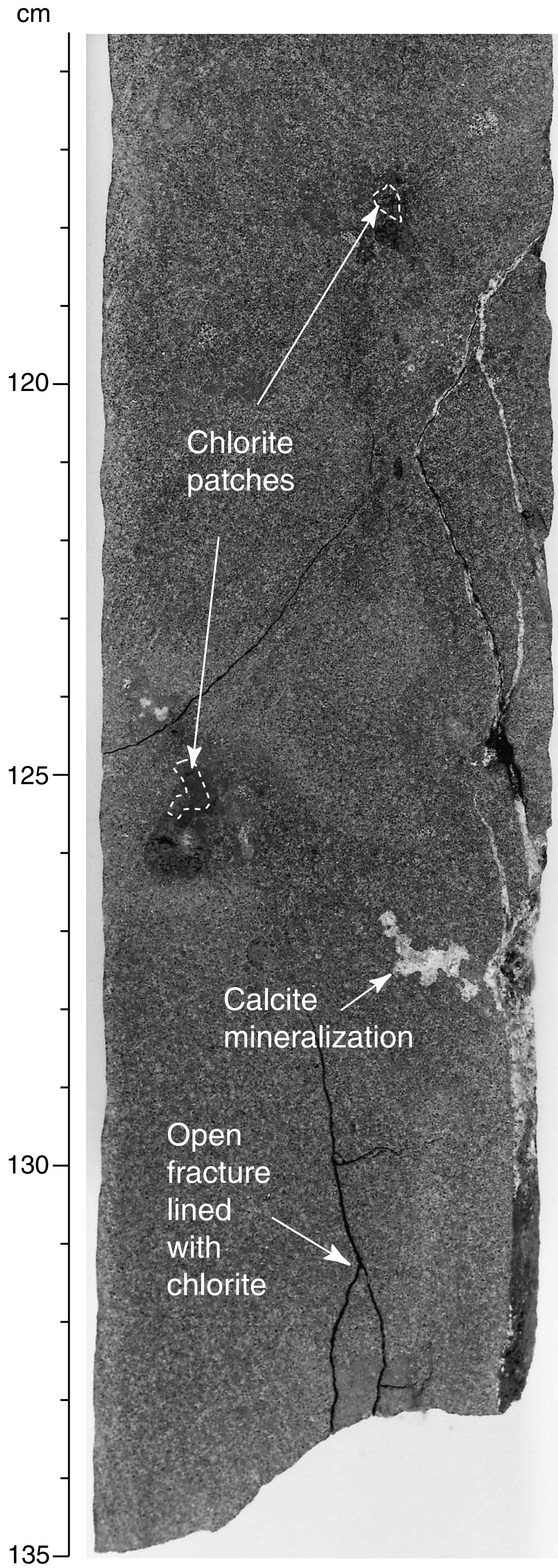


Figure F17. Photograph of interval 187-1160B-4R-2, 1–19 cm, showing the outside of a core in Unit 2 that is crosscut by a calcite + Fe oxyhydroxide–bearing vein surrounded by a ~2.5-cm-wide asymmetric alteration halo (alteration Facies II).

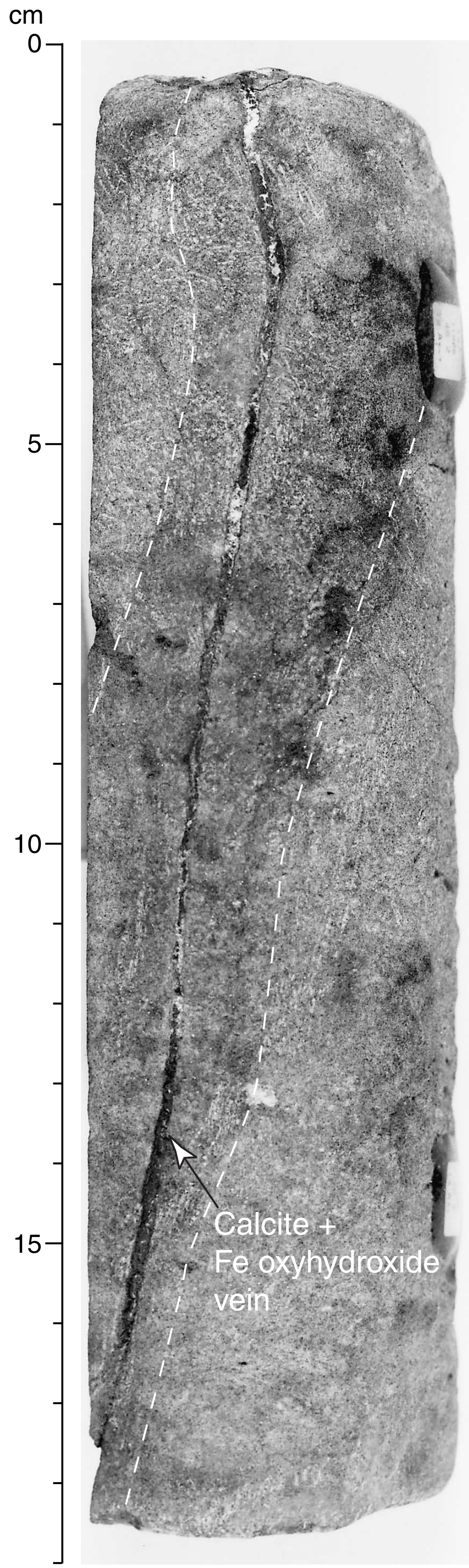


Figure F18. Photomicrograph in plane-polarized light of Sample 187-1160B-4R-1, 59–62 cm (see "Site 1160 Thin Sections," p. 23), showing the unaltered groundmass of massive basalt in Unit 2 (alteration Facies II).

