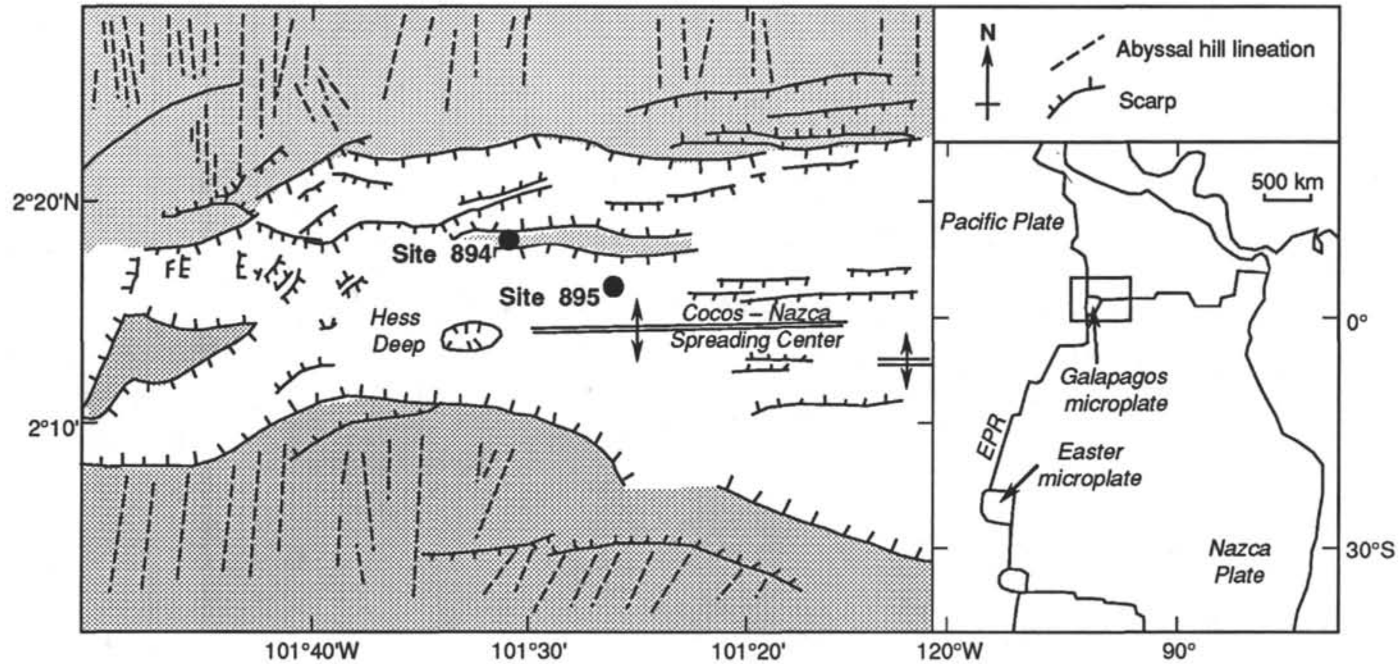

Site 894
Site 895
Hess Deep
Cocos – Nazca Spreading Center
2°20'N
2°10'
101°40'W
101°30'
101°20'
N
Abyssal hill lineation
Scarp
500 km
Pacific Plate
Galapagos microplate
EPR
Easter microplate
Nazca Plate
0°
30°S
120°W
90°

OCEAN DRILLING PROGRAM

LEG 147 PRELIMINARY REPORT

HESS DEEP RIFT VALLEY

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SCIENTIFIC REPORT

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ABSTRACT

The principal success of Leg 147 was the recovery of continuous sections of crustal gabbroic rocks and shallow mantle harzburgite, dunite, and intercalated gabbroic rocks from the Hess Deep. These cored crustal sections at Site 894 were generated at the fast-spreading East Pacific Rise (EPR), approximately 1 Ma. Hess Deep is the deepest part of a westward-propagating rift valley that is opening up the eastern flank of the equatorial EPR in advance of the propagating Cocos-Nazca spreading center. The exposures cored at Sites 894 (2°18.0'N, 101°31.5'W) and 895 (2°16.7'N, 101°26.7'W) were located on the crest and southern slope of an intra-rift ridge, respectively. At Site 894, 219.9 m was cored in seven holes, recovering 58.5 m of gabbroic rocks, principally gabbronorite with lesser amounts of gabbros, olivine gabbros and gabbronorites, oxide gabbros and gabbronorites, and basaltic dikes. Operations at Site 895 recovered shallow mantle rocks, interpreted as lying close to the petrological Moho, from six holes that penetrated a total of 272.9 m and recovered 64.56 m of rock. The rocks recovered were predominantly dunite and harzburgite, with intercalated, less abundant gabbro, olivine gabbro, and troctolite. This recovery of deep crustal and upper mantle gabbroic rocks and peridotites should prove critical to the characterization of the igneous, metamorphic, and structural evolution of the lower crust and upper mantle generated at a fast-spreading ridge, as well as for understanding variation in physical and magnetic properties of the lower crust and upper mantle. This leg represents the first of a proposed multi-leg program.

INTRODUCTION

Detailed bathymetric, petrologic, and geophysical surveys along the global mid-ocean-ridge system have greatly modified our view of the stratigraphy of the oceanic crust and upper mantle during the past decade. The simple layer-cake model, which requires a continuous elongate magma chamber along an axis, has evolved to a segmented ridge system with a hierarchy of discontinuities which likely reflect mantle dynamics and magma-melting processes. Recent models suggest that magma chambers are discontinuous features that are fed intermittently from below at regularly spaced points (e.g., Whitehead *et al.*, 1984; Crane, 1985; MacDonald, 1987). Most models that attempt to predict how the internal stratigraphy of the oceanic crust is influenced by the rate of magma supply, spreading rate, and magmatic vs. amagmatic extension have been developed on the basis of remote geophysical techniques. To test these models, it is important to study not only the basalts erupted on the seafloor but also plutonic rocks that crystallized within a magma chamber and the upper mantle rocks which are the ultimate magmatic source. Because plutonic and ultramafic rocks may show considerable mineralogical and geochemical heterogeneity at a very small scale, it is essential to study continuous sections of the lower crust and upper mantle by deep drilling.

The broad elevated topography of axial summit grabens at fast-spreading ridges is thought to reflect a high rate of magma supply which would require fairly steady-state magma chambers (MacDonald, 1987). Until recently, it has been predicted that large, steady-state magma chambers would produce a thick layered sequence in the lower crust similar to the layered sequences in the Oman Ophiolite and continental layered intrusions (e.g., Pallister and Hopson, 1981). New geophysical data from the East Pacific Rise (EPR) indicate the presence of a thin lens of magma that is underlain by an extensive crystal mush zone that may extend down to the base of the crust (Detrick, 1991; Kent *et al.*, 1990). Gaps in the axial magma chamber reflector along the EPR axis are interpreted as the boundaries of discrete magma chambers which may account for the chemical diversity seen in the volcanics along axis (Kent *et al.*, 1990). The igneous stratigraphy should vary with the relative size and geometry of the chamber and crystal mush zone, and may or may not show evidence for anhydrous ductile deformation. The evolution of cumulates and the mechanism of melt extraction from long-lived crystal mush zones is not known, but it must differ from crystal mush zones in small, ephemeral magma chambers. Ductile deformation at fast-spreading ridges should preclude the early penetration of seawater into the solidified lower crust, raising the possibility that high-temperature metamorphism is not a significant process beneath fast-spreading ridges (Mével and Cannat, 1991).

Thus, it is probable that the lower crust in oceanic crust generated at fast-spreading ridges is significantly different than that formed at slow-spreading ridges with a low magma budget. The gabbroic core recovered during Leg 147 will provide important new insights into processes of crustal formation at fast-spreading ridges and will be an important comparison to the gabbroic core recovered at the slow-spreading Southwest Indian Ridge during Leg 118.

Another major issue of lithosphere creation and evolution at mid-oceanic ridges is the understanding of processes occurring in the upper mantle and the crust-mantle transition. In ophiolites, a more or less thick transition zone is composed of alternating dunite and harzburgite tectonites, with the proportion of harzburgite increasing downward. The internal stratigraphy and composition of dunites/harzburgites reflect the processes of melt migration and extraction critical to understanding the evolution of ocean-ridge basalt. The extent to which these processes occur beneath ocean ridges is a key unknown in modeling the generation of ridge basalts.

The nature of the seismically defined Moho beneath ridges is still being debated. Although the Moho is generally viewed as a simple igneous stratigraphic boundary, investigations of ophiolites demonstrate that it may be either a wide transition zone or a tectonic contact. A well-preserved, intact igneous Moho is most likely to occur beneath fast-spreading ridges, as extension accompanying divergence of the plates may be simply accommodated by flow in a crystal mush zone and partially molten mantle. Processes controlling seawater penetration in the mantle are still poorly understood; the chemical effects of serpentinization are of primary importance with respect to the chemical budget of the oceans. Serpentinization decreases the density and velocity of mantle rocks and therefore may play a major role in the seismic and gravity data. Serpentinization is also responsible for the formation of secondary magnetite, which may allow mantle rocks to significantly contribute to the formation of magnetic anomalies.

Questions concerning crustal and upper mantle processes were specifically addressed by Leg 147 coring into exposures of the lower crust and shallow mantle at the Hess Deep.

GEOLOGIC AND TECTONIC SETTING

Hess Deep is the deepest part of a westward-propagating oceanic rift valley that is opening up the eastern flank of the equatorial EPR in advance of the westward-propagating Cocos-Nazca spreading center (Lonsdale, 1988; Fig. 1). The western end of the rift valley is 30 km from the EPR axis, where approximately 0.5-Ma EPR crust is broken by two 5-km-wide east-west grabens, which join a few kilometers farther east. As the rift valley extends eastward, it broadens to 20 km and deepens to >5400 m; its uplifted shoulders rise to depths less than 2200 m. Approximately 70 km east of the EPR axis, the Cocos-Nazca spreading center begins to build a volcanic ridge in the rift valley, and the rift escarpments are locally uplifted an additional 500 m at narrow horsts. Farther east, the wedge of newly accreted crust formed by north-south spreading expands to a mature, medium-rate (50 mm/yr total) spreading center, and the rift escarpments become the "rough-smooth boundary" of the Galapagos gore.

The Hess Deep rift valley is propagating into a random part of the EPR at a rate that matches the 65 km/m.y. half-rate of EPR spreading (Lonsdale, 1988). Prior to ~1.3 Ma, the Hess Deep area was a steady-state triple junction between the Cocos-Nazca ridge and the EPR. A change in the spreading direction of the EPR at ~1.3 Ma corresponds with the initiation of the Galapagos microplate, making the Hess Deep rift valley the Cocos-Galapagos rather than the Cocos-Nazca boundary. A recent SeaBeam survey on the conjugate flank of the EPR shows similar variation, suggesting that discrete blocks of crust were rotated during transport off-axis (P. Lonsdale, pers. comm.). An interpretation of these data suggests that the overlapping spreading center (OSC) currently centered at 2°20'N has alternated between northern and southern propagation since the change in spreading direction at ~1.3 Ma. This model predicts that the crust exposed at Hess Deep is composed of crustal blocks generated at different margins of the EPR.

The scarps as well as the intra-rift ridge were investigated during a *Nautile* (Francheteau *et al.*, 1990; Francheteau *et al.*, 1992; Hekinian *et al.*, in press) and an *Alvin* (Karson *et al.*, in press; Lonsdale, unpubl. data) dive programs. The fault scarps that bound the rift valley are seismically active (Neprochnov *et al.*, 1980) and expose 0.5- to 1.0-Ma crust. Rocks observed on these scarps appear to have been freshly exposed and are not encrusted with manganese oxides. The rift valley is asymmetric, with the Hess Deep ridge axis occurring closer to the southern than the northern wall. The southern wall rises continuously in large steps to a crest of 2200 m depth, approximately 7 km south of the deep. The EPR plateau is fairly flat, and abyssal-hill lineations intersect the scarp. Abyssal-hill lineations within the northern scarp generally extend up to the scarp except in the area of a rift-shoulder horst, where a crustal block has been rotated. Multichannel reflection profiling along the EPR flanks indicates that seismic Layers 2A (lava sequence) and 2B (dike complex) are of normal thickness (about 2 km) and that Layer 3 (gabbroic complex) may be somewhat thinner than usual (3-3.5 km) (Zonenshain *et al.*, 1980). A major intra-rift ridge occurs between the Hess Deep and the northern scarp and extends eastward, overlapping the western end of the Cocos-Nazca ridge; Sites 894 and 895 are both located on this ridge (Fig. 2).

Volcanics, sheeted dikes, and, locally, gabbros crop out along the scarps that bound the Hess Deep rift valley (Francheteau *et al.*, 1990; Blum, 1991; Francheteau *et al.*, 1992; Karson *et al.*, 1992; Hekinian *et al.*, in press; P. Lonsdale, unpubl. data). A talus ramp, approximately 1200 m thick, intersects the scarps within the sheeted-dike complex. Dikes are generally subvertical and strike north-south, parallel to the EPR fabric. Gabbros underlie the sheeted dikes within a rift shoulder horst along the northern scarp. In this region, the dikes are locally rotated. Typically, a 100-300-m-thick layer of pillow lavas is separated from the sheeted dikes by an intermediate zone of variable thickness (50-500 m), consisting of a mixture of extrusives and intrusives, including thick horizontal layers that may represent sills.

A complete, albeit dismembered, crustal section of the EPR, including volcanics, sheeted dikes, gabbros, and peridotites, is exposed on the floor of the Hess Deep rift valley and the intra-rift ridge. This area was investigated with the Nautile along two north-south-trending transects that were centered at the western (3040 m) and eastern (2900 m) summits of the intra-rift ridge (Francheteau *et al.*, 1990; Hekinian *et al.*, in press). Along the western transect, the slope that rises southward from the axis of Hess Deep averages 45° and is covered with basaltic and diabasic rubble. A gentle, 15°-20° slope, stepped with secondary high-angle faults, extends north of Hess Deep for 5-6 km. Lower crustal rocks with rare dunites crop out in ledges that dip into the lower slope from 5400 and 4500 m depth, and semi-horizontal ledges of dolerite occur in a mainly sedimented terrain between 4500 and 4000 m. A change in slope at 4000 m marks the southern edge of the east-west-trending intra-rift ridge, which culminates at 2900 mbsl. In this area, gabbros crop out along the southern and northern slopes, with an isolated basalt outcrop at its crest. Along the eastern transect, north of the tip of the Cocos-Nazca ridge, plutonic and ultramafic rocks crop out between 4500 and 3500 m depth along a gentle slope that is locally <10°. Cr-spinel-bearing dunites and harzburgites were sampled from subhorizontal ledges that dip to the north. Pillow lavas and dikes form the crest of the ridge at the eastern summit, and low-temperature hydrothermal activity was observed. *In-situ* north-south trending dikes crop out on the northern slope of this summit. Gabbros have been recovered by well-positioned dredges between these two transects. Along both transects, the slope south of the intra-rift ridge and north of Hess Deep and the Coco-Nazca rift tip has undergone significant mass wasting and talus accumulation.

The distribution of rock types along the eastern and western transects shows that the structure of Hess Deep is complex. There is no lateral continuity in rock type along the intra-rift ridge such that gabbros crop out at the western end and dolerites and basalts at the eastern; the geology between these two areas is unknown. Similarly, cumulate gabbros occur at greater depths along the western transect than harzburgites along the eastern one. Observations suggest that the western and eastern ends of the intra-rift ridge are comprised of a massive block of gabbros and upper crustal rocks, respectively. Two alternative rifting models have been proposed for the Hess Deep rift valley

(Francheteau *et al.*, 1990). One emphasizes the vertical movement of mantle horsts or serpentine diapirs to expose mantle rocks. The other postulates rupture of the lithosphere by low-angle detachment faults similar to those mapped and imaged at rifting sites in continental lithosphere and recently postulated for the regenerating axial rift valleys of slow-spreading ridges. Leg 147 coring results are compatible with an origin of the intra-rift ridge by block faulting; the coring results should prove critical toward understanding the rifting mechanisms of the Hess Deep.

RESULTS

Site 894

Site 894 is located close to the summit of the intra-rift ridge in the Hess Deep, at approximately 2°18.0'N, 101°31.5'W. The objective of drilling at Site 894 was to sample a section of oceanic gabbros created at a fast-spreading center, by starting a hole directly on gabbros exposed at the top of the ridge. Six camera surveys were conducted at this site, covering a total area of 1.0 by 1.2 km, and seven sites were selected for test drilling to locate appropriate rock types and optimal drilling conditions. Shallow holes were drilled on the flat, slightly sedimented summit of the ridge (Holes 894A, 894D, 894E), and on ledges close to the southern edge of the summit (Holes 894B, 894F). An attempt to start Hole 894C with a guide base failed. A second guide base was successfully deployed to start Hole 894G, close to test Hole 894F. A total of 219.9 m was cored, with a recovery of 58.5 m (26.6%). Hole 894G represents the principal hole and most of the recovery at this site, and its recovered lithology is summarized in Figure 3 and Table 1.

