OCEAN DRILLING PROGRAM

LEG 109 PRELIMINARY REPORT

BARE ROCK DRILLING IN THE MID-ATLANTIC RIDGE RIFT VALLEY

Wilfred B. Bryan
Co-Chief Scientist, Leg 109
Department of Geology and Geophysics
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

Thierry Juteau
Co-Chief Scientist, Leg 109
Universite de Bretagne Occidentale
Faculte des Sciences
6 Avenue LeGorgeu
29287 Brest
France

Andrew C. Adamson
Staff Scientist, Leg 109
Ocean Drilling Program
Texas A & M University
College Station, TX 77843-3469

Philip D. Rabinowitz
Director
Ocean Drilling Program

Robert B. Kidd
Manager of
Science Operations
Ocean Drilling Program

Louis E. Garrison
Deputy Director
Ocean Drilling Program

August, 1986

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Preliminary Report No. 9

First Printing 1986

Distribution

Copies of this publication may be obtained from the Director, Ocean Drilling Program, Texas A & M University, College Station, Texas 77843-3469. In some cases, orders for copies may require a payment for postage and handling.

D I S C L A I M E R

This publication was prepared by the Ocean Drilling Program, Texas A & M University, as an account of work performed under the international Ocean Drilling Program which is managed by Joint Oceanographic Institutions, Inc., under contract with the National Science Foundation. Funding for the program is provided by the following agencies:

Department of Energy, Mines and Resources (Canada)

Deutsche Forschungsgemeinschaft (Federal Republic of Germany)

Institut Francais de Recherche pour l'Exploitation de la Mer (France)

Ocean Research Institute of the University of Tokyo (Japan)

National Science Foundation (United States)

Natural Environment Research Council (United Kingdom)

European Science Foundation Consortium for the Ocean Drilling Program (Belgium, Denmark, Finland, Iceland, Italy, Greece, the Netherlands, Norway, Spain, Sweden, Switzerland and Turkey)

Any opinions, findings and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation, the participating agencies, Joint Oceanographic Institutions, Inc., Texas A & M University, or Texas A & M Research Foundation.

SCIENTIFIC REPORT

The scientific party aboard JOIDES *Resolution* for Leg 109 of the Ocean Drilling Program consisted of:

Bryan, Wilfred, Co-Chief Scientist (Woods Hole Oceanographic Institution, Woods Hole, MA)

Juteau, Thierry, Co-Chief Scientist (Universite de Bretagne Occidentale, Brest, France)

Adamson, Andrew, Staff Scientist (Ocean Drilling Program, TAMU, College Station, TX)

Autio, Laurie (University of Massachusetts, Amherst, MA)

Becker, Keir (University of Miami, Miami, FL)

Bina, Mansour (Laboratoire de Geomagnetisme du Parc St. Maur, St. Maur des Fosses, France)

Eissen, Jean-Philippe (Centre Orstom, Noumea, New Caledonia)

Fujii, Toshitsugu (University of Tokyo, Tokyo, Japan)

Grove, Timothy (Massachusetts Inst. of Technology, Cambridge, MA)

Hamano, Yozo (University of Tokyo, Tokyo, Japan)

Hebert, Rejean (Univerite Laval, Quebec, Canada)

Komor, Stephen (Bureau of Mines, Avondale, MD)

Kopietz, Johannes (Federal Inst. for Geosciences and Natural Resources, Hannover, FRG)

Krammer, Kristian (University of Munich, Munich, FRG)

Loubet, Michel (Universite Paul Sabatier, Toulouse, France)

Moos, Dan (Lamont-Doherty Geological Observatory, Palisades, NY)

Richards, Hugh (University of Newcastle upon Tyne, Newcastle upon Tyne, U.K.)

INTRODUCTION

Leg 109 of the Ocean Drilling Program began in Dakar, Senegal on April 23 and ended on June 19, 1986 in Bridgetown, Barbados. The overall objective of Leg 109 was to increase our understanding of crustal accretion processes at oceanic spreading centers. Leg 109 was the second of two legs largely dedicated to drilling young ocean crust and upper mantle in and near the median valley of the Mid-Atlantic Ridge south of the Kane Fracture Zone (Figure 1). Leg 106 was the first of these legs and started drilling a hole (648B) on the summit plateau of a small axial volcano 70 km south of the Kane Fracture Zone using a newly designed hardrock guide base (Detrick et al., 1986). On Leg 109, Hole 648B was deepened and basalts were recovered for petrologic and geophysical studies. Other activities on Leg 109 included collecting a complete suite of geophysical logs from Hole 395A, and bare-rock spud-ins on gabbro and peridotite outcrops exposed near the median valley. Of particular interest is the recovery at Site 670 of 6.52 m of variably serpentinized peridotites believed to be upper mantle samples.

REGIONAL GEOLOGIC SETTING

The Mid-Atlantic Ridge (MAR) is offset by the Kane Fracture Zone (KFZ) at 23° N. To the south of the KFZ where Leg 109 activities were concentrated, spreading is asymmetrical at 1.4 cm/yr to the west and 1.1 cm/yr to the east (Purdy et al., 1978). Basalts have been recovered along the median valley walls, and variably deformed and metamorphosed gabbroic and ultramafic rocks have been found along the fracture zone walls and at the north and south MAR-KFZ intersections (Melson et al., 1968; Miyashiro et al., 1969, 1970, 1971; van Andel et al., 1971; Dick et al., 1980; Bryan et al., 1981; Karson and Dick, 1983). Basalts and peridotites were also recovered at Site 395, located approximately 100 km west of the axial valley in 7 million year old crust (Arai and Fujii, 1979; Sinton, 1979).

Seismic refraction data from the 120 km long rift valley segment immediately south of the KFZ reveal crust of normal thickness (6-7 km) and upper mantle velocities of approximately 8 km/sec (Figure 2; Purdy and Detrick, 1984). No evidence was found for the presence of a large axial magma chamber in either the crust or upper mantle along this ridge segment. However, anomalous seismic velocities were found in the lower crust centered beneath the along-axis topographic high near 22° 55' N (Figure 3). These anomalous velocities are believed to derive from a region of elevated temperature and pervasive cracking generated by recent magmatic activity. anonymously thin crust has been reported from the eastern ridge-transform intersection and along the KFZ (Cormier et al., 1984; Detrick and Purdy, 1980).

Detailed Sea Beam (Detrick et al., 1984) and Sea MARC (Mayer et al., 1985) coverage of the rift valley has been obtained from 22° 44' N to the KFZ. These data indicate the presence of an inner rift valley 10-15 km wide that is bounded by two 500 m high N-S trending scarps. The inner rift valley structure is complex with changes in both cross-section and depth along its length. Hydrothermal activity was found along the ridge near 23° 22' N (Site 649) during Leg 106.

Leg 109 operations in the axial valley near 23° N coincided with a study by the submersible ALVIN of the same area. In daily communications with researchers aboard the ALVIN, we were advised that they had discovered a zone of serpentinized peridotite within and striking parallel to the axial valley (J. Karson, personal communication). This exposure of peridotite is about 30 km south of the MAR-KFZ intersection. Most previous observations and recoveries of peridotite have been in fracture zones, so their presence in the axial valley presented a unique drilling target for which the Resolution was uniquely suited. A description of the peridotite cored from this area is presented in the Site 670 section.

SITE 648

Site 648 was selected as the primary site for testing the feasibility of bare-rock spud-in using a weighted guide base and drilling motor. At the start of Leg 109, the guide base was in place and about 33 m of hole had been drilled by Leg 106. Our principal technological objective was to deepen the hole and to recover core, in support of the scientific goal of extending the hole at least until a significant lithologic boundary was crossed.

Technical improvements based on Leg 106 experience included emphasis on 9-7/8 inch coring bits and greater armoring on the outer surfaces of all bits used, and special light-weight 10-1/4 inch casing with a hanging adapter to fit it to the re-entry cone. The smaller diameter and armoring were expected to reduce caving and to extend bit life and penetration rate. Drilling jars appeared essential to combat sticking in the hole, and four of these were on board. If the drilling went well and reached significant depths, a detailed program of logging and down-hole measurements would be carried out.

Site 648 is located on the eastern side of the summit of Serocki Volcano, one of a group of volcanic cones on the central volcanic axis of the median valley (Figure 4). The cones are aligned about N 10° E and Serocki is offset to the east of the main group. It is about 800 m in diameter with a flat top and steep sides. There is a central crater about 250 m in diameter and about 60 m deep. A dive by ALVIN on Serocki Volcano and on several of the adjacent cones indicated that Serocki is slightly older than the other cones, based on the marginally greater sediment covering and tectonic disruption. Sea MARC sidescan images obtained during the site survey (Detrick et al., 1985) indicate a distinct set of N-S faults cutting the western half of the cone. A survey by Leg 106, using the sonar and TV camera, showed minor fracturing in the vicinity of the guidebase; Figure 5 shows that the guidebase was almost centered over one of these fissures.

Site 648 is located at almost the highest point of the north-south profile of the median valley (Figure 3). Originally it seemed probable that this elevation reflected the largest eruptive volume and therefore the hottest and most active volcanic area. However the ALVIN and ATLANTIS II survey conducted after drilling was completed at Site 648 did not find any active hydrothermal vents near 648B, and although the diving scientists reported the crust near Serocki Volcano as relatively young, it was thought not to be as young or as active as the area centered on Site 649. The dives and camera surveys also showed that the low area of the median valley between Sites 648 and 649 is covered by even older, tectonically disrupted volcanic terrain. From this it appears likely that eruptions at Sites 648 and 649 have been supplied at different times, from different sources.

Electron microprobe analyses of glasses obtained by Leg 106 from Sites 648 and 649 show that the Site 649 glasses are "more primitive" than most of the data reported by Bryan et al. (1981) from the 22° - 25° N region. To define more clearly the regional affinities of the two sites, the glass analysis file of dredged samples was enlarged to include published glass data from the nearby drill Sites 395 and 396 (Melson, Rabinowitz, et al., 1978). This file was filtered using limits for TiO_2 and MgO just above or below the range of values observed at Sites 648 and 649. No glasses from the area, other than glasses from group G2 at Site 396 (Melson, 1978), resemble the Site 649 glasses. It is not surprising that the closest match to the Site 648 glasses is found in the samples from AII-92 dredge stations 29 and 30, which come from the valley axis a short distance north of Site 648 (Bryan and Sargent, 1978). A few other median valley samples from GS104 stations 17 and 20 also pass the filter; these are part of a group recognized by Bryan et al. (1981) as "anomalous" in their relatively high MgO combined with high TiO_2. Among the two other drill sites, the closest affinity is to groups G1 and G7 in Hole 395A (Melson, 1978).

Although only a limited amount of sample was recovered from Site 648 (and 649) the glass and whole rock analyses show that these samples tend to fill compositional gaps in the data recovered from other parts of the median valley. The relatively high MgO combined with relatively high TiO_2 are distinctive features shared by samples from only a few other median valley sites. Bryan et al. (1981) tried to explain these compositional peculiarities in terms of magma mixing; however, a more careful evaluation of this mechanism indicates that it is not possible to find adequate end-member compositions within the local data set, and when possible end-members from other locations are used as end-members, it is difficult to match both major and trace elements simultaneously. Unless these problems can be resolved, the compositional characteristics of these samples may be better explained in terms of unique melting and/or polybaric fractionation histories.

Petrographic data, magnetic measurements, and physical properties all confirm a stratigraphic sequence passing from somewhat disrupted and disoriented pillowed flows in the upper 30 m, through a dense, aphanitic zone less than 1.0 m thick which appears to be a rapidly quenched crust at the top of a distinctive vesicular unit (3 m thick) which suggests rising gas trapped beneath the crust. Beneath this, the basalt becomes more coarsely crystalline and massive as might be expected of the slowly cooled interior of a lava pond. Major and trace element analyses through these lithologically distinct units show, in contrast, a monotonous compositional uniformity. All of these data are consistent with the interpretation of the cone and its massive interior lava fill as part of a single eruptive pulse. The pillowed unit must represent the active growth phase of the cone; at the maximum point of growth the pillowed rim would have formed a circular dam around a central lava lake. The flat upper surface of the cone represents the quenched surface of the lake. Lava draining away through a breach or tube at the base of the cone probably partly drained the lake and the crater formed by collapse of the surface crust. The aphanitic basalt, vesicular basalt, and massive basalt penetrated between 30 and 50.5 m appear to represent a section through the upper part of a lower stand of the lava pond after this drain-away event.

In spite of limited penetration and core recovery, the combined Leg 106/109 drilling provided a unique profile through what appears to have been a local "holding tank" for lava erupted along the valley axis. Also, several remarkable technological feats kept the hole alive; it was primarily the lack of adequate drilling jars that forced abandonment of an otherwise drillable hole.

The armored 9-7/8 inch bits did show improved life compared to Leg 106 experience, but still suffered substantial wear in the shirt-tail area. Only one bit lost a cone; the probability of cone loss or other significant damage seems to increase substantially as bit life approaches 20 hours. The bits cored and penetrated well on the relatively few runs in which they operated on new hole instead of fill. The casing also was set and latched in with no major difficulty. Cementing appears to be at best a temporary solution to caving problems; in 648B it seemed to work for about two bit runs. However, without the cementing technique Hole 648B drilling operations may have been suspended much earlier in the leg. Core recovery averaged about 13 % in the intervals in which new hole was made.

Caving and severe sticking were major problems. The casing undoubtedly eliminated caving in the upper part of the hole but obviously did not eliminate sticking; we did not have the opportunity to learn whether caving would return as a major problem at greater depths, though we suspect it would. Cementing might have been more effective in preventing caving at those greater depths, where there would be less lateral pipe wobble. Perhaps the most basic lesson learned is that bare-rock spud-in is easier than the subsequent problems of maintaining and deepening the hole, and getting adequate core recovery.

SITE 669

Site 669 is located on the gently sloping summit of a mountain forming the western rift valley wall of the MAR, immediately to the south of the KFZ at 23° 31.02' N, 45° 02.75' W (Figure 1). The site lies in 1979 m of water - to the east, the mountain shelves rapidly into a 6200 m deep nodal basin 5 miles distant (Figure 6). Site 669 was chosen to deploy a positive displacement coring motor in an attempt at an unsupported bare-rock spud-in. Submersible dives in this area have shown the top of the rift mountain to be composed of gabbros with surficial rubble and intermixed sediment. The aim of drilling here was to sample these gabbros.

Site 669 is located on a gently sloping area about 1.5 miles southeast of the main summit. A 3.5 hour combined TV/sonar survey of the area revealed an almost smooth bottom comprising rubble with intermixed sediment, with local sediment ponds covered by north-south trending ripples. The site chosen for drilling was on a low north-south ridge formed of angular rubble. It was felt this type of bottom would best constrain the coring motor until a hole in the underlying basement could be started.

A single hole was drilled (Hole 669A) to a total depth of 4.0 m sub-bottom through basalt rubble and sediments. At 4.0 m sub-bottom, extremely hard basement was encountered and the bit was no longer able to advance. A total of 0.1 m of fine-grained aphyric basalt rubble was recovered with distinct alteration halos and orange clays on the outer surfaces. The basalt presumably derives from the higher slopes of the mountain; the nature of the underlying basement remains unknown.

SITE 395

Hole 395A (Figure 7) was drilled during Leg 45 in 1975-1976, in a sediment pond on 7.2-m.y.-old crust directly west of the Site 648 on the MAR (Figure 8). Leg 45 cored through 92 m of sediment and 574 m of basement, leaving Hole 395A cased to a depth of 112 m below seafloor. Some logging was attempted during Leg 45, but it was quickly terminated when a hydrophone was lost in the hole.

Leg 78B returned to Hole 395A in 1981 with the principal purpose of logging the hole, but numerous instrumental and operational problems were encountered. As a result, Leg 78B returned with no porosity data from Hole 395A, and only marginal geothermal, density, velocity, resistivity, and permeability data. During Leg 78B operations, an impenetrable bridge was encountered 55 m above the Leg 45 hole bottom, and a bit was released above this bridge.

A nine-day program of logging and downhole experiments was carried out in Hole 395A. The goals of this logging program were to:

(a) Determine the in situ velocity structure in young Atlantic crust.
(b) Determine the variation of porosity with depth in Hole 395A.
(c) Determine the permeability of young Atlantic crust.
(d) Determine the temperature profiles in the hole and in the sediments at Site 395, to verify whether heat transfer occurs by conduction and/or convection.
(e) Assess whether or not the underpressures and downhole flow of ocean bottom water that were observed during Leg 78B still persist.
(f) Re-sample and analyze the chemistry of borehole fluids in partial equilibrium with pore fluids in young crust.
(g) Refine the eruptive history of the Layer 2 extrusive pile from variations in magnetic susceptibility and NRM intensity, inclination, and declination.

The logging experiments carried out in Hole 395A during Leg 109 are included here in Figure 9 and summarized in Table 1. All but one of the planned tools (BHTV) was run in Hole 395A.

Logging results show that the uppermost 380 m of basement at Site 395 is quite heterogeneous and composed primarily of 10-50 m thick pillow basalt units. Several distinct flow units are also present. Units are delineated by both physical properties and neutron activation measurements of Ca, Al, Fe, and Si. Enlarged sections of the borehole with sharply higher porosity and lower resistivity may correspond to unit boundaries. Physical properties vary on the scale of a few meters; compressional velocities vary between 3 and 5 km/s, densities between 2.4 and 2.7 gm/cc, porosities between 10 and 20 percent and resistivities between 10 and 100 ohm-m. From 320 to 500 m into basement compressional velocity increases to more than 5 km/s, densities are greater than 2.6 gm/cc, porosities are less than 15 percent and resistivities increase to 200 ohm-m. This change is gradational and due primarily to an increase in the degree of cementation of the pillows.

Magnetic susceptibility in the uppermost 500 m of basement is somewhat low and is remarkably constant throughout the logged interval, due to the constant size of titanomagnetite grains. A few zones near the top of the basement section have higher susceptibilities. Magnetometer results reveal a reversal in the remanent field at a unit boundary 150 m into basement.