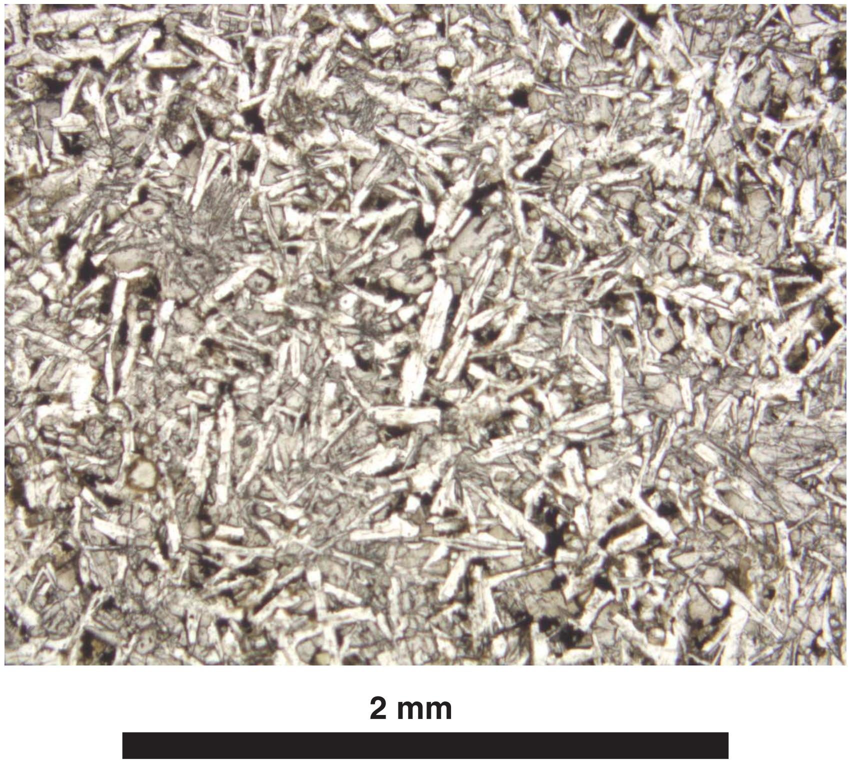


Figure F19. Photomicrograph in plane-polarized light of Sample 187-1160B-9R-3, 8–12 cm (see **"Site 1160 Thin Sections,"** p. 30), showing smectite replacing groundmass and filling vesicles, typical of Facies II alteration (Unit 7).

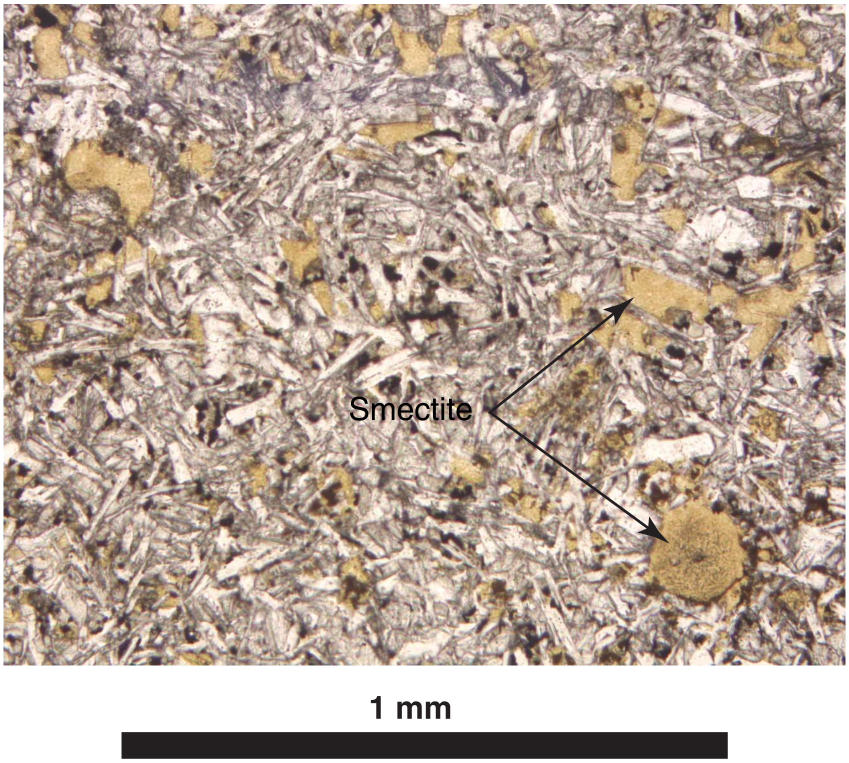


Figure F20. Track chart of the *JOIDES Resolution* single-channel seismic survey line S8. Crosses = 50-shot intervals. Holes 1160A and 1160B (solid circles) are 1.3 and 1.5 km, respectively, north of the prospectus site AAD-14c (open circle).

