Storms, M. A., Natland, J. H., et al., 1991
Proceedings of the Ocean Drilling Program, Initial Reports, Vol. 132

1. INTRODUCTION: SEAFLOOR ENGINEERING IN THE CENTRAL AND WESTERN PACIFIC[1]

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ABSTRACT

The primary goals of Leg 132 were to test the new "Phase II" version of the ODP developmental diamond-coring system (DCS), a new drill-in bottom-hole assembly (DI-BHA), and a redesigned hard rock base (HRB), which is a seafloor structure for bare-rock spudding. The DCS was modified from a prototype tested previously during Leg 124E. The other system components were developed for testing during Leg 132.

Operations were conducted at Sumisu Rift, an incipient back-arc basin west of the Izu-Bonin arc system in the western Pacific, and at Shatsky Rise, a thickly sedimented plateau of Mesozoic age on the Pacific plate east of Japan. The DCS was put into operation at the first site, but time lost in placing a functioning HRB severely limited coring operations at the site and for the remainder of the leg. At Shatsky Rise, a series of piston cores was obtained prior to emplacement of a reentry cone, but time constraints and deteriorating weather did not allow rigging of the DCS. A planned third site was dropped altogether.

Despite the difficulties, modifications to the HRB at the first site eventually led to full testing of the DCS in coring fractured basalts at Sumisu Rift. Almost all components of the system, including a computer-controlled secondary heave compensator, were thoroughly evaluated and brought into operation. In several cases, significant modifications to equipment were designed and fabricated on board ship. This was the first successful coring of near "zero-age" basalt in volcanic terrain on the seafloor. A hole 79 m deep was cored with significant recovery and no problems with side-wall stability. This opens the way to planning scientific drilling in igneous basement at unsedimented ridges.

Test data gained during Leg 132 will lead to more efficient and superior operating capabilities on future legs. Apart from testing the DCS, a great deal of information was obtained about the procedures for placing HRB's on bare volcanic rock on the seafloor. Design changes suggested by this experience will improve the flexibility and stability of this system. Experience gained during coring also indicates directions for improving the core-retention capability of the system.

Overall, the diamond-coring system can now be considered as operational, although much remains to be learned about how to use it in diverse, hostile geological environments.

INTRODUCTION

Leg 132 was the second of an anticipated sequence of cruises designed to support the development and refinement of the hardware and techniques necessary to meet the ODP scientific mandate of the future. As the technical complexity required to address high-priority scientific problems continues to grow, so too does the demand for dedicated ship time enabling the required technology to be developed, tested, and refined to an operational level. Although the Ocean Drilling Program continues to emphasize comprehensive shore-based testing of developmental equipment, these tests cannot adequately simulate the offshore marine environment in which the tools will ultimately operate. Engineering legs are therefore essential to the successful attainment of the required technology.

During Leg 132, we thoroughly field-tested a second-generation mining-type diamond coring system (DCS) designed for deep-water drilling, and two new types of seafloor reentry assemblies. A complete set of tests was conducted in one environment, and partially carried out in another, where previous rotary coring had proven inadequate — young, fractured basalts at an unsedimented spreading ridge, and alternating hard and soft chert-chalk sequences in the Mesozoic western Pacific. Drilling in fractured basalt was a particular impetus to the development of the DCS. Two full legs of the Ocean Drilling Program, 106 and 109, had previously been devoted to an unsuccessful attempt to establish a deep hole in the axial rift of the Mid-Atlantic Ridge (Detrick, Honnorez, Bryan, Juteau, et al., 1988). Although a hole was spudded into bare rock for the first time using a hard rock guide base (HRB), only 50.5 m of basalt were penetrated using rotary coring, recovery was very low, sidewall stability was a continual problem, and the hole ultimately was abandoned. This simply confirmed previous experience with rotary coring in very young ocean crust at thinly sedimented ridges during Deep Sea Drilling Project Legs 34 (Yeats, Hart, et al., 1976), 49 (Cann, Luyendyk, et al., 1979), and 54 (Natland and Rosendahl, 1980).

Accordingly, on the repeated and urgent recommendations of the JOIDES Ocean Crust and Lithospheric Panels, as well as the JOIDES Planning Committee, the Ocean Drilling Program undertook adaptation of high-speed diamond coring technology, used successfully in fractured rock on land by the mining industry, to the deep-sea environment and the particular configuration of the drilling vessel, *JOIDES Resolution* (*SEDCO/BP 471*). A DCS prototype was tested in January 1989 at sea near the Philippines during Leg 124E (Harding, Storms, et al., 1990). Then followed 14 months of development of new top-drive and heave-compensation systems, as well as of seafloor installation hardware to provide opportunities for DCS coring at both unsedimented and sediment-covered locations.

Leg 132 was the first full-scale operational field testing of the integrated systems. This volume reports the results — both technological and scientific—of these tests. In this chapter we provide a background for the engineering objectives of the leg, discuss the scientific rationale for selection of sites, and present a brief summary of principal results.

LEG 124E ENGINEERING TEST RESULTS

Diamond coring as practiced by mining companies on land makes use of three principles to recover fractured rock. These are

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[1] Storms, M. A., Natland, J. H., et al., 1991. *Proc. ODP, Init. Repts.,* 132: College Station, TX (Ocean Drilling Program).

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(1) small hole diameter; (2) high rotation speed with a narrow-kerf diamond bit; and (3) uniform low weight on bit. The prototype system tested on Leg 124E cut a 4 in. hole (compared with 9-7/8 in. by rotary coring), at 60–120 rpm (vs. 45–75 rpm for rotary coring), with 2000–5000 lb weight on bit (vs. 25–45,000 lb for rotary coring). Fluctuations in weight-on-bit were less than 500 lb, whereas in typical rotary coring, they may reach ± 30,000 lb.

To undertake high-speed diamond coring at sea on *JOIDES Resolution* during Leg 124E, a high-speed hydraulically-driven top-drive and control system were installed in the rig. A special platform was constructed from which to suspend a long tubing string with a 4-in.-diameter bit for drilling at the end; the entire length of tubing was rotated by the top drive. The thin-walled tubing string was laterally supported by running it through standard drill pipe which extended from the ship to the seafloor. The platform itself was suspended below the ship's primary heave compensator in the derrick. To reduce residual heave even further, to within appropriate limits for diamond coring, a separate secondary heave compensation system was configured to act on the tubing string alone.

Leg 124E sailed with several objectives, one of which was to test this new concept of high-speed diamond coring in basaltic basement. The leg demonstrated the technical feasibility of the DCS, although coring in basalt was not accomplished. State-of-the-art "high-tech" sensor technology, coupled with a microprocessor unit, were used to drive the secondary heave compensation system. The system was designed to maintain extremely accurate control of weight on bit (± 500 lb). The DCS heave compensation system was effective in maintaining accurate weight-on-bit control even under extreme weather conditions. A 3-1/2 in. outer-diameter (OD) tubing string, with Hydril series 500 wedge-lock threaded connections, was used as a work string inside the ODP API 5-1/2 in. drill pipe. The tubing string performed well, with no failures or detectable wear occurring while rotating the string at 60–120 revolutions per minute (rpm). The skidding and storage of the fully-assembled diamond coring system platform back from well center, when not in operation, proved effective. Though space beneath the derrick was limited, it was possible to trip drill pipe conventionally using the iron roughneck (make-up, break-out unit) while the DCS platform was positioned to the starboard side of the rig floor. Though only limited coring operations were performed, the viability and utility of deploying a diamond coring system from a floating vessel was clearly demonstrated from both technical and operational viewpoints.

Drilling an exploratory pilot hole with the ODP 5-1/2 in. drill string, and then deploying the diamond coring system through the drill string, with the large bit remaining on bottom in open hole, was only partly successful. Owing to the limited amount of overhead clearance in the derrick, the large roller cone bit had to be drilled to a precise depth, providing the proper spacing for the top drive/heave compensator traveling assembly. Had the drill pipe became stuck off bottom while tripping in the 3-1/2 in. tubing work string or while rigging up the DCS platform, it would have been necessary to free the stuck drill pipe before continuing with the diamond coring operation. Deployment of the DCS coring assembly through the 11-5/8 in. Extended Core Barrel (XCB) bit positioned 15–20 ft off bottom could have buckled the 3-1/2 in. tubing in the open hole below the bit. Had this happened, the rotating tubing would have made contact with the 11-5/8 in. XCB roller cones.

Because it was necessary to move the bit on and off bottom during deployment and during the DCS core bit run, good hole stability had to be maintained. Lack of good hole stability hampered the deployment and testing of the DCS throughout Leg 124E. A total of 16-1/2 days was allocated to testing the DCS; 51% of this time was spent en route to prospective sites and drilling/coring seven holes ranging in depth from 6 to 361 m below the seafloor. The larger-diameter holes were drilled in an effort to establish a borehole penetration near basement that would be stable enough for deployment of the DCS. For the DCS to be used effectively as a scientific coring system, a means to provide upper hole stability (in sediments as well as in fractured rock) needed to be devised.

Though only 5% of the allotted time on Leg 124E was actually spent coring with the DCS, five cores were successfully cut. The material cored was clay and silty clay. Though the DCS core bits run were specifically designed for coring basalt, the clay cores recovered demonstrated that soft formations also can be cut effectively. One core in particular (124E-773B-4M) was deemed by several of the shipboard scientists to be of excellent quality for a sediment core, having little drilling disturbance. A total of 7% of the time was spent in tripping tubing. The remaining 36% of the time was spent in rigging and handling the DCS platform on the rig floor and in the derrick.

Though the objective to core in basement (basalt) was not accomplished during Leg 124E, a significant amount of operational and technical information was obtained. The DCS was deployed in weather and heave conditions that in many instances exceeded the original design parameters. The handling and operational characteristics of the core-drill platform were well defined. As a result of the DCS testing on Leg 124E, modifications to the DCS platform, secondary heave compensator, and coring equipment were made that allowed the system to be streamlined and made more efficient for Leg 132 operations.

SYSTEM COMPONENTS

The DCS used during Leg 124E was developed and configured in the most inexpensive mode possible. The program was very limited in scope and there was little test time. Thus, this "Phase I" test of the DCS system represented only a conceptual evaluation or feasibility study. The hardware was not suitable for achieving any full-scale scientific or engineering goals.

Nevertheless, with the potential of the system established on Leg 124E, several important new features were incorporated into the design of the DCS. The new system, tested on Leg 132, is referred to as the "Phase II" (4500 m) system. It was the first viable attempt at fully evaluating the system components and achieving limited scientific goals. Although operations during Leg 132 only reached to 1900 m, the system is designed to operate with up to 4500 m of tubing suspended from the DCS platform.

A major Phase-II innovation was development of an electric top drive to replace the more cumbersome and less responsive hydraulic top drive used during Leg 124E. The heave-compensation system was greatly modified, and two new seafloor structures were designed and constructed, to allow drilling on unsedimented volcanic rock, and in formations covered with sediment. Finally, a drill-in bottom-hole assembly was designed, to leave in the hole and stabilize the upper, more fractured formation.

Diamond Coring System Platform Assembly

The DCS built for Leg 132 (Fig. 1) also involved running small diameter, high-strength, 3-1/2 in. tubing inside 5 and/or 5-1/2 in. drill pipe, which provides lateral support for the tubing to the seafloor. A high-speed, thin-kerf, diamond core bit (3.96 in. OD × 2.20 in. ID) is attached to an outer core-barrel assembly on the end of the tubing string. The core barrel is a modified Longyear HQ-3 type, specially developed for this application. The core barrel is capable of recovering 10.0 ft × 2.20 in. cores in acetate butyrate core liners.

