experiments could be modeled and animated, while Compact Disk/Read Only Memory devices would provide the convenience of having a subset or bibliographic data base at hand.

The technology exists at affordable prices, yet problems remain: standardization, policy objectives, education of managers and geoscientists, coöperation, and quality control. The meeting's resolutions suggest that technological advances create a more flexible user environment and changing economic conditions cause new information needs. Information services should be used for strategic decision making. The use of integrated systems was encouraged, as well as coöperation of such organizations as the Commission of Geological Documentation, Geoscience Information Society, and Australian Geoscience Information Association.

The highlight of the meeting was a field trip to the Southern Vales, Port Willunga, Maslin Beach, and Hallett Cove. Hallett Cove is a faulted hills landscape dotted with upper Paleozoic glacial pavements.

The 1990 meeting will be held in Ottawa. Until then, those in geoscience information will continue to stress the quality of information and its availability.

G.N. Rassam
GeoRef Information System, American Geological Institute, 4220 King St., Alexandria, Va., 22302

on the Mid-Atlantic Ridge

ODP Leg 109 explores normal ocean crust

Basalts from the Mid-Atlantic Ridge between 22°N and 28°N were among the first ocean-ridge rocks to be recovered in quantity and analyzed for both major and trace elements. Those normal basalts are now the standard on which basalt from other ocean locations is judged; chemical, petrographic, and mineralogical characteristics are shared by dredged basalts from widely scattered locations in the Pacific and Indian oceans. Compared to basalt associated with ocean islands and platforms such as the Azores or Iceland, normal mid-ocean ridge basalt (MORB) is characterized geochemically by its less radiogenic isotope ratios and lower contents of K, La, Zr, Nb, and other incompatible elements, and mineralogically, in its higher proportion of plagioclase relative to mafic minerals, and of pyroxene relative to olivine. More subtle differences in the amounts and compositions of minerals such as spinel and iron-titanium oxides also characterize normal MORB.

In addition to distinctive basalt compositions, normal oceanic lithosphere is expected to have certain physical properties distributed through a standard stratigraphic section. Geophysical remote sensing of density, seismic velocity, magnetic polarity and intensity can be done over the vast areas of ocean floor that are covered by hundreds of meters of sediment. For proper interpretation, those observations require highly accurate data obtained *in situ* by direct observation and sampling of sections of typical ocean crust.

Since the Mid-Atlantic Ridge from 22°N to 28°N is the type section for normal MORB, and also is traversed by an apparently normal fracture zone at about 24°N, the Ocean Drilling Program chose it as one of the main targets for 2 drilling legs in the early phases of the new program. Although the new drill ship has many enhanced capabilities, the current drilling technology is still based on methods best suited to sampling deep-sea sediments rather than crystalline basement rocks. But it is those rocks that hold many of the clues to mechanisms of sea-floor spreading and the genesis of new crust at ocean ridges. A major objective of the early legs has also been to test new methods of drilling and coring that will extend possibilities of drilling to areas previously inaccessible and to improve core recovery in typical basement lithologies.

The most dynamic areas of sea floor that must be studied to understand active tectonic and volcanic processes often expose fresh rock surfaces that do not have the 50 m or more of sediment cover required to start a drill hole. Accordingly, a main technical objective has been to develop a bare-rock spud-in capability. The feasibility of that had already been shown on Leg 106. ODP engineers successfully established Hole 648B on a small volcanic cone on the Mid-Altlantic Ridge volcanic axis at about 22°55'N, about 70 km south of the Kane Fracture Zone (May Geotimes). To do that, several weeks were spent setting a large, heavily weighted guide base to stabilize the drill bit on the sea floor. Leg 109 objectives included re-entering the hole and coring it until significant lithologic changes were observed. We also wanted to experiment with unsupported spud-in and coring in a more varied terrain, including the fracture zone, median valley walls, or rift mountains. Priority was also given to logging of Hole 395A, which had been drilled in 1976 about 110 km west of the median valley axis. That is still one of the few holes that has penetrated more than 500 m of ocean basement; it is an important window into normal ocean crust less than 8 million years old. The work at 395A would also be an opportunity to test other new downhole measurement tools that will be essential to the success of several drilling legs planned for the near future.

