HOLE 669A

Date occupied: 31 May 1986, 0815L
Date departed: 2 June 1986, 0500L
Time on hole: 1 day, 20 hr, 45 min (includes television-sonar survey time)
Position: 23°31.02'N, 45°02.75'W
Water depth (sea level; corrected m; echo-sounding): 1971.2
Water depth (rig floor; corrected m; echo-sounding): 1983.3
Bottom felt (m, drill pipe): 1979
Distance between rig floor and sea level (m): 11.1
Total depth (rig floor; m): 1983
Penetration (m): 4.0
Number of cores: 1
Total length of cored section (m): 4.0
Total core recovered (m): 0.10
Core recovery (%): 2.5
Sediment: basalt rubble with intermixed sediment

Basement:
Depth sub-bottom (m): approximately 4 m (resistance to drilling increased markedly at approximately 4 mbsf, interpreted as being the top of the basement).
Nature: unknown—none recovered
Velocity range of basalt rubble (km/s): 5.59

Principal Results: JOIDES Resolution occupied Site 669 from 31 May to 2 June 1986 and drilled in a water depth of 1979 m. The site was chosen on top of a hill at 23°31.02'N, 45°02.75'W, on the western flank of the rift valley and southwestern slope of the deep, funnel-shaped nodal basin marking the intersection of the median valley and the Kane Fracture Zone. Surface exposures of plutonic rocks, mainly gabbros, had been located in this area during previous ALVIN diving programs.

A site survey was conducted using the television-sonar system, which was run down on the coaxial cable without the drill pipe. The flat bottom appeared to be covered with basaltic rubble and sediment. We then spudded-in Hole 669 successfully, using a positive displacement coring motor (PDCM). Drilling progress was monitored by the television-sonar system, which had been run back down on the drill string. Four meters of penetration were realized rapidly. At this point, the penetration rate fell off dramatically, probably indicating that the gabbro basement had been reached. Despite an increase in the flow rate through the motors and an increase in the weight on the bit, the PDCM continually stalled. Moreover, a large piece of rubble became jammed in the core catcher, preventing retrieval. Drilling operations at Site 669A were then suspended.

We penetrated a total of 4 m in Hole 669A and recovered 0.1 m of core (two pieces of basalt from the rubble cover). The two pieces of aphyric basalt are tholeiitic basalts, similar to some of the olivine phyric basalts collected from the walls of the Kane Fracture Zone, and show evidence of incipient alteration characterized by the “dark halos” stage (mainly orange smectites, green to yellow clays, and iron hydroxyxides). Aragonite crystals were found in some vesicles and mircaroles.

BACKGROUND AND OBJECTIVES

One of the main goals of Leg 109 was testing the feasibility of unsupported spud-in and coring in exposed plutonic rock outcrops in the Kane Fracture Zone area. The success of such a test could have important consequences on the future of drilling plans in this difficult environment.

The ALVIN diving program in 1980 (Karson and Dick, 1983) and the Sea Beam map of Detrick et al. (1985) provided the survey data used for site selection. Exposures of plutonic rocks had been located on the western flank of the rift valley and southwestern slope of the deep, funnel-shaped nodal basin marking the intersection of the median valley and the Kane Fracture Zone (Fig. 1). The nodal basin, which is >6000 m below sea level (mbsl), was ruled out as a possible site because it would be time consuming for the pipe runs, unsafe for the television-sonar system, and probably difficult to drill because of a large thickness of rubble. To minimize these problems, we chose the top of a hill at 23°31.02'N, 45°02.75'W for the following reasons: (1) during ALVIN dive number 1012, plutonic gabbros were observed and sampled along small scarps in several places on the flanks of the hill; (2) its flat surface and shallow depth, nearly 2000 mbsl, were thought to be adequate for spudding-in, which would facilitate short pipe runs; and (3) this topographic high is the dominant elevation of the whole area, so that the rubble thickness should logically be at a minimum.

With these criteria in mind, we selected Site 669, located on a flat area just on the southeastern flank of the hill, at the 2000-m isobath on the Sea Beam map (Fig. 2). Our scientific and engineering objectives were to try spudding-in over a basement outcrop and to use the PDCM to establish and core a hole in gabbric plutonic rock. We expected the core to yield important in-
because of the poor penetration rate, we pulled the bit out of the hole. We planned to offset 100 m in hopes of finding a more desirable drilling location; however, we encountered difficulties while attempting to retrieve the core barrel. After making three unsuccessful attempts to retrieve the barrel, we tripped the drilling assembly out of the hole. A large piece of rubble, jammed in the core catcher and throat of the bit, had induced a torsional load on the core-barrel system, which resulted in torsional failure of the threaded connection between the two 15-ft core-barrel sections. The induced torsional load also backed off several other core-barrel system connections to varying degrees.

