OCEAN DRILLING PROGRAM

LEG 176 SCIENTIFIC PROSPECTUS

RETURN TO HOLE 735B

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ABSTRACT

Hole 735B is located 18 km east of the Atlantis II Transform Fault on the Southwest Indian Ridge (SWIR) at a unique outcrop of lower oceanic crust exposed on a 15-km-long wave-cut terrace at 700 m water depth. The hole represents the deepest penetration into plutonic basement in the world’s oceans. Leg 176 will deepen Hole 735B to a nominal depth of 1.5 km, although it will attempt to go deeper if conditions permit. The proposed drilling has two principle objectives: (1) to test whether seismic layer 3 is principally constituted of gabbroic rock produced by igneous intrusion or whether it may contain substantial portions of partially serpentinized peridotite; and (2) to obtain a representative section of seismic layer 3 from which the magmatic, tectonic, and hydrothermal processes responsible for the accretion of the lower crust at slow-spreading ridges can be accurately inferred. The drilling results will provide a direct test of the accuracy of common assumptions made as to the composition of the lower crust and its thickness when computing global geochemical fluxes between the earth's interior, its crust, the oceans, and the atmospheres.

Extensive logging will be conducted, including Formation MicroScanner and a downhole Vertical Seismic Profile with a packer set for stability during the experiment. Downhole temperatures will be obtained along with the caliper log upon first re-occupying the hole.

If drilling conditions prevent deepening of Hole 735B, an alternate strategy, originally envisioned as the second of a two-leg drilling plan, will be adopted. This alternate strategy will test the lateral and temporal variability in the deep ocean crust by drilling a series of 500-m-deep holes offset by 100,000-yr increments along a lithospheric flow line. In the event that further drilling on the bare-rock platform becomes impossible, or if the time remaining in the leg is short, the drill ship will move to backup Site SWIR 6 to drill a single-bit hole as deep as possible through a sediment pond and into basaltic basement. This site is located on crust of the same age as Hole 735B, but is situated north of the SW Indian Ridge where a volcanic carapace like the one that once covered Site 735 is preserved.

INTRODUCTION

From the earliest studies, analyses of seismic refraction profiles have suggested that the structure of the oceanic crust is surprisingly uncomplicated and uniform (Christensen and Salisbury, 1975; Hill, 1957; Raitt, 1963). Earth scientists have long equated the seismic structure to a simple layer cake sequence of sediment, pillow basalt and diabase, and a thick gabbro section overlying the earth's mantle, with the igneous crust/mantle boundary corresponding to the Mohorovicic seismic discontinuity (MOHO). Accretion of the lower crust was seen as a result of crystallization from some form of near steady-state magma chamber or crystal mush zone where magmas accumulated beneath a sheeted dike/pillow lava sequence over the ascending mantle. It was believed that a simple stratigraphy of primitive layered gabbros was overlain by more evolved isotropic gabbros—all of which were equated to seismic layer 3. This simple hypothesis has been modified somewhat over the past 20 years. Provisions have been made for thinner crust areas near large transforms (e.g., Dick, 1989; Mutter and Detrick, 1984) and for areas with spreading rates that are significantly below 10 mm/yr (i.e., half-rate) (Bown and White, 1994; Reid and Jackson, 1981). At the same time, models of the internal stratigraphy of the lower crust have become increasingly complex with the introduction of narrow accumulation zones, ephemeral magma chambers, and a host of complexities arising from variations in thermal structure and spreading rate (e.g., Sinton and Detrick, 1992) such as provision for tectonism and hydrothermal alteration in the accretion zone at the slow-spreading rates (e.g., Dick et al., 1992)

Interpretations derived from plate tectonic theory about the rate of formation of new ocean crust over the last few hundred million years, and the remarkably uniform seismic structure of the ocean crust and the geologic model used to explain it, have been taken to provide an estimate of the transfer of heat and mass from the earth's deep interior to the crust, oceans, and atmosphere. Fossil sections of ocean crust, termed ophiolite complexes, preserved on land in tectonic collision zones at continental margins and island arcs, have been used both to support this hypothesis and to allow more direct inference into the internal structure and composition of the ocean crust and the igneous, hydrothermal, and tectonic processes by which it was created. Nonetheless, it has long been known that significant differences exist between these fossil sections and what is known of the in situ ocean crust—both in the details of their rock chemistries and in the inferred thickness of many ophiolites, which are often much thinner than commonly observed in the modern ocean (Coleman and Irwin, 1974). Thus, ophiolites have an inherently ambiguous provenance, with most attributed to a supra-subduction zone environment atypical of the world's oceans.

Hess (1962) originally proposed that the MOHO was an alteration front in the mantle and that seismic layer 3 was largely partially serpentinized peridotite. In his model, the MOHO was produced by auto-metasomatism of peridotite by deuteric water as the mantle cooled into the stability field of serpentine after being emplaced by solid-state flow to the base of the crust. Later investigators, however, found that it was difficult to match laboratory observations of both seismic *P*- and *S*-wave velocities for partially serpentinized peridotite to those of layer 3 (Christensen, 1972; Christensen and Salisbury, 1975) and rejected Hess's model in favor of a gabbroic lower crust. Recent studies now suggest that the ocean crust has a complex, three-dimensional structure that is highly dependent on magma supply and spreading rates without large steady-state magma chambers (e.g., Whitehead et al., 1984; Detrick et al., 1990; Sinton and Detrick, 1992; Barth, 1994; Carbotte and MacDonald, 1994). Compilations of dredge results and seismic data have indicated that a continuous gabbroic layer does not exist at slow-spreading ridges (Mutter et al., 1985; McCarthy et al., 1988; Dick, 1989; Cannat et al., 1992; Tucholke, unpubl. data), and that its internal stratigraphy is governed by dynamic processes of alteration and tectonism as much as by igneous processes. The exceptional abundance of serpentinized peridotite in dredge hauls from the walls of rift valleys in fracture zones and in the rift mountains away from fracture zones (Aumento and Loubat, 1971; Cannat et al., 1992; Dick, 1989; Thompson and Melson, 1972) raises the serious possibility that serpentinite is a major component of seismic layer 3. In these scenarios, the MOHO does not correspond everywhere in the oceans to the boundary between igneous crust and the mantle, but may be an alteration front, corresponding locally to the depth of circulation of seawater down cracks into the earth's interior.

These factors, and an increasing awareness that spreading rate, ridge geometry, and proximity to mantle hot spots have major impacts on ocean crust thickness and lithostratigraphy, make in situ observation of the lower ocean crust by drilling a necessity if the processes of ocean crust accretion and the nature of the ocean crust are ever to be understood. The Deep Sea Drilling Project (DSDP), and its successor the Ocean Drilling Program (ODP), have directly sampled in situ ocean crust down to 2 km in a variety of spreading environments, confirming many inferences from ophiolites as to its shallow-depth structure and composition. The results show that the seismic layer 2/layer 3 boundary may be an alteration front rather than simply the boundary between diabase and gabbro, thus raising questions about the nature of the MOHO as well. Despite the recovery of short sections of lower ocean crust and mantle by several ODP legs, however, no true representative section of seismic layer 3 has ever been obtained in situ from the oceans, leaving its composition, state of alteration, and internal structure largely a matter of inference.

ODP Hole 735B came closest to this goal, recovering a 500-m section of coarsely crystalline gabbroic rock drilled in a tectonically exposed lower crustal section on a wave-cut platform that flanks the Atlantis II Fracture Zone on the slow-spreading SW Indian Ridge (Fig. 1). Hole 735B cores radically changed our perception of the lower ocean crust at slow-spreading ridges. The data indicate the crust formed by a complex interaction of magmatic, tectonic, and hydrothermal processes (e.g., Dick et al., 1992), quite unlike the simple large magma chamber once envisioned as the primary driver of crustal accretion (e.g., Cann, 1974). Given the typical thicknesses of seismic layer 3, this section is not long enough to adequately characterize the lower crust, even at a very slow-spreading ridge. No other known place, however, offers the excellent drilling conditions, high recovery, ease of guide-base placement, and superb shallow exposures of lower crust. It is, therefore, the ideal place to go to begin drilling representative sections of the lower ocean crust to test the nature of the MOHO and the crust.

BACKGROUND

Tectonic Setting

Site 735 is located in the rift mountains of the Southwest Indian Ridge (SWIR), 18 km east of the present-day axis of the Atlantis II Transform Fault (Fig. 2). The Southwest Indian Ridge has existed since the initial breakup of Gondwanaland in the Mesozoic (Norton and Sclater, 1979). Shortly before 80 Ma, plate readjustment in the Indian Ocean connected the newly formed Central Indian Ridge to the Southwest Indian Ridge and the Southeast Indian Ridge to form the Indian Ocean Triple Junction (Fisher and Sclater, 1983; Sclater et al., 1981; Tapscott et al., 1980). Steady migration of the triple junction to the northeast has created a succession of new ridge segments and fracture zones including the Atlantis II. Thus, the Atlantis II Fracture Zone and the adjacent ocean crust is entirely oceanic in origin, free from complications due to continental breakup as postulated for some equatorial fracture zones along the Mid-Atlantic Ridge (Bonatti and Honnorez, 1976).

Over the last 34 m.y., the spreading rate along the Southwest Indian Ridge has been relatively constant, near 0.8 cm/yr, at the very slow end of the spreading-rate spectrum (Fisher and Sclater, 1983). All the characteristic features of slow-spreading ridges, including rough topography, deep rift valleys, and abundant exposures of plutonic and mantle rocks are present on the Southwest Indian Ridge (Dick, 1989). Significantly, two thirds of the rocks dredged from the walls of the active transform valleys are altered mantle peridotites, whereas most of the remainder are weathered pillow basalts. This exceptional abundance of peridotite, compared to dredge collections of similar size from the North Atlantic Ocean, indicates an unusually thin crustal section in the vicinity of Southwest Indian Ridge transforms. Moreover, the paucity of dredged gabbro along the Southwest Indian Ridge suggests that magma chambers were small or absent near fracture zones.