Crystalline basement rocks hold many of the clues to mechanisms of sea-floor spreading and the genesis of new crust at ocean ridges.

Original plans had included a detailed survey of the proposed drill sites by the submersible *Alvin* and its support ship *R.V. Atlantis II*. Revised scheduling placed the drill ship and the submersible in the area at the same time; at times they worked within 8 to 10 km of each other. Real-time feedback from the submersible dives and camera surveys became an important element in planning and selecting drill sites. The enhanced survey capabilities of the drill ship, using the Mesotech sonar scanner and real-time television imaging, were also used extensively. This experience has shown the practical possibilities of such dual operations in remote areas where long lead times between surveys and drilling may not be possible. It also showed the value of fine-scale submersible mapping before bare-rock spud-in. Several unforeseen accidents also forced us to push the re-entry capabilities of the drill ship to new records. They included placing a 1-m diameter cone on a fishing tool over the end of a broken bottom-hole assembly projecting above the sea floor at Hole 648B, and a coneless re-entry into Hole 670A after the drill pipe had to be pulled to recover a broken core barrel.

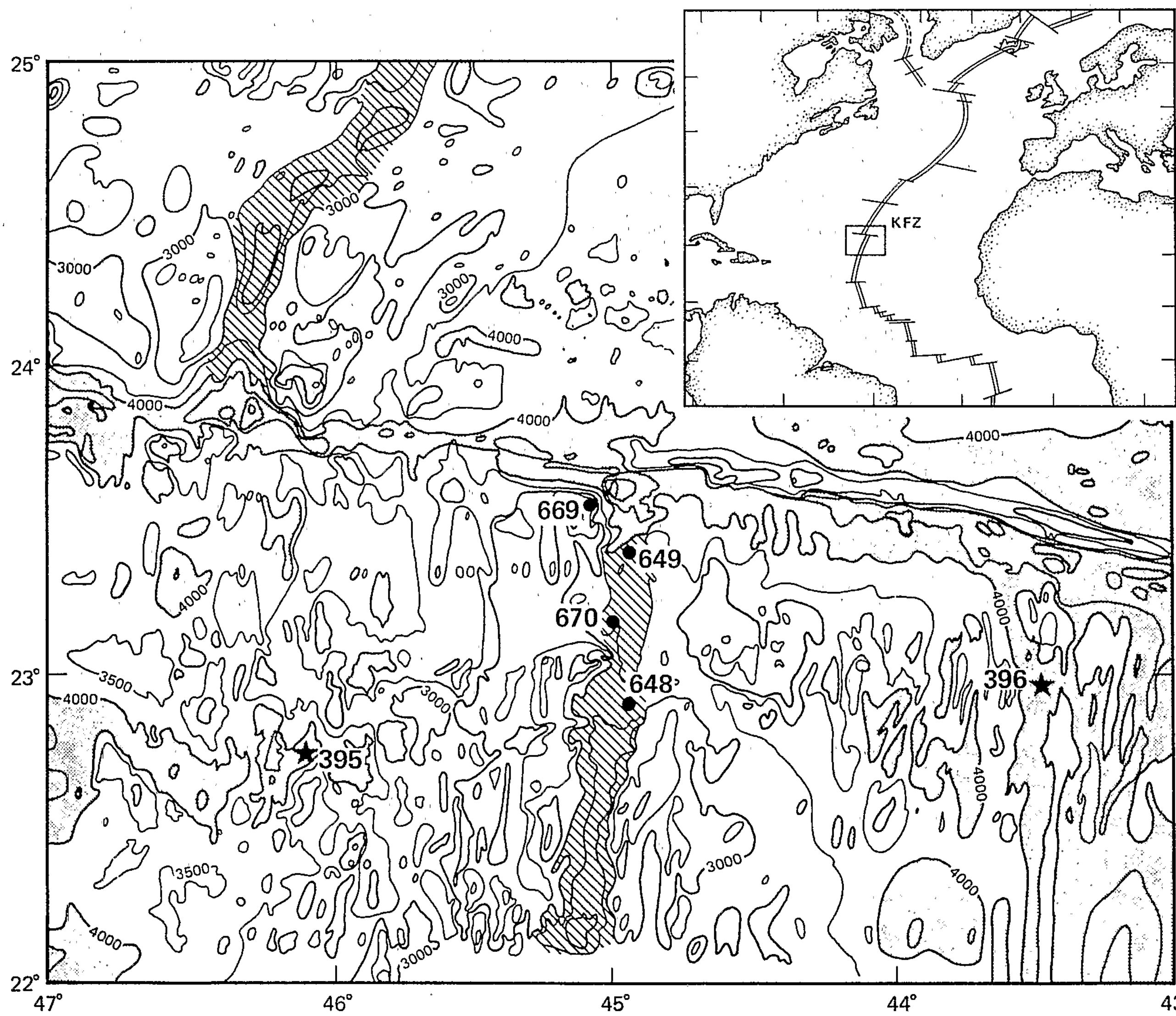
Site 648 was located quickly and we re-entered 648B easily with the aid of the sonar scanner and television. However, we ran into difficulty almost immediately. Afrer drilling out a plug of cement left by Leg 106, the bottom-hole assembly broke off within the hole. It was soon recovered with a fishing tool. The following day drilling resumed on 15 m of fill, which prevented the bottom-hole assembly from completely re-entering the hole. After only about 7 hours of drilling, a sudden weight loss indicated that the bottom-hole assembly had broken away again. When the television was lowered it showed about 4 m of the bottom-hole assembly projecting above the opening in the cone. In both failures, the breaks occurred in the drilling jars that are used to deliver a blow to the bit if it becomes stuck in the hole.

