5. SITE 734[1]

Shipboard Scientific Party[2]

HOLE 734A

Date occupied: 6 November 1987

Date departed: 9 November 1987

Time on Hole: 45 hr 15 min

Position: 32°06.83′S, 57°07.81′E

Bottom felt (rig floor, m; drill pipe measurement): 3670.7

Distance between rig floor and sea level (m): 11.10

Water depth (drill pipe measurement from sea level, m): 3659.6

Total depth (rig floor, m): 3678.30

Penetration (m): 7.60

Number of cores (including cores with no recovery): 1

Total length of cored section (m): 7.60

Total core recovered (m): 0.05

Core recovery (%): 0.7

Hard rock:
Depth (mbsf): Not known
Nature: serpentinized lherzolite

HOLE 734B

Date occupied: 9 November 1987

Date departed: 9 November 1987

Time on hole: 16 hr 15 min

Position: 32°06.82′S, 57°07.80′E

Bottom felt (rig floor, m; drill pipe measurement): 3681.5

Distance between rig floor and sea level (m): 11.10

Water depth (drill pipe measurement from sea level, m): 3670.4

Total depth (rig floor, m): 3729.0

Penetration (m): 47.50

Number of cores (including cores with no recovery): 5

Total length of cored section (m): 47.50

Total core recovered (m): 1.10

Core recovery (%): 2.3

Oldest sediment cored:
Depth (mbsf): 9.50
Nature: foraminiferal ooze, sand, and gravel
Earliest age: Holocene
Hard rock: gravel component of sediment
Nature: serpentinite, amphibolite, metagabbro, metabasalt, and alteration minerals

[1] Robinson, P. T., Von Herzen, R. P., et al., 1989. *Proc. ODP, Init. Repts.*, 118: College Station, TX (Ocean Drilling Program).

[2] Shipboard Scientific Party is as given in the list of participants preceding the contents.

HOLE 734C

Date occupied: 9 November 1987

Date departed: 9 November 1987

Time on hole: 1 hr 30 min

Position: 32°06.81′S, 57°07.84′E

Bottom felt (rig floor, m; drill pipe measurement): 3706.0

Distance between rig floor and sea level (m): 11.10

Water depth (drill pipe measurement from sea level, m): 3694.9

Total depth (rig floor, m): 3725.0

Penetration (m): 19.0

Number of cores (including cores with no recovery): 1

Total length of cored section (m): 19.0

Total core recovered (m): 0

Core recovery (%): 0

HOLE 734D

Date occupied: 9 November 1987

Date departed: 9 November 1987

Time on hole: 3 hr

Position: 32°06.79′S, 57°07.84′E

Bottom felt (rig floor, m; drill pipe measurement): 3720.0

Distance between rig floor and sea level (m): 11.10

Water depth (drill pipe measurement from sea level, m): 3708.9

Total depth (rig floor, m): 3739.50

Penetration (m): 19.50

Number of cores (including cores with no recovery): 1

Total length of cored section (m): 19.50

Total core recovered (m): 0.79

Core recovery (%): 4.0

Oldest sediment cored:
Depth (mbsf): 19.50
Nature: foraminiferal ooze, sand, and gravel
Earliest age: Holocene
Hard rock: gravel component of sediment
Nature: serpentinite, amphibolite mylonite, metagabbro, metabasalt, and alteration minerals

HOLE 734E

Date occupied: 9 November 1987

Date departed: 10 November 1987

Time on hole: 20 hr

Position: 32°06.76′S, 57°07.75′E

Bottom felt (rig floor, m; drill pipe measurement): 3746.2

Distance between rig floor and sea level (m): 11.10

Water depth (drill pipe measurement from sea level, m): 3735.1

Total depth (rig floor, m): 3755.70

Penetration (m): 9.50

Number of cores (including cores with no recovery): 1

Total length of cored section (m): 9.50

Total core recovered (m): 0

Core recovery (%): 0

HOLE 734F

Date occupied: 11 November 1987

Date departed: 12 November 1987

Time on hole: 18 hr

Position: 32°06.87′S, 57°08.22′E

Bottom felt (rig floor, m; drill pipe measurement): 3436.0

Distance between rig floor and sea level (m): 11.10

Water depth (drill pipe measurement from sea level, m): 3424.9

Total depth (rig floor, m): 3450.0

Penetration (m): 14.0

Number of cores (including cores with no recovery): 1

Total length of cored section (m): 14.0

Total core recovered (m): 0.10

Core recovery (%): 0.7

Hard rock:
Depth (mbsf): not known
Nature: serpentinized peridotite rubble

HOLE 734G

Date occupied: 12 November 1987

Date departed: 13 November 1987

Time on hole: 38 hr

Position: 32°06.87′S, 57°08.24′E

Bottom felt (rig floor, m; drill pipe measurement): 3428.5

Distance between rig floor and sea level (m): 11.10

Water depth (drill pipe measurement from sea level, m): 3417.4

Total depth (rig floor, m): 3459.50

Penetration (m): 31.0

Number of cores (including cores with no recovery): 3

Total length of cored section (m): 31.0

Total core recovered (m): 5.95

Core recovery (%): 19.1

Oldest sediment cored:
Depth (mbsf): 23.50
Nature: calcareous and foraminiferal ooze, drill cuttings, and breccia
Earliest age: early Pleistocene
Hard rock: cuttings/breccia component of sediment
Nature: serpentinite, metagabbro, metabasalt, and alteration minerals

Principal results: Site 734 is located on the east wall of the Atlantis II Transform at about 32°07′S, 57°08′E. The objectives at this site were to sample a section of upper mantle peridotite and to drill a deep basement hole that could be used to conduct downhole geophysical measurements and experiments. Mostly peridotite and dunite with minor basalt were recovered from two dredge hauls done during the pre-cruise site survey in this vicinity. Site 734 was selected for basement drilling because the topography indicated a steep, regular slope for this part of the transform wall without any indication of slumping or landsliding. We hoped that a small, relatively flat bench could be found on which to deploy the hard-rock guidebase. This would allow us to drill into the underlying peridotite.

JOIDES Resolution arrived at Site 734 on the morning of 6 November 1987 and dropped two beacons. A television/sonar survey located two areas of basement outcrop: one on the wall of a gully or small canyon at a water depth of about 3750 m and the other about 700 m to the east and about 350 m shallower, probably on a small fault scarp.

Seven holes were drilled at this site: Holes 734A through 734E at the deeper site and Holes 734F and 734G at the shallower site. Significant penetration was achieved only in Holes 734B and 734G (47.5 and 31.0 meters below seafloor [mbsf], respectively). A total of about 8 m sediment containing various clasts of igneous and metamorphic rock was recovered, chiefly from Holes 734B, 734D, and 734G.

Similar sequences of graded sand and gravel, each about 80 cm long, were recovered in Holes 734B and 734D. The grain size in these sequences decreases upward regularly, from pebbles at the base to fine sand at the top. The upper few centimeters in each sequence consist of foraminiferal ooze and sand. Rock fragments in the gravels range up to 3.5 cm long and are angular to subangular. These fragments consist of serpentinite, amphibolite mylonite, metagabbro, and metabasalt. Fragments of aragonite and other alteration minerals, such as prehnite, talc, and tremolite, make up 10% to 15%.

A 6-m-long section of highly disturbed, soupy sand and gravel composed of ultramafic material was recovered in Hole 734G. Based on its soupy nature, lack of stratification, and poorly sorted texture, we believe that this material represents drill cuttings or sediment that slumped into the hole from above.

The uppermost sediments in Holes 734B and 734D contain abundant, well-preserved foraminifers and calcareous nannofossils; the nannofossils are dated as Holocene. The sediments recovered from Hole 734G are probably early Pleistocene in age, somewhere between 1.37 and 1.88 Ma.

Most of the recovered clasts in the sediment consist of highly metamorphosed and deformed peridotite and metagabbro; a few are composed of amphibolite mylonite, metabasalt, and carbonate-cemented breccia containing amphibolite and serpentinite clasts. The ultramafic rocks are foliated lherzolite and harzburgite composed of about 75% serpentine, 10% magnetite, and 10% to 15% relict primary olivine, orthopyroxene, and clinopyroxene. Two of the ultramafic samples are cut by calcium silicate veins composed chiefly of prehnite. In the metagabbros, the original plagioclase and clinopyroxene have been largely replaced by clay minerals, albite, actinolite, and prehnite. Both the mylonite and breccia are almost devoid of primary minerals.