Vigorous downward flow of ocean bottom waters depresses in-situ temperatures in the upper 300 m of basement, suggesting that this interval is highly permeable and that pore pressures are below hydrostatic. Similar results were seen in young crust at DSDP Site 504 (Anderson and Zoback, 1982; Becker et al., 1983; Williams et al., 1986), but in Hole 395A the downward flow has persisted, whereas flow into Hole 504B has steadily decreased. Although downward flow into Hole 395A is restricted to the uppermost few hundred meters (the temperature gradient indicates purely conductive heat transport in the lowermost sections of the hole) packer flow tests of the lowermost 210 m and 80 m demonstrate that high permeabilities persist to greater depths. In fact, permeability in the upper 500 m of Hole 395A is greater than permeability in the uppermost 200 m of Hole 504B.

These results suggest that most of Hole 395A was drilled through the highly porous, permeable low-velocity pillows of seismic Layer 2A, before penetrating the gradational boundary between Layers 2A and 2B.

Overall, Leg 109 was very successful in logging Hole 395A, thereby establishing a third geophysical reference section to complement results from the two other deep basement holes (418A and 504B).

SITE 670

Site 670 is located at 23° 10.00' N, 45° 01.93' W in 3625 m of water, on the sloping west wall of the median valley (Figure 10), between Sites 648 and 649. The floor of the median valley to the east of Site 670 is a seismically-defined transition or "anomalous" zone separating basaltic crust of "normal" thickness to the south from thinned crust to the north (Detrick and Purdy, 1980; Cormier et al., 1984). This zone, extending from about 23° 08' N to about 23° 18' N, is also magnetically and bathymetrically anomalous, in that the central magnetic anomaly is shifted to the west, the western valley wall is poorly defined in the bathymetry and the volcanic axis is deeper and poorly defined morphologically compared to its development at Sites 648 and 649 (Purdy et al., 1978; Detrick et al., 1985). The absence of distinct rift mountains to the west has been evident in bathymetric charts for some time.

Studies by Melson et al. (1968) showed that the median valley walls to the south of Site 670 are composed of greenstone and weathered basalt, while to the north, gabbros, serpentinized peridotite, and greenstones are the dominant lithologies on the west wall of the median valley near the KFZ (Bryan et al., 1981; Karson and Dick, 1983). Within the valley inner walls and floor, fresh to moderately fresh basalts have been recovered along an east-west traverse at about 23° 01' N; only basalt was recovered in the dredge on the western wall (Bryan and Sargent, 1978).

A detailed survey and sampling program was carried out in the "anomalous" zone by the ATLANTIS II and the submersible ALVIN concurrently with the Leg

109 drilling program. Preliminary results showed that the median valley floor is composed of manganese-encrusted older basalt flows with light to moderate sediment cover, and evidence of significant tectonic modification of constructional volcanic morphology. Two of the dives on the lower slopes of the western valley wall traversed broad areas of serpentinized peridotite in moderately sedimented, relatively old terrain; these areas were almost free of basalt talus and surface rubble. The larger of the two areas, centered at 23° 10' N, 45° 02' W, was selected for drilling Site 670. This area of serpentinized peridotite was selected for drilling because it provided an opportunity to clarify the possible influence of this material on the magnetic anomaly shift on the west side of the valley. Further, textural and mineralogical studies of the peridotite could provide evidence for the mode of emplacement of the peridotite, and possibly, some clues as to the tectonic history of the anomalous crust. Also, this seemed to be an ideal place to test unsupported spud-in and coring capabilities in another lithology typical of those likely to be encountered in future drilling in or near a major fracture zone.

Hole 670A washed through 6.4 m of soft sediment and drilled 86.1 m into ultramafic rocks, from which a total of 6.52 m of core was recovered. The two distinct lithologic types in the core are serpentinite and partially serpentinized harzburgite in sub-equal proportions. Primary minerals are present in various stages of preservation and are sometimes fresh and sometimes pseudomorphed, allowing identification of the primary mineralogy. Primary silicate minerals in the serpentinite have been entirely replaced by serpentine + talc or serpentine + talc + tremolite assemblages. These rocks may have been dunites. In the serpentinized harzburgites, olivine, orthopyroxene, clinopyroxene and chromian spinel are present in various stages of preservation. There is a strong, shallow-dipping foliation in these rocks, macroscopically marked by the flattening and stretching of the orthopyroxenes and chromian spinels.

One of the most intriguing aspects of the Hole 670 harzburgites and serpentinites is their presence in the MAR axial valley, approximately 30 km south of the KFZ. This direct exposure of upper mantle material occurs in an area where volcanism is restricted or absent. This situation might occur commonly at slow spreading centers where magma chambers are ephemeral or discontinuous. As long as convective divergence continues, upwelling mantle material rises to the surface and is transported off-axis by sea floor spreading. Prolonged divergence without volcanic activity might produce an exposed strip of mantle striking parallel to the axial valley. Circulation of seawater through the exposed mantle could cause near-surface, _in-situ_ serpentinization.

REFERENCES

Anderson, R.N., and Zoback, M.D., 1982. Permeability, underpressures, and convection in the oceanic crust near the Costa Rica Rift, Eastern Equatorial Pacific. J. Geophys. Res., 87: 2860-2868.

Arai, S., and Fujii, T., 1979. Petrology of Ultramafic Rocks from Site 395, Leg 45. In W.G. Melson, P.D. Rabinowitz, et al., Init. Repts. Deep Sea Drilling Proj., 45: Washington (U.S. Govt. Printing Office): 587-594.

Becker, K., Langseth, M.G., Von Herzen, R.P., and Anderson, R.N., 1983. Deep crustal geothermal measurements, Hole 504B, Costa Rica Rift. J. Geophys. Res., 88: 3447-3457.

Bryan, W.B., and Sargent, D., 1978. Basalt from 22-23° N., Mid-Atlantic Ridge Median Valley. In W.G. Melson, P.D. Rabinowitz, et al., Init. Repts. Deep Sea Drilling Proj., 45: Washington (U.S. Govt. Printing Office): 653-655.

Bryan, W.B., Thompson, G., and Ludden, J.N., 1981. Compositional variations in normal MORB from 22-25° N: Mid-Atlantic ridge and Kane Fracture Zone. J. Geophys. Res., 86: 11815-11836.

Cormier, M.-H., Detrick, R.S., and Purdy. G.M., 1984. Anomalously thin crust in oceanic fracture zones: New seismic constraints from the Kane Fracture Zone. J. Geophys. Res., 89: 10249-10266.

Detrick, R.S., Fox, P.J., Kastens, K., Ryan, W.B.F., and Karson, J., 1984. A seabeam survey of the Kane Fracture Zone and the adjacent Mid-Atlantic Ridge rift valley. EOS (Trans. Amer. Geophys. Union), 65: 1106.

Detrick, R.S., Honnorez, J., Adamson, A.C., Brass, G.W., Gillis, K.M., Humphris, S.E., Mevel, C., Meyer, P.S., Petersen, N., Rautenschlein, M., Shibata, T., Staudigel, H., Wooldridge, A., and Yamamoto, K., 1986. Mid-Atlantic bare-rock drilling and hydrothermal vents. Nature, 321: 14-15.

Detrick, R.S., and Purdy, G.M., 1980. Crustal structure of the Kane Fracture Zone from seismic refraction studies. J. Geophys. Res., 85: 3759-3777.

Detrick, R.S., Ryan, W.B.F., Mayer, L., Fox, P.J., Kong, L., Manchester, K., Kastens, K., Karson, J., and Pockalny, R., 1985. Mid-Atlantic Ridge/Kane Fracture Zone final site survey report. J.O.I., 67 pp.

Dick, H.J.B., Thompson, G., and Lowenstein, T., 1980. Layered gabbros from the Kane Fracture Zone near 23° 45' N on the Mid-Atlantic Ridge. Geol. Soc. Amer. Abstracts with Programs, 12: 412-413.

Karson, J.A., and Dick, H.J.B., 1983. Tectonics of ridge transform intersections at the Kane Fracture Zone. Marine Geophys. Res., 6: 51-98.

Mayer, L.A., Ryan, W.B.F., Detrick, R.S., Fox, P.J., Kong, L., Manchester, K., 1985. Structure and Tectonics of the Mid-Atlantic Ridge South of the Kane Fracture Zone Based on Sea MARC I and Sea Beam Site Surveys. EOS (Trans. Amer. Geophys. Union), 66: 1092.

Melson, W.G., 1978. Chemical Stratigraphy of Leg 45 Basalts: Electron Probe Analyses of Glasses. In W.G. Melson, P.D. Rabinowitz, et al., Init. Repts. Deep Sea Drilling Proj., 45: Washington (U.S. Govt. Printing Office): 493-506.

Melson, W.G., Rabinowitz, P.D., et al., 1978. Init. Repts. Deep Sea Drilling Proj., 45: Washington (U. S. Govt. Printing Office).

Melson, W.G., Thompson, G., and van Andel, T.H., 1968. Volcanism and metamorphism in the Mid-Atlantic Ridge, 21° N latitude. J. Geophys. Res., 73: 5925-5941.

Miyashiro, A., Shido, F., and Ewing, M., 1969. Composition and origin of serpentinites from the mid-Atlantic Ridge near 24° and 30° North Latitude. Contrib. Min. Petrol., 23: 117-127.

Miyashiro, A., Shido, F., and Ewing, M., 1970. Crystallization and differentiation in abyssal tholeiites and gabbros from mid-ocean ridges. Earth Planet. Sci. Lett., 7: 361-365.

Miyashiro, A., Shido, F., and Ewing, M., 1971. Metamorphism in the Mid-Atlantic Ridge near 24° N and 30° N. Phil. Trans. Roy. Soc. Lond., 268: 589-603.

Purdy, G.M., and Detrick, R.S., 1984. Along axis changes in structure beneath the median valley of the Mid-Atlantic Ridge (MAR) at latitude 23° N. EOS (Trans. Amer. Geophys. Union), 65: 1009.

Purdy, G.M., and Detrick, R.S., in press. The crustal structure of the Mid-Atlantic Ridge at 23° N from seismic refraction studies. J. Geophys. Res.

Purdy. G.M., Rabinowitz, P.D., and Schouten, H., 1978. The Mid-Atlantic Ridge at 23° N: Bathymetry and Magnetics. In W.G. Melson, P.D. Rabinowitz, et al., Init. Repts. Deep Sea Drilling Proj., 45: Washington (U.S. Govt. Printing Office): 119-128.

Sinton, J., 1979. Petrology of (Alpine Type) Peridotites from Site 395, DSDP Leg 45. In W.G. Melson, P.D. Rabinowitz, et al., Init. Repts. Deep Sea Drilling Proj., 45: Washington (U.S. Govt. Printing Office): 595-602.

van Andel, Y.H., Von Herzen, R.P., and Phillips, J.D., 1971. The Vema Fracture Zone and the tectonics of transform shear zones in oceanic crustal plates. Marine Geophys. Res., 1: 261-283.

Williams, C.F., Narasimhan, T.N., Anderson, R.N., Zoback, M.D., and Becker, K., 1986. Convection in the oceanic crust: Simulation of observations from Deep Sea Drilling Project Hole 504B, Costa Rica Rift. J. Geophys. Res., 91: 4877-4889.

FIGURE CAPTIONS

Figure 1. Bathymetric map of the Kane Fracture Zone showing position of drill sites. Contour intervals at 500 m. Depths greater than 4000 m are shaded. Location of the Mid-Atlantic Ridge shown by diagonal lines. Sites first occupied by DSDP are shown by *; sites first occupied by ODP shown by o. (After Detrick and Purdy, 1980).

Figure 2. Seismic crustal section of the Mid-Atlantic Ridge rift valley south of the Kane Fracture Zone. Approximate locations of drill sites are also shown.

Figure 3. Bathymetry profile along the axis of the Mid-Atlantic Ridge rift valley showing the position of Sites 648, 670 and 649 relative to the Kane Fracture Zone and variations in the depth of the median valley floor (from Purdy and Detrick, in press).

Figure 4. Detailed bathymetry in the vicinity of Site 648 (star). Depths are in meters below sea level. Based on Seabeam bathymetry in Detrick et al. (1985).

Figure 5. Geologic sketch map (from Leg 106 preliminary report) showing principal features adjacent to the guide base at Site 648.

Figure 6. Detailed bathymetry around Site 669. Seabeam map after Detrick et al. (1985).

Figure 7. Location of Holes 395A, 418A, and 504B.

Figure 8. Bathymetry in corrected meters and sediment isopachs, in seconds of two-way travel time in the vicinity of Site 395. Also shown are boundaries of magnetic anomaly 4 and heat flow stations, with values in mW/m^2. (From Purdy et al., 1978).

Figure 9. Operational summary of Hole 395A logging. Lithostratigraphy determined from cores recovered during Leg 45 is shown for reference. The base of the sediments, the bottom of casing, and the current total depth of the hole are shown in meters below sea level. Estimates of the quality of the logging results are indicated by the line styles. The two lines below the German temperature log indicate the relative quality of the general profile and of the temperature gradient. The Japanese temperature log is graded "fair" because it was recorded with the tool moving in-hole.

Figure 10. Detailed Seabeam bathymetry at Site 670. The low point below 4000 m marks the western boundary of the median valley floor.

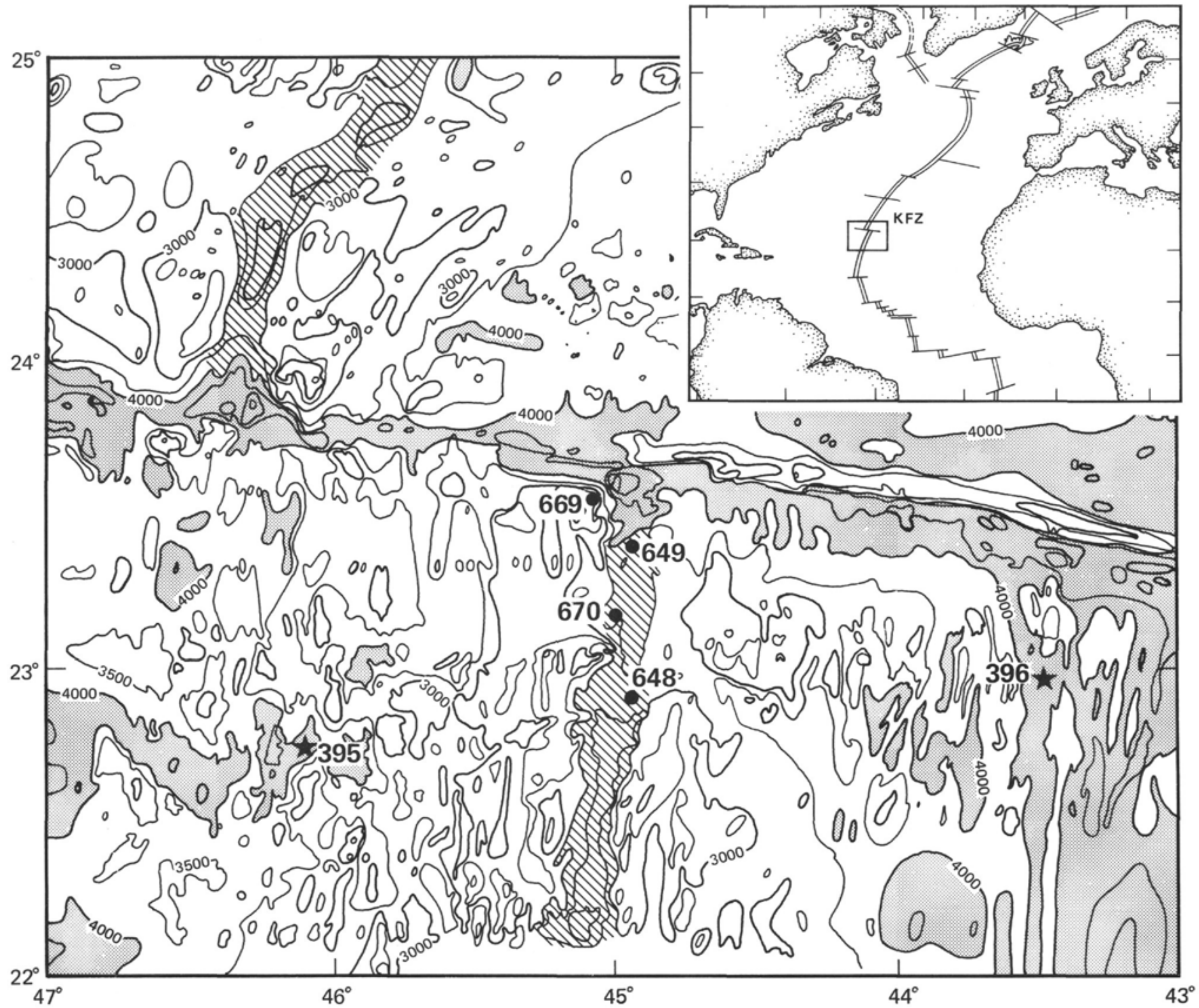
25°
24°
23°
22°
47°
46°
45°
44°
43°
669
649
670
648
395
396
3000
3500
4000
KFZ