The thin crust adjacent to fracture zones is thought to reflect segmented magmatism along the Southwest Indian Ridge, which produces rapid along-strike changes in the structure and stratigraphy of the lower ocean crust (Whitehead et al., 1984). This model views the Southwest Indian Ridge as a series of regularly spaced, long-lived shield volcanoes and underlying magmatic centers, which undergo continuous extension to form the ocean crust (Dick, 1989). Site 735 is located some 18 km from the Atlantis II Transform Fault, and was accordingly situated near the mid-point of a hypothetical magmatic center beneath the Southwest Indian Ridge 11.5 Ma (Dick et al., 1991a).

Geology of the Atlantis II Fracture Zone

The Atlantis II fracture zone (FZ) (Fig. 3) was first described by Engel and Fisher (1975) and mapped in detail by Dick et al. (1991a, 1991b). It is a 199-km, 20-Ma left lateral offset of the SW Indian Ridge running almost due north-south at about 57°E longitude. The transform is marked by a 6480-m-deep transform valley, with high flanking transverse ridges shoaling to as little as 700 m. The valley walls are extremely steep for large distances, sloping from 25° to 40°, and are covered with extensive talus and debris. The floor of the transform has a thick, >500-m sequence of turbidites shed from the walls of the transform and is bisected by a 1.5-km-high median tectonic ridge. The ridge/transform intersections are marked by deep nodal basins lying on the transform side of the neovolcanic zones that define the present-day spreading axes and intersect clearly defined rift valleys with a relief of more than 2200 m and widths of 22 to 38 km. Extensive dredging showed that more than two-thirds of the crust exposed in the transform valley and its walls are plutonic rocks, principally gabbros and partially serpentinized peridotites. By contrast, only relatively undisrupted pillow lavas appear to be exposed on crust of the same age and position relative to the transform fault on the conjugate lithospheric flow line to the north (Fig. 3).

Well-defined magnetic anomalies were mapped out to 11 Ma over the flanking transverse ridges and transform valley, even over large areas where dredging during the site survey for Leg 118 showed that basalts are absent, including Site 735. This was the first direct demonstration that the gabbros and peridotites can constitute a magnetic source layer (Dick et al., 1991a), a possibility raised by the early laboratory work of Kent et al. (1978), and subsequently confirmed by down-hole logging (Pariso et al., 1991) and measurements on recovered cores from Hole 735B (Kikawa and Ozawa, 1992; Kikawa and Pariso, 1991; Pariso and Johnson, 1993). In fact, the gabbro massif at Site 735 is the only location in the ocean where the age pick of the magnetic anomaly (anomaly 5A", 11.5 Ma; Dick et al., 1991a) has been confirmed, within error, by a zircon U-Pb isotopic age date of 11.3 Ma from a trondhjemite sampled in situ in basement (Stakes et al., 1991).

Hole 735B is located on a shallow bank, informally named Atlantis Bank, on the crest of a 5-km-high mountain range, termed a transverse ridge, which constitutes the eastern wall of the Atlantis II Transform valley. It is situated some 93 km south of the present day Southwest Indian Ridge axis, and is 18.4 km from the inferred axis of transform faulting on the floor of the Atlantis II Fracture Zone (Dick et al., 1991a). The bank consists of a platform, roughly 9 km long in a north-south direction and 4 km wide, which is the shallowest of a series of uplifted blocks and connecting saddles that form a long, linear ridge parallel to the transform. The top of the platform is flat, with only about 100 m relief over 20 km^2. A video survey of a 200- x 200-m area in the vicinity of the hole showed a smooth, flat wave-cut platform exposing foliated and massive jointed gabbro locally covered by sediment drift (Robinson, Von Herzen, et al., 1989). The platform was probably formed by erosion of an island similar to St. Paul's Rocks in the central Atlantic, and then subsided to its present depth from normal lithospheric cooling (Dick et al., 1991a). A similar wave-cut platform occurs on the ridge flanking the DuToit Fracture Zone (Fisher et al., 1986).

The boundary between magnetic anomaly 5 and 5A crosses east-west directly over the platform (Fig. 4). The boundary trends southward down the wall of the transform at a sufficiently shallow angle that, based on a simple projection into the massif, a successful penetration down to 2 km below seafloor at Hole 735B would likely penetrate the magnetic transition between them.

The foliation apparent in the images from the Leg 118 video survey and at the top of the drill core strikes east-west, parallel to the ridge axis and orthogonal to the fracture zone. The orientation of similarly foliated peridotites exposed on St. Paul's Rocks has been measured and is also parallel to the Mid-Atlantic Ridge and orthogonal to St. Paul's Fracture Zone (Melson and Thompson, 1970). This foliation, projected along strike across the Atlantic Bank platform, intersects a long ridge coming up the wall of the fracture zone, which is oriented obliquely west-northwest to the transform. Ridges produced by land-slips and debris flows normally are oriented orthogonal to the fracture zone. Our suspicion then is that this oblique ridge, and a similar one 2 km to the north, represent the trace of the thick zone of foliated gabbros down the wall of the transform. Given the once shallow water depth, the canyon between the two ridges may be erosional and the foliated gneissic amphibolites may be resistant remnants. A three-point solution for the dip of the shear zone, based on the trend of this ridge and an east-west strike, gives a dip of approximately 40°, which is close to that observed in the drilled amphibolites.

This shear zone represents a ductile fault and, thus, does not represent a simple stratigraphic discontinuity. The rocks at the top of the shear zone are gabbronorites that pass gradually into a zone of olivine gabbro toward its base. The shear sense determined from drill cores is normal, and the rocks north of the drill site are down-thrown an unspecified amount. Any offset drill sites to the north would, therefore, start higher in the stratigraphic section. Given the position of the site, the relatively constant spreading direction over the last 11 m.y., and the ridge-parallel strike of the local foliation, the Atlantis Bank gabbros must have crystallized and been ductily deformed (~11.5 Ma) beneath the median valley of the Southwest Indian Ridge 15 to 19 km from the ridge/transform intersection.

The gabbros were subsequently uplifted in a large horst from beneath the rift valley 5 to 6 km up into the transverse ridge (Dick et al., 1991a; Magde et al., 1995). The single uniform magnetic inclination throughout the section demonstrates that there has been no late tectonic disruption of the section, although the relatively steep inclination suggests block rotation of up to 18° (Pariso et al., 1991). Thus, unlike dredge samples from the transform walls, those drilled in Hole 735B formed beneath the rift-valley floor away from the transform fault and faults formed during formation of the valley. Petrologically, these rocks likely represent a typical igneous section of Southwest Indian Ridge ocean crust with an intact metamorphic and tectonic stratigraphy recording brittle-ductile deformation and alteration at high temperatures beneath the rift valley, as well as subsequent unroofing and emplacement on ridge-parallel faults.

The unroofing and exposure of the Hole 735B section relates to the present-day asymmetric distribution of plutonic and volcanic rocks north and south of the ridge axis near the fracture zone, as well as to the striking physiographic contrast between crust spreading in opposite directions at the ridge/transform intersection (Dick et al., 1991a; Fig. 3). These features suggest that a crustal weld periodically formed between the shallow levels of the ocean crust and the old cold lithospheric plate at the ridge/transform intersection. This weld caused the shallow levels of the newly formed ocean crust to spread with the older plate away from the active transform, thereby causing the creation of long-lived detachment faults. Beneath the faults, the deep-ocean crust that was spreading parallel to the transform was unroofed and emplaced up into the rift mountains to form a transverse ridge. A similar model was proposed (Dick et al., 1981; Karson and Dick, 1983) to explain the asymmetric physiography and distribution of plutonic and volcanic rocks at the Kane Fracture Zone in the North Atlantic. There, the surface of the detachment fault has actually been observed by submersible (Dick et al., 1981; Mével and Cannat, 1991). It has been suggested that detachment faults similar to the one proposed to explain unroofing of the lower crust at the Atlantic Fracture Zone occur periodically within rift valleys by fault capture during amagmatic periods (Dick et al., 1981; Harper, 1985; Karson, 1991). Thus, the structures and fabrics seen in core from Hole 735B are likely to be representative of the kinds of fabrics generally found in lower crustal sections formed at slow-spreading ridges (Fig. 5). It is true, however, that because of the proximity to the transform the extent of the ductile shear may be greater than elsewhere beneath the rift valley.

Previous Investigations of Hole 735B

During Leg 118, a large intact 500-m section of gabbros was recovered from Site 735. These gabbros were unroofed and uplifted on the transverse ridge flanking the Atlantis II Fracture Zone. The complex internal structure and stratigraphy of the recovered section provided a first look at the processes of crustal accretion and ongoing tectonism, alteration, and ephemeral magmatism at a slow-spreading ocean ridge. Results from the leg showed that the section was not formed in a large steady-state magma chamber, but by continuous intrusion and reintrusion of numerous small, rapidly crystallized bodies of magma. There is little evidence of the process of magmatic sedimentation important in layered intrusions. Instead, new batches of magma were intruded into a lower ocean crust consisting of crystalline rock and semisolidified crystal mush. This led to undercooling and rapid initial crystallization of new magmas to form a highly viscous or rigid crystal mush, largely preventing the formation of magmatic sediments. Initial crystallization was followed by a longer, and petrologically more important, period of intercumulus melt evolution in a highly viscous crystal mush or rigid melt-crystal aggregate.

Thus, if the 437 m of gabbro recovered from Hole 735B is representative, long-lived magma chambers or melt lenses were virtually absent throughout most of the formation of the oceanic crust beneath the Southwest Indian Ridge (Bloomer et al., 1991; Dick et al., 1991a; Natland et al., 1991; Ozawa et al., 1991). Melts in the highly viscous or rigid intrusions were largely uneruptable throughout most of their crystallization. This explains the near absence of highly evolved magmas such as ferrobasalts along the Southwest Indian Ridge (Dick, 1989), as opposed to fast-spreading ridges where they are common, and a long-lived melt lens is believed to underlie the ridge axis (e.g., Sinton and Detrick, 1992).