We suspended drilling operations at Hole 669A because of lack of basement penetration and mechanical problems with the PDCM. A total of 4-m penetration was made in Hole 669A and 0.1 m of core was recovered (Table 1). While in transit to Hole 395A, we made repairs to the coring motor, readying it for use later in the leg.

LITHOSTRATIGRAPHY

Drilling operations at Site 669A recovered two pieces of macroscopically aphyric basalt. Only one plagioclase phenocryst is visible in Sample 109-669A-1D-1, 11-13 cm. Vesicles (0.2-1.0 mm) are round and either empty, partly filled with microcrystalline groundmass, or lined by secondary minerals. Irregularly shaped mafic minerals are also partly filled by secondary minerals.

One thin section of Sample 109-669A-1D-1, 7-9 cm, and two thin sections of Sample 109-669A-1D-1, 11-13 cm, were prepared. The basalts are predominantly fresh with <2%-4% alteration products, except in the marginal halos (see "Alteration section", this chapter). The groundmass texture in both thin sections of Sample 109-669A-1D-1, 11-13 cm, varies from spherulitic-subvariolitic to felty (microcrystalline intergranular texture; average diameter, 0.1 mm; MacKenzie et al., 1982; Fig. 3), whereas it is subvariolitic to microlitic and coarser grained (average diameter, 0.2 mm) in Sample 109-669A-1D-1, 7-9 cm, thin section. The mode contains as much as 0.6% olivine phenocrysts (Table 2), which are isolated or in clusters. Individual olivine phenocrysts (0.2-0.6 mm) are euhedral to anhedral, and some contain light-brown devitrified glass and colorless bubbles; containing nondevitrified glass inclusions (Fig. 4). The groundmass in both samples is composed of plagioclase-clinoxyroxene and clinoxyroxene spherulites, olivine microphenocrysts, and mesostasis. The mesostasis (20%-24%) in fine-grained samples, 54% in the coarser grained Sample 109-669A-1D-1, 7-9 cm) consists of plagioclase and clinoxyroxene microlites, interstitial glass, and opaque minerals. The opaque minerals are dendritic titanomagnetite, needlelike ilmenite (only in Sample 109-669A-1D-1, 7-9 cm, thin section), and sulfide, listed in order of decreasing abundances. The spherulites and variolelike microstructures (0.5-1.2 mm) are formed by acicular plagioclase (0.1-0.6 mm in diameter but as much as 2 mm in length in Sample 109-669A-1D-1, 7-9 cm), and bladed clinoxyroxene (0.1-0.4 mm), radiating from nuclei of plagioclase. Olivine microphenocrysts (<0.1 mm in Sample 109-669A-1D-1, 11-13 cm, <0.2 mm in Sample 109-669A-1D-1, 7-9 cm) exhibit quenched morphology similar to the swallowtail shapes described by Bryan (1972) and are attached to plagioclase microlites. Olivine microphenocrysts account for 2.6%-6% of the groundmass. Plagioclase (0.05-0.6
mm wide) is acicular to hopper shaped and is found as bundles or in close association with clinopyroxene as spherulites (Figs. 5 and 6). Plagioclase content varies from 26% to 33% of the groundmass. Clinopyroxene (0.1-0.4 mm) is a microcrystalline groundmass phase interpenetrated with plagioclase microlites, and its shape ranges from plumose to arborescent to spherulitic (Fig. 6). Modal groundmass clinopyroxene varies from 32% to 38% in both of the Sample 109-669A-1D-1, 11-13 cm, thin sections.

Spherical segregation vesicles (0.5-1.0 mm) that have been completely filled by residual liquid are also present. The residual liquid has crystallized into a microcrystalline to cryptocrystalline texture and mineral composition, which are both similar to the mesostasis. The clinopyroxene is more arborescent in the vesicles. Sharp color differences between the central part (light brown), the outer rim of the segregation vesicles (dark brown), and the mesostasis (medium dark brown) make them easily recognized.