The tubing string is driven with an electric top-drive capable of operating at speeds of up to 540 rpm. The new, 800-horsepower, electric version is capable of producing higher torque

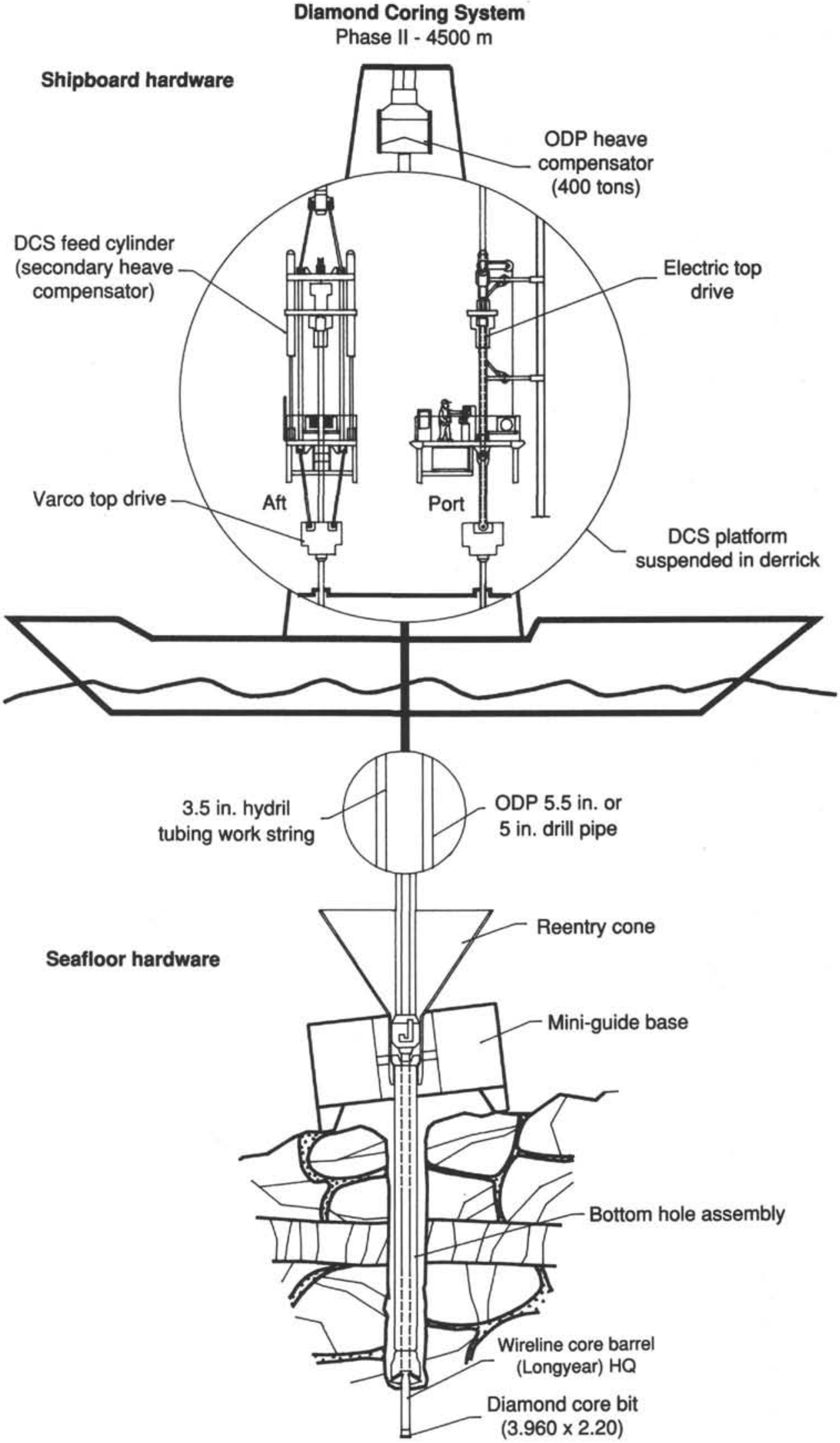

Figure 1. Schematic diagram of the diamond-coring system in place in the derrick of *JOIDES Resolution* showing modified reentry cone.

(11,000 ft-lb) and has a larger load-carrying capacity than the leased prototype hydraulic top-drive used on Leg 124E.

The most important consideration when coring with the DCS is precise control of weight on bit. This is accomplished by using a secondary heave compensator (Fig. 2). The secondary compensator removes load fluctuations resulting from the mechanical inefficiencies of the primary 400 ton passive heave compensator. It is arranged in series beneath the larger compensator. This system is intended to provide control for weight-on-bit fluctuations of 500 lb and compensate for residual vessel heave of ±12 in. at the DCS platform. The secondary heave compensator is rated for 140 tons of tubing-string weight.

Another important consideration when coring with the DCS is precise control of mud flow and pressure. This was accomplished on Leg 132 by installing 4 in. liners in one of the standard triplex-rig mud pumps and by designing special control circuitry allowing very slow and precise operation of the pump from the DCS platform. This important design feature allows the driller to identify core blockage or other downhole problems when they occur, thus allowing maximum core recovery.

All diamond coring operations and drilling functions are performed from a manned platform suspended in the derrick about 14 m above the rig floor. A control console is situated on the platform to allow operation of the DCS drilling systems. The platform is picked up once the HRB or modified reentry cone is installed, and the drill pipe with the DCS tubing string inside is connected and "tensioned up."

The platform is put into operation by tripping the remaining tubing (3 m drilling joints) to just above the bottom of the borehole, then activating the secondary heave compensator and automatic feed system. The diamond core bit automatically advances to the bottom of the borehole and the desired bit weight is established for the coring run. When the coring run has been completed, the bit retracts off bottom and the inner barrel with core is retrieved via the wireline. Coring operations can resume once an empty inner barrel is pumped down, landed, and properly latched into the outer barrel.

The DCS platform used on Leg 132 is a modified version of the one used on Leg 124E. The platform is approximately 45 ft tall and weighs 40 tons. The work area inside the platform is approximate 8 ft × 12 ft, allowing two to three workers to move about comfortably during coring operations. The platform is stored out of the way on the rig floor and rolled into position via a moveable dolly/track system when required. Power to operate the console top drive and heave compensator is supplied by two electrical umbilical connections.

Seafloor Structures

The two types of seafloor structures used during Leg 132 were developed specifically for use with the DCS. Both structures were deployed and tested during the leg. The new "mini" hard-rock base (mini HRB) is equipped with a gimballed reentry cone allowing the structure to be placed on an irregular or sloping hard rock seafloor, and still retain a vertical orientation for the reentry cone (Fig. 3). The cone itself is free to swing on the gimbals, but is held to the vertical by buoyant syntactic foam panels strapped to the outer walls of the cone. The base can be set on seafloor with a slope of up to 20°, and the cone will still pivot to a vertical position.

A specially modified reentry cone (Fig. 4) was also developed to conduct DCS operations in areas where there is sufficient sediment to allow washing in the cone and casing in a more conventional manner.

With either system, drill string is lowered into the cone to a landing seat, then rotated clockwise (jayed-in), to lock the end of the string into the cone. During coring operations, the drill string is pulled in tension (to 50,000 lb) against the weight of the guide base, or — in the case of the reentry cone — against the skin friction of a washed-in bottom-hole assembly.

Tensioning/Mini-Riser System

In addition to the DCS and seafloor structures, several other pieces of hardware and concepts had to be developed and refined. These include use of the 5 and 5-1/2 in. drill pipe as a mini-riser, tensioning tool, tapered stress joint, and a modified jay-type casing hanger. These systems all work in tandem with each other allowing the 5 or 5-1/2 in. drill string to be attached to a seafloor structure and "tensioned up."

The DCS tubing string requires lateral stabilization in order to be deployed in deep water. To accomplish this, the outer string is held in tension by exerting a tensile overpull on a weighted or otherwise anchored seafloor structure. In providing the required lateral support, the primary 5 or 5-1/2 in. drill string acts much like a smaller version of an oilfield riser, hence the term "mini-riser." Although no attempt was made during Leg 132 to return cuttings to the ship, which is also the function of a riser, this capability is potentially there for future operations.

To attach the drill string to the structure, a modified jay-type latching device or tensioning sub, was designed and built. The concept of using a riser to support drilling operations is not new, but the small size and length that ODP requires makes this operation somewhat unique. Typical overpull tension on either seafloor structure is 35–40 tons.

A tapered stress joint was also developed as an integral part of the required tensioning system. The specially designed, 30 ft long, tapered drill collar is placed on top of the tensioning sub just above the jay-slot in the reentry cone (Fig. 5). It is required to take out, or at least reduce, any lateral moment introduced by vessel offset during DCS drilling operations. The entire mini-riser tensioning concept required a thorough dynamic riser analysis before any of the equipment was designed. The analysis proved critical not only for the design of the stress joint and tensioning sub, but also for the feasibility of performing deep-water DCS coring operations.

Drill-in BHA System

To allow DCS coring operations to progress once a seafloor structure is deployed, a mechanical back-off device which can be used to release a drill-in bottom-hole assembly (DI-BHA) had to be developed. The device operates when the BHA is drilled in to the point when it is stopped by a landing shoulder in the casing hanger. Continued rotation of the drill string then unthreads the BHA, freeing it from the rest of the drill string (Fig. 6).

This device allows the flexibility to drill through hard fractured rock where hole instability prevents conventional casing strings from being set. The DI-BHA itself serves as a casing, isolating unstable formation in the upper portion of a hole, which otherwise might prevent drilling with the DCS. The DI-BHA is inserted into the formation by drilling through the HRB or modified reentry cone using a mud motor placed above the BHA and back-off assembly. Once the DI-BHA is drilled to a pre-determined depth, the back-off sub beneath the mud motor is activated, releasing the lower portion of the DI-BHA. A test hole drilled prior to setting the seafloor structure is required to ensure that some minimum attainable depth can be reached for the DI-BHA. This allows proper placement of the back-off assembly within the BHA.

LEG 132 ENGINEERING OBJECTIVES

Primary engineering goals for Leg 132 included the evaluation of the DCS system in problematic geologic environments and the testing of new techniques for spudding and controlling unstable

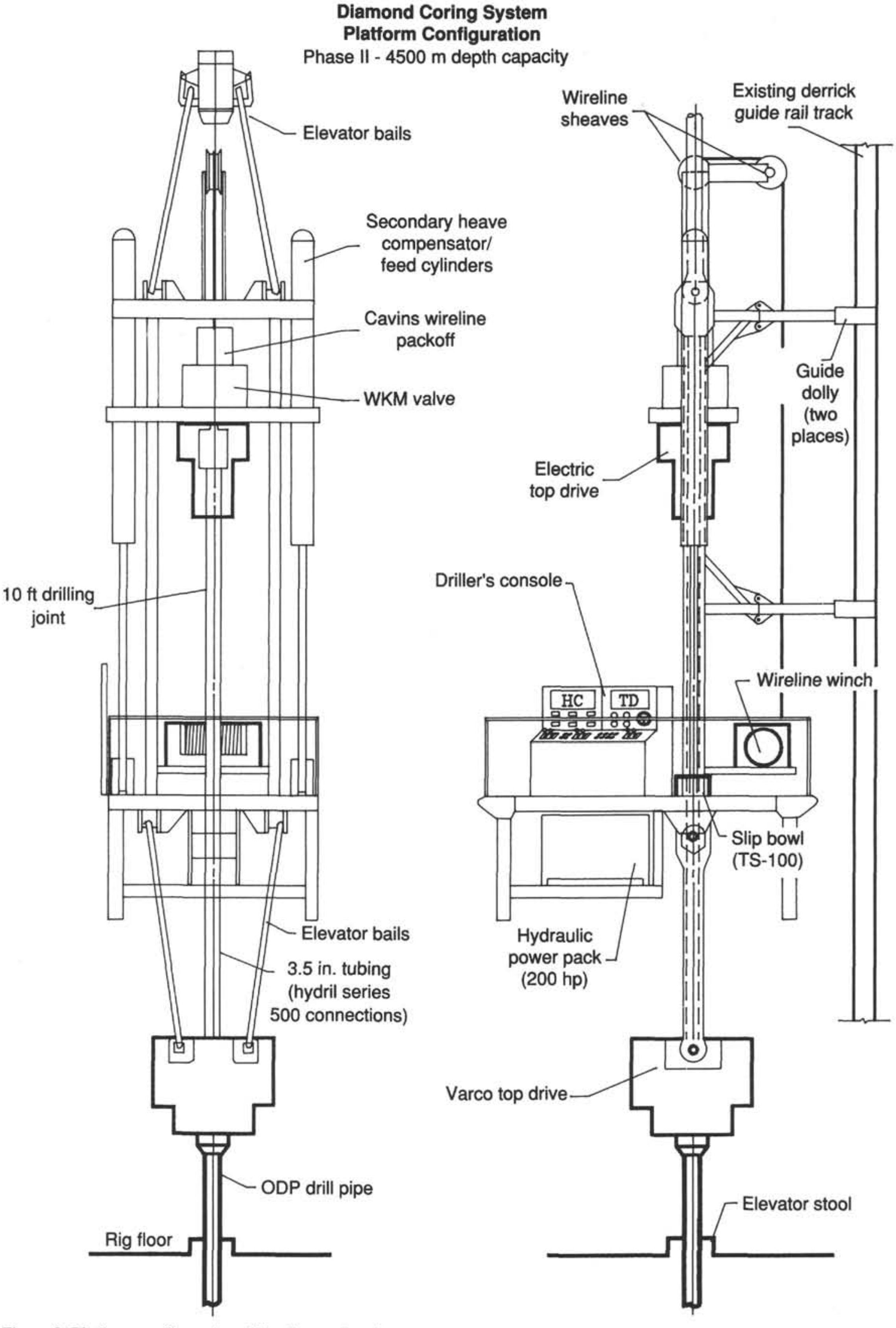

Figure 2. Platform configuration of the diamond-coring system.

