OCEAN DRILLING PROGRAM

LEG 206 SCIENTIFIC PROSPECTUS

AN IN SITU SECTION OF UPPER OCEANIC CRUST CREATED BY SUPERFAST SEAFLOOR SPREADING

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This Scientific Prospectus is based on precruise JOIDES panel discussions and scientific input from the designated Co-chief Scientists on behalf of the drilling proponents. The operational plans within reflect JOIDES Planning Committee and thematic panel priorities. During the course of the cruise, actual site operations may indicate to the Co-chief Scientists and the Operations Manager that it would be scientifically or operationally advantageous to amend the plan detailed in this prospectus. It should be understood that any proposed changes to the plan presented here are contingent upon the approval of the Director of the Ocean Drilling Program in consultation with the Science and Operations Committees (successors to the Planning Committee) and the Pollution Prevention and Safety Panel.

ABSTRACT

Leg 206 will be the first leg of a multi-leg program to recover a complete section of the upper oceanic crust including volcanic extrusive rocks, sheeted dikes, and gabbros as well as the geologically important transition zones between these rock types. Leg 206 is dedicated to coring the upper section of 15-Ma crust on the Cocos plate generated during superfast seafloor spreading (~200 mm/yr) in the eastern Pacific (6°44.19′N, 91°56.06′W; water depth = 3655 m) and will initiate a single cased deep hole for future reentry. This site is optimal for this objective for a number of reasons. First, the depth to axial low-velocity zones, interpreted to be magma chambers at mid-ocean ridges, decreases with increasing seafloor spreading rate. The top of the low-velocity zone, which by inference is the lid of the magma chamber, is thought to correspond to the location of the dike–gabbro transition in normal oceanic crust. Given the superfast spreading rate at the proposed site, the dike–gabbro transition should be relatively shallow, possibly as shallow as 900–1300 m subbasement. Second, the 15-Ma age of the lithosphere should result in lower heat flow with depth than was encountered for the 6-Ma lithosphere in Hole 504B, resulting in reduced thermal stresses during drilling. Third, rapid sedimentation at the site should have increased cementation in the basement rocks, producing favorable drilling conditions. In addition, the resulting sediment thickness of 240 m is more than sufficient for installing a reentry cone with 20-in casing and establishing a reentry hole for deep penetration into basaltic basement. Fourth, the location of the proposed site, <3 days transit from Panama, provides maximum time on site for a 2-month drilling cruise and makes the site more accessible for return visits during future cruises.

In one or two legs we will sample the fast spreading rate end-member of mid-ocean-ridge upper crust geometry, where a steady-state melt lens generates the idealized "Penrose stratigraphy" of plutonic rocks underlying a sheeted dike sequence in turn underlying an extrusive basalt sequence. One primary site will be cored and will focus on determining the depth to and nature of the dike–gabbro transition and the seismic Layer 2–Layer 3 transition. Other topics to be investigated during Leg 206 include fluid flow in and alteration of oceanic crust, petrology and geochemistry of typical oceanic crust, paleomagnetic signature of oceanic crust, the relationship between seismic boundaries and observed lithologic contacts, and further deep biosphere studies.

At the primary drilling target, 240 m of nannofossil ooze will be cored in a pilot hole that will also penetrate <10 m into the extrusive basalt section. A second hole will provide cores across the sediment basement interface and to a depth of ~120 m into basement. In preparation for a deep penetration effort, a third hole will be cased through the sediment and into the upper basement, and the remainder of the leg will be directed at achieving maximum depth of penetration while coring. Our tentative goal is to exceed 600 m of basement penetration, possibly coring as deep as 1 km subbasement, during Leg 206.

BACKGROUND AND GEOLOGIC SETTING

Drilling a complete crustal section has always been a major goal of deep ocean drilling, but because of technical difficulties and the time investments required, our sampling of the ocean crust remains rudimentary (Table T1). Hole 504B remains our only complete section of in situ upper crust and the only hole to penetrate the extrusive lavas and most of the way through the sheeted dike complex. Our poor sampling of ocean crust at different spreading rates and crustal ages compromises our ability to extrapolate observations from specific sites to global descriptions of the magmatic accretion processes and hydrothermal exchange in the ocean crust.

The transition from sheeted dikes to gabbros has never been drilled, and this remains an important objective in achieving a complete or composite crustal section by either offset or deep drilling strategies.

The dike–gabbro transition and the uppermost plutonic rocks are the frozen axial melt lens and the fossil thermal boundary layer between magma chambers and vigorous hydrothermal circulation (Fig. F1). Detailed knowledge of this transition zone is critical to our understanding of the mechanisms of crustal accretion and hydrothermal cooling of the ocean crust. The uppermost gabbros and the overlying sheeted dikes and extrusive lavas provide a time-integrated record of the processes of hydrothermal exchange and fluid and chemical fluxes. The geochemistry of the frozen melt lens when compared with the overlying dikes and lavas will place important controls on crustal accretion processes and magma chamber geometry and will give a geological context to geophysical observations of low-velocity zones (Fig. F2).

Offset drilling strategies, where deeper portions of the ocean crust are sampled by drilling in tectonic windows, have recently been high priorities for ocean drilling (COSOD II, 1987; Ocean Drilling Program [ODP] Long Range Plan, 1996). Drilling at several sites has provided a wealth of new data and understanding of gabbros and peridotites from the lower crust and upper mantle, but problems still exist with drilling tectonized rocks and it is commonly difficult to relate drilled sections to the regional geology. Drilling a deep hole to obtain a complete crustal section and to more fully utilize the capabilities of the drill ship was reemphasized as an important drilling priority at the ODP-InterRidge-IAVCEI workshop in 1996 (Dick and Mevel, 1996) and was identified as one of two highest priority goals at the recent Architecture of the Ocean Lithosphere Program Planning Group meeting (held in 1998; meeting minutes available at http://joides.rsmas.miami.edu/panels/reports.html). Moreover, the ODP Long Range Plan points out that despite recent successes, offset or composite sections of the ocean crust are not substitutes for the primary goal of deep holes through the entire crustal section.

Drilling crust generated at a superfast spreading rate will provide one end-member of mid-ocean-ridge accretion (COSOD II; Long Range Plan). Recent assessment of drilling accomplishments and goals has pointed out that there has been no significant penetration (>100 m) of crust generated at a fast or superfast spreading ridge, making this fundamental objective a current high priority for drilling (Dick and Mevel, 1996). One of the major drilling objectives of the ODP Long Range Plan is to understand the architecture of ocean crust, including the lithology, geochemistry, and thicknesses of the volcanic and sheeted dike sections and the nature of the transition from dikes to gabbros, and to correlate and calibrate geological, geochemical, seismic, and magnetic observations of the structure of the crust. How does structure within Layer 2 and the seismic Layer 2–Layer 3 transition relate to alteration in the volcanics and dikes and to the dike–gabbro transition? At Site 504 in crust generated at an intermediate spreading ridge, the Layer 2–Layer 3 transition lies within the 1-km-thick sheeted dike complex and coincides with a metamorphic change (Detrick et al., 1994). Is this typical for ocean crust and for crust generated at faster spreading rates? Is the depth to gabbros shallower in crust generated at a superfast spreading rate, as predicted? Is the volcanic section thinner than that generated at slow or intermediate spreading rates? Francheteau et al. (1992) estimated a thickness of ~200 m at Hess Deep vs. >500 m at Site 504 and in the Atlantic; measurements of the thickness of seismic Layer 2A suggest 500–600 m for the East Pacific Rise (e.g., Kent et al., 1994).

A second objective is to understand magmatic and alteration processes, including the relationships among extrusive volcanics, the feeder sheeted dikes, and the underlying gabbroic rocks from the melt lens and subjacent sills/intrusions, as well as a comparison with abundant data for crust from slow spreading centers. Intraplate stresses can be determined, as well as the state of fracturing and permeability of the crust. Hydrothermal processes to be addressed by drilling, as outlined by the ODP Long Range Plan and the 1996 Woods Hole workshop, include fluid flow and alteration and the feedback between these and the nature of the subsurface hydrothermal "reaction zone." These will be addressed by examining the alteration "stratigraphy" within the extrusive lavas, whether disseminated sulfide mineralization and evidence for fluid mixing is present at the volcanic–dike transition (as in Hole 504B and many ophiolites), and the grade and intensity of alteration in the lower dikes and upper gabbros. In particular, the lowermost dikes and upper gabbros are predicted to be the subsurface reaction zone where fluids penetrate downward along fractures above the axial magma chamber and vent fluids acquire their final characteristics. Evidence for such fractures has previously been recovered, but an intact section has never been drilled. Drilling this lithologic transition will allow tracing of fluids and linking hydrothermal alteration in sheeted dikes and underlying gabbros to magmatic processes in the melt lens.

Although there are several questions that can be answered well with shallow holes in tectonic windows such as Hess Deep, other questions on topics from in situ permeability to alteration history will give answers that cannot be generalized to normal crust. Furthermore, at sites that are tectonized at very young ages, doubts will remain as to whether the same factors that cause the tectonic exposures also perturb the ridge axis from the normal state.

