OCEAN DRILLING PROGRAM

LEG 140 PRELIMINARY REPORT

HOLE 504B

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ABSTRACT

During Leg 140 of the Ocean Drilling Program, the *JOIDES Resolution* achieved the deepest hole ever drilled into oceanic crust, through the dike/gabbro and/or layer 2/3 transition, by deepening Hole 504B to a total depth of 2000.4 m below the seafloor (mbsf). Located in 5.9-m.y.-old crust, Hole 504B is perhaps the most important reference hole for the composition and structure of "normal" oceanic crust. It represents the best opportunity for sampling the transition between the sheeted dike complex and the underlying gabbros in the context of a complete crustal section.

JOIDES Resolution departed Victoria, Canada, on 15 September 1991, and started operations after arriving at Site 504 on 1 October 1991. After 1 day of logging, 10 days of fishing operations, 26 days of coring, and another 3 days of downhole measurements, the drill ship departed Site 504 for Panama on 10 November.

Scientific coring was straightforward, without any unexpected drilling problems. Hole 504B remains stable and was left open and clean for further deepening. The changes in alteration mineralogy, the increasing average grain size, the general increase in actinolite abundance, and the absence of glassy chilled dike margins in the newly drilled section of Hole 504B indicate that Leg 140 may have reached the lower part of the sheeted dike section.

INTRODUCTION

The primary objective of Leg 140 was to revisit Hole 504B in the eastern equatorial Pacific (Fig. 1) to deepen it into the sheeted dike complex through the dike/gabbro and/or seismic layer 2/3 transitions. Site 504 is located 201 km south of the Costa Rica Rift, the easternmost arm of the Galapagos Spreading Center (at 1°13.611'N, 83°43.818'W, with a water depth of 3460 m), in 5.9-m.y.-old crust. Hole 504B is by far the deepest hole ever drilled into oceanic crust, and provides our most important *in situ* reference section for shallow ocean-crust structure (Fig. 2). It was temporarily abandoned at the end of Leg 111, ending within a 295-m section of sheeted dikes beneath 1/2 km of extrusive pillow lavas. A vertical seismic profile conducted in Hole 504B during Leg 111, however, indicated a reflector between 1660 and 1860 mbsf, only 100-300 m below the bottom of the hole (Becker, Sakai, et al., 1988). This reflector was interpreted as the transition between the sheeted dikes of seismic layer 2C and gabbros of seismic layer 3 and provided a major incentive for the Ocean Drilling Program to return to Hole 504B. Although the sheeted dike/gabbro transition, believed by many to be the layer 2/3 seismic reflector, has been sampled and observed by submersibles in tectonic exposures in both the Atlantic and the Pacific, this transition has never been sampled in an undisrupted section, and its equivalence to the seismic 2/3 transition never directly confirmed. As a result, the JOIDES Planning Committee committed two legs to reoccupy Site 504B. A 41-day engineering leg, Leg 137, cleaned out a large diamond bit and other hardware lost in the hole at the end of Leg 111, as well as conducted a suite of downhole measurements. Leg 140 devoted 40 days to clean, deepen, and log the hole.

DRILLING HISTORY

Leg 140 was the seventh leg of DSDP/ODP to occupy Hole 504B. An early pilot hole, Hole 501, was drilled 73 m into basement during Leg 68. Hole 504B was spudded in October 1979 during DSDP Leg 69, several hundred meters east of Hole 501. Hole 504B was subsequently deepened and/or logged during parts of five other legs, including Leg 70 (1979), Leg 83 (1981-1982), Leg 92 (1983), Leg 111 (1986), and Leg 137 (1991), as shown in Figure 2. These legs provided a wealth of scientific results, many of which are summarized by CRRUST (1982); Cann, Langseth, Honnorez, Von Herzen, White, et al. (1983); Anderson, Honnorez, et al. (1982); Anderson, Honnorez, Becker, et al. (1985); Leinen, Rea, et al. (1986); Becker, Sakai, et al. (1988, 1989a, 1989b); Alt et al. (1986); and Becker, Foss, et al. (in press).

Although previous coring, logging, and geophysical programs at Hole 504B achieved unprecedented scientific success, the operational history of the hole was marred by repeated downhole hardware losses and by disappointing rates of core recovery. These problems have increased with depth and were a particular problem during Leg 111, which experienced four significant losses of hardware in the hole, and a rash of premature bit failures. Leg 137 successfully fished and milled the junk left in the hole from Leg 111, and succeeded in deepening it by 59.2 m. Operations throughout the leg showed no indication of previously supposed problems with the casing. Unfortunately an 18-m outer core barrel with a diamond drilling bit broke off and was lost at the bottom of the hole near the end of Leg 137. Leg 137 was not able to fish this junk because of a defective fishing tool, and a lack of time to obtain and deploy any further appropriate tools. As the new junk in the hole was not deemed a serious impediment, fishing operations were scheduled to be completed by Leg 140, which would return to the hole with new fishing tools.

DRILLING RESULTS OF LEG 140

JOIDES Resolution left Victoria, Canada, 15 September, and started operations after arriving at Site 504 on 1 October 1991. After 1 day of logging (temperature and formation microscanner, FMS), 10 days were needed to fish the core barrel lost at the bottom of the hole during the end of Leg 137, and to clean the hole for further coring. Coring (26 days) and more downhole measurements (3 days), including temperature, acoustic velocity, resistivity, digital borehole televiewer, geochemical combination and a permeability test, were performed before the ship left Site 504 for Panama on 10 November.

Leg 140 has established the most complete reference section to date through the upper oceanic crust, by deepening Hole 504B to a total depth of 2000.4 mbsf. Hole 504B is now the deepest hole ever drilled by DSDP/ODP, and extends almost three times as deep into oceanic basement as any other hole.

The temperature profile, which was recorded between 200 and 550 mbsf before fishing and coring operations were begun, is characterized by a gradient inversion between 283 and 288 mbsf, possibly due to local fluid inflow from the basement into the borehole (Figs. 3 and 4). Below 288 mbsf, a downhole flow of ocean bottom-water into the basement, which was also observed during earlier legs, is still active, but has decayed considerably since Leg 137. The linear temperature gradient in the deeper hole is still 61°C/km, which extrapolates to a temperature of 195°C at 2000 mbsf. The FMS produced two good images from 290 to 940 mbsf and 1563 to 1575 mbsf, and the first shipboard data are given below.

Coring was straightforward, without any unexpected drilling problems. However, the penetration rate of less than 2 m/hr and recovery of 13% were low, but adequate. Hole 504B remains stable, with negligible evidence of hole ellipticity, and it was left open and clean for further deepening.

At present, Hole 504B extends through 274.5 m of sediment and 1725.9 m into basement, and is the only hole which clearly penetrates through the extrusive pillow lavas and into the sheeted dike complex predicted from studies of ophiolites. The Hole 504B basement section includes 571.5 m of pillow lavas and minor flows, underlain by a 209-m transition zone of mixed pillow lavas, thin flows and dikes, and 945.4 m of sheeted dikes and massive units.

Coring on Leg 140 recovered 47.69 m, of which 11.4% is aphyric, 18.6% sparsely phyric, and

70% moderately phyric plagioclase-pyroxene-olivine diabase, which has been divided into 59 lithological units. The coarsest unit identified has an average grain size of 1.5 mm, but in terms of texture and grain size, it is clearly a diabase and not a gabbro. Although there is not a simple systematic increase in grain size with depth, coarser grained diabases do become more common, and glassy chilled margins virtually disappear, consistent with emplacement of dikes at greater depth and at higher temperatures. Phenocrysts include plagioclase, augite, olivine, and Cr-rich augite. The groundmass is dominated by plagioclase, augite, and magnetite. In a few units Cr-spinel is present as inclusions in olivine and plagioclase. Most of the rocks examined are seriate porphyritic, a texture in which there is a continuous range of grain sizes from the phenocrysts down to the groundmass. A variety of "gabbroic" clots were observed in hand specimen and thin section. Some individual clots contain up to 20% Fe-Ti oxide minerals, and many contain small fine-grained patches with up to 50% Fe-Ti oxide minerals. These fine-grained patches are interpreted to be crystallized pockets of trapped Fe-Ti-rich magma.

In hand specimen there is no evidence for any pervasive deformation, and the rock exhibits well-preserved primary characteristics. The rocks are generally isotropic, both in hand specimen and in thin section, and there is no evidence for extensive recrystallization associated with ductile deformation. No significant fault-rocks have been recovered, and we see little evidence for local increases in the intensity of microfaulting, so it is unlikely that we have drilled through, but not recovered, a major fault zone.

Chemically, the Leg 140 rocks can be classified as olivine tholeiites with compositions that are similar to moderately evolved mid-ocean-ridge basalts (MgO = 7.7-10.1%, $Fe_2O_3^{total}$ = 8.1-11.4%, Ni = 79-189 ppm, Mg value = 0.60-0.75). However, the Leg 140 rocks are strongly depleted in incompatible elements (TiO_2 = 0.67-1.1%, Nb $\leq$0.3-0.7 ppm, Zr = 35-58 ppm). These characteristics encompass over 98% of all investigated samples recovered from Hole 504B, through 2000 mbsf. There appear to be no major igneous enrichment or depletion trends with depth, nor are there large-scale fractionation trends throughout this crustal section. However, Zn content decreases systematically from an average of 70 ppm at 1500 mbsf to 30 ppm at 2000 mbsf.

All of the recovered rocks are mineralogically and chemically altered to some extent and exhibit a pervasive slight "background" alteration. Locally more extensively altered zones occur around veins and in cm-sized patches. The background alteration is characterized by a 10%-20% replacement of primary minerals by secondary phases (Fig. 5). Olivine in most of the rocks is completely altered; pseudomorphs have been interpreted to reflect multiple stages of alteration, with early formation of talc + magnetite, followed later by chlorite or mixed-layer clay. Fresh olivine is present in some samples. Clinopyroxene in the rocks is partly replaced by actinolite. Plagioclase is generally only slightly altered to albite and chlorite along fractures and grain boundaries. A characteristic feature of Leg 140 rocks is the common presence of cm-sized, green to light-gray "patches" of alteration, similar to those identified on previous legs. These alteration patches comprise 8% of the core recovered. Irregularly shaped amygdules, 0.1-2.0 mm in size and filled with actinolite and chlorite, are surrounded by alteration halos (2-10.0 mm wide) in which the rock is extensively altered (about 80%) to actinolite, chlorite, albite, and titanite. Rocks from 1710 to 1790 mbsf, however, are characterized by generally slight alteration, with lower abundances of actinolite and chlorite, by the presence of talc replacing olivine, and by the presence of relict igneous olivine in the rocks. These rocks also lack the cm-sized patches of more extensively altered rock. These rocks are interpreted to reflect alteration at relatively low water/rock ratios. Such rocks occur sporadically at the bottom of the hole, and the deepest sample recovered is among the least altered. Alteration is strongly influenced by local permeability. Although the secondary mineralogy of the Leg 140 and Leg 111 rocks is generally the same, the proportion of actinolite is greater in the Leg 140 rocks, actinolite veins are more abundant, and the Leg 140 rocks are slightly more altered.