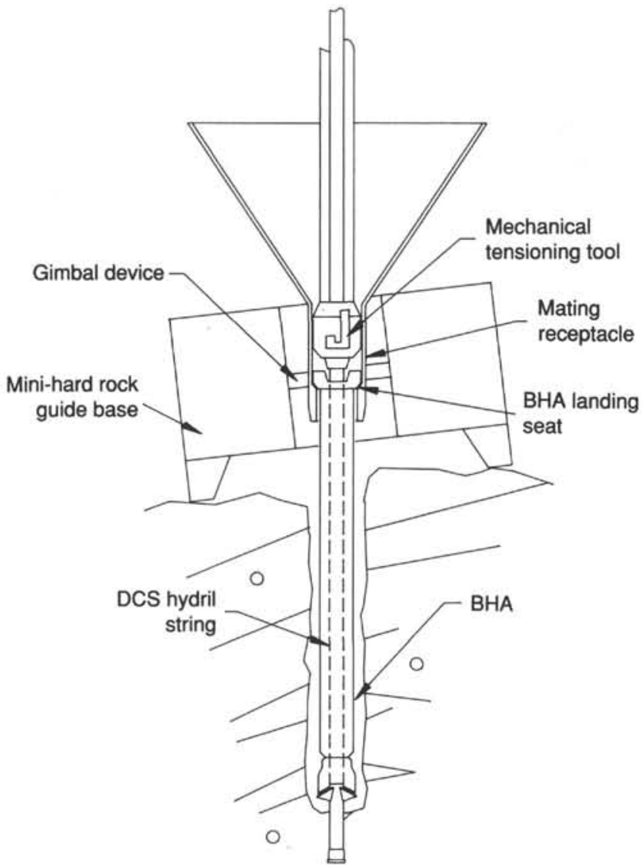

Figure 3. Schematic cross section of the weighted HRB (mini-guide base) in place on sloping seafloor.

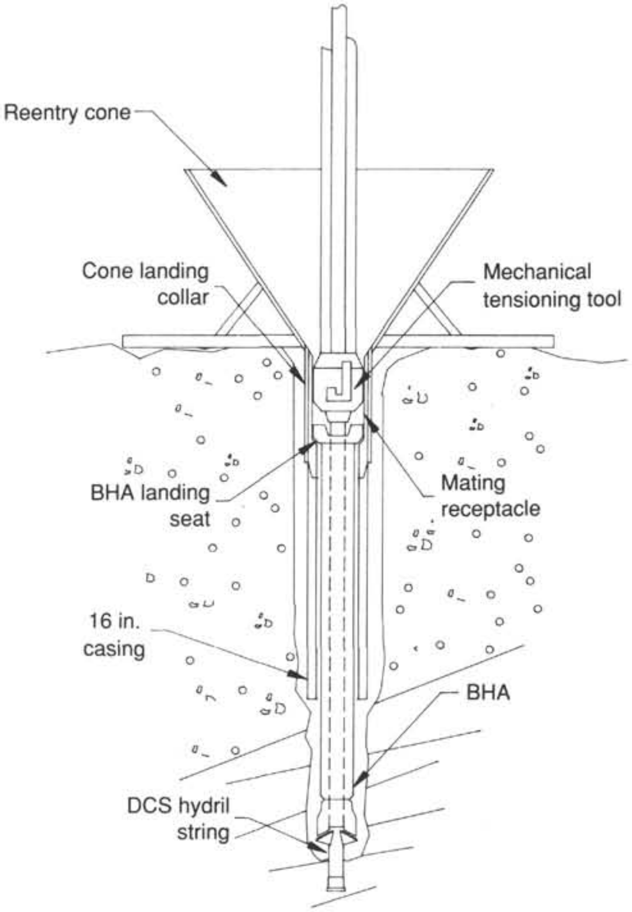

Figure 4. Schematic cross section of the modified reentry cone in place on sediments above a hard-rock surface on the seafloor.

formations. As such, the test plan for Leg 132 focused on the ability to spud a hole on bare rock, stabilize fractured or unstable formations, and deploy the DCS for coring operations in crystalline rock and interbedded chalk/chert formations. A third planned objective, to drill shallow-water lagoonal and reefal limestones on a submerged atoll, was not carried out because of engineering and operational requirements during the leg.

The principal engineering objectives of Leg 132 were the following:

1. Evaluating the overall performance and efficiency of the redesigned DCS in water depths ranging from 1000 to 3000 m. The DCS was evaluated at the distinctive geological environments of bare and/or fractured crystalline rock at Sumisu Rift in the western Pacific.
2. Deploying and testing the new mini-HRB designed for more efficient and economical spudding on bare and/or fractured rock.
3. Deploying and testing a modified reentry cone designed for compatibility with the DCS. This was evaluated in a second distinctive environment — interbedded cherts and chalks at Shatsky Rise.
4. Evaluating developmental techniques and hardware for establishing and maintaining upper hole stability allowing successful deployment of the DCS for scientific coring operations in unstable formations.
5. Evaluating the HRB or reentry cone/API drill string tensioning system for use as a drill string mini-riser.

Specific engineering and operational objectives included the following:

Mini-Hard Rock Guide Base/Upper Hole Stabilization

1. Test gimbal concept for greater rotational freedom of reentry cone.
2. Evaluate use of weighted cement (with iron ingots) for ballast.
3. Evaluate use of ODP API drill pipe as a mini-riser in deeper water and at higher RPM then was attempted on Leg 124E.
4. Install and evaluate performance of a new tapered stress joint above the breakaway mechanical tensioning device.
5. Evaluate use of a mechanical tensioning tool to hold tension on guide base.
6. Test modified 16 in. casing hanger designed to accept the mechanical tensioning tool and landing seat for the back-off sub.
7. Evaluate drill-in/back-off release mechanism allowing use of BHA for bare fractured rock spudding and upper hole stabilization.
8. Evaluate adaption of mini-riser tensioning system to standard reentry cone design.

Diamond Coring System—4500 m Capability (Phase II)

1. Continue evaluation of DCS in offshore environment.
2. Operate and evaluate an upgraded and modified version of the HQ-3 core barrel system.
3. Test redesigned heavy duty, self-winding, wireline winch for core barrel retrieval.

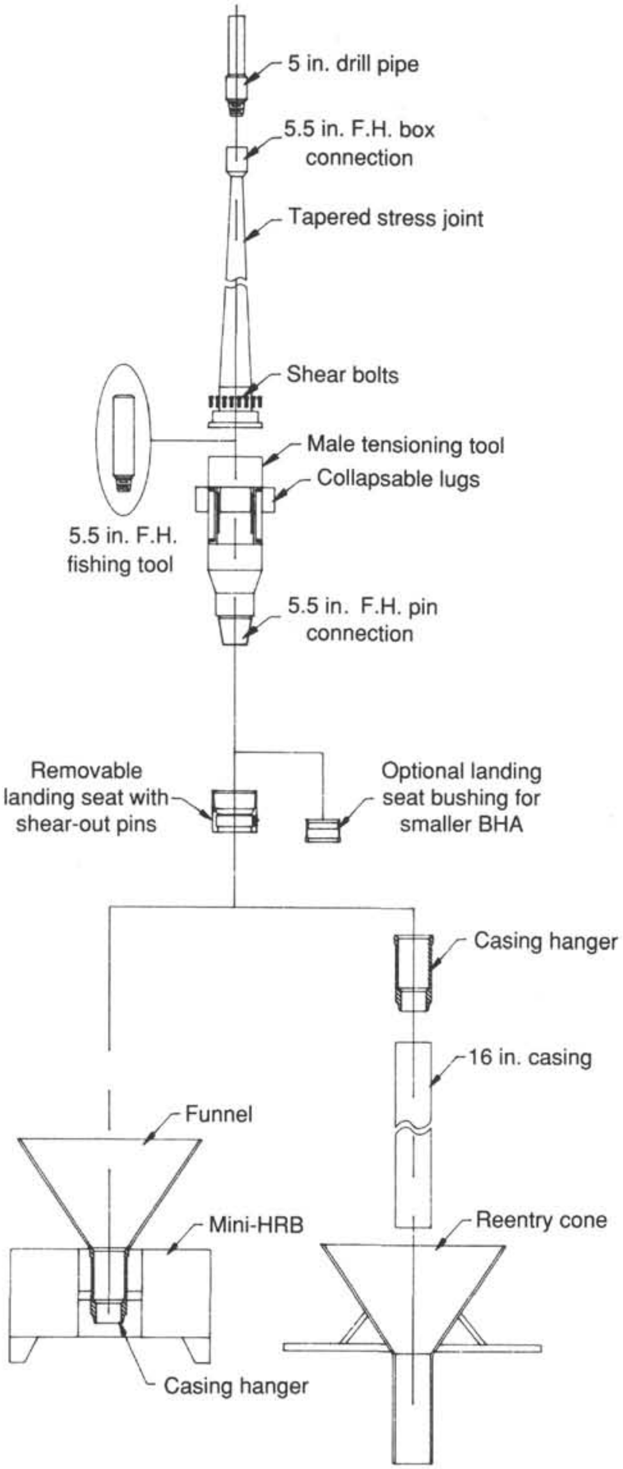

Figure 5. Drawing showing the relationship of the drill pipe, tensioning tool, and landing seats to the casing hanger and optional HRB or reentry cone on the seafloor.

4. Operate and evaluate upgraded dual cylinder secondary heave compensation system with simplified computer network.
5. Evaluate use of safer, operationally improved, DCS platform.
6. Operate and evaluate new electric top-drive system with higher load and higher torque capability.
7. Deploy and evaluate high strength tubing (DCS core string) in a production mode and locate nodal vibration points at varied RPM and string lengths.
8. Evaluate new umbilical design for DCS platform.
9. Evaluate new upgraded DCS mud pump system.
10. Evaluate performance of new hybrid drill-in bit for drilling BHA into fractured basalt.

SCIENTIFIC OBJECTIVES OF LEG 132

The scientific objectives of Leg 132 were closely related to the development and successful use of the DCS and seafloor hardware systems. The DCS was designed to improve both coring and recovery of rock. Leg 132 was to test the DCS in two previously difficult drilling environments, where it was expected to provide materials of sufficient coherence and continuity to understand detailed relationships of lithology, stratigraphy, sedimentary diagenesis, and igneous alteration.

Although we cored only a short section with the DCS at one of the sites, the results bear considerably on plans for drilling in similar environments elsewhere. The two environments were (1) fractured, uncemented pillow basalts in axial, hydrothermally active regions of spreading ridges and (2) Mesozoic sequences of layered chert-porcellanite and chalk with alternating hard and soft characteristics. Originally, a third environment was planned for DCS testing on Leg 132. This was reef-lagoonal deposits with contrasting coarse (loose) and fine-grained (firm) characteristics atop a Cretaceous guyot in the western Pacific. This target was deleted during the leg when it became clear that the first (and foremost) objective, on unsedimented igneous rock, required considerably more time than was originally anticipated.

Previous experience with conventional rotary coring in chert/chalk sequences (as well as reefal limestones) is that, although drilling can proceed, recovery is typically too poor, particularly in the soft or coarse intervals, to provide either biostratigraphic control or sufficient material for the study of pore fluids and the mechanisms of diagenesis. Critical intervals (such as black shales which we have reason to believe should exist based on Aptian/Albian exposures on land), have apparently been missed in several of the Mesozoic chert/chalk sequences cored in the Pacific to date.

In pillow basalts at young ridges, coring results have been even worse. The drilling literature concerned with this is replete with accounts of torn-up core bits, blown-off bottom-hole assemblies, low recovery (or no recovery), and endlessly foiled attempts to drill holes more than a few tens of meters deep. Coring such basalts has long been a major concern of scientists interested in crustal drilling, and was an important motivation in the development of the DCS. The results of the drilling on Leg 132 were to determine the feasibility of two drilling legs planned for the East Pacific Rise in 1992-1993.

In terms of the immediate drilling targets of Leg 132, two scientific objectives can be summarized very simply. First, make hole. Develop a system which will core in fractured rock without problems of hole stability. Second, more is better; specifically, more recovery. It is impossible to judge lithologic relationships meaningfully, understand processes of sedimentary diagenesis or crustal alteration, relate cores to logging results, or obtain a sensible magnetic stratigraphy without acquisition of fully cored, oriented rock samples. In basalts, fragile breccias and hydrothermal deposits are almost completely destroyed in the process of rotary coring. In chert/chalk sequences, almost all the chalk and perhaps much of the chert is ground to paste and washed out rather than recovered in the core barrel.