The new failure could have been a

After only 7 hours of drilling, a sudden weight loss indicated that the bottom-hole assembly had broken away again.

fatal obstacle to continuing the hole, because we could not use the re-entry cone to guide a fishing tool over the top of the broken drilling jar. We decided to try a reverse re-entry by welding a 1-m diameter inverted cone to the bottom of an overshot grapple. The exercise is like trying to put an inverted ice cream cone over a pencil stuck in the ground, while manipulating the cone on a string from the top of a 40-story building.

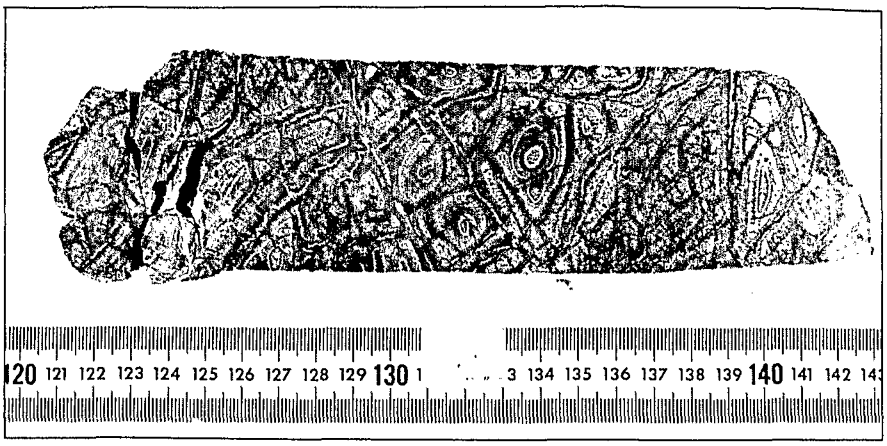
During the first recovery attempt, the modified grapple was placed over the end of the pipe on 3 different occasions during about 8 hours of maneuvering. In each case it pulled free without recovering the bottom-hole assembly. Another special fishing tool was constructed on board, the inverted cone was again welded in place, and another attempt was made. Only 18 minutes were needed to place the cone over the end of the broken jar. The cone failed to take hold during several attempts. The tool was recovered, minor modifications were made, and the exercise was repeated. About 45 minutes were needed to place the cone over the broken jar. The tool slipped over it and held in place. A few minutes later