Figure 1

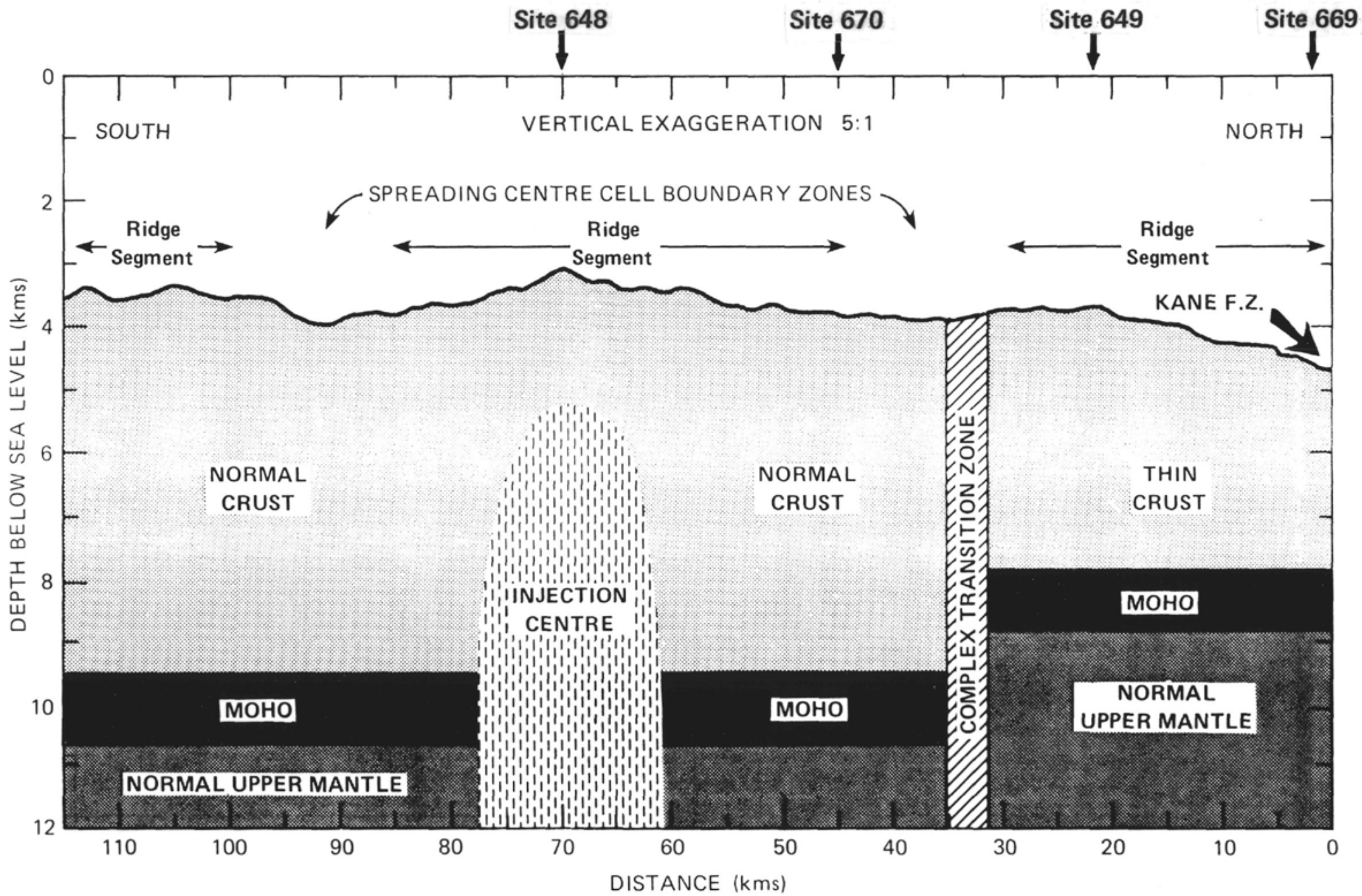
Site 648
Site 670
Site 649
Site 669
SOUTH
VERTICAL EXAGGERATION 5:1
NORTH
SPREADING CENTRE CELL BOUNDARY ZONES
Ridge Segment
Ridge Segment
Ridge Segment
KANE F.Z.
NORMAL CRUST
NORMAL CRUST
THIN CRUST
INJECTION CENTRE
COMPLEX TRANSITION ZONE
MOHO
MOHO
MOHO
NORMAL UPPER MANTLE
NORMAL UPPER MANTLE
DEPTH BELOW SEA LEVEL (kms)
0
2
4
6
8
10
12
110
100
90
80
70
60
50
40
30
20
10
0
DISTANCE (kms)

Figure 2

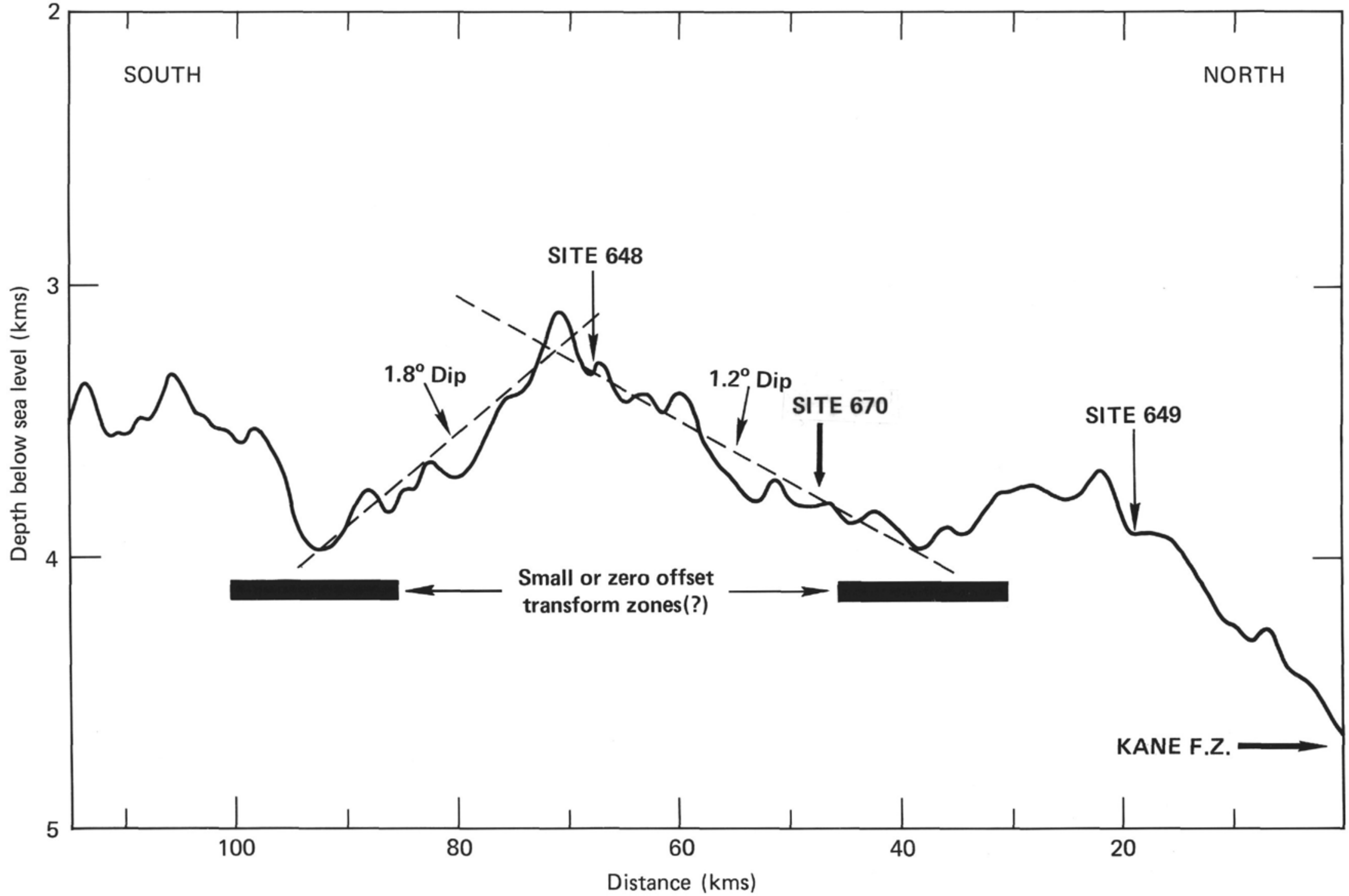
SOUTH
NORTH
SITE 648
1.8° Dip
1.2° Dip
SITE 670
SITE 649
Small or zero offset
transform zones(?)
KANE F.Z.
Depth below sea level (kms)
Distance (kms)
2
3
4
5
100
80
60
40
20

Figure 3

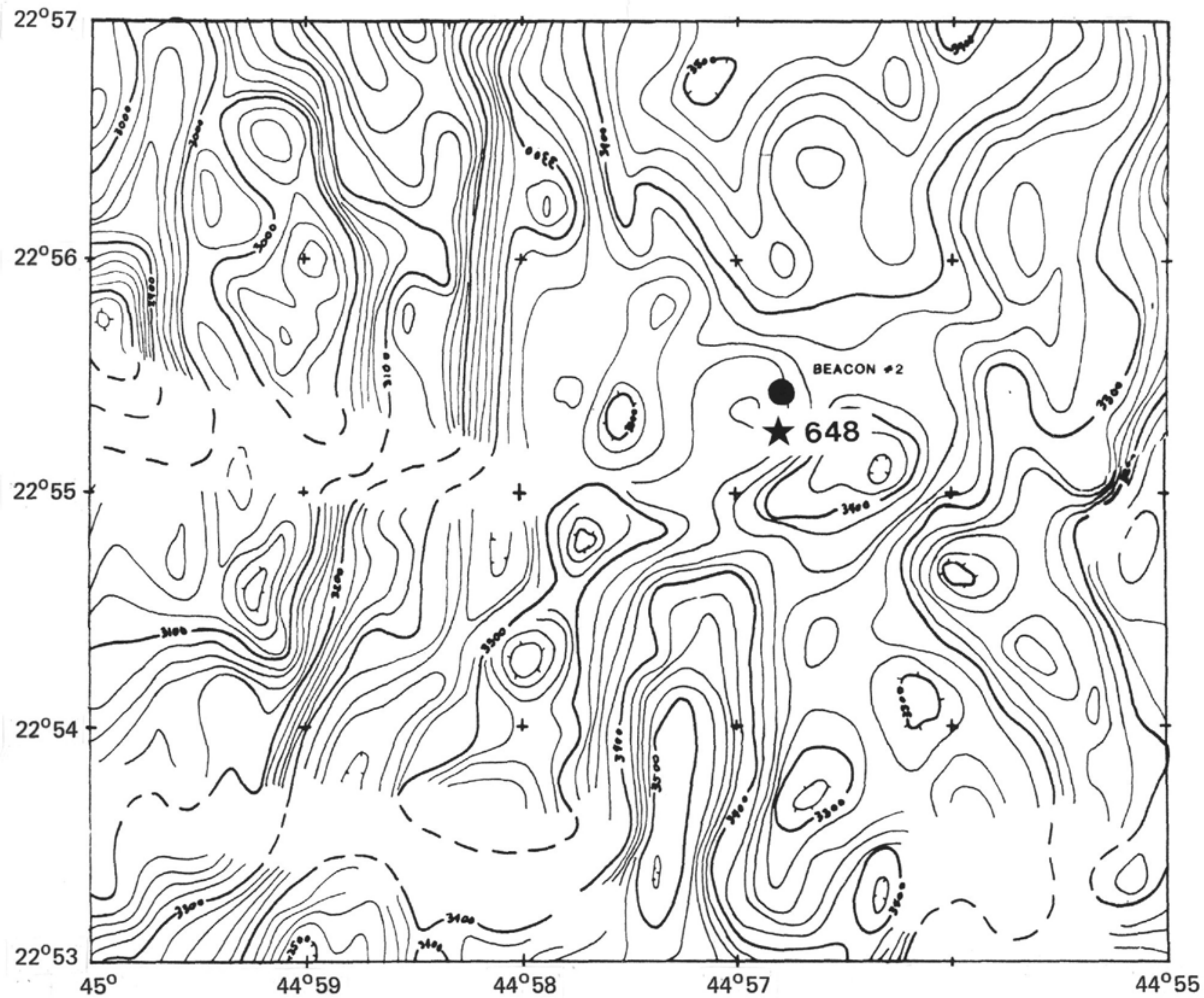

Figure 1

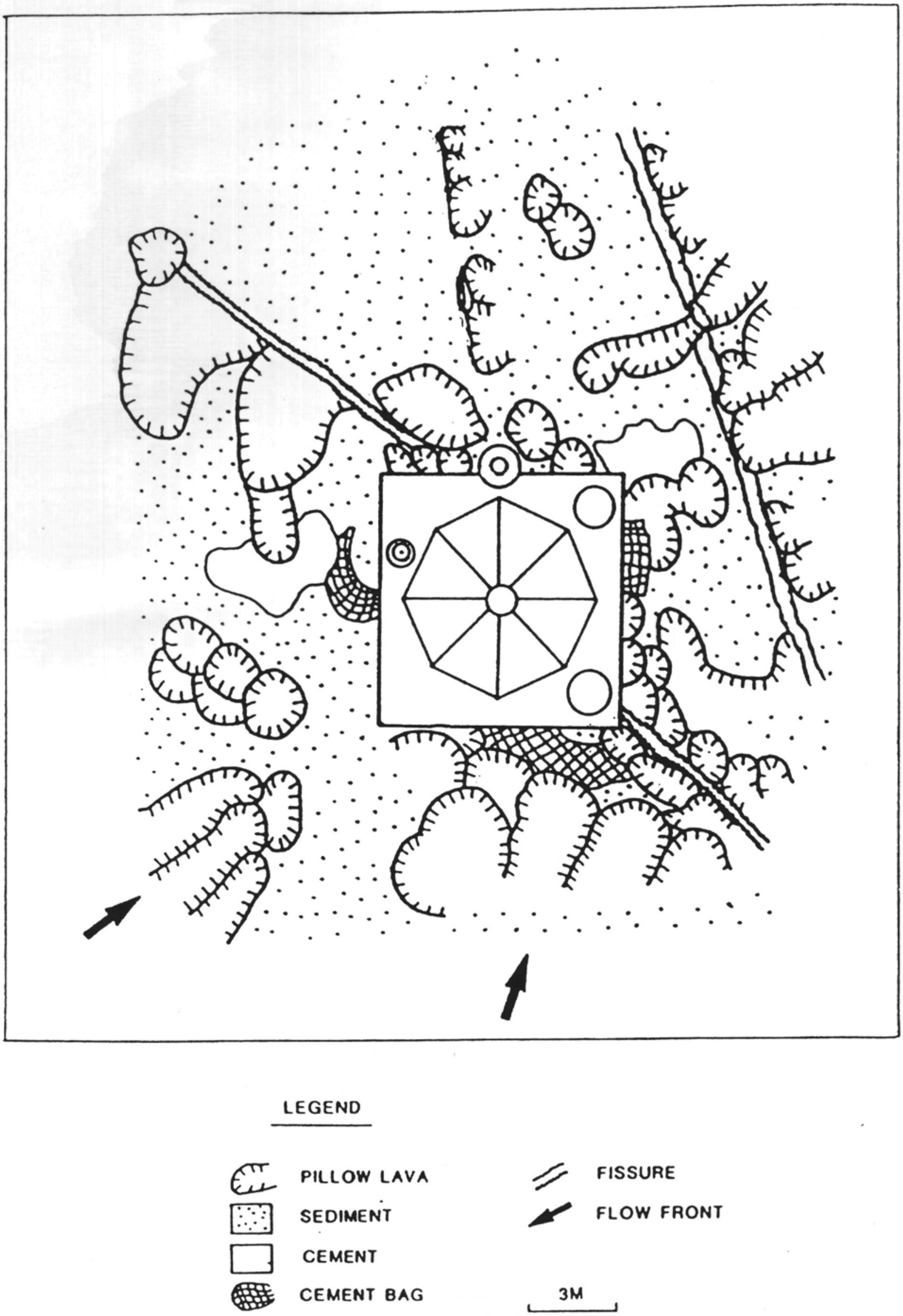
LEGEND
PILLOW LAVA
SEDIMENT
CEMENT
CEMENT BAG
FISSURE
FLOW FRONT
3M

Figure 5

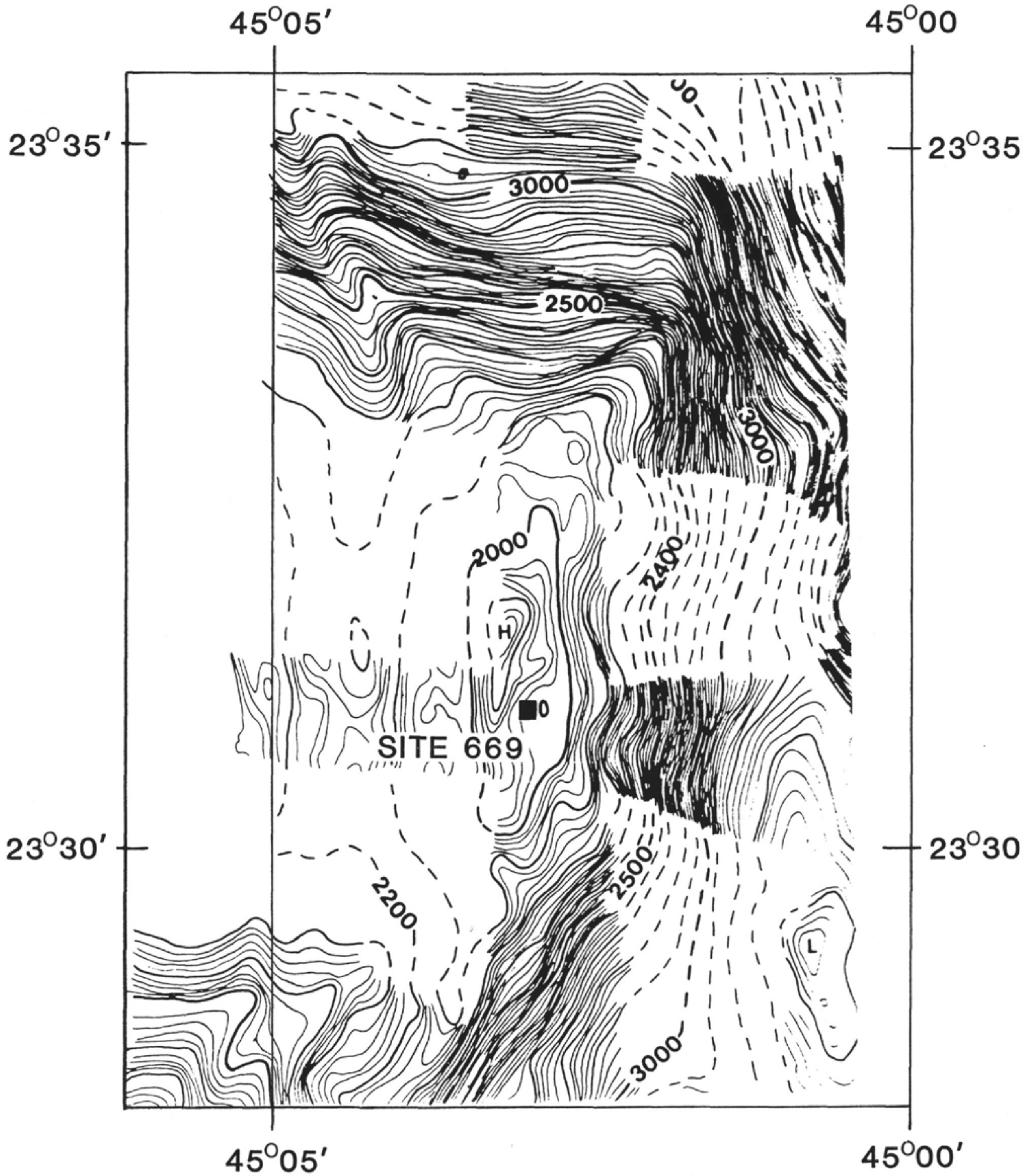
45°05′
45°00
23°35′
23°35′
3000
2500
3000
2000
2400
H
0
SITE 669
23°30′
23°30′
2200
2500
L
3000
45°05′
45°00′