Penetration by hydrothermal fluids resulted in pervasive, but heterogeneous, veining of at least five macroscopic vein types (chlorite, chlorite/actinolite, actinolite, epidote/quartz, and chlorite/pyrite) ranging from ≤0.5 to 2 mm in width. The only consistent crosscutting sequence established among these vein types indicates that the epidote/quartz veins formed relatively late. The apparently random orientation of the veins suggests that their genesis is mainly influenced by the local stress regime, dominated by contractional cooling. Dips of open fractures fall into two dominant groups, one shallow and one steep. Both features seem to be late, associated with the drilling process. Most of the fractures are shallow and dip less than 30°. Some shallow-dipping veins exhibit the typical saddle morphology of disking fractures which may reflect the *in situ* stress field. The borehole ellipticity measured by the FMS calipers supports these interpretations. Steeply dipping fractures mostly strike east-southeast, a trend which again generally corresponds to the initial interpretations of the FMS data, and perhaps also reflects the *in situ* stress field.

Several chilled dike contacts were observed, and some have been oriented using paleomagnetic stable remanence. Oriented dikes indicate an east-west strike, subparallel to the spreading axis of the ridge. The dikes dip between 79° and 85° to the north, so the crustal sequence has probably tilted by only a few degrees. The natural remanent magnetization of the Leg 140 samples is of moderate intensity (2.6-3.0 A/m) and stability. The range of the stable magnetic inclination values (-57° to 43°) is similar to that observed in the upper part of the hole. Thus the mean value observed in Leg 140 samples falls within the range predicted by normal variations of the geomagnetic field for Site 504, and does not indicate significant tilting or rotation of the crustal section.

The mean value of magnetic susceptibility (0.016 SI units) for these samples is nearly identical to the mean value from the upper part of the dike section (1055 to 1570 mbsf). However, the range of susceptibility values is much wider than previously observed. This suggests that, for significant parts of the newly drilled section, the degree of hydrothermal alteration varies dramatically.

Compressional wave velocities in 50 horizontally oriented and water-saturated minicore samples have a mean of 5719 $\pm$ 257 m/s. This average is lower than the values measured from samples obtained during the later stages of Legs 111 and 137. If two highly altered samples are excluded, the mean value of the average wet bulk density is 2.98 $g/cm^3 \pm 0.023$ g/cm^3. This value is higher than the average determined during Leg 111 (2.91 $g/cm^3 \pm 0.06$ g/cm^3). Excluding the altered samples, the mean wet porosity of the rocks is 0.52% $\pm$ 0.60%, and the average thermal conductivity of 2.410 W/mK (homogeneous samples) is considerably higher than the mean value of 2.01 W/mK obtained during Leg 111. The downhole distribution of the physical rock properties shows an increase in velocity at 1600 mbsf, and a porosity and conductivity minimum at 1720 and 1800 mbsf, respectively.

A vertical seismic profile experiment conducted in Hole 504B during Leg 111 shows a relatively weak seismic reflector between 1660 and 1860 mbsf. This reflector was interpreted by the Leg 111 Shipboard Scientific Party as the transition between sheeted dikes in seismic layer 2C and gabbros in layer 3. Leg 140 clearly penetrated through this depth section. The observed changes in intensity of alteration and in physical rock properties may have caused an impedance difference somewhere around 1750 mbsf, which resulted in the observed reflector. This "boundary" was clearly not the transition from the dike complex into the gabbros at Site 504. The changes in alteration mineralogy, the increasing average grain size, the general increase in actinolite abundance, and the absence of glassy chilled dike margins in the newly drilled section of Hole 504B may indicate that Leg 140 has reached the lower part of the sheeted dike section.

Final logging

After drilling was terminated, an additional temperature log was run from seafloor to the bottom of the hole (2000.4 mbsf) to determine the temperature rebound after 5 weeks of operations. The maximum temperature recorded was 142°C, near the bottom of the hole; temperature at the bottom increased at a rate of 1.96°C/hr (Fig. 3). Next, the geochemical combination tool logged from 1811 to 1896 and from 1350 to 1686 mbsf with good data recovery. The resistivity/sonic log was successfully conducted from 1990 to 275 mbsf. The first run of the digital borehole televiewer (BHTV) failed, but following a repair of the cable head, the sections from 1885 to 1985 mbsf and 1485 to 1685 mbsf were successfully logged. A flowmeter was then deployed to test the permeability of the upper basement, and finally the geochemical combination tool was run again to log the missing section of Hole 504B from 1648 to 1826 mbsf.

REFERENCES

Alt, J. C., Honnorez, J. , Laverne, C., and Emmermann, R., 1986. Hydrothermal alteration of a 1-km section through the upper oceanic crust, Deep Sea Drilling Project Hole 504B: The mineralogy, chemistry and evolution of basalt-seawater interactions. *J. Geophys. Res.*, 91:10,309-10,335.

Anderson, R. N., Honnorez, J., et al., 1982. DSDP Hole 504B, the first reference section over 1 km through layer 2 of the oceanic crust. *Nature*, 300:589-594.

Anderson, R. N., Honnorez, J., Becker, K., et al., 1985. *Init. Repts. DSDP*, 83: Washington (U.S. Govt. Printing Office).

Becker, K., Foss, G., et al., in press. *Proc. ODP, Init. Repts.*, 137: College Station, TX (Ocean Drilling Program).

Becker, K., Sakai, H., et al., 1988. *Proc. ODP, Init. Repts.*, 111: College Station, TX (Ocean Drilling Program).

Becker, K., Sakai, H., Adamson, A. C., Alexandrovich, J., Alt, J. C., Anderson, R. N., Bideau, D., Gable, R., Herzig, P. M., Houghton, S., Ishizuka, H., Kawahata, H., Kinoshita, H., Langseth, M. G., Lovell, M. A., Malpas, J., Masuda, H., Merrill, R. B., Morin, R. H., Mottl, M. J., Pariso, J. E., Pezard, P., Phillips, J., Sparks, J., and Uhlig, S., 1989a. Drilling deep into young oceanic crust, Hole 504B, Costa Rica Rift. *Reviews Geophys.*, 27:79-102.

Becker, K., Sakai, H., et al., 1989b. *Proc. ODP, Sci. Results*, 111: College Station, TX (Ocean Drilling Program).

Cann, J. R., Langseth, M. G., Honnorez, J., Von Herzen, R. P., White, S. M., et al., 1983. *Init. Repts. DSDP*, 69: Washington (U.S. Govt. Printing Office).

CRRUST (Costa Rica Rift United Scientific Team), 1982. Geothermal regimes of the Costa Rica Rift, east Pacific, investigated by drilling, DSDP-IPOD Legs 68, 69, and 70. *Bull. Geol. Soc. Am.*, 93:862-875.

Hobart, M. A., Langseth, M. G., and Anderson, R. N., 1985. A geothermal and geophysical survey on the south flank of the Costa Rica Rift: Sites 504 and 505. In Anderson, R. N., Honnorez, J., Becker, K., et al., *Init. Repts. DSDP*, 83: Washington (U.S. Govt. Printing Office), 379-404.

Leinen, M., Rea, D. K., et al., 1986. *Init. Repts. DSDP,* 92: Washington (U.S. Govt. Printing Office).

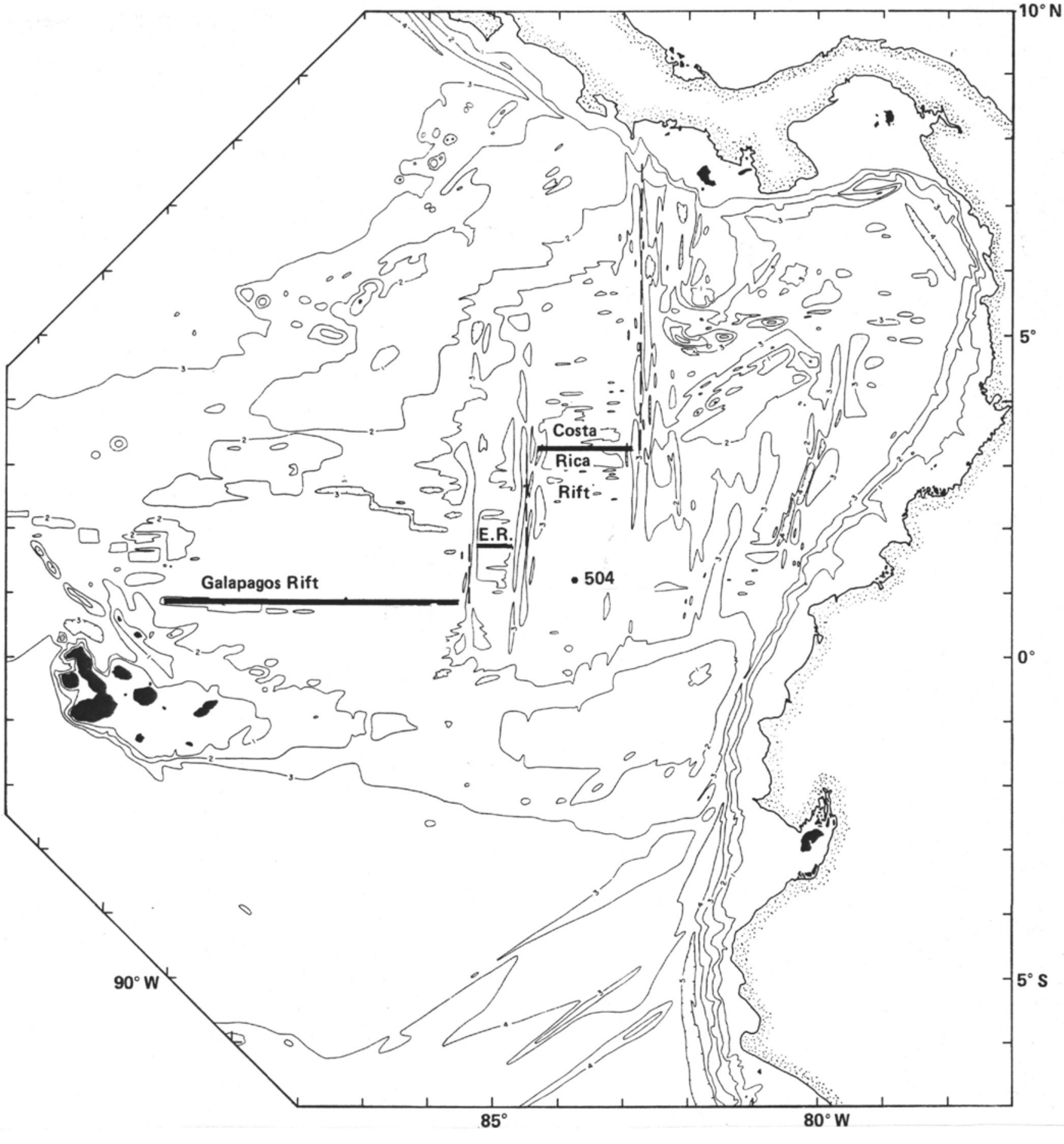


Figure 1. Location of DSDP/ODP Site 504 south of the Costa Rica Rift and east of the Ecuador and Galapagos Rifts in the eastern equatorial Pacific Ocean (after Hobart, et al., 1985).