The television/sonar survey conducted at this site revealed a steep slope (about 24°) heavily mantled with talus and sediment. Basement crops out only along steep cliffs on the walls of gullies and canyons or on fault scarps. None of the recovered core can be unequivocally interpreted as basement, but the abundance of ultramafic clasts and fragments suggests that such material is present beneath the rubble and talus.

Site 734 was abandoned after numerous unsuccessful attempts to sample basement. We encountered considerable difficulty in starting a hole on such a steeply sloping cliff. For those holes where spud-in was successful (Holes 734B and 734G), drilling conditions were poor; thus, we decided the site was unsuitable for deployment of the hard-rock guidebase.

BACKGROUND AND SCIENTIFIC OBJECTIVES

While searching for an outcrop of peridotite on which the hard-rock guidebase could be deployed for drilling a deep basement hole, we moved to Site 734 on the east wall of the Atlantis II Transform (Fig. 1). After considering several possible locations on the transform walls, we selected Site 734 because the topography indicated a steep, regular slope with no sign of landsliding. From two dredge hauls in this vicinity performed during the pre-cruise site survey, peridotite and dunite were recovered; thus, we expected these steep slopes to provide good locations for outcrop. Structural models for development of the trans-

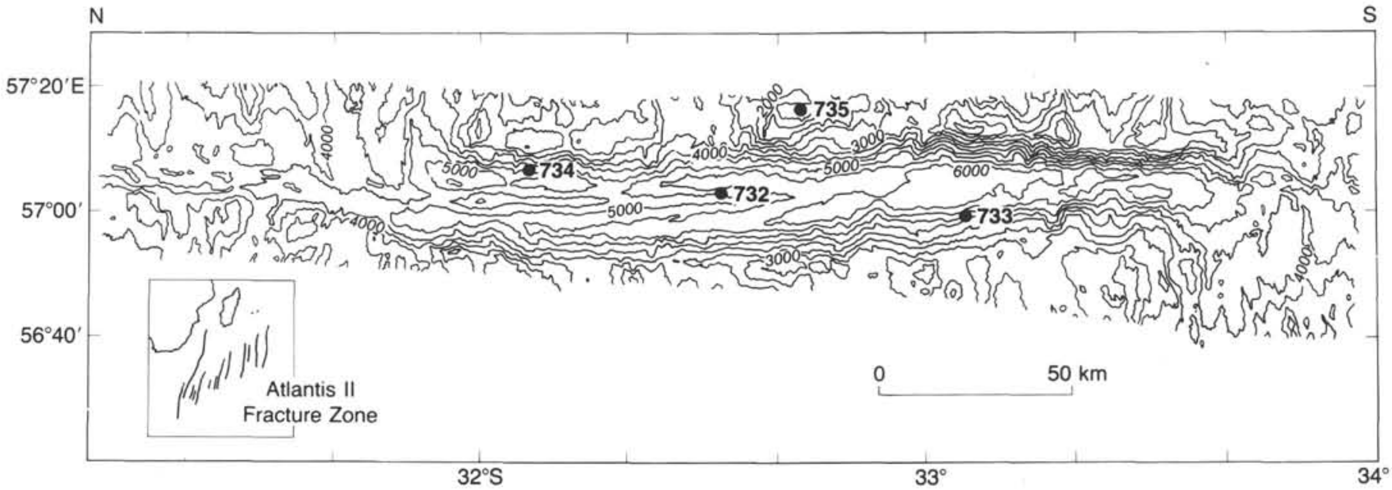

Figure 1. Bathymetric map at 500-m contour intervals of the Atlantis II Fracture Zone, Southwest Indian Ridge, showing Leg 118 drill sites. Survey from *Conrad* cruise 27-09, 1986 (H. Dick, Chief Scientist, with D. Gallo and R. Tyce).

form wall suggested a series of steep normal faults separated by small, relatively flat benches on which a guidebase could be deployed (H. Dick, pers. comm., 1987).

Two television/sonar survey lines run down the transform wall revealed bare-rock outcrops on the northern survey line. Two sites along this line were then selected for more detailed study. We found that at the lower site (at a water depth of about 3750 m), outcrops of igneous rock occurred on the wall of a gully or small canyon. The upper site, about 700 m to the east and about 350 m shallower, has massive outcrops along a small fault scarp.

The objectives at this site were (1) to sample a section of mantle peridotite and (2) to drill a deep hole in basement that could be used to perform downhole geophysical measurements and experiments.

GEOLOGIC AND TECTONIC SETTING

Site 734 is located on the east wall of the Atlantis II Transform at about 32°07′S and 57°08′E (Fig. 1), on a straight section of the transform wall, where there is no indication of landsliding or slumping. This part of the wall has a relief of about 2500 m over a horizontal distance of about 5.5 km, which results in an average slope of about 24°. Based on its location in magnetic anomaly 2, this part of the transform has an age of about 3 Ma.

One structural model of the transform walls suggests that the slopes are composed of a number of steep normal faults separated by relatively small, flat benches (H. Dick, pers. comm., 1987). From two dredge hauls conducted during the pre-cruise site survey, peridotite, dunite, and a small amount of basalt were recovered (H. Dick, pers. comm., 1987). The steep slope of this wall near the location of Site 734, suggested that outcrops would be less likely to be covered with talus and rubble than was the case at Site 733.

A television/sonar survey performed in the vicinity of Site 734, however, showed that the transform wall was heavily mantled with talus and finer-grained sediment. Basement was seen to crop out in only two areas: on the walls of a gully or small canyon and along a small fault scarp at a relatively high position on the transform wall. These outcrops consist of coherent, massive rock, probably peridotite, as this was the dominant rock type recovered by drilling at this site.

OPERATIONS

Introduction

Site 734 was selected to contrast with the previously occupied sites of Leg 118. It is located on the relatively steep (25° to 35°) east wall of the transform in relatively young crust created at the northern spreading center adjacent to the transform. We hoped that there would be significantly less rubble and breccia on this steep wall than we encountered at the previous two sites, and that basement rocks might crop out at the surface. The site was selected using data from the site survey for Leg 118 (H. Dick, pers. comm., 1987). The Sea Beam bathymetric maps created during that survey allowed us to select a location with a relatively uniform slope over a depth range from about 2 to 6 km, including a small bench at its southern extremity. Two dredge hauls (DR-18 and DR-19), recovered at the northern end of this site, consisted primarily of peridotite and dunite, respectively, rock types which we wished to drill during this leg.

Approach to Site 734

Site 734 was approached from the south along the transform valley as the ship transited from the previous site. An S-shaped track pattern (Fig. 2) was used to locate the appropriate depths along the north-south lineated east wall where we could deploy the location beacons. At this site we decided to drop two beacons about 2 nmi apart in a north-south direction so as to survey more of the transform wall than was possible at previous sites. The separation distance between beacons was approximately the maximum for which they could be tied together navigationally, using the ship's acoustic positioning system.

As with previous approaches, the ship was slowed to about 5-6 kt, with the seismic profiling system operating so that reliable bottom depths were recorded. Global positioning system (GPS) navigation was generally available for the approach, although not as continuously as we had expected. After dropping beacon 1 at a location determined by GPS navigation and bathymetry, a hiatus in GPS coverage during the survey caused the ship to turn eastward prematurely toward the anticipated deployment location of beacon 2, which was quickly rectified by changing to a more northerly course after re-acquiring GPS navigation. The Sea Beam bathymetric contour map appeared nearly coincident with depth soundings acquired during the drill ship's approach, and the beacons were dropped at the planned