Figure 6

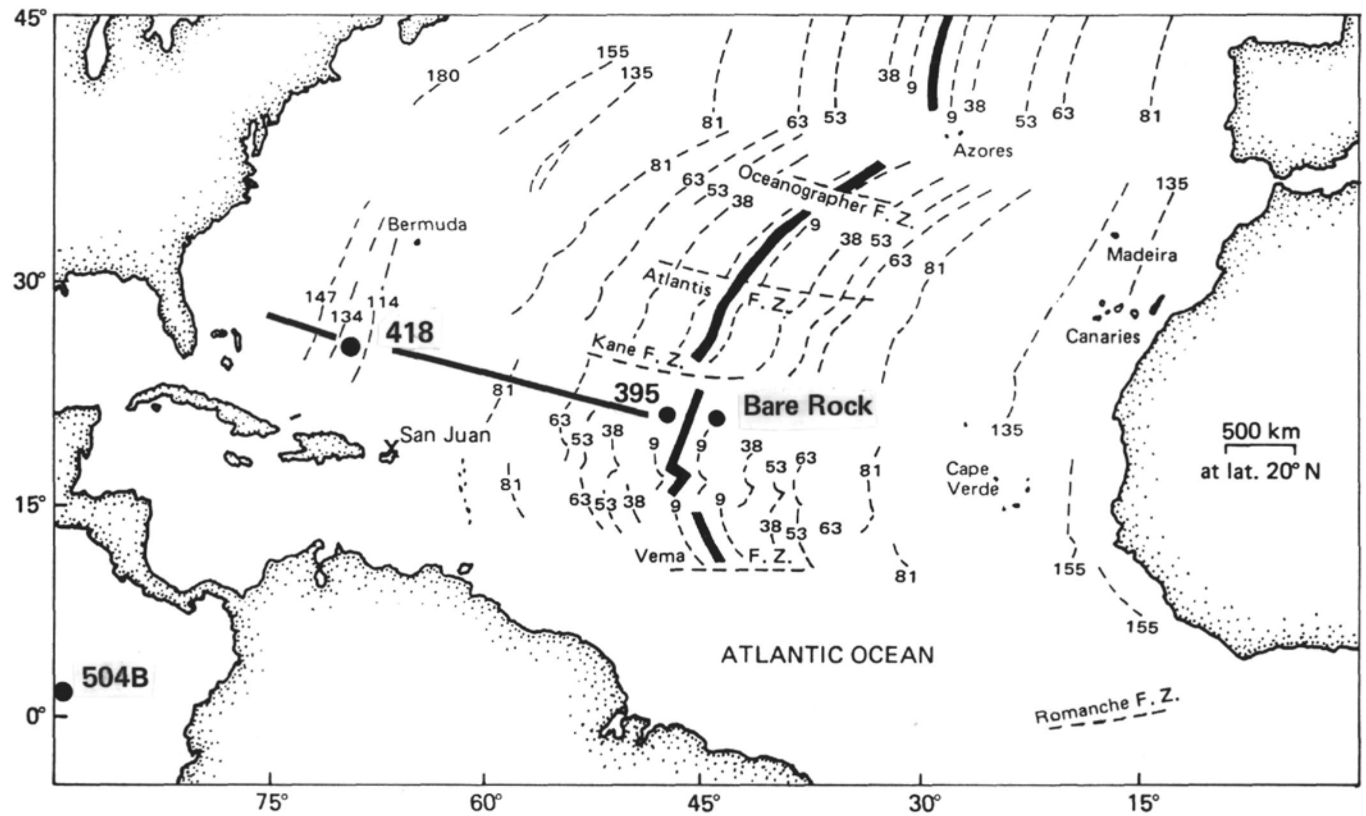
45°
30°
15°
0°
75°
60°
45°
30°
15°
180
155
135
81
63
53
38
9
Azores
Oceanographer F. Z.
Bermuda
Atlantis
F. Z.
Kane F. Z.
147
134
114
418
395
Bare Rock
San Juan
Madeira
Canaries
Cape Verde
500 km
at lat. 20° N
Vema
F. Z.
ATLANTIC OCEAN
Romanche F. Z.
504B

Figure 7

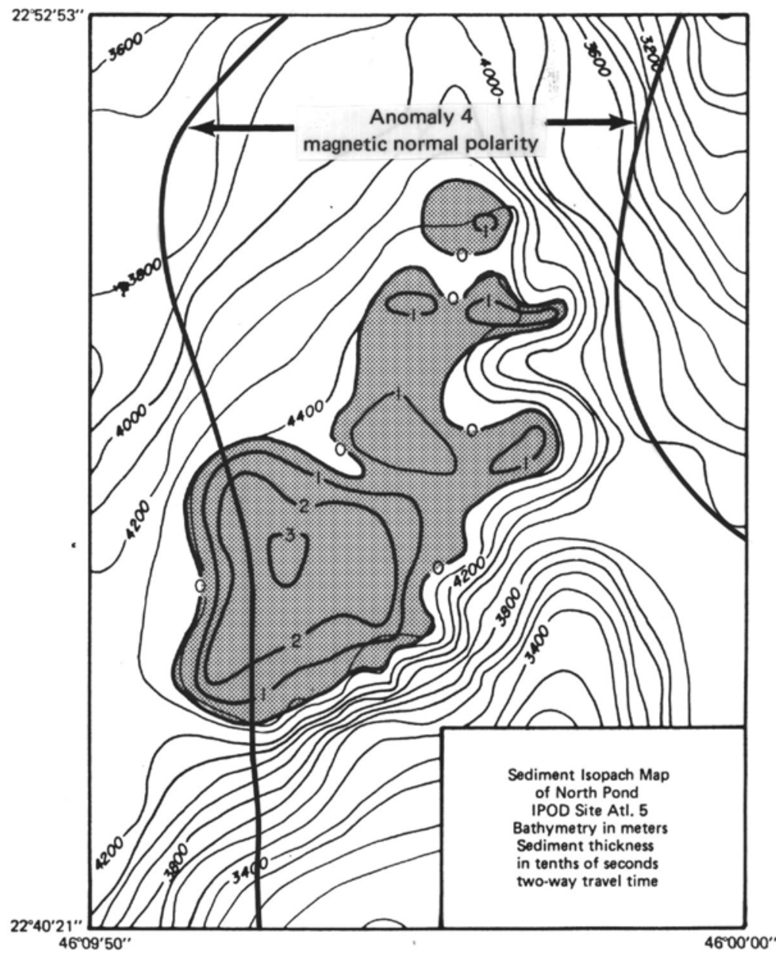
22°52'53"
3600
4000
3600
3200
Anomaly 4
magnetic normal polarity
3800
4000
4400
4200
4200
3800
3400
4200
3800
3400
Sediment Isopach Map
of North Pond
IPOD Site Atl. 5
Bathymetry in meters
Sediment thickness
in tenths of seconds
two-way travel time
22°40'21"
46°09'50"
46°00'00"

Figure 8

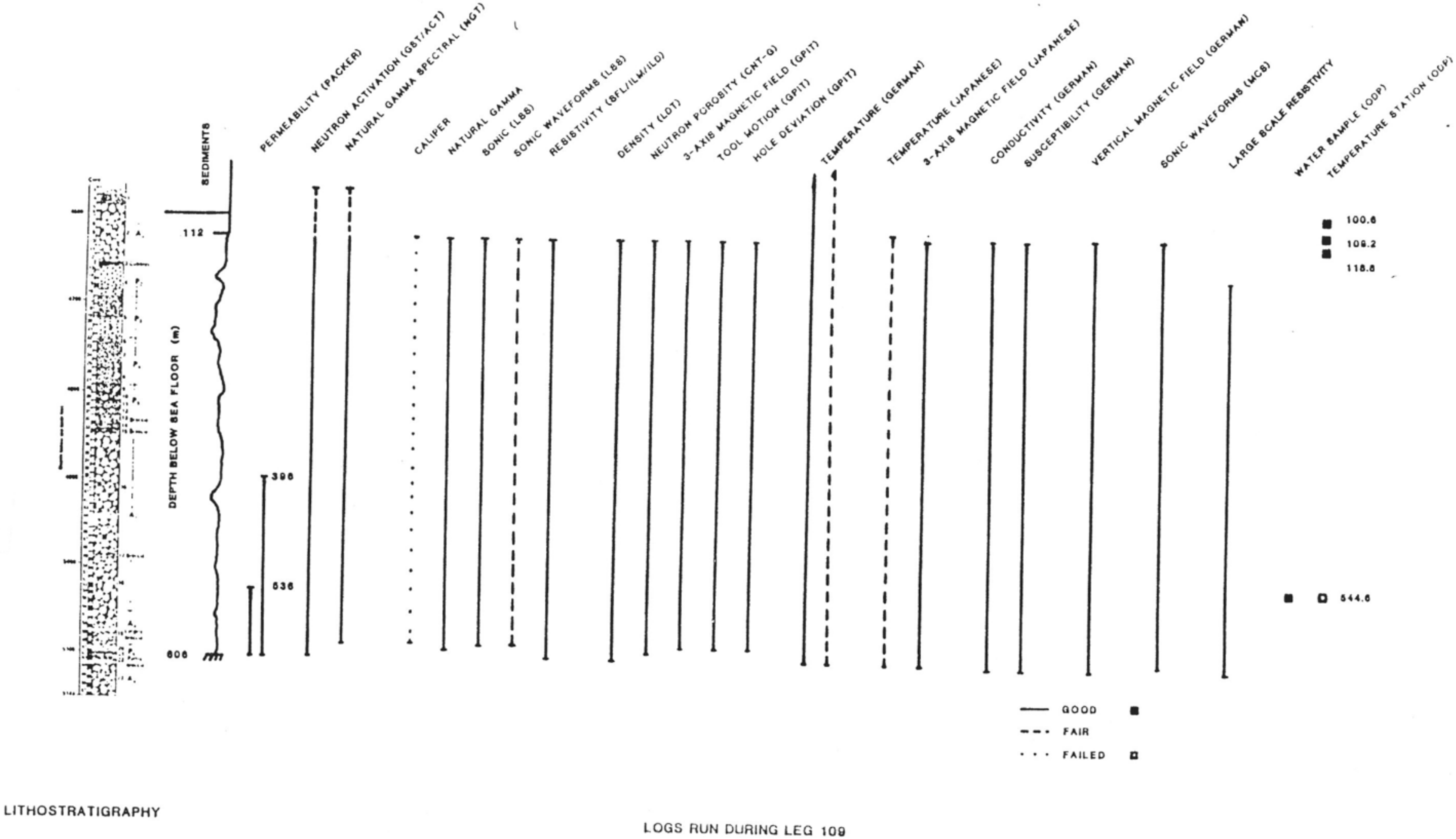
SEDIMENTS
DEPTH BELOW SEA FLOOR (m)
112
396
536
606
PERMEABILITY (PACKER)
NEUTRON ACTIVATION (GST/ACT)
NATURAL GAMMA SPECTRAL (NGT)
CALIPER
NATURAL GAMMA
SONIC (LSS)
SONIC WAVEFORMS (LSS)
RESISTIVITY (SFL/ILM/ILD)
DENSITY (LDT)
NEUTRON POROSITY (CNT-G)
3-AXIS MAGNETIC FIELD (GPIT)
TOOL MOTION (GPIT)
HOLE DEVIATION (GPIT)
TEMPERATURE (GERMAN)
TEMPERATURE (JAPANESE)
3-AXIS MAGNETIC FIELD (JAPANESE)
CONDUCTIVITY (GERMAN)
SUSCEPTIBILITY (GERMAN)
VERTICAL MAGNETIC FIELD (GERMAN)
SONIC WAVEFORMS (MCS)
LARGE SCALE RESISTIVITY
WATER SAMPLE (ODP)
TEMPERATURE STATION (ODP)
100.6
106.2
116.6
544.6
GOOD
FAIR
FAILED
LITHOSTRATIGRAPHY
LOGS RUN DURING LEG 109

Figure 9

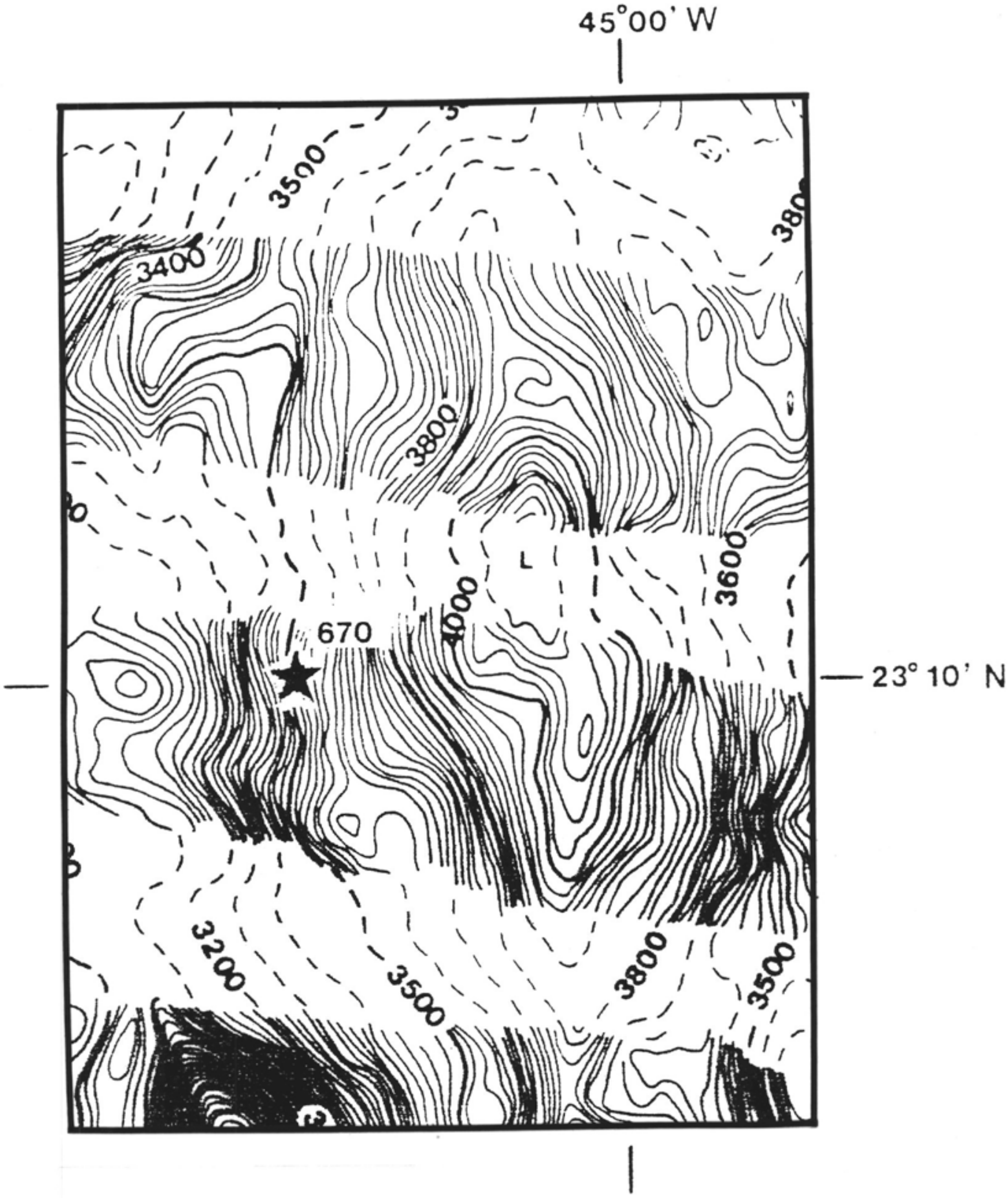

Figure 10

TABLE 1
OPERATIONAL SUMMARY - SITE 395

ORDER/START TIME	LOG/EXPERIMENT
<u>First pipe trip</u> (clean-out/logging bit)	
(1) 1800 3 June	Temperatures to 118 m bsf - ODP HPC tool very good results
(2) 0200 4 June	Temperature/water sample at 544 m bsf ODP Barnes/Uyeda + HPC tools -- 45 ml sample
0255 4 June	Ran pipe to touchdown at 5100 m brf. Hole was in excellent condition and pipe was left in the hole to run German BGR temperature probe.
(3) 0640 4 June	BGR temperature log -- very good results
1400 4 June	Hole conditioned for logging
(4) 1900 4 June	Schlumberger LSS-DIL-SFL malfunctioned/postponed
(5) 0300 5 June	Schlumberger GST-ACT run into hole after solving problem with calibration results.
(6) 1600 5 June	GST-ACT on deck, rig up German magnetometer
1830 5 June	Magnetometer test in pipe -- lost 3-axis sensor at 1000m, but logged vertical field in hole
0700 6 June	Magnetometer on deck, less lowermost 2 m of tool, which was left in hole
0900 6 June	'Wiper' pipe run to clear lost magnetometer piece
(7) 1200 6 June	Schlumberger LSS-DIL-SFL -- required 2 runs because of computer problem on first run - excellent results
(8) 0200 7 June	German magnetic susceptibility (with added weight) -- very good results
(9) 1100 7 June	LDGO MCS + Japanese magnetometer - excellent data
(10) 2100 7 June	Large-scale resistivity - excellent results
(11) 0730 8 June	Schlumberger LDT - excellent results

(12)	1800 8 June	Offset to Hole 395C for sediment temperatures - ODP Von Herzen HPC -- very good data
	0015 9 June	Rig up to trip pipe out of hole
	0715 9 June	De-torque reentry TV cable

Second pipe trip (packer in BHA)

	0700 10 June	Re-enter
(13)	1200 10 June	Packer - permeability tests at 396 and 536 m bsf
	0945 11 June	Pull out of hole - time expired

No time left to run:

((14))	LDGO BHTV
((15))	German temperature log
((16?))	Flowmeter - not needed
((17?))	Schlumberger DLL and possible repeat runs of logging tools that may not have performed as well as possible the first time.