Rationale

There are three factors that lead us to believe that there are very good chances of reaching gabbro in normal oceanic crust in a two-leg drilling program:

1. Purdy et al. (1992) describe an inverse relation between spreading rate and depth to an axial low-velocity zone, interpreted as a melt lens (Fig. F2). Since Purdy et al.'s compilation, careful velocity analysis, summarized by Hooft et al. (1996), has refined the conversion from traveltime to depth, and data from additional sites have been collected (Carbotte et al., 1997). The fastest-rate spreading centers surveyed with modern multichannel seismic reflection, ~140 mm/yr at 14°–18°S on the East Pacific Rise (EPR), show a reflector interpreted as the axial melt lens at depths typically of 940 to 1260 meters below seafloor (mbsf) (Detrick et al., 1993; Kent et al., 1994, Hooft et al., 1994, 1996). At 9°–16°N on the EPR where spreading rates are 80–110 mm/yr, depths to the melt reflector are mostly 1350–1650 mbsf, where well constrained (Kent et al., 1994; Hooft et al., 1996; Carbotte et al., 1997). Recent identification of magnetic anomalies formed at the southern end of the Pacific/Cocos plate boundary indicate full spreading rates of ~200 mm/yr from 20 to 11 Ma (Fig. F3), implying that these areas are underlain by relatively thin upper crust and shallow gabbro sections.
2. A possible factor in the good drilling conditions in the 6-m.y.-old crust in Hole 504B compared with very young fast-spreading crust from Legs 54 and 142 is the equatorial latitude of formation, with high sedimentation rate leading to rapid burial of the igneous crust while middle levels of the crust are still hot. Alteration under those conditions may increase cementation in the basement and increase the competency of healed fractures in young crust during drilling. The fast spreading rates highlighted in Figure F3 were formed near the equator, and rapid initial sedimentation rates (at least 35 m/m.y.) have been confirmed at ODP Sites 844 and 851 from Leg 138 and Deep Sea Drilling Project (DSDP) Site 572 from Leg 85. A sediment cover of ~240 m is estimated for the proposed drill site. This sediment cover will also facilitate the installation of the reentry cone and 40 to 80 m of 20-in casing, which together are jetted into the sediment until the reentry platform rests on the seafloor.
3. Thermal stresses that resulted in drilling-induced fracturing deep in Hole 504B should be diminished in this older crust (~15 Ma, compared with 6 Ma for Hole 504B). Although such fracturing did not prohibit deep penetration in Hole 504B, this provides some indication that deep drilling conditions can be expected to be better than at Site 504.

The theoretical basis for expecting an inverse relation between spreading rate and melt lens depth is quite simple. The latent heat released in crystallizing the gabbroic crust must be conducted through the lid of the melt lens to the base of the axial hydrothermal system, which then advects the heat to the ocean. The temperature contrast across the lid is governed by the properties of magma (1100°–1200°C) and thermodynamic properties of seawater (350°–450°C where circulating in large volumes) and will vary only slightly with spreading rate. The heat flux through the lid per unit ridge length will therefore be proportional to the width of the lens and inversely proportional to the lid thickness. For reasons which are not understood, seismic observations show uniform width of the melt lens, independent of spreading rate. With width and temperature contrast not varying, the extra heat supplied by more magma at faster spreading rates must be conducted through a thinner lid (dike layer) to maintain steady state (see Phipps Morgan and Chen [1993] for a more complete discussion). To reach the dike–gabbro transition in normal oceanic crust with minimal drilling, it is therefore best to choose the fastest possible spreading rates. A setting similar to the modern well-surveyed area at 14°–18°S could be expected to reach gabbro at a depth of ~1400 m, based on 1100 m to the axial magma chamber (AMC) reflector and subsequent burial by an additional 300 m of extrusives (Kent et al., 1994). At faster rates, depths could possibly be hundreds of meters shallower. In contrast, seismic velocity inversions at the axes of the Juan de Fuca Ridge and Valu Fa Ridge, Lau Basin, are at depths of ~3 km (Purdy et al., 1992) at intermediate spreading rates comparable to Site 504.

Although perhaps only 20% of the global ridge axis is separating at fast spreading rates (>80 mm/yr full rate), this end-member style of the ocean spreading produced ~50% of the present-day ocean crust and ~30% of the total Earth's surface. At least in terms of seismic structure (Raitt, 1963; Menard, 1964), crust formed at fast spreading rates is relatively simple and uniform. Hence, the successful deep sampling of such crust in a single location can reasonably be extrapolated to describe a significant portion of the Earth's surface.

Drilling of the fast spreading crust has been mostly unsuccessful (e.g., DSDP/ODP Legs 34, 54, and 142). Apart from surface sampling of recent basalts at ridge axes, little is known of the shallow and intermediate depth structure of fast-spreading crust (Table T1). One recent exception is the coring completed at Site 1224 during Leg 200 in the eastern North Pacific, which sampled a 146.5-m-thick section of basaltic oceanic crust created by fast seafloor spreading (142 mm/yr full rate). Studies of Site 1224 are just getting underway but will be limited to the extrusive basalt flows recovered. A continuous section through the upper oceanic crust and ultimately into mid-crustal gabbros is imperative to calibrate geophysical observations and numerical models of the ocean crust.

Site Selection

A recent synthesis of magnetic anomaly data for the central Cocos plate and corresponding regions of the Pacific plate demonstrated that the spreading rate on the southern Cocos/Pacific plate boundary during the middle Miocene was ~200 mm/yr, ~30% to 40% faster than the fastest modern spreading rate (Wilson, 1996). This episode of fast spreading ended fairly abruptly in a plate-motion reorganization at 10.5–11.0 Ma; subsequent motions have been similar to present-day motions. The southern limit of crust formed at the superfast rates is the trace of the Cocos-Nazca-Pacific triple junction, as Nazca-Pacific and Cocos-Nazca spreading rates were not as fast. The lower age limit of this spreading episode is hard to determine with the limited mapping and poor magnetic geometry of the Pacific plate. It is at least 18 Ma and could reasonably be 24–25 Ma. The northern limit of this province is entirely gradational, with rates dropping to ~150 mm/yr somewhat north of the Clipperton Fracture Zone. By apparent coincidence, the fastest spreading rates occurred within a few degrees of the equator.

Using the fastest possible spreading rate as a proxy for shallowest occurrence of gabbro still allows a range of possible drilling sites. There is no reason to expect a difference in crustal structure between the Cocos and Pacific plates, but logistics favor a site on the Cocos plate. Transits from a variety of Central American ports would be only 2–4 days, and sediments are about 200 m thinner than on the Pacific plate. It seems prudent to choose an anomaly segment at least 100 km long and a site at least 50 km from the end of the segment. For ages 12–16 Ma (anomalies 5AA–5B) these criteria are easy to satisfy because the southernmost segment of the Pacific-Cocos Ridge had a length of at least 400 km. For ages 17 Ma (anomaly 5D) and older there is a fracture zone to avoid, but the length of anomaly segments is at least 150 km. A possible option would be to reoccupy Site 844, near the young edge of anomaly 5D about 100 km from a fracture zone and roughly 150 km from the trace of the triple junction with the Cocos/Nazca boundary. The sedimentary section was redundantly cored during Leg 138 in 1991, with basalt chips recovered from 290 mbsf. Concordance between the age of the deepest sediments and the magnetic anomaly age (Wilson, 1996) indicates that there are no sills significantly above the base of the sediment column that would reflect magmatic rejuvenation of the site.

The only serious drawback to this area for a crustal reference section for fast spreading rates is the low original latitude, which makes magnetic polarity determinations impossible from azimuthally unoriented core samples and, given the nearly north-south ridge orientation, makes the magnetic inclination insensitive to structural tilting. The polarity problem could be solved with a reliable hard rock orienting device, but development efforts for such a tool have been abandoned. Magnetic logging with either the General Purpose Inclinometry Tool (GPIT) fluxgates that are part of the Formation MicroScanner/Dipole Shear Sonic Imager (FMS/sonic) tool string or preferably a separate magnetic tool with gyroscopic orientation, such as the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) borehole magnetometer, should also be adequate for polarity determination, as demonstrated in Holes 504B and 896A with logs collected during Leg 148 (Worm et al., 1996). Alternative sites have other, often more serious, drawbacks. Sites flanking the EPR south of the equator generally have poor accessibility and for the age range 10–25 Ma have a complicated tectonic setting and often uncertain spreading rates. North of the equator, sites are available in the same Cocos-Pacific system, which is better understood and more tectonically stable, but there is a severe tradeoff between latitude and spreading rate. A magnetically desirable latitude of 20° would reduce the spreading rate to ~60% of the rate for the sites we propose, which may significantly reduce the chances of reaching gabbro in limited drilling time. To detect structural rotations about a nearly north-south ridge axis, paleolatitude should probably exceed 25°, which means that no site satisfying this criterion will also offer fast spreading rate and short transit to common ports.

Site Survey Results

The site survey cruise for this proposal took place in March and April 1999, aboard the *Maurice Ewing,* led by D. Wilson, A. Harding, and G. Kent. At the urging of the Architecture of Oceanic Lithosphere Program Planning Group, we modified our original plan for four sites in the Guatemala Basin to instead cover three sites there and a separate site near Alijos Rocks west of Southern Baja California (Figs. F4, F5, F6, F7). The principal advantage of the Alijos site is higher paleolatitude, allowing determination of magnetic polarity with azimuthally unoriented cores. The other significant difference recognized before survey work is lower spreading rate, ~120–130 mm/yr instead of 200–210 mm/yr.

The site survey work focused on seismic reflection and refraction. Multichannel seismic reflection (MCS) and refraction work to ocean bottom hydrophones (OBHs) were conducted separately because of differences in desired shot intervals. MCS work used a tuned array of 10 air guns shooting to a new 480-channel, 6-km streamer, with a nominal shot interval of 37.5 m (15–18 s). With a hydrophone spacing of 12.5 m, this geometry gives 80-fold coverage with 6.25-m midpoint spacing. Refraction shooting to grids of 10–11 OBHs using 20 air guns was at a shot interval of 90 s (130–180 m) for most of the grid and 150 s (300 m) for the outermost shots. The grid geometry was designed for well-constrained measurements of velocities in both across-strike and along-strike directions to depths of 1.5–2.0 km and to cover to Moho depths in the across-strike direction only (Figs. F5, F6, F7). Because of time constraints and delays from several causes, refraction surveying was only done at two of the three Guatemala Basin sites.

The Guatemala Basin sites have 200–300 m of sediment cover resulting from their formation near the paleoequator. Referring to the sites in the order MCS was collected, grid 1 was chosen to include ODP Site 844 at a line crossing and to be centered near the C5D(y) magnetic anomaly boundary, and grids 2 and 3 were centered on anomalies C5C(y) and C5B(o) along a flow line perpendicular to anomaly strike (Fig. F4). Grids 1 and 3 have refraction data. Grid 1 is quite shallow for its ~17-Ma age at 3400–3500 m, and basement at Site 844 is at 3705 m (Fig. F6). Relief on basement as seen in MCS is extremely low, with largest scarps having ~30-m amplitude. Subtle horizontal reflections ~1.6–1.7 s below basement suggest Moho. A cluster of seamounts with minimum depth of 2790 m is present near the southern tip of the grid.