Figure 2. Detailed bathymetry around Site 669. Depths >4000 m are shaded. Sea Beam map after Detrick et al. (1985).

Table 1. Coring summary, Site 669.

<table>
<thead>
<tr>
<th>Core no.</th>
<th>Date (June 1986)</th>
<th>Time on deck</th>
<th>Total depth (m)</th>
<th>Sub-bottom depths (m)</th>
<th>Advanced (m)</th>
<th>Length cored (m)</th>
<th>Length recovered (m)</th>
<th>Recovery (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>109-669A-1D</td>
<td>0200</td>
<td>1979-1983</td>
<td>0.0-4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>0.10</td>
<td>2.5</td>
<td></td>
</tr>
</tbody>
</table>

SITE 699
Figure 3. Detail of subvariolitic texture in thin section of Sample 109-669A-1D-1, 11-13 cm, showing radiating clinopyroxene and plagioclase. Field of view = 3 mm.

Figure 4. Olivine phenocryst with glass inclusion in thin section of Sample 109-669A-1D-1, 11-13 cm. Field of view = 3 mm.

Table 2. Modal data, Hole 669A^a^.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Piece no.</th>
<th>Texture^b^</th>
<th>Phenocryst^c^</th>
<th>Groundmass^d^</th>
</tr>
</thead>
<tbody>
<tr>
<td>109-669A-1D-1, 07-09 cm</td>
<td>1</td>
<td>VAR-MIC</td>
<td>OL 2.6 PLAG 29.1 CPX 10.8</td>
<td>MESO 254.0 OPAQ 1.7 GLAS 1.0 VES 1</td>
</tr>
<tr>
<td>109-1D-1, 11-13A</td>
<td>2</td>
<td>SPH-VAR</td>
<td>OL 6.0 PLAG 33.1 CPX 26.2</td>
<td>MESO 24.3 OPAQ 1.5 GLAS 0.8 VES 2</td>
</tr>
<tr>
<td>109-1D-1, 11-13B</td>
<td>2</td>
<td>FEL</td>
<td>OL 0.6 PLAG 26.3 CPX 33.8</td>
<td>MESO 20.9 OPAQ 5.4 GLAS 0.3 VES 2</td>
</tr>
</tbody>
</table>

^a^ Modes are based on 1,000 points counted on 0.5-mm grid spacing. Alteration products are not included in the sums. Vesicles are visual estimates and are not included in the modal sums.

^b^ Textural abbreviations are listed in order of predominance in thin sections: SPH: spherulitic; VAR: subvariolitic; FEL: felt; MIC: microlitic.

^c^ Phenocryst category includes crystals obviously larger than groundmass phases. Olivine typically is 0.2-0.6 mm in diameter.

^d^ OL: olivine; PLAG: plagioclase; CPX: clinopyroxene; MESO: mesostasis; OPAQ: opaques; GLAS: glass (interstitial glass, segregation vesicles, and glass inclusions); VES: vesicles.

^e^ General abundance of opaque minerals is titanomagnetite >> sulfide. Ilmenite is present only in thin sample of Sample 109-669A-1D-1, 7-9 cm, where it occurs as an intermediate in abundance between titanomagnetite and sulfide.

^f^ Includes microlites that form 25% of all voids.

^g^ Includes minute clinopyroxene and plagioclase microlites and cryptocrystalline groundmass.

^h^ Occurrence of plagioclase phenocryst is observed on a macroscopic scale only.

Geochemistry

An analysis of Sample 109-669A-1D-1, 11-13 cm (Table 3) shows that it is type I mid-ocean ridge basalt (MORB) (Bryan et al., 1976) with Zr/Nb > 40. This basalt is similar to other relatively high TiO_2 basalts recovered by dredging near the median valley, especially from KNR-79 Station 27 (W. B. Bryan, pers. comm., 1986), and to some basalts drilled during Leg 49 along the Mid-Atlantic Ridge (Tarney et al., 1979). The Hole 669A sample has the same tendency toward relatively high TiO_2 (1.9%) at moderate MgO levels (7.5%) exhibited by basalts from Sites 648 and 649. The trace element abundances reflect a similar dis-
position with relatively high abundances of incompatible elements (Zr = 151 ppm, Y = 40 ppm) at moderate levels of compatible elements (e.g., Ni = 96 ppm).