OPERATIONAL REPORT

The ODP Operations personnel aboard *JOIDES Resolution* for Leg 109 of the Ocean Drilling Program were:

Operations Superintendent:	Steve Howard
Drilling Consultant:	Bob Rawls
Special Tools Engineer: (Cementing Specialist)	Andy Housley

INTRODUCTION

JOIDES Resolution returned to the Mid-Atlantic Ridge during Leg 109 to continue the development of the unsupported drilling and coring operations started on Leg 106. The ship departed Dakar, Senegal at 1800 hours on April 23, 1986 and ended the voyage on June 19, 1986 in Bridgetown, Barbados. The total length of the cruise was 63.8 days, of which 47.8 days were spent on site, 9.5 days in transit, and 6.5 days in port.

The primary objective of Leg 109 was to demonstrate the capability to drill and core young fractured basalt and to obtain core samples in Hole 648B to a target depth of 200-250 meters below sea floor (m BSF). Secondary coring and drilling objectives included the evaluation of reduced hole sizes, specialized cementing techniques for improving hole stability, and new bit design (12-1/4 inch drill bits and 9-7/8 inch core bits). Additional unsupported spud-in and coring operations on bare rock and/or in hydrothermal sediments were also considered important objectives in providing additional operational and engineering data utilizing the positive displacement coring motors (PDCM) and positive displacement drilling motors (PDM).

Leg 109 encountered many operational difficulties. Two bottom-hole assemblies (BHAs) were successfully fished out of Hole 648B, one of which protruded several meters above the top of the reentry cone. The leg was notable for successfully spudding a hole with an unsupported PDCM and then reentering the hole with a rotary coring system without the presence of a reentry cone.

DAKAR PORT CALL

Leg 109 commenced at 0645 hours on April 17, 1986 in Dakar, Senegal. A major port task was to replace one of the main piston rods in the heave compensator damaged during Leg 108. A representative from the manufacturer of the heave compensator, Western Gear, supervised the repair work. Other major activities included repair of a reduction gear and the steering system, inspection/alignment of guide rails, and loading of Sedco and ODP freight. A considerable amount of hardware critical to drilling operations was loaded: positive displacement drilling and coring motors, drilling jars (two types), prototype 9-7/8 inch coring bits, prototype 12-1/4 inch drill bits, a special 10-3/4 inch casing string, and TV reentry equipment.

UNDER WAY TO SITE 648B

JOIDES Resolution departed Dakar at 1800 hours on April 23, 1986. The ship averaged 12.3 knots during the transit. Light easterly winds and seas with partly cloudy to clear skies prevailed throughout the cruise. While the vessel was under way, preparations were made for the start of drilling operations at Hole 648B. Several drilling "schools" were held for the drilling personnel and the scientific party, so as to acquaint shipboard personnel with the drilling, coring, and reentry equipment and specialized operational procedures to be used during Leg 109.

A cementing standpipe and manifold system were installed on the rig floor under the supervision of Mr. Andy Housley, a cementing consultant. Modifications were also made to the cementing pumps to enhance operation of the equipment.

JOIDES Resolution approached Site 648 during a Global Positioning System (GPS) satellite window; the beacon on the guide base reentry cone was turned on and the ship was established in dynamic positioning mode. After a non-commandable beacon had been dropped, the beacon on the guide base reentry cone was turned off.

SITE 648B

Hole 648B - Drilling & Coring Operations

It was observed during Leg 106 that drilling and coring smaller hole sizes resulted in increased penetration rates and hole stability. Consequently, in an effort to reduce hole sizes, 10-3/4 inch casing with special flush joint connections was run in place of the 11-3/4 inch casing originally proposed. This allowed a reduction in hole diameter from 14-3/4 inch to 12-1/4 inch. Drill collars 9-1/2 inch in diameter were run with the 12-1/4 inch drill bits to reduce the size of the hole annulus. The reduction in hole annulus was observed to increase hole stability and to improve hole cleaning with the limited volume of viscous bentonite and XP polymer sweeps that could be pumped. The reduced hole annuli also helped to prevent rubble from falling down the hole on top of the bit.

Though improvements were observed using the 12-1/4 inch bits and 9-1/2 inch drill collars when compared to Leg 106 operations, considerable torque was still required to effect and maintain rotation to the bit. In order to minimize the chance of backing off part of the BHA or drillstring due to backlash torque, a maximum of 12,000 ft-lbs of drilling torque was applied to the drill string with the top drive. The sticky hole conditions encountered prevented effective rotation of the bit with the torque that was available for safe operation.

It was felt that increasing bit RPM would help to some extent. The bit stalled continuously at 40-60 bit RPM, but when speed was increased to 120-180 RPM it was found that the momentum of the large diameter drill collars helped to maintain rotation of the bit, and a drilling rate of 1.2 m/hr was realized. Good progress was made using this technique; however, a low cycle fatigue failure of the hydraulic drilling jars resulted in the loss of the BHA.

The damaged jar and BHA were successfully fished out of the hole using a conventional 9-1/2 inch O.D. Bowen "Slim Hole" overshot with an 8 inch spiral grapple. The drilling jar failure may be attributed to rotation of the partially unsupported BHA. It was necessary to drill with the jars partially unsupported until the hole was deepened adequately to provide complete support. The jars would have been adequately supported in the hole if problems had not been encountered with rubble backfill. Jars were located two drill collars (20 m) above the bit.

In an effort to minimize the risk of running drilling jars, a mechanical jar intended for use with the rotary coring system was run. The McCullough Torque Jar is considerably shorter than the hydraulic jar and was thought to better withstand the stresses induced while drilling with the BHA partially unsupported. In order to maintain effective rotation, drilling continued with high bit speeds (120-180 RPM). After working in the hole with the BHA still partially unsupported the jars again failed. This failure resulted in three 9-1/2 inch drill collars and the jar mandrel being left in the hole. The top of the jar mandrel (fish) protruded 3-4 m above the top of the reentry cone.

A three-foot diameter cone was welded to the bottom of a 9-1/2 inch Bowen slim hole overshot lip guide in order to attempt a "reverse reentry" (Figure 1). That is, instead of lowering the BHA into the reentry cone, a reentry cone (95% smaller in area than a standard reentry cone) was to be lowered onto the top of the BHA protruding from the hole. The three-foot diameter cone provided a guide mechanism for allowing the overshot and grapple to capture the top of the fish (Figure 1). This was accomplished with the help of the television system, coupled with precise manipulation of the fishing/reentry funnel using the ship's computer-controlled dynamic positioning system.

Though several "reverse reentries" were made on top of the fish, no positive engagement was accomplished using the 9-1/2 inch overshot, and the grapple was destroyed. A double "J" fishing tool was manufactured that would engage the two loading dogs on the jar mandrel, and the three-foot diameter guide/reentry funnel was welded to the bottom of the double "J" fishing tool.

The first trip was unsuccessful in retrieving the fish from the hole. Numerous "reverse reentries" were made on top of the fish, but the double "J" slots in the fishing tool would not engage with the loading dogs. The drill pipe was tripped out to examine the fishing tool. Modifications were made to the jay slots and the tool was run back for a second fishing attempt. This time the loading dogs were successfully engaged in the two jay slots of the fishing tool. The parted BHA (fish) was pulled out of the hole and brought to the surface.

It was decided to evaluate the feasibility of working in the hole for an extended period of time (30 days) without setting the 10-3/4 inch casing. Owing to the high risk of drilling with the 12-1/4 inch bits, it was desirable to obtain a minimal amount of core prior to attempting to set the casing. It was also necessary to verify that there were no large pieces of metal in the hole that might suspend drilling operations in Hole 648B. This meant drilling/coring 1-2 m past the point in the hole where the jar failure had occurred. One mill and six core bit runs were required to reach that point. Progress was hindered significantly by rubble backfill after each bit run. Most of the coring was done through rubble or with rubble in the hole. This limited core recovery significantly.

During these six core bit runs, approximately 63 m of basalt and basalt rubble, and 39 m of cement were cored. Core recovery for these runs was 4.9 m of basalt and 12.45 m of cement. A depth of 49.5 m BSF (3390.5 meters below rig floor: m BRF) was reached, which represented a penetration of approximately 16 m of new hole. Eventually, a point was reached where the time required to drill and core the rubble zone to get back to bottom was approaching that of the rotating life for the 9-7/8 inch core bits. At this point the decision was made to set casing, since we could no longer make substantial progress with the 9-7/8 inch coring strategy. A 12-1/4 inch bit run was made to clean out the existing 12-1/4 inch hole to a depth of 29 m BSF (3370 m BRF). The hole was then filled with cement from 26-15 m BSF (3367-3356 m BRF). A second 12-1/4 inch bit run was made with a 12-1/4 inch roller reamer assembly to remove any ledges in the hole that might prevent the casing from being run to the bottom of the hole. An increase in torque downhole was an indication that the reamers were cutting a ledge away. The hole was cleaned out to a depth of 34 m BSF (3375 m BRF). The bit was tripped from the casing shoe to the bottom of the hole several times to ensure that the hole was open.

The 10-3/4 inch casing string was made up to the 11-3/4 inch casing hanger and running assembly. The special Hydril Tripleseal connections on the casing made up very easily. Each joint was drifted after being made up to ensure that the light weight casing was not crushed while being tightened to the specified makeup torque of 12,000 ft-lbs. All casing connections were locked with a thread adhesive and tack welded. The hex kelly running tool and stinger assembly (the bumper sub/drill pipe assembly that is run inside the casing to allow cement to be pumped out of the casing shoe and up around the casing) was made up and latched into place.

For this reentry, the TV system was used instead of the sonar system because of the limited amount of casing to be run. With longer casing strings, the driller can see a loss in string weight on the weight indicator as an indication that the casing assembly is released, but this was not possible with the light-weight string used in Hole 648B. A TV centralizing sleeve was installed on top of the hex kelly landing tool nut to facilitate passage of the TV frame over the casing hanger assembly and down onto the casing, in order to position the TV low enough (40-50 ft off bottom) to be in the range of the TV camera for making the reentry.

The casing assembly and TV centralizing sub were lowered 300 m below the keel, and the TV frame with a 27 inch I.D. running sleeve was run down the drill pipe to ensure that the TV frame passed freely over the hanger assembly. The prototype TV running hardware worked very well. The TV was pulled back to the surface and the casing was run to the sea floor. The TV frame was picked up and run down over the casing hanger into position for reentry. After reentry was made, the casing was slowly lowered into the hole. A restriction was encountered at 15 m BSF (3356 m BRF). The casing was picked up and slowly worked past the restriction. The casing shoe was lowered to a depth of 28 m BSF (3369 m BRF), the casing hanger was latched into the throat of the reentry cone, and the casing hanger was released from the drill pipe.

The TV was used to visually verify that the casing hanger was properly latched-in and released. Visual monitoring also minimized the chances of crushing or bending the casing during the reentry operation. When making a sonar reentry, the drillpipe is lowered rapidly, which in this case could cause damage to the light-weight casing. Excellent visibility using the TV, coupled with precise movements using the ship's dynamic positioning system, allowed the casing to be run into the hole and released safely and efficiently.

After the casing had been cemented in place, a 9-7/8 inch tricone bit was used to drill out the casing shoe and to clean the hole out to a depth of 47 m

BSF (3388 m BRF). Several "check" trips were made from the bottom of the casing to the bottom of the hole. No fill or rubble was encountered. It appeared that the zone between 13 m BSF and 28 m BSF (3354-3369 m BRF) was the major source of rubble which had repeatedly filled the hole after each core bit run. Setting casing to 28 m BSF (3369 m BRF) isolated the major source of rubble and made it possible to continue coring operations. The 10-3/4 inch casing string also vastly improved hole cleaning capabilities by isolating the large-diameter hole sections located in the upper portion of the hole.

A 9-7/8 inch core bit and coring BHA were picked up and run into the hole. The hole was reamed several times between 42 m BSF and 47 m BSF (3383-3388 m BRF) after a tight spot was encountered at 3383 m. Again there was no evidence of rubble falling in the hole and a core was cut to a depth of 50.5 m BSF (3391.5 m BRF), making one meter of new hole (Figure 2). The cone lost on core bit run 6 was now assumed to have been either milled or drilled up.

At 50.5 m BSF (3391.5 m BRF) the bit stalled out on bottom. When picked up off bottom to re-establish rotation, an overpull of 100k lbs was noted. An increased overpull of 250k lbs was exerted on the pipe, but the bit remained stuck in the hole. The pipe was continually worked for 31 hrs to 44 m BSF (3385 m BRF) with up to 250k lbs overpull exerted on the drillstring. It seemed that a rock or possibly the core bit cone in the hole had wedged between the bit and the side of the hole. This was evidenced by the fact that up to 1000 gal/min of fluid could be circulated past the bit. If there had been large amounts of rubble packed off around the bit, the flow rate would have been restricted.

Because of the lack of progress that had been made in freeing the pipe using conventional techniques, it was decided to run an explosive charge out the end of the bit and detonate it in hopes that the concussion from the explosion would jar the stuck pipe free. An explosive charge (severing tool rigged up on a core barrel) was run down the drill pipe. The explosive was carefully run out of the bit and positioned 2 m below the bit. The charge was detonated while pulling 250k lbs overpull on the drillstring. No immediate movement of the pipe was noted after detonation. The pipe was continually worked for approximately two hours. Gradually it came free with an overpull of 250k lbs.

Drilling operations were suspended at Hole 648B after freeing the pipe. To continue operations in Hole 648B, it will be necessary to make a mill run to remove the cone (junk) from the hole. Once the cone has been removed, drilling and coring operations may be resumed cautiously with the use of drilling jars.

CONCLUSIONS AND RECOMMENDATIONS

Borehole Considerations

Reduced hole sizes and hole annuli considerably improved hole stability and hole cleaning capability.

Drilling and Core Bits

The two 9-7/8 inch core bit designs resulted in a considerable increase in bit life. Core bits run on Leg 106 had an average bit life of 6 hours. The new core bits designed for use on Leg 109 had a bit life exceeding 12 hours.

Both the Type 7 conical and Type 75 chisel structures held up well under the adverse drilling conditions. The tungsten carbide wear buttons and hardfacing applied to the shirt tail area and along the leading edge of the bit legs provided considerable wear resistance. The increase in bit life can most likely be attributed to the wear protection design features. Penetration rates for both core bit designs (Type 7 and Type 75) averaged 2 m/hour.

The 12-1/4 inch Q7JSL Tricone bits also held up well in the hole. The tungsten carbide wear pads and wear buttons located in the shirttail area and along the leading edge of the bit legs provided considerable wear resistance. The Type 7 conical cutting structure held up well in the adverse drilling conditions. Penetration rates for the 12-1/4 inch core bits was 1.2 m/hour.

The limiting factors for both the 9-7/8 inch core bits and the 12-1/4 inch hard formation drill bits were the lack of adequate drilling weight and the limited torque that could be applied to the bit while drilling unstable hole intervals.

12-1/4 Inch Packed-Hole Drilling Reaming Assembly

The 12-1/4 inch reamer assembly run with the 9-1/2 inch drill collars and 12-1/4 inch Q7JSL drill bit appeared to help minimize hole disturbance and allowed the bit to run smoothly while reaming the existing 12-1/4 inch hole and drilling out the cement. However, when the bit-reamer assembly encountered new hole, excessive torque was required to maintain bit rotation. It is, therefore, questionable whether this type of drilling assembly could be safely used for making new hole without having the BHA adequately supported.

Specialized Cementing Techniques

Unstable hole conditions were experienced to varying degrees during all phases of drilling and coring operations. In an effort to enhance hole stability, open hole cement plugs were pumped frequently at the end of selected bit runs. The cement plugs prevented the hole from caving in when the bits were pulled from the hole, as well as cementing together fractures in the hole wall. The cement plugs were effective, and had the special cementing techniques not been used, drilling operations would have been suspended early on prior to running casing. The cement plugs provided enough stabilization to the upper part of the hole to allow limited coring operations to be performed. The cement plugs also provided enough temporary hole stability to allow casing to be successfully run to 28 m BSF (3369 m BRF).

10-3/4 inch Casing Hardware

The newly designed 10-3/4 inch casing string worked very well with the 11-3/4 inch casing hanger. The limited clearance between the inside diameter of the casing and the 9-7/8 inch bit (0.040 inch radially) was found to be adequate.

Prototype TV Running Hardware For Casing Reentry

The prototype TV centralizing sleeve for the 11-3/4 inch casing hanger and the 27 inch I.D. TV running sleeve worked as designed. The TV frame passed freely in both directions over the casing hanger assembly and enabled the TV to be positioned on the 10-3/4 inch casing at the desired depth to make a safe and effective reentry.

Utilization of Explosive Charges In Well Bore To Free Stuck Pipe

The technique of using an explosive charge outside the bit appears to be a viable measure in the event no other jarring force is available. It should be noted that this type of technique should only be used as a last resort prior to severing the drill pipe stuck in the hole.

Drilling Jars

Both the mechanical and hydraulic drilling jars lacked sufficient strength for aggressive drilling when unsupported above the sea floor. Both a hydraulic jar and a mechanical torque jar failed in the hole, resulting in two time-consuming fishing operations. Both jars are of proven design and have been used in the oil industry for many years. Development of a special set of drill jars will be required for future unsupported drilling. It should be noted that both mechanical and hydraulic jars were used successfully numerous times when supported downhole in Hole 648B.