Wall-rock assimilation occurring while small batches of melt work their way up through the partially solidified lower crust appears to have played a significant role in the chemical evolution of the section and, therefore, in the chemistry of the erupted basalt (Dick et al., 1992). This process has been largely unevaluated for basalt petrogenesis to date, but raises questions for simple models of the formation of mid-ocean-ridge basalt (MORB) drawn from experimental studies that assume equilibrium crystallization and melting processes throughout magma genesis.

An unanticipated major feature of the recovered core is the evidence of deformation and ductile faulting of the still partially molten gabbros (Bloomer et al., 1991; Dick, Meyer et al., 1991; Dick et al., 1992; Natland et al., 1991). This deformation apparently occurred over a narrow window, late in the cooling history of the gabbros (probably at 70%-90% crystallization) when they became sufficiently rigid to support a shear stress. This produced numerous small and large shear zones, creating zones of enhanced permeability into which the late intercumulus melt moved. This synkinematic igneous differentiation of intercumulus melts into the shear zones transformed the gabbro there into oxide-rich ferrogabbros. The net effect of these magmatic and tectonic processes was to produce a complex igneous stratigraphy with undeformed oxide-free olivine gabbros and microgabbros criss-crossed by bands of sheared ferrogabbro. Synkinematic differentiation is probably ubiquitous in lower ocean crust formed at slow-spreading ocean ridges, and should be recorded in ophiolite suites formed in similar tectonic regimes.

At Site 735, ductile deformation and shearing continued into the subsolidus regime, causing recrystallization of the primary igneous assemblage under granulite facies conditions and the formation of amphibole-rich shear zones (Cannat, et al., 1991; Cannat, 1991; Dick, Meyer et al., 1991; Dick et al., 1992; Mével and Cannat, 1991; Stakes et al., 1991; Vanko and Stakes, 1991). Here again, formation of ductile shear zones localized late fluid flow, with the most intense alteration occurring in the ductile faults (Dick, Meyer, et al., 1991). Undeformed sections of gabbro also underwent enhanced alteration at this time, principally by replacement of pyroxene and olivine by amphibole.

A consequence of simultaneous extension and alteration has been far more extensive alteration at high temperatures than found in layered intrusions that were intruded and cooled in a static environment (Dick, Meyer, et al., 1991; Stakes et al., 1991). An abrupt change in alteration conditions of the Hole 735B gabbros, however, occurred in the middle amphibolite facies with the cessation of shearing and ductile deformation (Dick, Meyer et al., 1991; Magde et al., 1995; Stakes et al., 1991; Stakes, 1991; Vanko and Stakes, 1991). Mineral vein assemblages changed from amphibole-rich to diopside-rich, reflecting different fluid chemistry. Continued alteration and cooling to low temperature occurred under static conditions similar to those found for large layered intrusions. These changes likely occurred due to an inward jump of the master faults defining the rift valley walls, thus transferring the section out of the zone of extension and lithospheric necking beneath the rift valley into a zone of simple block uplift in the adjoining rift mountains. Ongoing hydrothermal circulation, no longer enhanced by stresses related to extension, was greatly reduced, driven only by thermal-dilation cracking as the section cooled to ambient temperature.

The complex section of rock drilled at Site 735 formed beneath the very slow-spreading Southwest Indian Ridge (0.8 cm/yr half rate) and represents the slow end of the spectrum for crust formation at major ocean ridges far from hot spots. Such ridges have the lowest rates of ocean ridge magma supply, and crustal accretion is most heavily influenced by deformation and alteration. At the opposite end of the spreading rate spectrum (7-9 cm/yr), where the majority of the seafloor has formed, the crustal stratigraphy is likely different. Judging from the results of Hole 735B, the critical brittle-ductile transition has migrated up and down through the lower crust because of the waxing and waning of magmatism beneath the Southwest Indian Ridge. In contrast, this transition may be more stable near the sheeted dike gabbro transition at faster spreading ridges such as the East Pacific Rise, reflecting a near steady-state magma chamber or crystal mush zone. This should produce an internal stratigraphy for the lower crust quite different than that described here.

SCIENTIFIC OBJECTIVES

Primary Objectives

- Obtain a section of layer 3 gabbros to adequately document the nature of magmatic, hydrothermal, and tectonic processes in the lower ocean crust at a slow-spreading ridge.
- Determine if the boundary between igneous crust and the depleted mantle lies above the Mohorovicic discontinuity.

Supplementary Objectives (if deepening Hole 735B is not achieved)

- Begin a transect of 500-m-deep offset holes, which will have the eventual goal of determining how the stratigraphy of the lower crust at a very slow-spreading ridge varies in time and space.
- Establish a natural laboratory for future hole-to-hole seismic, magnetotelluric, and permeability experiments for in situ direct determination of the physical properties of oceanic seismic layer 3 at geologically relevant intervals.
- Recover the shallow basaltic carapace originally emplaced above Site 735 by drilling a single-bit hole into the pillow basalt sequence at the conjugate drill site north of the SWIR on crust of the same age.

The principal goal of Leg 176 will be to deepen Hole 735B to a depth sufficient to determine the nature of the magmatic, metamorphic, and tectonic processes in the lower oceanic crust and seismic layer 3. At the present time several different models fit the existing Hole 735B stratigraphy. This is because the 500-m sequence drilled to date may represent only the uppermost portion of the gabbroic crust, which could be anywhere from 1.5 to 5 km thick at this location. As this zone effectively represents a major thermal boundary layer during accretion of the crust, these rocks may not be representative of all of the remaining section. For example, three different models for the stratigraphy of the lower ocean crust are shown in Figure 6, any one of which can be reconciled with the cores already recovered from Hole 735B.

Model "A" proposes that the crust is made of relatively small gabbroic bodies discordantly cutting each other and partially serpentinized upper mantle. The proportion of gabbroic bodies to mantle lithologies diminishes with depth (see Swift and Stephen, 1992; Cannat, 1993; Sleep and Barth, 1994). This model suggests that the primitive troctolites recovered from the bottom of Hole 735B represent deep level gabbroic rocks, and continued drilling should rapidly intersect upper mantle lithologies. A second interpretation (Fig. 6B) is that the lower crust is made up of an assembly of small discordant gabbroic bodies that transit abruptly into the upper mantle following the concept proposed by Cann (1970) and Nisbet and Fowler (1978) and recently amplified by Smith and Cann (1993). Finally, a third model, based on ophiolite studies (Fig. 6C) suggests that the discordant gabbroic bodies occur only in the upper crust, and then grade downward into large layered gabbro intrusions, which have a sharp magmatic contact with upper mantle peridotite (Pallister and Hopson, 1981; Smewing, 1981).

An additional goal for this leg is to determine if seismic layer 3 can contain substantial quantities of partially serpentinized peridotite, and whether the MOHO could be an alteration front in the mantle. Inversion of the major and trace element composition of the basalts from crust that is the same age and in a similar position as Hole 735B on the conjugate lithospheric flow line north of the present day spreading center (Fig. 3) indicates an original igneous crustal thickness of about 3±1 km (Muller et al., 1997). At the same time the presence of coarse troctolites at the base of Hole 735B and serpentinized peridotite dredged downslope suggest that the igneous crust/mantle transition may occur within a kilometer or so of the bottom of Hole 735B (Dick et al., 1992). Wide-angle seismic refraction profiles over and around the Atlantis II Bank, however, image a distinct MOHO 4-5 km below the seafloor (Muller et al., 1997; Fig. 7), despite the fact that the original basaltic carapace of pillow lavas and dikes has been tectonically removed. The seismic boundary could represent a magmatic transition from gabbroic rocks to peridotite; however, it is much deeper than anticipated for gabbroic crust at the SWIR. The MOHO reflector can also be traced eastward into "normal" ocean crust away from the transform, where it shoals to about 4 km below basement. At the same time, crust with layer 2 velocities, which is absent at Site 735, also appears about 3 km to the east of Hole 735B, and gradually increases in thickness to about 1.5 km. Thus, the seismic crustal section becomes thinner away from Site 735B, and seismic layer 3 thins to about 2.5 km. The increase of seismic layer 3 from 2.5 km thick well away from the Atlantis II Transform to 5 km near the transform seems inexplicable in the light of current ocean crust models, unless layer 3 can, at least locally, contain significant amounts of partially serpentinized peridotite and the MOHO beneath Site 735 is an alteration front in the mantle (Dick, 1996; Muller et al., 1997).

Thus, Leg 176 will return to Site 735 on the Southwest Indian Ridge with the objective of deepening Hole 735B to at least 1.5 km or deeper, if conditions permit. Such a section should be sufficient to adequately characterize the lower ocean crust at a slow-spreading ridge and may be sufficient to penetrate the igneous crust/mantle boundary, if this indeed does not coincide with the Mohorovicic discontinuity. If the latter occurs, scientists will have their first opportunity to sample the fundamental transition between rocks produced by crystallization of magma extracted from the Earth’s mantle and the residues from which these liquids were derived. Our goals include documenting the depths to which fluids penetrate the lower ocean crust and perhaps the sub-oceanic mantle, and defining gradients in metamorphic facies, if they exist. From a tectonic perspective, deepening Hole 735B will establish the spacing and morphology of the major ductile-shear zones recognized in the earlier cores, and hence the role of tectonic extension as opposed to simple magmatic accretion in the formation of the lower ocean crust. Layered cumulate gabbros, as might be expected according to the ophiolite model of ocean crust stratigraphy, were not included in the nearly complete section recovered during Leg 118, and continued drilling will establish whether they are absent in this environment, thereby discounting the hypothesis of a long-lived magma chamber.

In the event that drilling conditions preclude deepening Hole 735B, we will start a new hole, based on a short local-scale survey with the video camera. This would be drilled to the maximum depth possible in the remaining time to fulfill our original objectives to the extent possible. The position of this hole would be in the proposed offset transect of 500-m-deep holes centered around Hole

735B. This transect would be situated either along a lithospheric flow line or on an isochron to the east depending on the local geology and site availability. A nominal spacing of 800 m was originally proposed for these holes, as a suite of five holes would represent a distance of 3.2 km, which is roughly equal to the typical half-width of the inner rift valley floor of the SWIR, and thus a logical length scale to first test the variability of crustal accretion. This spacing equates to 80,000 yr age increments along the lithospheric flow line. The precise location of the first offset hole, however, will be based on geologic information from the further deepening of Hole 735B and on-site local surveys with the *Resolution's* video system, and it is possible that the co-chiefs, with the advice of the shipboard party, may find that a site offset along an isochron to the east may produce a greater scientific return.