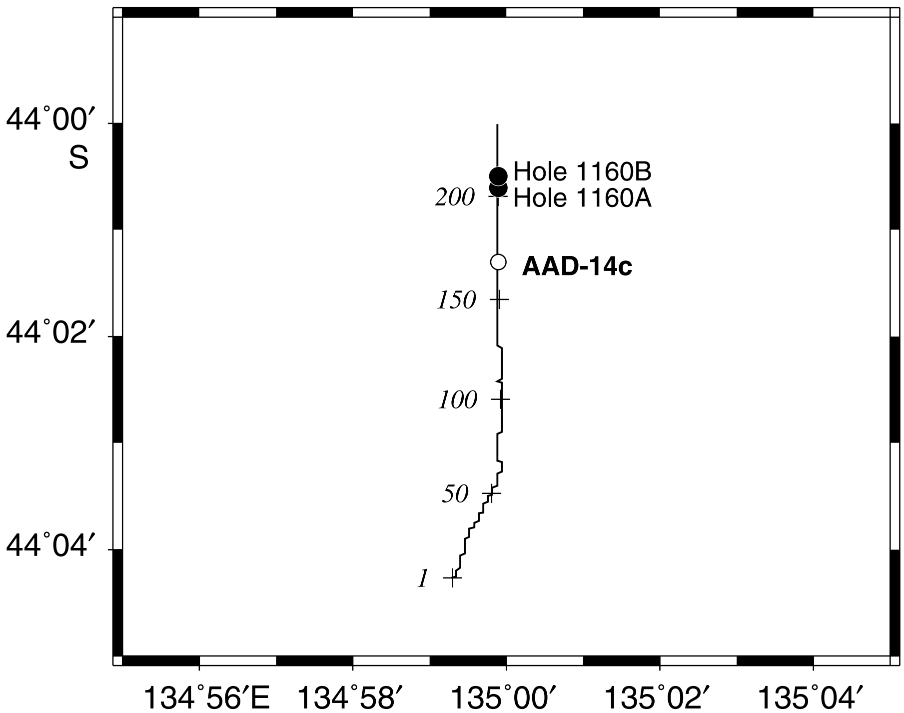


Figure F21. A single-channel seismic profile of line S8 from shotpoints 1 to 232. The large arrow marks the position of Site 1160.