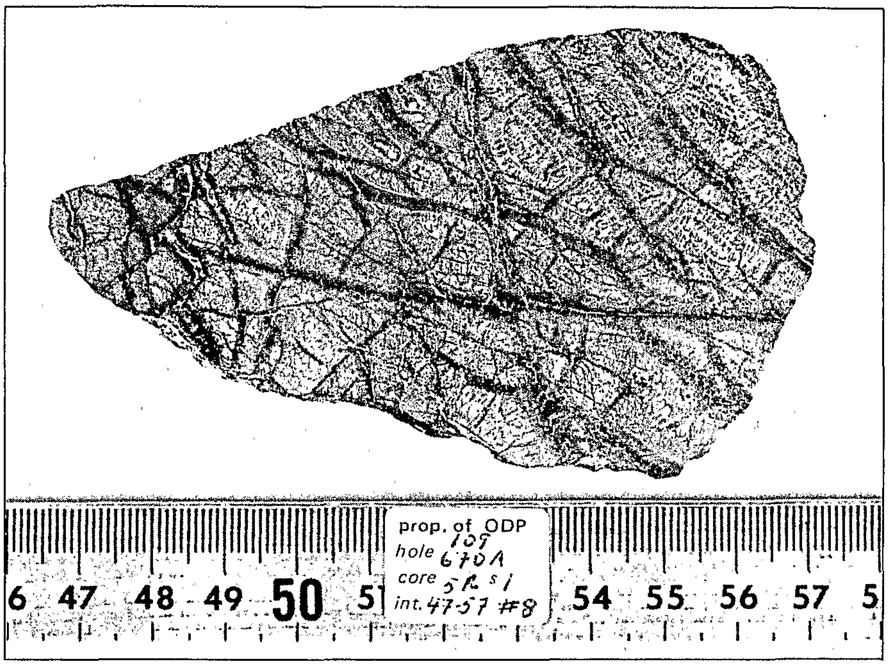


Leg 109 drill sites are shown on this bathymetric map of the Kane Fracture Zone. Contour intervals are 500 m. Depths greater than 4,000 m are shaded. The Mid-Atlantic Ridge is indicated by diagonal lines. Stars mark sites first occupied by Deep Sea Drilling Program. Sites first occupied by ODP are indicated with black dots. (After Detrick & Purdy, 1980. Journal of Geophysical Research, 85: 3,759-3,777) the bottom-hole assembly was pulled from the hole.

In spite of that successful attempt, technical problems continued to frustrate attempts to deepen the hole and to obtain core. The most serious problem was the continued caving of the upper part of the hole. Each time we went back in with a new bit it was necessary to redrill most of the length of the hole, and little life remained in the bit to drill new core and to extend the hole. We tried cementing the hole to control caving. The cement had to be redrilled each time, but that was less damaging to the bit than drilling basalt rubble. We obtained excellent cement cores in the upper pillowed section of the hole. Oriented samples were taken at closely spaced intervals for paleomagnetic study, because the cement picks up the polarity of the adjacent rock while it sets. In this way the cement can be used as a fine-scale downhole magnetic logging device.

Cement proved to be only a temporary solution to caving; it was evident that casing would have to be set. The casing was in place by May 27, and we aimed to make substantial progress in the hole. New cores indicated that we were now well into a unit of massive basalt—core recovery was beginning to improve. On May 29 we re-entered with a new coring bit, drilled 3 m of new hole to a depth of 50.5 m below the sea floor, and became firmly stuck. Without reliable drilling jars, we were reduced to 18 hours of futile pulling. Finally, an explosive charge was run down on a tool, suspended below the bit, and detonated. In a few more hours the pipe was free. At this point we had a cased and drillable hole completed to 50.5 m depth that could be re-entered and deepened with modified equipment. It was time to try something new.