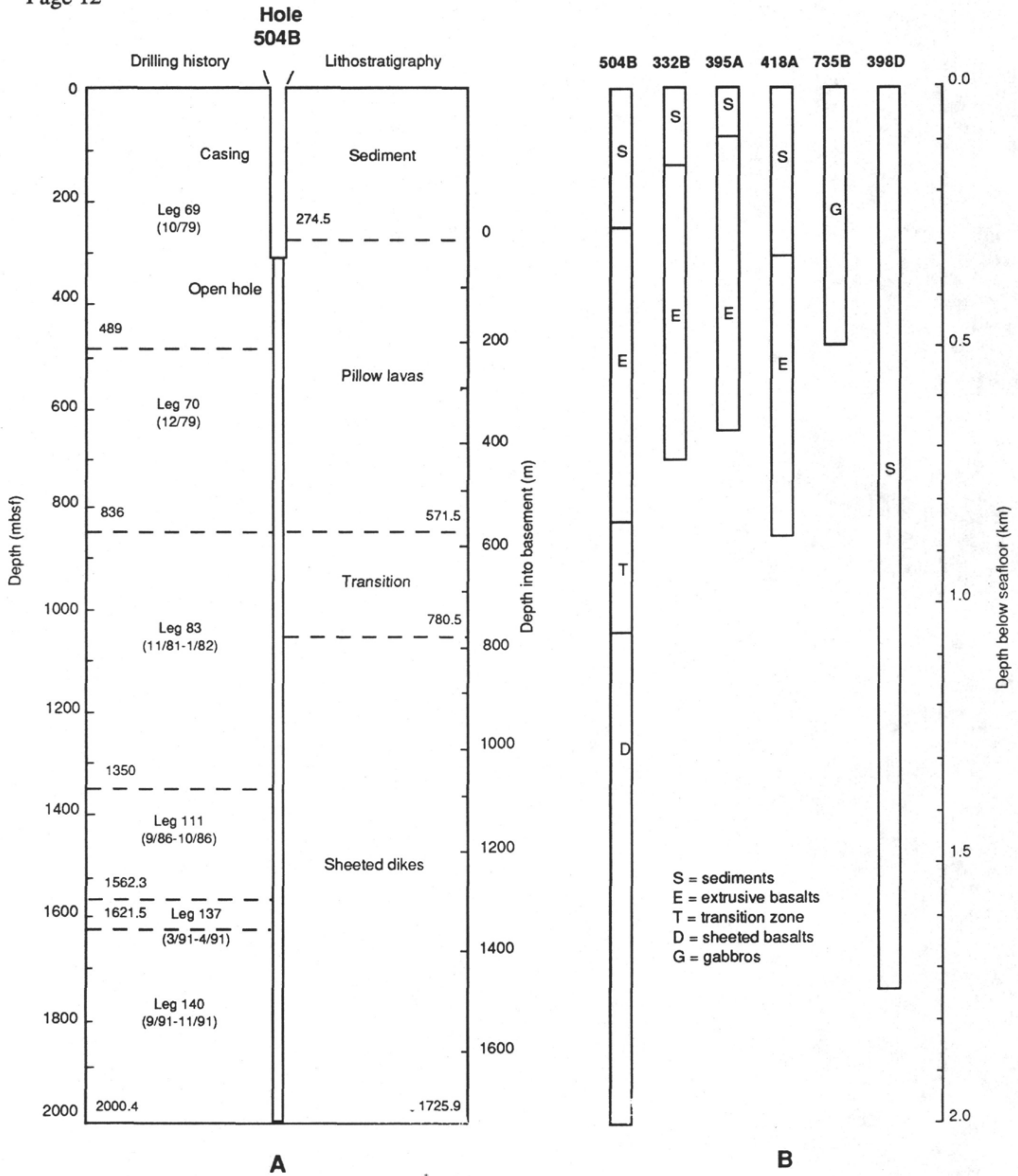


Figure 2. A) Generalized drilling history and lithostratigraphy of Hole 504B as drilled during Legs 69, 70, 83, 111, 137, and 140 (Leg 92 is not included because Hole 504B was logged only on that leg). B) Generalized lithostratigraphy of selected DSDP/ODP holes.

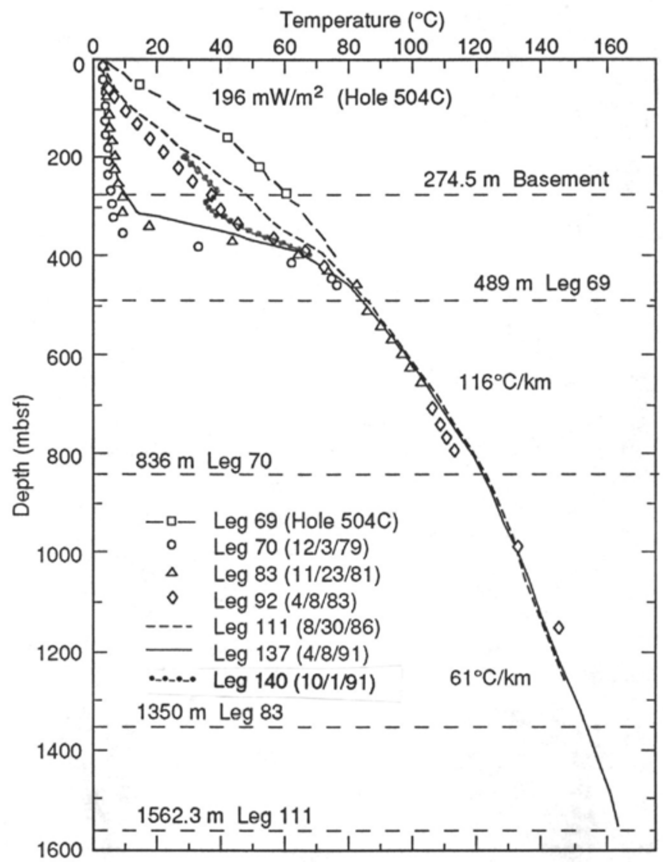


Figure 3. Composite of temperature logs obtained in Hole 504B during Legs 69, 70, 83, 92, 111, 137, and 140. The depressed temperatures in the upper 400 m reflect the downhole flow of cold ocean bottom water through the casing into the upper 100 to 150 m of the basement. Processing and plotting of Leg 140 temperature data were not completed at the time of this report, but will be available by February 1992.

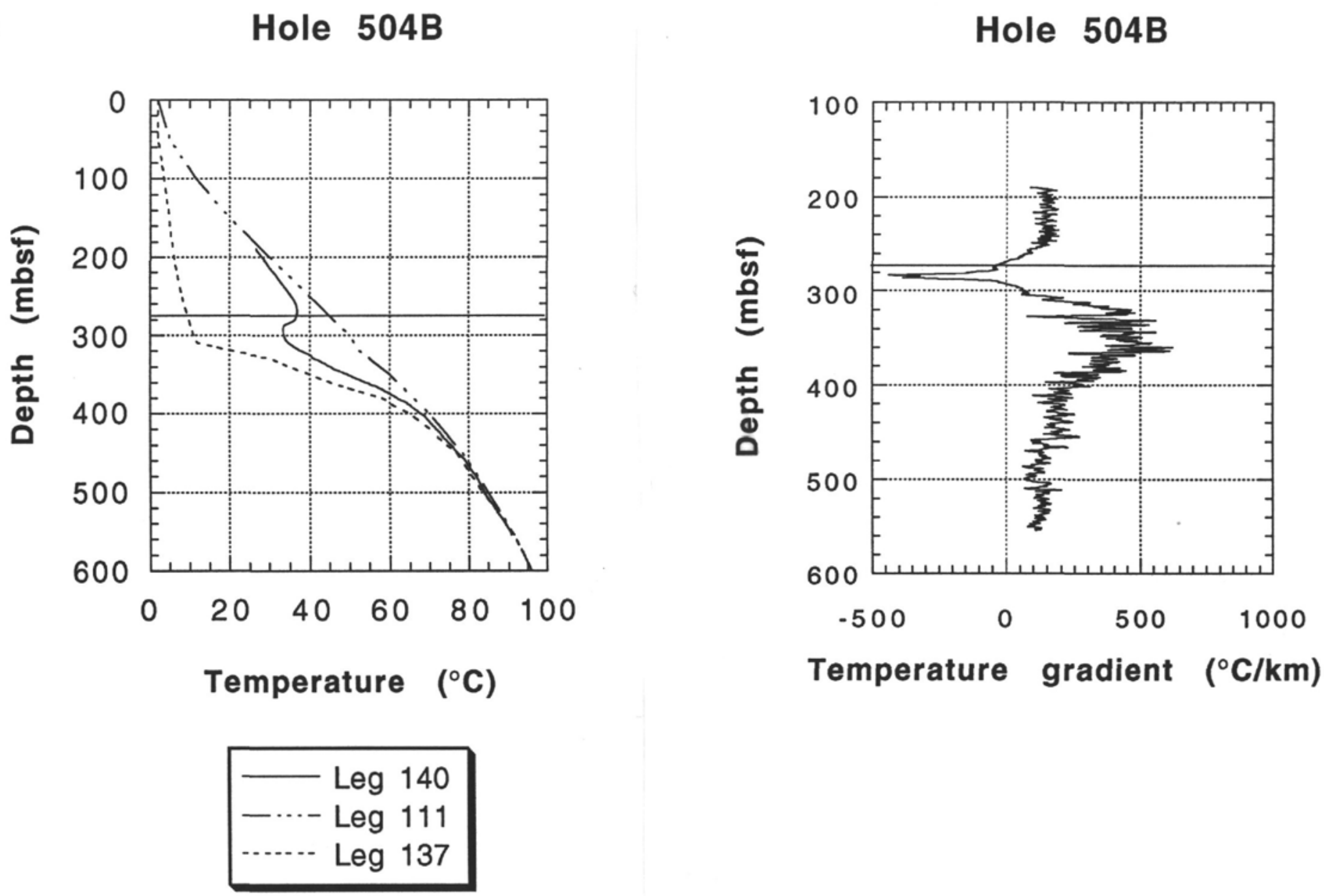


Figure 4. Leg 111, 137, and 140 temperature profiles.