A final back-up site is located at SWIR 6 (Fig. 2). This site will be drilled in the event that further drilling at Site 735 is precluded, or the time remaining does not warrant setting a new guide base. This site is situated on crust of the same age as Site 735 on the counter-lithospheric flow line to the north of the present day SWIR axis. Based on seafloor morphology, dredging, and single channel seismics the volcanic carapace corresponding to the Hole 735B gabbros is preserved intact beneath a sediment cover. This would be a single-bit hole, drilled to destruction or until time allotted for operations expires, and spudded in a sediment pond designed to recover a 100-m section of the volcanics.

DRILLING STRATEGY

It is reasonable to assume that drilling conditions will remain roughly constant from the hole's present depth until thermal problems occur or when serpentinized peridotite is encountered. While the depth at which the latter will occur is difficult to predict, it is unlikely that thermal problems will be encountered due to the old age and the uplift of the crustal block on which Hole 735B is located.

Based on the hypothesis that brittle fracture and brecciation decrease with depth in plutonic layer 3 due to the steep geotherm beneath an ocean ridge, and that fine-grained rocks are unlikely to be encountered lower in the section, it is reasonable to suspect that the overall penetration rate would remain close to that for Leg 118. Five hundred meters were drilled at Hole 735B in 19 days, including setting a guide base and starting with the mud motor rather than the top drive, and using minimum bit weight and a high degree of operational conservatism. Improved bit design subsequent to Leg 118 and the observed lack of bit wear during Leg 118 suggest that operations during Leg 176 should not decrease bit life, which should make up for increased trip time as the hole is deepened.

The priorities for Hole 735B drilling defined by the Planning Committee (PCOM) are as follows:

1. Deepen Hole 735B to at least 1.5 km below the seafloor.

2. Log the deepened hole.

3. Conduct vertical seismic profiling (VSP) experiments in the deepened hole.

In the event difficulties are encountered while drilling, the following priorities will be pursued:

1. A brief 12-hr video survey will be made on the wave-cut terrace to the east and south of Hole 735B, which, in conjunction with the drilling results to date, will provide a geologic basis for an offset drill hole to be sited either on an isochron to the east or close to a north-south lithospheric flow line centered on Hole 735B.

2. A hard rock guide base with a casing stub to 10-20 m will be set, and drilled to the maximum depth possible, allowing for an appropriate amount of time for logging and VSP.

3. In the event of further difficulties, the offset drilling strategy will proceed, siting holes as geologically appropriate on an isochron or lithospheric flow line based on the results of the video survey and drilling.

4. In the event that starting a new hole is required close to the end of the leg (6-7 days), and would not result in sufficient recovery to justify the effort, the priority will be to drill a single-bit hole at SWIR 6, bit-to-destruction, to recover the basaltic carapace corresponding to Hole 735B.

LOGGING PLAN

The principle objective of deepening Hole 735B, which may reach the lower crust/upper mantle boundary, is to determine the nature of magmatic, metamorphic, and tectonic processes occurring in the lower oceanic crust. During Leg 118, the first phase of drilling Hole 735B included compressional- and shear-wave velocity, resistivity, VSP, borehole televiewer (BHTV), and magnetic susceptibility logs. These were especially useful in delineating structural and stratigraphic features such as magmatic layering and fractures. The downhole measurement tools planned for use during Leg 176 include the full set of Schlumberger tool logs, the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR; German Geological Survey) magnetometer and a Schlumberger vertical seismic profiling tool. The set of Schlumberger logging tools will include the triple-combo with natural gamma-ray sonde (NGS), porosity (accelerator porosity sonde [APS]), density (hostile environment lithodensity sonde [HLDS]), resistivity (dual lateral log [DLL]), caliper and temperature (Lamont temperature tool [TLT]) probes, the Formation MicroScanner (FMS)/sonic combination, and the Prakla Seismos VSP tool.

Depending on time constraints and depth of penetration, the logging program will be divided into two or three parts. At the beginning of the leg, the Triple-combo will be used for obtaining a temperature profile, assessing borehole conditions, and determining possible variations in alteration. The FMS will provide information regarding the ellipticity of the borehole as well as high-resolution images of stratigraphic boundaries and structural features. The second and third logging runs will include the triple-combo, FMS/sonic, magnetometer, and VSP deployments. Pending funding, the sonic probe (digital array sonic tool [SDT]) commonly used in the FMS/Sonic combination will be substituted with the Dipole Shear Sonic Imager (DSI). The DSI will produce a full set of waveforms (*P*-, *S*-, and Stoneley waves); the shear-wave velocity and amplitude measured at different azimuths in the borehole may indicate preferred mineral and/or fracture orientations as well as paleostress directions. During Leg 176, the verification of depth/seismic ties by means of a VSP and synthetic seismograms will be essential for identifying deep crustal reflectors. The location and abundance of Fe-Ti oxide intervals will be determined by using the magnetometer.

A core-log integration program will be essential for the reorientation of cored samples recovered from Hole 735B. Correlation of digital core images obtained with a DMT Color Scanner and FMS images potentially will provide the opportunity for the reorientation of structural and stratigraphic features. The reorientation of the core from Hole 735B may prove to be essential for the determination of the lateral extent of structural features as well as the association of local strikes and dips with the regional tectonic environment. In addition, the FMS high-resolution images will vastly improve the determination of the fracture and alteration zone distribution in the crust and correlations between geophysical logs and discrete laboratory data will provide information regarding compositional variations with depth.

Depending on hole conditions and depth of penetration the approximate time estimates for the logging program during Leg 176 will be as follows:

	No Hole Conditioning	*Hole Conditioning*
Time Estimate	121.8 hrs (5.1 days)	147.7 hours (6.2 days)

Special Operations

Pending future funding, drilling operations may include the testing and recording of drill-string pilot sensor data for seismic-while-drilling operations in Hole 735B. This technique allows the drill bit signal to travel up the drill string as axial waves, which can be detected by placing sensors on the top drive. These signals are considered to contain both the source signature for the experiment as well as drill pipe reverberations and other extraneous sources of noise. The acquisition and processing of these data may enable the extraction of axial vibrations generated by the bit which can be correlated with the energy radiating into the formation and received by a geophone (ocean bottom seismometers [OBS]) array on the seafloor around the ship. Cross-correlation of drill string data with the OBS signals may also be used to synchronize the waveforms produced at a specific time with depth of the bit in the hole. When merged with drill-string pilot sensor and depth data, seismic-while-drilling can produce a "real-time" zero offset VSP. These operations will require the deployment of eight ocean bottom seismometers.

SAMPLING STRATEGY

New sampling guidelines specify that a formal, leg-specific sampling strategy be prepared by the Sample Allocation Committee (SAC = co-chiefs, staff scientist, and ODP Curator onshore—Curatorial Representative on board ship) for each prospectus. Modifications to the strategy during the leg must be approved by the Curatorial Representative on board ship, co-chiefs, and staff scientist. The sampling strategy here is keyed to the new guidelines, and will be refined as the sample requests are evaluated and considered by the entire shipboard party before reaching site.

Minimum Permanent Archive

The minimum permanent archive will be the standard archive half of each core.

Sample Limit

Shipboard scientists may nominally expect to obtain up to 100 samples up to 15 cm^3 in size. Additional samples may be obtained upon written request onshore soon after the cores return to the ODP Repository. This guideline will be adjusted upward or downward by the shipboard SAC, depending on the penetration and recovery during Leg 176. All sample requests of whatever number and volume must be justified in writing on the standard sample request form and approved by the SAC.

Large Samples

Samples larger than 15 cm^3 may be obtained with approval of the SAC but shall be considered the equivalent of multiple samples in partial or complete increments of 15 cm^3. Requests for large samples must be specified on the sample request form except where they are for detailed stratigraphic studies of specific intervals of the core in which case they must be approved on an individual basis for each interval by the co-chief scientists.

Redundancy of Studies

Some redundancy of measurement is unavoidable, but minimizing redundancy of measurement among the shipboard party and identified shore-based collaborators will be a factor in evaluating sample requests. Requests for independent shore-based studies that substantially replicate the intent and measurements of shipboard participants will require the approval of both those shipboard investigators and the SAC.

Shipboard Samples and Data

Following core labeling, measuring nondestructive properties, and splitting, samples will be selected from core working halves by members of the shipboard party for routine measurement of physical and magnetic properties, bulk chemical analyses by X-ray fluorescence (XRF) and carbon-hydrogen-nitrogen-sulpher (CHNS) analyzer, and X-ray diffraction as necessary. Polished thin sections will be prepared for identification of minerals, determination of mineral modes by point counting, and studies of texture and fabric.

We shall identify a suite of samples for full measurement characterization. At approximately 9.5-m intervals (once per full core), slabs measuring 10 x 6 x 1.5 cm, with a previously-sampled central mini-core, will be cut to be used for all shipboard measurements, then subdivided and split appropriately for further shore-based geochemical, mineralogical, and petrographic studies. Where necessary to avoid or include features like veins and alteration, full half-round slices or quarter slices may be taken instead of slabs.

Data from all shipboard studies, regardless of method or observer, including all core descriptions and measurements and the nondestructive measurements of physical and magnetic properties, are the property of the entire shipboard party and may be used exclusively by them in publication and for preparation of manuscripts with proper citation to the *Initial Report* up until the publication of the *Initial Report* or 12 months post cruise, whichever is later.

Shipboard Thin Sections

Shipboard thin sections will be selected from representative sections of the core and at some critical intervals. These sections will remain the property of ODP. The thin section chips from which the sections are made will be retained by ODP and should normally be thick enough to allow for the production of additional sections unless the sampling plan for a critical interval precludes this. Members of the shipboard party can request the production of a thin section from these thin section chips for their personal use at their own expense as part of their nominal 100 sample limit, but must arrange for the prepaid manufacture of these thin sections with a third-party commercial service unless otherwise approved by the ODP core lab curator. The thin-section chip will then be sent directly to the commercial service and returned directly to ODP by them.