Special Fishing and Reentry Techniques

The three-foot diameter funnel attached to the bottom of the fishing tools was a very effective guide for making "reverse reentries" onto the jar mandrel protruding above the reentry cone. Using the TV system and the ship's dynamic positioning system, efficient reentries were consistently made onto the jar mandrel.

The three-foot diameter guide funnel represents a reentry target area that is approximately 95% smaller than that of a standard reentry cone. A good comparison of the scale of making a reentry with a three-foot diameter target in 10,942 ft (3341 m) of water would be standing on the top of a derrick 142 ft tall and trying to thread a needle with an eye 0.040 inch in diameter.

Statistics for the Coring and Drilling Operations at 648B

66.25 m basalt/basalt rubble cored
5.15 m basalt recovered

39.0 m cement cored
12.45 m cement recovered

60.0 m rubble and cement drilled with 12-1/4 inch Q7JSL bits
13.2 m milled with 12-1/4 inch and 9-7/8 inch junk mills

165.3 m total meters drilled and cored includes drilling fill and rubble. Does not include redrilling intervals on same bit run.

87.5 hours rotating using 4 - 12-1/4 inch Tricone bits Q7JSL Smith
1 - 9-7/8 inch Tricone bit FDGH Smith
1 - 12-1/4 inch concave junk mill
1 - 9-7/8 inch concave junk mill

57 hours coring using 5 - 9-7/8 inch RBI Type 75 core bits
2 - 9-7/8 inch RBI Type 7 core bits

Over 70 miles of pipe were tripped during operations at Hole 648B.

175 barrels of cement were pumped to enhance hole stability.

3,256 barrels of gel and XP polymer were pumped to clean the hole.

Average penetration rate of 9-7/8 inch core bits = 2.2 m/hr in cement/basalt rubble.

Average penetration rate of 9-7/8 inch core bits = 2 m/hr in basalt (new hole).

Average penetration rate of 12-1/4 inch Q7JSL bits = 1.2 m/hr in cement/basalt rubble.

The low core recovery rate can be attributed to the large amount of rubble that had to be redrilled on each core bit run.

Figure 2 shows the present configuration of the Hole 648B.

Drilling Fluids

Viscous slugs of bentonite (gel) and XP polymer were pumped in individual volumes of 25-100 barrels in an effort to improve hole cleaning in Hole 648B. Although the results were variable, the overall effectiveness of this technique, as on Leg 106, was marginal at best. Due to the large-diameter hole sections present in the upper hole, effective annular velocities were degraded below the effective slip velocities of cuttings that were being swept from the hole.

Future Unsupported Hard Rock Drilling Considerations

The following comments are intended to reflect current thoughts about drilling hard rock, based on the recent drilling and coring operations conducted in 648B during Leg 109.

To continue drilling operations in Hole 648B, or possibly to drill other sites with similar geological features, emphasis must be placed on drilling smaller diameter holes. Significant improvements were noted when the hole size was reduced from 12-1/4 inch to 9-7/8 inch in diameter. It can be expected that reducing the hole size further would result in continued improvement in drilling conditions. This would necessitate developing special size drill bits, drill collars, and casing not currently in the suite of tools utilized by the Ocean Drilling Program. The use of high speed small diamond bits powered by downhole motors/turbines capable of being run down inside the drill string in a manner similar to current ODP coring systems should be considered. A system of this type is in the preliminary stages of development at this time.

The guide base has proven to be an effective means of spudding a hole on hard rock with only minimal support for the BHA. The drilling techniques used to date have provided reasonable penetration rates. However, the pacing factor in drilling young fractured basalt formations is the lack of hole stability. Emphasis needs to be placed on a means of addressing the unstable hole conditions early on while establishing the upper strings of casing. If this can be accomplished, progress could be realized on a single drill leg at future hard rock drilling sites.

CORING WITH AN UNSUPPORTED BOTTOM HOLE ASSEMBLY

SITE 669

Hole 669A

The drillship departed Site 648 at 0430 hours on May 31, 1986. The transit to Site 669 took 5-1/2 hours. On arrival a commandable beacon was dropped and the ship was put into the dynamic positioning mode. Prior to running the drilling assembly in the hole, a site survey was conducted using the TV/sonar system, which was run down on the coaxial cable without the drillpipe. The bottom was sediment covered with low relief. A drill site was selected that consisted of sediment and rubble forming a low N-S winding ridge. It was hoped that this type of bottom would provide limited bit confinement during the spudding operation. A sonar reflector was released from the TV frame and positioned at the desired drill site.

A positive displacement coring motor (PDCM) was used for drilling operations at Hole 669A. On completion of the site survey, the TV sonar system was pulled back to the surface and the PDCM drilling assembly was run into the hole. A 10 1/2 inch x 2.25 inch core bit with a Type 9 conical cutting structure was used. The TV/sonar system was then run back on the drillpipe to locate the drill site.

The bit was positioned 10-15 ft from the buoyed sonar reflector. The hole was spudded using the TV system to monitor drilling operations, tagging the seafloor at 1979 m. Two to three m of penetration were realized very rapidly due to the lack of consolidation of upper sediments. The hole was spudded in with 0-4K lbs weight, a 260 gal/min flow through the motor, 300 psi standpipe pressure, and a 40-50 RPM bit rotation.

Progress was made to a depth of 4 m BSF (1983 m BRF) at which point the penetration rate fell off dramatically at what was thought to mark the top of the underlying gabbro. The flow rates through the motor were increased to 570 gal/min, resulting in rotational speeds of 90 RPM. An attempt was made to increase the weight on the bit, but this resulted in the motor continually stalling out. A maximum of 4K weight could be applied to the bit while still maintaining effective bit rotation. The bit appeared to skid on the gabbro rather than to penetrate it.

Due to the poor penetration rate, the bit was pulled out of the hole. After pulling the core barrel, it was planned to offset 100 m in hopes of finding a more desirable drilling location. However, difficulties were encountered during attempts to retrieve the core barrel. After three unsuccessful attempts the drilling assembly was tripped out of the hole.

A large piece of rubble was found jammed in the core catcher and throat of the bit. The piece of rubble induced a torsional load in the core barrel system that resulted in a torsional failure of the threaded connection between the two 15-ft core barrel sections and also backed off several other core barrel system connections to varying degrees.

Drilling operations were suspended at Hole 669A due to difficulties with the penetration rate 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. Repairs were made to the coring motor while in transit to the next site and it was made ready for use later on in the leg.

DSDP SITE 395

Hole 395A

After suspension of drilling operations at Site 669 the ship departed for DSDP Site 395 at 0500 hours on June 2, 1986. A beacon was dropped at 1210 hours on June 2 to begin an extensive eight day logging program in Hole 395A. A cleanout bit was run prior to any open-hole logging work to ensure that there were no bridges in the hole that might foul the logging tools and cable. In order to obtain the desired undisturbed temperature measurements and water samples in the hole, the Von Herzen APC Heat Flow/Uyeda temperature probes and Barnes Water Sampler were run on a core barrel ahead of the cleanout bit. As the pipe was lowered into the hole, temperature and water samples were taken successfully at preselected depth intervals. The junk (bit/bit release and hydrophone) left in the hole from previous legs was tagged at 606 m BSF (5100 m BRF). Prior to positioning the cleanout bit inside the casing for open hole logging work, a German temperature logging tool was run through the drill pipe to the bottom of the hole.

To minimize hole disturbance, no circulation was allowed while the cleanout bit was being run into the hole. Excellent results were obtained with the German temperature log inside the drill pipe, temperatures correlating very well with previous temperature data taken in Hole 395A. This technique can be considered in the future for use in holes where undisturbed hole environments are a requirement for selected downhole measurements.

After completion of the temperature measurements and water sampling, the following logs were run successfully: Schlumberger GST-ACT-NGT (neutron activation); German magnetometer (vertical field only); Schlumberger LSS-DIL-SFL (sonic and resistivity); German magnetic susceptibility; Lamont-Doherty Geological Observatory MCS (multi-channel sonic); Japanese magnetometer/temperature probe; Large Scale Resistivity; and Schlumberger LDT-CNT-NGT (lithodensity-inclinometer).

After extensive logging in Hole 395A, the pipe was pulled 6 m above the seafloor and the ship offset 100 m to the northwest. The HPC temperature probe was latched into the BHA and spaced out approximately 0.3 m ahead of the bit. The bit/HPC heat flow assembly was washed into the sediments to selected depths of 396 m BSF (4890 m BRF) and 536 m BSF (5030 m BRF) where temperature measurements were taken. Though no core was cut, the hole was designated 395C. A technique was used of washing to within 5-6 m of the selected depth where temperature measurements were to be taken. At this point the pumps were turned off and the bit was pushed down, without circulating, to the desired depth to minimize disturbing the sediment temperature to be measured. Very good results were obtained using this method.

After completing the temperature measurements in Hole 395C, the drill pipe was pulled and the ship was offset back to Hole 395A. Due to electronic problems encountered with the Mesotech sonar tool while making the first reentry into Hole 395A, the TV was used for making the second reentry with the straddle packer assembly. It was necessary first to detorque 1000 m of the coaxial TV cable which had not been off the cable reel. Difficulties had been encountered during Leg 106 from the TV cable not being detorqued properly at the factory; the residual cable torque resulted in the coaxial cable wrapping 17 times around the drill pipe when the TV frame was deployed for the first time.

To avoid a repeat of this situation, the TV frame was lowered on the coaxial cable (off the drill pipe) and allowed to detorque. When the TV was lowered to 4481 m, the frame spun slowly, removing cable twists for more than an hour. While the coaxial cable was detorquing the TV was used to inspect the Hole 395A reentry cone. The cone was found to be in excellent condition with no signs of corrosion or damage from the many previous reentries. The cone was first placed on the seafloor in December, 1975 on Leg 45, and revisited on Leg 78B in March of 1981. Three glass balls were still tethered to the rim of the reentry cone, and were used as secondary sonar reflectors. The mud box on the cone was positioned correctly at the mud line, which was an indication that the cone had not settled since its original emplacement.

After detorquing the coaxial cable and completing the visual inspection of the reentry cone, the TV was brought to the surface. The BHA with the straddle packer was then run into the hole using the TV for reentry, and permeability tests were run at 4890 and 5030 m. This completed the major logging objectives at Hole 395A and the drillship departed Site 395 at 1930 hours on June 11, 1986.

SITE 670

Hole 670A

A commandable beacon was dropped at Site 670 at 0130 hours on June 12, 1986. Selection of Site 670 was based on survey work done by the deep-sea submersible ALVIN while JOIDES Resolution was at Hole 395A. A positive displacement coring motor (PDCM) was selected to establish Hole 670A. Due to the extensive bottom survey conducted by ALVIN it was unnecessary to conduct a site survey using the TV/sonar system. The drilling assembly was lowered to the seafloor and a sonar reflector released from the TV frame at the desired drilling location.

With the TV system monitoring drilling operations, Hole 670A was spudded using the unsupported PDCM drilling assembly. Five to seven m of sediment were penetrated before any weight was taken by the bit. The seafloor depth was established at 3625 m.

Drilling parameters were maintained as follows: 2-4K lbs weight on the bit, 456 gal/min flow rate through the motor, 650 psi standpipe pressure and 100-110 RPM bit speed. The PDCM ran very effectively and provided adequate torque for coring the peridotite formation.

The PDCM was used to core 0-35.7 m BSF (3625-3660.7 m BRF). Core barrel #1 was recovered without any mechanical problems associated with the core barrel or latch assembly. When the second core barrel was retrieved, two latch fingers were found to be broken off and remained in the motor. The lower core barrel also remained in the motor due to a failure in the connection between the upper and lower core barrels. The PDCM drilling assembly was tripped out of the hole and laid down. A total of 0.75 m of core was recovered with the PDCM system.

A Rotary Coring System (RCB) was picked up and using the TV-sonar system on the drillpipe, Hole 670A was successfully reentered. The crater was approximately 4' x 8' (1.22 x 2.5 m) and was filled with gel mud. On lowering the TV-sonar system to the seafloor, a sonar return of the reflector was received, and the crater of Hole 670A was then sighted with the TV.

Reentry into Hole 670A was accomplished in less than 20 minutes. The bit was lowered 7 m BSF (3632 m BRF), and was then washed down to 12 m BSF (3637 m BRF) with no weight on the bit. When coring past 7 m BSF (3632 m BRF) on the previous bit run, 2-4K lbs weight on bit was required. This was a positive indication that the RCB was in the original borehole.

Eight cores were cut with the RCB between sea floor (3625 m BRF) and 92.5 m BSF (3717.5 m BRF) with a total recovery of 5.77 m. Recovery ranged from 2% to 17%. The lower recovery rate with the proven rotary coring system may be attributed to jamming of core/rubble in the core catchers. A total of 92.5 m was cored in Hole 670A and a total of 6.52 m of core was recovered.

CONCLUSIONS; HOLES 669A-670A

Evaluation of the Positive Displacement Coring Motor (PDCM)Performance

The PDCMs have adequate torque/weight for unsupported spudding of a hole into fractured basalt with voids (hollow pillows), which helps to provide adequate bit confinement. The PDCMs do not appear to have adequate torque/ weight for spudding into a gabbro type formation with an unsupported BHA (Hole 669A). In softer formations (such as peridotite), where 2-6K weight on bit is required, the PDCM unsupported spud-in technique is very effective (Hole 670A).

Prior to further deployment of the PDCM system, the core barrels and latch system will require more development. The core barrel wall thickness will need to be increased significantly to obtain adequate strength in the core barrel connections. A stronger core barrel latch system is also required.

The PDCM concept has proven to be a viable means of establishing bore holes in regions of the ocean where there is less than 40 m of sediment on the seafloor. Prior to the development of the PDCM unsupported coring system, attempts to spud in with conventional rotary coring systems repeatedly resulted in BHA failures. To date, 14 holes have been spudded in using both the positive displacement drilling motors and the positive displacement coring motors, without any BHA failures. The holes have been established in a wide range of lithologies that includes young fractured basalts, gabbro, peridotite, and hydrothermal sulfide deposits. Penetration rates vary considerably depending on the type of formation being cored/drilled.

Based on experiences at Hole 670A, it should be feasible in the future to establish bore holes in selected formations having little or no sediment cover using the unsupported motor technology. A reentry could then be made into the borehole with one of the conventional rotary coring systems and cored to the desired depth.

Reentry Systems

Reentries were made very efficiently with both the TV and sonar systems. Though deployment of the TV system takes more time than the sonar system, the actual maneuvering/reentry time is considerably less with the TV system. The total time for reentries balanced out for the sonar and TV systems. The selection of a reentry system for a particular reentry was based on operational circumstances rather than on time considerations.

Colmek TV System

The TV system was crucial to the many specialized operations conducted on Leg 109. The TV was used for making 19 reentries, 2 site surveys, and spudding 2 holes with unsupported BHAs. Of the 19 reentries, 7 "reverse reentries" were made with a 3-foot diameter cone attached to a fishing tool that was lowered onto the top of a BHA protruding above the reentry cone. The twisted-off BHA was successfully fished out of 648B, allowing drilling and coring operations to continue.

A hole was spudded with an unsupported PDCM assembly at Site 670. After the hole was established, it was successfully reentered with a rotary coring assembly. The ship's position was maintained over the hole during the pipe trip to change drilling assemblies. The reentry took 20 minutes. It should be noted that the highly efficient reentry was attributed to the unusually accurate position that was maintained over the hole with the ship's dynamic positioning system.

The coaxial TV cable had to be reheaded during the leg. The cable had not been reheaded since the TV was originally put into service on Leg 106. The cable was cut and found to be wet for several hundred feet necessitating the removal of 300 ft of cable. The outer armor on this cable was worn significantly. The drive chain on the TV winch failed while the TV was at a depth of 4480 m due to the master link pin fracturing, causing the chain to be thrown off the winch sprockets onto the moonpool doors. The chain was replaced and winch operation was restored. No other problems occurred with either the electrical or mechanical TV system components during the extensive day-to-day TV deployment.

Mesotech Sonar System

Six reentries were made with the Mesotech sonar tool. Considerable difficulties had been encountered interpreting the sonar signal due to problems with double imaging and back scatter sonar reflections during deployments on previous legs. Modifications were made to the electronics package at the factory, which allowed sonar reentries to be made in reentry cones situated on both hard rock and in sediments.

Mechanical Repairs -- Rig Down Time

Very little time was lost due to mechanical failure of rig or ship equipment (Figure 3). Sixteen hours were lost when the #1 mud pump and manifold were found to be plugged with cement. A new overboard discharge line that was installed during Leg 109 was inadvertently tied into the existing standpipe overboard blowdown line. Ten barrels of cement were mixed for instructional purposes and pumped overboard. When the cement was pumped through the overboard discharge line a portion of the cement flowed back through the standpipe blowdown line to the standpipe manifold on the rig floor. The cement then flowed through the standpipe manifold and down the #1 standpipe to the manifold on the #1 mud pump. The manifold on the #1 pump was disassembled and the cement removed from the manifold assembly and mud pump lower end - the standpipe was clear above the manifold. An independent overboard discharge line was installed to correct this problem.

VISIT TO RESOLUTION BY THE ATLANTIS II

During Leg 109 the research vessel ATLANTIS II, mothership for ALVIN submersible, was working in the same general area as JOIDES Resolution. Several dives were made by ALVIN to the hydrothermal vents (Site 649) and to Serocki Volcano (Site 648). JOIDES Resolution and ATLANTIS II maintained daily communications to coordinate dive and drill sites.

On June 12, 1986 at 1600 hours ATLANTIS II came alongside JOIDES Resolution. A number of groups of personnel from each vessel were exchanged by Z-boats for short visits. One of the scientists that inspected the guide base from the submersible came aboard and briefed ODP personnel on observations made. These were as follows:

* Only three legs of the guide base were found to be in contact with the seafloor. Two legs were in shallow sediment; one was between two basalt pillows and the fourth leg was positioned over a fissure.

* There were no fissures running under the guide base as originally thought, no visible damage to the guide base or reentry cone and no evidence of corrosion to any part of the structure.

* One cement bag was partially filled with cement. The other three bags were torn to varying degrees and contained only small amounts of cement. The cement bags did not conform to the seafloor and did not appear to be effective.