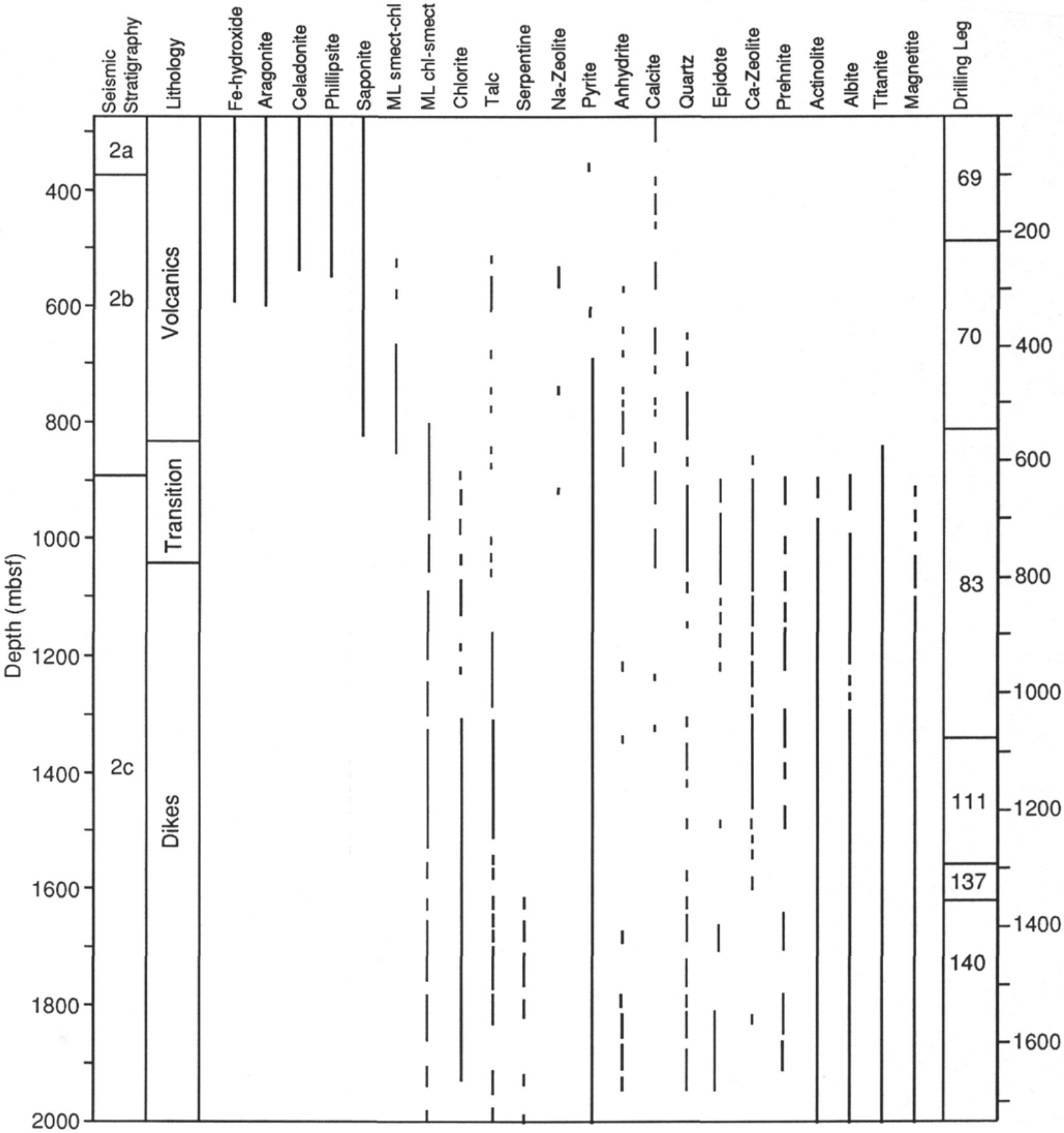


Figure 5. Distribution of secondary mineralogy with depth in Hole 504B. From Alt, et al. (1986); Becker, Sakai, et al., (1989a). 1) An upper alteration zone in the pillows (274.5 to 584.5 mbsf) displaying typical effects of oxidative alteration commonly observed in DSDP holes. 2) A lower alteration zone in the pillows (584.5 to 836 mbsf) that was presumably produced by reactions with low temperature suboxic to anoxic solutions at low water/rock ratios. This zone is characterized by smectite and pyrite. 3) A high temperature alteration zone (898 to 1621.5 mbsf) that produced the first *in situ* samples of ocean floor basalt containing greenschist-facies alteration minerals. The pronounced changes in alteration mineralogy observed from 836 to 898 mbsf are interpreted to have resulted from a steep temperature gradient between low-temperature (<100ºC) alteration solutions circulating in pillow lavas and very high temperature fluids (>300ºC) that affected the lower portion of basement at the site. The transition between pillow lavas and underlying dikes corresponds closely to the transition from low- to high-temperature alteration, because the bulk permeability and porosity of the dikes are orders of magnitude lower than in the pillows.

OPERATIONS REPORT

The following operations and engineering personnel were aboard *JOIDES Resolution* for Leg 140 of the Ocean Drilling Program:

ODP Operations Superintendent:	Gene Pollard
ODP Special Tools Engineer:	Pat Thompson
Schlumberger Engineer:	David Ritz

INTRODUCTION

During Leg 140 *JOIDES Resolution* returned to Hole 504B to clean out a diamond bit and core-barrel fish left in the hole on Leg 137 and to deepen the hole. Initial logging runs (temperature and formation microscanner) were completed in 1 day, and the junk left in the hole during Leg 137 was removed in the next 10 days of Leg 140 operations at Hole 504B. Logging and coring operations occupied the remaining 29 days on site at Hole 504B during Leg 140.

LEG 137 OPERATIONS SUMMARY

Hole 504B was cleaned out, drilled, and cored during Leg 137. While using a Christensen large-diameter (6-3/4 in.) rotary core barrel with a 7-7/8-in. diamond-impregnated core bit, penetration stopped at 1621.5 mbsf. The drill string was retrieved, revealing that the core barrel had parted below the inner barrel swivel. The drill string recovered the inner core barrel and core, but the outer core barrel and diamond-impregnated bit were left in the hole (Fig. 1A). A 9-1/2-in. slim-hole overshot, dressed with an extension, 6-3/4-in. basket grapple, and cut lip guide, was run to attempt to engage the core barrel.

Apparently, the overshot swallowed the core barrel: the bottom of the overshot drive sub contained a perfect imprint of the core-barrel tube, and the top of the core-barrel fish was clearly marked by the overshot cut lip guide. Faint marks 18 in. down on the hard tube of the core barrel may have been made by the overshot grapple. The grapple teeth were dull and chipped, suggesting that the grapple could have easily slipped off. The drive sub on top of the overshot pulled out of the extension bowl while being pulled up, possibly because of drag which may have been caused by the core barrel. The extension and overshot bowl were left in the hole on top of (and presumably connected to) the core-barrel fish.

In the short time remaining on Leg 137, an unsuccessful attempt was made to engage the overshot bowl using a shortened taper tap. The failure of the taper tap to engage the overshot bowl suggested again that the core barrel might have stuck above the basket grapple. The top of the overshot fish was tagged at 1589 mbsf. Assuming the overshot and core barrel were still together, the 18.4-m core barrel would also have been above the bottom of the hole. The bit was probably resting on a ledge that had been reamed out at least four times during the leg (Fig. 1B). The overshot may not have moved the core-barrel fish up the hole, but might simply have fallen off and become jammed in the hole.

LEG 140 OPERATIONS SUMMARY

Leg 140 operations are summarized in Table 1 and Figure 2, with Table 1 showing time expenditures and coring information and Figure 2 showing the chronological history of the leg. Figure 3 is a simplified summary of total time expenditures.

Transit from Victoria, B.C., to Hole 504B

Leg 140 began with the first mooring line on Victoria's Ogden Point dock at 1400 UTC, 11 September 1991. At 0530 UTC, 16 September, *JOIDES Resolution* departed Victoria, beginning the 15-day transit to Hole 504B which covered 4064 nmi in 369.0 hr at an average speed of 11.0 kt. Hurricane Kevin slowed progress to 6.5 kt; swells up to 20 ft and winds up to 40 kt required a course change to bypass the center of the storm by 65 nmi.

JOIDES Resolution approached Hole 504B at 1350 UTC, 1 October, and ship control was shifted to dynamic positioning (DP). A retrievable beacon was dropped on the global positioning system (GPS) location recorded during Leg 137 and hit bottom 55 m south-southeast of the reentry cone and 22 m southeast of the beacon drop point. The search and reentry into Hole 504B required

1.42 hr. The reentry bit was run to 58 mbsf for logging.