Holes 894A, 894D, and 894E recovered short sections of sediment consisting of foraminiferal ooze, basalt cobbles, basaltic lithic breccias, basaltic sand, and foraminiferal sand. The basaltic and foraminiferal sand are interpreted as turbidites that may have been deposited in a basin prior to the uplift of the intra-rift ridge. In Hole 894A, this formation overlies a monomict igneous breccia consisting of greenschist-facies metabasalts interpreted as being locally derived. Highly metamorphosed gabbro fragments, many of which are cataclastically deformed, were recovered in Holes 894B, 894D, 894E, and 894F.

The stratigraphy of Holes 894F and 894G is considered together, as they are only 18 m apart. The igneous plutonic rocks recovered from Holes 894F and 894G, in order of decreasing abundance, are gabbronorites, gabbros, olivine gabbros and gabbronorites, and oxide gabbros and gabbronorites. The gabbros occur in the upper parts of the section, and gabbronorites first appear at 45 mbsf. These plutonic rocks are non-layered, show textural variations from ophitic to equigranular, and grain-size variations from fine to coarse. Some of the textural variability is related to the presence of patches, pockets, and veins of more coarse-grained gabbronorite hosted in finer grained gabbros and gabbronorites. Zircon and apatite are abundant in many of these coarser grained pockets.

Although there is no apparent layering, magmatic penetrative fabrics are defined by the preferred orientation of euhedral plagioclase in many of the plutonics. A steeply dipping, magmatic foliation is regularly present, and the trend of lineations is subvertical. In fine-grained gabbros, the foliation is oblique to, and cross-cut by, coarser grained gabbronorite, which exhibits an irregularly distributed steeply dipping fabric. Although most medium-grained gabbronorites possess orthopyroxene oikocrysts, these noticeably disappear where a strong magmatic foliation is developed. This feature suggests that the foliation may have formed as a result of deformation of partly crystallized magma, and that deformation locally played a role in expelling evolved interstitial liquid.

Co-precipitation of plagioclase-clinopyroxene-orthopyroxene suggests that the magma indeed became more highly evolved than that which normally erupts along the East Pacific Rise. The zircon and apatite may have crystallized from a volatile-rich magma that segregated and/or percolated through the crystallizing matrix. The lack of layering and textural variability, and the presence of coarse-grained pockets in the recovered rocks, are most similar to gabbroic rocks found in the upper parts of the plutonic sequences of ophiolite complexes.

Several units of olivine-, plagioclase-, spinel-phyric basalts were recovered at Site 894. Two observed contact relations demonstrate that the basalts represent dikes chilled against the plutonic rocks. The dike phenocryst assemblage suggests relatively primitive magmas.

At least 80% of the rocks recovered at Site 894 are moderately altered to greenschist to amphibolite facies mineral assemblages. The extent of alteration increases with increasing grain size and does not correlate with depth below the seafloor. Metamorphic textures consist of pseudomorphic replacement of primary igneous minerals. Amphibolite-facies mineral assemblages define the earliest alteration and include amphibole, hydrothermal clinopyroxene, magnetite, and calcic plagioclase. These minerals are overgrown by transition to the amphibolite and greenschist-facies mineral assemblages dominated by actinolite, minor sodic plagioclase, and rare chlorite. The latest alteration includes zeolite after plagioclase and smectite after clinopyroxene, orthopyroxene, and olivine.

Core from Site 894 is cross-cut by several networks of filled tensile fractures that are devoid of displacement. Cataclastic zones occur primarily in the upper part of the section and are related to steeply dipping normal faults. Three types of macroscopic veins (≥0.1 mm wide) postdate the early amphibolite-facies mineral assemblages. The earliest veins range from continuous and sharp-sided to discontinuous and wispy and are filled primarily by green amphibole. Some associated minerals include pale brown amphibole, chlorite, and sphene. A second set of veins forms a much more regular, abundant, steeply dipping (40°-60°) network associated with strong greenschist-facies wall-rock alteration, and contains chlorite with varying amounts of prehnite, actinolite, and epidote. Reorientation of the veins relative to the stable remanent magnetization direction indicates a consistent west-northwest-east-southeast trend parallel to the Hess Deep rift valley. These veins and associated wall-rock alteration also occur near zones of cataclastic deformation. The youngest veins are filled by assemblages of layer silicates (chlorite to smectite), zeolites, and calcite. Veins of this type exhibit a wide range of dips and are associated with variable wall-rock alteration. The metamorphism and associated vein formation observed in the Site 894 plutonics require the migration of hydrothermal fluids through the gabbros from >500°C to ambient temperatures.

Paleomagnetic measurements show that the average intensity of natural remanent magnetization and magnetic susceptibility of samples from Hole 894G are 2.0 A/m and 0.016 SI units, respectively. The ratio of these two parameters suggests that the *in-situ* magnetization of this crustal section is dominated by remanent magnetization rather than magnetization induced by the Earth's field. Overall, these magnetic property values are similar to those observed on gabbros recovered from slow-spreading ridges as well as on most oceanic basalts. The remanent magnetization is observed to be very stable with respect to both alternating-field and thermal demagnetization, and the demagnetization data indicate that nearly pure magnetite is the only significant carrier of remanence.

The stable direction of magnetization dips downward at an average of 40° and is significantly different than the value expected for crust formed at this latitude (0°). Therefore , it seems likely that this crustal section experienced substantial tectonic rotation.

Physical properties are strongly dependent on the intensity of metamorphism. The average wet bulk density is 2.92 $g/cm^3 \pm 0.09$ g/cm^3. Porosity values center on a mean value of 1.2% ± 1.5%, while the water content mean value is 0.4% ± 0.6%. The most altered samples have the lowest densities and highest porosities. Compressional-wave velocities measured at atmospheric pressures and temperatures in horizontally oriented, water-saturated samples have a mean of 6600 m/s ± 500 m/s, with values ranging from 5330 m/s in the most altered zones to 7335 m/s for the freshest rocks. Velocities measured in several vertical samples do not show any significant anisotropy relative to adjacent horizontal samples. Thermal-conductivity measurements have a mean value of 2.22 W/m°C. Thermal conductivity increases from fine-grained dikes through altered gabbro to fresher gabbronorites. Separating the measurements by intensity of metamorphism shows that the heat flux through altered zones is mostly controlled by convective rather than conductive heat flow. Electrical-resistivity measurements performed in several water-saturated minicores show a strong inverse correlation with porosity, which suggests that ionic pore-fluid conduction dominates in these samples. Values ranging from 10,700 Ωm to 19.8 Ωm fall within values previously measured for this type of oceanic rock.

Site 895

Site 895 is located along the slope south of the intra-rift ridge crest, at the position of 2°16.7'N, 101°26.7'W, in an area where ultramafic rocks were recovered during a *Nautile* dive program. The aim of drilling at this site was to recover a section of the shallow mantle. Because of technological problems, it was not possible to drill a long section of mantle. Six holes, Hole 895A to 895F, penetrated a total of 272.9 m and recovered 64.56 m, with an average recovery of 27.5%. Among the six holes, only Holes 895D and 895E had a substantial penetration (93.7 and 87.60 m respectively) and recovery; an overview of Site 895 recovery is presented in Figure 4 and Table 2.

The igneous rocks recovered consist predominantly of ultramafic rocks (dunite and harzburgite) and less abundant mafic rocks (gabbro, olivine gabbro, and troctolite). Although all rock types are present in both holes, harzburgites predominate in Hole 895D, whereas dunites and gabbroic rocks are more abundant in Hole 894E. Several gradational and sharp contacts were sampled and appear to be largely subparallel and rather steep. Gradational changes from dunite, to sparsely plagioclase-bearing dunite, to interconnected veins of plagioclase and clinopyroxene separated by patches of dunite, occur in continuous sections of core and may suggest that these rocks were formed by melt migration and impregnation.

Despite pervasive serpentinization, harzburgites retain porphyroclastic textures. Spinel-shape fabric in both dunites and harzburgites defines a foliation attributed to high-temperature solid-state flow. In dunite and troctolite, traces of plastic deformation of olivine are observed in thin section. In Holes 895C, 895D, and 895E, the spinel foliation seems to show an increasing amount of dip with depth.

The relatively small amount (less than 2%) of modal clinopyroxene in the ultramafic rocks indicates that they are depleted abyssal peridotites. It is possible that the dunites are the simple residue of melting formed by more melt extraction than from the harzburgites. It is also possible that the dunites are simple cumulate products of melt crystallization. The association of harzburgite-dunite-gabbroic rocks recovered from these holes is similar to the transition zone in ophiolite complexes. The relative abundance of dunite suggests that the drilled sections of Site 895 are close to the mantle/crust boundary as recognized in these complexes and are likely located just below the petrological Moho.

All ultramafic lithologies are affected by extensive alteration, with 50% to 100% of the primary minerals replaced by secondary phases. Alteration is dominated by serpentine after olivine, with lesser amounts of bastite, talc, magnetite, chlorite, brucite, and trace antigorite. Serpentinization is more intense in dunites than in harzburgites, and in Hole 895E than in Hole 895D. Troctolitic and gabbroic rocks are moderately to pervasively altered and irregularly exhibit a mineral foliation. Secondary minerals commonly include chrysotile, tremolite, magnetite after olivine, and prehnite, chlorite, zeolite, and hydrogrossular after plagioclase.

Multiple generations of discrete fracture-filling veins cross-cut the pervasive background mesh serpentine texture of the peridotites and are filled with tremolite, chlorite, antigorite(?), magnetite, chrysotile, brucite, clays, zeolites, and aragonite. The moderate to pervasive metamorphism and associated vein formation in ultramafic and mafic rocks reflect extensive interaction with seawater-derived fluids during successive hydrothermal pulses. In the absence of mineral assemblages defining distinct metamorphic zones, the temperature of interaction is difficult to estimate. Gabbro assemblages suggest incipient interaction at temperatures close to 500°C with extensive reaction under greenschist- facies conditions. Serpentinization continued at lower temperatures as evidenced by the presence of zeolites, clays, and brucite. The close association of calcium metasomatized gabbroic rocks with the peridotites may reflect migration of calcium-rich fluids under greenschist-facies conditions which were generated during serpentinization of the peridotites (incipient rodingitization).

Paleomagnetic measurements were made on 36 minicores from Holes 895B, 895C, 895D, 895E, and 895F. The magnetization values obtained from 29 peridotite samples range from 0.3 to 25.0 A/m, with an arithmetic mean of 3.8 A/m. This mean is reduced to 3.0 A/m by excluding the highest value of 25.0 A/m, which is anomalous to the sample population. This magnetic intensity itself suggests that peridotites may be a significant source of marine magnetic anomalies. The average magnetization value for the gabbroic rocks is 0.4 A/m, significantly lower than that of the Hole 894G and Hole 735B gabbros (1-2 A/m). Thermal demagnetization data suggest that relatively pure multidomain magnetites are the dominant magnetic carriers.

Stable magnetic inclination values from Hole 895D samples are widely scattered and suggest that drilling may have penetrated several large blocks of crust which experienced different degrees of tectonic rotation. In contrast, the stable inclinations from Hole 895E fall within a fairly narrow range and have a similar average value (+36°) to that obtained for Hole 894G (+40°). These data suggest that tectonic rotation occurred after the major serpentinization event responsible for the formation of the magnetite that carries the bulk of the rock magnetization. Anisotropies of magnetic susceptibility (AMS) in these rocks are weak. Hole 895E has a consistent north-south-striking magnetic lineation caused by the preferred orientation of long magnetite axes.

Physical properties are strongly influenced by the degree of serpentinization and recrystallization. Peridotites display low densities and high porosities (mean value of 2.68 g/cm^3 and 2.30% for harzburgites, and 2.55 g/cm^3 and 3.31% for dunites, respectively), as opposed to the gabbroic rocks (2.81 g/cm^3 and 0.82% respectively). Compressional-wave velocities measured at atmospheric pressures and temperatures, in horizontally oriented water-saturated samples, have a mean of 5548 m/s ± 746 m/s. Low velocities correlate with high-porosity-low-density values. Velocities measured in several vertical and adjacent horizontal samples show systematically lower vertical velocities. The differences observed in directional velocities might be attributed to an existing mineral fabric or to preferred microcrack orientation. Thermal-conductivity measurements have a mean value of 2.833 W/m °C. The large standard deviation for all the different rock types suggests that the serpentinization process in the peridotites and the alteration of the gabbros play a very important role in the thermal conductivity of the lower crust and upper mantle. Electrical-resistivity measurements performed in several water-saturated minicores show a strong inverse correlation with porosity, which suggests that ionic pore-fluid conduction dominates in these samples, with the dunites having the lowest measured resistivities.

REFERENCES

Blum, N., 1991. *Structure and composition of oceanic crust and upper mantle exposed in Hess Deep of the Galapagos microplate.* PhD thesis, Universität Karlsruhe, Germany.

Crane, K., 1985. The spacing of rift axis highs: dependence upon diapiric processes in the underlying asthenosphere. *Earth Planet. Sci. Lett.*, 72:405-414.

Detrick, R.S., 1991. Ridge crest magma chambers : A review of results from marine seismic experiment at the East Pacific Rise. *In* Peters, Tj., Nicolas, A., and Coleman, R.G. (Eds.), *Ophiolite Genesis and Evolution of the Oceanic Lithosphere:* Kluwer Academic Publishers, 7-20.

Francheteau, J., Armijo, R., Cheminée, J.L., Hekinian, R., Lonsdale, P., and Blum, N., 1990. 1 Ma East Pacific Rise oceanic crust and uppermost mantle exposed by rifting in Hess Deep (equatorial Pacific Ocean). *Earth Planet. Sci. Lett.,* 101:281-295.

Francheteau, J., Armijo, R., Cheminée, J.L., Hekinian, R., Lonsdale, P., and Blum, N., 1992. Dyke complex of the East Pacific Rise exposed in the walls of Hess Deep and the structure of the upper oceanic crust. *Earth Planet. Sci. Lett.,* 111:109-121.

Hekinian, R., Bideau, D., Francheteau, J., Lonsdale, P., and Blum, N., in press. Petrology of the East Pacific Rise crust and upper mantle exposed in the Hess Deep (eastern equatorial Pacific). *J. Geophys. Res.*

Karson, J.A., Hurst, S.D., and Lonsdale, P., 1992. Tectonic rotations of dikes in fast-spread oceanic crust exposed near Hess Deep. *Geology*, 20:685-688.

Kent, G.M., Harding, A.J., and Orcutt, J.A., 1990. Evidence for a smaller magma chamber beneath the East Pacific Rise at 9°30'N. *Nature*, 344:650-653.

Lonsdale, P., 1988. Structural pattern of the Galapagos microplate and evolution of the Galapagos triple junction. *J. Geophys. Res.*, 93:13,551-13,574.

MacDonald, K., 1987. Tectonic evolution of ridge-axis discontinuities by the meeting, linking or self-decapitation of neighboring ridge sediments. *Geology,* 15:993-997.

Mével, C., and Cannat, M., 1991. Lithospheric stretching and hydrothermal processes in oceanic gabbros from slow-spreading ridges. *In* Peters, Tj., Nicolas, A., and Coleman, R.G. (Eds.), *Ophiolite Genesis and Evolution of the Oceanic Lithosphere:* Kluwer Academic Publishers, 293-312.

Neprochnov, Y.P., Sedov, V.V., Semenov, G.A., Yelnikov, I.N., and Filaktov, V.D., 1980. The crustal structure and seismicity of the Hess Basin area in the Pacific Ocean. *Oceanology*, 20:317-322.

Pallister, J.S., and Hopson, C.A., 1981. Samail ophiolite plutonic sequence: Field relations, phase variation, cryptic variation and layering, and a model of a spreading ridge magma chamber. *J. Geophys. Res.*, 86:2593-2644.

Whitehead, J.A., Dick, H.J.B., and Shouten, H., 1984. A mechanism for magmatic accretion under spreading centers. *Nature*, 312:146-148.

Zonenshain, L.P., Kogan, L.I., Savostin, L.A., Golmstock, A.J., and Gorodnitskii. A.M., 1980. Tectonics, crustal structure and evolution of the Galapagos Triple Junction. *Mar. Geol.*, 37:209-230.

FIGURES

Figure 1. Location of Hess Deep at the western end of the propagating Cocos-Nazca spreading axis (from Lonsdale, 1988, copyright American Geophysical Union).