Grid 3 is deeper than grid 1 at 3600–3700 m, and basement at ~3900 m is near normal depth for the ~15-Ma age (Fig. F5). In the southwest half of the grid, abyssal hill fabric is visible through the sediment cover, and larger scarps approach 100-m amplitude. The northeast half of the grid has low relief, comparable to grid 1. Reflection data here commonly show complex reflectors at 1.3–1.8 s below basement, indicating dipping interfaces in the lower crust or upper mantle, probably including some Moho reflections. Upper crustal reflectors at ~0.4–0.8 s into basement are often bright and tend to have shallow (~20°) apparent dips in the isochron direction, with more horizontal apparent dips in the spreading direction (Figs. F8, F9). Analysis of refraction data in this grid shows crustal structure that is fairly typical for off-axis Pacific seafloor. Upper Layer 2 velocities are 4.5–5 km/s, a gradual transition between Layers 2 and 3 is at ~1.5 km below basement, and total crustal thickness is ~5–5.5 km (Fig. F10). Velocities of the uppermost crust are slowest in the southwestern part of the grid where the abyssal-hill relief is greatest.

In contrast to the Cocos plate sites, grid 4 near Alijos Rocks has thin (50–100 m) sediment, slightly deep water (3800–4300 m) for the ~16.5-Ma age, and extremely high relief for the fast spreading rate (Fig. F7). Individual scarps are commonly 150 m, and up to 400 m. MCS data show no coherent reflections below Layer 2 in preliminary stacks. Receiver gathers for refraction data are broadly similar to the Cocos plate sites, perhaps suggestive of slightly slower velocities around 1 km below basement.

Magnetic data at the Cocos plate sites show trends parallel to the previously mapped regional trend, with no evidence for isochron offsets at ~1-km detection limit within the grids (Fig. F11) and perhaps 3- to 5-km detection limit outside the grids. The Alijos grid is located within an area where magnetic and topographic features are linear for 30–40 km, but right-stepping offsets of a few kilometers leave the local trend a few degrees counterclockwise of the regional trend.

Of the three survey grids with refraction data, we have chosen grid 3 (the southwesternmost and youngest of the Cocos plate grids) as our primary target because its depth and relief are closest to normal. Within this grid, several factors affected the final site selection. The slower seismic velocities in southwestern part of the grid indicate more porous and possibly more rubbly material that may lead to poorer drilling conditions. OBH failure on line 23 along the southeastern part of the grid led to limited constraints on velocity determinations there. A very bright upper crustal reflector is observed on much of line 21 in the northeastern part of the grid and for short distances on lines 27 and 28 where they cross line 21. The reflector dips northwest and projects updip to a hill ~50 m high with northeast strike, which is perpendicular to the normal abyssal-hill trend. The character of the reflection and its relation to the nearly vertical velocity gradient determined by refraction analysis are both more consistent with a narrow low-velocity zone rather than a simple interface between materials of different velocity. All of these relations suggest that the reflector might be a thrust fault, possibly driven by thermal contraction of the lower lithosphere. Because such a fault might lead to very poor drilling conditions at about the depths gabbro might be encountered on a return leg, we have chosen to avoid this area as well. The remaining area near the northern corner of the grid appears very suitable for deep drilling, and we have chosen the intersection of lines 22 and 27, where the velocity control is best, as the primary drilling site, GUATB-03C.

SCIENTIFIC OBJECTIVES

Drilling of superfast spreading rate ocean crust during Leg 206 will characterize the nature of magmatic accretion and the primary and secondary chemical composition, as well as the tectonic and seismic structure of the uppermost oceanic crust (the target depth for Leg 206 is 600–800 m subbasement). These cores will provide an essential link to relate geology to remote geophysical observations (seismics and magnetics) and ground-truth the relationship between seismic stratigraphy and lithostratigraphy. Paleomagnetic studies will establish the relative contributions of the major lithologic units to marine magnetic anomalies and the position of our site (~50 k.y. from a magnetic reversal) will provide information on crustal cooling rates and the contribution of deep plutonic rocks to surface magnetic anomalies. The holes drilled during Leg 206 will provide the first test of the lateral variability of the ocean crust and provide an essential comparison for the models of crustal accretion, hydrothermal alteration, and the secondary mineral/metamorphic stratigraphy principally developed from ODP Hole 504B. This will refine models for the vertical and temporal evolution of ocean crust, including the recognition and description of zones of hydrothermal and magmatic chemical exchange. Physical properties measurements of cores recovered from fast-spreading ocean crust will yield information on the porosity, permeability, and stress regime as well as the gradients of these properties with depth. A full suite of wireline logs will supplement geological, chemical, structural, and magnetic observations and physical properties studies on the core. The careful integration of borehole observations with measurements of the recovered core is imperative for the quantitative estimation of chemical exchange fluxes between the ocean crust and oceans.

A major objective of Leg 206 is to establish a cased reentry hole that is open for future drilling to the total depth penetrated during the leg. Though not impossible, the total depth will unlikely be deep enough to reach the dike–gabbro transition zone during Leg 206. Our efforts, however, will provide the groundwork for a second leg to return to the site and investigate the geological nature of the geophysically imaged “axial melt lens” believed to be present close to the gabbro–dike transition. Drilling of this boundary in situ will allow the relationships between vigorous hydrothermal circulation, mineralization, dike injection, and the accretion and freezing of the plutonic crust to be investigated.

UNDERWAY GEOPHYSICS

Standard ODP practice is to collect magnetometer and 3.5- and 12-kHz echo-sounder data during transit to each site. No additional surveys are planned, though the new generator-injector (GI) gun along with the Well Seismic Tool (WST)-3 logging tool will be used for a zero-offset vertical seismic profile in the reentry hole.

DRILLING STRATEGY

Site GUATB-03C, the proposed site for all drilling operations, was selected from the region surveyed to take advantage of faster upper crustal velocities, which may indicate the presence of massive basalt flows, and to avoid thrust faults that occur elsewhere in the region. The estimated sediment thickness of 240 m is more than sufficient for installing a reentry cone with 20-in casing and establishing a reentry hole for deep penetration into basaltic basement.

Our plan is to first core the sedimentary section and upper couple meters or so of basement with the advanced piston corer (APC) and extended core barrel (XCB) system (Table T2). Second, we will conduct a jet-in test to establish what length of 20-in casing can be jetted into the sediment. The test is conducted by setting the XCB bit on the seafloor and then circulating fluids through jets in the bit. The bit is gradually jetted into the sediments until further progress is inhibited by the increased induration of the sediments. Next, we will trip the pipe to the surface to switch to the rotary core barrel (RCB) system, trip the pipe back to the seafloor, drill through the sedimentary section to within about 20 m of basement, and then proceed with RCB coring to bit destruction. The RCB bit life is likely to be ~60 hr of rotation in basalt, which, at the estimated rate of 2 m/hr, will allow us to core ~120 m into basement. After preparing the hole for logging, the bit will be dropped in the bottom of the hole and the pipe raised to ~100–150 mbsf for logging. The basement and lower portion of the sedimentary section will be logged with the triple combination (Triple Combo) and the FMS/sonic tool strings and the BGR borehole magnetometer as described in the "Logging Plan" section.

This pilot hole will allow us to assess basement hole stability and to determine the depth to which the 16-in casing string should be run. Ideally, the casing will only need to extend into the upper few meters or tens of meters of basement, with the goal of casing off the lower sedimentary section, the sediment/basement contact, and any rubbly or fractured basalt that occurs at the top of basement. It is possible, however, that a greater amount of the basement will need to be cased. Thus, we provide two scenarios for the reentry hole (Table T2). In the first scenario (Fig. F12), only two casing strings are required, the 20-in and 16-in strings, with the 16-in casing string extending 20 m into basement. In the second scenario (Fig. F13), three casing strings are required. The depth of each casing string is purely hypothetical at this point, as the actual depths will depend on where or if unstable hole conditions are encountered.

Both scenarios begin with jetting-in the reentry cone with ~80 m of 20-in casing. A pipe trip is required to change to a new 18-in-diameter bi-center bit that cuts a $21^1/_2$-in-diameter hole. Bi-center bits have not been used previously by ODP. Their advantage is that they can fit into holes or casing with a diameter as narrow or narrower than the diameter of the hole they cut. Prior to acquiring the bi-center bit, we had planned to use an 18.5-in-diameter tricone bit in basement. The larger diameter hole created by the bi-center bit provides a greater safety margin for installation of the 16-in casing. The bi-center bit will thus be used to drill a $21^1/_2$-in hole through the sediment and into basement.

Assuming favorable hole conditions are encountered in the pilot hole, then we will follow the first scenario. In this scenario, the $21^1/_2$-in hole is drilled 30 m into basement. The hole is then cased with 16-in casing 20 m into basement, leaving a 10-m rat hole below casing. The casing is cemented into basement, and the pipe is tripped to the rig floor. Operations then consist of RCB coring, with multiple bit changes as necessary, until coring time expires. Given the estimated bit life and rate of penetration, we anticipate coring to ~1050 mbsf, or ~810 m into basement. Following completion of coring, the hole would be logged with the triple combo, the FMS/sonic, the BGR borehole magnetometer, the Ultrasonic Borehole Imager (UBI), and the three-component WST-3 logging tools as described in the "Logging Plan" section.

If unstable hole conditions are encountered in the basement, then operations may follow something like this second scenario. Again, after drilling through the sediments, the 21 1/2-in hole is drilled, though this time it penetrates 120 m into basement. This scenario assumes the upper 100 m or so of basement is found to be unstable in the pilot hole. The 16-in casing is thus installed and cemented 110 m into basement. RCB coring then proceeds. In this scenario, an unstable portion of the hole is encountered above 480 mbsf, though below the total depth of the pilot hole. In order to continue operations in the hole, casing would need to be set through the interval. First, however, we would attempt to log the interval because it would not have been logged in the pilot hole. The same tool strings as used in the pilot hole will be used for this interval. Depending on the depth of the unstable interval, either 13 3/8-in or 10 3/4-in casing could then be used. A decision to use 13 3/8-in casing would allow an additional 10 3/4-in casing string to be used later if necessary, though it also requires that we use a new bi-center bit. A 14 1/2-in-diameter bi-center bit that cuts a 18 1/2-in-diameter hole will be used if 13 3/8-in casing is installed. Again, the larger diameter hole cut by the bi-center bit provides a greater safety margin for installation of the 13 3/8-in casing. In this hypothetical second scenario, we open the hole with the bi-center bit to a depth of 490 mbsf and then install and cement the 13 3/8-in casing to 480 mbsf. Operations then consist of RCB coring, with multiple bit changes as necessary, until coring time expires. We anticipate coring to ~770 mbsf, or ~530 m into basement. Following completion of coring, the hole would be logged with the triple combo, the FMS/sonic, the BGR borehole magnetometer, the UBI, and the WST-3 logging tools as described in the "Logging Plan" section.