Logging: First Phase

A French Bureau de Recherche Géologique et Minières (BRGM) temperature tool logged 150 to 550 mbsf, and recorded a temperature of 90.5°C at 550 mbsf. A Schlumberger slim-hole formation microscanner (FMS) tool was run to 1576.6 mbsf (8 m above the top of the fish) and logged from 1570.6 to 1556 mbsf, where the telemetry failed, apparently because of the high temperature. The four spring-loaded arms could not be closed without telemetry, so the tool was pulled from the hole for repairs. At 1138 mbsf it became stuck and was eventually freed after 7800-lb pull (3500-lb overpull). The tool was pulled up to 946 mbsf, where telemetry was reestablished. The hole was logged up to 281 mbsf, but some of the readings were unreliable. The reentry into the casing and bottom-hole assembly (BHA) was normal, but the tool became stuck again about 20 m inside the BHA. About 2000-lb overpull was required to free the tool. The FMS tool had lost an arm, a bow spring, and pad parts. The bow spring of one pad had been bent upward to form a hook, which might have been caught in the BHA. The arms and hinge pins of this specially built slim-hole FMS are of light construction and are held open by bow-spring pressure (not by hydraulic pressure as in the normal FMS tool). The pads were built in three sections, and came apart in the hole. Hole 504B has a very rugose and hard wall, so a slim-hole FMS with a stronger arm, stronger hinge pin, and non-segmented pad is needed before rerunning the tool in equivalent formations.

Fishing

Leg 140 fishing was planned under the assumption that the outer core-barrel fish was still engaged in the overshot fish. The marks on the overshot drive sub indicated that the core-barrel fish had been above the grapple at one time; moreover, overshot basket grapples are known for their strong gripping power and seldom slip off. The fishing operation was expected to be straightforward and of little risk; however, the normal indicators of fishing problems, such as pressure drop, weight and torque changes, were masked by an open core barrel (inner diameter 5.38 in.) that may have been stuck above the bottom of the hole, a lightweight fish, a smooth diamond bit on a hard bottom, a fish that changed position in the hole, and loose rock rubble and junk. The fishing plan was to use an overshot tool first, a spear next, the taper tap last, and milling, if required.

The following fishing tools were purchased especially for Leg 140: a 9-1/2-in. slim-hole overshot with a cut lip guide and 6-3/4-in. basket grapple, an Itco 5-1/2-in. Bowen-type releasing spear with 5.367-in. grapple, a 5-3/8-in. x 7-in. taper tap, two 9-5/8-in. piloted junk mills, a 7-7/8-in. concave junk mill, a 9-5/8-in. lead impression block, and three reconditioned 9-5/8-in. concave junk mills.

The reentry bit had been run for temperature and FMS logging; it was therefore run to 1589 mbsf, where the fish was tagged. Little fill had collected above the fish, indicating that Hole 504B had been stable since Leg 137. Figure 2 includes a summary of fishing operations.

The reentry bit was pulled out of the hole, and a 9-1/2-in. slim-hole overshot, including a 6-3/4-in. basket grapple and flat shoe, was deployed. Initially it was thought that the overshot fish was farther down the core barrel so that the fishing overshot could engage the core barrel. Eight unsuccessful attempts were made to engage the fish, and the overshot fish was bumped 9 m downhole (top of fish now at 1600 mbsf). The fishing overshot contacted the fish, but the grapple did not engage. When the bottom of the overshot guide was examined later, it contained several indention marks, indicating that it had been on the top rim of the overshot bowl. The inside of the overshot contained no marks, however, showing that it never got over the core barrel. Thus the overshot fish must have been too far above the core barrel for the fishing overshot grapple to engage.

Next, a fishing spear was run to attempt to catch the core barrel through the overshot fish. An Itco releasing spear with a 5.367-in. nominal grapple was deployed to catch the core barrel (5.38 in. inner diameter). The spear was run to 1586 mbsf. The top of the fish was tagged again at 1590 mbsf, and unsuccessful attempts were made to engage the core-barrel fish. The spear had no marks on it, but showed some evidence of sliding on the kutrite shoe. The spear was probably not long enough to reach through the overshot fish to engage the core barrel.

A 7-in. x 4-1/4-in. taper tap was run next to engage the 6-3/4-in. basket grapple in the overshot fish, so the overshot could be removed to clear the top of the core barrel. The taper length of the tool should have been sufficient to engage both the 6-5/8-in. ID overshot grapple (and the 5.38-in. ID core barrel, if they were together). The taper tap tagged the fish at 1589 mbsf. The fish was engaged with 35,000 lb drag, but fell off after 2 m. The taper tap was hammered down, but would not reengage. The paint on the teeth of the tool was worn off from the tip up to a diameter of 5.33-in. (ID of core barrel) and also, 50 cm above, at a diameter of 6.75-in. (ID of the grapple) as if it had been washing through fill inside the core barrel. The marks on the taper tap were 19 in. apart, indicating that the core barrel top must have been just inside the overshot cut lip guide. The overshot fish prevented full engagement of the taper tap in the core barrel.

Another attempt was made to get both fish by running an extended spear through the overshot. A 1.88-m extension to the spear was constructed on the ship. The extended spear was run with a 5.367-in. nominal grapple (to catch the 5.38-in. ID core-barrel fish) and a milling nose. The top of the fish was tagged at 1599 mbsf, but the fish was not engaged. The spear advanced 0.3 m by rotation and was washed down 3.5 m with light rotation, but still did not engage. After pulling out the spear, mild wear was observed on the milling nose; however, the spear grapple had been lost in the hole.

The next strategy was to shorten the nose of the taper tap so it could engage the overshot grapple without having to wash down into the core barrel. The lower 40 cm of the taper tap was cut off, leaving a 6-7/8-in. x 5-1/8-in. wicker. The top of the fish was tagged at 1602.8 mbsf, but attempts to engage the overshot grapple failed. Unsuccessful attempts were made to circulate the taper tap farther down and use the jars to hammer down on the taper tap to engage it. When examined, the taper tap had no marks on the bottom, but the teeth at 6-3/4-in. to 7-in. diameter were polished and had some metal shavings. The taper tap appeared to have been driven down into the overshot fish grapple without engaging it.

Although the fish was engaged on several fishing runs, no solid connection had been achieved after 5.5 days of fishing. The overshot and core barrel were no longer together and were separated by rock rubble, making fishing much more difficult than originally anticipated. One more day of fishing was planned; if no progress was made, Hole 504B would be abandoned. An alternative fishing tool, designed to pass through the overshot grapple and open beneath it, was built on the ship for a last attempt.

The ship-built "double dog" fishing tool had three horizontal dogs activated by hydraulically shearing a forcing cone and two 45° flipper dogs built into a piece of 5-1/2-in. drill pipe. A 5-1/2-in. mill was built into the bottom in case the overshot or core barrel was full of debris. Six meters of fill was tagged at 1598.8 mbsf, and the fishing tool was washed down through fill. The fish was chased to 1604.6 mbsf and engaged, but came off at 35,000-lb overpull. An attempt was made to set the hydraulic dogs, and the fish was engaged again, but the tool slipped off at an overpull of 25,000 lb and could not be reengaged. The tool was spudded with 30,000 to 50,000 lb of weight, and was engaged successfully. However, the fish was stuck and could not be moved with 50,000-lb tension. After working the fish several times, it began to move, and the drag slowly decreased to 20,000 lb. The overshot fish was recovered, and the bottom mill was found wedged into the outer core barrel; however, the core barrel broke off at the top of the near-bit bottom stabilizer. The diamond-impregnated bit, near-bit bottom stabilizer, formation microscanner parts, and miscellaneous small pieces of junk were left in the hole. A 9-7/8-in. tri-cone bit (Bit Run 1) was run to clean out the fill to 1619 mbsf and open the 7-7/8-in. hole to 1620.1 mbsf. The hole was then circulated clean.

Only a taper tap could recover the bit and stabilizer and collect the remaining small junk without milling. A milling nose was added to the taper tap so it could drill out any junk in the stabilizer before engagement. The taper tap was washed down to the top of the fish at 1620.1 mbsf and engaged. Increasing circulation pressures indicated the fish was packing off; therefore, a 50-bbl high-viscosity mud pill was pumped to the fish to clean out debris and maintain circulation. The taper tap was engaged, 40,000-lb blows were struck to seat the tap firmly, and the fish was worked using 25,000-lb overpull while circulating the mud pill around the bit. Pump pressure broke back, and the fish was moved with 20,000-lb drag. The taper tap recovered the remainder of the fish: the 7-7/8-in. diamond bit, the near-bit stabilizer, spear grapple parts, an FMS pad, and miscellaneous overshot junk.

Most of the junk in Hole 504B was recovered. A 9-7/8-in. bit (Bit Run 2) was run with two junk subs to open the remaining 7-7/8-in. hole to 9-7/8-in. (1621.8 mbsf) and to remove any remaining junk.

Coring Operations

Bits and Bottom-Hole Assembly

During Leg 137, two 9-7/8-in. rotary coring bits were pulled after coring 25.3 m at a rate of 1.7 m/hr and 20.2 m at a rate of 1.8 m/hr to reveal that the outer driver-row inserts had broken off. The hard fractured basalt caused the driver-row (outer) cutting structure of these bits to fail. To deepen Hole 504B during Leg 140, 15 Security H87F bits with ovoid inserts (teeth) and more ductile (but less abrasion-resistant) tungsten carbide inserts were built.

The bottom-hole assembly used during Leg 140 consisted of a 9-7/8-in. x 2-7/16-in. four-cone rotary coring bit and core barrel, eleven 8-1/4-in. drill collars, hydrolex jars, two 8-1/4-in. drill collars, and a 7-1/4-in. drill collar. Six joints of 5-1/2-in. transition drill pipe and 120-130 stands of 5-in. drill pipe were connected to the bottom-hole assembly; the remainder of the string consisted of 5-1/2-in. drill pipe. The bottom-hole assembly design provided 250,000-lb overpull with 6° roll and 10,000-lb heave load. Rotary coring started at 1621.8 mbsf on 13 October.

Bit Run 3

A 9-7/8-in. rotary coring bit was run from 1621.8 to 1655.1 mbsf and cored 33.3 m in 27.28 hr for a penetration rate of 1.22 m/hr. The bit was run at 50 revolutions per minute, with 20-32,000-lb weight on bit. The penetration rate was 0.9 m/hr with 30%-49% recovery in unfractured basalt, and 1.8 m/hr with 5% recovery in fractured basalt. The bit run was terminated after 27 hr because it was the first bit of its type ever tested. The core catcher and liner sleeve were jammed with wedge-shaped fractured core; the bit was re-runnable.

Bit Run 4

A 9-7/8-in. rotary coring bit was run from 1655.1 to 1696.5 mbsf, coring 41.4 m in 26.58 hr for a penetration rate of 1.56 m/hr. Brief drilling tests running the bit at 50-70 rotations per minute with 20-35,000-lb weight on bit indicated that the best penetration rate was obtained at 50 revolutions per minute and a weight on bit of 35,000 lb. The penetration rate was 0.9 m/hr with 30%-49% recovery in unfractured basalt and 1.8 m/hr with 5% recovery in fractured basalt. Two cores were jammed when the butyrate core liner was deformed by core wedging, and the liner sleeve jammed with wedge-shaped fractured rock on one core. The bit was re-runnable. The butyrate core liners were not used for Core 140-504B-193R or for the remainder of the leg with the consent of the shipboard scientific party.