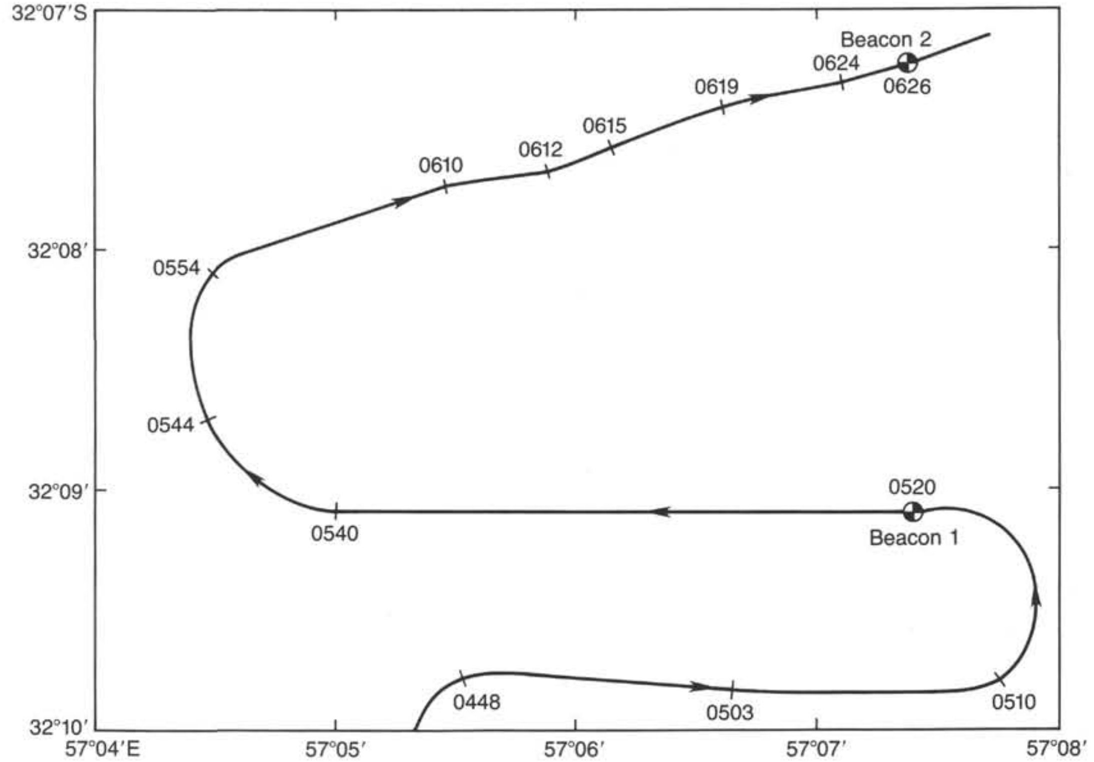

Figure 2. Ship track line followed for deployment of two beacons at Site 734 on 6 November 1987. Times along track are local (UTC + 4 hr). Beacon 1 is located at 32° 09.1′S, 57°07.5′E, and beacon 2 is located at 32°07.2′S, 57°07.4′E. Drill holes are located outside the boundaries of this plot.

locations (Fig. 2) in water depths of about 4.4 and 4.1 km, respectively, for beacons 1 and 2 (Fig. 3).

Television/Sonar Survey

The survey lines consist of three profiles run downslope (two of which are shown in Fig. 4), as on previous surveys during Leg 118, to minimize the possibility that the instrument might be caught on bottom irregularities. The first and northernmost profile, between bottom depths of about 3300 and 4400 m, was the most interesting because we observed several rock outcrop areas that were promising drilling targets. These were located at depths of about 3400 and 3750 m on the slope, the latter apparently on the side of a canyon or fault approximately subparallel to the survey track. The other two profiles were not as useful or interesting because they revealed sedimented or rubbly rock surfaces over their entire lengths, which made them problematical as drilling targets. The middle profile extended over bottom depths ranging from about 3300 to 4300 m, and the southernmost one (not shown in Fig. 4) ranged between a depth of about 3900 and 4900 m. A relatively flat bench was also observed in this profile. One drilling difficulty foreseen from the surveys was that most rock outcrops occurred on steep slopes, whereas less steep slopes were invariably obscured by sediment or rubble. This initial survey took 33.75 hr, including the time for camera deployment.

After drilling some of the initial holes at this site, two mini-surveys were performed around the outcrop areas located along the first survey line (Fig. 5). One of these surveys better defined the regions of outcrop at the shallowest site at a depth of 3400, and the other investigated a fault scarp along which occurred relatively sharp lateral transitions (only a few tens of meters) from sediment/rubble to extremely steep (up to vertical) canyon walls with massive rock outcrop. These two surveys were done by lowering the TV/sonar once, which took about 13 hr, including time for camera deployment. Several holes were drilled at each of two locations on the fracture zone wall at water depths of about 3750 and 3400 m (Table 1, Fig. 5), generally resulting in minimal recovery.

Hole 734A

We decided to use the positive displacement coring motor for the test spud-in. The bottom hole assembly (BHA) was composed of a 10 1/2 in. bit, coring motor, crossover, five 8 1/4 in. drill collars, crossover, one 7 1/4 in. drill collar, crossover, and six stands of 5 1/2 in. drill pipe. The bit was in contact with the seafloor at 3670.7 meters below rig floor (mbrf). The hole was cored to 7.6 mbsf in 75 min (Table 1), at which depth we had to connect more drill pipe. Although the bit was at 4 mbsf when the connection was made, the pipe pulled out of the hole when the ship heaved from a large wave. We recovered the core barrel, but two latch fingers were left in the motor and we had to pull the drill string to assure that its segments were not positioned so as to damage the core barrel and the motor.

Hole 734B

Because of the relatively favorable drilling conditions in Hole 734A, we decided to try the rotary drilling system in an effort to obtain deeper penetration. The bit took weight at 3681.5 mbrf and was advanced 9.5 m in 10 min (Table 1). A 1.1-m-long core composed of sand and gravel and foraminiferal ooze was recovered. Four more cores were attempted; little or no weight was required, and the drilling time for each core was only 2 to 4 min. No core was recovered. At 41.5 mbsf, we ran a deviation survey in an attempt to determine the angle of the BHA. We suspected that the drill pipe might be going down the side of a cliff, not drilling a hole. The pictures were blurred because of pipe mo-