The spreading-ridge target drilled at Site 809 is about 1 km from the topographic axial high of a small, volcanic ridge on the Sumisu Rift, a back-arc basin west of the Bonin/Volcano island

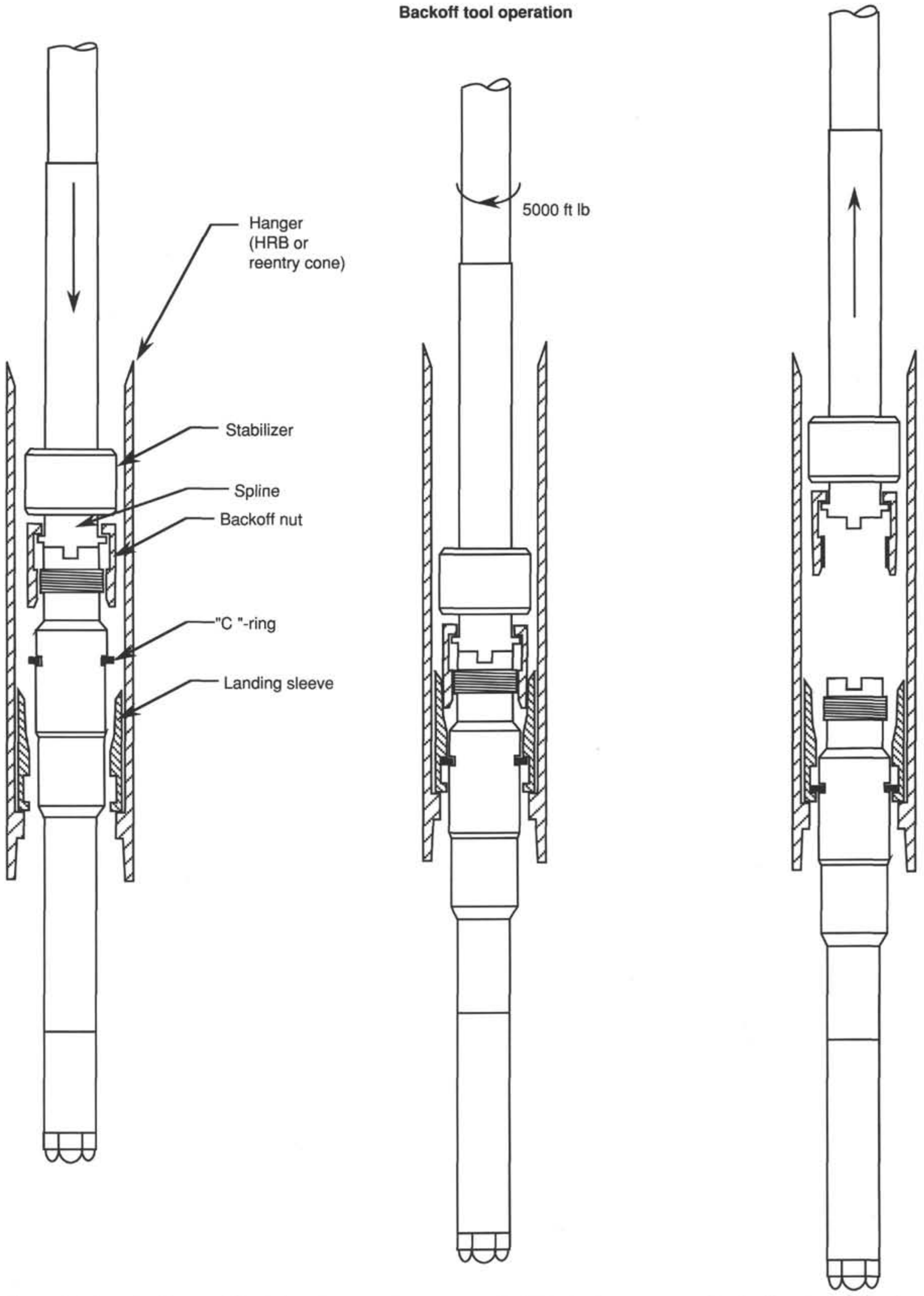

Figure 6. Schematic diagram of the drill-in bottom-hole assembly (DI-BHA), showing sequence of back-off tool operations (see text).

arc (Fig. 7). Submersible results previously established that the terrain is primarily pillow basalts only thinly dusted by sediments (Taylor et al., in press). Basalts obtained during dive operations and by dredging include fairly typical back-arc-basin basalts, despite the very close proximity of the arc, and some rhyodacites (Hochstaedter et al., in press; Fryer et al., in press). Previous drilling during ODP Leg 126 recovered both back-arc and arc-like basaltic basement rocks beneath thick sediments a few kilometers to the south at Sites 709 and 710 (Fujioka, Taylor, et al., in press). We expected to recover coherent cored sections of basaltic pillows and flows, to augment these studies.

The scientific objective at Site 810 was to drill a bedded chert-chalk sequence of Aptian-Albian age beneath an unconformable cap of largely eroded Paleogene-Neogene chalks and oozes about 125 m thick exposed on a flank of Shatsky Rise (Fig. 7). Previous drilling on DSDP Legs 6, 32, and 86 (Fischer, Heezen, et al., 1971; Larson, Moberly, et al., 1975; Heath, Burckle, et al., 1985) recovered primarily broken chert/porcellanite fragments in materials of this age from Shatsky Rise. The sedimentary rocks are of interest because they were deposited in moderate depths atop a volcanic plateau that probably formed at a hot-spot triple-junction intersection (Nakanishi et al., 1989). The sediments presumably preserve both siliceous and calcareous microfossil assemblages that were not all preserved in deeper waters at these times. Moreover, coring elsewhere in the Pacific together with observations in Franciscan exposures in California (Sliter, 1989) suggests that the intervals of high silica productivity recorded by the cherts were associated with or punctuated by intervals of anoxia, which may have been widespread at certain levels in the water column during the Cretaceous. Although scattered organic-rich sediments deposited at these times have been recovered by drilling in the Pacific, understanding them requires

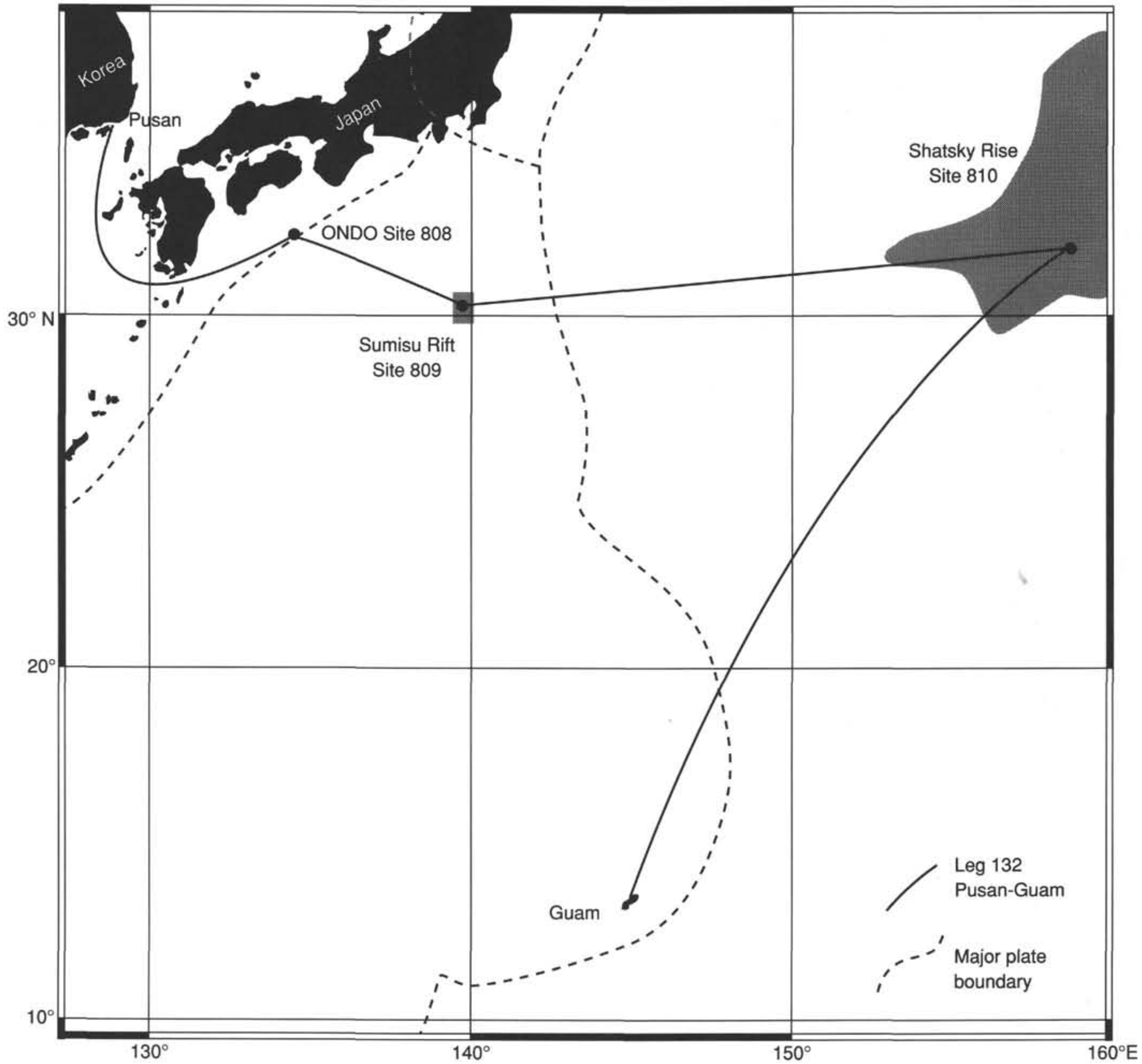

Figure 7. Cruise track in the western Pacific of *JOIDES Resolution* during Leg 132.

the precise multifaunal biostratigraphic control that only nearly continuous recovery can provide.

Two final scientific objectives were to test a slim-line combined gamma-caliper logging tool in a 4 in. diameter DCS hole, and to acquire several cores of sediment for a geriatric study, to monitor long-term changes to cores from the time they are first brought on deck through long intervals of storage on board ship and in the repositories.

LEG 132 ENGINEERING TEST SITES

Leg 132 departed Pusan, Republic of Korea, on 8 June 1990 and arrived in Guam on 5 August 1990. The leg was 59 days in duration and conducted coring operations in two distinct areas of the Western and Central Pacific Ocean (Fig. 7). Two sites, 809 and 810, were occupied (Tables 1 and 2). The sites were selected to maximize the value and efficiency of the engineering test objectives. At the same time, they provided an opportunity to obtain valuable scientific information in these selected areas.

Site 809 (31°03′N, 139°53′E, water depth 1850 m) is located east of Kyushu and south of Yokohama, Japan, in the Bonin back-arc basin (Fig. 8). This site was occupied for 36 days while evaluating the mini-HRB, bare rock spudding/hole stabilizing techniques, and performance of the improved Phase II (4500 m) DCS in fractured basalts, as a prelude to future operations at unsedimented spreading ridges.

Site 810 (32°27′N, 157°43′E, water depth 2700 m) is located approximately 912 nmi east of Site 809 on Shatsky Rise near DSDP Sites 47, 305, and 306 (Fig. 9). Nine days were planned at this site to emplace a modified reentry cone/casing system on the seafloor and carry out DCS coring in interbedded Mesozoic cherts and chalks.

SUMMARY OF LEG 132 ENGINEERING AND DRILLING OPERATIONS

The general plan of operations at each of the two sites followed the outline given below. Actual operations at both sites were considerably more complex (see "Leg 132 Operational Narrative" below), but the outline gives a sense of the drilling plan and what was accomplished.

Operational Summary for Site 809

At Site 809, an optimum "bare-rock" site location was selected following beacon drop during an underwater television survey. Two pilot holes (809A and 809B) were spudded and drilled using a conventional 9-1/2 in. positive- displacement coring motor (PDCM) and two different sized bits (11-5/8 in. and 9-7/8 in.). This established the degree of uppermost formation stability and determined the number of drill collars to be drilled in at the HRB location. The vicinity of the second hole was selected to place the HRB. Hole 809B also provided information necessary for proper location of the back-off sub in the drill-in BHA. Both pilot holes were drilled with a special DCS bit/center-bit assembly and no cores were taken.