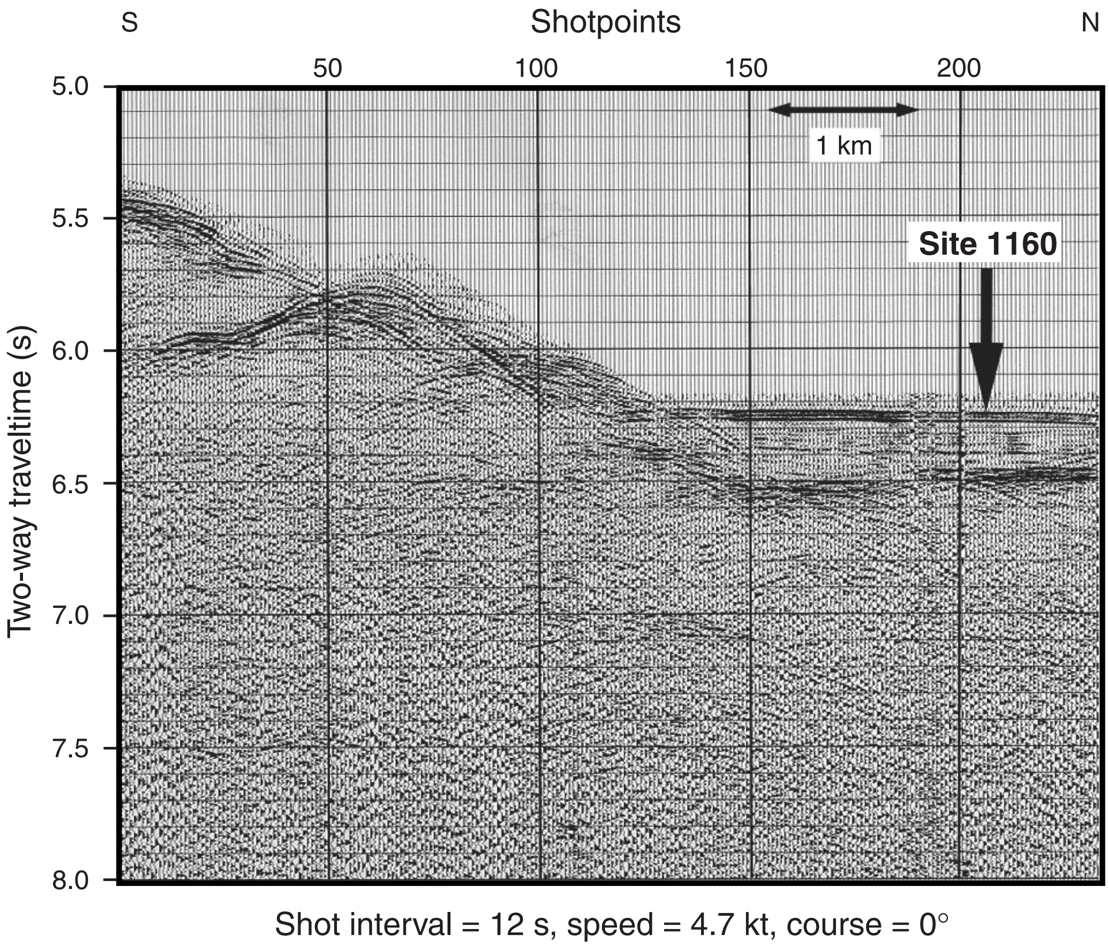


Figure F22. Major element variations vs. MgO for basalts from Holes 1160A and 1160B compared with Segments A2 and A3 axis lavas. All whole-rock analyses are X-ray fluorescence (XRF) results, except for Sample 187-1160B-2R-1, 17–20 cm. Glass analyses are by ICP-AES. Only the averages of XRF or ICP-AES analyses reported in Table T4, p. 41, are plotted. PRT = propagating rift tip lavas.

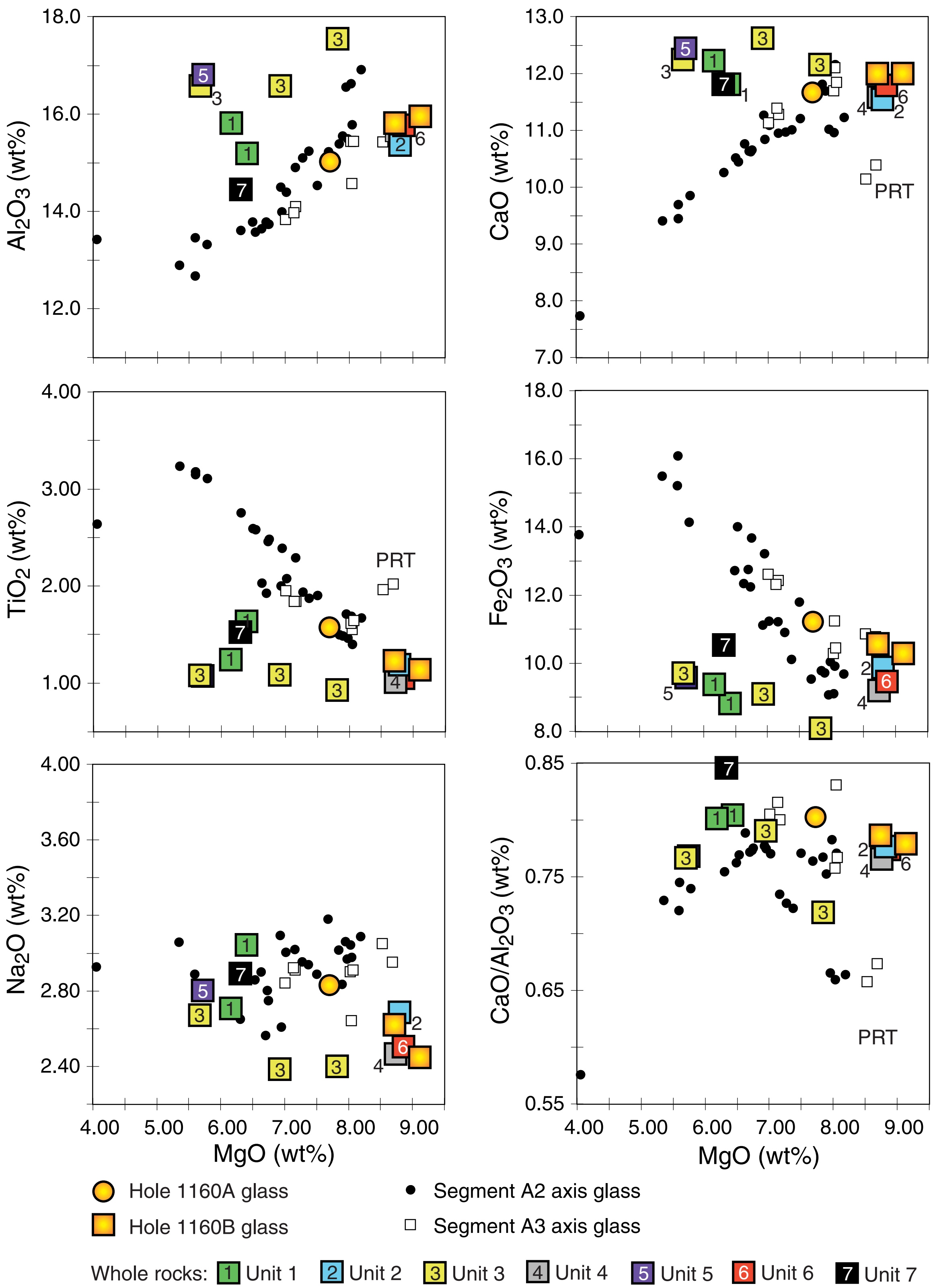


Figure F23. Trace element variations vs. MgO for basalts from Holes 1160A and 1160B.