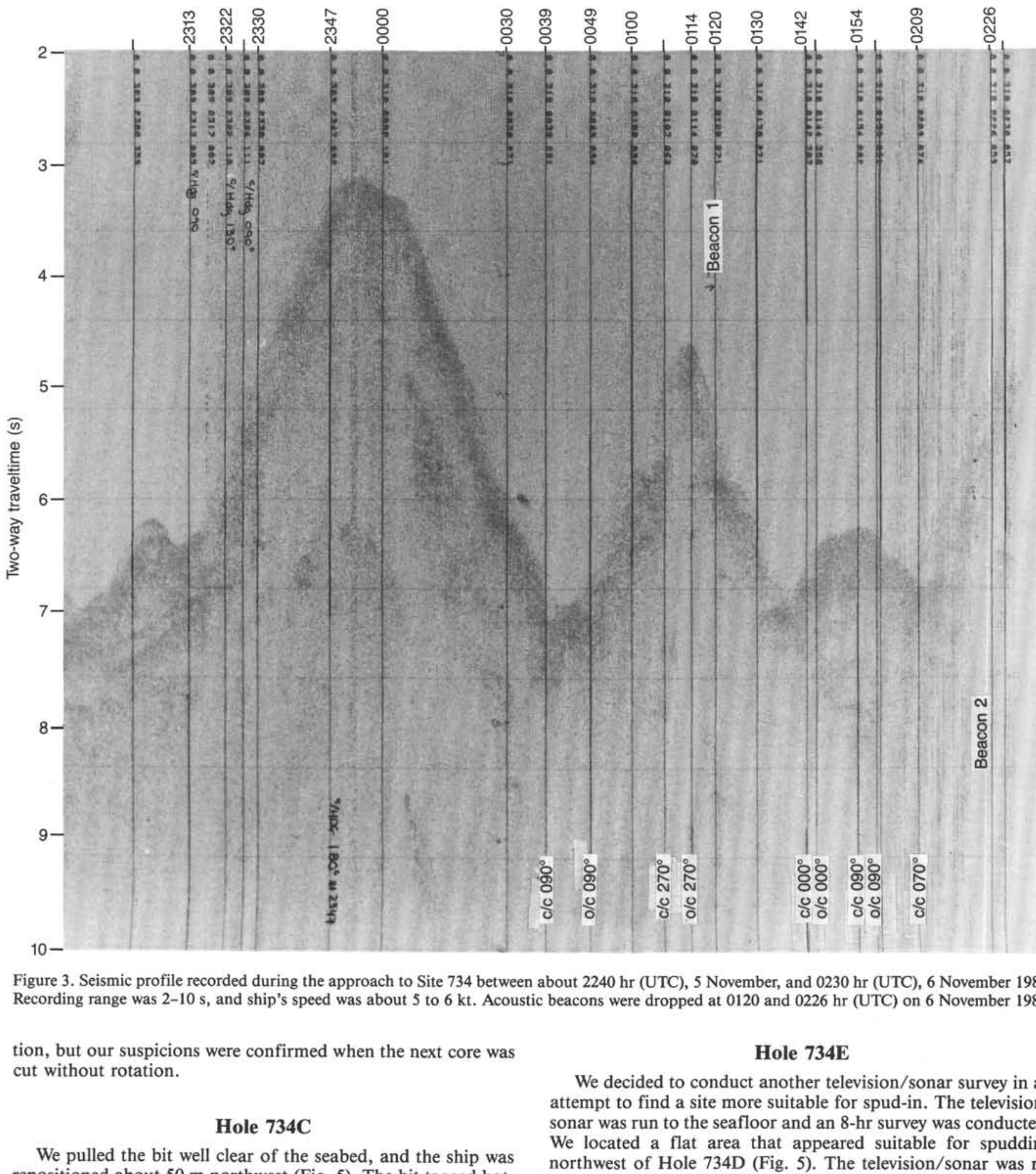

Figure 3. Seismic profile recorded during the approach to Site 734 between about 2240 hr (UTC), 5 November, and 0230 hr (UTC), 6 November 1987. Recording range was 2–10 s, and ship's speed was about 5 to 6 kt. Acoustic beacons were dropped at 0120 and 0226 hr (UTC) on 6 November 1987.

tion, but our suspicions were confirmed when the next core was cut without rotation.

Hole 734C

We pulled the bit well clear of the seabed, and the ship was repositioned about 50 m northwest (Fig. 5). The bit tagged bottom at 3706 mbrf and was advanced 19 m with 20 pump strikes per minute and 0 rpm. No doubt the bit went down the side of the hill again.

Hole 734D

The ship was repositioned 50 m north (Fig. 5). The bit tagged bottom at 3720 mbrf and was advanced 19.5 m in 6 min. Once again, the drill was going downslope. A total of 0.79 m of sand and gravel was recovered (Table 1).

Hole 734E

We decided to conduct another television/sonar survey in an attempt to find a site more suitable for spud-in. The television/sonar was run to the seafloor and an 8-hr survey was conducted. We located a flat area that appeared suitable for spudding northwest of Hole 734D (Fig. 5). The television/sonar was recovered, and the bit took weight at 3746.2 mbrf (Table 1). We rotated the pipe for 90 min, and it advanced 9.5 m. It looked as if we had achieved a successful spud-in using the rotary system. However, at 9.5 mbsf the bit suddenly became stuck. The pipe was worked with up to 200,000 lb overpull for 45 min. The stuck pipe was worked up the hole about 4 m, at which point it came free. Because of stretch, the drill pipe rebounded out of the hole.

The wireline was run to recover the core barrel, but the barrel could not be latched. We then checked the pump rate, but pressure was low, indicating that the BHA was open-ended.

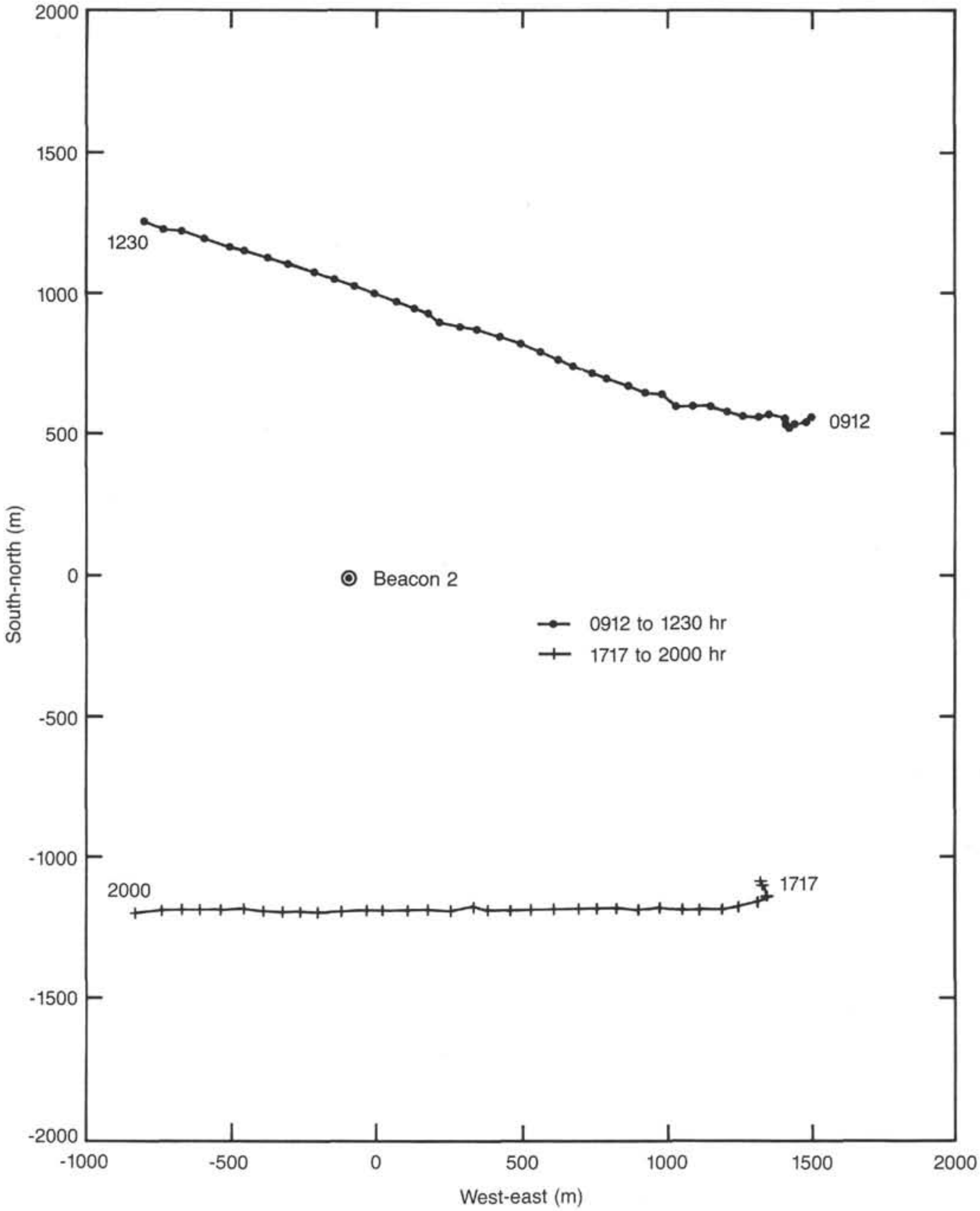

Figure 4. Navigation for two of the three television/sonar survey profiles at Site 734 on 6 November 1987. Symbols along profiles are shown approximately at 5-min intervals during surveys, between times (UTC) as indicated. Coordinates are in meters from beacon 2. The southernmost profile south of beacon 1 is not shown (survey data between 0450 and 0830 hr UTC, 7 November 1987).

We pulled the drill pipe to the surface and found that the bit had been torn from the bottom drill collar. The failure point was the pin of the collar. The fracture surface indicated a tension-bending overload. Note that it should take at least 1 million pounds of tension to pull apart this particular pin. Most amazingly, the drill collar was bent 4 m up from the pin. None of the experienced oilfield personnel onboard the ship had ever seen a bent drill collar.

Hole 734F

We again ran the television/sonar to the seafloor and found a flat area about 350 m upslope of Holes 734A through 734E. Because of our earlier problems when the bit of the rotary drilling assembly went downhill, the coring motor and a 10 1/2 in. bit were picked up. The BHA was inspected on its way into the hole, and we found a cracked drill-collar pin.

Using the television/sonar, we saw the bit skid around on a hard flat bottom, but after a few minutes we were able to begin drilling at 3436 mbrf. A few tenths of a meter of hole had been drilled before our view was obscured by a cloud of cuttings in the water. The television/sonar was raised several meters to remove it from the worst of the drill-pipe vibration. Surface indications were that we were drilling a new hole in a soft formation; a total of 14 m of hole was drilled in 14 min. The cloud of

Table 1. Coring summary for Site 734.