Figure 2. Bathymetric map (in meters) of the Hess Deep intra-rift ridge area, showing locations of Sites 894 and 895. Bathymetry from SeaBeam data collected during Sonne Cruise 60-Galapagos Microplate (courtesy of H. Puchelt, 1992).

Figure 3. Lithologic summary for Hole 894G. Lithology is "expanded," representing a normalization of the curated recovery for each core to that of the advance during coring.

Figure 4. Histogram showing relative "expanded" recovery of different rock types for the different holes of Site 895.

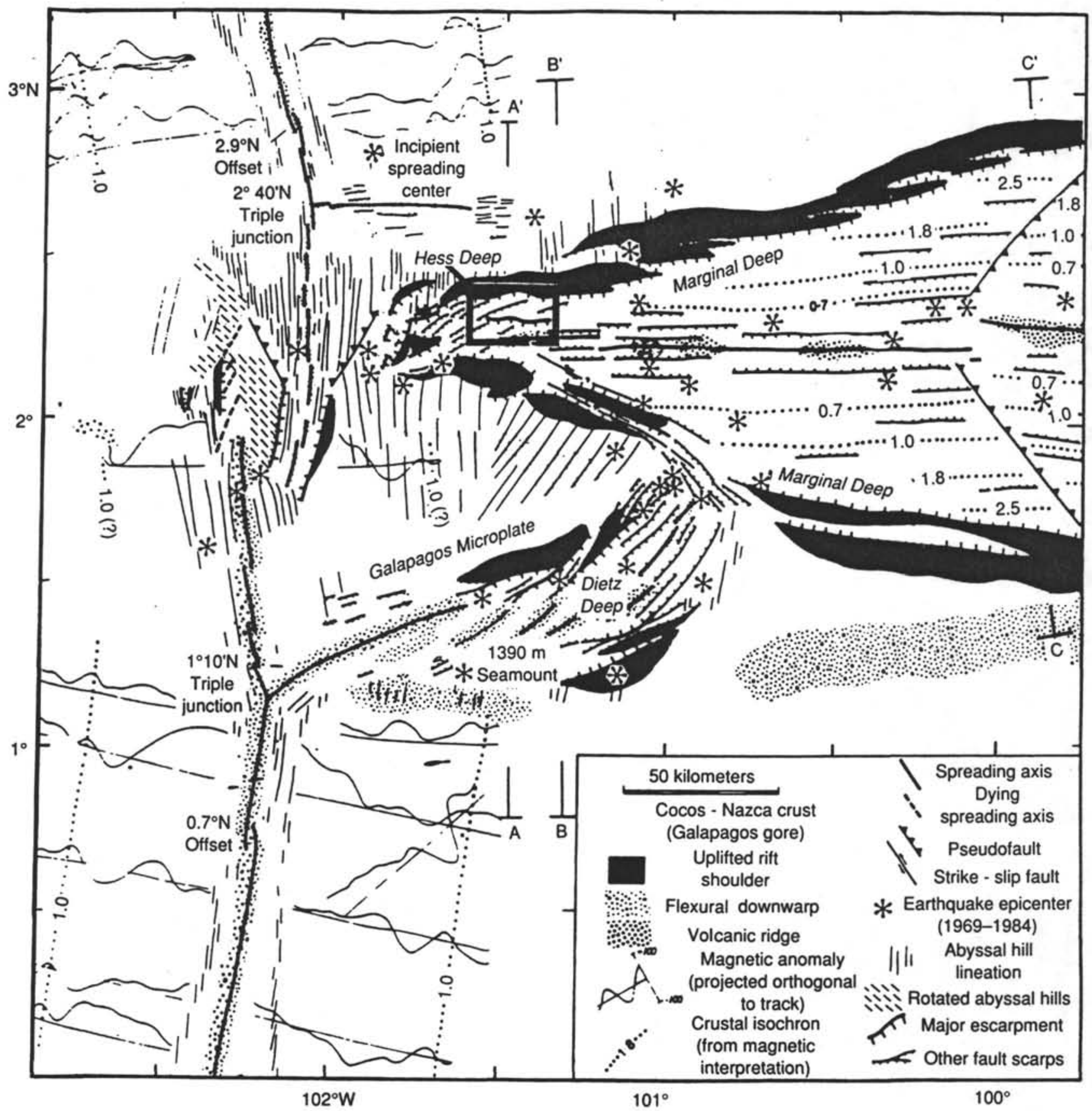
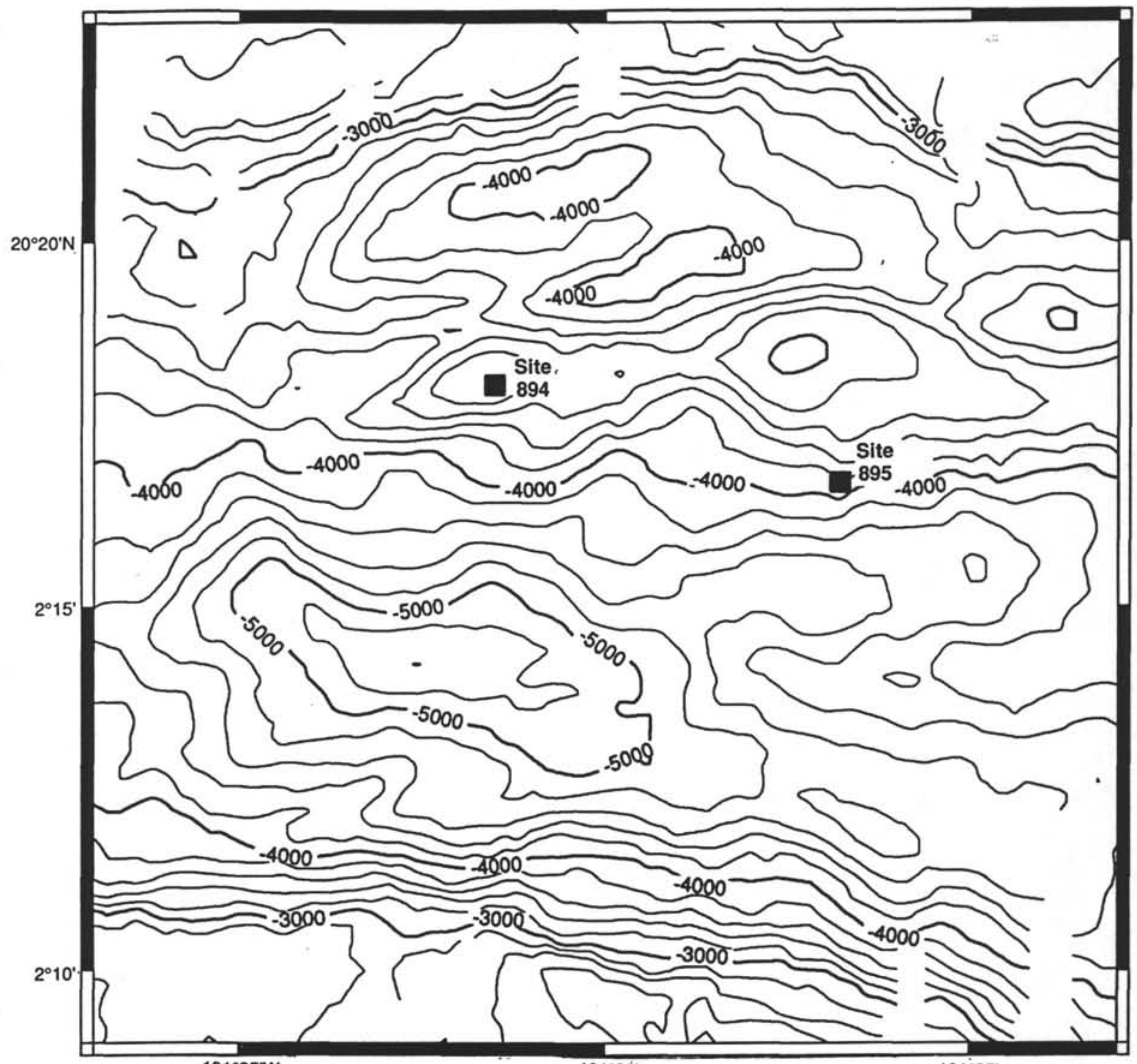

3°N
2°
1°
102°W
101°
100°
2.9°N
Offset
2° 40'N
Triple
junction
Incipient
spreading
center
Hess Deep
Marginal Deep
Galapagos Microplate
Dietz
Deep
1390 m
Seamount
1°10'N
Triple
junction
0.7°N
Offset
A'
B'
C'
A
B
C
50 kilometers
Cocos - Nazca crust
(Galapagos gore)
Uplifted rift
shoulder
Flexural downwarp
Volcanic ridge
Magnetic anomaly
(projected orthogonal
to track)
Crustal isochron
(from magnetic
interpretation)
Spreading axis
Dying
spreading axis
Pseudofault
Strike - slip fault
Earthquake epicenter
(1969–1984)
Abyssal hill
lineation
Rotated abyssal hills
Major escarpment
Other fault scarps

Figure 1


-3000
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-4000
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20°20'N
Site
894
Site
895
-4000
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2°15'
-5000
-5000
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-5000
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-4000
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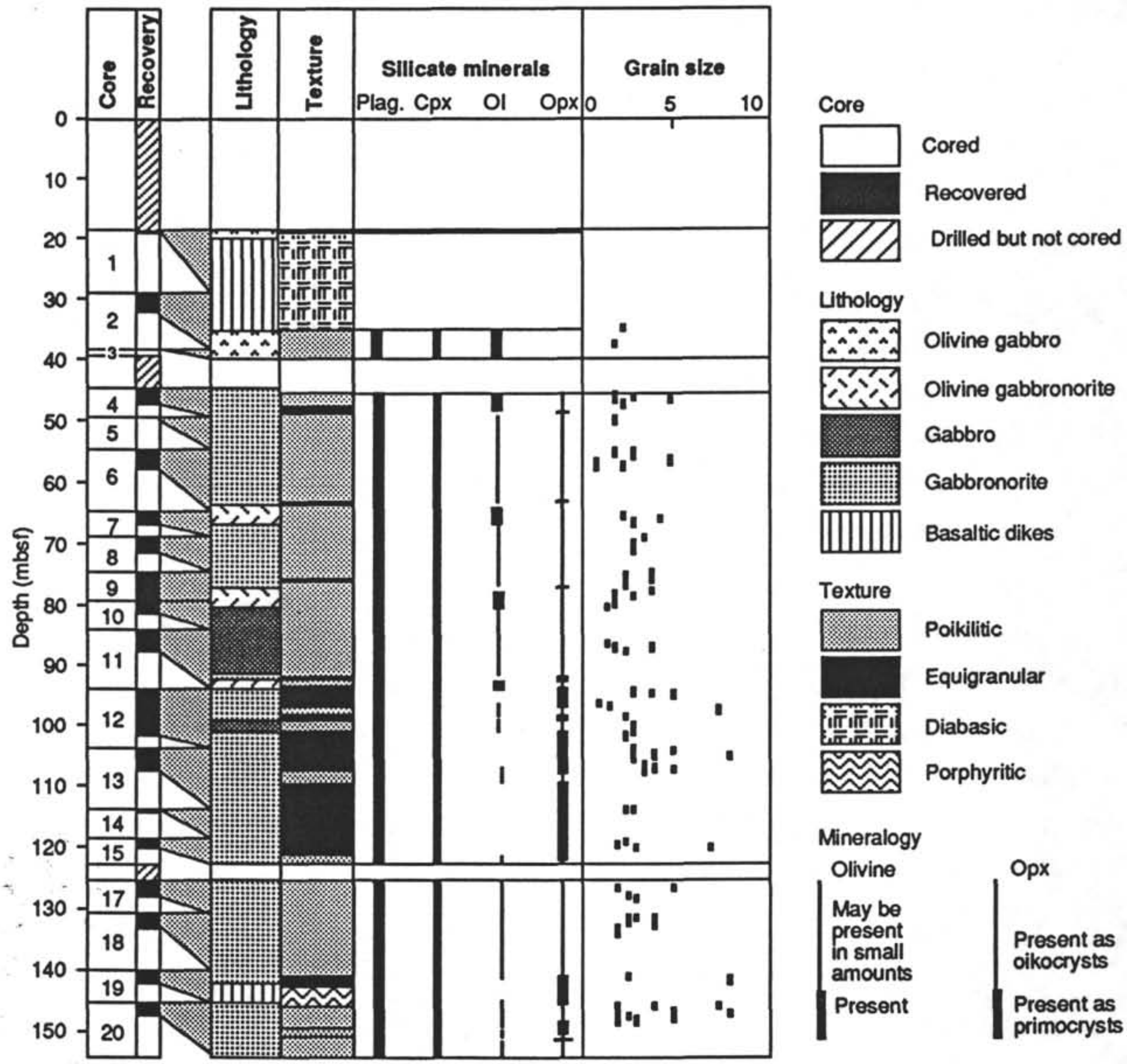
2°10'
101°35'W
101°30'
101°25'

Figure 2


Core
Recovery
Lithology
Texture
Silicate minerals
Plag. Cpx Ol Opx
Grain size
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Depth (mbsf)
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10
20
30
40
50
60
70
80
90
100
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130
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150
1
2
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8
9
10
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12
13
14
15
17
18
19
20
Core
Cored
Recovered
Drilled but not cored
Lithology
Olivine gabbro
Olivine gabbronorite
Gabbro
Gabbronorite
Basaltic dikes
Texture
Poikilitic
Equigranular
Diabasic
Porphyritic
Mineralogy
Olivine
May be present in small amounts
Present
Opx
Present as oikocrysts
Present as primocrysts

Figure 3

Site 895 Relative "Expanded" Recovery

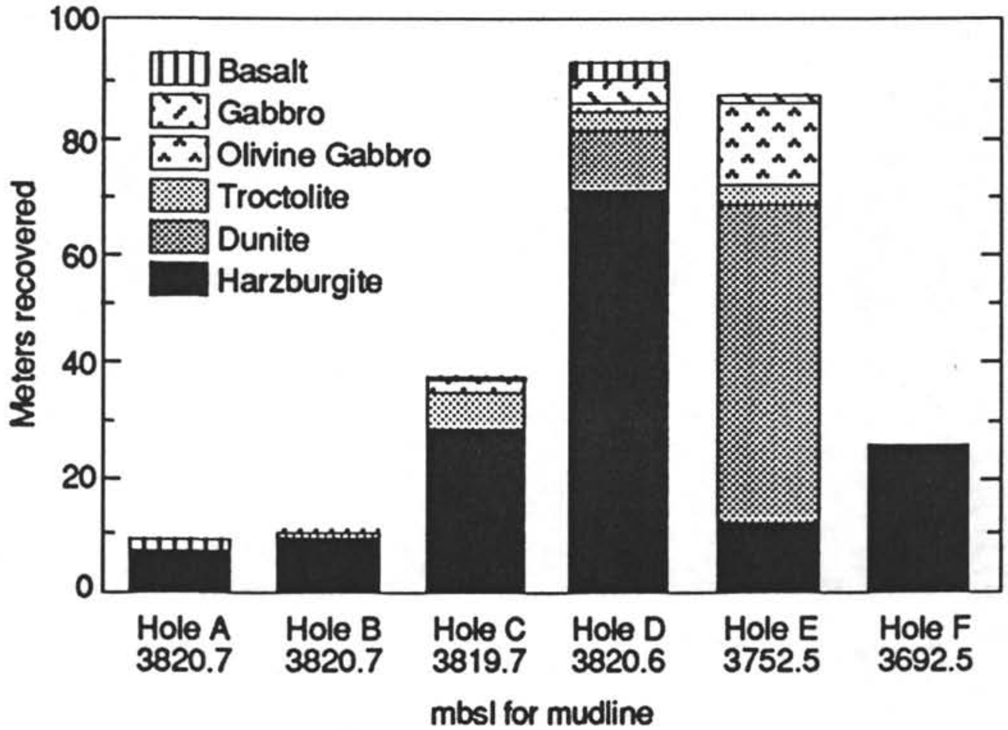


Figure 4

TABLE 1

Comparison of Lithologic Recovery for Hole 894G

Rock Type	Curated Length Recovered (m)	% Recovery
Basaltic Dikes	3.43	7.0
Oxide Gabbronorite	0.07	0.1
Gabbronorite	15.76	32.1
Poikilitic Gabbronorite	22.22	45.3
Gabbro	1.92	3.9
Olivine Gabbro	1.55	3.2
Olivine Gabbronorite	4.14	8.4
Total	49.09	100.0

TABLE 2

Comparison of Lithologic Recovery for Site 895

	Curated Length (m)			Percent Lithology		
	Site 895	Hole 895D	Hole 895E	Site 895	Hole 895D	Hole 895E
Serpentinite	0.63	0	0	0.86	0	0
Harzburgite	32.23	19.74	4.46	44.02	75.95	12.68
Dunite	28.12	2.87	24.92	38.41	11.04	70.92
Troctolite	5.71	1.85	1.41	7.8	7.12	4.01
Olivine Gabbro	4.31	0.3	4.01	5.88	1.15	11.4
Gabbro	1.41	1.02	26.5	1.92	3.92	0.75
Basalt	0.81	0.21	0.08	1.11	0.81	0.23
Total	73.22	25.99	61.38			

OPERATIONS REPORT

The ODP Operations and Engineering personnel aboard *JOIDES Resolution* for Leg 147 were:

Operations Superintendent:	Gene Pollard
Development Engineer:	Mike Storms
Schlumberger Engineer:	Dave Ritz

OVERVIEW

Leg 147 of the Ocean Drilling Program was dedicated to recovering a long, continuous gabbro core and, possibly, the shallow mantle generated at the fast-spreading East Pacific Rise (EPR). Hess Deep is the deepest part of a westward-propagating rift valley that is opening up the eastern flank of the equatorial EPR in advance of the propagating Cocos-Nazca spreading center. The exposure in the Hess Deep rift valley floor provided a unique opportunity to sample a representative section of the normal ocean crust formed at the fast-spreading EPR that is far from any fracture zone. Recovery of gabbros and peridotites is critical in order to characterize the igneous, metamorphic, and structural evolution of the lower crust and upper mantle generated at fast-spreading ridges, as well as the vertical variation in its physical and magnetic properties.