Sampling for Shore-based Studies and Sampling Parties

To minimize the time and physical effort required for additional sampling for shore-based studies, we shall organize sampling consortia among the principal scientific teams (igneous, metamorphic, structural, physical and magnetic properties), who will identify locations for similarly large (10 x 6 x 1.5 cm—a mini-core) or even larger samples, and also averaging approximately once per 9.5 m of core. The actual size will depend on the number of investigators in the group, and it will be subdivided among them, to count against the nominal 100-sample limit of each consortium investigator. Follow-up sampling will be organized as short sample parties during reentries or logging runs, for individuals using the second-look lab, or at the ODP Repository as necessary.

Critical Intervals

Short intervals of unusual scientific interest (e.g., veins, ores, narrow trondhjemite dikelets, a knife-edge crust/mantle transition) may require a higher sampling density, reduced sample size, or sampling techniques not available on board ship. These will be identified during the core description process, and the sampling protocol established by the interested scientists and shipboard SAC.

Small Samples

Studies requiring only small sample volumes (1 cm^3 or less, e.g., for veins, fluid inclusions, etc.) may require more than 100 samples to characterize the long section of core we anticipate recovering, and might be possible to obtain while the cores are being described. We shall review the appropriate sampling interval for such studies periodically as the cores are recovered. Ideally, many of these studies will be coordinated with the shipboard and shore-based sampling protocols outlined above.

Storage and Shipping Needs

The usual labeling, orientation, core-placement, and storage procedures should be all that is necessary for safe transportation to the ODP Repository. Core handlers should wear back supports while lifting and handling individual archive or working halves, and especially when maneuvering core storage boxes.

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FIGURE CAPTIONS

Figure 1. Location of the Atlantis II Fracture Zone. Position of the SW Indian Ridge based on recent satellite gravity maps of the southern oceans and available bathymetric data.

Figure 2. **A.** Hand-contoured 100-m contour bathymetric map of Site 735 showing the location of Hole 735B (modified from Dick et al., 1991a). SeaBeam tracks hand-shifted by eye to eliminate conflicts in the data. Solid lines indicate actual data, while hatched lines show inferred contours. Contour interval is 250 m. Small solid dots and arrows indicate the starting point and approximate track of dredge hauls. Large solid dots show the location of Sites 735 and 732 (just north of the contoured area on the crest of the median tectonic ridge). Filled circles indicate the approximate proportions of rock types recovered in each dredge: + = gabbro, white = basalt and diabase, light stipples = greenstone, and heavy stipples = serpentinized peridotite. **B.** Hand contoured bathymetric map of the eastern rift mountains north of the SW Indian Ridge axis showing crust of the same age as Site 735 and the conjugate position of Hole 735B (735B') on the counter-lithospheric flow line, based on magnetic anomalies and plate reconstruction. This conjugate site is the location of SWIR 6, the final backup site for Leg 176, where the volcanic carapace originally overlying Hole 735B is preserved intact.

Figure 3. Bathymetric map of the Atlantis II Fracture Zone modified from Dick et al. (1991b). Locations of Hole 735B and the conjugate Site 735B' (SWIR 6) shown. SWIR 6 is located on the counter lithospheric flow line on crust of the same age and position relative to the paleotransform as Hole 735B. Active southern and northern rift valleys are at 33°40'S and 31°50'S, respectively.

Figure 4. Magnetic anomalies over Site 735 based on the survey of Dick et al. (1991a). Bathymetry contoured at 200 m intervals. Crustal magnetization is shown shaded, with normal polarity crustal magnetization shown as gray and reverse polarity shown as white. Dark gray areas have crustal magnetization greater than 1 A/m. Polarity identifications and numbering modified from Dick et al. (1991a) by M. Tivey (pers. comm., 1997) based on the time scale of Cande and Kent, 1992.

Figure 5. Temporal cross sections across the Southwest Indian Ridge rift valley drawn parallel to the spreading direction (not across the fracture zone, but parallel to it), showing the postulated tectonic evolution of the transverse ridge and Hole 735B (Dick et al., 1991a). The sequential sections are drawn at about 18 km from the transform fault. Crust spreading to the right passes into the transverse ridge and spreads parallel to the transform valley. Crust spreading to the left spreads into the rift mountains of the Southwest Indian Ridge parallel to the inactive extension of the Atlantis II Fracture Zone. Dense stipple = mantle, filled diamonds = gabbro, inverted "v" = basalt. **A.** Initial symmetric spreading, possibly at the end of a magmatic pulse. Late magmatic brittle-ductile deformation occurs because of lithospheric necking above (and in the vicinity of whatever passes for a magma chamber at these spreading rates). Hydrothermal alteration at high temperatures accompanies necking and ductile flow in subsolidus regions. **B.** At some point, the shallow crust is welded to the old, cold lithosphere to which the ridge axis abuts, causing formation of a detachment fault and nodal basin, initiation of low-angle faulting, continued brittle-ductile faulting, and amphibolite-facies alteration of rocks drilled at Hole 735B. **C.** and **D.** Block uplift of the rift mountains at the ridge/transform corner forms a transverse ridge enhanced by regional isostatic compensation of the local negative mass anomaly at the nodal basin. Initiation of the block uplift terminates the extension driving cracking, and drastically reduces permeability in the Hole 735B rocks, effectively terminating most circulation of seawater and alteration. Greenschist-facies retrograde alteration continues along the faults on which the block is uplifted to account for the greenschist-facies alteration that predominates in dredged gabbros.

Figure 6. Possible north-south geologic cross sections of the Atlantis II Bank through Hole 735B consistent with existing geological and geophysical data, gravity, and magnetics. Except at Hole 735B, fault locations and geometries are uncertain. The presence of a dike-gabbro transition as shown on the right of all the models is also hypothetical. **A.** Crustal stratigraphy around Hole 735B as suggested by Cannat (1993) and Swift and Stephen (1992), consistent with earlier inferences of Hess (1962). **B.** Crustal stratigraphy assuming Hole 735B is representative of the lower crust down to the mantle (Dick et al., 1991a). **C.** Crustal stratigraphy based on the layered intrusion model for ophiolites as proposed for Oman (after Pallister and Hopson, 1981; Smewing, 1981).

Figure 7. Seismic velocity structure from Muller et al. (1997). **A)** *P*-wave seismic velocity model on the north-south seismic line CAM101 of Muller et al. (1997). The velocity contour interval is 0.3 km/s. OBS positions are shown on the seafloor. The position of ODP Hole 735B has been projected from 1 km west of the line. The MOHO is indicated as a thicker line where its depth is constrained by wide-angle reflections. **B)** Resolution contours for the seismic model with Layers 2 and 3 and Upper/Lower Layer 3 boundaries from (A) superimposed. Numbered OBS positions are shown on the seafloor. The resolution of each velocity node is given by the diagonal of the inversion resolution matrix, a number between 0.0 and 1.0, affected by the ray coverage sampling each node. Values >0.5 (stippled area) are considered well resolved and reliable.