After completing a drill pipe round trip, the HRB was deployed and landed at the seafloor. The sequence we planned to follow was as follows. Another drill pipe round trip was to be made to make-up the drill-in BHA and back-off sub hardware. This assembly was to be re-entered into the HRB and drilled with the PDCM to the appropriate depth. After landing and latching the lower portion of the BHA in the HRB, it was then to be released using a back-off sub. The released collars were to provide the casing required for deploying and coring ahead with the DCS system.

Although we expected to do this in the third hole at the site (809C), a variety of complications ensued requiring moving of the HRB three times before a BHA was finally emplaced 5.9 m

Table 1. Coring summary for Site 809.

Core	Date (June	Time 1990)	Depth (mbsf)	Cored (m)	Recovered (m)	Recovery (%)
Hole 809A-						
1Z	14	1700	0.0–0.0	0.0	0.01	100.0
Totals				0.0	0.01	100.0

Table 2. Coring summary for Site 810.

Core	Date (July	Time 1990)	Depth (mbsf)	Cored (m)	Recovered (m)	Recovery (%)
Hole 810A-						
1H	22	0445	0.0–9.5	9.5	9.74	102.0
Totals				9.5	9.74	102.0
Hole 810C-						
1H	22	0815	0.0–2.4	2.4	2.40	100.0
2H	22	0900	2.4–11.9	9.5	9.84	103.0
3H	22	0930	11.9–21.4	9.5	9.89	104.0
4H	22	1015	21.4–30.9	9.5	9.89	104.0
5H	22	1045	30.9–40.4	9.5	9.86	104.0
6H	22	1115	40.4–49.9	9.5	9.90	104.0
7H	22	1200	49.9–59.4	9.5	9.92	104.0
8H	22	1230	59.4–68.9	9.5	10.06	105.9
9H	22	1315	68.9–78.4	9.5	9.83	103.0
10H	22	1340	78.4–87.9	9.5	9.98	105.0
11H	22	1430	87.9–97.4	9.5	10.05	105.8
12H	22	1540	97.4–106.9	9.5	9.74	102.0
13H	22	1625	106.9–116.4	9.5	9.78	103.0
14H	22	1705	116.4–125.9	9.5	9.89	104.0
15H	22	1755	125.9–127.1	1.2	9.86	821.0
16X	22	1950	127.1–136.1	9.0	2.92	32.4
Totals				136.1	143.81	105.7
Hole 810F-						
Drill-in BHA			0.0–5.9			
1Z	6	1230	5.9–6.2	0.3	0.13	43.0
2Z	6	2015	6.2–6.9	0.7	0.85	120.0
3Z	6	2240	6.9–9.0	2.1	0.00	0.0
4Z	7	0030	9.0–10.6	1.6	0.00	0.0
5Z	7	0620	10.6–13.4	2.8	0.00	0.0
Center bit			13.4–13.7		(0.3 drilled)	
6Z	8	2025	13.7–13.8	0.1	0.20	200.0
7Z	9	0225	13.8–13.9	0.1	0.20	200.0
8Z	9	1445	13.9–14.0	0.1	0.12	20.0
9Z	9	1810	14.0–14.3	0.3	0.13	43.0
Center bit			14.3–14.4		(0.1 drilled)	
10Z	12	0015	14.4–14.6	0.2	0.14	70.0
11Z	12	0645	14.6–17.4	2.8	1.87	66.8
12Z	12	0730	17.4–19.4	2.0	0.75	37.5
13Z	12	1200	19.4–20.5	1.1	1.35	123.0
14Z	12	1420	20.5–23.5	3.0	1.79	59.6
15Z	12	1830	23.5–23.8	0.3	0.14	46.0
16Z	12	2130	23.8–26.3	2.5	1.19	47.6
17Z	13	0000	26.3–29.3	3.0	1.48	49.3
18Z	13	0200	29.3–32.3	3.0	0.27	9.0
19Z	13	0400	32.3–35.3	3.0	0.00	0.0
20Z	13	0900	35.3–38.3	3.0	0.00	0.0
21Z	13	1515	38.3–41.3	3.0	0.00	0.0
Center bit			41.3–41.6		(0.3 drilled)	
22Z	13	2310	41.6–44.2	2.6	0.09	3.5
23Z	14	0200	44.2–44.7	0.5	0.00	0.0
24Z	14	0445	44.7–47.2	2.5	0.00	0.0
Center bit			47.2–48.5		(1.3 drilled)	
25Z	14	1145	48.5–50.5	2.0	0.00	0.0
26Z	14	1520	50.5–53.5	3.0	0.00	0.0
27Z	14	2030	53.5–59.3	5.8	0.00	0.0
28Z	15	0300	59.3–61.9	2.6	0.00	0.0
			61.9–74.1		(12.2 drilled)	
29Z	15	1530	74.1–77.6	3.5	0.00	0.0
30Z	15	2030	77.6–78.1	0.5	0.00	0.0
31Z	16	0030	78.1–78.6	0.5	0.00	0.0
			78.6–78.7		(0.1 drilled)	
32Z	16	0830	78.7–78.8	0.1	0.08	80.0
33Z	16	1115	78.8–79.2	0.4	0.01	2.5
*34B	17	1800	(78.6)–(79.2)		0.34	
Total				59.0	11.13	18.7
			1881.7 (TD)	5.9	Drill-in BHA	
			1802.5 (WD)	59.0	Cored with DCS	
				14.3	Drilled with DCS	
			79.2 m	79.2 m		

*Bit samples from previously cored interval (78.6–79.2 mbsf).

into basalt. At Hole 809F, with the DCS, we ultimately cored and drilled 73 m beyond the BHA in a fractured, unsedimented, crystalline-rock environment.

Operational Summary for Site 810

Operations at Site 810 (Shatsky Rise) differed from the bare-rock deployment at Site 809 because there are 125 m of soft carbonate ooze overlying chert/chalk horizons at this location, which required a modified reentry cone through which DCS coring was to take place, rather than a HRB. The sediments were to provide skin friction against a BHA hung from the reentry cone against which the outer drill string, latched into the cone, could be placed in tension. Unfortunately, for a variety of operational and meteorological reasons, the reentry cone was never fully emplaced on the seafloor, and we were unable to attempt DCS coring before we had to depart for Guam.

Nevertheless, at Hole 810A, much information about the modified reentry cone was obtained, and we continuously cored an erosionally-shortened, 125 m section of nannofossil ooze and clayey ooze ranging in age from Late Cretaceous (Maestrichtian) through the Cenozoic. The sediments were cored with the advanced piston corer (APC), thus were largely undisturbed on recovery. An additional core was obtained by APC in a separate hole (810B) to evaluate long-term geriatric changes in sediments through time, a study sponsored by the curator of the Ocean Drilling Program.

LEG 132 OPERATIONAL NARRATIVE

ONDO Tool Deployment At Site 808, Nankai Trough

After leaving Pusan, Republic of Korea, at 0800 on 8 June 1990, we first sailed to Nankai Trough, east of Japan (Fig. 7), to complete some unfinished business of Leg 131. Three participants from that prior leg remained on board, including A. Taira, one of the co-chief scientists, to carry out the work. The assignment was to lower a complex temperature probe (ONDO tool) through a reentry cone into Hole 808E, which was drilled through a decollement at the Nankai accretionary prism. Several attempts to lower this tool during Leg 131 had not succeeded, because the dimensions of the tool were too large. Modifications were made during the Pusan port call, and the tool was successfully emplaced in the hole during Leg 132 on 11 June. The full operational account of this is given in Taira, Hill, et al. (in press).

We then proceeded to our first site on the Sumisu Rift, arriving in the early morning on 13 June. A boat came out to retrieve the three personnel from Leg 131 on 15 June.

Site 809 Narrative

13 June–25 June 1990: Initial Hard Rock Base Installation

During the approach to Site 809, we passed from north to south over the crest of a line of small volcanic ridges to locate ourselves precisely within the HIG SeaBeam bathymetric survey (Taylor et al., in press). The site was chosen to be as close as possible to the crest of the ridge at a saddle between two of the small peaks, this area appearing to offer the flattest seafloor for setting of a guide base. The crest line at the low point of the saddle was precisely located on an east to west pass, and the beacon was dropped there on the return pass. Currents carried the beacon about 150 m to the southeast before it reached the seafloor (Fig. 8).

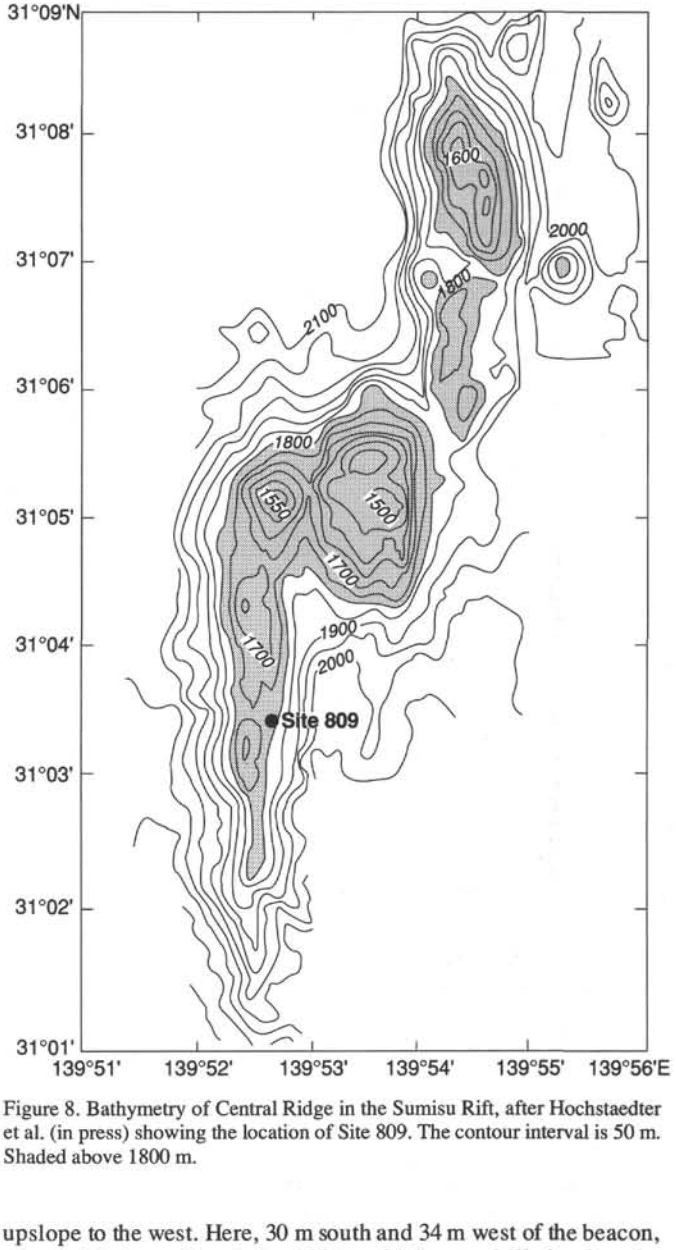

Figure 8. Bathymetry of Central Ridge in the Sumisu Rift, after Hochstaedter et al. (in press) showing the location of Site 809. The contour interval is 50 m. Shaded above 1800 m.

Two short surveys of the seafloor were carried out using a Mesotech acoustic scanner and TV camera, one before each of the first two holes we drilled. The seafloor consists of slightly sedimented scoriaceous pillow lava, with pillow diameters ranging from less than 0.5 m to more than 2 m. The beacon itself was located near a 10-m-high flow front, but the flow is fairly flat upslope to the west. Here, 30 m south and 34 m west of the beacon, we spudded our first hole, 809A, which was drilled using the positive-displacement coring motor to test the capability of a newly-designed 11-5/8 in. bit/center-bit assembly in coring volcanic rock. Using the coring motor, and 2000–5000 lb weight on bit, the hole reached 8.3 m below the seafloor (mbsf) in 7 hr, a rate of 1.2 m/hr. No cores were taken. Wear on the bit was negligible. The TV monitor revealed a crater about 2 m in diameter around the pipe, indicating that caving had occurred around the top of the hole. The caving was probably aggravated by the "whipping" action of the coring motor during the unsupported spudding operation.