Serpentinite with a texture like tortoise shell was recovered from Hole 670A. Top, chromite-rich seams are present in the bottom and top parts. Bottom, talc-rich concentric rims dominate. Fractures have been disrupted and filled by antigorite during late-stage deformation. (Photos from Ocean Drilling Program)

A terrace near the top of an underwater mountain near the intersection of the Kane Fracture Zone and the median valley was selected as Site 669. Earlier surveys had indicated only rock exposures of Layer 3 gabbro. That was an opportunity to sample a possible plutonic equivalent of the basalts, and to test bare-rock spud-in on another lithology typical of fracture zones. The site had another advantage: it was at a depth of only 2,000 m, which would minimize the time needed for pipe trips. One important scientific question we wanted to answer: How can a lithology normally created more than 2,000 m beneath the sea floor now be exposed some 1,500 m above it?

After a brief survey with the TV camera a site was selected on a low ridge with mixed sediment and rock rubble overburden that we hoped would provide sufficient lateral support to prevent bit wandering. The drilling began smoothly enough, with the drill motor penetrating about 4 m of loose rubble. However, little progress was made, and the bit seemed to be wandering on what presumably was the underlying gabbro surface. After we tried to retrieve the core barrel 3 times, we were forced to pull pipe to recover the core, which consisted of a few pieces of basalt rubble jammed in the lower end of the core barrel. Since it seemed that chances of starting a hole at this site were not good, we decided to go to Hole 395A to begin the detailed logging and downhole measurement program. Although Site 669 was not a scientific success, it did show that the drill ship could in principal transit to, and spud-in on, a small target; it also showed the need for alternative bits and drilling devices, some of which researchers are currently developing at ODP headquarters.

Site 395 was one of the first deep reentry sites drilled during the Deep Sea Drilling Program with the aid of a large steel cone at the top of the casing on the sea floor. Hole 395A is open to more than 500 m below the sea floor, and is still one of the deepest holes completed in ocean crust. We spent 8.5 days running thermal profiles, magnetic and geochemical logs, and resistivity and sonic logs. The work there ended with a successful set of permeability measurements using a downhole packer assembly. The measurements succeeded in making 395A another standard section of logged ocean crust. Only 2 other holes, 504B and 418A, have similar data.

Site 670 was chosen for drilling, based on a survey of the site made by scientists in the *Alvin*. They found an

ODP Leg 109 scientific party

Wilfred B. Bryan
Woods Hole Oceanographic Institution
Co-chief scientist

Thierry Juteau
Université de Bretagne Occidentale, France
Co-chief scientist

Andrew C. Adamson
Texas A&M University
ODP staff scientist

Laurie K. Autio
University of Massachusetts

Keir Becker
University of Miami

M. Mansour Bina
Laboratoire de Géomagnetisme du Parc St Maur, France

Jean-Philippe Eissen
Centre Orstom, New Caledonia

Toshitsugu Fujii
University of Tokyo, Japan

Timothy L. Grove
Massachusetts Institute of Technology

Yozo Hamano
University of Tokyo, Japan

Rejean Hebert
Université Laval, Quebec

Stephen C. Komor
U.S. Bureau of Mines

Johannes Kopietz
Federal Institute for Geosciences & Natural Resources, Federal Republic of Germany

Kristian Krammer
University of Munich, Federal Republic of Germany

Michel Loubet
Université Paul Sabatier, France

Dan Moos
Lamont-Doherty Geological Observatory

Hugh G. Richards
University of Newcastle upon Tyne, United Kingdom

extensive area of peridotite on the lower west wall of the median valley, about 30 km north of Site 648. With 4 days left before we were to leave for Barbados, we dropped a beacon at the position given us by radio from the *Atlantis II*. We planned to make as deep a penetration as possible, to see if this was a rootless fault slice; we also hoped to find relatively fresh peridotite at deeper levels. After washing through about 7 m of sediment and rubble, coring began and we made good penetration into the peridotite. All went well until the middle of the following day (Friday, June 13) when our luck ran out—this time, we recovered only half the core barrel. We had to pull the pipe to remove it from the coring motor and to recover any sample that might have been retained. We were fortunate—about 0.6 m of rubbly core was still in the motor when we got it on deck.