Bit Run 5

A 9-7/8-in. rotary coring bit was run from 1696.5 to 1719.4 mbsf, coring 22.9 m in 16.0 hr for a rate of penetration of 1.43 m/hr. The bit was run at 30-35,000-lb weight on bit, 50 revolutions per minute, and was pulled after an unexplained pressure drop, or "washout." The rate of penetration was 1.9-1.30 m/hr with 6%-19% recovery in fractured basalt. The bit was re-runnable.

Bit Run 6

A 9-7/8-in. rotary coring bit was run from 1719.4 to 1757.0 mbsf, coring 37.6 m in 34.25 hr for a penetration rate of 1.10 m/hr. The bit was run with 28-35,000-lb weight on bit, at 50 revolutions per minute. The bit was pulled for a drop in both pump pressure and penetration rate, and was re-runnable. The penetration rate was 0.45-1.67 m/hr, with 2%-86% recovery in altered fractured and unfractured basalt.

Bit Run 7

A 9-7/8-in. rotary coring bit was run from 1757.0 to 1806.0 mbsf, coring 49.0 m in 39.1 hr, and a penetration rate of 1.25 m/hr. The bit was run with 28-40,000-lb weight on bit, and 50 revolutions per minute. The bit was pulled because of irregular torque and was not re-runnable. The driver-row inserts on all four cones were badly chipped; however, the ductile tungsten carbide was still providing some cutting surface. The rate of penetration was 1.10-1.73 m/hr with 5%-45% recovery in altered fractured and unfractured basalt.

Bit Run 8

A 9-7/8-in. rotary coring bit was run from 1806.0 to 1865.5 mbsf, coring 59.5 m in 40.75 hr for a penetration rate of 1.46 m/hr. The bit was run with 35,000-lb weight on bit, at 50 revolutions per minute. The bit was pulled because of irregular torque and was not re-runnable. From 8% to 50% of the driver-row inserts were chipped about 50%; however, the ductile tungsten carbide was still providing some cutting surface. The penetration rate was 0.89-2.00 m/hr, with 2%-55% recovery in altered fractured and unfractured basalt. Recovery, however, averaged only 3.2% in the last four cores.

Bit Run 9

A 9-7/8-in. rotary coring bit was run from 1865.5 to 1920.0 mbsf, coring 54.5 m in 41.53 hr for a penetration rate of 1.31 m/hr. The bit was run with 30,000-lb weight on bit, at 50 revolutions per minute. The bit was not re-runnable. From 8% to 100% of the driver-row inserts were chipped about 50%; however, the ductile tungsten carbide was still providing some cutting surface. The rate of penetration was 2.62-0.87 m/hr, with 4%-30% recovery in altered fractured and unfractured basalt. Recovery, however, averaged only 9.5% for the bit run.

Bit Run 10

A 9-7/8-in. rotary coring bit was run from 1920.0 to 1957.3 mbsf, coring 37.3 m in 30.57 hr for a penetration rate of 1.22 m/hr. The bit was run with 30,000-lb weight on bit, at 50 revolutions per minute. The bit was pulled because of an unexplained pressure drop and was not re-runnable. The 300-psi pressure loss was the result of a core-barrel check valve that had sheared out (probably when the inner barrel was pumped down after getting caught in cuttings inside the outer core barrel). The cuttings apparently got into the core barrel when a roll pin slipped in and jammed the float open. The core was washed out, and only two cobbles were recovered in Core 231R. Almost 100% of the driver-row inserts on all four cones were chipped about 80%. The penetration rate was 1.48-1.12 m/hr, with 5%-67% recovery in altered fractured and unfractured basalt. Recovery, however, averaged 15.7% for the bit run.

Bit Run 11

A 9-7/8-in. x 2-7/16-in. rotary coring bit was run from 1957.3 to 1980.7 mbsf, coring 23.4 m. The bit was run with 30,000-lb weight on bit, at 50 revolutions per minute. It was pulled for erratic torque. The bit exhibited junk damage on shirt-tail, hence it could not be re-run. The inner 80% of each cone was missing, and only the outer-gauge row rings of all four cones were still on the bit. Spear points from two cones were recovered on a subsequent coring run. The spear points had been cut off just before the thrust bearings. The penetration rate was 1.16-0.66 m/hr, with a 3.2%-5.2% recovery in fractured and unfractured basalt.

Bit Run 12

A 9-7/8-in. x 2-7/16-in. rotary coring bit was run from 1980.7 to 2000.4 mbsf, coring 19.7 m in 14.88 hr for a penetration rate of 1.32 m/hr. The kelly was measured out with 0 weight on bit to confirm the depth measurement at intermediate tide. The bit was run with 26,000- to 30,000-lb weight on bit, at a rate of 50 revolutions per minute. Junk caused gauge damage and broke and chipped teeth on the driver rows. The bit was pulled because of time limitations. The bit was drilling at 2.0 m/hr, with normal torque, when coring was terminated. The bit was pulled with normal 20,000-lb overpull; hole conditions were normal. Damage to the driver rows was moderate to severe. The teeth on the inner rows were moderately chipped. All four cones of the outer gauge inserts were worn 20%. The gauge ring indicated that the bit was 3/16 in. undergauge; therefore, we felt it would be advisable to ream the lower 20 m of the hole before any future coring. The rate of penetration was 0.86 to 1.81 m/hr, and core recovery was 2.9%-24% in fractured basalts. Recovery averaged only 6.1% for the bit run.

Bit Summary

Ten 9-7/8-in. x 2-7/16-in. bits were run and performed significantly better than previous bits in hard fractured basalt, with an overall record of coring 378.9 m in 294.77 rotating hours for an average penetration rate of 1.28 m/hr with 12.6% recovery. Rate of penetration and recovery correlated directly with the type of basalt being cored. The penetration rate was 1.3 to 1.8 m/hr in fine-grained, fractured basalt and chilled margins with recovery of 6% or less. The penetration rate was 0.9 m/hr in coarser grained, relatively unfractured basalt, but recovery was 30%-50%. The driver-row and spearpoint inserts need to be harder formation cutters in future bit designs for Hole 504B.

Hole Conditions and Hydraulics

The hydraulics were maintained at 120 strokes per minute at 1800 psi (with bit seals) to 2300 psi (without bit seals). Hole cleaning while coring with single 50-bbl sweeps proved inadequate, even at 700 gallons per minute. Therefore, two 50-bbl viscous mudsweeps were circulated during each core. Additional sweeps were circulated whenever abnormal drag, fill, torque, or penetration rate was noted. Bit nozzle plugging (from inner core-barrel dropstones or cuttings from failed floats) was a frequent problem. Core jamming occurred in every conceivable part of the core barrel: the core catcher (jamming and wedging), butyrate core liner (swelling the walls), core liner sleeve, and steel inner barrel.

The hole was circulated at 500-m intervals when running in to cool the hole and to reduce thermal stresses, and also to cool the bit and jar seals. The hole appeared to be relatively stable; however, stress breakout chips (thermal or tectonic) were found in junk subs, cores were disked and fractured, and hand-sized wall breakouts (curved to hole diameter) were recovered in the core barrel. Fill on trips was minor, and a few cobbles (mostly from the pillow lava section) were recovered in the tops of some cores. Drag on pipe trips was consistently 10,000-20,000 lb (normal for this depth). The drill string was frequently trapped by what appeared to be small cobbles or boulders falling in the hole, but the string was eventually freed by working the pipe uphole with rotation, 40,000-lb overpull, and pumping 50-bbl viscous mud sweeps. Occasional ledges, light bridges, and undergauge hole required reaming with 2,000-lb weight on bit and light torque. Torque was monitored carefully to core as little undergauge hole as possible (so future bits would not be destroyed by the undergauge hole).

Logging: Second Phase

Prior to logging, at 0500 UTC, 7 November, a reentry logging bit was run to 104 mbsf. An additional temperature log was run initially, using the French Bureau de Recherche Géologique et Minières (BRGM) temperature tool, to determine the temperature rebound after circulation. The tool logged temperature while running into the hole, and tagged the bottom at 2000.4 mbsf. The maximum temperature recorded was 142°C, because of cooling from circulation. While recording temperature buildup, the logging winch failed. The temperature tool failed after 90 min, but recorded a temperature increase of 1.96°C/hr. The logging winch was subsequently repaired, and the tool was pulled out of the hole. Temperature logging was followed by a pipe trip to the bottom to circulate and cool the hole.

Next, the geochemical tool string was run to 700 mbsf, but was pulled out to switch cartridges. The tool was then run in and logged from 1896 to 1811 mbsf, where the minitron failed. While being pulled uphole the tool revived, and logging continued from 1686 to 1350 mbsf.

A resistivity/sonic log was run next, but failed at 526 mbsf. The tool was pulled, and water was found in the head. The tool was rerun, and the hole was logged successfully from 275 to 1990 mbsf.

The digital borehole televiewer was the fourth logging tool employed. It was run to 1980 mbsf, but was pulled because of bad readings. The cable head was damaged, and the conductors had shorted to ground. The head was rebuilt, and the hole was logged successfully from 1985 to 1885 mbsf and from 1685 to 1485 mbsf.

The flowmeter was then deployed and logged four passes from 256 to 468 mbsf. The geochemical tool string was deployed for a final run from 1826 to 1648 mbsf, ending the logging program. Plans to load sodium bromide in the hole as a borehole fluid tracer were canceled because of time limitations.

The drill string was pulled out of the hole with the corrosion inhibitor inside, clearing the sea floor at 0350 UTC 10 November. The two beacons on bottom were recalled and recovered.

Transit From Site 504 to Panama

JOIDES Resolution left Site 504 for Panama City at 0930 UTC, 10 November, and traveled the 528-nmi transit in 53.5 hr, at an average speed of 9.9 kt. The vessel dropped anchor at the Port Balboa outer buoy at 1500 UTC, 12 November, ending Leg 140.