Hole, Core no.	Date (Nov. 1987)	Time (local)	Total depth[a] (mbrf)	Depth (mbsf)	Length advanced (m)	Length cored (m)	Length recovered (m)	Recovery (%)
118-734A-1D	8	1630	3670.7-3678.3	0-7.6	7.6	7.6	0.05	0.7
734B-1R	9	1250	3681.5-3691.0	0.0-9.5	9.5	9.5	1.10	11.6
734B-2R	9	1345	3691.0-3700.5	9.5-19.0	9.5	9.5	0.0	0
734B-3R	9	1450	3700.5-3710.0	19.0-28.5	9.5	9.5	0.0	0
734B-4R	9	1555	3710.0-3719.5	28.5-38.0	9.5	9.5	0.0	0
734B-5R	9	1640	3719.5-3729.0	38.0-47.5	9.5	9.5	0.0	0
[b]734C-1R	9		3706.0-3725.0	0-19.0	19.0	19.0	0	0
734D-1R	9	2300	3720.0-3739.5	0-19.5	19.5	19.5	0.79	4.0
[c]734E-1R	9		3746.2-3755.7	0-9.5	9.5	9.5	0	0
734F-1D	12	0145	3436.0-3450.0	0-14.0	14.0	14.0	0.10	0.7
734G-1D	12	1240	3428.5-3441.5	0-13.0	13.0	13.0	0	0
734G-2D	12	1730	3441.5-3451.0	13.0-22.5	9.5	9.5	0	0
[d]734G-3D	13	1700	3451.0-3459.5	22.5-31.0	8.5	8.5	5.95	70.0

[a] Determined from pipe length below rig floor.
[b] Core barrel not retrieved.
[c] No core—lost BHA.
[d] Drill cuttings.

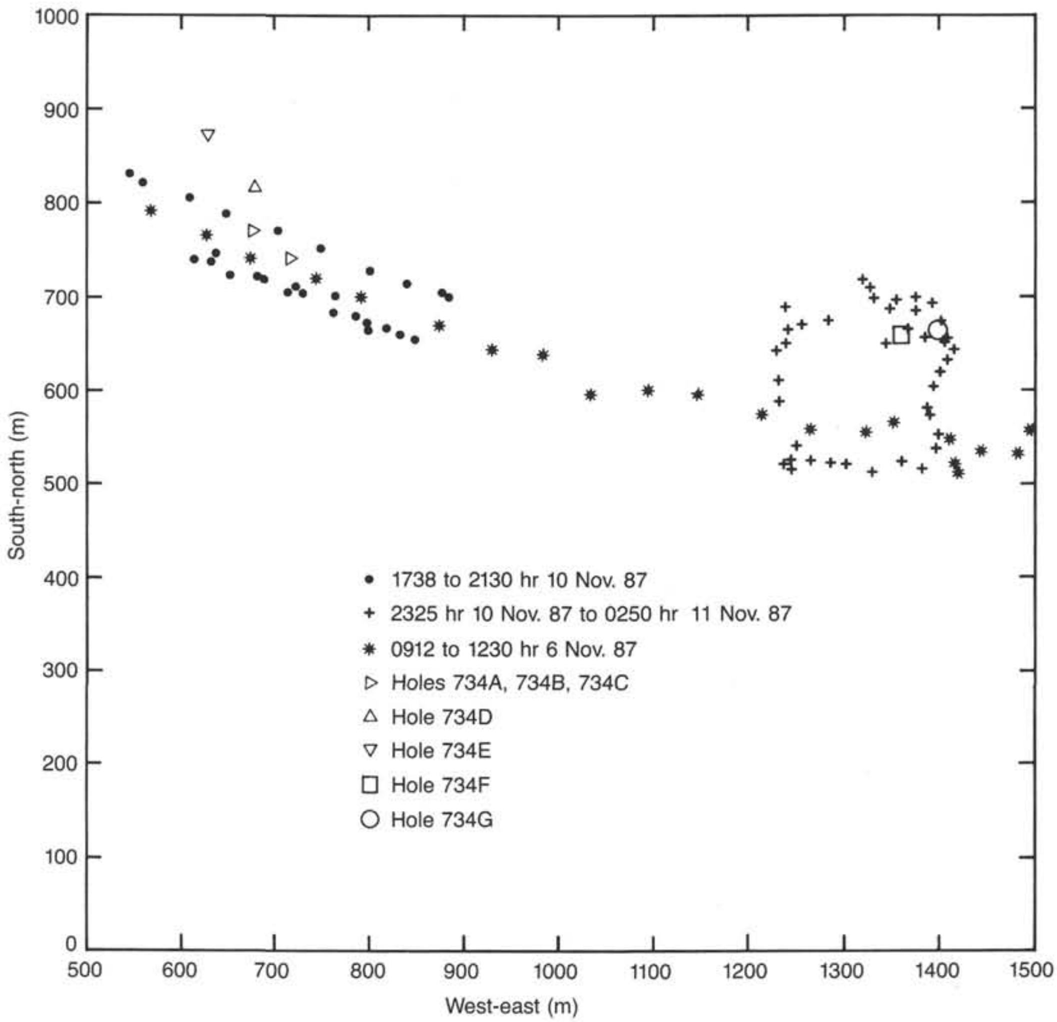

Figure 5. Navigation for television/sonar minisurveys at Site 734. Coordinates are in meters from beacon 2. Star symbols are part of northernmost survey line shown in Figure 4. Solid dots and plus symbols indicate locations along minisurvey tracks at approximate 5-min intervals, between times (UTC) as indicated. Open symbols are hole locations at this site.

cuttings was allowed to settle, and the television/sonar was lowered to observe the new hole. The bit had become unseated from the hole and once again had gone down a steep slope.

Hole 734G

The bit was raised to 3423 mbrf, and the ship repositioned a few meters east as we searched for a better drill site (Fig. 5). A likely spot was found, and Hole 734G was begun at 3428.5 mbrf (Table 1). The first core penetrated 13 mbsf, but there were serious problems with the hole collapsing when the bit was raised up off the bottom. Before attempting to wireline the core barrel, we filled the hole with 10.2 lb/gal ultra high-viscosity mud. Core recovery was zero. The second core advanced 9.5 m in 3.4 hr. Although more than 100 bbl of mud was used in slugs, the hole kept collapsing. Thus, while the barrel was wirelined, 8 m of hole was lost; again, nothing was recovered.

The third core advanced the bit 8.5 m in 7 hr to 31 mbsf (Table 1). Torque and drag were not abnormal, but nearly every time the bit was raised from bottom, the hole filled in beneath it. There were no incidents of the hole filling in from above, it was always from beneath the bit. We also saw that when the pumps were working, the caving problem was less serious. At 31 mbsf, we attempted to wireline the core barrel. The barrel was not latched during three runs; eventually, the collapsing hole drove the bit up to the mudline and the hole had to be abandoned. We recovered 5.95 m of drill cuttings and breccia, with some calcareous/foraminiferal ooze.

SEDIMENTOLOGY

Approximately 8 m of sediment was recovered in three of seven holes drilled at Site 734. In Hole 734B, coring from 0 to 9.5 mbsf recovered a single graded section 76 cm long (Section 118-734B-1R-1). Recovery from the core-catcher sample was a 35-cm-thick interval of pebble-sized material. Sediment at the base of Section 118-734B-1R-1 is well-sorted, dark to very dark grayish brown (2.5Y 4/2) gravel of igneous lithology: serpentinite, amphibolite, metagabbro, metabasalt, and 10%-15% alteration minerals (aragonite, prehnite, talc, and tremolite). Fragments range up to 3.5 cm long and are angular to subangular. Grain size decreases smoothly upward to a well-sorted coarse sand at a depth of about 50 cm, with no apparent change in lithology. There is no visual evidence of stratification within the graded interval. Most sand and gravel grains are angular. Many are platy, but there is no apparent preferred orientation. At a depth of 25 cm, foraminifers appear and increase in abundance upward to 30%-40% at a depth of about 5 cm; grain size decreases to medium sand. At a depth of 4 cm, there is a gradual color and compositional change over a 2- to 3-mm-thick interval. This contact curves down about 10 cm along the core liner, and a sediment gap of 2-3 cm occurs in the middle of the core. Above the contact, the sediment is homogeneous, light gray (2.5Y 7/2), well-sorted, foraminiferal ooze (fine sand). At a depth of 1 cm, there is a sharp contact overlain by homogeneous, light brownish-gray (2.5Y 6/2) foraminiferal ooze. The foraminifers are distinctly smaller above the contact.