Should the primary site prove to be unstable or should operations in the reentry hole become impossible for other reasons, we would plan to move to one of the alternate sites and repeat as much of the above plan as possible.

LOGGING PLAN

Downhole logging will be an essential component of Leg 206 scientific objectives by providing in situ information on the geophysical structure of the drilled basaltic formation. An extensive logging program is planned at proposed Site GUATB-03C to achieve objectives such as study of volcanic stratigraphy, eruptive morphology, variations in alteration, stress field, and seismic structure. Whereas core recovery is often biased and incomplete in igneous basement, downhole logging data are continuous and therefore provide information over intervals of low recovery.

As discussed in the "Drilling Strategy" section, we intend to log the entire section drilled, which requires logging the RCB pilot hole as well as the reentry hole. Specifically, the triple Combo and FMS/sonic tool strings and the BGR borehole magnetometer will be run both in the RCB pilot hole and the reentry hole. The WST-3 logging tool will be run in the reentry hole only because it is capable of providing seismic velocity data in the cased hole as well as the open hole. Similarly, we plan to run the UBI logging tool in the reentry hole and possibly in the RCB pilot hole, but use of this specialty tool is contingent on availability of funds, which will be determined prior to Leg 206. The characteristics of these logging tool strings can be found at the Lamont-Doherty Earth Observatory (LDEO) Borehole Research Group web site at http://www.ldeo.columbia.edu/BRG and are briefly described below.

Triple Combination Tool String

The triple combo consists of several probes or sondes:

1. The Accelerator Porosity Sonde (APS) uses an electronic neutron source to measure the porosity of the formation.
2. The Hostile Environment Litho-Density Sonde (HLDS) measures bulk density.
3. The Hostile Environment Gamma Ray Sonde (HNGS) measures the natural radioactivity of the formation and provides Th, U, and K contents, which can be used for determining alteration downhole variations.
4. Either the Dual Induction Tool (DIT) or the Dual Laterolog (DLL) tool can be used to measure rock resistivity. The DIT provides an indirect measurement of the resistivity and the spontaneous rock potential (SP), as well as the conductivity of the formation at three invasion depths, whereas the DLL measures the direct resistivity at two invasion depths. The tools also differ in their response range, which is 0.2–2000 Ωm for the DIT and 0.2–40000 Ωm for the DLL. We plan to use the DLL during Leg 206.
5. The LDEO Temperature/Acceleration/Pressure (TAP) tool will be attached at the bottom of the tool string to measure borehole temperature, tool acceleration, and hydrostatic pressure in situ. The data can be used to monitor for the presence of incoming fluids.
6. The third-party Multi-Sensor Spectral Gamma Ray Tool (MGT) developed by LDEO measures the natural gamma ray Th, U, and K contents, but the vertical resolution of this tool is about four times the vertical resolution of the HNGS. When deployed, the MGT is placed at the top of the triple combo tool string.

Formation MicroScanner/Dipole Sonic Imager Tool String

The FMS/sonic tool string has two main components:

1. The Dipole Sonic Imager (DSI) measures a full waveform, including the compressional wave (*P*-wave), the shear wave (*S*-wave), and the Stoneley wave (St-wave). This tool will provide information related to the seismic structure of the upper oceanic crust.
2. The FMS consists of four orthogonal pads with 16 electrodes on each pad. The FMS tool obtains a high-resolution microresistivity image of the borehole wall, which is useful for identification of lithologic units and tectonic features (e.g., the presence of fractures and faults and their orientations). The FMS tool includes a General Purpose Inclinometry Tool (GPIT), which provides tool acceleration and fluxgate magnetometer measurements that are used to orient the microresistivity images. The FMS arms are also used as calipers for hole size estimation. A Natural Gamma Ray Spectrometry Tool (NGT) is included in this tool string to allow correlation with other logging runs for establishing consistent depth estimates.

Ultrasonic Borehole Imager

The UBI measures the amplitude and transit time of an acoustic wave propagated into the formation. It provides high-resolution images with 100% borehole wall coverage, which allows detection of small-scale fractures. The GPIT is deployed with the UBI and allows orientation of the images; evaluation and orientation of fractures can provide information about the local stress field and borehole geometry even within the casing. An NGT is included in this tool string to allow correlation with other logging runs for establishing consistent depth estimates. Deployment of the UBI during Leg 206 is contingent on availability of funds.

BGR Borehole Magnetometer

The BGR borehole magnetometer is a third-party tool developed by Bundesanstalt für Geowissenschaften und Rohstoffe in Germany. It has been previously used in Holes 504B and 896A during ODP Leg 148 (Shipboard Scientific Party, 1993; Worm et al., 1996) and in the KTB (Kontinentales Tiefbohrprogramm Bundesrepublik) drill hole in Germany. It has three fluxgate sensors that measure three orthogonal components of the magnetic field. It can measure fields up to 100 µT with a resolution of 0.1 nT. The probe contains two inclinometers, aligned with the probe's x- and y-axes, that measure the tilt of the probe to 0.1°. The tool includes a gyroscope, which measures the tool rotation during data acquisition and allows the orientation of the tool to be determined. The data from the magnetometer will be used to monitor changes in the magnetic properties of the upper oceanic crust as well as changes in paleomagnetic direction that can aid in determination of the magnetic polarity. We are currently investigating whether the BGR borehole magnetometer will be available for Leg 206.

Three-Component Well Seismic Tool

The WST-3 records acoustic waves generated by an air gun located near the sea surface. It provides a complete check-shot survey, a depth-traveltime plot, and accurate estimates of the drilling depth.

SAMPLING PLAN

The Sample Distribution, Data Distribution, and Publications Policy is posted at http://www-odp.tamu.edu/publications/policy.html. The Sample Allocation Committee (SAC), which consists of the two Co-Chief Scientists, the Staff Scientist, the ODP Curator onshore, and the curatorial representative on board ship, will work with the entire science party to formulate a formal leg-specific sampling plan for shipboard and postcruise sampling.

During Leg 206, we expect to recover <500 m of basalt and ~250 m of sediment. All sample frequencies and sample volumes taken from the working half of the core must be justified on a scientific basis and will be dependent on core recovery, the full spectrum of other requests, and the cruise objectives. All sample requests must be made on the standard Web sample request form and approved by the SAC.

Leg 206 shipboard scientists may expect to obtain as many as 100 samples of no more than 15 cm^3 in size from basement cores. Additional samples may be obtained upon written request onshore after initial data are analyzed. Depending on the penetration and recovery during Leg 206, the number of samples taken may be increased by the shipboard SAC. For example, studies requiring only small sample volumes of 2 cm^3 or less (e.g., veins, fluid inclusions, etc.) may require >100 samples to characterize a long section of core. The SAC will review the appropriate sampling interval for such studies as the cores are recovered. Samples larger than 15 cm^3 may also be obtained with approval of the SAC. Request for large samples must be specified on the sample request form. Sample requests may be submitted by shore-based investigators as well as the shipboard scientists. Based on sample requests received 3 months precruise, the SAC will prepare a temporary sampling plan, which will be revised on the ship as needed. Some redundancy of measurement is unavoidable, but minimizing redundancy of measurements among the shipboard party and identified shore-based collaborators will be a factor in evaluating sample requests.

If some critical intervals are recovered (e.g., glass, fault gauge, veins, etc.), there may be considerable demand for samples from a limited amount of cored material. These intervals may require special handling, a higher sampling density, reduced sampling size, or continuous core sampling by a single investigator. A sampling plan coordinated by the SAC may be required before critical intervals are sampled.

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TABLE CAPTIONS

Table T1. Summary of holes drilled in "normal crust" in the central and eastern Pacific with an age <100 Ma, full spreading rate >75 mm/yr, and penetration into basement >10 m.

Table T2. Operations plan and time estimates for Leg 206.

FIGURE CAPTIONS

Figure F1. Schematic cross section of oceanic crust created by superfast seafloor spreading (after Karson et al., 2002). Approximate boundaries of seismic layers are given to the left. The black arrows show magma withdrawal in the subaxial magma chamber. The yellow arrows indicate deformation related to faulting, fracturing, and block rotation in the sheeted dikes and lower lavas.

Figure F2. Depth to axial low-velocity zone plotted against spreading rate, modified from Purdy et al. (1992) and Carbotte et al. (1997). Depth vs. rate predictions from two models of Phipps Morgan and Chen (1993) are shown, extrapolated subjectively to 200 mm/yr.

Figure F3. Age map of the Cocos plate and corresponding regions of the Pacific plate. Isochrons at 5-m.y. intervals have been converted from magnetic anomaly identifications according to the timescale of Cande and Kent (1995). Selected DSDP and ODP sites that reached basement are indicated by circles. The wide spacing of 10- to 20-Ma isochrons to the south reflects the extremely fast (200–210 mm/yr) full spreading rate.

Figure F4. Location of Guatemala basin MCS tracklines (bold) from the site survey conducted in March–April 1999. Gray shading shows normal magnetic polarity, based on digitized reversal boundaries (small circles, after Wilson, 1996). Anomaly ages: 5A = ~12 Ma, 5B = ~15 Ma, and 5D = ~17 Ma.

Figure F5. Bathymetry and site-survey track map for the primary site. Abyssal hill relief of up to 100 m is apparent in the southwest part of the area; relief to the northeast is lower and less organized. Line numbers 21–28 identify MCS lines for subsequent figures. Triangles show locations of OBHs recovered with data.

Figure F6. Bathymetry and track maps for alternative Site GUATB-01. Site GUATB-01 has very shallow depths and low relief, excluding seamounts, in contrast to Site ALIJOS (Fig. F7), which is slightly deep and has very high relief.