The next test hole, 809B, was drilled in the same manner with a smaller newly-designed bit 9-7/8 in. in diameter, again with a center bit. The hole was about 100 m farther to the northwest, on a similar but probably somewhat older flow of pillow lavas, with ponded sediment between the pillows. Here, closer to the presumed rift axis, we hoped for smoother drilling conditions and even less basement relief. The bit indeed produced a narrower hole (<1 m diameter) with less caving, and reached 13.4 m in 8.3

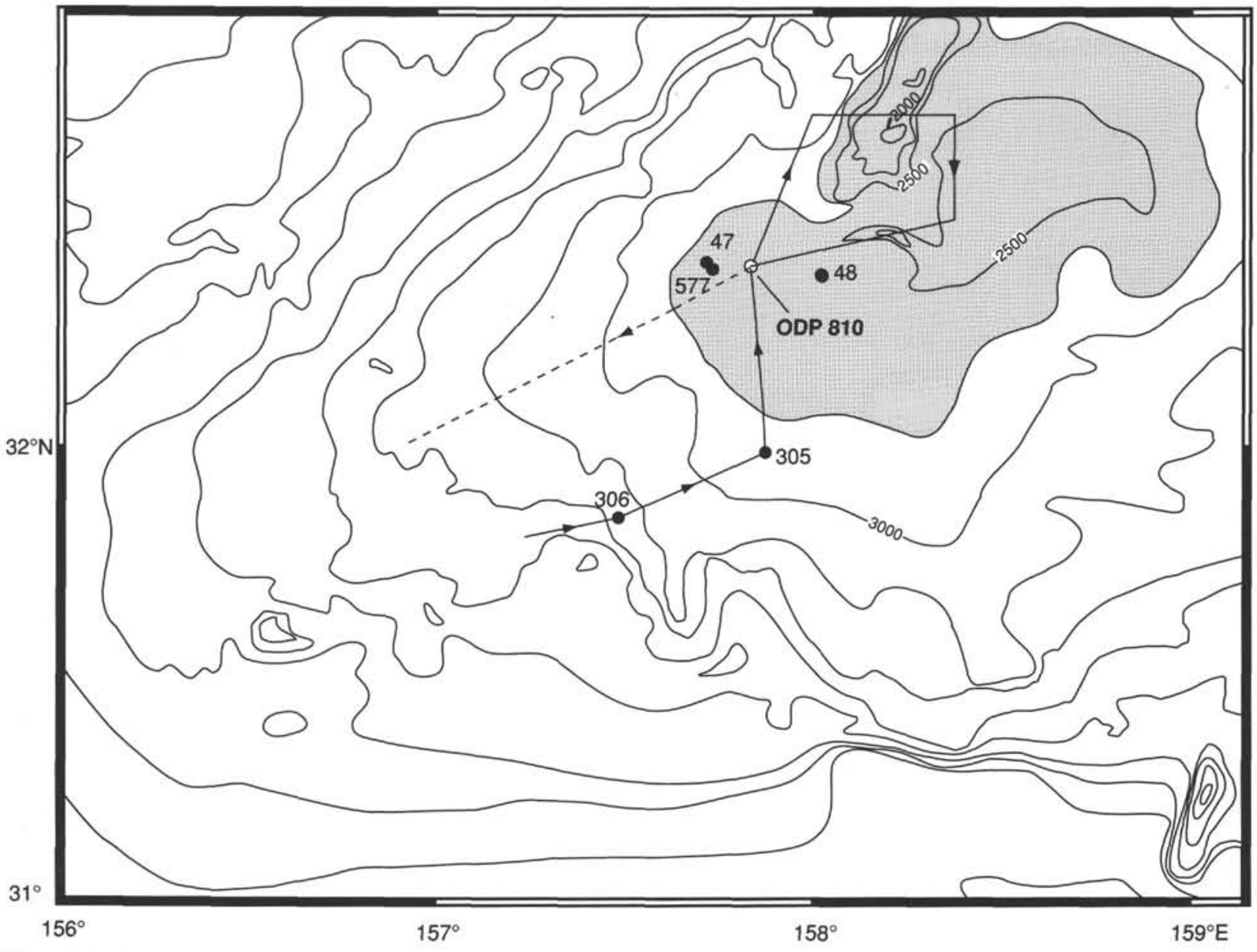

Figure 9. Bathymetry of a portion of Shatsky Rise (250 m contours) showing the location of DSDP sites and ODP Site 810. The incoming seismic line linking DSDP Sites 305 and 306 with Site 810 (Fig. 10) is shown as a solid line. The track of a post-site seismic survey is shown by the dashed line. Other DSDP sites are shown by dots.

hr, a rate of 1.6 m/hr. Again, bit wear was negligible. Using the Mesotech acoustic scanner, we identified a particularly flat area away from local flow fronts or pillow ridges that produced backscatter shadows of 2–3 m at distances of 20–30 m on the display. The coordinates of the flat patch relative to the beacon were noted for reference during the guide-base operation. This was fortunate because the Mesotech scanning sonar failed during the guide-base lowering and did not function thereafter.

The guide base, which during this time was being constructed over the moon pool, was lowered to start Hole 809C, and reached the seafloor at 1100 hr on 16 June. Setting the base on the seafloor was done blindly, since the VIT frame holding the TV camera was unable to see below the guide base to the bottom. With the weight of the base released from the drill string, we disconnected the pipe by rotating the jay-tool and backing out of the cone. To our great surprise, the cone quickly lurched away from the camera to one side, and then leaned into one corner of the central cavity within the HRB. Initially, we feared that the basement surface was too steep, but examination of video tapes and subsequent operations established instead that the problem was insufficient syntactic foam to provide buoyancy to right the cone to the vertical above its gimbal assembly. With the jay-tool still down, we did a test reentry and used the weight of the drill string plus the ship's dynamic positioning system to pull the cone upright.

With some reentry capability established, we retrieved the pipe and ran in with a core bit and drill-in BHA. The design was intended to case off about 6 m of hole and thus provide sidewall stability at the outset of diamond coring operations, and simultaneously to lock the cone into a vertical position. After drilling 6 m, the pipe was to separate automatically from the BHA by means of a tapered back-off sub, leaving the lower portion of the BHA in the hole and below the jay-slot. Unfortunately, the back-off sub rotated free after only 4.1 m of penetration at Hole 809C, leaving the top of the casing above the bottom of the jay-slot. This was confirmed during our next reentry with the jay-tool.

We tripped the pipe and sent down a tool to fish the BHA. The reentry and fishing operation went smoothly, but the cone — freed of the supporting casing — once again fell to the south corner of the weighted base. We elected this time to drill a "rat-hole" into which the same back-off system could simply be lowered without fear of premature operation of the back-off sub. However, on this reentry attempt, we had great difficulty in pulling the cone upright. We managed to get into the throat of the cone, but at an angle that did not allow the bottom-hole assembly to pass through the casing hanger to the seafloor. Reentry in this circumstance requires pivoting the cone to a nearly upright position, and then working the bit into the casing hanger. Alternatively, the string can be slid down one side of the inclined cone at an angle (produced by draping the pipe into the cone by means of offsetting the ship). Hopefully the angle can come close to that of the gimballed casing hanger. The risk is that such operations can produce strong excursions of the cone about the pipe as it rotates on its gimbal assembly. The situation was exacerbated by rocking of the weighted base itself on two legs as the cone swung and lurched into the sides of the box. This is because the four-legged base usually sits on three legs on an irregular basement surface. Bit weight on the sides of the cone applies moments to either side of the base which is centered on a line between the two stable legs. Thus it must wobble.

During one such pirouette on this reentry attempt, the cone swung out of a pinned position, and the drill string itself fell away, imparting a sharp lateral blow to the inner lower surface of the cone. This caused the cone to separate partially from its welded base and gusset support assembly where it joined the casing hanger. The cone could not safely be re-entered in this condition, so we elected to push it completely off the casing hanger using the drill string. The cone fell to the seafloor upside down, confirming that the flotation was inadequate to support the cone even without that portion of the casing hanger above the gimbals.

The casing hanger itself, however, offered a small, 24-in. diameter opening through which reentries might be accomplished. The hanger would still have to be pulled to an upright position, but there was no reason why we should not attempt it.

Regrettably, although we were able to put the end of the string into this tiny opening several times, and with more than one configuration of a bottom-hole assembly during two additional pipe trips, we never succeeded again in getting the drill-in BHA past the jay-tool assembly. Almost certainly this was because we could not hold the end of the string in the top of the hanger and relieve enough weight to drag it into a vertical position. The rocking HRB complicated these attempts.

At this point, our discussions turned to abandoning this guide base and setting the other one on board onto the seafloor. The flotation problem still existed, however. The only way to solve it was to retrieve the inverted cone with its flotation foam from the seafloor and use it together with the foam for the second guide base, all on one assembly. A fishing tool with four arms arranged like a molly-bolt was lowered to the seafloor and speared through the inverted opening at the cone's base. The simple tool worked well, and the cone was back on deck within a few hours.

Emboldened by this success, we decided to fish for the guide base. If this could be retrieved, then we would not lose the site planned for the second guide base later in the leg. A double jay-tool was lowered on flexible 5 in. drill pipe. No other BHA components were used. The HRB was located with the TV, and the 24 in. opening in the casing hanger re-entered. The hanger was pulled from the south to the north corner of the base by offsetting the ship to allow a maximum alignment of the flexible pipe with the tilted end of the hanger. After rotating the jay-tool with the coring motor, we finally found an orientation which allowed it to slip into the jay-assembly. Another partial turn engaged the tool, and we lifted the guide base from the seafloor to the moon pool.

Once on deck, the reincarnated guide base was then refitted by lightening the cone, doubling up the foam, and reattaching the cone to its base. We constructed a tilt beacon to be assured that the base would rest on sufficiently flat bottom, and added markings and inclinometers to the base to determine its orientation after we disconnected from the cone. This completed, the base with its cone was returned to the depths and landed. The base on the new hole (809D), had a 15° slope on a pillowed surface, and the cone floated freely from its gimbals above it.

25 June–18 July 1990: HRB Maneuvering and DCS Coring

After lowering the reconstructed guide base, several additional difficulties with the seafloor installation had to be overcome before we established a viable hole at Site 809. At Hole 809D, although we succeeded in emplacing the drill-in bottom hole assembly in the casing hanger and stabilizing the reentry cone, a failure of the jay-tool left a 6 in. slab of metal in the throat of the guide base. The damaged tool was retrieved and the remaining tool on board strengthened. This was then tripped back down to the cone, jayed-in, and then used to lift the base over the drill-in casing, leaving the casing embedded in the seafloor. We moved the HRB a few meters to Hole 809E. Using the TV monitor, the metal slab was seen resting on the top of the drill-in BHA after we lifted the base.

At Hole 809E, after some hours attempting to drill in another bottom-hole assembly, we managed to erode and undercut the basalt underlying one leg of the HRB, causing it to tilt beyond the 20° maximum allowed by the reentry-cone gimbal assembly. We retrieved the casing, tripped back to the cone, jayed-in, and once again moved the base across the seafloor to a new location, Hole 809F, where finally we succeeded in drilling in and latching a bottom-hole assembly to a depth of 5.9 mbsf.

There followed a period of assembly and testing of the DCS. Several problems were discovered with the secondary heave compensation system, most of them having to do with noise imparted to controlling accelerometers mounted on the DCS platform. The most serious complications were resonance sent down the pipe (which was held in tension against the weight of the HRB) and returned to the ship, and noise from the DCS platform's hydraulic feed cylinders. Both would change — sometimes hourly — as sea-state, wind, and ship's orientation changed. Eventually, the problem was overcome by shifting to a sensor system for the logging-cable heave compensator, which was attached to a bulkhead next to the moon pool. This bypassed the fluctuating, high-frequency motions of the platform and hydraulic system. For most of the time we were coring, however, the full heave compensation system was not in use.

Coring with the DCS began on 6 July. Adjustments had to be made to input parameters in the controlling computer program, inasmuch as changes in weight-on-bit caused simply by landing the bit on the bottom of the hole were initially interpreted by the computer as break-throughs in the formation ("void hits"). This triggered automatic pull-backs of the drill string. Also, about 2 m below the bottom of the casing, we encountered what we interpret as a flow-top breccia which was extremely quickly drilled, and which took almost no weight on bit. Virtually none of this material was recovered, evidently because it was either washed out ahead of the bit by down-the-pipe circulating fluids, or because it fell out of the core barrels as they were retrieved. Throughout this time, there were several indications of possible core jams, based on pressure readings of the fluid pumped down the tubing. At least one such reading may have been caused by aggregation of lumps of gel separated from the lubricant added to the drilling fluid. Also, some core barrels may not have latched in because of accumulated debris (lost core) lodged above the bit. We finally concluded that our core barrels indeed were functioning properly, but that the formation itself was too friable to be cored and retained.

We proceeded with coring, now in harder formation, but soon were unable to advance because of bit failure at 14.3 mbsf. We tripped the tubing, unjayed the drill string, suspended the string in the derrick, set back the DCS platform, and tripped the DCS tubing for a bit change. Reversing this sequence, we resumed drilling.