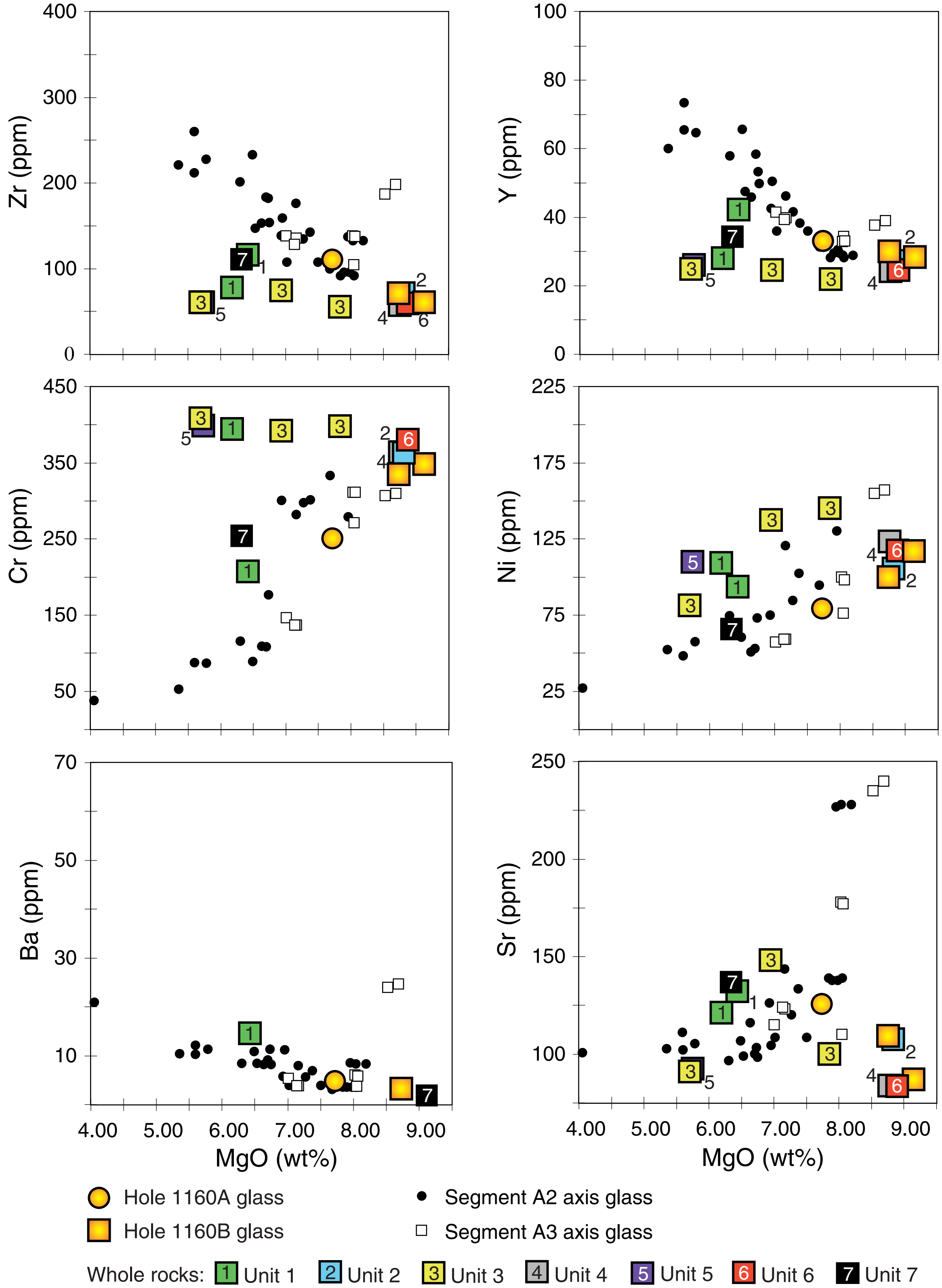


Figure F24. **A.** Variations of Zr/Ba vs. Ba for Holes 1160A and 1160B basaltic glass and whole-rock samples compared with Indian- and Pacific-type mid-ocean-ridge basalt (MORB) fields defined by zero-age Southeast Indian Ridge (SEIR) lavas dredged between 123°E and 133°E. TP = Transitional Pacific; PRT = propagating rift tip lavas. **B.** Variations of Na_2O/TiO_2 vs. MgO for Holes 1160A and 1160B basaltic glass and whole-rock samples compared with Indian- and Pacific-type MORB fields defined by zero-age SEIR lavas dredged between 123°E and 133°E. A dashed line separates Indian- and Pacific-type zero-age SEIR basalt glasses.