Figure F7. Bathymetry and track maps for Site ALIJOS, a surveyed site that is no longer under consideration for drilling.

Figure F8. Stacked, migrated section of MCS data from line 22, showing positions of primary drill Site GUATB-03C and alternate Site GUATB-03B. Crossing positions of lines 24–28 are labeled.

Figure F9. Stacked, migrated section of MCS data from line 27, showing the primary drill Site GUATB-03C and crossing positions of lines 21–23. The bright reflector at 5.5–5.7 s near the line 21 crossing may be a thrust fault, and site selection decisions avoided this feature.

Figure F10. One-dimensional velocity model based on inversion of refraction data. At shallow depths, separate inversions were performed on northeast and southwest data subsets, with slightly faster velocities found to the northeast where abyssal hill topography is very subdued. The Layer 2/3 boundary is present in the depth range 1.2–1.5 km. The velocity model of Detrick et al. (1998) for Site 504, also based on OBH refraction, is shown for comparison. Apparent differences are dominated by differences in the inversion techniques, but the differences at 1.3–1.7 km may be barely above uncertainties.

Figure F11. Underway geophysics plotted perpendicular to trackline for the Guatemala Basin sites. (**A**) Magnetic anomaly, with negative anomaly (normal polarity) shaded and identifications labeled. (**B**) Center-beam bathymetry. (**C**) Free-air gravity anomaly.

Figure F12. Schematic cross section of drilling Scenario A, in which the reentry hole has two casing strings, a 20-in string that extends ~80 m into sediments and a 16-in string that extends ~20 m into basement.

Figure F13. Schematic cross section of drilling Scenario B, in which the reentry hole has three casing strings, a 20-in string that extends ~80 m into sediments, a 16-in string that extends ~20 m into basement, and a 13$^3/_8$-in string that extends deeper into basement across an unstable zone. The existence of unstable zones is an unknown at this point, but such zones may be present and will be stabilized through the use of casing when feasible.

Table 1. Summary of holes drilled in normal crust in the central and eastern Pacific with an age <100 Ma, full spreading rate >75 mm/yr, and penetration into basement >10 m.

Hole	Leg	Age (Ma)	Location	Basement penetration (m)	Sediment thickness (m)
163	DSDP 16	72	11°N,150°W	18	176
319A	DSDP 34	17	13°S,102°W	59	110
320	DSDP 34	26	9°S,84°W	29	155
420	DSDP 54	3	9°N,106°W	29	118
421	DSDP 54	3	9°N,106°W	29	85
429A	DSDP 54	5	9°N,107°W	21	31
469	DSDP 63	17	33°N,121°W	58	391
470A	DSDP 63	15	29°N,118°W	48	167
471	DSDP 63	12	23°N,112°W	82	741
472	DSDP 63	15	23°N,114°W	25	112
487	DSDP 66	13	16°N,99°W	19	171
495	DSDP 67	23	12°N,91°W	27	428
597B	DSDP 92	29	19°S,130°W	25	48
597C†	DSDP 92	29	19°S,130°W	91	53
599B	DSDP 92	8	19°S,120°W	10	41
843B‡	ODP 136	95(110)**	19°N,159°W	71	243
864A	ODP 142	0	10°N,104°W	15	0
1224D*	ODP 200	45	28°N,142°W	31	28
1224F	ODP 200	45	28°N,142°W	147	28

Notes:
† = a reentry cone was emplaced at this site.
‡ = this is the location of borehole Observatory OSN-1.
* = this is the location of borehole Hawaii-2 Observatory (H2O).
** = basement age is older than overlying sediment.

Table T2. Operations plan and time estimates for Leg 206.

Site	Location and depth	Operations Description	Transit (days)	Drilling (days)	Logging (days)
		SCENARIO A (double casing)			
Balboa	8.57°N, 79.33°W	Transit from Balboa to GUATB-03C, 833 nmi @ 10.5 kt	3.3		
GUATB-03C	6°44.19′N, 91°56.06′W	Hole A: APC/XCB to 240 m sediment + 5 m basement, jet-in test		2.9	
	water depth = 3655 m	Hole B: Drill to 230 m, RCB to bit destruction (~360 mbsf),		4.6	
		Log (triple combo-MGT, FMS/sonic, and BGR magnetometer)			1.2
		Hole C: Set reentry cone, jet-in 80 m of 20-in casing		1.6	
		Drill 21.5-in-diameter hole to 270 mbsf with bi-center bit		4.8	
		Set 260 m of 16-in casing (20 m into basement) and cement		2.7	
		Drill through cement shoe, RCB core thru basalt to ~1050 mbsf		27.5	
		Wireline log (triple combo-MGT, FMS/sonic, and WST-3)			1.9
		Wireline log with the BGR borehole magnetometer			0.3
		Wireline log with the UBI			0.4
		Pipe trip to the surface and secure for transit		0.5	
Balboa	8.57°N, 79.33°W	Transit from GUATB-03C to Balboa, 833 nmi @ 10.5 kt	3.3		
		SUBTOTAL:	6.6	44.6	3.8
		TOTAL OPERATING DAYS:	55.0		
		SCENARIO B (triple casing):			
Balboa	8.57°N, 79.33°W	Transit from Balboa to GUATB-03C, 833 nmi @ 10.5 kt	3.3		
GUATB-03C	6°44.19′N, 91°56.06′W	Hole A: APC/XCB to 240 m sediment + 5 m basement, jet-in test		2.9	
	water depth = 3655 m	Hole B: Drill to 230 m, RCB to bit destruction (~360 mbsf),		4.6	
		Log (triple combo-MGT, FMS/sonic, and BGR magnetometer)			1.2
		Hole C: Set reentry cone, jet-in 80 m of 20-in casing		1.6	
		Drill 21.5-in-diameter hole to 360 mbsf with bi-center bit (2 bits)		10.0	
		Set 350 m of 16-in casing (110 m into basement) and cement		2.7	
		RCB core from 360 to 490 mbsf, or to whatever depth required		4.5	
		Log (triple combo-MGT, FMS/sonic, and BGR magnetometer)			1.4
		Open hole 360–490 mbsf to 18.5-in with bi-center bit (2 bits)		4.0	
		Set 480 m of 13 3/8-in casing (240 m into basement)		2.4	
		Drill through cement shoe, RCB core thru basalt to ~770 mbsf		10.5	
		Wireline log (triple combo-MGT, FMS/sonic, and WST-3)			1.5
		Wireline log with the BGR borehole magnetometer			0.3
		Wireline log with the UBI			0.3
		Pipe trip to the surface and secure for transit		0.5	
Balboa	8.57°N, 79.33°W	Transit from GUATB-03C to Balboa, 833 nmi @ 10.5 kt	3.3		
		SUBTOTAL:	6.6	43.7	4.7
		TOTAL OPERATING DAYS:	55.0		
		ALTERNATE SITES			
GUATB-03B	6°43.64′N, 91°56.66′W	The operations plan is the same as given above for primary site.			
	water depth = 3650 m				
GUATB-03A	6°40.64′N, 91°55.94′W	The operations plan is the same as given above for primary site.			
	water depth = 3621 m				
GUATB-01A	7°55.50′N, 90°32.64′W	The operations plan is the same as given above for primary site.			
	water depth = 3454 m				

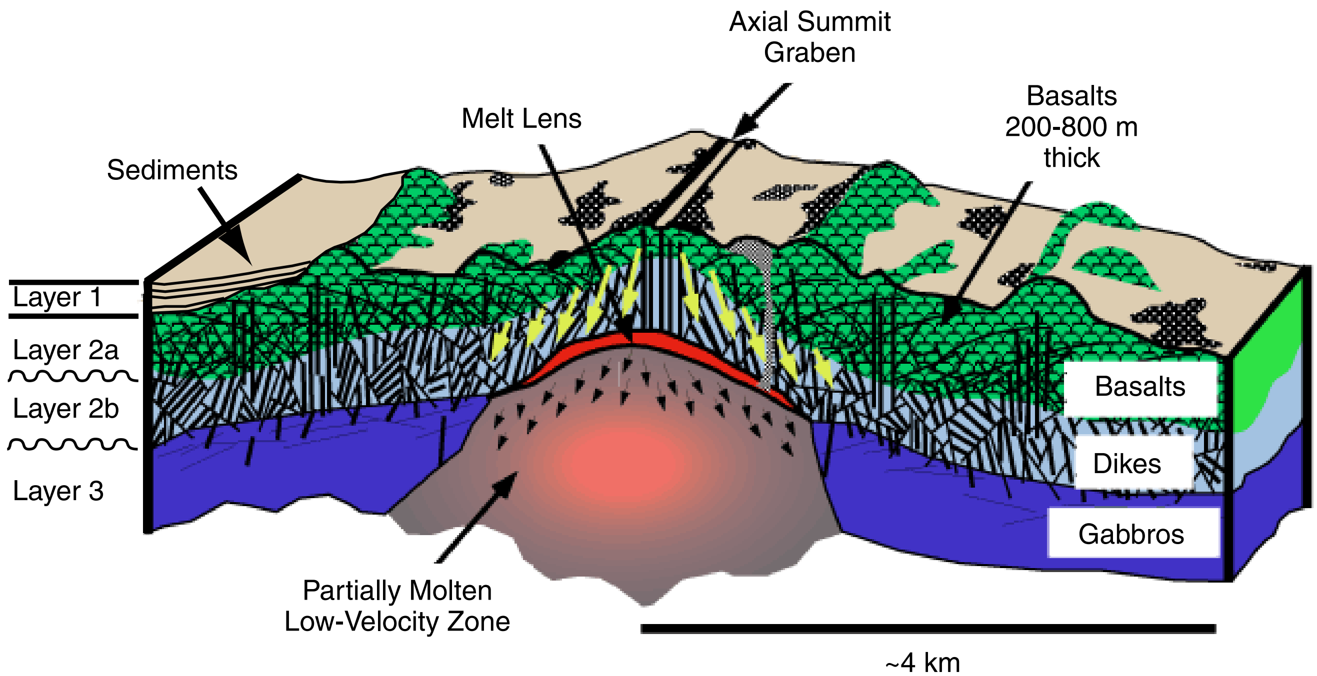

Axial Summit
Graben
Melt Lens
Basalts
200-800 m
thick
Sediments
Layer 1
Layer 2a
Layer 2b
Layer 3
Basalts
Dikes
Gabbros
Partially Molten
Low-Velocity Zone
~4 km