Leg 147 is the first of several legs planned to explore the concept of offset drilling on high-angle hard-rock sites exposing lower crust and mantle rocks. An intensive operations and engineering effort at ODP led to the development of new or modified tools to accommodate the new operating requirements. The three-legged hard-rock base (HRB), which has a gimballed cone and hanger capable of handling up to 35° slopes (if oriented correctly), was mated with a new Dril-Quip casing hanger system and running tools, which will allow up to four casing strings to be set. A Cam-Actuated Drill-Ahead (CADA) feature was added to the 20/16-in. Dril-Quip running tool to permit spudding the hole after the HRB is set without tripping the pipe.

New rotary core barrel (RCB) 4-cone core bits with tungsten carbide cutters for very hard rock (IADC Class 8) were developed with Smith International in Houston and Rock Bits International (RBI) in Fort Worth. The old RCB C-7 core-bit design was modified in an effort to reduce core breakage, jamming, and poor recovery in hard, highly fractured, poorly cemented rock. The new bit design catches the core pedestal much closer to the bottom of the hole. The bits were redesigned also to improve bit survivability (i.e., to reduce driver row and spear point tooth breakage) and have a higher rate of penetration (accept more weight on bit for better rock crushing). The bits were tested on Columbia River basalt at Terra Tek in Salt Lake City and showed up to a threefold increase in rate of penetration.

Igneous-rock samples were tested at Terra Tek to determine general rock properties and at Hughes Christensen in Salt Lake City to determine survivability for polycrystalline diamond compact

(PDC) bit development. A heavy-set PDC core bit with convex cutters at a high back rake angle was developed at Smith International in an effort to improve rotating hours and rate of penetration in hard-rock coring. RBI developed an RCB core bit with one cone reversed to overcome bit spear point breakage problems in fractured rock and to catch the core closer to bottom. In addition, the inner core barrel and subs were chrome lined and honed to reduce core jamming, the plastic core liner tube was eliminated to reduce jamming and provide a larger throat, and the core catchers were modified for better clearance and to permit rotation (to avoid lathing or torquing the core if the inner barrel jammed). The hard-rock orientation (HRO) tool was redesigned with new latch-assembly bearings and Tensor directional tool.

SAN DIEGO PORT CALL

Leg 147 of the Ocean Drilling Program began at 0745 hr 22 November 1992, with the first mooring line at 10th Avenue Pier, Berth 4, San Diego, California. SEDCO port-call activities included bunkering (43,000 gallons), taking on water, ABS inspection of safety equipment, ABS elevator survey, ABS subsea shop certification, changing air-conditioner evaporators in the hotel, Halliburton test on cementing surge tank (for future modifications) and installing a new drilling-line spool. The riser hold was loaded with 237 joints of 5-1/2-in. drillpipe (DP) and 51 joints of 5-in. DP. A new Colmek TV system was installed, but it could not be calibrated properly on deck due to signal isolation problems. The top drive was pull tested to calibrate the DCS load cells. A satellite antenna was loaded aboard for evaluation, but the required electronic decoders were not available.

ODP lab activities included liquid helium transfer, microscope and ARL service, and service calls by DEC (BRG and ODP VAXes), HP, and 2G. The XRF had high-voltage problems and one goniometer acting up, but it was repaired and function tested.

ODP engineering/operations activities included inspecting 50 stands of 5-1/2-in. DP and loading 6 joints of 13-3/8-in. flush joint casing, 25 joints of 10-3/4-in. flush joint casing, 20 joints of 8-1/4-in. DC, one hard-rock base, Dril-Quip casing hangers and running tools, chrome inner core barrels and subs, and core liner. Six joints of 5-1/2-in. DP and 6 joints of 5-in. DP were laid out for transport to the BHV bonded yard in Houston. Six pallets (150 sacks) of Baravis were offloaded and sent to ODP with six 9-1/2-in. DC and 5-in. perforated liner pipe. One bad 8-1/4-in.

DC (would not rabbit), one bad 7-1/4-in. DC (broken pin), and the VPC, PCS, CORK, and GEOPROPS equipment was sent to ODP. The seaphone installation was not completed because the installers arrived 23 November without installation directions or time to do the installation, and the shipboard phone system was not compatible with the seaphone. Lamont-Doherty Earth Observatory port-call activities included switching the spare Schlumberger line reels (not the active drum).

TRANSIT FROM SAN DIEGO TO HESS DEEP

The sea voyage from San Diego to Hess Deep covered 2034 nmi in 178 hr at 11.4 kt average. No seismic survey was run over proposed site HD-3. A Datasonics 354B commandable recall beacon, S/N 776, 14.0 kHz, 208 dB, was dropped at HD-3 on GPS coordinates 2°18.127'N, 101°31.628'W, at 0345 hr 3 December 1992. Thrusters and hydrophones were lowered, and the ship moved onto site in dynamic positioning (DP) mode.

SITE 894

Site 894 (proposed site HD-3) is located close to the summit of the intra-rift ridge where gabbro outcrops have been identified on *Nautile* submersible dives. The objective was to sample a section of oceanic gabbros created at a fast-spreading center, by starting a hole directly on gabbros exposed at the top of the ridge. The drill site was proposed on top of the ridge in 3075 m water depth on what appeared to be shallow sediment cover and small boulders near a steep slope with stacked, tilted gabbroic blocks exposed on the edge. A TV survey was planned to explore the immediate area to find a good site to set a hard-rock base (HRB). The mean location of the beacon is at 2°18.040'N, 101°31.564'W, about 80 m southwest of the intra-rift ridge.

A 9-7/8-in. Smith F9CB 4-cone RCB bit was run with a bit sub, outer core barrel/top sub/head sub (OCB/TS/HS), 6 each 8-1/2-in. DC, crossover, 1 each 7-1/4-in. DC, 2 stands of 5-1/2-in. DP, crossover, 105 stands of 5-in. DP and 5-1/2-in. DP as required. The 8-1/2-in. drill collars were run through an 8-9/16-in. gauge ring to confirm that they would clear the Dril-Quip running tool. The DP was rabbited, and steel-line measurements (SLM) were taken. The drill string was run with a 9-7/8-in. RCB bit and BHA so spot coring could be conducted as required during the survey. At 1042 hr 3 December 1992, the bit touched bottom. The VIT frame was run with the Colmek TV, Mesotec sonar, and VIT beacon to locate seafloor objects with respect to the ship and the original positioning beacon.

First TV Survey

A seafloor TV survey was planned based on information and coordinates identified during a *Nautile* dive. The first TV survey covered 5.65 km from 1030 to 2120 hr 3 December, started 16 m northeast of the beacon, and covered a 503 by 1020-m east-west-oriented rectangular area. The ridge summit is covered with a fairly continuous soft sediment, which was from 0.5 to 6.5 m thick (3 m average) based on bit punch-in tests (punching-in the bit until it supports 5K lb weight). Scattered patches of small cobbles 5-20 cm in diameter were not covered by sediment, and isolated massive outcrops were observed along the southern slope of the summit with large blocks up to 1-2 m in diameter.

Hole 894A

Hole 894A (proposed site HD-3) was selected for a test spud-in on the summit of the intra-rift ridge where a flat-lying outcrop is covered by 1 m of sediment. Hole 894A was spudded at 2345 hr 3 December 1992 at 2°18.030'N, 101°31.490'W, in 3023.0 m water depth. The bit was punch cored 2 m and dry cored 2 m in a special effort to recover sediments. Core 147-894A-1R, 3023.0-3029.0 m (0.0-6.0 mbsf), was cored 6.0 m and recovered 6.24 m of foraminifer-bearing sand, coarse basalt gravel, and gray chlorite clay-rich debris. The recovery was interpreted as regolith; therefore, coring was terminated. The bit cleared the seafloor at 0145 hr 4 December 1992, ending Hole 894A.

Second TV Survey

The second TV survey covered 1.1 km from 0330 to 0500 hr 4 December and resumed southeast of the beacon on the southern edge of the intra-rift ridge. An area of 250 by 240 m was surveyed. A series of gently dipping sedimented ledges separated by east-west scarps of massive gabbros was observed.

Hole 894B

Hole 894B was located midway up a 25-35-m-wide bench (with a slope of about 15°-20°) above a steep scarp about 15 m high. Hole 894B was spudded at 0630 hr 4 December 1992 at 2°17.960'N, 101°31.564'W, in 3031.0 m water depth. The bit was punch cored 1.5 m and dry cored 1.5 m to recover sediments. Core 147-894B-1R, 3031.0-3038.0 m (0.0-7.0 mbsf), was cored 7.0 m and recovered 0.14 m, consisting of two fragments of metagabbro. Coring was terminated, and the bit cleared the seafloor at 0800 hr 4 December, ending Hole 894B. Hole conditions were very good, and the area was the best site that had been located to establish a hard-rock base.

Third TV Survey

The third TV survey covered 2.0 km from 0930 to 1200 hr 4 December and continued to the west end of the ridge in the vicinity of the end of *Nautile* dive no. 5. An area of 500 by 500 m was surveyed. Steep east-west scarps of massive gabbro slabs were separated by talus slopes and deep sediment ramps. The terrain was so rugged on the west side of the ridge that the survey in that area was terminated at 1200 hr 4 December in favor of the more operationally acceptable area near Hole 894B. A northeast track was taken across the crest of the ridge toward the Scripps ocean bottom seismometers (OBS).

Scripps Ocean Bottom Seismometers

Scripps had lost two $80,000 OBSes while conducting a seismic survey of the Hess Deep area about 9 months earlier. The retrieval of the seismic data recorded on data disks in the OBSes was crucial to interpretation of the Hess Deep seismic survey; therefore, OBS designs and locations were obtained to aid in recovering any beacons encountered in the area of proposed site HD-3. During the transit to Hess Deep, a 4-prong grappling hook was made on a 9-1/2-in. ID by 0.6-m-long pipe so it could be dropped around the drill pipe and land on the bit, thereby avoiding a drill-string trip for fishing tools. The prongs had locking dogs to trap the seismometer handling ring. To control the hook better, a jet steering sub was made by drilling a 1/2-in. hole in a bit deplugger with a closed bottom.

The 3- by 3- by 5.5-ft Scripps OBS was reported at GPS position 2°18.338'N, 101°31.583'W, which was converted to X-Y beacon coordinates. A 1.4-km 30-min search with sonar and TV located the seismometer at 2°18.329'N, 101°31.569'W. The VIT frame was pulled, the 4-prong grappling hook was dropped around the DP, and the VIT was rerun while the steering sub was dropped. The grappling hook was positioned by maneuvering the ship with dynamic positioning. The steering sub was not very effective due to pressure loss through the bit jets. After eight near misses, the 1-ft-diameter top handling loop of the fish was engaged and locked in the flipper dogs to prevent loss on the trip to the surface. The seismometer weighed 200 lb in water (1500 lb in air). The OBS was recovered at 1700 hr 5 December, and Mark McDonald of Scripps removed the lithium batteries and data disk from the OBS.

Hole 894C

Hole 894B appeared to be the best site for an HRB deployment, so the ship was moved back there while the seismometer was retrieved. The HRB was deployed at 1623 hr 5 December at the coordinates recorded for Hole 894B. The 20/16-in. Dril-Quip running tool with the Cam-Actuated Drill-Ahead (CADA) feature was used for the first time. It was not possible to see around the HRB with the TV camera; therefore, the HRB had to be set on bottom at the intended location based on the composite X-Y coordinate offsets between the ship to VIT beacon and ship to location beacons. The water depth was 3040 m, and the tilt beacon and bullseye indicated 25°, but the general slope appeared to be 15°-20°. The HRB appeared to be at the correct site from the beacon coordinates; however, the HRB was moved 10 m south and downslope 4 m. The tilt beacon and calculated slope read 17°, but only one leg was downslope. The HRB was picked up, rotated 180°, and set down with 2 legs down slope. The tilt beacon, one bullseye and the cone position indicated a slope of about 9°.

The 20/16-in. Dril-Quip running tool with 4 tension pins (30,000 lb tension) and the CADA tool (with 4 torsional pins = 12,000 ft lb) did not permit unlatching for surveys and relatching to move the base. There was a danger of locking or shearing out the drill-ahead feature; moreover, the HRB location was believed to be correct based on the angle, water depth, and X-Y coordinates of the beacons.

The stability of the HRB on high-angle slopes was a major concern; therefore, a 15-min test was conducted with the drill string in 20K-lb tension to check HRB stability. Data were obtained on the primary heave compensator for the diamond coring system. The HRB appeared to be stable, so the full 35K-lb HRB weight was set down, and the pumps were run at 400 gpm to further test stability.

The Dril-Quip running tool was released, and the CADA tool unjayed for drilling. Hole 894C (proposed site HD-3) was spudded at 2100 hr 5 December in 3044 m water depth. The 14-3/4-in. hole was drilled from 3044 to 3075 m in 1.5 rotating hr with 5K WOB, 20 rpm, 350 gpm, and 100-200 amps torque. When washing to bottom after a wiper trip, the bottom was not found at 3075 m. The pump pressure was dropping, but washing continued to 3086 m on the assumption that the bit might have drilled out the side of the nearby cliff or be in soft fill or fractures between massive blocks.

The HRB was found lying on its side with obvious sediment slump features above and below. A TV survey confirmed that the 14-3/4-in. bit, bit sub, Dril-Quip running/CADA tool and two 8-1/2-in. drill collars were lying downslope to the south. The BHA had parted at the top of the zip lift groove on the second drill collar, which had been worn about 5/8 in. (probably by contact with the DQ tool as the HRB toppled over). The DQ tool's top shoulder should be tapered and rounded, and slick drill collars (without a zip lift groove) should be used. The BHA was inspected and the 1-by 8-1/4-in. and - by 8-1/2-in. bent drill collar was laid out. Two fragments of highly sheared gabbro were found jammed into the broken end of the drill collar, which tagged bottom near Site 894C during the TV survey. The bit core was curated as Core 147-894C-1M, 0.17 m recovery.

The HRB had been set by mistake on a steep sediment slope about 60 m east and 20 m downslope from the intended hard-rock ledge of Hole 894B. Despite extensive review, the cause of the positioning error was never determined. It is probable that the HRB swung (by pendulum momentum) out of position in the process of moving the vessel and resetting the legs. The tilt beacon readings were sporadic (apparently due to shielding by the tilted cone), and only one bullseye was visible and marginally readable.

Circulation while drilling had destabilized the sediment slope, causing it to slump. When the bit was pulled to the seafloor, the HRB cone and base tilted further, bowed, and cut into and broke the BHA, allowing the HRB to topple over downslope to the south. The HRB appeared to be undamaged, and two visible legs were OK; therefore, we felt it could be salvaged in the future.

Fourth TV Survey

A fourth TV survey was planned to locate a more level site with shallow sediments on top of the intra-rift ridge where a reentry cone could be deployed. A means was needed to mark small sites during TV surveys so they could be relocated precisely for drilling. The VIT frame was rigged with a deployable beacon (50-lb weight and short tether) using the release mechanism on the VIT beacon. The survey covered 1.3 km from 1700 to 2000 hr 6 December.

A 9-7/8-in. Security H87F RCB bit, S/N 498907, and 9 DC BHA was run. A TV survey was conducted from 1700 to 2000 hr starting at Hole 894C. The survey around Hole 894C again confirmed that the HRB had not been installed in the selected spot. The survey proceeded north and west to survey a very flat area on the west side of the ridge summit. Except for a few rubble piles, this area is covered with pelagic sediment. Two punch tests suggested a soft pelagic sediment cover of 5-6 m.