With this second bit, we advanced through several highly vesicular basalt flows or pillows, with substantial recovery (64%) to a depth of 29 mbsf. Coring was fairly smooth and rapid.

Below this, however, we again encountered unconsolidated formation, and here we faced the most significant weakness of the coring system. For nearly 50 m of subsequent penetration, we recovered virtually nothing. Two or three small chips of basalt would occasionally arrive on deck, but otherwise all we could discover about the formation was based on particles of sand twice found in returned core barrels, and once on the chiseled face of a bit deplugger. The sand suggests the presence of crystal-vitric tuffs, but the small particle size is probably a consequence of drilling. The rate of advance was rapid; at times, there were abrupt drop-throughs of up to 1 m, possibly representing voids in the formation. For most of this interval, weight-on-bit was low and impossible to sustain for much distance. We reduced circulation to a bare minimum (at one point to nearly half the minimum recommended by the bit manufacturer) and devised traps to place in the plastic core liners in an attempt to recover anything at all. But no amount of coaxing could be used, no trick devised, to persuade material even to enter the core barrels. At one point, we lowered a center bit and, after drilling ahead for some meters, recovered it without so much as a scratch on its painted surface.

To the limited degree that we understand it, the problem is a combination of the design of the core catcher, the bit chosen for the coring, and the unconsolidated nature of the formation. First, the core catcher is designed to capture fractured but competent rock recovered at full round core diameter. It has a wide throat. We had no expectation that unconsolidated breccias of such thickness would be at this location, thus we had no core catcher on board with fingers to capture gravel-sized or smaller rock fragments.

Secondly, we continuously pumped a viscous fluid combining seawater, weighted mud, and lubricant down the pipe while coring. This mixture passed through a narrow annulus at the base of the seated core barrel between it and the inner wall of the bit. The force of the spray was directed at the formation immediately ahead (1.5 cm) of the core barrel, evidently jetting the unconsolidated material away. This explains why not even the paint was removed from the center bit when it occupied the place of the core barrel.

Nonetheless, we eventually worked our way into more massive basalt flows once again, recovering a few fully cored pieces before the second bit expired at 79.2 mbsf. Probably, bit wear was accelerated or caused by a sand-blasting effect in the long interval of unconsolidated material we had just penetrated.

At this point, we set back the DCS platform, and rigged for logging through the DCS tubing. The slim-line combined caliper and gamma tool made it down the tubing, but did not pass an obstruction at the bit. The obstruction could not be cleared with the bit deplugger, so we retrieved the tubing to find 34 cm of basalt tightly wedged just above the throat of the bit. Sandy particles coated some of the rocks. Once again, we lowered the logging tool, this time through the drill pipe, but now we encountered another obstruction 2.3 m below the drill-in bottom-hole assembly. With the logging tool, we worked this down to 13.7 mbsf, but no further. As we no longer had the tubing string in place to drill out the obstruction, we elected to abandon the site after 1 month and 5 days of operations, leaving for Shatsky Rise (Site 810).

Science Summary, Site 809

In Hole 809F, three chemically distinct basalt types were encountered in the 73.3 m of igneous formation penetrated by the diamond coring system below the casing shoe at 5.9 m below the seafloor. Successively these are (1) fairly strongly fractionated ferrobasalt (Mg# = 0.43) From 5.9 to 21 mbsf; (2) moderately fractionated olivine tholeiite (Mg# = 0. 60) from 21 to 29 mbsf, just above the 50 m interval with very low recovery; and (3) another moderately fractionated olivine tholeiite (Mg# = 0.60) from just below this interval in the last core obtained, between 78.9 and 79.2 mbsf.

The basalts are all extremely sparsely phyric, highly vesicular tholeiites similar to basalts dredged, drilled, and sampled by submersible from this incipient back-arc rift. They are pillows or thin flows with glassy exteriors and more crystalline interiors. All the rocks are extremely fresh, with only minor oxidative alteration evident near some fractures. Most vesicles are partially lined with unaltered glass; only a few are lined with pale green clays or iron oxyhydroxides. The vesicles are a very prominent feature of these basalts. All the rocks contain myriad irregular to round pinhole vesicles, but there are some very large vesicles (to 1 cm diameter) especially in the more evolved upper ferrobasalt. In this basalt, some of the larger vesicles are arrayed in trains across the rock face within pillow or flow interiors. Many of the larger vesicles are segregation vesicles, being partly filled with frozen melt, itself vesicular, which leaked into them as their walls ruptured during crystallization of the rock. One rock contains a fracture into which melt also leaked, annealing it completely. There is a good correlation between physical properties (velocity, density) and vesicle distribution in the basalts.

The basalts are glassy to spherulitic near quench margins and more crystalline in the pillow/flow interiors. The less fractionated basalts carry minor olivine (no spinel) and have less abundant titanomagnetite than the ferrobasalt. There are a few rare plagioclase phenocrysts. Apart from the olivine, the crystallization sequence in all the basalts was the same: co-precipitating plagioclase and clinopyroxene were followed in intergranular spaces by spectacularly skeletal titanomagnetite and rare, tiny rods of ilmenite. Even tinier pyrrhotite spherules decorate the rims of the oxide minerals, thus segregated only during the very final stages of crystallization of the basalts.

The uppermost ferrobasalt and immediately underlying olivine tholeiite have the typical elevated K_2O (0.60% and 0.32%, respectively), Rb (10 and 5 ppm) and Ba (61 and 45 ppm) abundances, and the relatively low TiO_2 (1.7% at Mg# = 0.43; 1.2% at Mg# = 0.60), Zr (72 and 56 ppm), and Y (27 and 19 ppm) of many back-arc-basin basalts. They are virtually identical to basalts previously sampled from this volcanic ridge. The lowermost basalt, obtained below the 50 m interval with virtually no recovery, is similar in most respects to the olivine basalt above the interval of low recovery, but it has somewhat lower K_2O (0.29%) and much lower Ba (19 ppm) contents. In these respects it resembles basalts from Site 791 drilled during Leg 126 which are interpreted to represent syn-rift basalts dating from the early stages of the opening of the Sumisu rift (Fujioka, Taylor et al., 1989).

We speculate that the interval of very low recovery represents highly vesicular and expanded basaltic glass similar to the basalt "mousse" recovered at Site 791. The rock compositions and stratigraphy suggest that we cored through a thin carapace of back-arc basalts into syn-rift volcanic rocks deposited on subsided pre-rift basement, which projects on seismic profiler records to a shallow elevation at this location.

Site 810 Narrative

The principal objective of Site 810 was to drill interbedded cherts and chalks of Mesozoic age on Shatsky Rise using the diamond-coring system (DCS). This objective was not achieved because of difficulties in setting up a reentry cone on the seafloor, shortage of time toward the end of the leg, and approaching typhoons, which made operations on the suspended DCS platform in the derrick too dangerous to begin. We did manage to core a shortened section of Cretaceous (Maestrichtian)-Cenozoic nannofossil oozes with the APC, and attempted to set up the reentry cone, before abandoning the site.

Approach to Site and Coring Operations

Shatsky Rise was approached from the southwest, so that the ship could pass over previously drilled DSDP Sites 306 and 305 in that order at 8 kt (Fig. 9), to link them to Site 810 with a continuous seismic reflection profile (Fig. 10). Steaming from south to north, we traced the principal chert horizon seismically to a point where the pelagic sediments capping it are only 0.07 s thick, and dropped the beacon at 0600 hr on 22 July 1990. In order, we then recovered a single APC core for geriatric studies in Hole 810A, did a wash-in test to a sub-bottom depth of 60 m in Hole 810B to determine the length of conductor casing needed below the reentry cone, and continuously piston cored from a precisely located mud line to the uppermost substantial chert horizon at 125 mbsf in Hole 810C. One additional core was taken with the XCB in Hole 810C before we retrieved the drill pipe and lowered the reentry cone.

Attempts to Emplace a Reentry Cone

The principal difficulties with the reentry cone installation had to do with suspending casing in the casing hanger. Even before the reentry cone was lowered, one casing string was inadvertently dropped from the moon pool to the seafloor, evidently having become unthreaded while attempting to land the casing hanger. The hanger was removed and modified, but then became wedged in the cone on a test and could not be removed. This meant that no casing could be suspended from it. We decided to lower the cone as it was, but added 14 drums of pig-iron ingots, plentifully available on board ship, to the skirt at the base of the cone, in order to replace the weight the casing would have provided the assembly on the seafloor. This weight was required to tension the drill strong properly during anticipated DCS coring operations.

After this cone was landed on the seafloor, we experienced repeated difficulties in trying to seat a drill-in bottom-hole assembly (DI-BHA). At first, it appeared that the back-off nut was not operating properly, but when the drill string was retrieved to inspect it, we found that the mechanism had landed properly, but concluded that the key-slots which prevent the DI-BHA from unscrewing had failed, thus preventing back-off. We lowered the DI-BHA again, this time without tightening the back-off nut so that with only a small amount of frictional resistance it would unscrew. But once again, the mechanism did not work, and the DI-BHA became stuck. After we freed it and retrieved the drill string, we found that a proper landing again had occurred, but that the back-off nut had fused or jammed into its landing shoulder, possibly by means of the frictional heat produced by rotation, or loads imposed in varied seating attempts. This inadvertent "weld" managed to hold the entire 45,000 lb DI-BHA on its trip back to the ship.

We made one final attempt to land the DI-BHA, this time with a new beveled C-ring in the landing assembly. However, the bevel proved to be our undoing, since the landing shoulder was too narrow, and simply compressed the C-ring on the bevel, allowing the entire DI-BHA to slip through the cone and drop into the soft ooze below. However, this appeared on deck to be a proper landing of the DI-BHA. The problem was only discovered when we could not get a sinker bar to the anticipated bottom of the DI-BHA in order to recover the center bit. When the drill string was retrieved, the back-off nut again was found to be fused or wedged into the landing sleeve. Back-off had actually occurred, but this time the entire DI-BHA had fallen out of the cone.

Rig-down, Fishing the DI-BHA, and Subsequent Survey

With this reversal, there was no time left for DCS coring. With the approach of inclement weather, the DCS tubing was taken from its vertical rack in the derrick and laid out in joints for storage on the riser hatch. There was still sufficient time to attempt to fish the DI-BHA. This was accomplished, and all drill collars were on deck by late afternoon on 29 July 1990. All additional DCS hardware was then secured.

Since weather reports indicated that we still had as much as a day left before our departure would be mandatory, we proceeded to carry out a seismic survey of a portion of the summit of Shatsky Rise (Fig. 9). We cut the survey somewhat short at noon on 31 July, when the ship's barometer reading persuaded the Captain that we should leave the area with all possible speed.

Science Summary, Site 810

At Site 810, Holes A and C, we recovered 129.8 m of Cenozoic and Upper Cretaceous nannofossil ooze (Fig. 11). The shortened section records hiatuses in the upper Miocene–lower Eocene, lower Eocene–upper/lower Paleocene, and lower Paleocene–upper Maestrichtian. The oldest sediment recovered was early

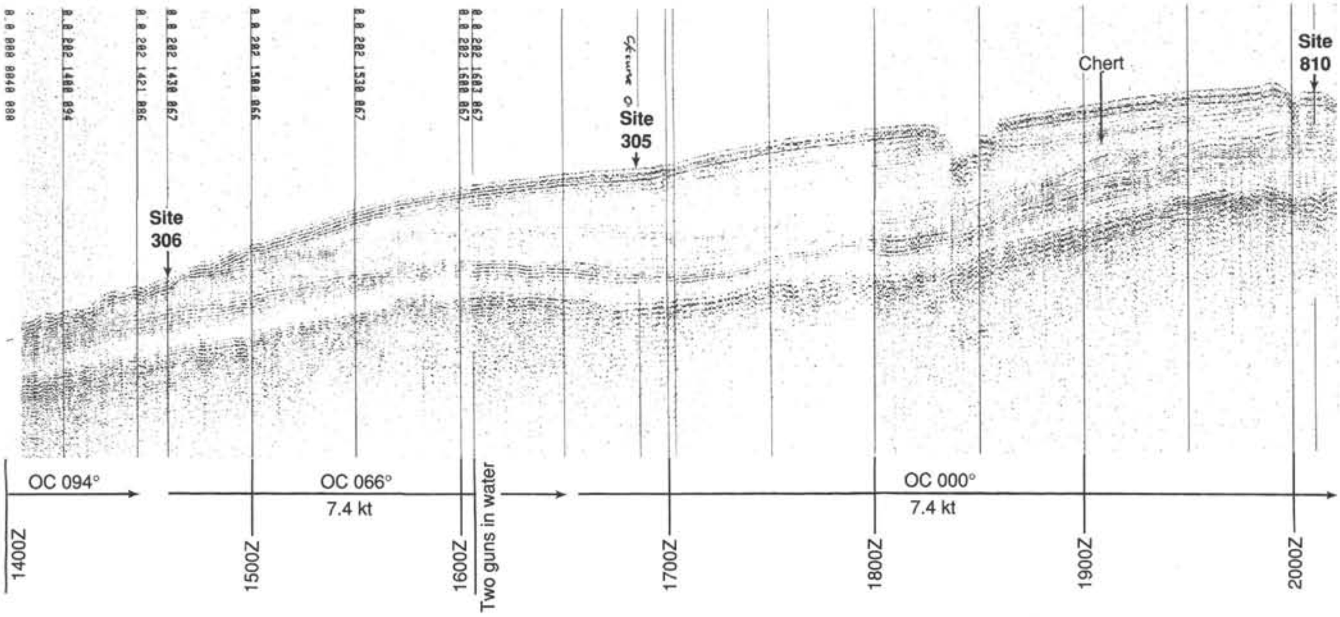

Figure 10. *JOIDES Resolution* seismic profiler record obtained during the approach to Site 810 on Shatsky Rise. The arrow indicates the principal seismic reflector (chert horizon) traced beneath the pelagic sediment cap.