In Hole 734D, we recovered a graded section 79 cm thick (Section 118-734D-1R-1) having texture and lithology similar to those at Hole 734B. Grain size decreases upward, with no stratification from gravel at the base to fine foraminiferal sand at the top. The principal lithology of the gravel pebbles is amphibolite mylonite. Carbonate veins (comb-textured aragonite) and coatings are common. Concretions, formed of silt and sand-sized igneous rock chips (commonly serpentinite) cemented by aragonite, make up 10%-20% of the gravel.

The material recovered in Hole 734D differs from that in Hole 734B in two respects. First, the core from Hole 734D has a large clast (about 6 cm in diameter) of foliated serpentinized peridotite resting in a matrix of unconsolidated sand at a depth of between 15 and 20 cm. Second, although foraminifers make up 70%-90% of the sediment in the upper 5 cm, there are no distinct layers of foraminiferal ooze. The size grading, angularity of the grains, and apparent lack of stratification and fabric in sediment recovered in Holes 734B and 734D are consistent with deposition from turbidity currents. However, the weight-on-bit record indicates that during drilling, the bit may have lifted off the bottom of the hole several times. The graded beds may have been sorted by repeated resuspensions and resettling of unconsolidated sediment within the core barrel, by physical movement of the core barrel, and by injection of fluid upward through the bit.

The longest section was obtained from Hole 734G. Although we drilled and cored to 22.5 mbsf in this hole, we recovered no material (Table 1), but after drilling to 31 mbsf, a 6-m-long section (118-734G-3D-1) of soupy sand and gravel having ultramafic lithology, as well as about 20 cm of sticky foraminiferal ooze, were recovered. Based on the soupy nature of the core on recovery, lack of stratification, and the poorly sorted texture, we believe that this sequence probably represents cavings from shallower sediment sections (sticky foraminiferal ooze) and from drill cuttings (rock fragments).

BIOSTRATIGRAPHY

The sediments recovered from Cores 118-734B-1R, 118-734D-1R, and 118-734G-3D were examined in smear slides and proved to contain abundant and well-preserved foraminifers and calcareous nannofossils. The sediments from Holes 734B and 734D are dated by calcareous nannofossils as Holocene, whereas lower Pleistocene sediments were obtained from Hole 734G.

Calcareous Nannofossils

From Hole 734B, we examined three levels: Samples 118-734B-1R-1, 1 cm; 118-734B-1R-1, 5 cm; and 118-734B-1R-1, 15 cm, in the light microscope, and Sample 118-734B-1R-1, 5 cm, in the scanning electron microscope as well. Sample 118-734D-1R, 3 cm, also was examined in the light microscope. The nannoflora is composed of dominant *Emiliania huxleyi*, *Gephyrocapsa oceanica*, and *Calcidiscus leptoporus*. Also observed were *Ceratolithus telesmus*, *Ceratolithus cristatus*, *Gephyrocapsa* spp., *Helicosphaera carteri*, *Oolithotus fragilis*, *Pontosphaera indoceanica*, *Pontosphaera japonica*, *Rhabdosphaera claviger*, small placoliths, *Scapholithus fossilis*, *Syracosphaera pulchra*, *Umbellosphaera irregularis*, and *Umbilicosphaera sibogae*.

These sediments belong to Zone NN21 of Martini (1971) and the *Emiliania huxleyi* Acme Zone of Gartner (1977). McIntyre et al. (1970) pointed out that the absence of *Coccolithus pelagicus* in the Southern Hemisphere is a post-glacial phenomenon. Gard (in press) observed that *C. pelagicus* is abundant in the southern Indian Ocean during the last glaciation (oxygen isotope stages 2-4), but is absent in Holocene sediments. As this species was not observed in Holes 734B and 734D, we concluded that these sediments are Holocene.

Three levels were analyzed from Hole 734G: Samples 118-734G-3D-1, 1 cm; 118-734G-3D-1, 10 cm; and 118-734G-3D-2, 1 cm. These samples contain the same nannofossil assemblage, which is dominated by *Gephyrocapsa caribbeanica*. Also present is *C. leptoporus*, *C. pelagicus*, *Helicosphaera sellii*, *H. carteri*, *Pontosphaera* sp., *Pseudoemiliania lacunosa*, *Syracosphaera* sp., *Umbilicosphaera* sp., and *R. claviger*. The presence of *P. lacunosa* and *H. sellii*, in combination with the absence of discoasters, suggests that these sediments are lower Pleistocene and belong to Zone NN19 of Martini (1971). Backman and Shackleton (1983) found that the last discoaster became extinct at 1.88 Ma and that *H. sellii* disappears at about 1.37 Ma, which thus gives maximum and minimum ages for the sediments from Hole 734G.

LITHOSTRATIGRAPHY

No coherent section was recovered from any of the holes at Site 734. From Core 118-734A-1D we recovered one serpentinized peridotite cobble, and from Core 118-734F-1D we recovered five angular serpentinite pebbles. Cores 118-734B-1R, 118-734D-1R, and 118-734G-3D all contained various amounts of drilling-disturbed sediments and drill cuttings. These cuttings are graded in each core from pebbles to coarse sand to fine sand. The upper intervals in each core also include foraminifers. There is a serpentinite cobble between 13 and 20 cm in Section 118-734D-1R-1. Clasts in these cuttings include serpentinite, metagabbro, calcite-cemented breccias, and metabasalt. Serpentinite and calcite-cemented breccias and veins appear to be the dominant constituent of the pebbles and sand.

PETROGRAPHY

Introduction

Approximately 8 m of rock and sediment was recovered from Holes 734A through 734G, with a maximum penetration depth of 47.5 m in Hole 734B. All material recovered was moderately to highly metamorphosed, altered and/or deformed, and includes predominantly serpentinized peridotite and metagabbro. In this section, the primary mineralogy was interpreted from petrographic descriptions of selected clasts. Detailed discussions of alteration, metamorphism, and deformation are given in the "Metamorphism, Deformation, and Alteration" section (this chapter). Recovered material ranges from silt to pebble-sized (<6 cm) angular clasts. In three cores (118-734B-1R, 118-734D-1R, and 118-734G-3D), the material increases in grain size from top to bottom of the core. Thin sections were prepared from selected rubble clasts and are described next.

Serpentinized Peridotites

Ultramafic rocks recovered at Site 734 consist predominantly of foliated porphyroclastic serpentinized lherzolite and harzburgite. Two of the samples, 118-734B-1R, CC, 8–10 cm, Piece 3 and 118-734D-1R-1, 18–24 cm, Piece 1, are crosscut by aragonite veins. Point-counting of two samples, 118-734A-1D-1, 0–5 cm, Piece 1, and 118-734D-1R-1, 18–24 cm, Piece 1, indicates that these rocks contain 71%–77% serpentine (lizardite), 10%–11% magnetite, and less than 10%–15% relict primary olivine, orthopyroxene, and clinopyroxene. Of the relict minerals, olivine is most abundant (5%–10%) and occurs as small crystals (0.1–0.2 mm in size) or granulated masses interspersed within the mesh-textured serpentine. Orthopyroxene is largely replaced by bastite, with relict orthopyroxene making up less than 3% of most samples. However, bastite pseudomorphs suggest that orthopyroxene may have composed 10%–20% of the primary mineral assemblage. Relict clinopyroxene generally constitutes 1%–5% of the rock and occurs as small clusters of equant crystals 0.5 to 2 mm in size, although a few crystals as large as 4 mm were observed in Sample 118-734B-1R, CC, 8–10 cm, Piece 3. Golden brown, holly-leaf chromium-spinel occurs in abundances of less than 1%, but is largely unaltered. In Sample 118-734D-1R-1, 18–24 cm, Piece 1, spinel was observed in symplectic intergrowth with clinopyroxene. The present abundance of clinopyroxene (<5%) in these samples suggests that they were originally clinopyroxene-poor lherzolites or harzburgites.