TABLE 1
OCEAN DRILLING PROGRAM
OPERATIONS RESUME
LEG 140

Total Days (11 September - 12 November, 1991)	62.1
Total Days in Port	4.6
Total Days Under Way	17.1
Total Days on Site	40.4

Trip Time	11.6
Coring Time	15.1
Drilling Time	0.1
Logging/Downhole Science Time	3.7
Reentry Time	0.5
Fishing & Remedial Time	9.4

Total Distance Traveled (nautical miles)	4592
Average Speed (knots)	10.9
Number of Sites	1
Number of Holes	1
Number of Reentries	21
Total Interval Cored (m)	378.9
Total Core Recovery (m)	47.7
Percent Core Recovered	12.6
Total Interval Drilled (m)	.8
Total Penetration (m)	379.4
Maximum Penetration (m)	2000.4
Maximum Water Depth (m from drilling datum)	3474.0
Minimum Water Depth (m from drilling datum)	3474.0

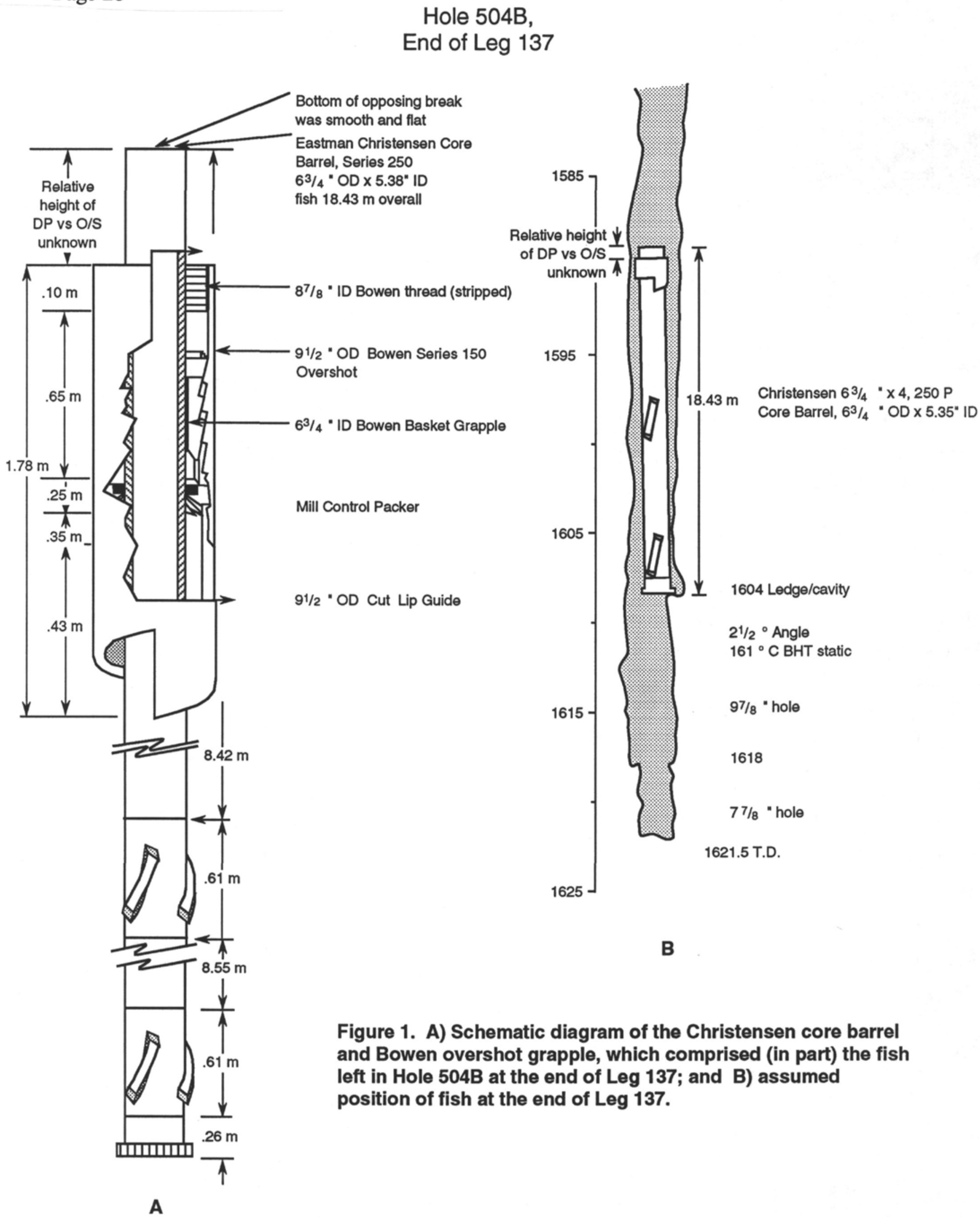


Figure 1. A) Schematic diagram of the Christensen core barrel and Bowen overshot grapple, which comprised (in part) the fish left in Hole 504B at the end of Leg 137; and B) assumed position of fish at the end of Leg 137.

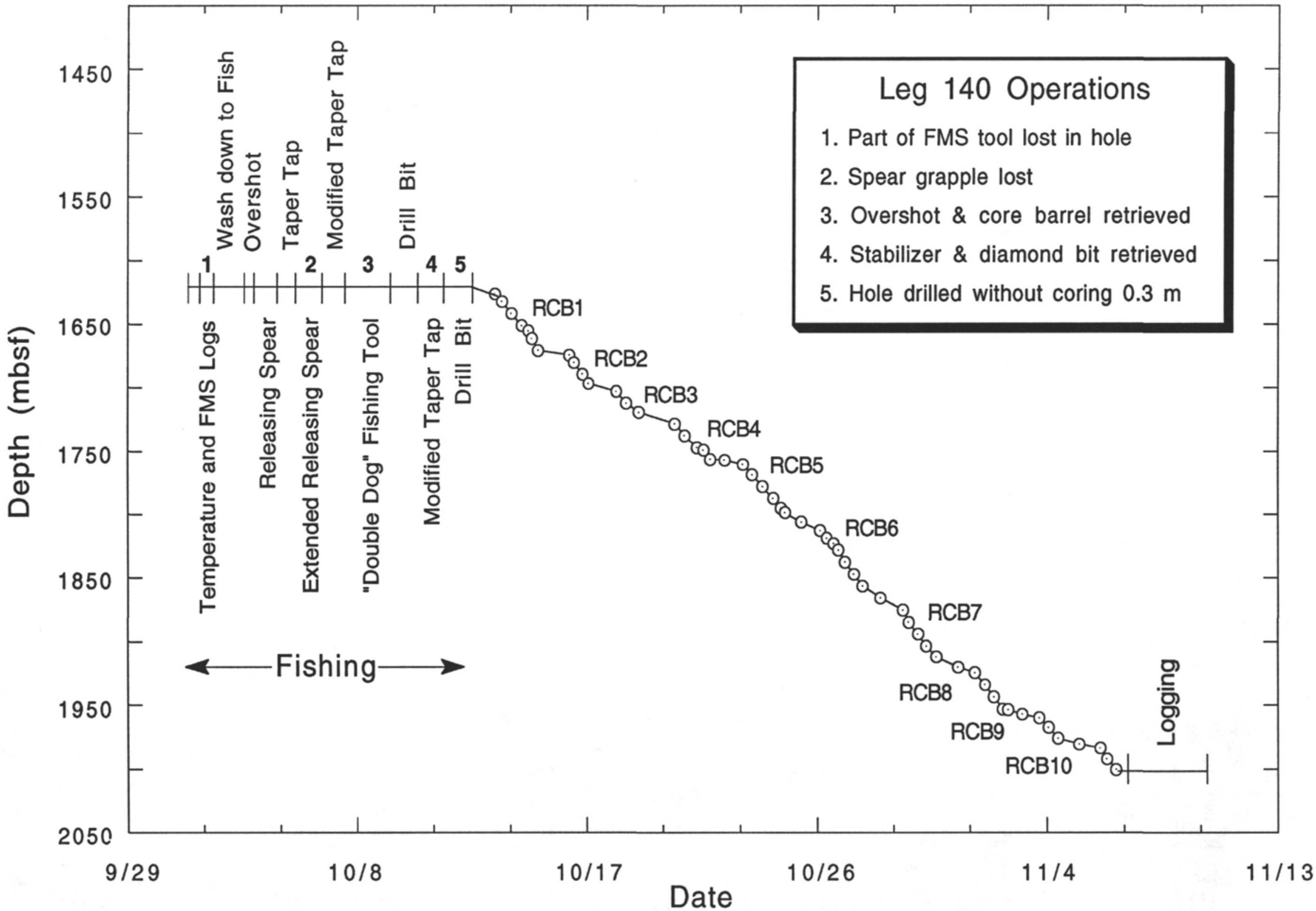
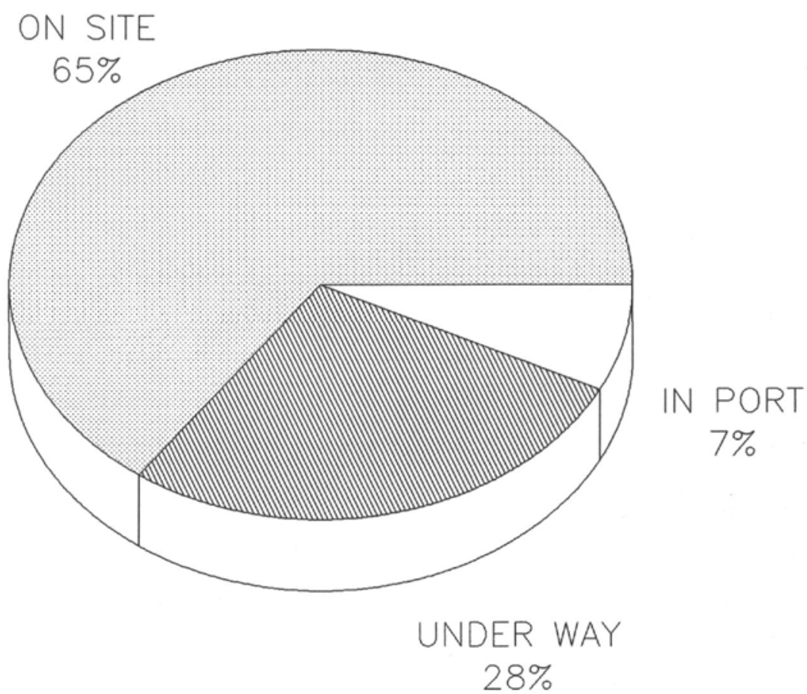


Figure 2. Summary of fishing, drilling, and logging operations conducted during Leg 140.