Summary and Conclusions

The very fine-grained spherulitic-subvariolitic to felty-micro­
litic textures suggest that the recovered samples come from the outer part of a cooling unit (pillow or lava flow) close to the chilled margin. The textures are typical of rapidly cooled lava erupted in undersea conditions. The occurrence of olivine as the main phenocryst phase and the relatively abundant olivine microphenocrysts indicate that these basalts may be similar to other olivine phryic basalt samples collected from the walls of the Kane Fracture Zone (Bryan et al., 1981).

ALTERATION

The two basalt pieces recovered from Site 669 show somewhat different styles of alteration and are thus described separately here. The optical properties of most of the alteration products that occur are described in the “Alteration” section of Site 648 chapter (this volume).

Sample 109-669A-1D-1 (Piece 1, 4-6 cm)

Alteration within the Rock

The sawn surface is bounded on most sides by a dark halo, which is uniformly 4 mm thick, except where truncated by frac­

<table>
<thead>
<tr>
<th>Sample 109-669A-1D-1,</th>
<th>Hole-core-</th>
<th>11-13 cm</th>
<th>analyst</th>
<th>SiO₂</th>
<th>TiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>FeO</th>
<th>MgO</th>
<th>CaO</th>
<th>Na₂O</th>
<th>K₂O</th>
<th>P₂O₅</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hole-section-interval</td>
<td>109-669A-1D-1,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ship</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11-13 cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Whole-rock analyses, Hole 669A.

a Analyzed shipboard on Leg 109.
b Total Fe analyzed as FeO₂.
c Mg' value calculated from molar (MgO/MgO + FeO), where Fe²⁺ / (Fe³⁺ + Fe²⁺) = 0.9.

Figure 5. Detail of spherulitic texture in thin section of Sample 109-669A-1D-1,11-13, showing bundles of clinopyroxene and minor amounts of plagioclase in groundmass. Field of view = 2 mm.

Figure 6. Hopper-shaped plagioclase in groundmass in thin section of Sample 109-669A-1D-1, 11-13 cm. Field of view = 3 mm.
tures. A few vesicles in the halo zone are lined with a bluish clay that appears yellow in transmitted light (probably potassium-rich smectite, by comparison to Hole 648B). The interior of the sample is lighter gray.

In thin section, the halo zones are seen to contain about 7% secondary minerals (500 point counts within a halo), of which >5% is yellow birefringent clay. Most of the clay in this sample occurs as nearly complete fillings of miarolitic cavities, from submicroscopic to 3-4 mm in size. Euhedral plagioclase, olivine, and uncommonly large magnetite project into the larger cavities and are overgrown by homogeneously colored botryoidal, locally radiating clay (Fig. 7). Trace amounts of orange-red clay and red (and sometimes opaque) iron-hydroxyoxides occur in some cavities. The typical mineral sequence appears to range from clays to an increasing iron-hydroxyoxide content in the centers of the fillings, where opaque iron-hydroxyoxide may occur. However, in some cavities, small (30-50 μm) blebs of red iron-hydroxyoxide attached to the walls are overgrown by a thin layer of yellow clay. Cracks are common in this sample, locally occurring roughly parallel at about 0.1-mm intervals. The cracks are <5 μm wide and are filled with yellow clay or red iron-hydroxyoxide. In contrast to the miarolitic cavities, the vesicles in the halo zones are mainly empty. A few have yellow clay or red iron-hydroxyoxide linings as much as 50 μm thick. Sulfide globules remain in the halo zones, but they are less abundant than in the lighter gray zone, and the larger (as much as 6 μm) globules seen in the lighter zone are lacking in the halo zones.

The central, lighter gray zone of the sample appears relatively fresh, apart from some pale greenish yellow staining in the miarolitic cavities and the occurrence of radiating acicular aragonite in two irregular vesicles in the working half. In thin section, the greenish yellow staining is seen to be due to miarolitic linings of nonbirefringent yellowish brown “clay” about 10 μm thick. Sparse flecks of orange to red iron-hydroxyoxide occur near the edges of vesicles or on vesicle walls, including the aragonite-containing vesicles. All these vesicles were probably in communication with the halo zones.

Before thin sections were made of aragonite, it was photographed using the SEM (Figs. 8 and 9). The bladed habit of some of the crystals (Fig. 9) differs from the more typical hexagonal prismatic habit of aragonite but is consistent with the orthorhombic symmetry. Optical properties are diagnostic of aragonite. The two prominent aragonite-containing vesicles (Fig. 8) are partly miarolitic, so that hopper-shaped olivine and other euhedral primary minerals occur partly enclosed in aragonite. Aragonite also completely fills smaller miarolitic cavities near one of the halo boundaries.