Figure F1

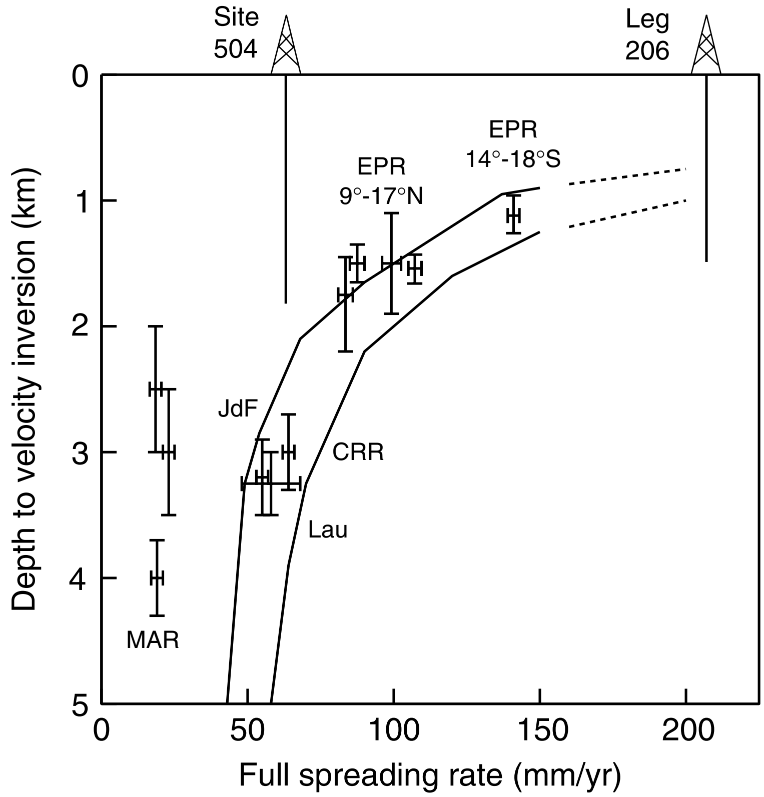

Site
504
Leg
206
EPR
14°-18°S
EPR
9°-17°N
JdF
CRR
Lau
MAR
Depth to velocity inversion (km)
0
1
2
3
4
5
0
50
100
150
200
Full spreading rate (mm/yr)

Figure F2

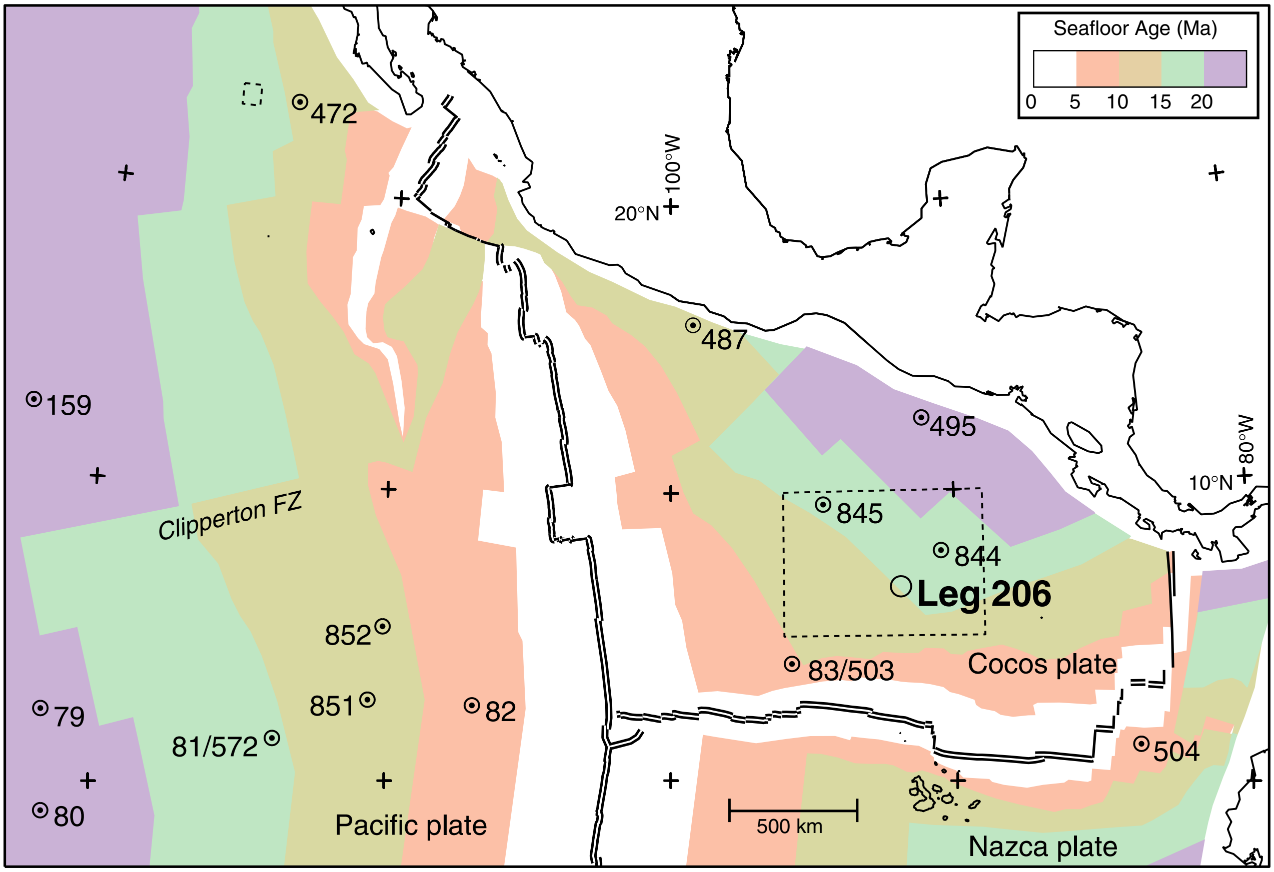
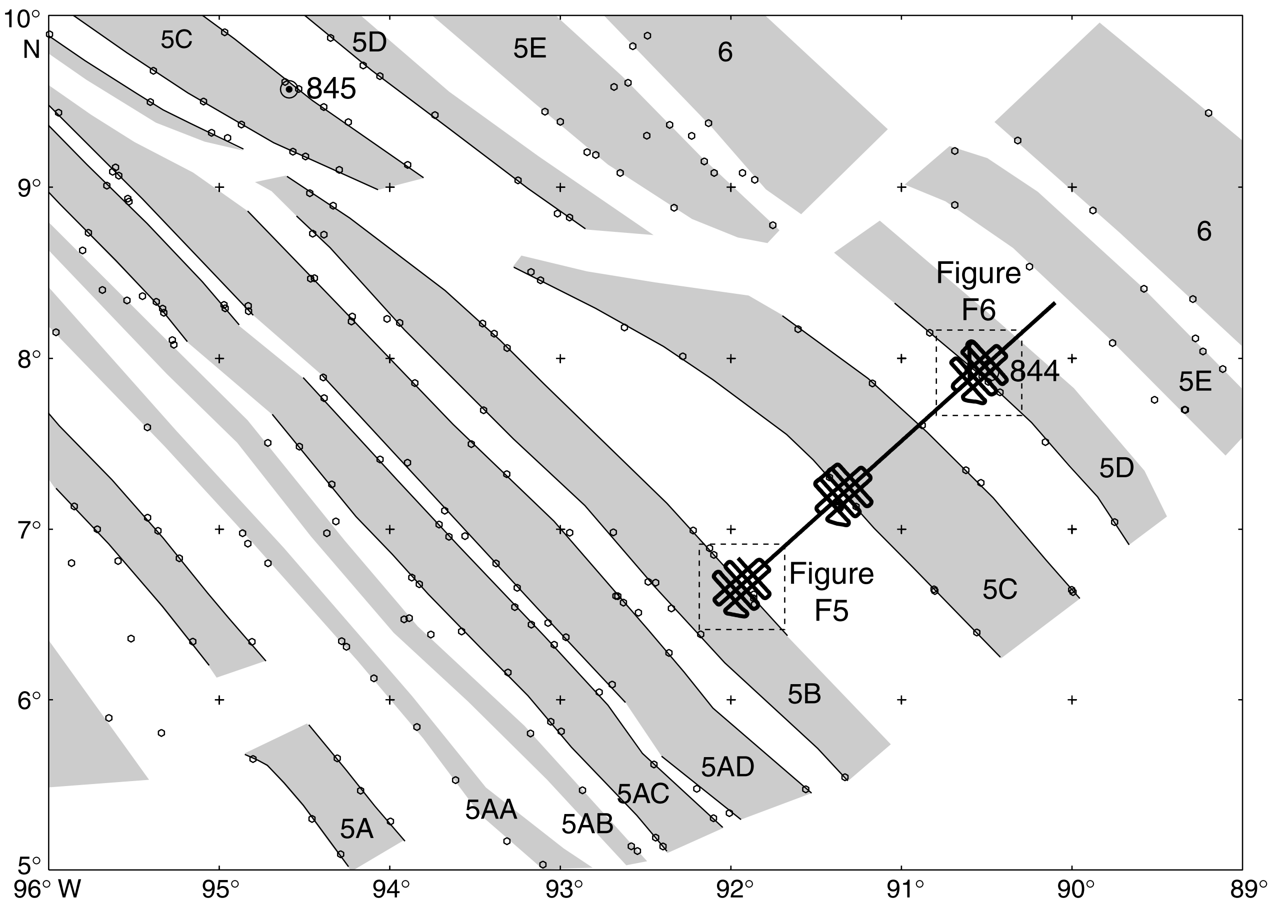

Seafloor Age (Ma)
0
5
10
15
20
472
20°N
100°W
487
159
495
10°N
80°W
Clipperton FZ
845
844
Leg 206
852
83/503
Cocos plate
79
851
82
81/572
504
80
Pacific plate
500 km
Nazca plate