A flat spot was selected for a test spud in order to evaluate the possibility of deploying a reentry cone. A bit penetration test went in 5.5 m and an additional 0.5 m with pump. The deployable beacon release mechanism was tested with a drop weight, but the release rope jammed in the release hook. The release rope was rigged differently for a retest.

Hole 894D

Hole 894D was spudded at 2200 hr 5 December on a flat, continuously sedimented terrain near the crest of the intra-ridge summit at 2°18.091'N, 101°31.590'W, in 3024 m water depth. Core 147-894D-1R to 2R, 3024.0-3043.5 m (0-19.5 mbsf), was cored 19.5 m and recovered 1.52 m of sandy sediment and basaltic fragments. The hole was abandoned because of the very unstable upper hole with high torque and 40K-lb overpull, which ruled out the possibility of using a reentry cone.

Fifth TV Survey

The fifth TV survey covered 1.1 km from 0530 to 0915 hr 7 December on the crest of the central intra-rift ridge. The purpose of the survey was to locate flat-lying drill sites suitable for deploying a reentry cone to sink an exploratory cased hole in gabbros (and to preserve the remaining HRB for later use).

Hole 894E

Hole 894E was spudded at 1115 hr 7 December on a flat, continuously sedimented terrain at the summit of the intra-ridge at 2°18.059'N, 101°31.526'W, in 3024.6 m water depth. Cores 147-894E-1R to 3R, 3024.6-3053.3 m (0-28.7 mbsf), were cored 28.7 m and recovered 3.03 m of foraminifer ooze, gabbroic sand, gabbro, and basalt. The hole was very unstable (7 m fill), with high torque to 500 amps and 100K-lb overpull, which ruled out the possibility of using a reentry cone; therefore, coring was terminated. The bit was pulled, clearing the seafloor at 1730 hr 7 December.

Sixth TV Survey

A flat-lying spot suitable for deploying a reentry cone could not be located; therefore, a site was sought where the second HRB would be committed. A 0.8-km survey was conducted from 1830 to 2230 hr 7 December in an area southwest of the summit on the south central part of the ridge. A north-south ledge about 60 m in length was identified with flat-lying, blocky outcrops covered by a 1-m-thick soft sediment layer.

Hole 894F

Hole 894F was spudded at 0030 hr 8 December at 2°17.978'N, 101°31.567'W, just north and upslope of Hole 894B (where the first HRB was supposed to be set). Cores 147-894F-1R to 3R, 3035.5-3061.2 m (0-25.7 mbsf), cored 25.7 m and recovered 1.80 m of gabbro and basalt. Hole conditions were good; therefore, it was necessary to mark the spot precisely for HRB deployment. the VIT frame was run with a Datasonics model 354B commandable release beacon, which was successfully deployed (for the first time from a VIT frame) 1.0 m south of Hole 894F. The bit was pulled, clearing the rotary at 1700 hr 8 December, ending Hole 894F.

Hole 894G

The persistent hole problems led to a decision to set the only remaining HRB as a retrievable installation (i.e., not locking-in or cementing the casing strings); however, in retrospect this may have contributed to hole-cleaning problems, because the casings never packed-off in the annulus. The problem in locating the HRB correctly on Hole 894C led to a decision to use the 20/16-in. Dril-Quip running tool in the run/release/rerun mode (rather than the CADA tool in the drill-ahead mode) so a TV survey could verify the location before a decision to drill was made.

The HRB was moved over the moonpool, and a 14-3/4-in. Smith F4 bit, S/N ER6164, was made up with 6- by 8-1/2-in. drill collars. The 20/16-in. Dril-Quip running tool was made up (with 4 tension pins = 30,000 lb tension) and the Cam-Actuated Drill-Ahead (CADA) feature locked out. The HRB was set about 5 m north-northeast of Hole 894F in 3033.4 m water depth. The pumps were run 10 min to confirm that the base was stable. The tilt beacon read 9° by 17°; however, the HRB was moved 10 m north-northeast of Hole 894F and rotated so two legs were downslope to the south. The Dril-Quip running tool released smoothly, and a short TV survey was conducted, verifying that the location was correct. The legs had a uniform 1 m of penetration into the soft-sediment cover. The tilt beacon read 11° by 20°, and the tilt chains read 15° on the north-south side and 5° on the east-west side. The mean location of the HRB is 2°17.977'N, 101°31.555'W, in 3033.4 m water depth.

Hole 849G was spudded at 1830 hr 9 December. The 14-3/4-in. hole was drilled 18.0 m in 10.75 hr from 3034.4 to 3053.0 m (0-18.6 mbsf). The hole condition was good with no fill on the short trip; therefore, the bit was pulled to run casing. The casing string consisted of 17.68 m of 13-3/8-in. casing with flush joint Atlas Bradford ST-L connections (due to the narrow clearance in the annulus). The casing shoe was flat and tapered to the inside (like a Texas pattern shoe). The casing stopped on the lip of the hard-rock hole at 3035.4 m. A 1.5-kt surface current at the time of drilling had required an 80-m offset to the east for reentry and drilling; therefore, assuming a misalignment problem, the ship was further offset up to 30 m in all four quadrants. The casing was rotated slowly to the left and circulated at 400 gpm without success. The tilt beacon reading remained steady at 11° by 20° on the HRB.

The 13-3/8-in. casing was pulled, and the 14-3/4-in. bit was rerun, reentering the HRB at 1045 hr 11 December. The bit stopped at 3035.4 m and would not reenter the old hole despite the ship's having been moved for realignment. The top few meters drilled very hard with high torque and overpull, but the bottom of the hole was clean. The hole was conditioned, and a second attempt was made to run casing. The 13-3/8-in. casing was shortened to 16.67 m so a 12-1/4-in. pilot bit could be extended 0.15 m below the casing. The casing stopped 1.25 m below the top of the hard rock, and unsuccessful attempts were made to realign the casing, cone throat, and hole by offsetting the ship in all four quadrants. The HRB tilt beacon and vessel/beacon coordinates appeared to be the same.

Subsequent information from logging, core examination and equipment recovered confirmed that there was a combination of problems:

a) A misalignment caused by ship offset when spudding, started the hole with a 4° to 5° angle and destabilized surface boulders. This explains the apparent upper hole instability and redrilling. A slant hole also would accentuate problems with ledges.

b) A non-concentric hole was drilled because no centering bushing was used (i.e., the 8-1/2-in. drill collar would stay on the low side of the reentry cone throat and drill a non-concentric hole). The 13-3/8-in. casing in the 15-in. cone throat would encounter a 1-3/4-in. ledge due to the non-concentric hole. This explains the problems in getting casing started in the hole and running deeper casing strings.

c) Logs confirmed that the hole deflected to the southwest following the slope of the hard rock. The slant hole increased rapidly in angle below the ledge at 3100 m, which explains the increasing torque and drag.

d) The HRB was settling as sediments were washed out from under the downslope legs. The inability to set the first string of casing rapidly probably exacerbated this problem.

As we were unable to run 13-3/8-in. casing, and being unwilling to sacrifice the 10-3/4-in. casing so shallow, a 9-7/8-in. RBI C-7, S/N BC758, 4-cone bit was run to core ahead and determine deeper hole conditions. The bit tagged fill at 4 mbsf, and the hole was quickly cleaned out to TD. Cores 147-894G-1R to 3R, 3053.0-3074.0 m (18.6-39.6 mbsf), were cored 21.0 m and recovered 3.85 m of olivine gabbro and basalt. Coring parameters were 5-10K lb WOB, 50 rpm, 100-200 amp torque, and 400 gpm. Except for slab boulders in the top few meters of hole, conditions were good in gabbro to 20 mbsf; however, the formation changed to extensively sheared, fractured, and metamorphosed gabbro. Dislodged wedges of fractured gabbro started falling into the hole (a piece of the wall was recovered in Core 147-894G-3R). Hard rocks at 40 and 42 mbsf drilled very slowly and resulted in ledges that caused torque and overpull problems. The hole was reamed and rereamed for 4.5 hr. Coring was continued, but at 1.4 m into Core 147-894G-3R, high torque to 700 amp stalled the top drive, and overpull to 40K lb forced a halt to coring. The core bit had to be back reamed out of the hole, which wore away 1/4 in. of metal from the top 2 in. of the bit. The bit graded T2B3, I, WG, SE, TD but was not reusable because of severe wear to the stabilizer pad metal.

The unstable upper-hole problem confirmed fears that 13-3/8-in. casing would have to be set as deep as possible for us to have any chance of deepening the hole substantially before the final 10-3/4-in. casing had to be used. Non-concentric hole/cone throat was considered to be the major problem with the first 14-3/4-in. hole; therefore, a 14-3/4-in. Smith F4, S/N ER6164, 3-cone drill bit was rerun with the 16/20-in. Dril-Quip CADA running tool (with 2 tension shear pins = 15,000 lb and 4 torsional shear pins = 12,000 ft lb). The 14-3/4-in. bit encountered hard drilling for the entire 40 m of hole, with erratic torque after 20 mbsf.

A sediment slump crack 1 m upslope (north) of the HRB had been monitored since drilling commenced and indicated that soft sediment was sloughing downslope as circulation washed out the supporting sediment below. On 14 December, the tilt beacon on the HRB changed from 21° resolved (20° by 11°) to 23° resolved (21° by 12°).

The new 14-3/4-in. hole was open above 3059 m but had to be drilled out twice to TD. The hole could be kept open only to 3067 m (because of a ledge); therefore, 31 m of 13-3/8-in. casing was spaced out with a 12-1/4-in. pilot bit to attempt to work the casing to bottom. The casing had to be rotated to enter the hole, took weight at 3 mbsf, and was worked down with rotation and circulation to 4.6 mbsf. The casing would go no farther despite left-hand rotation and circulation, so it was pulled.

A 5.88-m 13-3/8-in. 61.0 lb/ft K-55 AB ST-L casing with a Dril-Quip hanger was run (to attempt to pin the HRB to prevent further movement downslope) before trying to clean out the hole for 10-3/4-in. casing. The HRB was reentered at 1835 hr 16 December, and the 13-3/8-in. casing was landed at 3038.15 m (3.75 mbsf). The release of the 13-3/8/10-3/4-in. Dril-Quip running tool was very smooth.

A 12-1/4-in. RBI C-3, S/N BD004, 3-cone drill bit was run to clean out the 14-3/4-in. hole from 3058 to 3074 m; however, the persistent ledge from 3067 to 3069 m again required repeated reaming. The hole was deepened 5.4 m from 3074.0 to 3079.4 m (39.6-45.0 mbsf) and reamed until clear. A wiper trip was made from 3039 to 3079 m without rotation or circulation and found 1 m of soft fill. On 17 December, the tilt beacon reported an increase in HRB angle to 24.5° resolved (22° by 13°), indicating some settlement of the downslope legs. A 41.56-m 10-3/4-in. casing string was run with a 13-3/8/10-3/4-in. Dril-Quip running tool and a 12-1/4-in. pilot bit; however, it would not pass the ledge at 3067 m despite rotation and circulation, The 10-3/4-in. casing was pulled, the 12-1/4-in. bit was laid down, and 6 m was cut off the 10-3/4-in. casing shoe. The 10-3/4-in. 40.5 lb/ft K-55 AB ST-L casing (35.56 m) was rerun and set with the shoe at 3067.4 m (33.0 mbsf) on 18 December. The Dril-Quip running tool released smoothly on the second attempt with 5K lb weight down. The 20/16-in. and 13-3/8/10-3/4-in. Dril-Quip running tools performed smoothly in their first field test, and were well received by the drilling crew. The CADA drill-ahead feature requires a tapered and rounded top to avoid drill-collar wear, the drill collars should be slick collars (to avoid hanging up and wearing in the zip lift grooves), and drilling assemblies need to be centered in the reentry cone with a bushing (to avoid eccentric holes).

On 19 December, a 9-7/8-in. RBI C-7 4-cone RCB core bit, S/N BA257, was run with a slick BHA. The hole was reamed in 1.5 hr to 3079.4 m TD and found 3 m of fill. RCB Cores 147-894G-4R to 14R, 3079.4-3153.2 m (45.0-118.8 mbsf), were cored 73.8 m in 27.42 rotating hr and recovered 32.32 m of gabbronorite. A 20-bbl high-viscosity mud sweep was pumped 3 to 5 times per core, and the hole was rereamed repeatedly until clear; however, the hole repeatedly packed-off (i.e., pump pressure increased, indicating cuttings or slough buildup in the annulus), torque was erratic and high (the top drive stalled at up to 800 amp), and the pipe stuck (requiring up to 200K lb overpull). Wiper trips were made at 74.4 and 113.1 mbsf. At 118.1 mbsf the rotary stalled repeatedly with any weight on bit; therefore, the bit was pulled as a precaution. The stabilizer pads were worn away down to the bit legs, and the body was worn down 1/4 in.. All three Datasonics 354B beacons released simultaneously at 0500 hr 22 December while the drill string was run in. The three beacons were recovered, and the ship returned to the GPS position for Hole 894G. Beacon 776 (14.0 kHz) had been working for 18.05 days, and beacon 782 (16.0 kHz) had been working 2.29 days. Beacon 785 (15.0 kHz) stopped transmitting at 2100 hr 19 December after 11.39 days and was found to have been turned off (not failed). A Datasonics 354B beacon, 16.0 kHz, S/N 771, was dropped as a replacement beacon at 1015 hr 22 December. The incident cost 3.75 hr of lost time. A backup Datasonics 354B beacon, S/N 782, 16.0 kHz, was dropped 23 December with a confirmed release repeat count of 5/20 s (instead of the normal 3/20 s) to reduce the probability of accidental release. No activities were in progress on the ship to cause beacon release. The signal from the tilt beacon on Hole 894G was lost on 18 December, and subsequent recovery of the tilt beacon (Datasonics 359, S/N 842, 14.0/14.5/15.0 kHz) confirmed that the transmission frequency drifts as the batteries get weak. The battery life of the tilt beacon could be increased by changing the transmission rate from 1 to 10 s. The frequency-control circuitry should be on a separate battery from the transmitter (like the release mechanism is now) to prevent the transmitter battery drain from altering the frequency.

On 22 December, a 9-7/8-in. RBI C-7 4-cone RCB core bit, S/N BC750, was run with a slick BHA. The hole was cleaned out to 3138 m, with occasional minor torque and reamed with light weight and torque to 3153.2 m. RCB Core 147-894G-15R, 3153.2-3157.2 m (118.8-122.8 mbsf), was cored 4.0 m and recovered 0.83 m. Despite a wiper trip and repeated reaming, the core barrel could not be reamed back to TD because high torque stalled the top-drive rotary. The core barrel was pulled at 3108 m, and wash barrel 894G-16W recovered 0.40 m. The bit had the wear pads worn off, and the bit body was worn down 1/2 in. by contact with the formation while back-reaming out of a tight hole with the top drive.

On 23 December, a 9-7/8-in. Smith F-7, S/N ES7016, 3-cone drill bit, bit sub, and stabilizer were run to wipe out ledges and doglegs in the hole. Light torque was noted to 3149.0 m; however, heavy reaming with high torque was required from 3149.0 to a TD of 3157.2 m. The hole was reamed repeatedly until clear, and drilled 3.0 m (3157.2-3160.2 m). The bit sub and stabilizer blades had heavy wear from abrasion, but the bit showed no wear.

On 24 December, a 9-7/8-in. RBI CC-9, S/N BD936, 4-cone RCB bit with integral spiral stabilizer blades and close catch design was run with a slick BHA in an effort to clean out the hole to TD and core ahead with lower torque. The hole was reamed to 3160.2 m TD, and RCB Cores 147-894G-17R to 19R, 3160.2-3180.0 m (125.8-145.6 mbsf), were cored 19.8 m and recovered 5.75 m of gabbronorite and moderately olivine plagioclase phyric basalt. The core was cut with 15-20K lb WOB, 60-70 rpm, 200-700 amp torque, and 125-350 gpm at 250-600 psi. The hole could not be reamed back to bottom after the connection because the hole was packing off with high torque, stalling the TD rotary and overpull to 150K lb. The bit had vertical abrasion marks on the top of the stabilizer blades, and two stabilizer buttons were lost.