**Alteration Products Coating the Rock**

The sample has various coating minerals. The surfaces parallel to which the dark halo developed are heterogeneously coated with a soft, creamy-colored mineral that locally has a crudely tabular habit. This appears to overlie patches of black MnO₂(?). There are also scattered shiny botryoidal protuberances of red iron-hydroxyoxide and black MnO₂(?) or manganese-rich hydroxyoxides (“micromanganese nodules”) as large as 0.1 mm.

A second type of coating is a very thin layer of dull olive-green cryptocrystalline clay (smectite?) developed on fracture surfaces that truncate the dark halos. These coatings apparently represent places where the rock was broken by the drilling along clay-filled fractures, whereas the other type of coating represents the weathering surfaces that were exposed on the seafloor.

**Sample 109-669A-1D-1 (Piece 2, 10-16 cm)**

**Alteration within the Rock**

The groundmass of most of the sample is altered to a dark gray. Macroscopically visible alteration products are chiefly iron...
Figure 8. Radiating aragonite in irregular vesicles. Sample 109-669A-1D-1, 4-6 cm. SEM photograph.

Figure 9. Bladed habit of some of the aragonite in Figure 8 SEM photograph. Apparent undulations in some crystal edges are due to ship’s motion.
hydroxyxides lining some of the vesicles and most of the miiarolitic cavities. At one end of the sample, a lighter gray, fresher-looking, irregular oval patch about 3-4 cm across is enclosed entirely within the dark-gray zone. The minimum distance between the light/dark contact and the exterior of the sample is 5 mm.

Two thin sections of this sample were made from the routinely taken minicore, which was entirely from the dark-gray zone. The general appearance of the rock in thin section is fresh. No birefringent clays occur. The only visible alteration products are a yellow, transparent, isotropic “clay,” poorly reflective in reflected light, and a dark-red, isotropic, higher relief, moderately reflective iron-hydroxyxide. Of these, the yellow material is much the more abundant and occurs mainly as miiarolitic linings and fillings and as vesicle linings. The red iron-hydroxyxide occurs in the same textural sites as does the yellow material. Where both occur together, the yellow material overgrows the iron-hydroxyxide. The distribution of these alteration products in the sections is heterogeneous, but no distinct alteration domains are apparent.

Little indication of replacive alteration exists. The mesostasis is microcrystalline and appears fresh in reflected light, apart from some angular pitting that might represent minor hydrated glass. A few primary sulfide globules are observed. Their scarcity may or may not indicate that some of the original sulfide has been oxidized.

**Alteration Products Coating the Rock**

The exterior of the sample (including any vesicles exposed at the surface) has various types of secondary coating, some of which resemble the coatings on Piece 1:

1. Very thin, homogeneous dull olive-green coatings, probably smectite (as in Piece 1).
2. Dull orange-red coatings, locally microscopically botryoidal, probably iron-hydroxyxide.
3. Rusty red to pale-orange patchy coating, accompanied by scattered “micromanganese nodules.”

In addition to these coatings, a crack running across the drifted surface of the archive half has controlled the deposition of a pale-yellow to cream-colored, locally rusty-stained soft clay(?) mineral, accompanied by aggregates of black MnO2(?) as much as 0.3 mm across. Whether these materials constitute a fracture-filling within the rock or merely a localized surficial deposit, similar to that described from Piece 1, is unclear.

**X-Ray Diffractometry**

A small amount of the soft, orange to cream-colored external alteration material coating Piece 1 was scraped off and mounted on a glass slide for XRD. No reliable peaks other than the strongest lines of plagioclase were obtained. This result probably reflects the inadequate sample volume rather than any characteristic of the material. A small thin-section billet-sized piece was sawn from a dark halo in Piece 1, and a “clay concentrate” was prepared from it and run on the XRD as described in the Site 648 chapter “Alteration” section (this volume). More clay was separated from this sample than from the Hole 648B samples, yet the clay peaks obtained were broad and of low intensity (Fig. 10). This was at least in part due to flocculation of the clay into unoriented aggregates as the suspension dried on the slide. The observed clay peaks (Table 4) indicate that the principal alteration phase (as in Hole 648B) is smectite.