Mafic Rocks

Gabbroic rocks recovered from Site 734 (Samples 118-734D-1R-1, 59–61 cm, Piece 1, and 118-734B-1R, CC, 5–7 cm, Piece 2) are plagioclase plus clinopyroxene rocks containing less than 40% of the primary mineralogy presented. Original proportions of plagioclase and clinopyroxene are estimated at 70%–85% and 15%–30%, respectively. Sample 118-734B-1R, CC (5–7 cm, Piece 2) is richer in plagioclase and was interpreted as an orthocumulate. In the gabbroic rocks, plagioclase is replaced by clay minerals, albite, actinolite, and prehnite, whereas clinopyroxene is replaced by amphibole. No relict iron-titanium oxides are present.

The remaining mafic rocks recovered include two samples of amphibolite mylonite (Samples 118-734D-1R-1, 74–77 cm, Piece 1, and 118-734D-1R-1, 67–68 cm, Piece 1) and one carbonate-cemented breccia that contains amphibolite and serpentinite clasts (Sample 118-734B-1R, CC, 0–4 cm, Piece 1). Two of these samples, 118-734B-1R, CC, 0–4 cm, Piece 1, and 118-734D-1R-1, 67–68 cm, Piece 1, are devoid of primary minerals, and Sample 118-734D-1R-1, 74–77 cm, Piece 1, has only about 2% primary subhedral plagioclase, with possible magmatic twinning. Sample 118-834D-1R-1, 67–68 cm, Piece 1, is fine-grained and was probably metamorphosed from a basalt, whereas the coarse grain size of porphyroclasts in Sample 118-734D-1R-1, 74–77 cm, Piece 1, suggests a gabbroic protolith.

METAMORPHISM, DEFORMATION, AND ALTERATION

Introduction

Coring at Site 734 recovered pebbles from unconsolidated rubble. The pebbles included: serpentinized peridotite, metamorphosed basalt and gabbro, foliated amphibolite with protolith unclear, a crosscutting network of calcium silicate and carbonate veins, and a carbonate-cemented breccia containing clasts of both foliated amphibolite and serpentinized peridotite, cut by veins of aragonite. Here, we describe the metamorphism, deformation, and alteration of the lithic fragments and summarize the mineralogy of the calcium silicate veins. This description is based on thin sections from selected pebbles: Samples 118-734A-1D-1, 0–5 cm, Piece 1; 118-734B-1R, CC, 8–10 cm, Piece 3; and 118-734D-1R-1, 18–24 cm, Piece 1; for the serpentinized peridotites; Samples 118-734B-1R, CC, 5–7 cm, Piece 2, and 118-734D-1R-1, 59–61 cm, Piece 1 for the metagabbro; Sample 118-734D-1R-1, 74–77 cm, Piece 1 for the metabasalt; Sample 118-734D-1R-1, 67–68 cm, Piece 1, for a foliated amphibolite; and Sample 118-734B-1R, CC, 0–4 cm, Piece 1, for the carbonate-cemented breccia.

Serpentinized Peridotites

The serpentinized peridotites consist of tectonized harzburgite and lherzolite (see "Petrography" section, this chapter), about 70% serpentinized. The serpentinization was static and preferentially affected the olivine-rich parts of the samples, now almost entirely replaced by a mesh of serpentine containing disseminated magnetite grains and brown clay minerals. Fresh pyroxene and spinel are still abundant. Extension fractures 1-mm-wide are filled with serpentine. In two of the three samples studied (118-734B-1R, CC, 8–10 cm, Piece 3, and 118-734D-1R-1, 18–24 cm, Piece 1), these extension fractures are nearly perpendicular to the spinel foliation and lineation. In all three of the samples studied, the serpentine mesh and extension veins are crosscut by 1-mm-wide, undeformed, carbonate veins.

The peridotites have a primary porphyroclastic texture, with a foliation and lineation defined by the elongation of spinel and pyroxene grains. The olivine grains (less than 1 mm in size) have straight grain boundaries and display deformation subgrain boundaries. Orthopyroxene and clinopyroxene grains are kinked and locally recrystallized to very small grains (less than 0.05 mm). These textures of the primary peridotites (see "Petrography" section, this chapter) suggest that the samples were plastically deformed at high temperatures (probably mantle temperatures) and moderate to relatively high differential stresses.

Metamorphosed Mafic Rocks

Two metagabbros (Samples 118-734B-1R, CC, 5–7 cm, Piece 2, and 118-734D-1R-1, 59–61 cm, Piece 1), one metabasalt (Sample 118-734D-1R-1, 74–77, Piece 1), an amphibolite mylonite (Sample 118-734D-1R-1, 67–68 cm, Piece 1) and clasts of foliated amphibolite in the carbonate-cemented breccia (Sample 118-734B-1R, CC, 0–4 cm, Piece 1) were examined petrographically. The extent of plastic deformation varies, being greater in the foliated amphibolite and in the metabasalt and comparatively less in metagabbro Sample 118-734D-1R-1, 59–61 cm, Piece 1. The only undeformed sample (118-734B-1R, CC [5–7 cm, Piece 2]) is a metagabbro.

All samples examined show evidence of an early high-temperature metamorphism that includes replacement of clinopyroxene by green or pale brown amphibole and recrystallization of the igneous plagioclase in the metagabbros. The clasts of foliated amphibolite in the carbonate breccia are similarly composed of aligned crystals of pale brown amphibole and metamorphic plagioclase. In the amphibolite mylonite, the amphiboles exhibit deformation twins, and the plagioclase and amphibole are somewhat segregated into layers. In all deformed samples, the formation of amphibole and recrystallization of plagioclase appear to be syndeformational. In the metagabbro (Sample 118-734D-1R-1, 59–61 cm, Piece 1), large grains of an unusually deep yellow sphene intermix with recrystallized amphibole that forms a metamorphic halo around a clinopyroxene porphyroclast. Gray sphene is found as small grains in this halo, and inclusions in the amphibolitized rim of the original pyroxene.

Static Alteration and the Calcium Silicate Veins

Early high-temperature deformation and metamorphism were followed by static metasomatic (?) or hydrothermal alteration at moderate temperatures. This alteration includes the following:

1. Replacement of plagioclase by prehnite and/or albite mixed with brown clay minerals.
2. Replacement of serpentine by tremolite and talc in the clasts of serpentinized peridotite of the carbonate breccia. The talc and tremolite mimics the mesh texture of the serpentine; euhedral magnetite grains contained within the serpentinite were replaced by hematite.
3. Limited replacement of primary hornblende by actinolite.

These replacements are all related to the network of fractures and calc-silicate veins that crosscuts most samples from Site 734. Prehnite is the most abundant vein-forming mineral in the metagabbro. The intergrown talc and tremolite fill veins in the breccia, as well as replace earlier minerals. A yellowish carbonate fills veins in the deformed metagabbro. A very tiny vein of chlorite crosscuts the mylonite. Other calcium silicates may be present in trace amounts. The vein network is best developed in the carbonate breccia (Sample 118-734B-1R, CC [0–4 cm, Piece 1]). An X-ray diffractogram revealed that all the multiple carbonate veins are aragonite. This mineral occurs as coarse twinned crystals and "stalactites" perpendicular to, and penetrating into, the fractures to form a comb texture. These vein fragments having comb textures are common in the rubble and may also make up the veins in the serpentinites.

GEOCHEMISTRY

Five fragments from the coarse gravels recovered at Site 734 were analyzed for major and trace elements using the shipboard X-ray fluorescence system. The analytical procedure is described in the "Introduction and Explanatory Notes" (this volume). Results are listed in Table 2.

Table 2. Compositions of major and trace elements of Site 734 samples.