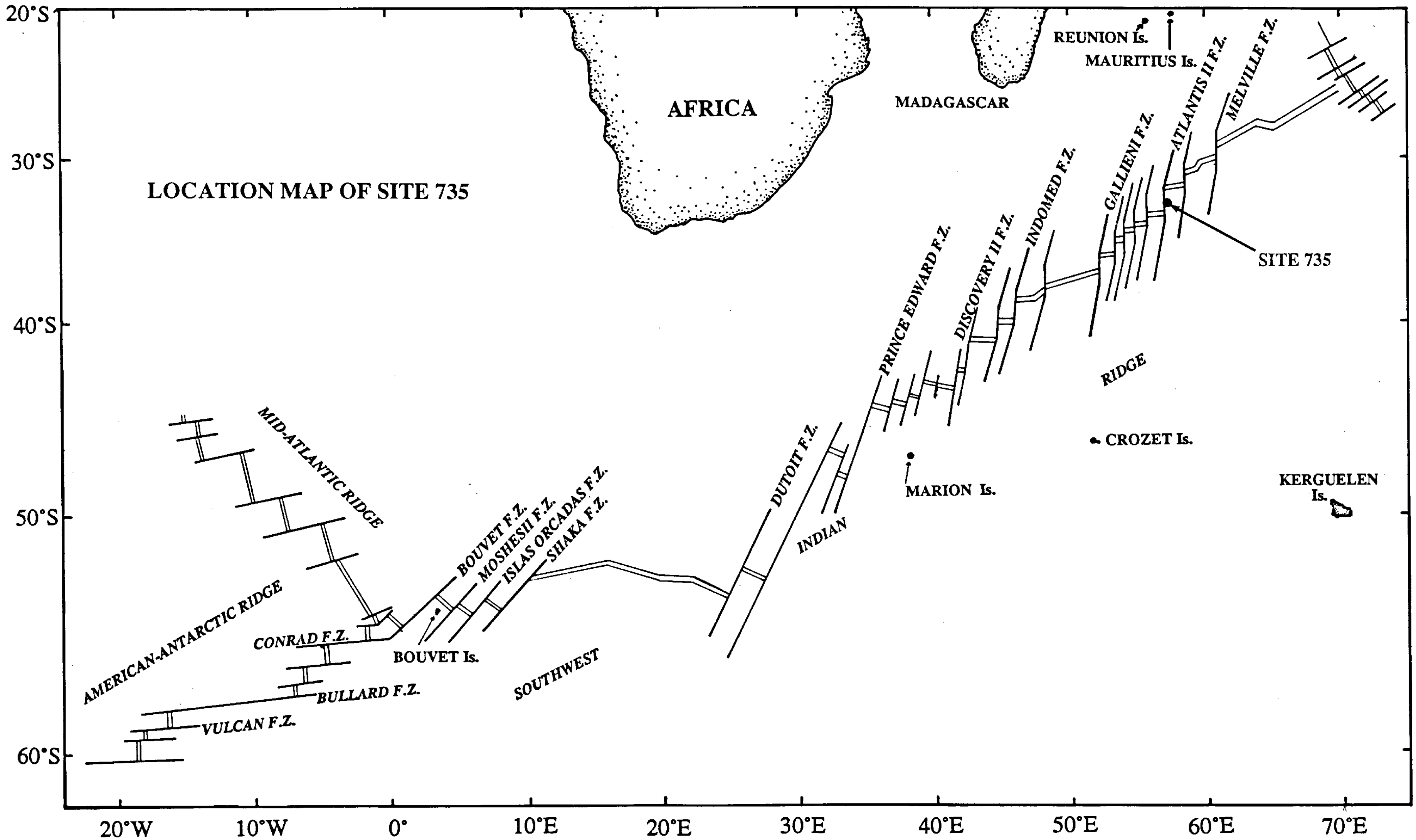

LOCATION MAP OF SITE 735
AFRICA
MADAGASCAR
REUNION Is.
MAURITIUS Is.
MELVILLE F.Z.
ATLANTIS II F.Z.
GALLIENI F.Z.
INDOMED F.Z.
DISCOVERY II F.Z.
PRINCE EDWARD F.Z.
SITE 735
RIDGE
CROZET Is.
MARION Is.
KERGUELEN Is.
DUTOIT F.Z.
INDIAN
SOUTHWEST
MID-ATLANTIC RIDGE
BOUVET F.Z.
MOSHESII F.Z.
ISLAS ORCADAS F.Z.
SHAKA F.Z.
BOUVET Is.
AMERICAN-ANTARCTIC RIDGE
CONRAD F.Z.
BULLARD F.Z.
VULCAN F.Z.
20°S
30°S
40°S
50°S
60°S
20°W
10°W
0°
10°E
20°E
30°E
40°E
50°E
60°E
70°E

Figure 1

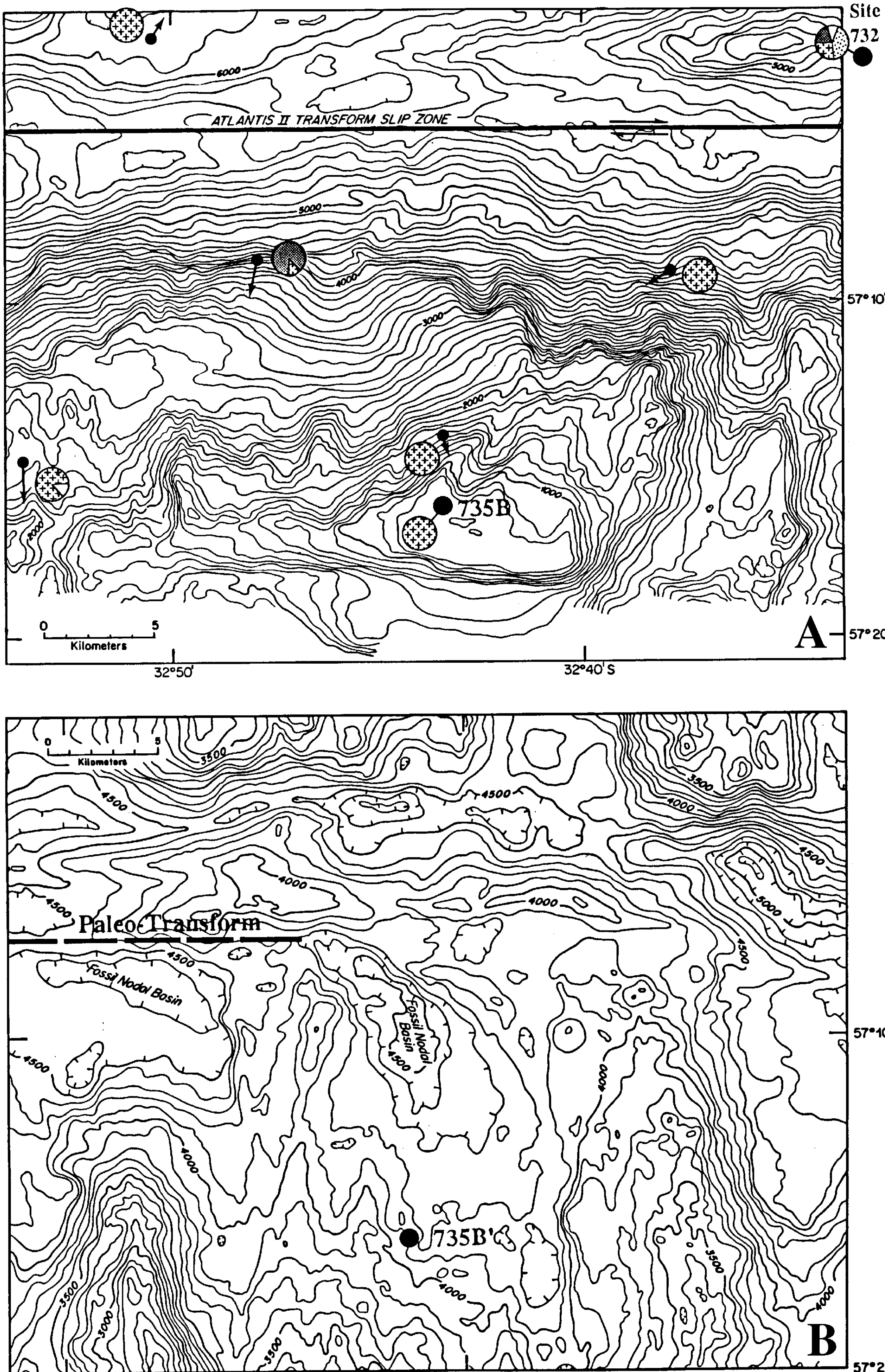

Site
732
6000
5000
ATLANTIS II TRANSFORM SLIP ZONE
5000
4000
3000
2000
1000
735B
2000
57°10'
0
5
Kilometers
A
57°20'E
32°50'
32°40'S
0
5
Kilometers
3500
4500
4500
3500
4000
4000
4500
4000
4000
5000
4500
Paleo-Transform
4500
Fossil Nodal Basin
Fossil Nodal Basin
4500
4500
57°10'E
4000
4000
735B'
4000
3500
3500
3000
3500
4000
B
57°20'
31°30'
31°20'S

Figure 2

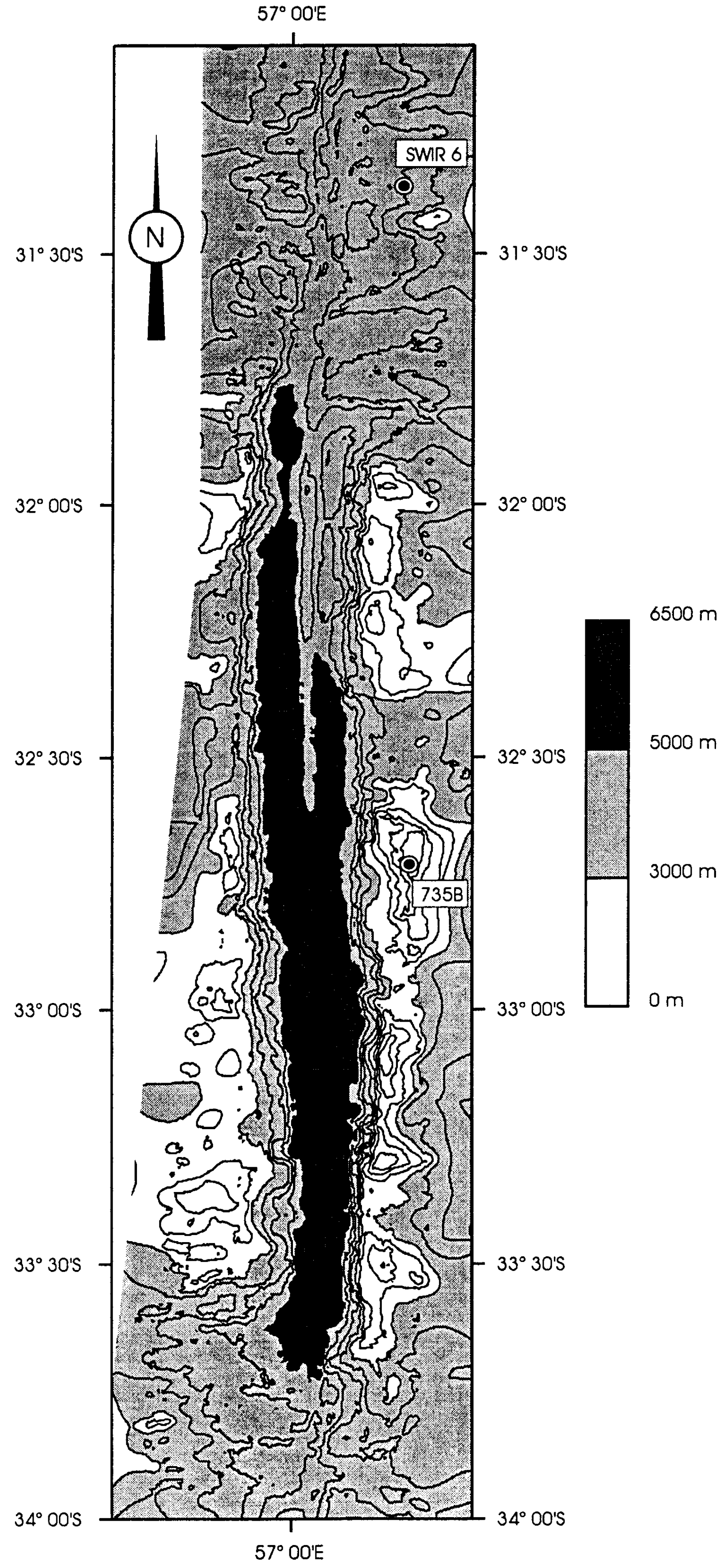
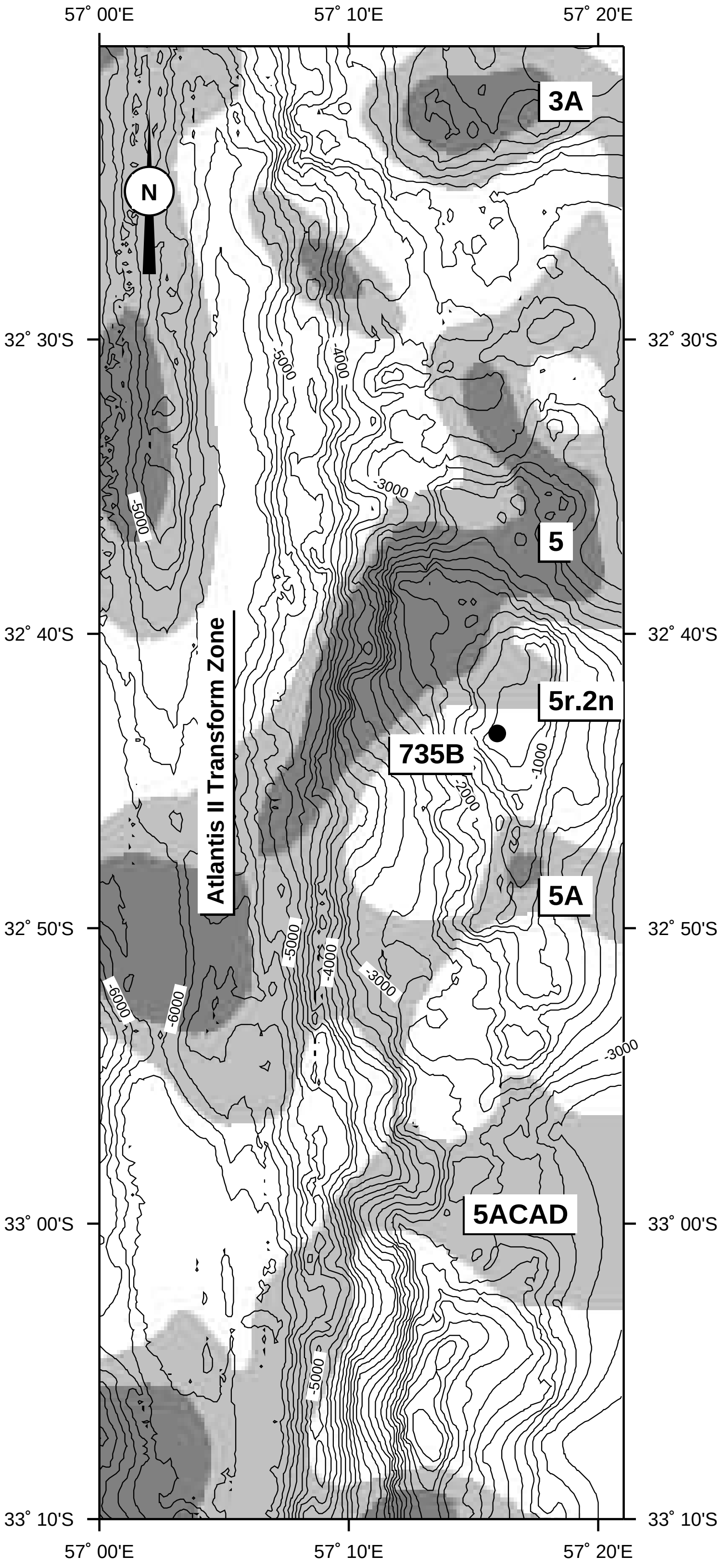