**Summary and Interpretation**

A tentative sequence of alteration stages can be reconstructed for the Site 669 samples. Piece 1 probably became a detached clast while still almost fresh. As part of a rubble pile, it was altered in similar fashion to the Site 648 samples, developing a type 1 dark halo. A thin oxidized coating, including “micromanganese nodules,” developed on the exterior, and solutes (from this oxidation and alteration of other rubble pieces and/or from seafloor waters) entered the halo zone, initiating precipitation of significant amounts of smectite and minor amounts of iron-hydroxyxides, mainly as miiarolitic fillings. The presence of large, irregular vesicles permitted the precipitation of some secondary minerals within the otherwise fresh interior. Green clay (smectite?) precipitated along cracks in the samples, but no dark halos developed parallel to these cracks. In time, the voids between the rubble pieces became filled with calcareous sediment. This provided a source of CaCO3 and probably a high-pH environment that allowed aragonite to precipitate in voids. The sediment may also have inhibited further oxidative alteration because the dark halo has not advanced as far as the type 2 halos in Hole 648B, where the rocks are much younger.

Piece 2, less comprehensively studied than Piece 1, appears to have had a sequence of alteration stages similar to Piece 1, but the dark halo has advanced to a Hole-648B-type 2 state. Most of the altered zone is of a clay-poor oxidized type mineralogically resembling the light zones of Hole 648B type 2 halos but is dark, perhaps because of the fine grain size. Whether a clay-rich band exists between this type of alteration and the apparently fresh interior zone is unclear. No aragonite occurs in Piece 2.

Both pieces from Site 669 show no alteration of primary silicate minerals, despite their greater age (1-2 m.y.) than Site 648.
PHYSICAL PROPERTIES

A physical-properties sample was obtained from the largest piece of basalt recovered from Hole 669A, and bulk and grain density, porosity, and ultrasonic compressional velocity were determined using standard shipboard techniques. The techniques are described in the Site 648 chapter “Physical Properties” section (this volume).

Results

For Sample 109-669A-1D-1, 11-13 cm, the values are as follows (numbers in parentheses represent the range in the measurements):

- Wet weight: 27.485 g (average of two measurements)
- Dry weight: 26.92 g (average of two measurements)
- GRAPE wet-bulk density: 2.866 g/cm\(^3\) (± 0.015)
- GRAPE dry-bulk density: 2.814 g/cm\(^3\) (± 0.035)
- Ultrasonic velocity:
  - Saturated: 5.59 km/s (± 0.1)
  - Dry: unreliable
- Sample volume: 9.590 cm\(^3\)
- Porosity: 5.8%
- Grain density: 2.978 g/cm\(^3\)

These results are within the range of expected values for oceanic basalts (e.g., Hyndman et al., 1984; Salisbury et al., 1985). The compressional velocity is somewhat higher than that measured on samples from Hole 648B, but the density and porosity are essentially the same. In fact, this sample has a somewhat higher porosity than does the nonvesicular Hole 648B basalts.

The average grain size is smaller in this sample than in samples from Hole 648B. Furthermore, although only a few small vesicles are visible in hand specimen, many small (<0.2 mm), irregular vesicles can be seen under the microscope. In contrast to the samples from Hole 648B, no evidence exists of a significant component of groundmass porosity. Theoretical results suggest that velocity is less sensitive to equidimensional porosity than to an equivalent amount of crack porosity (e.g., O'Connell and Budiansky, 1974; Toksoz et al., 1976). This implies that the porosity (which is primarily vesicular) does not greatly affect velocity; the absence of a significant component of low-aspect-ratio intergranular porosity results in a much higher compressional velocity than in the somewhat less porous Hole 648B rocks. However, a determination of shear velocity would be required to confirm this explanation.

THERMAL CONDUCTIVITY

The thermal conductivity of one basalt sample recovered from Hole 669A was measured using the Thermcon half-space needle device as outlined in detail in the thermal-conductivity section (“Site 648” chapter, this volume). Table 5 shows the results of the measurements. The mean value of 1.76 W/m·°C is within the variation of the thermal conductivities measured on the basalt samples from Hole 648B.