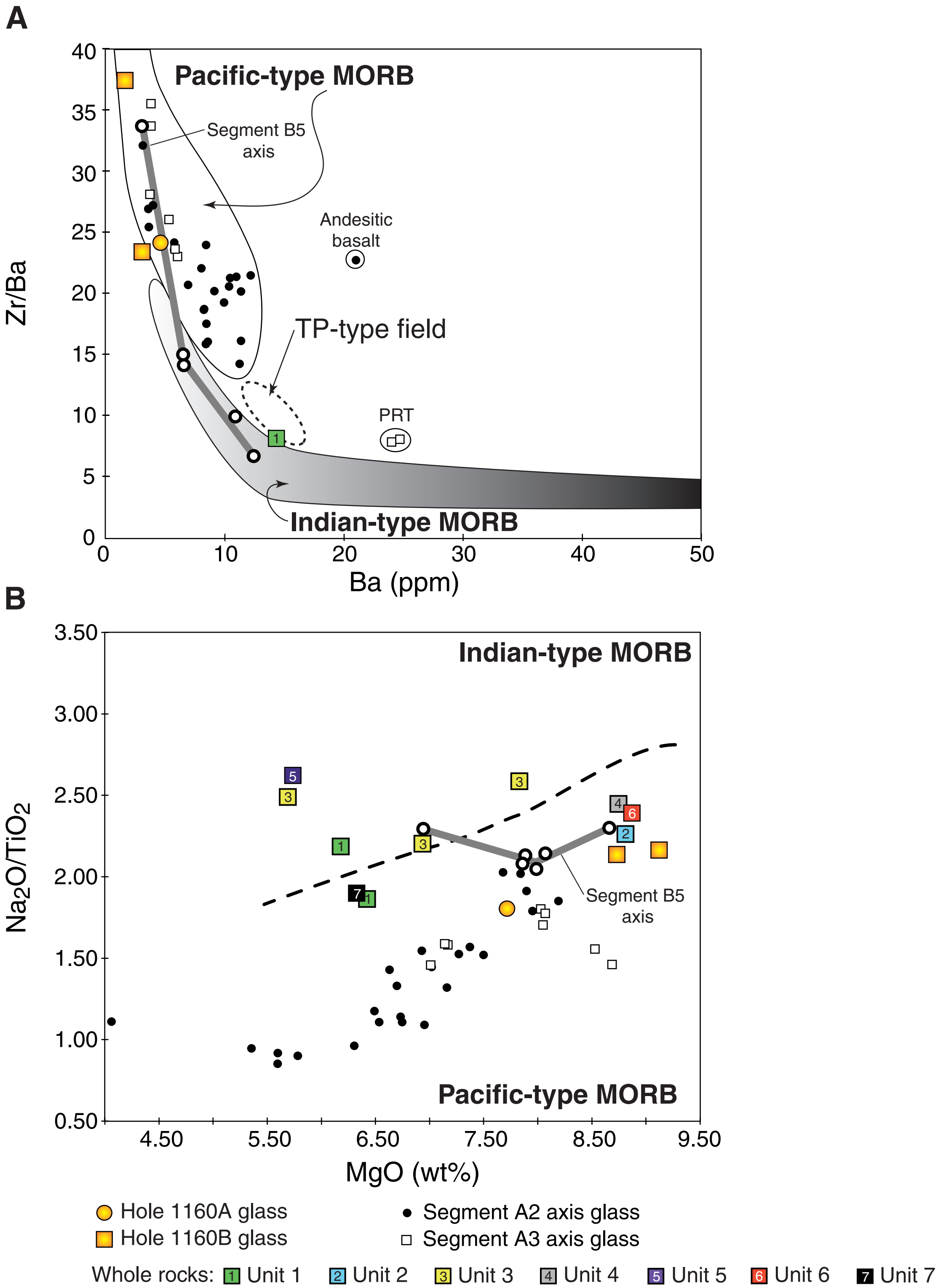


Table T1. Coring summary, Site 1160.

Hole 1160A
Latitude: 44°0.5987′S
Longitude: 134°59.8971′E
Time on hole: 1730 hr, 21 Dec 99–1045 hr, 22 Dec 99 (17.25 hr)
Time on site: 1730 hr, 21Dec 99–0600 hr, 24 Dec 99 (84.5 hr)
Seafloor (drill-pipe measurement from rig floor, mbrf): 4636.4
Distance between rig floor and sea level (m): 11.2
Water depth (drill-pipe measurement from sea level, m): 4625.2
Total depth (from rig floor, mbrf): 4807.5
Total penetration (mbsf): 171.0
Total length of cored section (m): 5.1
Total length of drilled intervals (m): 166.0
Total core recovered (m): 8.43
Core recovery (%): 8.4
Total number of cores: 2
Total number of drilled cores: 1

Hole 1160B
Latitude: 44°0.4938′S
Longitude: 134°59.9008′E
Time on hole: 1045 hr, 22 Dec 99–0600 hr, 24 Dec 99 (67.25 hr)
Seafloor (drill-pipe measurement from rig floor, mbrf): 4636.4
Distance between rig floor and sea level (m): 11.2
Water depth (drill-pipe measurement from sea level, m): 4625.2
Total depth (from rig floor, mbrf): 4841.6
Total penetration (mbsf): 205.2
Total length of cored section (m): 45.1
Total length of drilled intervals (m): 160.1
Total core recovered (m): 13.01
Core recovery (%): 28.8
Total number of cores: 8
Total number of drilled cores: 1