Ledges, probable deviation, and inability to clean the hole continued to frustrate attempts to core; therefore, a stabilized BHA was run in an attempt to straighten the hole and wipe out ledges. On 25 December a 9-7/8-in. Smith M89T, S/N 497802, 4-cone RCB core bit, near bit stabilizer, OCB/TS/HS, stabilizer and 10 DC was run. The hole was reamed from 3154.0 to 3180.0 m with 200-600 amp torque on the stabilizer (no weight on bit). Core 147-894G-20R was taken from 3180.0 to 3188.9 m (145.6-154.5 mbsf) and recovered 1.37 m of gabbronorite and moderately olivine plagioclase phyric basalt. The drill pipe subsequently plugged and was cleared only to plug again four times. Three core-barrel runs were made in an attempt to clear the pipe, and they recovered an additional 0.28, 0.40, and 0.35 m of core, which was credited as dropped core to 894G-20R (2.40 m final total).

The ledges in the hole could not be cleaned out with a stabilized BHA despite persistent reaming, and the hole could not be cleaned out by circulating mud sweeps. High torque to 700 amp stalled the top-drive rotary, and circulating pressures increased to 150 gpm at 1500 psi. The pipe stuck 27 December while reaming to bottom, with the bit at 3181.0 m. The top-drive rotary stalled at 700 amp, the hole packed-off at 150 gpm at 1500 psi, and the pipe was pulled to 235K lb overpull. The pipe was freed after working it for 3.0 hr. The pipe was pulled out, and the top stabilizer was laid down with severe blade wear. The bottom stabilizer and bit sub had minor wear, and the bit had negligible wear. The top stabilizer had been doing most of the work in the attempt to straighten the deviated hole.

A 9-7/8-in. RBI CC-9, S/N BD940, 4-cone RCB core bit was run with a slick BHA in a final attempt to clean out the hole and core ahead. The hole was reamed from 3092 to 3165 m, with high torque to 700 amp stalling the rotary, the hole packing-off, and high overpull to 150K lb. The pipe stuck at 0345 hr 28 December and was worked with up to 230K overpull for 2-1/2 hr before coming free. The core barrel was retrieved with wash Core 147-894G-21W, recovering 0.23 m. Coring was terminated, and a 9-1/4-in. reentry/logging bit was run to 3068 m (1 m below the 10-3/4-in. casing shoe) for logging. The TV showed a new washout in the sediment on the south (downslope) edge of the HRB. This might help explain hole-cleaning problems despite voluminous mud sweeps and high circulating rates. After changing out the NGT, the HLDT/NGT/SDT/TLT tool was run to 3117 m, where it would not pass a ledge. The hole was logged from 3117 to 3034 m (mud line). A second attempt to run deeper only reached 3105 m; therefore, the tool was pulled out. The HLDT one-arm caliper indicated alternating cavities to 18 in.in diameter and ledges to 13-15 in. in diameter from 3068 to 3102 m. A ledge from 3102 to 3113 m was down to 10.2 in. in diameter. The hole below 3113 m exceeded 18 in. in diameter. The drill string was lowered to 3108 m, but 45 min of reaming with the logging bit did not remove the ledge. The bit was pulled back to 3068 m with a multishot survey instrument, which read a 5° angle at 3090 m (56 mbsf). The digital bore-hole televiewer (BHTV) was run but lost the signal at 1600 m, when a power supply on the surface monitor overheated. The unit was checked out for 9-3/4 hr without success and was rigged down. The logging bit cleared the rotary table at 0300 hr 30 December, ending Hole 894G.

Recovery in the gabbros was poor because of a dense network of fractures filled with low temperature minerals. The unstable hole created cleaning problems in the cavities and ledges, which led to torque and drag problems. Hole conditions in the bottom half of the hole were consistently too unstable to risk leaving the pipe hanging for a survey, and attempts to straighten the hole had already been made; however, a Totco multishot drift survey was taken in the upper hole as follows: 0° at 3834.4 m (0.0 mbsf), 3° at 3088.4 m (54.0 mbsf), 4° at 3098.4 m (64.0 mbsf), and 5° at 3108.4 m (74.0 mbsf). The caliper log showed a steady decrease in hole diameter through successive ledges, culminating in a 10.2-in. diameter through the large ledge at 74 mbsf. Heavy reaming with stabilizers required below 74 mbsf indicates that the hole angle probably continued to increase below that point by about 1°/10 m to a maximum of 12°-15° at 154.5 mbsf TD.

SITE 894 CORING PROBLEMS

Gabbroic rock with basalt dikes were the primary rock type cored at proposed site HD-3. Holes in surface rubble exhibited extreme hole instability. Most gabbro holes exhibited instability below 25 mbsf with high torque, overpull, and packing-off from unstable rock falling into the hole.

The problems were similar to drilling in large gravel and small boulders with hard ledges. Hole stability seemed to deteriorate about 24-48 hr after drilling.

Hole 894G was drilled and cored to 154.4 mbsf but was abandoned because of high torque from deviation and ledges and inability to clean the hole. Unstable hole conditions with high torque stalling the rotary, overpull, and packing-off with large cuttings and unstable rock falling into the hole were constant problems. The hole was probably started on an angle, and drilling/casing/coring operations in general were compromised because of the reentry cone/ship misalignment in high surface currents to 3 kt. The 14-3/4-in. hole was spudded and drilled without a centering bushing; therefore, the 14-3/4-in. hole was eccentric with the 15-in. reentry cone throat, and 13-3/8-in. casing left a 1-3/4-in. overlap. A few hard basalt dikes had intruded into the softer fractured gabbro, leaving ledges and cavities, which contributed to hole-cleaning, deviation, and rotating problems. Highly fractured gabbros were loosely cemented with soft, low-temperature alteration products and became unstable. The hole angle at 56 mbsf was 4°-5°; however, the hole below must have deviated sharply to 12°-20° based on drilling reactions. The caliper log showed progressively smaller hole diameters.

Future drilling programs in such formations would benefit from first coring a bare-rock pilot hole as deep as possible and logging, and then setting an HRB and drilling a separate large hole, running casing, and cementing as soon as possible (without coring or logging). The drilling would be done with stabilized BHAs to wipe out the ledges and control deviation. Multiple casing strings would be run as required (probably about every 100 m) for deep penetrations in unstable formations. The HRB should be locked to the slope as soon as possible with an initial conductor casing and cemented to anchor it and prevent sediment washout.

TRANSIT TO SITE 895

The 5-nmi transit from Hole 894G (proposed site HD-3) to proposed site HD-4 required 4-3/4 hr in dynamic-positioning mode, during which the drill string was pulled, the bit was changed to a 9-7/8-in. RBI CC-9, S/N BD941, 4-cone core bit, and the drill string was rerun. A Datasonics 354B beacon, S/N 785, 15.0 kHz, was deployed at 0745 hr 30 December at HD-4 GPS coordinates 2°16.680'N and 101°26.850'W.

SITE 895

Seventh TV Survey

The VIT frame was run with TV, sonar, and a VIT beacon with a deployable float (attached to the VIT beacon release) to mark a drill site. A 1.0-km 2.5-hr TV survey was run from 0940 to 1340 hr 30 December in a 200- by 300-m rectangle in the southeast quadrant of the ridge. A prospective site 270 m east of the beacon was marked by a float deployed from the VIT.

Hole 895A

The vessel was moved 10 m west of the float, and Hole 895A was spudded at 1345 hr 30 December at a water depth of 3832 mbrf. RCB Core 147-895A-1R to 2R was cut from 3832.0 to 3841.2 m (0.0-17.2 mbsf), coring 17.2 m and recovering 2.38 m of serpentinized breccia and harzburgite, clay, and basalt. Occasional heave to 3 m in long-period swells required a higher WOB of 5-15K lb. Erratic high torque of 200-500 amp required 20-50 rpm to maintain rotation. Loose surface rubble resulted in heavy fill and overpull to 50K lb. A 9.7-m core (Core 147-895A-3R) was cut from 3841.2 to 3858.9 m (17.2-26.9 mbsf) but could not be recovered because the DC pin parted at the top of the second drill collar 5.5 m below the mud line at 3837.5 m. The seafloor was cleared at 0145 hr 31 December 1992. Left in the hole were a 9-7/8-in. RBI CC-9 bit, OCB/TS/HS, and a 1- by 8-1/2-in. DC.

Hole 895B

The vessel was moved 15 m north by 10 m east, and Hole 895B was spudded at 2115 hr 31 December 1992 in 3832.0 m water depth. RCB Core 147-895B-1R, 3832.0-3842.3 m (0.0-10.3 mbsf), was cored 10.3 m and recovered 1.02 m of serpentinized harzburgite and dunite. The hole was unstable, with high erratic torque at 25 rpm of 100-500 amp with 10K lb WOB. The hole was filling in rapidly and could not be cleaned out; therefore, the bit was pulled, clearing the seafloor at 0215 hr 1 January 1993.

Hole 895C

The vessel was moved 30 m east by 20 m south, and Hole C was spudded at 0300 hr 1 January 1993 in 3831.0 m water depth. RCB Core C-1R to 4R was cut from 3831.0 to 3868.6 m (0.0-37.6 mbsf), with 37.6 m cored and 5.79 m recovered. Hole conditions were good (the best of the leg), and coring parameters were 5-10K lb WOB, 30-60 rpm, 150-600 amp torque, and 225-350 gpm at 300-600 psi. Core 5R was cut 4.9 m to 3842.3 m (42.5 mbsf), but pump pressure and string weight dropped, indicating a BHA failure. The BHA parted 0.55 m down on the fourth drill collar at the top of the zip lift groove. The pin above the failure was badly cracked. Left in the hole were the bit, bit sub, OCB/TS/HS, 3 by 8-1/4-in. DC, and core barrel 5R. The drill collars were last inspected after Hole 894C, when the HRB toppled over, and might have been damaged when drilling previous Holes 894D/E/F/G and 895A/B. The top stand from Hole 894C (where the HRB toppled over) was inspected, and two bad pins were found. Hard-rock spudding will probably require more frequent BHA inspections each trip.

The top of the 39.12-m BHA fish was 3.5 mbsf, hole conditions were the best of the leg, and there were recurring problems with BHAs parting; therefore, the decision was made to attempt to fish the BHA. A 9-5/8-in. overshot was run with a cut lip guide, 7-1/2-in. basket grapple, mill control, and packer rubber (made on the rig from two 8-1/8-in. rubbers with an o-ring splice kit). The open hole on the seafloor at Hole C was reentered after a 2-hr survey and 2-hr vessel-positioning effort. The overshot was run in to 2 mbsf and worked down to 5 mbsf with light torque. Torque increased to 300 amp forcing an end to the effort, and the fishing tool was pulled. The lip of the cut lip guide was bent back, but the fish had not been contacted.

Hole 895D

The vessel was not moved, and Hole 895D was spudded about 5 m south of Hole C at 0900 hr 3 January 1993 in 3832.0 m water depth. RCB Core 147-895D-1R to 9R, 3832.0-3925.7 m (0.0-93.7 mbsf), was cored 93.7 m and recovered 19.99 m of serpentinized harzburgite and dunite, aphyric basalt, and troctolite. A wash barrel, Core 147-895D-10W, recovered 0.91 m of cuttings after reaming 3911.0-3921.0 m. Coring was accomplished in spite of constant high torque, packing-off, and having to ream every connection back to bottom several times. Large 1/2-in. rock fragments were accumulating above the bit, choking off circulation, stalling the top-drive rotary, and causing overpull to 50K lb. Pac-R polymer (1/2 ppb) was added to the 35 ppb prehydrated gel sweeps to increase the funnel viscosity from 70 to 300+ s. Adding salt water reduced the viscosity back to 110 s; therefore, the sweeps were pumped as whole mud.

The RBI CC-9 bit reached 94.7 mbsf with 39.25 coring hr (and more than 9 hr of reaming), but high torque was stalling the rotary near bottom, suggesting a possible undergauge-bit problem. A bit trip was required because this was the first long run with the RBI CC-9 bit; therefore, a mini-free fall funnel (mini-FFF) was made with a 46-in. diameter to clear the 46-3/4-in. diverter bushing below the rotary. A 2-m section of 10-3/4-in. casing was attached. The mini-FFF was dropped and landed upright in the 2-m-deep cavity at the seafloor. A Datasonics 354B beacon, 14.0 kHz, S/N 776, 208 db, was dropped with the VIT frame beacon-release system about 3 m west of the hole. When the bit was pulled out, the mini-FFF rode out on the bit and dropped off 4 m north-northwest of the hole. The 6 DC BHA was pulled, and the RBI CC-9 bit, S/N BD943, graded T2B4, I, SE, TD, RR, with moderate gauge wear.

Another RBI CC-9 bit, S/N BD934, was run with a 9 DC BHA on 6 January. The hole was reamed from 23 to 90 mbsf (3.7 m off bottom) in 8-3/4 hr; however, the crossover between the 8-1/2-in. and 7-1/4-in. DC parted in the crossover box threads 7 cm below the top. The 86.09-m-long fish consisted of a bit, bit sub, OCB/TS/HS, 6 by 8-1/2-in. DC, 2 by 8-1/4-in. DC, and the crossover. A decision was made to attempt to fish the BHA because of the 4 days invested in the hole under difficult drilling conditions, the high geological interest in deepening the hole, remaining time constraints, the risk of starting a new hole, and having a well-marked, freshly reamed hole with a shallow fish. A 9-5/8-in. overshot was run with a cut lip guide (lip cut at a 45° angle), 7-1/4-in. basket grapple, mill control, and packoff rubber (made on the rig). Six joints of 5-1/2-in. transition DP were laid down for later inspection as a precaution due to failures in the BHAs below. The open hole was reentered in 1-1/2 hr, and the fish was tagged at 3839.0 m (7 mbsf). The overshot was worked over the fish, and the pressure increased from 150 to 550 psi at 150 gpm. The overshot slipped off the fish with 15K overpull twice, and the overshot could not be engaged firmly. When the overshot grapple was examined, rusty metal shavings were found, indicating the fish had been swallowed completely but was too rusty for the overshot grapple to engage good metal.

Eighth TV Survey

The vessel was moved in dynamic-positioning mode 300 m north of Hole 895D, and a 0.85-km TV camera survey was made from 1500 to 2200 hr 8 January in a 200-m east by 100-m north rectangle. A large vertical scarp was encountered in the southeast corner of the survey, but no suitable site could be located because of large blocks on the surface. A site was selected on a gentle slope about 270 m north of Hole 895D, and a punch test showed 3 m of sediment. The positioning beacons for Holes 895A/B/C/D were still usable.

Hole 895E

Hole 895E was spudded at 0030 hr 9 January in 3764 m water depth. RCB Cores 147-895E-1R to 8R, 3764.0-3851.6 (0.0-87.6 mbsf), were cored 87.6 m and recovered 32.93 m. Coring parameters were 5-10K lb WOB, 30-50 rpm, 150-300 amp torque, and circulating 150-300 gpm at 300-400 psi. The hole recovered spinel-bearing olivine gabbro, serpentinized dunite and harzburgite, and troctolite (37.6% average recovery).

Hole conditions started deteriorating after Core 5R, and torque and overpull increased apparently from unstable rock falling into the hole. The hole had to be reamed back to bottom after Cores 6R-8R. Wash barrel 895E-9W was retrieved and recovered 0.46 m; however, the pipe stuck, the rotary stalled at 700 amp, and the hole started packing off at 250 gpm at 1500 psi. The bit was worked up the hole 14 m to 3831.6 m (67.6 mbsf) with up to 250K lb overpull. Circulating at up to 1000 gpm at 3000 psi with multiple viscous gel/polymer sweeps was not successful in cleaning the hole, suggesting that the hole had caved in and/or was losing circulation. The pipe could not be freed; therefore, a Schlumberger severing charge was run in to just above the bit at 3831 m. The first shot was attempted at the bit to recover the BHA and leave enough hole to log if possible. A bit no-go stop was machined and installed on the severing charge to avoid wireline depth errors. The shot was fired with 250K overpull and 400 amp torque but did not free the pipe. A second severing charge was shot at 3768 m (4 mbsf) in the first joint of 5-1/2-in. DP. A 65.35-m fish was lost in the hole as follows: 9-7/8-in. RBI C-7 bit, S/N BC759, bit sub, OCB/TS/HS, 5 by 8-1/2-in. DC, crossover, and 6.64 m of 5-1/2-in. DP.

Ninth TV Survey

The vessel was moved 200 m north of Hole 895E, and a 1.1-km rectangular survey was conducted 200 m east by 200 m north in an effort to find a drill site upsection from the peridotites recovered at Hole 895E. The few outcrops proved to be too steep to spud in. The area was covered by a large boulder slope, and a suitable site could not be located. The vessel was moved back to a sediment slope with small boulders and cobbles 200 m north by 9 m east of Hole 895E.