Figure F3


10°
N
9°
8°
7°
6°
5°
96° W
95°
94°
93°
92°
91°
90°
89°
5C
5D
5E
6
845
6
Figure
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5C
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5AC
5AB
5AA
5A

Figure F4

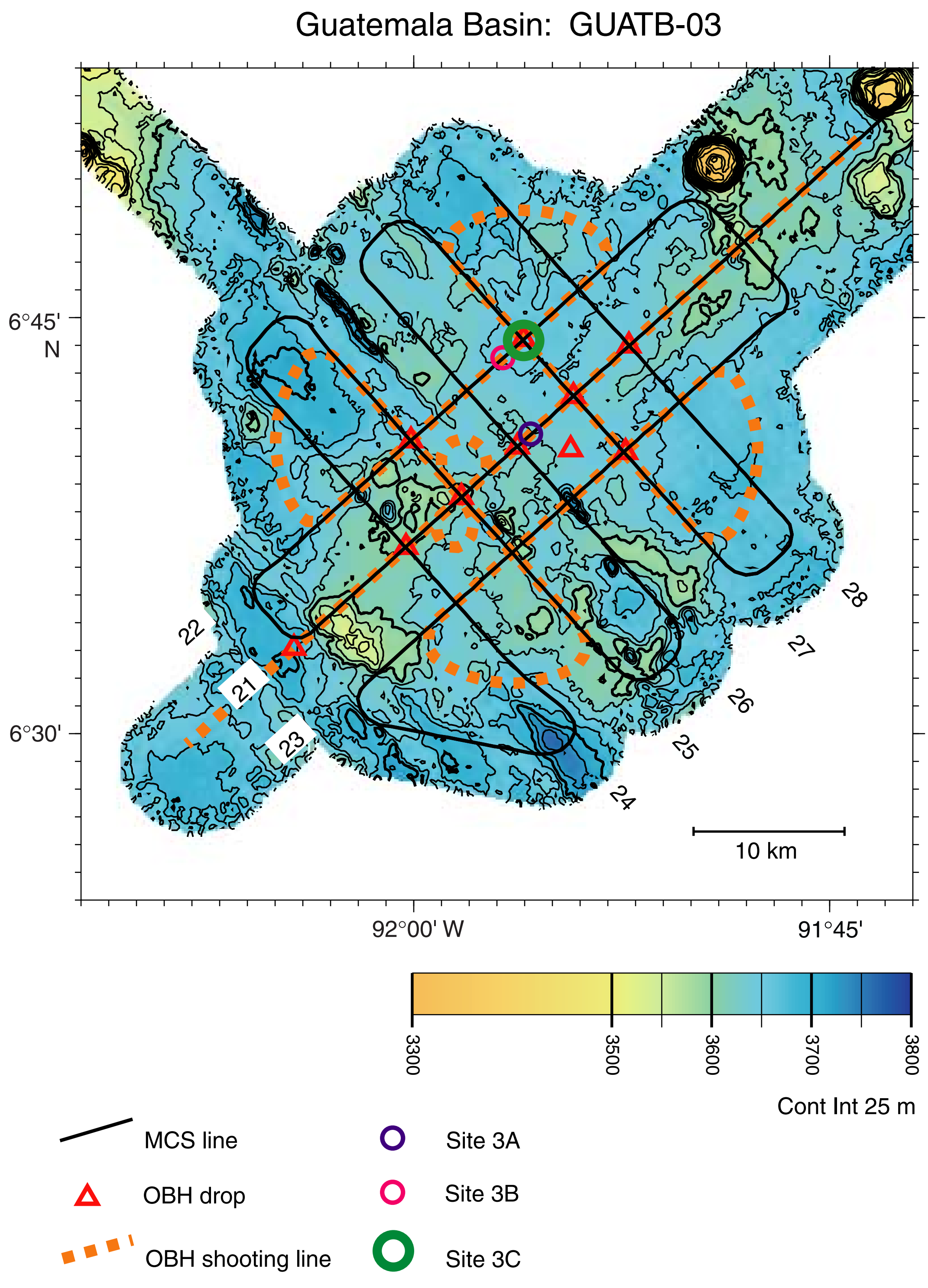

Guatemala Basin: GUATB-03
6°45' N
6°30'
92°00' W
91°45'
22
21
23
24
25
26
27
28
10 km
3300
3500
3600
3700
3800
Cont Int 25 m
MCS line
OBH drop
OBH shooting line
Site 3A
Site 3B
Site 3C

Figure F5

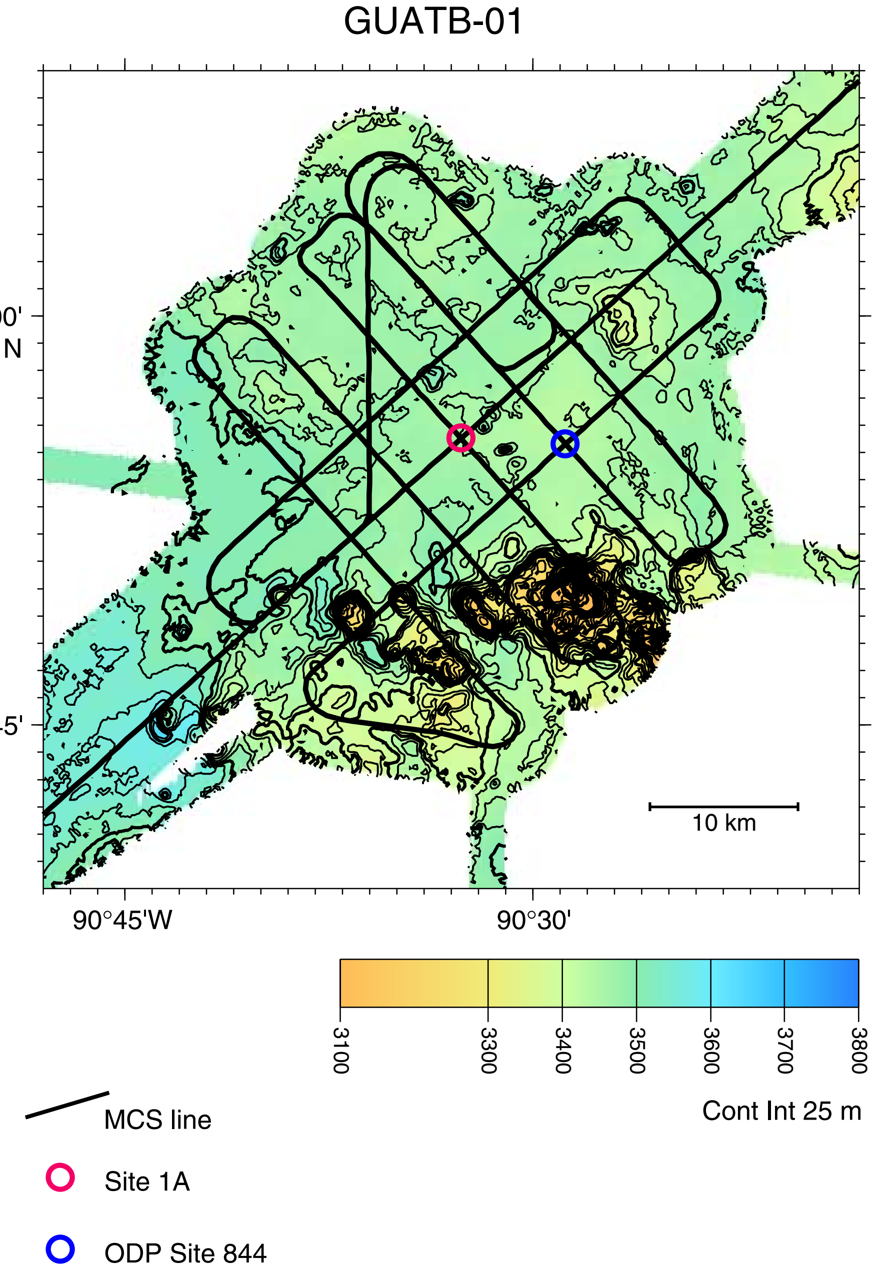

GUATB-01
8°00' N
7°45'
90°45'W
90°30'
10 km
3100
3300
3400
3500
3600
3700
3800
Cont Int 25 m
MCS line
Site 1A
ODP Site 844