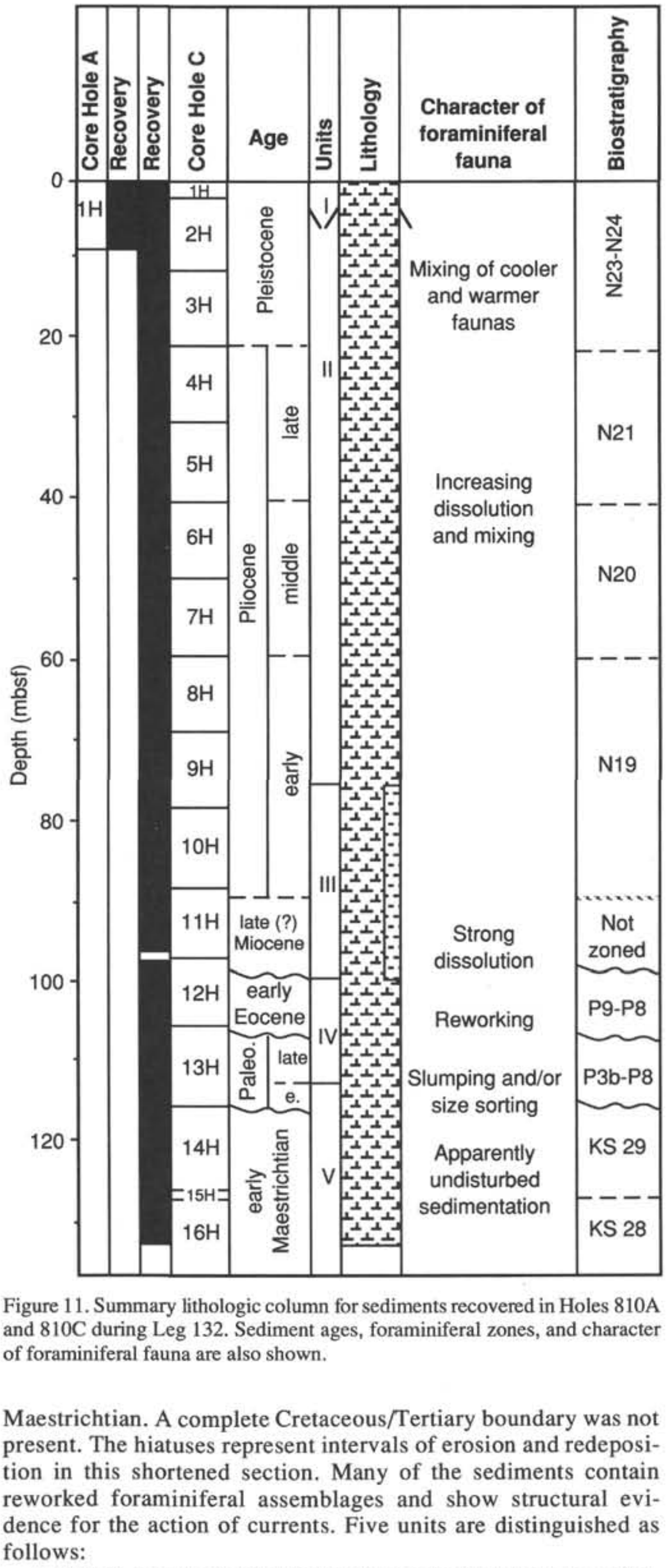

Figure 11. Summary lithologic column for sediments recovered in Holes 810A and 810C during Leg 132. Sediment ages, foraminiferal zones, and character of foraminiferal fauna are also shown.

Maestrichtian. A complete Cretaceous/Tertiary boundary was not present. The hiatuses represent intervals of erosion and redeposition in this shortened section. Many of the sediments contain reworked foraminiferal assemblages and show structural evidence for the action of currents. Five units are distinguished as follows:

Unit I (0–4.2 mbsf). Pleistocene brown to dark gray nannofossil ooze with cut-and-fill structures, and evidence for mixing of cooler and warmer-water faunas.

Unit II (4.2–76.0 mbsf). Lower Pliocene to Pleistocene light gray to white nannofossil ooze, characterized by evidence for increasing dissolution and mixing downsection. The unit contains a number of thin and one quite thick (14 cm) ash beds and rounded pumiceous dropstones, derived from arc systems to the west.

Unit III (76.0–99.5 mbsf). Upper(?) Miocene to lower Pliocene pale tan to tan clayey nannofossil ooze and calcareous clay, with rhythmic color alternations corresponding to varying clay contents (highest estimated 70%). Foraminiferal assemblages show evidence for strong dissolution. The base of the Unit is at a hiatus.

Unit IV (99.5–113.3 mbsf). Upper Paleocene and lower Eocene pale tan nannofossil ooze, separated by a hiatus. Paleocene foraminiferal assemblages are strongly reworked, and include some Cretaceous forms. There is evidence for slumping and size sorting.

Unit V (113.3–136.1 mbsf). Upper Cretaceous to upper Paleocene white nannofossil ooze with large coccolith plates and small chert nodules. The pale color and coring deformation in the lower 10 m makes identification of structures difficult, but there is a hiatus across the Cretaceous/Tertiary boundary.

We obtained an excellent array of measurements for physical properties and magnetic susceptibility, which show strong correlations with cyclical lithological variations in the sediments. Although the section is broken by hiatuses, the upper two units carry detailed information relating to the development of eolian transport from the Asian mainland during the climatic deterioration that occurred between the Pliocene and Pleistocene.

ENGINEERING RESULTS AND ACCOMPLISHMENTS OF LEG 132

Site 809

Although it took a great deal longer than originally planned, all primary and specific engineering objectives for Site 809 were met. The difficulties with the HRB installation, the failure of the jay-tool, and the unforseen complexities of configuring the secondary heave compensation system, all contributed to delays in testing the DCS in coring operations, and ultimately meant that one of the planned sites for the leg had to be dropped, and that coring was severely curtailed at both Sites 809 and 810. There were also unsolved difficulties with core recovery. Nevertheless, the full DCS eventually was brought completely on-line, including the secondary heave compensation system, which operated well, keeping weight-on-bit to ± 200–500 lb, depending on the sea state. The computer was also exceptionally reliable compared with the system used on Leg 124E, which was fraught with problems resulting from operating in the derrick under severe weather conditions.

In all, we penetrated the seafloor a total of 79.2 m. The drill-in BHA was set in basement to 5.9 mbsf. Of the remaining 73.3 m, 50.9 m were cored and 14.3 m were drilled without coring using the DCS. Recovery was fairly good (>60%) in fractured but competent rock. Several impressive cores were recovered, demonstrating the potential of the system. The DCS also managed to penetrate a thick, extremely incompetent and evidently very friable zone of rock without loss of hole stability, although the coring system was utterly incapable of retrieving this material. The fact that this material was penetrated without loss of hole stability is the consequence of the small-diameter (4 in.) hole, the low weight-on-bit, the precise cutting action of the narrow-kerf bit rotating at high speeds, and the continuous circulation of mud throughout coring operations. This compares with the torquing and pipe sticking experienced with conventional rotary coring right at the tops of exploratory Holes 809A and 809B.

This comparative success, however, must be weighed against the certainty that neither highly vesicular basalts nor thick vitroclastic breccias are known from the East Pacific Rise. Basalts there are considerably tougher and will be harder to drill. During the 10 days of DCS operations at Site 809, only 3-1/2 days were actually spent in coring. There was not enough time to learn how to core basalts in this terrain that was considerably less challenging to the DCS than the East Pacific Rise will be.

Operational efficiency and understanding of the system increased steadily each day, and toward the end of the site, the SEDCO drill crew was handling most of the routine operations. The time required to perform such operations as tripping of tubing and drilling joints, strip-over operations, core-barrel handling and turnaround, etc., was cut nearly in half.

Additional experience was gained in using mud/coring motors for bare-rock spudding. In addition, we tested the new drill-in BHA system for the first time, demonstrating the importance and viability of casing off the upper portions of unstable holes. The experience gained will allow future multi-stage drill-in BHA systems to be developed which will provide stability in holes to even greater depths.

We learned a tremendous amount about how to place a HRB on locally complex seafloor. Relatively routine reentries into the open-ended casing hanger (≤ 24 in.) will give rise to a much smaller reentry cone design. This singular achievement, although accomplished under duress, will eventually result in a far superior, cheaper, and operationally more efficient seafloor guide-base design.

Last, but not least, the techniques used in the recovery of the failed reentry cone, and the recovery and multiple placements of the HRB, demonstrate a considerable proficiency in the handling of heavy hardware at the end of a long drill string using the dynamic positioning system of *JOIDES Resolution*. This capability, which was not previously appreciated, provides a new dimension to the scientific planning of drilling operations in difficult environments such as spreading ridges. The concept of "pogo" drilling is now fully proven. The capability of retrieving guide bases will also have important budgetary ramifications.

Hole 809F was the first successful bare-rock drilling/coring of basalt at an active submarine volcanic rift. The hole, although apparently bridged at the top, remains available for future drilling with a conventional rotary or an advanced diamond-coring system.

Site 810

At Site 810, we confirmed that chert cannot be piston cored, nor can undisturbed sediments be sampled between chert layers with the extended core barrel. Probably this material would have been extremely difficult to recover by DCS coring with the open-throat core catchers we had on board. The problem very clearly is how to recover extremely hard rock (chert) embedded in buttery ooze. Such a sequence is probably unique to the marine environment; nothing comparable has been attempted with diamond coring on land. Before attempting to core in such material again, serious thought has to be given about how to recover the material.

Finally, we discovered problems with the design and construction of the landing structure used for seating casing or a drill-in bottom-hole assembly in the modified reentry cone. We successfully fished one such DI-BHA after it had fallen completely through the reentry cone, and dropped some 25 m into soft oozes beneath it. The reentry cone is still on the seafloor for future DCS coring.

CONCLUSIONS

Leg 132 may seem to have been one long series of trials and difficulties. To a degree, it was. However, as an engineering leg, it accomplished what it set out to do. Every single component of the DCS and both seafloor installations were evaluated at sea. Although we managed far less coring time than was desired with the DCS, that system now is fully functional. So, too, after a difficult period of evaluation, is the dual heave compensation system. Even the difficulties with the HRB were eventually overcome, the effectiveness of the drill-in bottom hole assembly was demonstrated, and only lack of time prevented emplacement of the drill-in bottom-hole assembly at Site 810.

There are two components of the integrated system that need some redesign and more attention to construction. These are the seafloor installations and the core recovery system. However, in both cases, the modifications that will insure future success are very obvious. The HRB probably should be mounted on three legs rather than four, the gimballed reentry cone should be counterweighted rather than held upright by flotation, and devices should be installed to assess guide-base orientation on the seafloor before separation from the drill string. Variations in leg length and size of pad may allow installation of the HRB in steeper, rougher terrain. The jay-tool needs more robust construction. A more uniform lighting system for the TV camera needs to be added to the VIT frame, and a stereographic camera system should be added to return high-quality still photographs of the HRB and surrounding seafloor to the ship.

For future coring, there needs to be much more flexibility in core-barrel assemblies, particularly in the design of core catchers. A means must be devised to prevent circulating fluids from eroding unconsolidated sediments and breccias before they can enter the core barrel. An adaptation of the advanced piston corer to the DCS, but one that would penetrate soft sediments very slowly, may be the only way to capture buttery nannofossil ooze between chert layers.

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Ms 132A-101