Core	Date (Dec 1999)	Ship local time	Depth (mbsf)		Length (m)		Recovery (%)	Comment
			Top	Bottom	Cored	Recovered		
187-1160A-								
1W	22	0555	0.0	166.0	166.0	1.67	N/A	
2R	22	0740	166.0	169.6	3.6	0.21	5.8	
3R	22	0945	169.6	171.1	1.5	0.22	14.7	
				Cored:	5.1	0.43	8.4	
				Drilled:	166.0			
				Total:	171.1			
187-1160B-								
1W	22	1745	0.0	160.1	160.1	0.48	N/A	
2R	22	2130	160.1	164.5	4.4	0.54	12.3	Whirl-Pak
3R	23	0040	164.5	169.5	5.0	0.63	12.6	
4R	23	0430	169.5	174.1	4.6	2.63	57.2	
5R	23	0700	174.1	178.9	4.8	0.71	14.8	
6R	23	1015	178.9	188.0	9.1	2.23	24.5	
7R	23	1430	188.0	193.7	5.7	3.09	54.2	
8R	23	1715	193.7	197.2	3.5	0.77	22.0	
9R	23	2200	197.2	205.2	8.0	2.41	30.1	
				Cored:	45.1	13.01	28.8	
				Drilled:	160.1			
				Total:	205.2			

Notes: N/A = not applicable. This table is also available in **ASCII** format.

Table T2. Summary of lithologic units, Site 1160.

Hole	Unit	Lithology	Cored interval		Alteration	Lava type
			From	To		
1160A	1	Aphyric basalt	2R-1 (Piece 1)	3R-1 (Piece 8)	Slight to moderate	Pillow basalt rubble
1160B	1	Aphyric basalt	1W-1 (Piece 1)	4R-1 (Piece 5)	Moderate	Pillow basalt
1160B	2	Aphyric basalt	4R-1 (Piece 6)	4R-2 (Piece 3)	Slight	Massive flow
1160B	3	Moderately plagioclase phyric basalt	4R-2 (Piece 4)	7R-1 (Piece 9)	Moderate to high	Pillow basalt
1160B	4	Moderately plagioclase ± olivine phyric basalt	7R-1 (Piece 10)	8R-1 (Piece 1)	Slight	Massive flow
1160B	5	Moderately plagioclase-olivine phyric basalt	8R-1 (Piece 2)	9R-1 (Piece 17)	Moderate to high	Pillow basalt
1160B	6	Moderately plagioclase phyric basalt	9R-1 (Piece 18)	9R-2 (Piece 15)	Slight to moderate	Massive flow
1160B	7	Aphyric basalt	9R-2 (Piece 16)	9R-3 (Piece 5)	Slight	Pillow basalt

Note: This table is also available in **ASCII** format.

Table T3. Rock samples incubated for enrichment cultures and prepared for DNA analysis and electron microscope studies and microspheres evaluated for contamination studies.

			Enrichment cultures				DNA analysis		SEM/TEM samples	
Core	Depth (mbsf)	Sample type	Anaerobic	Aerobic	Microcosm*	High pressure	Wash	Fixed	Fixed	Air dried
187-1160B-										
1W	0-160.1	Chilled margin	9	3	1 Mn	X	X	X	X	X
4R	169.5-174.1	Chilled margin	9	3	1 Fe/S	X	X	X		X
6R	178.9-188.0	Fine-grained basalt	9	3			X	X		X
8R	193.7-197.2	Chilled margin			1 Mn + 1 Fe/S		X	X	X	X

Notes: * = microcosm for iron and sulfur (Fe/S) or manganese (Mn) redox cycles; SEM = scanning electron microscope; TEM = transmission electron microscopy; X = samples prepared on board. This table is also available in **ASCII** format.

Table T4. Glass and whole-rock major and trace element compositions of basalts, Site 1160. (**See table notes.** Continued on next page.)