Hole 895F

Hole 895F was spudded at 2000 hr 12 January 1993 in 3704.0 mbrf water depth. The bit encountered 4 m of soft sediment and punched in 3 m with 10K lb WOB. RCB Core 147-895F was cut from 3704.0 to 3730.2 m (0.0-26.2 mbsf), with 26.2 m cored and 1.98 m recovered of serpentinized harzburgite and dunite. Coring parameters were 5K lb WOB, 30-50 rpm, 100-300 amp torque, and 250-375 gpm at 180-650 psi. Hole conditions were unstable from the start, with high erratic torque and 40K lb overpull on connections. The hole was reamed to bottom four times after Core 2R, but filled in 3-4 m instantly each time. The hole could not be kept open; therefore, coring was terminated, and the bit was pulled, clearing the seafloor at 1230 hr 13 January. The bit cleared the rotary at 2030 hr, ending Hole 895F. The three Datasonics 354B beacons at proposed site HD-4 were recalled and recovered.

LOGGING AND HRB RECOVERY AT HOLE 894G

The vessel was moved in DP mode back to Hole 894G, proposed site HD-3, while the drill string was pulled. The reentry/logging bit, 1 by 8-1/4-in. DC, 3.80-in. landing sub, 10-3/4-in. Dril-Quip running tool and 2- by 8-1/4-in. DC were run. The HRB was reentered, and the bit was positioned for logging at 3039.2 m (4.8 mbsf). The 10-3/4-in. casing shoe was at 3067.4 m (33.0 mbsf). LDEO's FMS/TLT logging tool was run in to 3106 m but could not be worked past a ledge. Five logging passes were run from 3106 to 3070 m in 4 hr. Some data were obtained from contact with the ledges, and the tool indicated a fairly constant hole angle of 4° at a 240° azimuth. The tool hung up while being pulled into the pipe. The arms would not open or close initially and were forced closed by pulling the tool up into the pipe with 9000 lb line pull (5000 lb overpull). The arms were cycled several times to closed position, but the tool stuck in the drill string at 3034-3021 m by Schlumberger measurement (the FMS/TLT tool was jammed by a broken sensor pad, with the bottom stuck out of the bit about 1 m).

The Kinley wireline crimper was dropped, and the line was worked 30 min. The Kinley line cutter was dropped and cut the LDEO logging line about 10 min later at 2340 m (700 m above the tool). The crimper had stopped on a flat spot in the cable. The 10-3/4-in. Dril-Quip running tool was engaged in the casing hanger, and the 10-3/4-in. casing was picked up smoothly with 30K lb tension. The casing and hanger were pulled out with the FMS tool. The 10-3/4-in. Dril-Quip casing hanger had 1/8-in. wear on one side and rotation marks on the bottom. A wear bushing will be required for long drilling periods, and some friction surface needs to be put on the hanger upset to restrict rotation. The Kinley crimper and cutter were found at 600 m, where both tools had stopped at a crimp in the cable. The rest of the pipe was pulled, and the cable was cut every stand. A T-bar safety clamp was put on the cable at the top of the drill collars. A lighter T-bar quick-connect clamp would be useful for future cable jobs. The FMS was jammed on a broken sensor pad in the logging bit, and the pad arm was bent (as if tool weight had been dropped on it). This LDEO FMS tool was the redesigned (stronger arms) version for hard-rock logging; however, the sensor pad had to break only two flimsy 1/8-in. rivets to come off the arm. The sensor pads need to be fastened with 4 by 1/4-in. solid rivets.

The 16-in. Dril-Quip running tool was run and made up easily in the HRB. The HRB was picked up smoothly with 60K lb tension, and was set on the moonpool doors at 0700 hr 15 January 1993. The legs, tilt beacon bracket, and cone were cut-off the HRB. The base halves had about 1 m of silt in them; therefore, drain doors were cut to facilitate draining and cleaning. The 13-3/8-in. hanger was pulled without shearing out because it had never been engaged fully. The HRB was moved from the moonpool in 8 hr. The anodized aluminum case of the Datasonics 359 tilt beacon, S/N 842, 14.0 kHz, was coated in seawater salts and had been acting as an anode for the steel guide base. Galvanic pitting was noted beneath the hold-down bolts and at the top of the case. The tilt beacon was connected to a variable DC power supply to simulate low battery voltage, and the transmitter frequency shifted through a large range as voltage decreased. This probably explains the beacon release of S/N 785, 776, and 782 on 22 December 1992, the shutoff of beacon S/N 785 on 19 December, and the (probable) premature release of beacon S/N 782 after 30 December. The frequency-control circuit should be wired to a separate battery from the transmitter (the release already is) and equipped with a low-voltage shutoff. The tilt-beacon case should be plastic coated to reduce corrosion. The tilt beacon should be equipped with a buoyant float and recall release system so they can be recovered.

The pipe and wirelines were coated with corrosion inhibitor, and the BHA was inspected. Some coating was done earlier in deeper water. The six drill collars were laid down at the Captain's request. Datasonics 354B beacons S/N 771 (14.0 kHz) and S/N 782 (16.0 kHz) failed to release and were lost.

SITE 895 CORING PROBLEMS

Serpentinized peridotites impregnated or cross-cut by gabbros were the primary rock type drilled at proposed site HD-4. A total of 272.9 m of peridotite was cored and 64.56 m was recovered. Unstable hole conditions were encountered, with constant high torque stalling the rotary, high overpull, and the annulus packing-off at circulation rates above 150 gpm. Unstable rock was falling into the hole, and large rock chips were accumulating above the bit. An attempt to raise the pump rate and pressure caused the debris to pack-off above the bit; therefore, it was not possible to clean the hole with normal circulation rates and viscous gel sweeps.

Holes 895B/C were more stable holes, and 20-bbl 50% mud/50% seawater or whole-mud sweeps were fairly effective in cleaning the hole. Mud was prepared by prehydrating 35-ppb gel in fresh water with 1/4-ppb soda ash and 1/2-ppb caustic to produce a 70-s funnel viscosity. Fill was a minor problem when spudding and after drilling highly fractured sections. As Hole C was deepened beyond 40 mbsf, hole cleaning became a problem. A more viscous mud sweep was prepared by adding 0.25 ppb of Pac-R polymer to the prehydrated gel to increase funnel viscosity from 70 to 300+ s. Mixing the gel/polymer 50/50 with seawater reduced viscosity to about 100 s. The polymer serves to cross-link (extend) the colloidal viscosity of the gels, coat the gels, and should act to prevent disbursement of the sweep mud during transit. Tandem mud sweeps (20 bbl gel/polymer, followed by 10 bbl seawater and 20 bbl gel/polymer) were more effective in removing large, heavy rock chips from the annulus.

Each cored section had to be reamed to bottom apparently because the rock was relieving internal stresses by closing-off the well bore. Pad wear on bits and stabilizers at proposed site HD-4 can be attributed to reopening tectonically closed hole while reaming to bottom. Many core sections exhibited a pronounced curvature in one vertical plane on about a 0.5-m radius. The bit cannot be bending or flexing to that extent (because it would jam first even if the stiff drill collars permitted it to do so); therefore, the core must be bending during cutting to relieve internal stresses. The bent sections eventually contact the inner-core-barrel walls and break off in roughly 0.2-m sections.

Future drilling programs in such formations would benefit from first coring a bare-rock pilot hole as deep as possible and logging, and then setting an HRB and drilling a separate large hole, running casing, and cementing as soon as possible (without coring or logging). The drilling would be done with stabilized BHAs to wipe out the ledges and control deviation. Multiple casing strings would be run as required (probably about every 100 m) for deep penetrations in unstable formations. The HRB should be locked to the slope as soon as possible with an initial conductor casing and cemented to anchor it and prevent sediment washout.

TRANSIT TO PANAMA

The vessel departed Hess Deep at 2000 hr 15 January 1993, and covered 1438.5 nmi in 129.25 hr at an average speed of 11.12 kt. The vessel had a following North Equatorial Counter Current and reached speeds of 14.0 kt at 150 rpm in calm seas with light ballast. One engine was dropped on 18 January to save fuel, which reduced the speed to 11.5 kt at 140 rpm. The ship arrived at the pilot station and dropped anchor at 0715 hr 21 January 1993. The A-frame on the derrick was dropped and, during low tide, the vessel crossed under the under the Bridge of the Americas at 0900 hr. The first line ashore in Bilboa Harbor dock 18C was at 0945 hr 21 January 1993, ending Leg 147.

OCEAN DRILLING PROGRAM
OPERATIONS RESUME
LEG 147

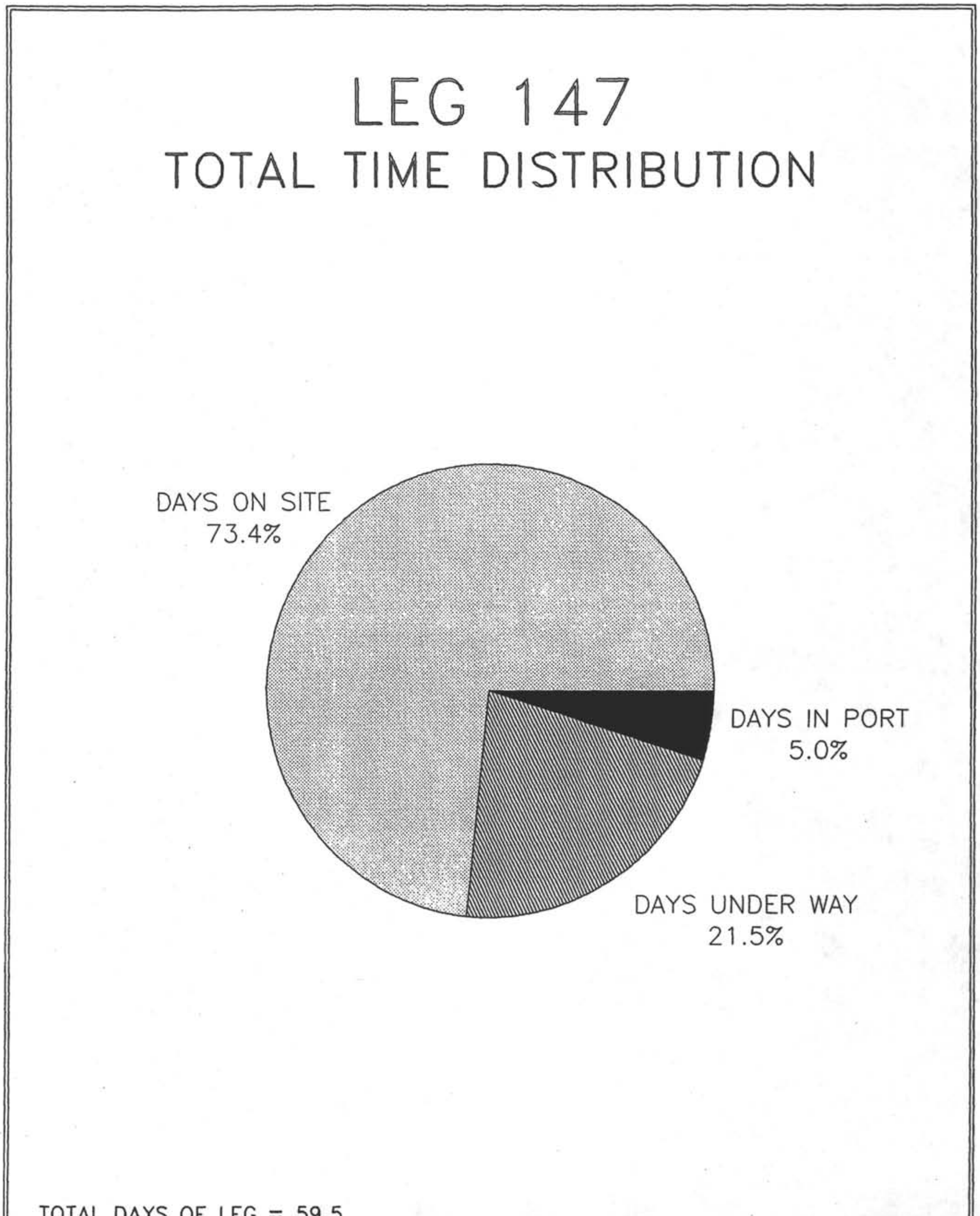
Total Days (November 22, 1992 - January 21, 1993)	59.5
Total Days in Port	3.0
Total Days Under Way	12.8
Total Days on Site	43.7

Trip Time	12.2
Coring Time	11.1
Drilling Time	1.5
Logging/Downhole Science Time	1.5
Reentry Time	1.9
Repair Time (Contractor)	0.1
Casing and Cementing Time	3.3
Downhole Trouble Time	4.8
Survey Time	2.0
Fishing & Remedial Time	2.0
Other	3.3

Total Distance Traveled (nautical miles)	3487
Average Speed (knots)	11
Number of Sites	2
Number of Holes	13
Number of Reentries	21
Total Interval Cored (m)	487.0
Total Core Recovery (m)	122.8
Percent Core Recovered	25.2
Total Interval Drilled (m)	58.0
Total Penetration (m)	559.6
Maximum Penetration (m)	154.5
Maximum Water Depth (m from drilling datum)	3873.5
Minimum Water Depth (m from drilling datum)	3029.0

OCEAN DRILLING PROGRAM
SITE SUMMARY
LEG 147

HOLE	LATITUDE	LONGITUDE	SEA FLOOR DEPTH (M)	NUMBER OF CORES	INTERVAL CORED (M)	RECOVERED CORE (M)	PERCENT RECOVERED	INTERVAL DRILLED (M)	TOTAL PENETRATION (M)	TIME (HRS)
894A	02-18.03N	101-31.49W	3023.0	1	6.0	6.2	103.3	.0	6.0	22.00
894B	02-17.96N	101-31.56W	3031.0	1	7.0	.1	1.4	.0	7.0	24.25
894C	02-17.95N	101-31.55W	3044.0	0	.0	.2	.0	31.0	31.0	32.25
894D	02-18.09N	101-31.59W	3024.0	2	19.5	1.5	7.7	.0	19.5	17.50
894E	02-18.06N	101-31.53W	3024.6	3	28.7	3.0	10.5	.0	28.7	37.75
894F	02-17.98N	101-31.57W	3035.5	3	25.7	1.8	7.0	.0	25.7	23.75
894G	02-17.98N	101-31.56W	3034.4	21	127.5	45.8	35.9	27.0	154.5	394.00
	SITE TOTALS:			31	214.4	58.6	27.3	58.0	272.4	551.50
895A	02-16.64N	101-26.77W	3832.0	2	17.2	2.4	14.0	.0	17.2	25.00
895B	02-16.64N	101-26.76W	3832.0	1	10.3	1.0	9.7	.0	10.3	17.75
895C	02-16.63N	101-26.77W	3831.0	4	37.6	5.8	15.4	.0	37.6	25.25
895D	02-16.64N	101-26.78W	3832.0	9	93.7	20.0	21.3	.0	93.7	148.50
895E	02-16.79N	101-26.79W	3764.0	8	87.6	32.9	37.6	.0	87.6	93.25
895F	02-16.90N	101-26.80W	3704.0	2	26.2	2.0	7.6	.0	26.2	39.25
	SITE TOTALS:			26	272.6	64.1	23.5	.0	272.6	349.00
	LEG TOTALS:			57	487.0	122.7	25.2	58.0	545.0	900.50


LEG 147
TOTAL TIME DISTRIBUTION
DAYS ON SITE
73.4%
DAYS IN PORT
5.0%
DAYS UNDER WAY
21.5%
TOTAL DAYS OF LEG = 59.5

TECHNICAL REPORT

The following ODP Technical and Logistics personnel were aboard *JOIDES Resolution* for Leg 147 of the Ocean Drilling Program:

Laboratory Officer:	Burney Hamlin
Senior Marine Laboratory Specialist:	Don Sims
Marine Computer Specialists/System Managers:	Ed Garrett Joel Huddleston
Marine Electronics and Downhole Tool Specialists:	Roger Ball Eric Meissner
Marine Laboratory Specialist/Photography:	Barry Cochran
Marine Laboratory Specialist/Curatorial Representative:	Lorraine Southey
Marine Laboratory Specialist/Yeoperson:	Michiko Hitchcox
Marine Laboratory Specialist/Chemistry:	Chieh Peng Philip Rumford
Marine Laboratory Specialist/X-ray:	Mary Ann Cusimano
Marine Laboratory Specialist/Thin Section:	"Gus" Gustafson
Marine Laboratory Specialist/Underway Geophysics:	Robert Kemp
Marine Laboratory Specialist/Physical Properties:	Jean Mahoney
Marine Laboratory Specialist/Paleomagnetics:	Monica Sweitzer
Marine Laboratory Specialist	Claudia Müller

PORT CALL, SAN DIEGO

The port call events went mostly as scheduled. Crossover between the two technical staffs seemed more complete than usual and less rushed because the schedule was not disrupted and our logistics shipments were deferred until the last couple of days.

Bill Goodman of 2G arranged a liquid helium delivery, and the cryogenic magnetometer was filled with no problems. Marine Specialist Monica Sweitzer was in attendance and was instructed on several points in tuning the electronics. A Kappabridge Anisotrophy System was also installed in the cryomag area by two representatives from Geofyzika Brno.