* Drill cuttings were found to be deposited in the guide base funnel, on top of the guide base, and in the secondary reentry cone. Very fine cuttings and bentonite were present on the seafloor around the guide base.

* The guide base was found to be positioned only 7 ft from the test hole (Hole 648A) drilled prior to setting the guide base. The surface of the volcano around the guide base contained many fissures.

After the tours on both vessels had been completed, all personnel were safely returned to their respective ships. At dusk <u>ATLANTIS II</u> steamed towards the dive site scheduled for the next morning. Coring operations continued uninterrupted during the <u>ATLANTIS II</u> visit.

COMMUNICATION

Telex traffic to and from the ship was heavy throughout the leg. Due to difficulties with receiving telex communications on the beach, an unusual number of Marisat telephone calls was necessary to keep the ODP management updated on critical operations on the ship.

Over 100 "HAM" radio phone patches were made by shipboard personnel. The radio phone patches were made available at two different time periods each day. The purchase of the ham radio equipment has been a very good investment.

WEATHER

The weather during Leg 109 followed the climatological norm for this period. All drilling sites were on the southern periphery of the Bermuda High, placing the ship in the trade wind zone. As such, winds and seas maintained an easterly component. Winds were generally light to occasionally moderate in force and seas seldom exceeded 6 ft in height.

With the exception of some infrequent rain showers, days were sunny. The air temperature ranged from 29°C/84°F to 22°C/72°F. Seawater temperature was almost constantly 24°C/75°F.

PERSONNEL

The poor core recovery rate and unusually difficult drilling conditions were hard on the ship's crew and scientific party. However, morale was good and all concerned worked tirelessly, recovering from one difficult operational situation after another. Throughout the leg there was a unified team effort among the scientific party, SEDCO and ODP operations.

A motorman sustained back and leg injuries from a fall and was transferred to a passing freighter for medical treatment on shore. One other lost-time accident occurred when an assistant driller sustained a broken foot from a piece of drillpipe that was hung in the pipe racker and rolled free unexpectedly.

FIGURE AND TABLE CAPTIONS

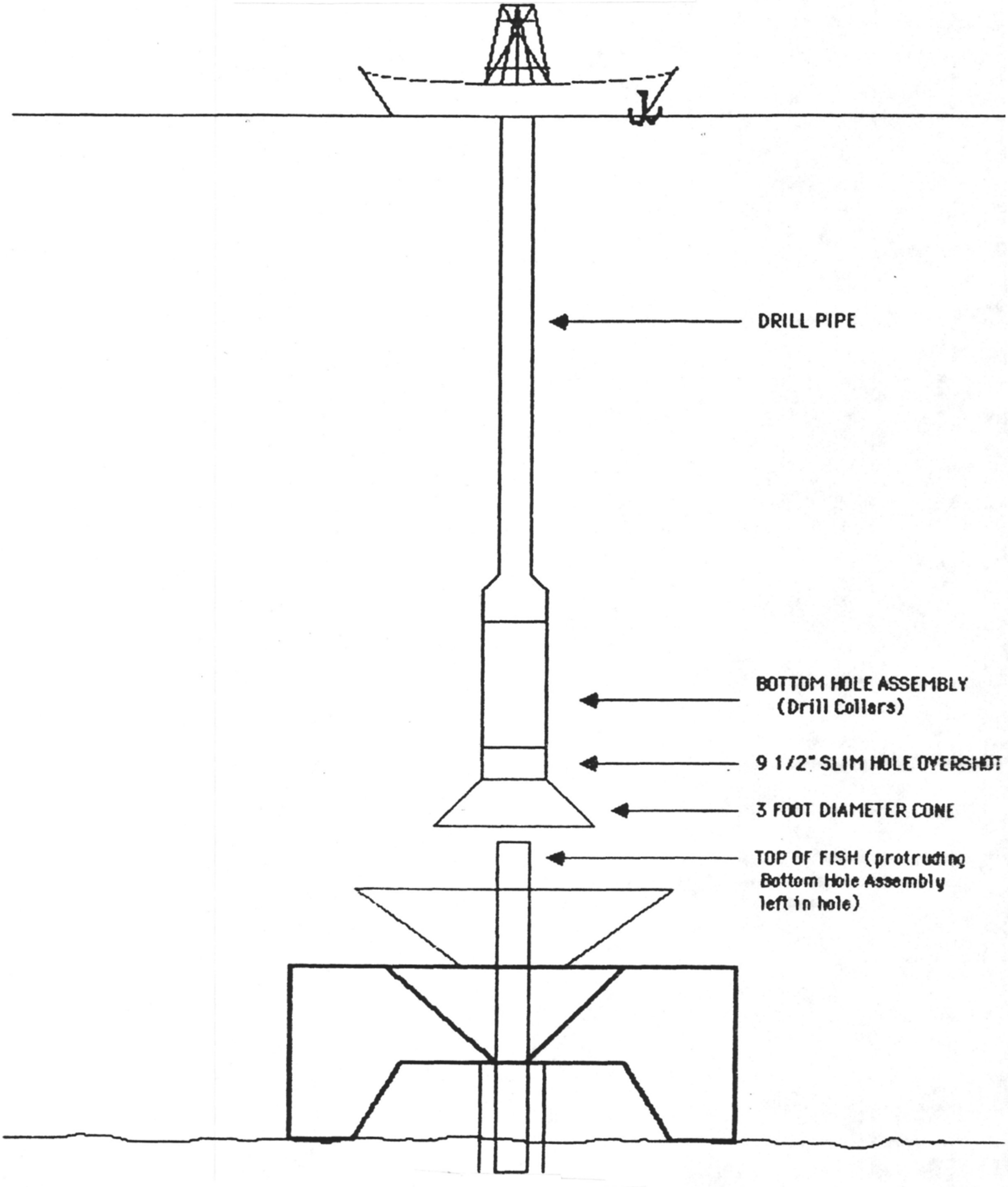
DRILL PIPE
BOTTOM HOLE ASSEMBLY
(Drill Collars)
9 1/2" SLIM HOLE OVERSHOT
3 FOOT DIAMETER CONE
TOP OF FISH (protruding
Bottom Hole Assembly
left in hole)

Figure 1

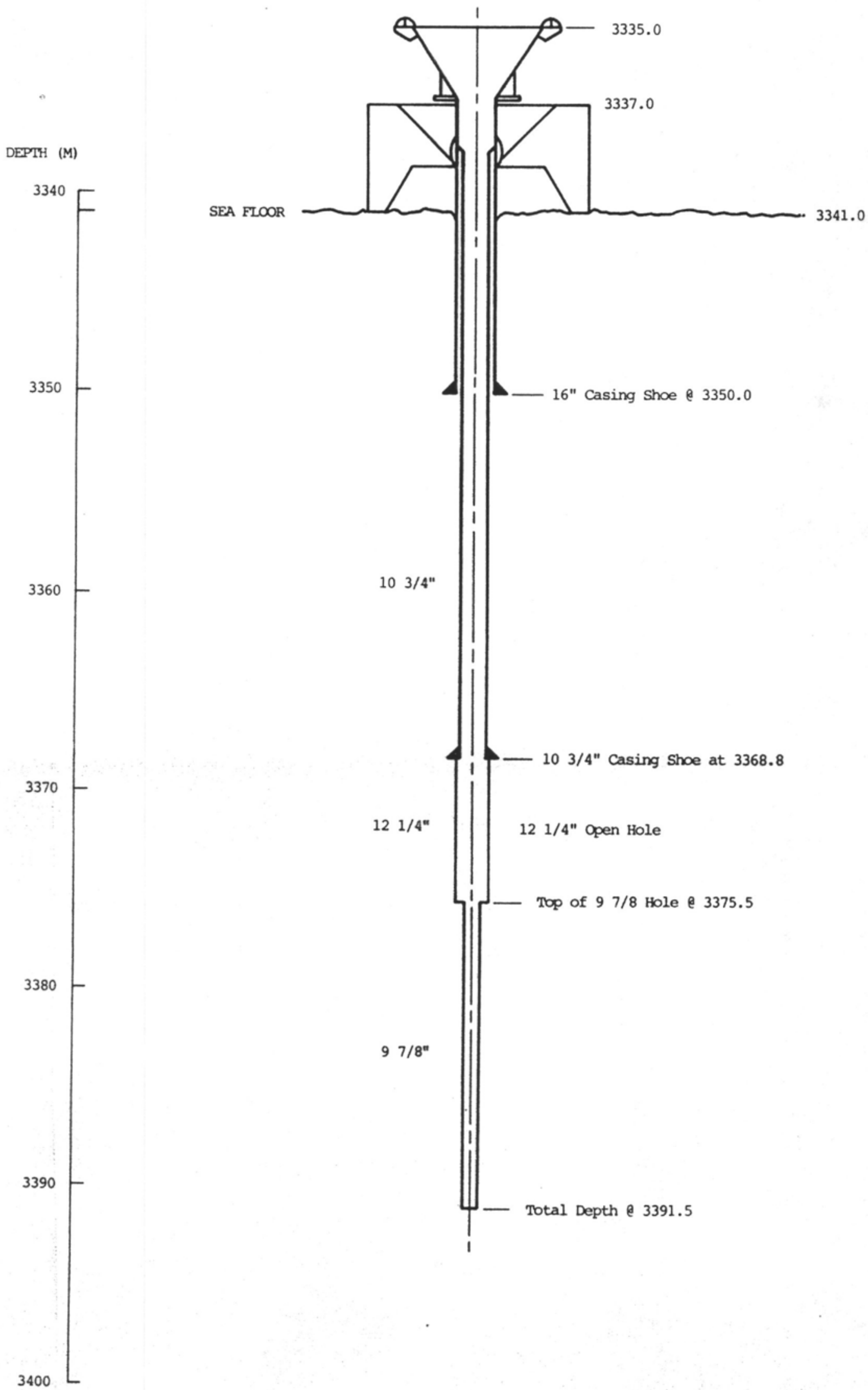
DEPTH (M)
3340
3350
3360
3370
3380
3390
3400
3335.0
3337.0
SEA FLOOR
3341.0
16" Casing Shoe @ 3350.0
10 3/4"
10 3/4" Casing Shoe at 3368.8
12 1/4"
12 1/4" Open Hole
Top of 9 7/8 Hole @ 3375.5
9 7/8"
Total Depth @ 3391.5

Figure 2

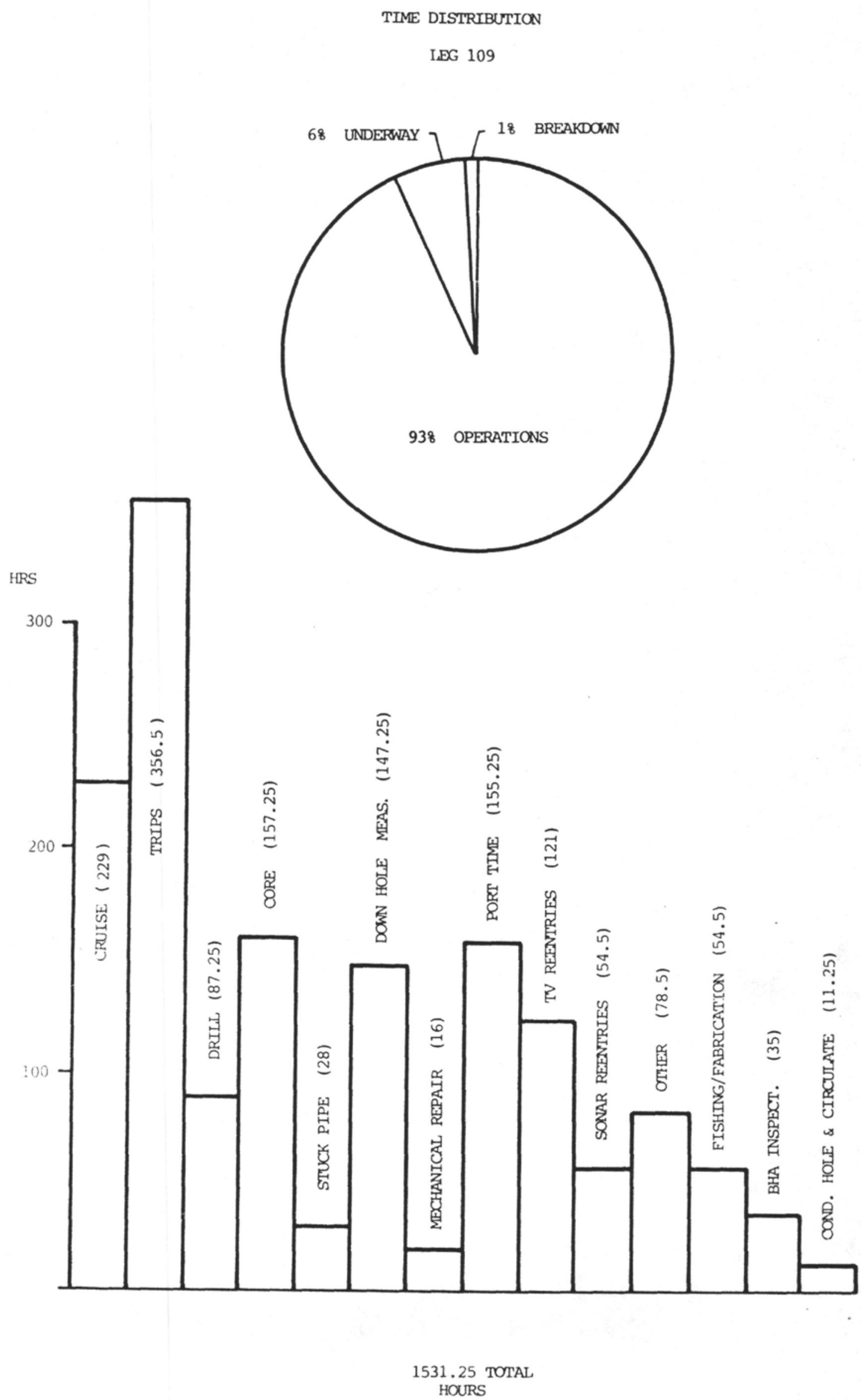
TIME DISTRIBUTION
LEG 109
6% UNDERWAY
1% BREAKDOWN
93% OPERATIONS
HRS
300
200
100
CRUISE (229)
TRIPS (356.5)
DRILL (87.25)
CORE (157.25)
STUCK PIPE (28)
DOWN HOLE MEAS. (147.25)
MECHANICAL REPAIR (16)
PORT TIME (155.25)
TV REENTRIES (121)
SONAR REENTRIES (54.5)
OTHER (78.5)
FISHING/FABRICATION (54.5)
BHA INSPECT. (35)
COND. HOLE & CIRCULATE (11.25)
1531.25 TOTAL
HOURS

Figure 3

OCEAN DRILLING PROGRAM
TIME DISTRIBUTION CHART
LEG 109

DATES	SITE	CRUISE	TRIPS	DRILL	CORE	STUCK PIPE	DOWN-HOLE MSMTS.	MECH. REPAIR	PORT TIME	REENTRIES TV	REENTRIES SONAR	OTHER	FISH-ING	BHA INSPEC.	COND. HOLE & CIRCULATE	TOTAL TIME
4-17-86 4-23-86									155.25				(Fabrication Fishing tools & on bottom fishing time only.)			155.25
4-23-86 4-29-86		134.0														134.0
4-29-86 5-31-86	648B		271.0	85.75	81.25	28.0		16.0		85.5	38.75	61.0	54.5	35.0	10.75	767.5
5-31-86		3.75														3.75
5-31-86 6-2-86	669A		11.0		9.5					11.5		12.75				44.75
6-2-86		7.25														7.25
6-2-86 6-11-86	395A 395C		38.75 9.0				142.25 5.0			12.0	15.75				0.5	209.25 14.0
6-11-86 6-12-86		6.0														6.0
6-12-86 6-16-86	670A		26.75	1.5	66.5					12.0		4.75				111.5
6-16-86 6-19-86		78.0														78.0
TOTALS		229.0	356.50	87.25	157.25	28.0	147.25	16.0	155.25	121	54.5	78.5	54.5	35	11.25	1531.25

Table 1

OCEAN DRILLING PROGRAM
BEACON SUMMARY
LEG 109

	SITE	MAKE/MODEL	FREQ. KHZ	SERIAL NUMBER	SITE TIME HOURS	WATER DEPTH METERS	REMARKS
1)	648B	DATASONICS MODEL 352	14.5	274	768 HRS	3341	Dropped beacon 0455 hrs 4-29-68. Used 32 days. Very weak signal. Not reliable to position off of when ship left site.
2)	648B	DATASONICS MODEL 352DC	15.5	225	72 HRS (106 & 109)	3341	Turned off. Still working properly when last used.
3)	669A	DATASONICS MODEL 352DC	14.5	224	44.25 HRS	1979	Dropped 0800 hrs 5-31-86. Turned off 0415 hrs 6-2-86.
4)	395A	DATASONICS MODEL 352	16.5	276	209 HRS	4494	Turned on 1130 hrs 6-2-86. Still operating normally 6-11-86 when ship left site.
5)	670A	DATASONICS MODEL 352DC	16.5	238	216 HRS	3625	Dropped beacon 0130 hrs 6-12-86. Turned off 1200 hrs 6-16-86. Was also used at 648B on TV Frame for 16 TV re-entries.

MODEL 352 = NON-COMMANDABLE

MODEL 352DC = 208db COMMANDABLE

Table 2

OCEAN DRILLING PROGRAM
SITE SUMMARY
LEG 109

HOLE	LATITUDE	LONGITUDE	DEPTH METERS	NUMBER OF CORES	METERS CORED	METERS RECOVERED	PERCENT RECOVERED	METERS DRILLED	TOTAL PENET.	TIME ON HOLE	TIME ON SITE
648B	22-55.3'N	44-56.8'W	3341	3	CEMENT 39.00	CEMENT 12.45	39.26%	73.20	139.45	767.5	767.5
				17	BASALT 66.25	BASALT 5.15	7.8%				
669A	23-31.0'N	45-2.7'W	1979	1	4.0	0.1	.03%	---	4.0	44.75	44.75
395A	22-45.5'N	46-04.9'W	4494	--- NO CORING OR DRILLING, LOGGED EXISTING HOLE ---						209.25	
395C	22-45.5'N	46.04.9'W	4494	0	0	0	---	80.0	80..0	14.0	223.25
			--- OFFSET 350 FEET NW OF 395A AND TOOK TEMPERATURE MEASUREMENTS IN SEDIMENTS TO A DEPTH OF 4574M. NO CORING OR DRILLING WAS DONE ---								
670A	23-09.9'N	45-1.9'W	3625	10	92.5	6.52	7.0	---	92.5	111.5	111.5
		TOTALS		28*	162.8*	11.8*		73.2	316.0*	1147.0	1147.0

* TOTALS DO NOT INCLUDE CEMENT CORED/RECOVERED.