57° 00'E
SWIR 6
N
31° 30'S
32° 00'S
32° 30'S
33° 00'S
33° 30'S
34° 00'S
735B
6500 m
5000 m
3000 m
0 m
57° 00'E

Figure 3



57° 00'E
57° 10'E
57° 20'E
32° 30'S
32° 40'S
32° 50'S
33° 00'S
33° 10'S
N
3A
5
5r.2n
735B
5A
5ACAD
Atlantis II Transform Zone
-5000
-4000
-3000
-2000
-1000
-6000

Figure 4

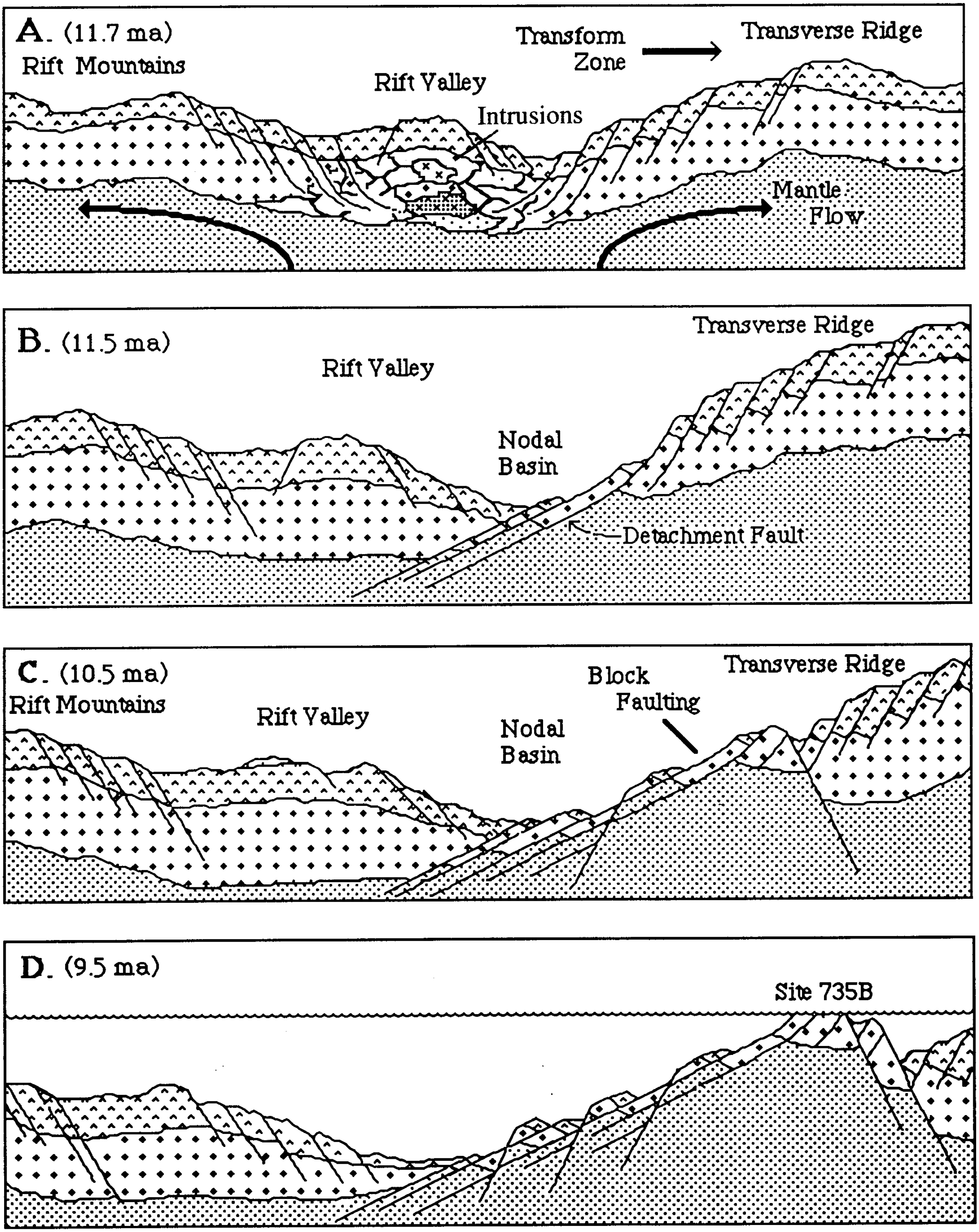

A. (11.7 ma)
Rift Mountains
Rift Valley
Transform Zone
Transverse Ridge
Intrusions
Mantle Flow
B. (11.5 ma)
Rift Valley
Transverse Ridge
Nodal Basin
Detachment Fault
C. (10.5 ma)
Rift Mountains
Rift Valley
Block Faulting
Transverse Ridge
Nodal Basin
D. (9.5 ma)
Site 735B