<table>
<thead>
<tr>
<th>Core section</th>
<th>Distance from top of section (cm)</th>
<th>Thermal conductivity (W/m·°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>109-669A-1D-1</td>
<td>0-10</td>
<td>1.76 (1.71)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.77 (1.77)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.75 (1.63)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.76 (1.70)</td>
</tr>
</tbody>
</table>

REFERENCES


UNIT 1: ASSORTED RUBBLE

Pieces 1–2: APHYRIC BASALT

GLASS: None, no contacts.

PHENOCRYSTS: Piece 2: One plagioclase phenocryst near lower edge.

Plagioclase: 1%, 2 mm, euhedral, fresh.

GROUNDMASS: Uniformly fine grained.

COLOR: Gray.

VESICLES: 2–3%, 0.2–1.0 mm, round, empty, filled with microcrystalline groundmass, or lined by bluish smectite in alteration halos, homogeneous distribution.

Miaroles: Approximately 25% of all voids, 0.1–0.5 mm, sub-circular to elongate-irregular, empty or lined by bluish smectite in alteration halos, homogeneous distribution.

ALTERATION: Fresh to slightly altered.

Piece 1: Dark alteration halo 2–4 mm wide developed parallel to edges; vesicles lined with bluish smectite, iron oxide/clay mixture, yellow brown clay and zeolites; edges coated with yellow brown clay and zeolites.

Piece 2: Dark alteration halo 2–25 mm wide developed around outside of sample, vesicles lined with bluish smectite.

VEINS/FRACTURES: Piece 2 contains crack filled with yellow clay.
THIN SECTION DESCRIPTION

ROCK NAME: Aphyric basalt
WHERE SAMPLED: Unit 1, pillow or flow interior, cut perpendicular to dark halos
TEXTURE: Varoliitic to microlitic
GRAIN SIZE: Fine

109-669A-1D-1 (Piece 1, 7-9 cm)

ROCK NAME: Aphyric basalt
WHERE SAMPLED: Unit 1, pillow or flow interior, cut perpendicular to dark halos
TEXTURE: Varoliitic to microlitic
GRAIN SIZE: Fine

PRIMARY MINERALOGY

<table>
<thead>
<tr>
<th>PHENOCRYSTS</th>
<th>PERCENT</th>
<th>PERCENT ORIGINAL</th>
<th>SIZE RANGE (mm)</th>
<th>APPROX. COMPOSITION</th>
<th>MORPHOLOGY</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olivine</td>
<td>Tr</td>
<td>Tr</td>
<td>0.3-0.6</td>
<td></td>
<td>Subhedral</td>
<td>Radiating, Associated with rare ol nucleus of</td>
</tr>
<tr>
<td>Groundmass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>plagioclase racemos.</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>29</td>
<td>29</td>
<td>0.05-0.2</td>
<td>Acicular, bunches</td>
<td>Euhedral, skeletal</td>
<td>Generally attached to plag.</td>
</tr>
<tr>
<td>Olivine</td>
<td>3</td>
<td>3</td>
<td>&lt;0.1</td>
<td>Radiating,</td>
<td>Radiating,</td>
<td>Rare small grain associated with radiating plagioclase racemos.</td>
</tr>
<tr>
<td>Clinopyroxene</td>
<td>11</td>
<td>11</td>
<td>3-10m</td>
<td>Yellow birefringent clay.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesostasis</td>
<td>54</td>
<td>54</td>
<td>0.5</td>
<td>Aragonite, radiating</td>
<td>Anhedral-euhedral</td>
<td>Tiny grains distributed in the mesostasis.</td>
</tr>
<tr>
<td>Opaques</td>
<td>0.5</td>
<td>0.5</td>
<td>0.05-0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SECONDARY MINERALOGY

<table>
<thead>
<tr>
<th>Clays</th>
<th>2</th>
<th>Mesostasis</th>
<th>Yellow birefringent clay.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonate</td>
<td>Tr</td>
<td>Miaroles</td>
<td>Aragonite, radiating, SEM photo taken before sectioning.</td>
</tr>
<tr>
<td>Fe hydroxide</td>
<td>0.5</td>
<td>Mesostasis</td>
<td>Both red and opaque varieties.</td>
</tr>
</tbody>
</table>

HALO ZONE 34 mm wide

Yellow Clay

Strongly colored, almost cryptocrystalline. Low birefringence. Occurs mainly as homogeneous partial fillings of miaroles. These fillings are up to 3.5 mm in extent, with groundmass plagioclase, olivine, and magnetite projecting into the clay. Clay has botryoidal, locally radiate growth structure. The same clay also forms partial replacements of brown mesostasis-(?)glassy component. Replacement of miarostasis occasionally nearly complete.