	Hole 1160A		Hole 1160B														
Core, section:	3R-1	3R-1	2R-1	3R-1	3R-1	3R-1	3R-1	4R-1	4R-1	4R-2	4R-2	6R-1	6R-1	7R-1	7R-1	7R-1
Interval (cm):	19-21	19-21	21-25	7-16	7-16	63-66	63-66	59-62	59-62	122-126	122-126	110-113	110-113	25-29	25-29	53-56
Depth (mbsf):	169.79	169.79	160.31	164.57	164.57	165.13	165.13	170.09	170.09	172.22	172.22	180.00	180.00	188.25	188.25	188.53
Piece:	5	5	5	3	3	13	13	8C	8C	7C	7C	19A	19A	6	6	10
Unit:	1	1	1	1	1	1	1	2	2	3	3	3	3	3	3	4
Analysis:	ICP	ICP	ICP	ICP	ICP	XRF	XRF	XRF	XRF	XRF	XRF	XRF	XRF	XRF	XRF	XRF
Rock type:	Glass	Glass	Aphyric basalt	Glass	Glass	Aphyric basalt		Aphyric basalt		Moderately plagioclase phyric basalt		Moderately plagioclase phyric basalt		Moderately plagioclase phyric basalt		Moderately plagioclase phyric basalt
Major element (wt%)																
SiO_2	51.13	50.49	51.89	49.71	50.45	49.70	49.95	49.20	49.40	48.57	48.08	48.61	48.53	48.29	49.01	48.12
TiO_2	1.58	1.56	1.63	1.22	1.24	1.23	1.25	1.19	1.19	0.92	0.94	1.09	1.08	1.07	1.08	1.01
Al_2O_3	14.98	15.08	15.19	15.84	15.78	15.79	15.85	15.34	15.40	17.63	17.46	16.58	16.57	16.51	16.64	15.65
Fe_2O_3	11.23	11.20	8.80	10.40	10.71	9.30	9.41	9.83	9.88	8.11	8.03	9.05	9.10	9.63	9.74	9.18
MnO	0.19	0.20	0.16	0.17	0.17	0.14	0.15	0.15	0.15	0.11	0.11	0.14	0.15	0.15	0.15	0.13
MgO	7.76	7.68	6.43	8.56	8.93	6.14	6.22	8.86	8.79	7.90	7.78	6.92	6.96	5.71	5.67	8.76
CaO	12.09	12.03	12.21	12.39	12.46	12.64	12.69	11.93	11.91	12.67	12.51	13.13	13.05	12.64	12.74	11.97
Na_2O	2.81	2.86	3.05	2.62	2.63	2.71	2.71	2.67	2.71	2.45	2.36	2.42	2.36	2.65	2.70	2.47
K_2O	0.09	0.09	0.28	0.07	0.07	0.23	0.23	0.07	0.07	0.06	0.06	0.20	0.20	0.20	0.20	0.04
P_2O_5	0.14	0.15	0.15	0.11	0.09	0.09	0.09	0.09	0.09	0.07	0.07	0.08	0.09	0.08	0.08	0.06
LOI						1.14	1.14	0.66	0.66	0.81	0.81	1.63	1.63	1.51	1.51	0.77
CO_2																
H_2O																
Total:	102.01	101.34	99.78	101.08	102.53	99.11	99.69	99.99	100.25	99.30	98.21	99.85	99.72	98.44	99.52	98.16
Trace element (ppm)																
Nb						3		3		3		3		2		3
Zr	110	111	116	73	70	78		71		55		74		61		58
Y	36	30	42	29	32	28		27		22		25		25		24
Sr	131	122	133	109	112	122		108		101		149		92		85
Rb						5		0		0		4		4		0
Zn						84		72		65		72		90		70
Cu						94		88		73		85		92		82
Ni	68	72	83	87	90	97		94		129		122		72		110
Cr	245	257	207	338	333	394		363		398		392		409		364
V						247		238		197		231		250		218
Ce						20		18		11		20		12		12
Ba	5	5	14		3											
Sc	44	46	44	40	39											

Table T4 (continued).

	Hole 1160B							
Core, section:	8R-1	8R-1	9R-1	9R-1	9R-1	9R-1	9R-3	9R-3
Interval (cm):	66-70	66-70	5-7	5-7	125-129	125-129	8-12	8-12
Depth (mbsf):	194.36	194.36	197.25	197.25	198.45	198.45	200.20	200.20
Piece:	14	14	2	2	21	21	3	3
Unit:	5	5	5	5	6	6	7	7
Analysis:	XRF	XRF	ICP	ICP	XRF	XRF	XRF	XRF
Rock type:	Moderately plagioclase-olivine phyric basalt		Glass	Glass	Moderately plagioclase phyric basalt		Aphyric basalt	
Major element (wt%)								
SiO_2	49.38	49.04	49.21	50.06	49.45	48.93	49.42	50.02
TiO_2	1.08	1.06	1.14	1.12	1.04	1.06	1.52	1.53
Al_2O_3	16.85	16.76	15.99	15.93	15.77	15.77	14.36	14.55
Fe_2O_3	9.36	9.76	10.24	10.28	9.48	9.40	10.43	10.61
MnO	0.14	0.13	0.16	0.17	0.13	0.14	0.17	0.17
MgO	5.74	5.73	9.19	9.08	8.90	8.87	6.28	6.38
CaO	12.94	12.85	12.40	12.44	12.25	12.14	12.11	12.32
Na_2O	2.82	2.79	2.41	2.50	2.50	2.52	2.88	2.91
K_2O	0.15	0.15	0.04	0.04	0.04	0.05	0.25	0.26
P_2O_5	0.07	0.07	0.08	0.09	0.07	0.06	0.14	0.14
LOI	1.50	1.50			0.71	0.71	0.72	0.72
CO_2								
H_2O								
Total:	100.03	99.84	100.87	101.70	100.34	99.65	98.28	99.61
Trace element (ppm)								
Nb	3				3		4	
Zr	61		57	64	59		111	
Y	26		29	28	25		34	
Sr	94		91	86	85		138	
Rb	2				0		6	
Zn	70				66		91	
Cu	94				89		75	
Ni	98		100	107	104		59	
Cr	399		339	359	381		254	
V	232				223		295	
Ce	12				11		29	
Ba			2	2				
Sc			37	39				

Notes: LOI = loss on ignition. This table is also available in **ASCII** format.