Figure 5

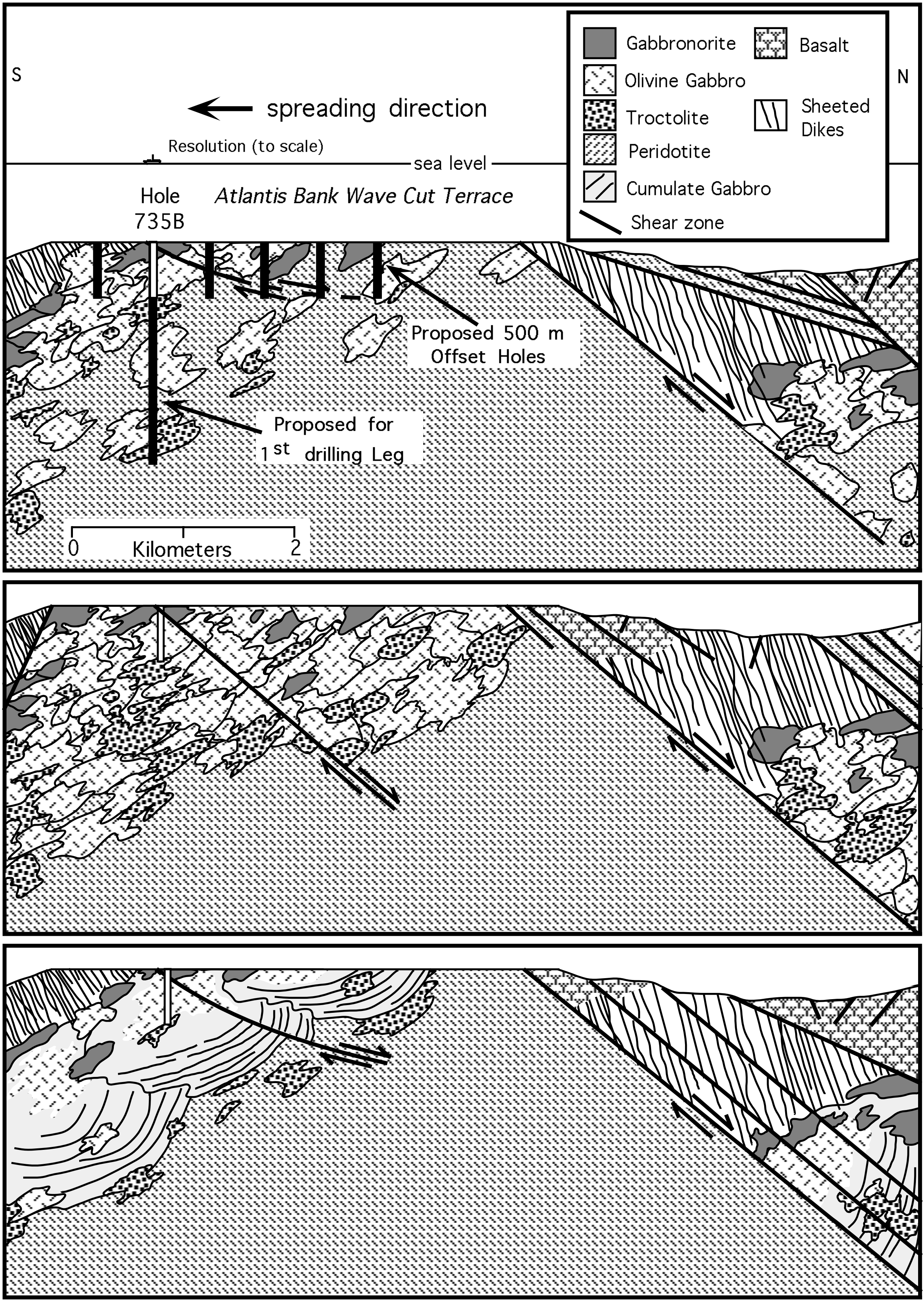
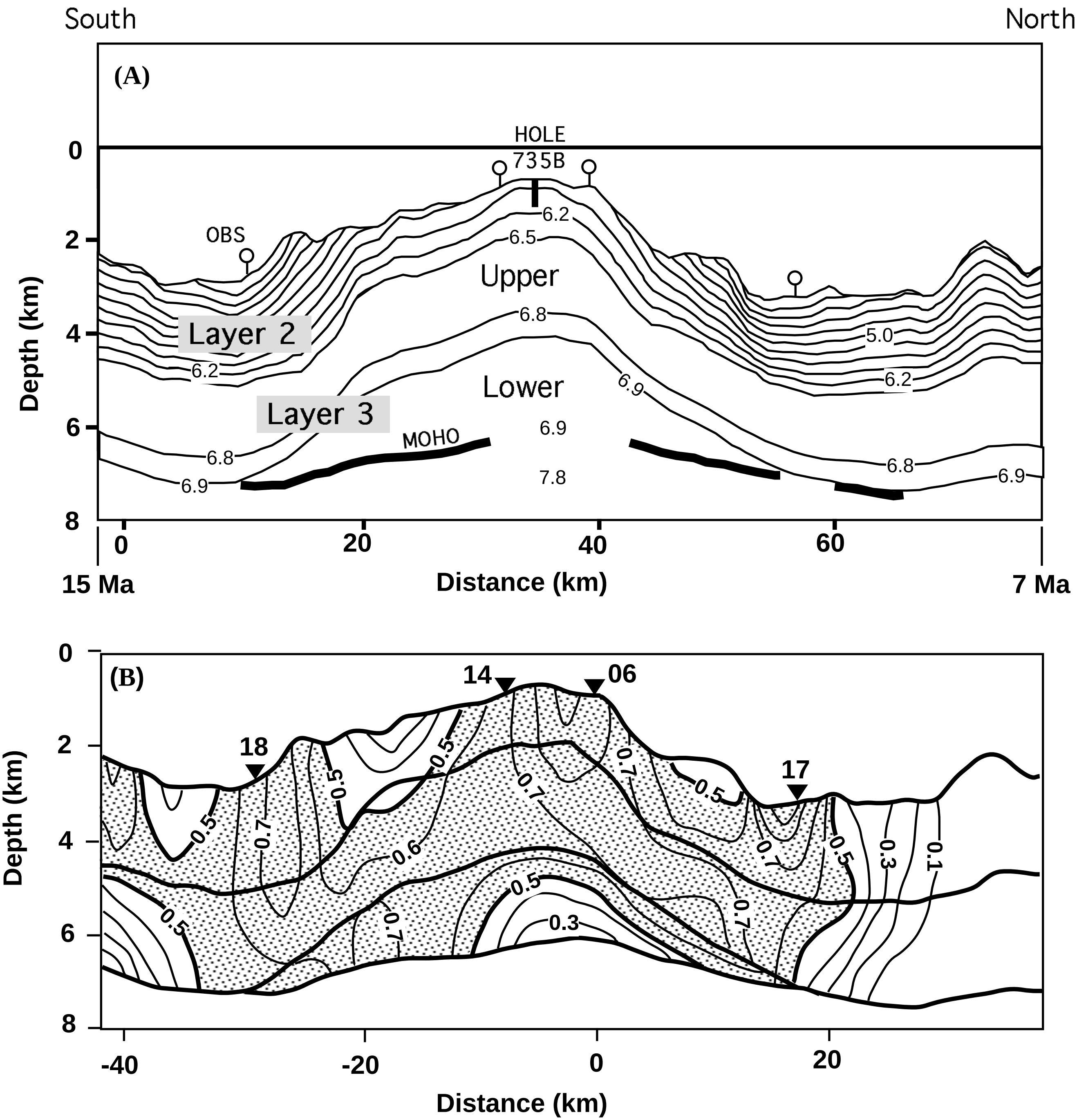

S
N
spreading direction
Resolution (to scale)
sea level
Hole
735B
Atlantis Bank Wave Cut Terrace
Gabbronorite
Basalt
Olivine Gabbro
Troctolite
Sheeted Dikes
Peridotite
Cumulate Gabbro
Shear zone
Proposed 500 m Offset Holes
Proposed for 1st drilling Leg
0
Kilometers
2

Figure 6



South
North
(A)
HOLE
735B
OBS
Upper
Layer 2
Layer 3
Lower
MOHO
6.2
6.5
6.8
6.9
7.8
5.0
Depth (km)
Distance (km)
15 Ma
7 Ma
(B)
14
06
18
17
0.5
0.7
0.6
0.3
0.1

Figure 7

Table 1. Site Time Estimates

PRIMARY SITES:

Site	Location Lat/Long	Water Depth	Projected Operations Plan (Based on an ROP of 2.5 m/hr and includes 5.1 days of logging	Transit (days)	Drilling (days)	Logging (days)	Total On-site
Cape Town	33° 56.0'S		Transit - Cape Town, South Africa to 735B (1940 nmi @10.5 kt = 1)	7.7			
	18° 22.0'E						
735B	32° 43.395'S	731 m	Wireline temperature/caliper and FMS survey (18 hr)		35.5	5.1	40.6
	57° 15.959'E		Continuous RCB coring from 500 mbsf to 1200 mbsf				
			Intermediate wire line logging & VSP (52 hr)				
			Continuous RCB coring from 1200 mbsf to 1750 mbsf				
			Final wire line logging & VSP (52 hr)				
Cape Town	33° 56.0'S		Transit - 735B to Cape Town, South Africa (1940 nmi @10.5 kt = 1)	7.7			
	18° 22.0'E						
				15.4	35.5	5.1	40.6
					TOTAL DAYS:		56.0

ALTERNATE SITES:

Alternate Site	Location Lat/Long	Water Depth	Projected Alternate Operations Plans	Transit (days)	Drilling (days)	Logging (days)	Total (days)
735F	TBD	~720 m	Conduct limited subsea TV survey (~12 hrs)/plus transit to site	0.6	36.7	1.9	39.2
			Offset ~500 m from Hole 735B (direction TBD)				
			Deploy new HRB				
			Drill 14-3/4" hole and install stub of 13-3/8" casing				
			Continuously RCB core from sea floor to 1150 mbsf				
			Wire line logging & VSP (45 hr)				
SWIR-6	31° 21.5'S	~4150m	Adds ~20 hrs additional transit time to leg	0.8	3.9	0.0	4.7
	57° 16.0'E		Spud hole and wash/drill w/center bit through ~50 m of pelagic ooze				
			Continuously RCB core in pillow basalts to 150 mbsf (100m of basement)				
735C	33° 56.0'S	731 m	Deploy new HRB adjacent to 735B	0.0	37.3	1.9	39.2
	18° 22.0'E		Drill 14-3/4" hole and install stub of 13-3/8" casing				
			Drill 9-7/8" hole to 500 mbsf				
			Continuously RCB core from 500 mbsf to 1300 mbsf				
			Wire line logging & VSP (45 hr)				

SITE SUMMARIES

Site: 735

Priority: 1
Position: 32°43.31'S, 57°15.864'E
Water Depth: 731 m
Sediment Thickness: 0 m
Approved Maximum Penetration: As deep as possible
Seismic Coverage: Single channel: RC 27-09, Oct. 13 1630-2000

Objectives:

1. Obtain a section of layer 3 gabbros to adequately document the nature of magmatic, hydrothermal, and tectonic processes in the lower ocean crust at a slow-spreading ridge**.**

2. Determine if the boundary between igneous crust and the depleted mantle lies above the Mohorovicic discontinuity.

Drilling Program: Multiple reentry with rotary coring bits in existing Hole 735B. If conditions preclude deepening Hole 735B, offset ~500 m and start a transect of multiple reentry holes.

Logging and Downhole: Full Schlumberger tool suite, VSP, magnetometer

Nature of Rock Anticipated: Massive amphibolite, gabbro, and partially serpentinized peridotite.

Site: SWIR 6

Priority: 2
Position: 31°21.5'S, 57°16'E
Water Depth: 4150 m
Sediment Thickness: 50 m
Approved Maximum Penetration: Bit-to-destruction
Seismic Coverage: Single Channel, RC 27-09 15 Oct '86 1230-1420, 12 Oct '86 1530-1720

Objectives: Obtain the basaltic carapace originally overlying Site 735B

Drilling Program: Single-bit penetration, bit-to-destruction

Logging and Downhole: None

Nature of Rock Anticipated: Pillow basalt

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