FIGURE 3

LEG 140

TOTAL TIME DISTRIBUTION



Total Days = 62.1

TECHNICAL REPORT

The following ODP Technical and Logistics personnel were aboard *JOIDES Resolution* for Leg 140 of the Ocean Drilling Program:

Laboratory Officer:	Dennis Graham
Assistant Laboratory Officer/ Assistant System Manager:	Wendy Autio
Marine Laboratory Specialist/Yeoperson:	Jo Claesgens
Marine Laboratory Specialist/Curatorial Representative:	Erinn McCarty
Marine Computer Specialist/System Manager:	John Eastlund
Marine Electronic Specialists:	Eric Meissner Barry Weber
Marine Laboratory Specialist/Photography:	Mark Gilmore
Marine Laboratory Specialist/Chemistry:	Valerie Clark
Marine Laboratory Specialists:	Daniel Bontempo Tim Bronk Brad Cook "Kuro" Kuroki Jon Lloyd

TECHNICAL OBJECTIVES OF LEG 140

The technical staff supported the scientific mission by operating and maintaining the laboratory equipment and assisting scientists as needed. During the initial 16-day transit, technicians cross-trained in the various shipboard labs. Only 14 technicians sailed on Leg 140 because the scientific and operational objectives did not warrant a full complement of 18 technicians.

PORT CALL: VICTORIA, B.C., CANADA

The Leg 140 technical staff arrived in Victoria on 10 September 1991. On 11 September, *JOIDES Resolution* docked in Victoria, ending Leg 139. Technician crossovers began immediately, and most Leg 139 technicians were released from work the same day. Three Leg 139 technicians stayed 2 extra days to assist with tour groups. The Leg 139 storekeeper, paleomagnetics technician, assistant lab officer, and lab officer remained an additional day for extended crossovers.

Representatives from 2G Enterprises, Philips Electronics, Digital Equipment Corporation, Zeiss, and Photolab Fabricators visited the ship to repair ODP laboratory equipment.

ODP Canada representatives and ODP/TAMU personnel conducted tours of the laboratory facilities on 4 of the 5 days of port call. Tours were conducted for hundreds of guests, the majority visiting during the last 2 days in Victoria, when the ship was open to the general public.

The Leg 139 cores and freight were offloaded and new supplies loaded for the upcoming leg.

Lines were cast on the evening of 16 September.

UNDERWAY GEOPHYSICS

During the 15.5 days of transit to Site 504, and during the run from Site 504 to Panama, magnetometer, bathymetric, and navigation data were continuously collected. As a voluntary observing ship for the Shipboard Environmental Data Acquisition System (SEAS), bathythermograph and meteorological data were collected every 6 hours and transmitted to NOAA once a day during the transit. Seismic profiles were not required on this leg.

An AMETEK Doppler Sonar was installed in a sea chest gate valve. Unfortunately the sonar sensor could not be lowered below the hull of the ship because of the sea growth accumulation in the sea-chest trunk. The trunk must be cleaned before the doppler sonar can be put in service.

We received new streamer equipment this cruise (one new active section and two new stretch sections). The port seismic winch contains a reinforced streamer and stretch section which will be used for high-speed seismic tests. The electronics technicians prepared connectors for a fiber optic signal cable. We hope the fiber optic cable will be less susceptible to the electromagnetic noise generated by the diesel electric propulsion system under the fantail.

LABORATORY OPERATIONS

Chemistry Lab

This leg provided a good opportunity to organize the chemistry lab. All obsolete supplies, parts, and manuals were removed from the lab. An orderly arrangement of workspace is necessary to work efficiently and safely in the chemistry lab. Only one chemistry technician sailed on Leg 140.

Seventy-nine XRF sample splits were analyzed for carbon dioxide and water content on the Carlo Erba NCHS elemental analyzer.

Qualitative tests for low alloy steels were performed using ASTM methods for an engineering analysis.

The chemistry technician analyzed a sodium bromide downhole pill sample on the Dionex ion chromatograph. The pill was not pumped into the hole because of time constraints.

Routine operational checks were performed on the chemistry lab equipment. All equipment is in good operational order.

Core Lab

Forty-eight meters of hard rock core were split and curated in the core lab. All sections, including the entire Leg 137 core collection, were stored in the lab for observation and easy access. We did not use core liners while drilling, but this caused no handling problems. The curator compiled a new version of the curatorial "cookbook" with updated information on hard rock curation.

Computer Lab

Problems experienced with the VAX cluster on the last two legs did not reappear. We conclude that the DEC service call in Victoria was successful.

In addition to the computer system manager, an assistant system manager sailed as a member of the technical staff. The 15.5-day transit at the beginning of the cruise afforded some time for training and for inventorying spare computer parts. In preparation for a major computer network upgrade, the system manager and assistant system manager carefully traced and documented the existing network complex. Once coring started, however, the assistant system manager had other responsibilities, including FMS processing, XRF training, and assistant lab officer duties, and could not provide computer support.

The need for computer support does not vary as a function of the scientific objectives, as does the need for support in other shipboard labs. Although there are fewer data to process on low core recovery legs, the computing equipment and scientists require about the same level of support as on high-recovery legs. As with past legs, this leg would have benefited from having two dedicated system managers.

We added a Macintosh IIci with 19-in. color monitor to the physical properties lab. An IBM 486 clone replaced the aging DEC PDP11 X-ray-diffraction (XRD) computer. The XRD goniometer was off the ship for repair, so we could not fully evaluate the computer and XRD software.

New Macintosh software installed this leg includes Macintosh WordPerfect 2.0, Macintosh Excel 3.0, Capture 4.0, TrueBasic, DOS Mounter, and geology-specific programs Stereonet, Ternary, and Vector Rose.

Downhole Measurements

Formation Microscanner (FMS)

Only one FMS run was attempted this leg. This run consisted of a single pass, covering 37 m at the base of the hole and 649 m below the casing. Only two of the four sensor pads functioned at any one time during this run. Because of the amount of hole logged and the loss of two pads, rigorous non-standard processing was required.

Water Sample Temperature Probe (WSTP)

The electronics technician prepared the WSTP for collecting an *in situ* borehole fluid sample spiked with sodium bromide. Unfortunately, we did not have time to run this instrument.

Vertical Seismic Profile (VSP)

We readied the 400 $in.^3$ water gun and associated equipment in anticipation of deploying the VSP seismometer. The VSP experiment was canceled at the end of the leg.

Inventory Management

The storekeeper performed a complete inventory physical count during the long initial transit. Inventory was adjusted as necessary, resulting in over 20 requisitions for scientific supplies and spare parts.

Storeroom combination locks were changed during the leg, and access limited to key personnel.

As a routine procedure the storekeeper will stay an extra day in port at the end of the leg to make sure offgoing shipment paperwork is complete and shipping containers are properly labeled and identified.

Microscope Lab

During the Victoria port call a Zeiss representative removed the Nomarski attachments from two of the microscopes. The alignment was off and realignment can be done only at the factory. The Nomarski attachments are not required for shipboard work and will not be re-attached until further notice.

There was a large demand for photomicrographs this leg. The Photomicroscope III was used predominantly for this work. The photographer documented procedures for using this photomicroscope and updated the "Shipboard Microscope Manual" with these current procedures.

Paleomagnetics Lab

A representative from 2G Enterprises attended the port call to direct the transfer of liquid helium into the cryogenic magnetometer. Due to problems with the lab's cryocoolers, the magnetometer had to be cooled to superconducting temperatures from near room temperature in a relatively short amount of time.

Although few samples were analyzed, analyses of these samples were extensive. In addition to the usual measurement of remanent magnetization after successively larger AF/thermal cleaning steps, PARM (partial anhysteretic remanent magnetization) and SIRM (saturation isothermal remanent magnetization) studies were conducted using the new Dtech PARM unit and new ASC IM-10 impulse magnetizer. Both the spinner and cryogenic magnetometers were used for magnetization measurements. The Schonstedt GSD-1 and the 2G 2600 degaussing system were used for AF cleaning. The cryogenic CUBE program was modified to allow entry of AF cleaning information previously applied, and a PIECE program was written to allow discrete measurement of archive-half pieces. The new CRYO software development is well under way.

Petrography Lab

One-hundred forty-four polished thin sections were produced; eight of these were made on large slides. Surface impregnations were required occasionally, when the sample was fractured.

X-ray Lab

A technical representative from Philips installed new X-ray-diffraction (XRD) software on a 486 IBM PC clone during the port call. The aging DEC PDP11 computer will no longer be used with this equipment. The representative also attempted to repair the XRD's goniometer, but determined that it must be returned to the factory; therefore, the XRD could not operate during Leg 140.

Eighty-five samples from Hole 504B were run for major and 84 for trace elements on the shipboard X-ray-fluorescence (XRF) unit. The XRF instrument produced precise results with major element percentage weight totals ranging from 99.2% to 100.5%. The DEC PDP11 computer that controls this instrument was not reliable. A computer upgrade for this instrument will be necessary in the near future.

Physical Properties

The multi-sensor track (MST) was not used this cruise, but new GEOTEK *P*-wave transducers were installed and tested. Discrete susceptibility measurements were made on all minicores. Thermal conductivity measurements were taken using the half-space configuration. The Hamilton Frame velocimeter was used to determine velocities of rock samples. Hardware and software upgrades that will allow the new digital sonic velocimeter (DSV) system to measure indurated samples are under way. The penta-pycnometer worked well for collection of index properties, and the balance system was improved with the addition of new electronics and a vibration isolation table. Manuals were updated for thermal conductivity, index properties, and the MST.

Photo Lab

The photo lab was busy this cruise with photomicroscopy and engineering photos, in addition to the normal workload. A representative from Photo Lab Fabricators overhauled the Kreonite print processor during the Victoria port call. Tests of wet vs. dry hard rock close-up photography showed that the wet surface brought out many features not apparent in the dry sample.

LABORATORY MEASUREMENT SUMMARY

Holes:	1
Meters cored:	378.9
Meters recovered:	47.69
Total number of samples:	924

ANALYSES

Paleomagnetics Lab	
Susceptibility:	48 samples
Cryogenic magnetometer:	48 samples, 1300 analyses
Spinner magnetometer:	6 samples, 100 analyses
Impulse magnetometer:	6 samples
Physical Properties Lab	
Density:	75 measurements
Velocity:	49 measurements
Thermal conductivity:	94 measurements
Chemistry Lab	
CHNS	79 analyses
X-ray Lab	
Fluorescence	
Major elements:	85 samples x 10 elements = 850
Trace elements:	84 samples x 12 elements = 1008
Petrography Lab	
Thin sections:	144 slides
Underway Geophysics Lab	
Bathymetric data:	4081 nmi
Magnetics data:	4067 nmi