* DUE TO THE HIGHLY UNSTABLE HOLE CONDITIONS IN 648B, THE TOTALS DO REFLECT HOLE INTERVALS THAT WERE RECORED AND REDRILLED (648B ONLY).

Table 3

OCEAN DRILLING PROGRAM
BIT SUMMARY
LEG 109
648B

	HOLE	MFG	SIZE	TYPE	SERIAL NUMBER	METERS CORED/ RECORED	METERS DRILLED	TOTAL PENET	CUMULATIVE METERS	HOURS THIS HOLE	TOTAL HOURS	CONDITION	REMARKS
1.	648B	STC	12 1/4	Q7JSL	ER7393	----	17.9	17.9	17.9	13	13	T-2 B-4 1/4	Legs of bit worn severely. Particularly around grease reservoirs. Moderate wear on stabilizer pads. Drill rubble.
2.	648B	STC	12 1/4	Q7JSL	EW1189	----	13	13	13	6	6	T-2 B-2 I	BHA failure 6 hours into bit run. Drill rubble.
3.	648B	RBI	9 7/8	C-75	AV726	18.54	----	18.54	18.54	6.75	6.75	T-2 B-3 1/16	Broken Inserts. Wear noted on legs in area around grease reservoir. Stabilizer pads worn moderately. Core rubble/cement.
4.	648B	RBI	9 7/8	C-75	AV725	9.76	----	9.76	9.76	5.0	5.0	T-2 B-3 1/8	No broken inserts. Legs, shirt tails, grease reservoir areas and stabilizer pads all worn severely. Grease seal plugs close to point of falling out. Grease seeping from reservoirs. Core rubble.
5.	648B	RBI	9 7/8	C-75	AV728	20.46	----	20.46	20.46	10.5	10.5	T-2 B-4 1/16	Grease reservoir plugs worn severely. Stabilizer pads significantly worn. Bearing seal in one cone near failure. Core rubble/ cement.
6.	648B	RBI	9 7/8	C-75	AV727	10.0	----	10.0	10.0	7.5	7.5	T-2 B-4 1/8	Legs severely worn. Shirt tail of one cone eroded severely and grease seal leaking. Core rubble.
7.	648B	RBI	9 7/8	C-75	AV724	22.26	----	22.26	22.26	11.0	11.0	T-2 B-4 1/4	Stabilizer pads worn away. Grease reservoirs leaking. Broken inserts. Severe leg and body wear. Core rubble.

Table 4

BIT SUMMARY LEG 109
648B CONTINUED

	HOLE	MFG	SIZE	TYPE	SERIAL NUMBER	METERS CORED/ RECORED	METERS DRILLED	TOTAL PENET	CUMULATIVE METERS	HOURS THIS HOLE	TOTAL HOURS	CONDITION	REMARKS
8.	648B	RBI	9 7/8	CC-7	AV723	28.46	----	28.46	28.46	16.5	16.5	T-2 B-4LC	Lost 1 cone. Cone bearing spindle (Pin) failed. Cone leg still intact. Shirt tails and legs severe-ly worn. Core guides bent in. All grease reservoir plugs in place. Cone appeared to have wedged down in body of bit allowing core to continue to be cut after failure occurred. Very little stalling and no indi-cation of excessive downhole torque. Core rubble. New hole.
9.	648B	STC	12 1/4	Q7JSL	EW1187	----	18.00	18.00	18.00	20.0	20.0	T-2 B-4 1/8	Legs and shirt tails moderately worn. Drill fill.
10.	648B	STC	12 1/4	Q7JSL	EW1196	----	20.91	20.91	20.91	22.0	22.0	T-2 B-3 I	All grease reservoir plugs worn down and leaking. Seal failure noted. Excessive leg and shirt tail wear.
11.	648B	STC	9 7/8	FDGH	CP4309	----	19.20	19.20	19.20	8.5	8.5	T-4 B-4 1/16	Drill out 10-3/4 casing shoe. Legs and shirt tails worn but not excessively. Upon drilling thru shoe used bit to drill fill below shoe and clean out hole.

BIT SUMMARY LEG 109
648B CONTINUED

	HOLE	MFG	SIZE	TYPE	SERIAL NUMBER	METERS CORED/ RECORED	METERS DRILLED	TOTAL PENET	CUMULATIVE METERS	HOURS THIS HOLE	TOTAL HOURS	CONDITION	REMARKS
12.	648B	RBI	9 7/8	CC-7	AV719	1.5		1.5	1.5	4.5	4.5	T-2 B-4 1/4	Broken inserts. Severe shank wear. Several deep grooves noted in bit body. Grooves most probably caused by cone lost on earlier bit run be- coming wedged between side of hole and bit body. No damage caused to bit from explosive charge detonated outside bit. Explosive charge used to free stuck bit. Suspended drilling operations upon free- ing bit.

BIT SUMMARY
LEG 109
669A

1.	669A	RBI	10 1/2	C-9	AT519	3.0	----	3.0	3.0	6.25	6.25	T-2 B-2 1/8	Ran on PDCM

BIT SUMMARY
LEG 109
670A

1.	670A	RBI	10 1/2	C-9	AT518	35.7	----	35.7	35.7	21 3/4	21 3/4	T-2 B-2 1/8	Ran on PDCM
2.	670A	RBI	9 7/8	C-3	AS011	56.8	----	56.8	56.8	25	25	T-2 B-2 0	Ran on RCB

TECHNICAL REPORT

The ODP Technical and Logistics personnel aboard JOIDES Resolution for Leg 109 of the Ocean Drilling Program were:

Laboratory Officer:	Ted "Gus" Gustafson
Laboratory Officer:	Bill Mills
Curatorial Representative:	Diana Stockdale
System Manager:	John Eastlund
Electronics Technician:	Randy Current
Electronics Technician:	Dwight Mossman
Yeoperson:	Jessy Jones
Photographer:	Roy Davis
Marine Technician:	Wendy Autio
Marine Technician:	Larry Bernstein
Marine Technician:	Bettina Domeyer
Marine Technician:	Tamara Frank
Marine Technician:	Henrike Groschel
Marine Technician:	Harry "Skip" Hutton
Marine Technician:	Mark "Trapper" Neschleba
Marine Technician:	John Weisbruch
Marine Technician:	Dawn Wright
Weather Observer:	Vernon Rockwell

Other technical personnel aboard JOIDES Resolution were:

Christoph Czora, Downhole Magnetometer Engineer (Federal Inst. for Geosciences and Natural Resources, Hannover, FRG)

Steve Diana, Schlumberger Logger (Schlumberger, Houston, TX)

INTRODUCTION

Leg 109 began in Dakar, Senegal on April 20, 1986 and was terminated in Bridgetown, Barbados on June 20, 1986. A total of 58 operational days were spent at sea. The primary operational and scientific objectives were to deepen and log Hole 648B, previously started on Leg 106. Secondary objectives were to reoccupy and log DSDP Hole 395A, and to attempt bare-rock unsupported spud-ins in the Kane Fracture Zone and/or in the active hydrothermal zone discovered on Leg 106. A total of 3 holes were drilled, from which 25.22 m of core was recovered (including 12.45 m of cement); approximately 125 samples were taken for immediate shipboard analysis. Sampling for shore-based investigations was coordinated with Leg 106 sampling and took place in Bridgetown, Barbados immediately following Leg 109.

DAKAR PORT CALL

JOIDES Resolution and the Leg 108 participants steamed into port two days early. The Leg 109 technician group arrived in Dakar April 20, 1986 and technician crossover activities began early the following morning. Port call work was started by the 108 crew as soon as the ship arrived and was completed by the Leg 109 crew prior to sailing on April 23, 1986, two days earlier than scheduled. Port call work included routine logistics, ship tours for local university personnel, and a visit by Japanese Broadcasting Corporation's NHK television crew who were filming a documentary on the Sahara Desert; Leg 108 cores were to be a part of the documentary. A radiation survey of ODP X-ray equipment and G.R.A.P.E. was conducted for the Texas A&M Radiological Safety Office. No service calls were scheduled for Dakar.

CRUISE ACTIVITIES

Transits and Underway Geophysics

Geophysical site selection survey equipment was not deployed during Leg 109. Locations of Holes 648B and 395A were based on known geographical coordinates from having occupied the sites on previous ODP or DSDP Legs. Site locations for Holes 669A and 670A were based on coordinates and depths selected from detailed bathymetric surveys conducted by ATLANTIS II, ALVIN and others. As a result, the sites were found easily using GPS, transit satellite, and bathymetric navigation alone. Header data for SMOOTH plotting was collected on all transits throughout the cruise. The magnetometer was deployed on several occasions; unfortunately, the rig noise rendered meaningful data collection impossible for most of the cruise. We are attempting to have signal cables rerouted, but this has not been accomplished as yet. Both the 12 kHz and 3.5 kHz depth sounders were reliable for site approaches; however, weak returns in deeper waters at high speeds were a problem. A safety circuit bypass switch was added to the 3.5 kHz transducer which allows maximum output at maximum pulse length. This test, recommended by Raytheon, gave encouraging but limited results. New GPS software installed in Dakar markedly improved the existing system, but problems remain with almanac updating. Magnavox assures us that future software versions will resolve these difficulties.

The levelwinds installed on two of the fantail winches work well. The fleet angle sensor arm and roller assembly for the streamer levelwind required modifications; additional changes may be required for optimum performance.

The underway geophysics lab was renovated this cruise to generate more useable space and make room for a plotting table which has been ordered for installation on Leg 111.

Operations

Drilling at Hole 648B was difficult. Poor hole conditions and various problems with drilling equipment forced the abandonment of this site after 30 days of work. No logs were attempted. Hole 669A attempted to spud into gabbros in the Kane Fracture Zone using a coring motor. A full suite of downhole measurements was successfully accomplished at DSDP Hole 395A, which was culminated with a successful packer experiment. Drilling operations for this cruise were concluded with Hole 670A, located in an area of serpentine outcrops to the northwest of Hole 648B. Hole 670A was spudded using a coring motor and subsequently re-entered with a standard rotary coring system.

Both the TV and sonar reentry systems were utilized at Holes 648B and 395A. Both systems suffered minor problems but generally worked well and complemented each other. The TV system was used to spud Holes 669A and 670A; Hole 670A was reentered without the aid of a cone using only the TV.

The pipe severing system was used successfully to jar loose pipe stuck in Hole 648B. The charge was passed through the bit into open hole using a specially rigged core barrel.

An injured crewman was transferred to a passing freighter for medical examination onshore midway through the cruise. The ATLANTIS II rendezvoused with us while on location at Hole 670A; both parties exchanged ship tours and scientific information.

Laboratory Activities

Little core was recovered due to the coring and operational restraints imposed by difficult drilling conditions. Sampling was limited to that required for immediate shipboard analysis. Shipboard analytical work was accomplished in the following areas: physical properties measurements, magnetic studies, petrology, X-ray diffraction, X-ray fluorescence, and scanning electron microscopy. Ample time was available in all lab areas for personnel cross training, specialty projects, non routine equipment troubleshooting and maintenance, and general improvements. Visiting scientists were encouraged to bring their own work to the ship and many did so. ODP repository work and staff scientist projects were brought to the ship as well.

Bridge Deck

Equipment problems on the bridge deck were minor, with one exception. It was necessary to vent the cryogenic magnetometer's liquid helium in a controlled manner when dewar pressures climbed to an alarmingly high level. The exact cause of the pressure buildup is not clear at this time. The vendor is scheduled to work on the unit in Barbados following Leg 109 and will most likely determine the cause of the pressure buildup. This was the first problem of this kind in over twelve months of operation and a new experience for ODP personnel. The potential hazards encountered during the controlled vent down have highlighted numerous questions and problems to be resolved with the vendor.

Due to overcrowding in the downhole measurements lab, several downhole tools were rigged, dressed, and repaired in the core lab on the bridge deck. This caused no major problems. However, conflicts over space utilization would have arisen had this been a cruise with normal core recovery.

Foc'sle Deck

The foc'sle deck was the scene of much intense activity. The chemists, who were not overloaded with routine work, had time available to tackle new projects, troubleshoot equipment, set up new equipment, upgrade computer skills, and run samples for ODP staff scientists. One downhole water sample taken in Hole 395A was analyzed as were almost 400 samples from Leg 107. The Hole 395A sample and results are being kept aboard for review by Dr. Joris Geiskes during Leg 110. Equipment problems were mostly routine, with the frustrating exception of the C.H.N. analyzer, which appears to have a gas leak in the detector block housing. We were unable to fix the problem. The broken chemical fume hood overhead was repaired. A new Carle gas chromatograph was set up and successfully tested. The HP-1000 L.A.S., although not used for Leg 109 work, was utilized for graphics training purposes. Two graphics programs, designed specifically to handle hydrocarbon gas and Rock Eval data, are currently under development. A Fortran program has been developed to accept and file hydrocarbon gas data and graph C_1/C_2 ratios and $C_1/C_2 - C_6$ ratios with the aforementioned graphic routine. The design of this program should facilitate use by ODP operations personnel as well as technical and scientific staff.

The scanning electron microscope was utilized primarily to document textures from Leg 106 and Leg 109 samples; scientists' personal samples were also studied. Preliminary training for two ODP technicians was started. The SEM was operational the entire cruise without problems; 30K magnification using the backscatter option was possible at times. Photography is still problematic because of ship's motion. It is currently thought that image movement seen at 2K magnification is most likely caused by a deflection of the electron beam by the ship's magnetic field as it rolls; magnetic field measurements in the lab are high. Ship's vibration does cause problems at much higher magnifications.

The X-ray diffraction equipment worked well throughout the cruise. Approximately 500 analyses, performed on personal samples as well as on samples obtained on Legs 107 and 109, were completed. The Phillips Plotter stopped working and will be returned to the beach for repairs. The performance quality of the X-ray fluorescence unit improved appreciably during Leg 109. Sample preparation techniques and program software were improved with expert guidance and help from shipboard scientists. Toward the end of the cruise, the XRF unit was operational, without major problems, and producing acceptable analyses. A comprehensive review of the present status of the XRF unit has been prepared by the shipboard scientific party and will be presented to ODP along with recommendations for improvements. High laboratory temperatures continue to be a concern even though an auxiliary air conditioning unit was installed on Leg 108.

Over 200 thin sections were made from repository samples, scientists' personal samples, and Leg 109 core material. Three members of the technical staff received hands-on training in this lab. Problems noted on previous cruises have been resolved, and no major new ones encountered. A new resin flow valve seal for the impregnation machine was designed, fabricated, and installed. It was necessary to have one of the grinding machine lap wheels resurfaced in the machine shop.

The paleontology lab was used for the preparation of XRF samples, a convenience that will not be available on future sediment cruises. We are considering a plan to renovate the SEM Lab to make room for a dedicated XRF sample preparation area. Hopefully this will be done on Leg 111.

The major highlight in the computer facility was the installation of ETHERNET, which was connected in a continuous manner to five of our six deck levels to ease some of the load from the PRO stations to the VAX. JAX memory was increased an additional 2 megabytes. Most equipment problems were routine and normal. A much-needed DEC service call will be scheduled following the Leg 111 transit to Panama to address non-routine problems that have accumulated to date. Overall system usage was high in spite of the low core recovery. The VAX was mostly used as an intermediary between other systems. Ample time was available to look into software problems. The scientific party initiated many productive changes that will help make some non-CSG generated programs more versatile and easy to use. CT*OS classes were well attended by the scientific party. There were no major environmental problems for the computer facility; however, there are several noteworthy concerns. Water flow to the auxiliary air conditioning unit in the user's room continues to be extremely noisy and irritating. A one way valve is required in the auxiliary air conditioning duct to eliminate the back flow of air from the machine room through to the user's room. Finally, it has been suggested that air circulation in the machine room be improved by the installation of additional louvers on top of the forward machine room door to help remove warm air.

We have proposed another plan that addresses dedicated work areas for the co-chief scientists, staff scientists, and yeoperson. The project involves turning the customer stateroom on the bridge deck into an office space for the co-chief scientists and the conversion of the present main deck co-chief scientist and yeoperson office spaces into a single larger work area for the staff scientist and yeoperson. In our opinion, the beneficial aspects of the proposed plan far outweigh the negative elements. Should the plan be approved, we hope to begin modifications on Leg 111.

The core photo business was slow; the lab worked well with few equipment problems. Time was available to begin a comprehensive technician cross training program which covered the major photo lab operations. It is hoped that additional training can be made available to technicians while ashore. Many photos of thin sections, SEM photomicrographs, and core close-ups were taken for the scientific party as requested. Photos were also taken of ODP and SEDCO operations as needed. Routine and specialty P.R. work was done for ODP headquarters. The lab worked well with few equipment problems.

In addition to routine problems encountered in various labs, the electronics technicians were involved in many activities ranging from re-entry and shooting operations to logging operations and instrument development. The latter included the addition of another digital balance and the interfacing of a multichannel recorder package, originally developed at DSDP, to a PRO-350. This is to be used in conjunction with the Barnes/Uyeda pore water, heat flow, and pressure measurement tool. The combination tool was set up and bench tested but has not yet been operationally tested downhole.

Storekeeping

Storekeeping was routine this cruise. A partial GFE inventory was taken to assure that various pieces of equipment were properly identified aboard ship. A second version of the prototype computerized shipping program originally developed on Leg 106 was implemented. It is still experimental and under review and evaluation; the program should evolve over the next year or so into a fully operational, easy to use, versatile shipping program.

Personnel

The METS team continues to address laboratory safety concerns and participate in weekly drills. The entire technician team is to be applauded for their efficient and productive use of time on this cruise.