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Ocean Drilling Program

Coring the crust and the mantle

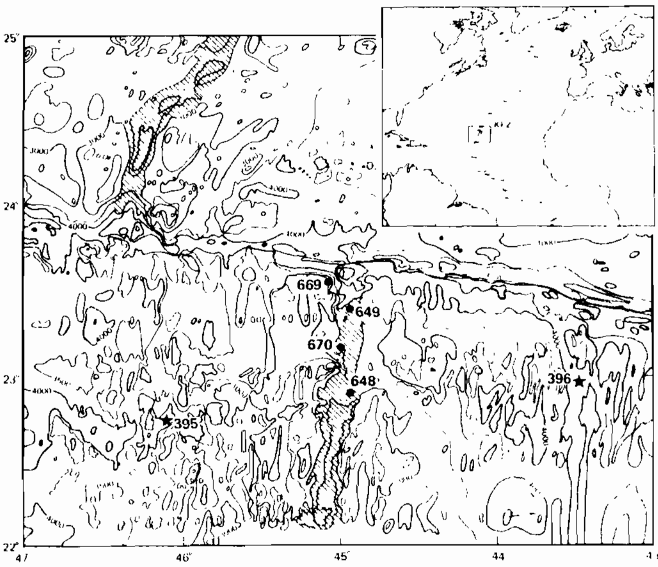
*From the Leg 109 shipboard scientific party**

LEG 109 of the Ocean Drilling Program extended hole 648B in zero-age crust at the volcanically active axis of the Mid-Atlantic Ridge drilled by Leg 106 (see *Nature News and Views* **321**, 14; 1986). Leg 109 planned to deepen the hole (see figure), which had been left open to 33 m below the sea floor, and to log the physical and chemical properties of layer 2 in hole 395A, located about 130 km west of the ridge axis (see figure) in 6–7 million-year-old crust. Drilled in 1976, hole 395A was one of the first holes to make use of a large conical re-entry cone, and is still one of the few deep ocean holes which penetrates more than 500 m of layer 2 basalt.

The area selected for Leg 109 drilling lies within a broad area of geochemically normal layer 2 basalt extending south about 140 km from the Kane Fracture Zone, which crosses the Mid-Atlantic Ridge at about 23°N (see figure). Detailed surveys using the submersible *Alvin* and the *Angus* deep-sea camera system have shown that typical layer 3 (gabbro) and layer 4 (peridotite) lithologies were exposed in fault blocks on the west wall of the median valley near its intersection with the Kane Fracture Zone. *Alvin* was surveying the median valley floor and walls south of the fracture zone at the same time that the drilling ship was in the area, providing an opportunity to respond at short notice to any promising sites discovered by the submersible.

On two successive attempts to begin drilling and coring hole 648B, the bottom-hole assembly was broken off. On the first occasion it was removed with a standard fishing tool, but the second failure occurred about 4 m above the re-entry cone, so the cone and sides of the hole could not be used to guide a tool over the end of the broken pipe. The problem was solved by welding a 1-m-diameter cone to the bottom of the fishing tool which was lowered over the end of the broken pipe, locked on and the bottom-hole assembly pulled up.

The core recovered in hole 648B provides a unique view of the internal plumbing system of the small volcanic cone on which it was drilled. The uppermost 30 m consist of plagioclase and olivine phyric pillow lava, representing extrusive growth of the cone. Beneath this, there is a layer of fine-grained to glassy basalt less than 1m thick which grades downwards into a coarsely vesicular aphyric basalt about 3 m thick. Below this, the basalt becomes massive and holocrystalline with some plagioclase–phyric intervals. This lithological sequence, combined with textural evidence in thin sections, indicates that the glassy zone must represent the quenched top of a lava pond within the cone, which probably served as a holding tank for lava being fed to flows on the valley floor. Rising gas trapped beneath the quenched surface must account for the vesicular unit, while the holocrystalline unit represents the more slowly cooled interior of the pond. Further laboratory studies of these samples may elucidate late-stage fractionation and extrusive processes operating at the sea floor.



Bathymetric map of the Kane Fracture Zone showing position of drill sites. Contour intervals, 500 m. Depths greater than 4,000 m are shaded. Location of Mid-Atlantic Ridge shown by diagonal lines. Stars, sites first occupied by the Deep Sea Drilling Project; closed circles, sites first occupied by ODP. (Re-drawn from Detrick, R.S. & Purdy, G.M. *J. geophys. Res.* **85**, 3759; 1980.)

After a brief and unsuccessful attempt to spud-in a gabbro outcrop at site 669, we moved to site 395. There, we obtained an excellent set of data from hole 395A, including downhole temperature profiles; magnetic polarity and susceptibility; chemical variation; and resistivity and sonic velocity logs. One success was the packer experiment, completed previously in only one other hole, which measures permeability at different levels in the hole.

While these data from hole 395A were being collected, scientists diving in *Alvin* reported by radio that they had found a substantial area of serpentinized peridotite exposed on the lower west wall of the median valley. This seemed to be a promising place to test our spud-in capability on layer 4 material while obtaining mineralogical and textural evidence for the source and mode of emplacement of this unusual material. Site 670 was located in the centre of the area defined by the submersible survey, only 6 km from the active volcanic axis in the median valley (see figure) in about 3,600 m of water. Relying entirely on the submersible survey, we ran pipe immediately and monitored the spud-in.

In the initial spud-in there was rapid penetration through about 7 m of sediment and rubble and into the serpentinite. When the first core was pulled, however, only half the core barrel was recovered and it was necessary to pull the pipe to recover the core and the rest of the core barrel from the coring motor. With less than four days left in the area we faced the choice of making a coneless re-entry, and continuing the drilling with the standard rotary system instead of the coring motor because the core-barrel design in the motor was obviously unreliable; or, if the re-entry failed, to spud-in a new hole with the standard rotary system.

We lowered pipe with the television monitoring the re-entry. We saw an oval pit about 2 × 3 m across filled with drilling mud, and, after a few adjustments in the positioning thrusters of the ship, the pipe moved out over the pit and disappeared into the mud. The whole re-entry took less than 15 min. We continued coring to a depth of 92.5 m below the sea floor.

The core showed that the peridotite became less serpentinized below 30 m depth. The fresher material is partially serpentinized harzburgite, containing olivine, orthopyroxene, minor clinopyroxene and spinel. Flattening and stretching of primary mineral phases, especially the orthopyroxene, produces a foliation almost perpendicular to the core. These relations suggest that the serpentinization is a consequence of its exposure at the sea floor, and that emplacement may be by low-angle transport up and out of the median valley rather than by diapiric intrusion.

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Peridotite boulders found interbedded with basalt at site 395 (Melson, W.G. *et al.* *Init. Rep. DSDP* Leg **45**; 1978) suggests that the relationships observed at site 670 were common, at least over the past 7 million years. At present, talus moving down the wall of the median valley from the peridotite exposure is being periodically interbedded with basalt flows from the axis of the valley only a few kilometres away. Such areas of thin or missing layer 2 (and possibly missing layer 3) seem to be common at slow-spreading centres such as the Mid-Atlantic Ridge. □

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