It was evident that the core barrels used in the coring motor, an experimental design, were not up to the task. The only choice seemed to be to switch back to the standard coring bit and bottom-hole assembly, which would be driven from the surface by rotating the whole drill string. At that point the hole was only 35 m deep, substantially less than the sediment depth usually required for drilling with this equipment. If we could not re-enter the hole our only option would be to start a new one, an even more risky undertaking. With 3 days to go, re-entry seemed worth trying.

By 2 p.m. on the following day, pipe had again been run almost to the sea floor. The TV and sonar scanner were run down alongside the pipe, and immediately we had a view of both the sonar reflector and a muddy pit measuring about 4'x8', which marked the position of our hole. After a few adjustments to the positioning thrusters on the ship, the end of the bit moved out over the pit and disappeared into the mud. Re-entry was confirmed by 2:30 p.m. as pipe was extended easily below the rock/sediment interface. Drilling then went well. 3 cores recovered partly serpentinized harzburgite, the fresher material we had been hoping for. By mid-morning on June 16, our deadline to stop drilling, we had reached 92.5 m without passing out of the peridotite. A suite of samples of apparent direct upper mantle origin had been cored.

The discovery of this obviously substantial peridotite intrusion within 5 km of a normal spreading axis is at odds with the usual perception of oceanic lithosphere stratigraphy. It does not fit the notion of orderly creation of new crust by basaltic extrusions at ocean spreading centers and its symmetrical distribution to either side by spreading. Laboratory study of the mineral assemblages in the peridotite, and of deformation textures, may provide some insight into the source of this material and its mode of emplacement.

Although Leg 109 certainly set no records for core recovery, we obtained some unique insights into formation of oceanic lithosphere at its extreme endpoints. At Site 648, we had looked into the interior of a small extrusive volcanic cone on the spreading axis, and learned that the uppermost pillow lavas were replaced at about a 30 m depth by ponded lava, indicating that this cone was probably a major holding tank from which adjacent flows were fed. Study of those samples, in conjunction with those collected around the cone by the submersible, should provide new data on the late-stage processes of fractionation and extrusion at the sea floor. Although we failed to sample the gabbro at Site 669, an analysis of one of the basalts recovered there showed it was, like the basalts from Site 648, characterized by unusually high Ti, Zr, and Y combined with high Mg and Ni. Those peculiarities are matched by few other basalts from the area obtained from dredge and submersible samples, and from drill Sites 395 and 396. The basalts seem to require different sources or processes to explain their compositions. Peridotite samples previously recovered interbedded with basalt at Site 395 require re-interpretation in the light of our discoveries at Site 670. Juxtaposition of a basalt extrusion and mantle diapirs may be a relatively common feature of ocean spreading centers. In this area of normal crust it appears to have been common over the past 7 million years. Finally, basalt data already available from Hole 395A can be profitably re-examined within the context of the very complete logging records now available.

We also learned many lessons that will help to make future drilling legs less costly and more productive. Our remarkable success with reverse re-

The discovery of this obviously substantial peridotite intrusion within 5 km of a normal spreading axis is at odds with the usual perception of oceanic lithosphere stratigraphy.

entry using a 1-m diameter cone, and our coneless re-entry at Site 670, are likely to lead to routine use of smaller and less costly re-entry cones in the future, which will also be much more easily handled and more quickly set. We showed that bare-rock spud-in does not necessarily require a large and expensive guide base; in appropriate lithologies, unsupported spud-in may even be accomplished successfully with standard drilling tools. Spud-in is not as great a problem as penetrating and getting good core recovery once the hole is started. Future developments will focus on new bit and core-barrel designs and on new types of down-hole coring motors.

Leg 109 Scientific Drilling Party
Ocean Drilling Program, Texas A&M University, College Station, 77843-3469