Orange-red clay

Trace amounts, mainly as miarole lining. Transitioned between yellow clay and red Fe hydroxide. Occurs mainly in fractures, lining vesicles and forming the central parts of miarole fillings. Vesicle linings up to 50m. Cracks < 10m wide locally spaced at 100m intervals. Occasionally occurs as 300-500m grains attached to miarole walls, then overgrown by yellow clay. In one case, a bleb of Fe hydroxide attached to a miarole wall is continuous with a 31m thick Fe hydroxide veinlet.

Opaque Fe hydroxide

Occurs as central parts of two or three miarole linings. Point count of halo zone: 28 yellow clay (5%), 7 red Fe hydroxides (1.5%), 1 opaque Fe hydroxide (T1), 466 primary phases.

CENTRAL ZONE (fresh)

Traces of orange to red Fe hydroxide, mainly near vesicle walls. Radiating aggregates of aragonite (blasiacl, low 2V, extreme birefrigence) in large (5 mm), irregular miaroles (also containing hopper ol). This and a smaller aragonite-filled miaroles are in fact in connection with the halo zone.

VESICLES/CAVITIES

<table>
<thead>
<tr>
<th>VESICLES</th>
<th>PERCENT</th>
<th>LOCATION</th>
<th>SIZE RANGE (mm)</th>
<th>FILLING</th>
<th>SHAPE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vesicles</td>
<td>1.5</td>
<td>Even</td>
<td>0.2-0.8</td>
<td></td>
<td>Rounded to irregular</td>
<td>Miaroles in alteration halos more commonly filled with clays than the vesicles. Empty in fresh mesostasis.</td>
</tr>
</tbody>
</table>

COMMENTS: Rare ol phenocrysts are rather microphenocrysts. Mesostasis is cryptocrystalline to microcrystalline with plagioclase, cpx, and ol microlites. This section might represent a coarser equivalent of Section 669A-1D-1 (Piece 2, 11-13 cm).
### THIN SECTION DESCRIPTION

**ROCK NAME:** Aphyric basalt  
**WHERE SAMPLED:** Unit 1, pillow or flow interior  
**TEXTURE:** Intergranular (felty)  
**GRAIN SIZE:** Microcrystalline to fine

109-669A-1D-1 (Piece 2, 11–13 cm)

<table>
<thead>
<tr>
<th>PRIMARY MINERALOGY</th>
<th>PERCENT PRESENT</th>
<th>PERCENT ORIGINAL</th>
<th>SIZE RANGE (mm)</th>
<th>APPROX. COMPOSITION</th>
<th>MORPHOLOGY</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHENOCRYSTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olivine</td>
<td>0.5</td>
<td>0.5</td>
<td>0.2–0.4</td>
<td>Euhedral–subhedral</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**GROUNDMASS**

| Olivine             | 5               | 7                | <0.1            | Euhedral–quenched   | Radiating, swallow tail. |
| Plagioclase         | 26              | 26               | <0.1            | Acicular            | Radiating, spherulites. |
| Clinopyroxene       | 39              | 40               | 0.1–0.3         | Hopper-shape        | Christmas-tree texture, product of glass devitrification. |
| Mesostasis          | 21              | 21               | <0.1            | Magnetite           | Dark brown with some cpx and plag crystallites. |
| Opaques             | 4.5             | 5.5              | <0.1            | Anhedral            | Very minute grains in mesostasis or cpx. |
| Segregation vesicles| Tr              | Tr               | 0.2–0.5         | Rounded             | Mostly devitrified glass. |

**SECONDARY MINERALOGY**

| Clays               | 3               | Viscerales,      | Yellow. Replaces olivine and clinopyroxene (staining). |
| Fe hydroxide        | 1               | Opaques          | Reddish brown to red. Individual granules. |

**VESICLES/CAVITIES**

| Vesicles, miaroles  | 2               | Even             | 0.2–0.4         | Clays, Fe hydroxide | Rounded or irregular | Can be empty or lined. |

**COMMENTS:**

- Olivine phenocrysts are in fact microphenocrysts. These are, however, different from quenched ol grains. Mesostasis is cryptocrystalline with recognizable cpx and plag in a radiating pattern. Segregation vesicles consisting of minute crystals of plag + cpx + cryptocrystalline material constitute approximately 1% of the rock.