SERCO Tech Services of San Diego cleaned and repaired our microscopes, installed and aligned two new petrographic scopes, and conducted a short maintenance class for the photographers from both crews. More time had been planned for instruction, but technical problems with the microscopes and an early departure abbreviated it.

A FISONS representative worked on the ARL X-ray-fluorescence firmware upgrade and, after finding a faulty high-voltage connector/housing, had to arrange an emergency parts shipment from Michigan to ensure that the instrument would be operating. This service call had been a continuation of one started in Victoria, B.C.

Hewlett-Packard representatives came aboard to install a circuit board in one of the gas chromatographs to link it to the new HP CHEMSTATION, which will eventually replace the HP Lab Automation System (LAS).

A DEC representative repaired two ODP hard disks and some serial ports. They also worked with Lamont personnel to repair a VAX microcomputer that seemed to have video board problems but, in fact, had a bad ethernet card. New hardware included a larger hard drive and a replacement printer. Software to support the LDEO formation microscanner (FMS) was installed but not tested.

A GRAPE wipe test was conducted for the TAMU Radiation Safety Office with our Physical Properties Marine Specialist Jean Mahoney assisting.

COMSAT again tried to work on the SEAPHONE installation but came late and then verified that the unit would not work with our old MARISAT system and our phones. Hookup of the installation was deferred to a Lisbon port call.

A curatorial conference was held in San Diego that Marine Specialist Lorraine Southey attended for two days. A curation oriented meeting was held with the marine specialists, and a short presentation made to reinforce the idea that shipboard processing is only the first step in the curation process that makes high-quality material available to investigators.

Several group tours were arranged and conducted with a familiar personality, Audrey Meyer. Also, some smaller tours were given to visitors, leaving a few of us nearly voiceless.

The first couple of days of the port call were dominated by pipe, casing, and drill-collar lifts and handling and securing the hard-rock guide bases. Cores were then unloaded and added to some cores from the West Coast Repository and transported by truck to the Gulf Coast Repository. Air and surface freight from the ship was handled the third day. Our 40-ft resupply container came aboard last, and we were busy stowing things away as our Thanksgiving eve departure approached. We were under way at 1600 hr 25 November.

UNDERWAY OPERATIONS

Navigation tapes were begun immediately, though underway watches were postponed a day while the ETs and the underway specialist checked out the laboratory and equipment and conducted a few short classes for the new technical staff. This San Diego approach has been surveyed innumerable time by SIO and the Navy. The following day, watches began with the magnetometer sensor being deployed and the 12-kHz and 3.5-kHz depth recorders turned on. No seismic gear was streamed as we followed the Baja coastline and then over the East Pacific Rise to the Hess Deep. The area had been surveyed extensively prior to our arrival by previous expeditions, so the *JOIDES Resolution* simply stopped at the selected position.

Expendable bathythermograph probes were dropped at 6-hr intervals; the data were relayed to NOAA via a satellite link.

A seminar was conducted for TAMU employees to sensitize them to situations and conduct that can be construed as sexual harassment. A video was shown and a discussion conducted for most of the staff. Texas A&M University is a supporter of a work environment free of this type of conduct. The tape was borrowed by the Captain and others.

The long transit south to the site was filled with a series of presentations by the scientific party.

The ship was under way, sailing for Panama City, at 2000 hr on 15 January 1993; underway watches were started again. The laboratory was secured, except navigation, approximately a day out of port, as we entered the sea lanes to the Panama Canal. The transit took 5 days, with the ship arriving at the pilot station and the Bridge of the Americas at 0900 hr on 21 January 1993.

SURVEYS

An EXCEL routine was used to make moonpool corrections from GPS positions during the surveys conducted from DP. Surveys of the selected drill site were tracked with GPS fixes for later plotting, but, as on Leg 118, they proved too imprecise to use when considering the 800 by 1200 m and smaller areas of interest. There is a possibility that this military positioning system dithers position accuracy at this scale. Offsets were also recorded from a known bottom beacon. These positions and drill-pipe lengths were used to update previous bathymetric drawings and to map local features.

VHS video tapes were recorded during the total 8.9-nmi survey, annotated with time and date. Underwater image quality is difficult to achieve because of poor lighting and low contrast. One tape review was attempted on our large-screen TV to characterize the various rock outcrops, but the image quality was too poor, curtailing the effort.

The survey covered the position of an ocean bottom seismograph (OBS) that had failed to release for a previous expedition. A grapple was fixed to the drill pipe, and after a 2 hr of making passes over an invisible bail, a connection was made and the device was recovered. The data disks were recovered.

CURATION

Only the first few cores were recovered in a plastic liner. This is the first leg on which the inner surface of a core barrel was chromed to reduce friction. Alternating regular and chromed barrels over the leg resulted in 7%-10% higher recovery for the chromed barrels, as calculated by the Operations Superintendent.

It is a higher risk operation transferring cored rocks without liners from the core barrel, which is cleared by elevating and hammering on the high end of the barrel while a team at the other eases pieces out into a split liner. Low core recovery slows down the development of a routine by the eight or so people involved.

A problem pointed out by a scientist involves some inconsistency in determining piece orientation when drilling without liners. Orientation marks put on the rocks on the drill floor may be augmented by personnel handling the core after it is placed in liners. The core barrel has a larger ID, allowing more rotational freedom than the liner. The addition of a test or verification gauge with the core-barrel ID was suggested for the splitting bench.

Sampling parties experienced some difficulty and were characterized by several conflicts and many hours of discussion and negotiation.

LABORATORY OPERATIONS

Core Laboratory

Few changes were made in the core laboratory and core flow was easily accommodated. A 300-W quartz work light was used over the splitting table in the cutting room to aid those in trying to align features in the recovered rocks.

The rocks split with the Felker saw were fairly heavy but cut readily. One core of banana-shaped segments perhaps reflected the stress the in-situ mantle blocks were under.

The diamond blades used on this leg were a masonry blade on the super saw, 9-in. notched blades on the cutting-room Felker, and continuous-rim thin blades on the mini-Felker, used for sample cutting. All five of the very thin 6-in. blades, preferred for critical cutting, were damaged. The long core drill worked well until the last sampling party, when it jammed, bending itself and the drill-press spindle and chuck.

The new parallel-blade saw with a water bath was used but will likely be modified to reduce spray generated when cutting. It is still limited, as it cannot cut physical-properties (PP) cubes like the larger parallel saw. Most often used was the Leco Vari-cut saw from the thin-section laboratory. It was used to trim the ends from the longer minicores, drilled on the vertical axis, and so was used on the other samples also. PP scientists still hand-lapped the cut cylinders flat in a 5-piece jig on a glass plate. There is still a need for a portable lap wheel to reduce this tedium.

The MST was used to measure the magnetic susceptibility of 140 sections and to obtain discrete density measurements at selected intervals. Minicore volumes were determined using the pentapycnometer. The old Hamilton frame was again relied on for velocity measurements on the minicores. Resistivity measurements of minicores were made using the Wayne-Kerr analyzer.

Progress was made on revising and updating the manual collection supporting the physical-properties laboratory. The conversion of the vane shear to a digital system went as far as possible, lacking only some software components to allow it to compile.

The cryogenic magnetometer was used to measure fields in 60 half sections and 75 minicore samples. Routine maintenance was performed and laboratory improvements made. No problems were noted. The new Kappabridge was used to determine values for 71 samples. Work was done on its program by one of the scientists to make ASCII instead of binary files. There is an effort to integrate ODP sample ID convention into the program next.

At Hole 894G, five passes were made in the open part of the hole with the LDEO formation microscanner. The data were processed and the images printed for the investigators to review.

It was noticeable on several days during the cruise that the aft end of the core laboratory was several degrees warmer than the other, related to the heat that was exhausted into the laboratory from the downhole measurements laboratory.

Chemistry Laboratory

It was a quiet leg with respect to the number of samples that were processed in the chemistry laboratory. Inorganic carbon analyses were made on a few sediment samples; the remainder of the work was done on powdered rock from XRF splits. These determinations were made with the Carl Erba CNHS. The unit, with some tips via fax from COSTECH, was optimized to detect accurately low levels of sulfur in the rocks. Laboratory notes explaining the procedure were made.

With the new CHEMSTATION connected to the GC1, numerous calibrations and trial runs were made to see how it preformed in relation to the integrators used before. Considerable time was spent working on methods to analyze two signals simultaneously with different calibrations for each. Other problems with high and low concentrations were also worked on. Files and printout examples were collected to be shared ashore and explained.

A Cahn balance failed at the end of the leg and will be returned for repair. It was replaced with a rebuilt spare.

X-Ray Laboratory

The ARL XRF was troublesome on this leg, with numerous computer-related difficulties. The numerous glitches observed and dealt with on Legs 146 and 147 are likely the result of firmware upgrades in the instrument for a new computer that is not yet installed. The FISON representative rolled back a couple of these changes, and the unit was believed functional when we sailed. Both of the goniometers soon lost position; only one could be re-calibrated for the leg after the initial weeks of errors and problems. The instrument was used to determine the chemistry of 33 samples.

Sample preparation was hampered, as weighing was time-consuming and, at times, not possible. The vertical motion "shudders" common when tripping pipe may be responsible for some of the problem, as weighing conditions improved when the ship was under way. Accuracy was a problem with the MAC/LabView-controlled weighing station. The station was returned to PRO-based control and ±1/2 MG accuracy was easier to attain. High drift rates are still a problem.

Large sample sizes overwhelmed the mechanized rock crusher, and a hand-operated device was used instead. An impasse on grinding methods nearly occurred, as investigators did not want to use the tungsten carbide grinding vessel because of contamination concerns. Alumina vessels failed, and the steel ones, too, contaminated. The motorized agate mortar and pestle were eventually used.

A new powder diffraction library was added to the XRD PC, and the instrument was used to determine the mineralogy of 36 samples, 13 of which were glycolated for clay mineral identification.

Thin-Section Laboratory

Over 113 thin sections, 18 of them oversized, were made. Several stages of polishing were used to satisfy the reflected-light needs of the petrologists. The laboratory microscope was fitted for reflected-light work, and some training was provided. Permission was granted to return the Logitech Vacuum Impregnator to ODP until specifically needed again.

Computer Service

There were few problems with the computer system or network on this leg. The hardware worked well after the DEC service call in San Diego; software problems mainly concerned incompatible versions of programs and the discovery that there are more than the 50 workstations the server software was designed to handle. Some effort was put into determining what would be needed to upgrade the current system, with the hope of extending Ethernet to other parts of the ship and retiring or replacing the outdated VAX 11/750s. The Ethernet cable from the downhole measurements laboratory to the underway laboratory was located and successfully tested.

Photography Laboratory

In spite of this being a low-recovery hard-rock leg, the photo laboratory was very busy. Engineering's request of photographs to document the hardware used on this leg, its assembly, failure, modification, etc., coupled with public-relations requests, generated a respectable work load. Routine maintenance supported the 4000 prints requested on this leg.

A rush of photomicrograph requests, contact sheets, and enlargements, which demanded seven each copies of all, and then projected for each of the scientists, created a worst-case scenario that nearly overwhelmed our new photographer. Policy was reviewed, and the requests were modified, to control the situation. Some very nice color macrophotographs of the large crystal in the thin sections were taken.

A louver assembly was added to the air-distribution ducting to increase the air volume to the laboratory, which still is low.

Microscopes

Two new petrographic microscopes were added to the paleontology laboratory, and other scopes were prepared for petrographic work during the port call. Three microscopes were retired, one each to WCR, ECR, and GCR. Problems with the scopes were few, though a few of the staff had a difficult time taking photomicrographs while others had success. There were a couple of perplexing incidents of disappearing and reappearing accessories. Little use was made of the video system or printers.

A new inventory control system was initiated that removes the color codes from the various components and accounts for them individually.

Electronics Shop

With the exception of the problems concerning XRF work needed in the first week of the cruise, equipment problems in the laboratories were few. A sample holder was made for a scientist so that resistivity measurements could be made. Downhole-temperature (ADARA) tools were repaired, tested, and calibrated, and a new heat-flow-only tool was assembled. Depth transducers on the water guns were tested, and other towing harness circuits refurbished and checked. The copy machines performed well with routine preventative maintenance until the last two days, when minor problems developed.

Storekeeping

Low recovery was reflected in the low usage of the consumables. This, coupled with the long TAMU holidays, required few MATMAN updates to keep caught up. An oversupply of some bulky items was reduced by returning them to ODP: legal-size copy paper, yellow writing pads, and red end caps. Liquid-nitrogen dewars were left in Panama to be refilled.

Permission was given to return to ODP much of the loose spare/replaced equipment for storage or surplus that had accumulated in the second-look laboratory. We encourage those with leg specific equipment to store it ashore until needed. As ship stores has expanded its inventory, some backup laboratory equipment was displaced to the second-look laboratory.

SPECIAL PROJECTS

A hydraulic hose handler was mounted in the overhead on the starboard side, fantail, to assist in the deployment and retrieval of the 200-in.^{3} water gun. Tests into port demonstrated the desired result; one person instead of four or five can handle the hose bundles associated with deployment of the 200-in.^{3} water guns. Investigations of the DSDP hydraulic system over past years have indicated that the power pack delivered less that the optimum fluid volume specified for the motors in the boom and retrieval system. This low-volume problem is demonstrated in lower than advertised retrieval speeds and the inability to operate both boom systems simultaneously. The motors on the hose handler are small, using a gallon or two a minute, and the effects expected would be either minimal, slower, or non-operating. Retrieval speeds were reduced, but there is also a chattering induced into the system that is being addressed. An eventual upgrading of the power pack is likely indicated.

SAFETY

A bottle of fuming nitric acid failed in the acid cabinet in the upper 'tween mezzanine, splattering the inside of the cabinet. The situation was discovered by a marine specialist, who noticed discoloration on some newly cleaned cold-weather gear that was being stored nearby. The discoloration was traced to fumes escaping from the nitric acid cabinet and considerable heat. The bridge was notified, and forced-air ventilation was turned on to dissipate the strong and potentially overpowering brown fumes. The mess was cleaned up by three of the specialists in protective clothing, one with a Scott breathing apparatus. Appropriate dry acid neutralizers were used to control the problem. The incident was reported to ODP and an investigation was conducted, though there has been no explanation for the incident.

Concern was expressed about the practice of storing our cold-weather gear and survival suits in the area and about some of the bulk packing material. These bulky items had nowhere to go when the acid cabinets were moved to the casing-hold mezzanine. If the cabinets remain, lighting will be improved and consideration given to plans to plumb water for safety and cleanup purposes. Coping and a drain line, too, will be considered.

The METS team was complemented by a new member, Jean Mahoney, who participated in the weekly drill. On one occasion a "fire" in the casing hold was staged to acquaint the fire-fighting team with the area and the location of the fire hoses and the sprinkler-system control.

PROBLEMS

Again, the downhole measurements laboratory generated complaints of warm/hot conditions in the laboratory when all the logging computers were on. Cool air is being ducted to the area, but there is not enough when this laboratory is in full use. Cooling the entire laboratory stack, and then turning on the heaters in the laboratories, is not the way to solve this chronic problem. Chief Engineer Scott found that the ventilation/heat-extraction fan was off in the Koomey room for some reason. Turning it back on was an incremental improvement.

Chief Scott suggested adding a wall- or a ceiling-mounted chill-water AC unit to alleviate the problem. Chill water is available at the old cryomag location in the core laboratory. With the added air-conditioning capacity installed prior to Leg 139, there must now be some reserve capacity to spare for a small unit.

Water from the core laboratory entry sink and the thin-section laboratory sink began backing up into the thin-section laboratory's floor drain. The most likely place for line blockage to occur was in the lateral section of drain line that ran down the user-room wall and into the void between the laboratory stack and the main deck. A manhole was cut in the floor of the user room immediately in front of the elevator. It was tight, but access was gained and the blockage cleared.

LEG 147 STATISTICS

GENERAL:

Sites:	2
Holes:	13
Meters Drilled:	559.6
Meters Cored:	487.0
Meters Recovered:	122.8
% Core Recovery:	25.2
Number of Samples:	1896.0
Final Positions:	Hole 894H: 02°17.977'N, 101°31.555'W Hole 895F: 02°16.899'N, 101°26.796'W

Analysis

Magnetics Laboratory	
Half section measurements:	60
Discrete measurements:	75
Physical Properties:	
Index properties:	85
Velocity:	85
Thermcon:	95

Chemistry

CHNS	36
Carbonates	4

X-ray Laboratory

XRF:	15 Major elements 39 Trace elements
XRD:	36

Thin Sections 113

Underway Geophysics

Total transit nautical miles:	3153
Bathymetry:	2344
Magnetics:	2314