Hole:	734B*	734B**	734D	734D	734D	734G
Section:	1R-1	1R-1	1R-1	1R-1	1R-1	3D-3
Interval (cm):	68–69	68–69	59–61	66–67	74–77	47–51
Type	SE		MG	SE	MB	SE
(in wt%)						
SiO_2	35.15	46.7	49.28	46.21	45.03	45.04
TiO_2	0.03	0.04	4.16	0.06	2.89	0.78
Al_2O_3	2.04	2.7	15.21	1.54	15.46	4.12
Fe_2O_3	6.09	8.1	11.01	10.72	9.82	10.61
MnO	0.09	0.12	0.25	0.30	0.19	0.15
MgO	30.92	41.0	6.77	40.31	13.50	31.98
CaO	23.67	0.6	6.93	0.63	9.68	5.99
Na_2O	0	0	5.64	0	3.46	0.61
K_2O	0	0	0.45	0.07	0.09	0.08
P_2O_5	0.01	0.01	0.62	0.04	0.41	0.13
Cr_2O_3	0.37	0.5	—	0.18	—	0.24
NiO	0.22	0.3	—	0.29	—	0.19
SrO	0.50	—	—		—	
Sum	99.09	100.00	100.32	100.35	100.32	99.92
LOI	23.2		2.81	13	3.62	11.9
(in ppm)						
V	59		359	89	308	92
Cr	2510		33	1233	217	1607
Ni	1705		177	2260	307	1553
Cu	61		105	95	31	32
Zn	50		47	160	47	86
Rb	—		4	1	2	1
Sr	4211		192	25	122	397
Y	1.2		76	2.4	73	18
Zr	20		388	9.7	304	34
Nb	0.8		10	1	9	2.8

* Mixture of serpentine and aragonite vein material.
** Approximate composition of silicate fraction.
Major and trace elements on anhydrous basis; Sum is as measured by XRF on ignited samples; Type is SE = serpentinite; MG = porphyroclastic metagabbro; MB = foliated metabasalt; LOI = loss on ignition.

Sample 118-734D-1R-1, 59–61 cm, Piece 1, is a medium- to coarse-grained porphyroclastic metagabbro in which primary plagioclase is almost completely replaced by clay minerals and albite. The high titanium and iron contents and the uniformly high abundances of the strongly to moderately incompatible trace elements vanadium, yttrium, zirconium, and niobium set this metagabbro apart from the mesocumulate gabbros of Site 733 ("Geochemistry" section, Site 733 chapter). Because the zirconium/niobium (38.8), zirconium/yttrium (5.1), and yttrium/niobium (7.6) ratios are indistinguishable from primary magmatic ratios of depleted-normal mid-ocean ridge basalts (see "Geochemistry" section, Site 732 chapter), we believe it improbable that the enrichment of iron, titanium, vanadium, yttrium, zirconium, and niobium is from secondary alteration. Thus, the chemical composition of this rock corresponds to an iron- and titanium-enriched magmatic liquid, probably a recrystallized, altered basaltic dike (diabase) rather than a cumulate gabbro.

Sample 118-734D-1R-1, 74–77 cm, Piece 1, is a fine-grained foliated granoblastic metabasalt. It is less enriched in iron and titanium than Sample 118-734D-1R-1, 59–61 cm, Piece 1, but shows a similar enrichment of the incompatible trace elements vanadium, yttrium, zirconium, and niobium. Zirconium/niobium, zirconium/yttrium, and yttrium/niobium ratios are nearly the same in both samples. The relatively high MgO, chromium, and nickel contents of the metabasalt may be an artifact of sampling and reflect admixture of ultramafic fragments in the sample taken for analysis.

The other three samples analyzed are serpentinized peridotite. Judging from the high CaO content and high loss on ignition (loss of CO_2 in addition to H_2O), calcium carbonate vein material makes up about 30% of Sample 118-734B-1R-1, 68–69 cm. As is usually the case for serpentinized oceanic ultramafic rocks (e.g., Bonatti and Hamlyn, 1981), the calcium carbonate is fibrous aragonite (see "Metamorphism, Deformation, and Alteration" section, this chapter). The presence of aragonite explains the extremely high strontium content of this sample (8000–10,000 ppm strontium in marine aragonite vs. 1500–2500 ppm strontium in marine calcite).

Sample 118-734G-3D-3, 47–51 cm, consists of sand-sized (1 to 5 mm), lithic rubble and apparently is a mixture of serpentinite, aragonite (see high strontium content) and gabbro/metabasalt (see higher titanium, aluminum, yttrium, and niobium contents).

Sample 118-734D-1R-1, 66–67 cm, consists of a few serpentinized fragments, 1–2 cm in size, containing only minor amounts of carbonate vein material. This sample is probably the most representative of the ultramafic rocks that crop out at Site 734. The rather low titanium, aluminum, and calcium contents suggest that the serpentinites were derived from fairly depleted precursors of harzburgite.

SUMMARY AND CONCLUSIONS

Site 734 is located on the east wall of the Atlantis II Transform at about 32°07′S and 57°08′E. The objectives at this site were (1) to sample a section of upper mantle peridotite and (2) to drill a deep basement hole that could be used to conduct downhole geophysical measurements and experiments. From two dredge hauls in this vicinity, performed during the precruise site survey, mostly peridotite and dunite, with minor basalt, were recovered. Site 734 was selected for basement drilling because the topography indicated a steep, regular slope for this part of the wall with no indication of slumping or landsliding. One structural model for the transform wall suggested formation along a series of steep, normal faults separated by relatively flat benches (H. Dick, pers. comm., 1987). The presence of steep slopes on this part of the transform wall suggested that it might be a good location for finding basement outcrops. We planned to find a bench on which the hard-rock guidebase might be deployed and to drill into the underlying peridotite.

Two areas of basement outcrop were located during a television/sonar survey of the area: one on the wall of a gully or small canyon at a water depth of about 3750 m and the other on a small fault scarp, about 700 m to the east and 350 m shallower. Seven holes were drilled at this site: Holes 734A through 734E at the deeper site and Holes 734F and 734G at the shallower site. Significant penetration was achieved only in Holes 734B and 734G (47.5 mbsf and 31.0 mbsf, respectively). A total of about 8 m of sediment containing various clasts of igneous and metamorphic rock was recovered, chiefly from Holes 734B, 734D, and 734G.

Similar sequences of graded sand and gravel, each about 80 cm long, were recovered in Holes 734B and 734D. The grain size in these sequences decreases regularly upward from pebbles at the base to fine sand at the top. The upper few centimeters in each sequence consist of foraminiferal ooze and sand. Rock fragments in the gravels range up to 3.5 cm long and are angular to subangular. They consist of serpentinite, amphibolite mylonite, metagabbro, and metabasalt. Fragments of aragonite and other alteration minerals, such as prehnite, talc, and tremolite, make up 10%–15%.

A 6-m-long section of highly disturbed, soupy sand and gravel composed of ultramafic material was recovered in Hole 734G. Based on its soupy nature, lack of stratification, and poorly sorted texture, we believe that this material represents drill cuttings or sediment that slumped into the hole from above.

The uppermost sediments in Holes 734B and 734D contain abundant and well-preserved foraminifers and calcareous nannofossils. The nannofossils were assigned to Zone NN21 of Martini (1971) and are dated as Holocene based on the absence of *Coccolithus pelagicus*. The sediments recovered from Hole 734G contain a nannofossil assemblage dominated by *Gephyrocapsa caribbeanica* and were assigned to Zone NN19 of Martini (1971). Based on the absence of discoasters, the sediments are probably lower Pleistocene, between 1.37 and 1.88 Ma.

Most of the recovered clasts in the sediment consist of highly metamorphosed and deformed peridotite and metagabbro; a few clasts are composed of amphibolite mylonite, metabasalt, and carbonate-cemented breccia that contain amphibolite and serpentinite. The ultramafic rocks are foliated lherzolite and harzburgite composed of about 75% serpentine, 10% magnetite, and 10%–15% relict primary olivine, orthopyroxene, and clinopyroxene. Two of the ultramafic samples are cut by calc-silicate veins composed chiefly of prehnite. In the metagabbros the original plagioclase and clinopyroxene have been largely replaced by clay minerals, albite, actinolite, and prehnite. Both the mylonite and breccia are almost devoid of primary minerals.

The television/sonar survey conducted at this site revealed a steep slope (about 24°) heavily mantled with talus and sediment. Basement crops out only along steep cliffs on the walls of gullies and canyons or on fault scarps. None of the recovered core can be unequivocally interpreted as basement, but the abundance of ultramafic clasts and fragments suggests that such material is present beneath the rubble and talus.

Site 734 was abandoned after we made numerous unsuccessful attempts to sample basement. We encountered considerable difficulty in starting a hole on such a steeply sloping cliff. For those holes where spud-in was successful (Holes 734B and 734G), drilling conditions were poor, and we decided that the site was unsuitable for deployment of the hard-rock guidebase.

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