Figure F6

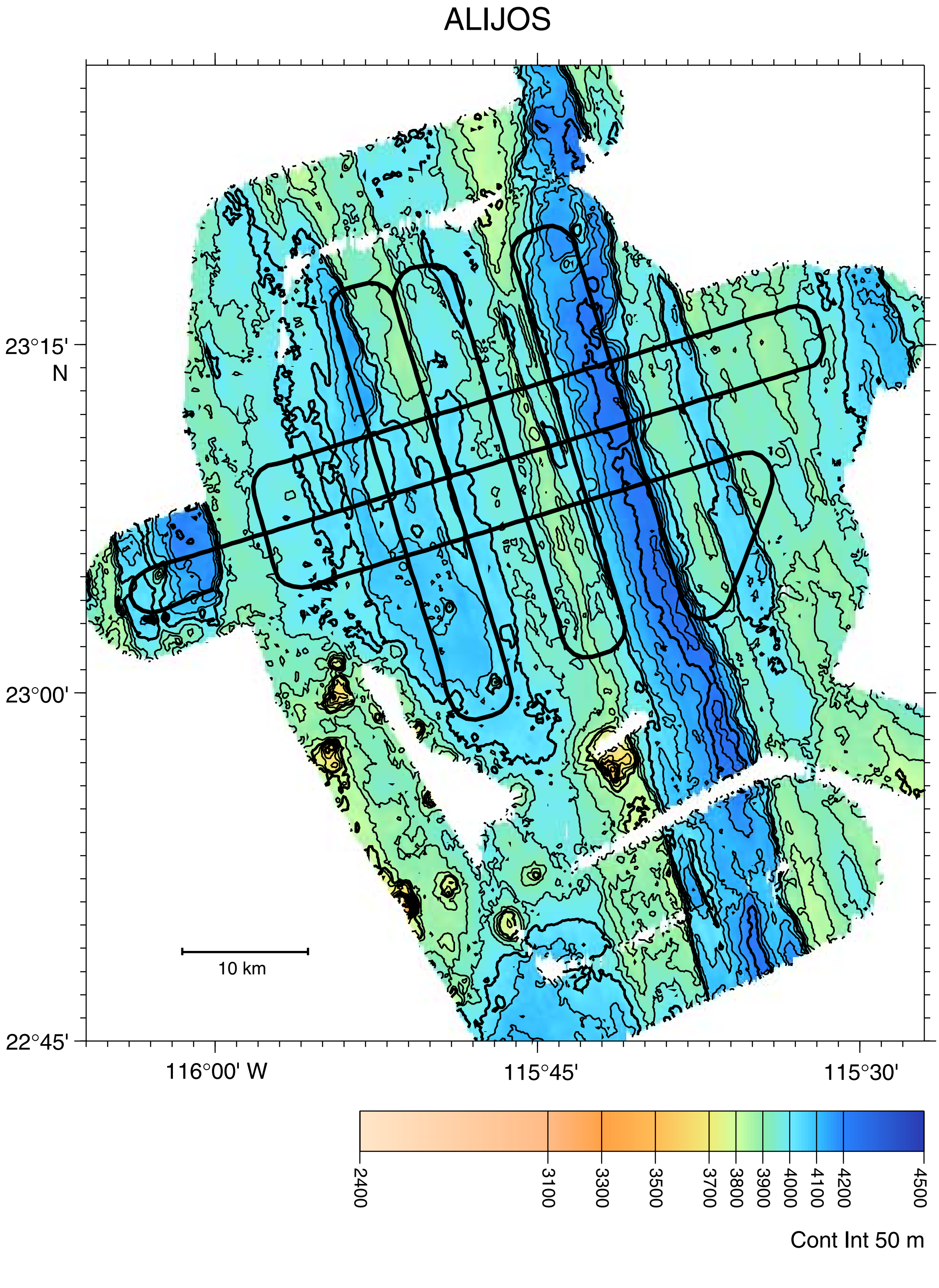

ALIJOS
23°15'
N
23°00'
22°45'
116°00' W
115°45'
115°30'
10 km
2400
3100
3300
3500
3700
3800
3900
4000
4100
4200
4500
Cont Int 50 m

Figure F7

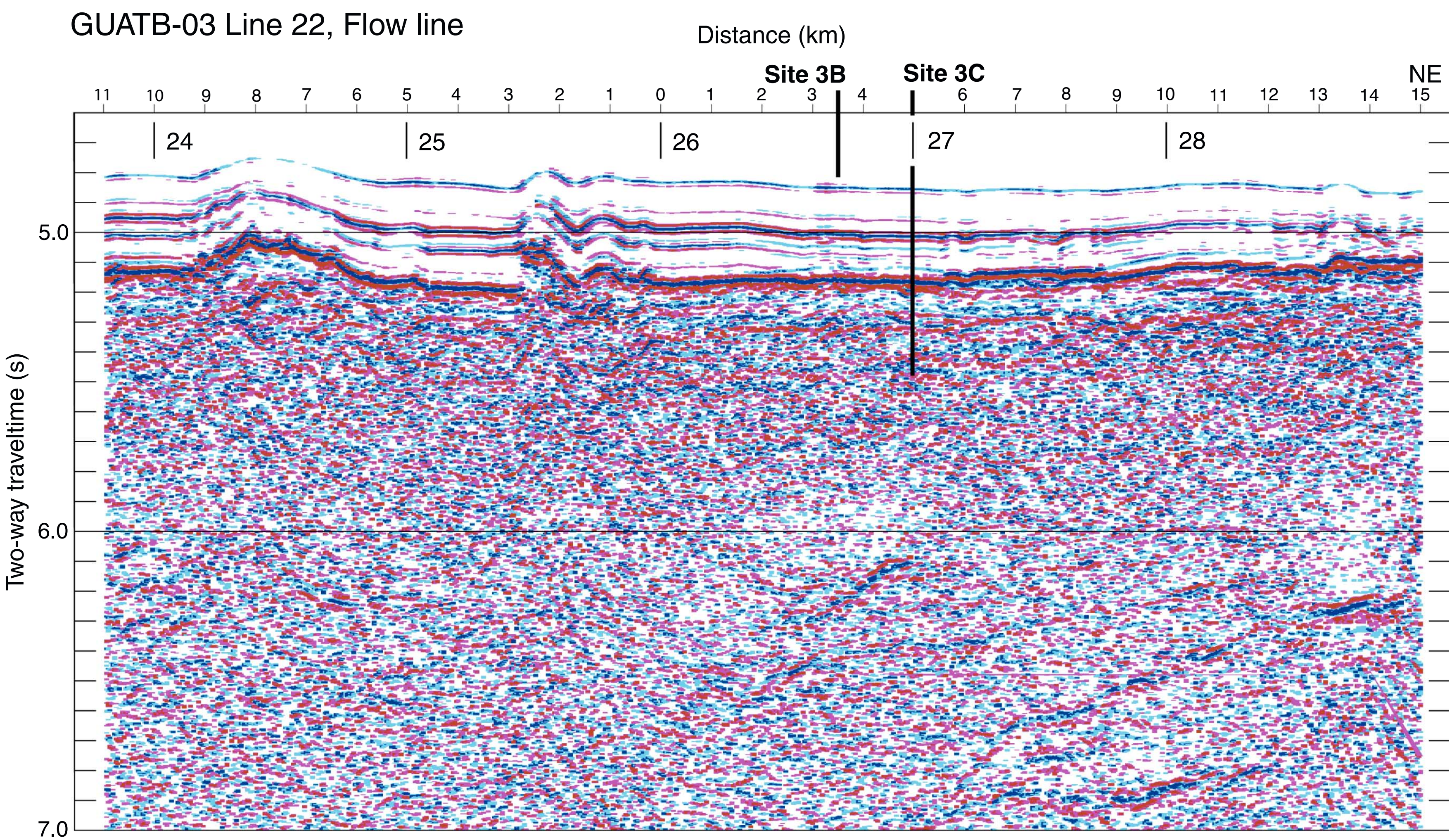

GUATB-03 Line 22, Flow line
Distance (km)
Site 3B
Site 3C
NE
11 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 6 7 8 9 10 11 12 13 14 15
24
25
26
27
28
Two-way traveltime (s)
5.0
6.0
7.0

Figure F8

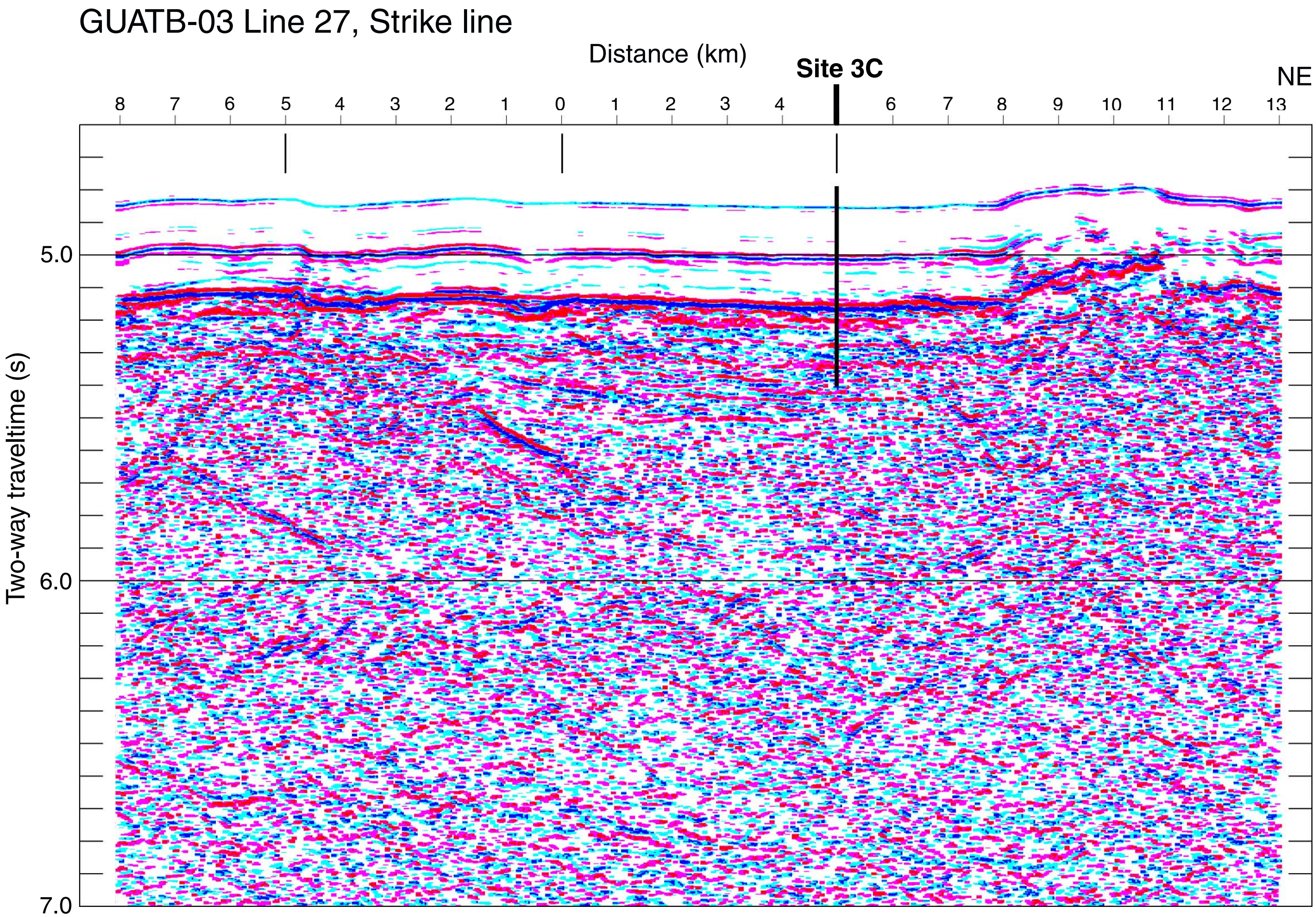

GUATB-03 Line 27, Strike line
Distance (km)
Site 3C
NE
8 7 6 5 4 3 2 1 0 1 2 3 4 6 7 8 9 10 11 12 13
Two-way traveltime (s)
5.0
6.0
7.0

Figure F9

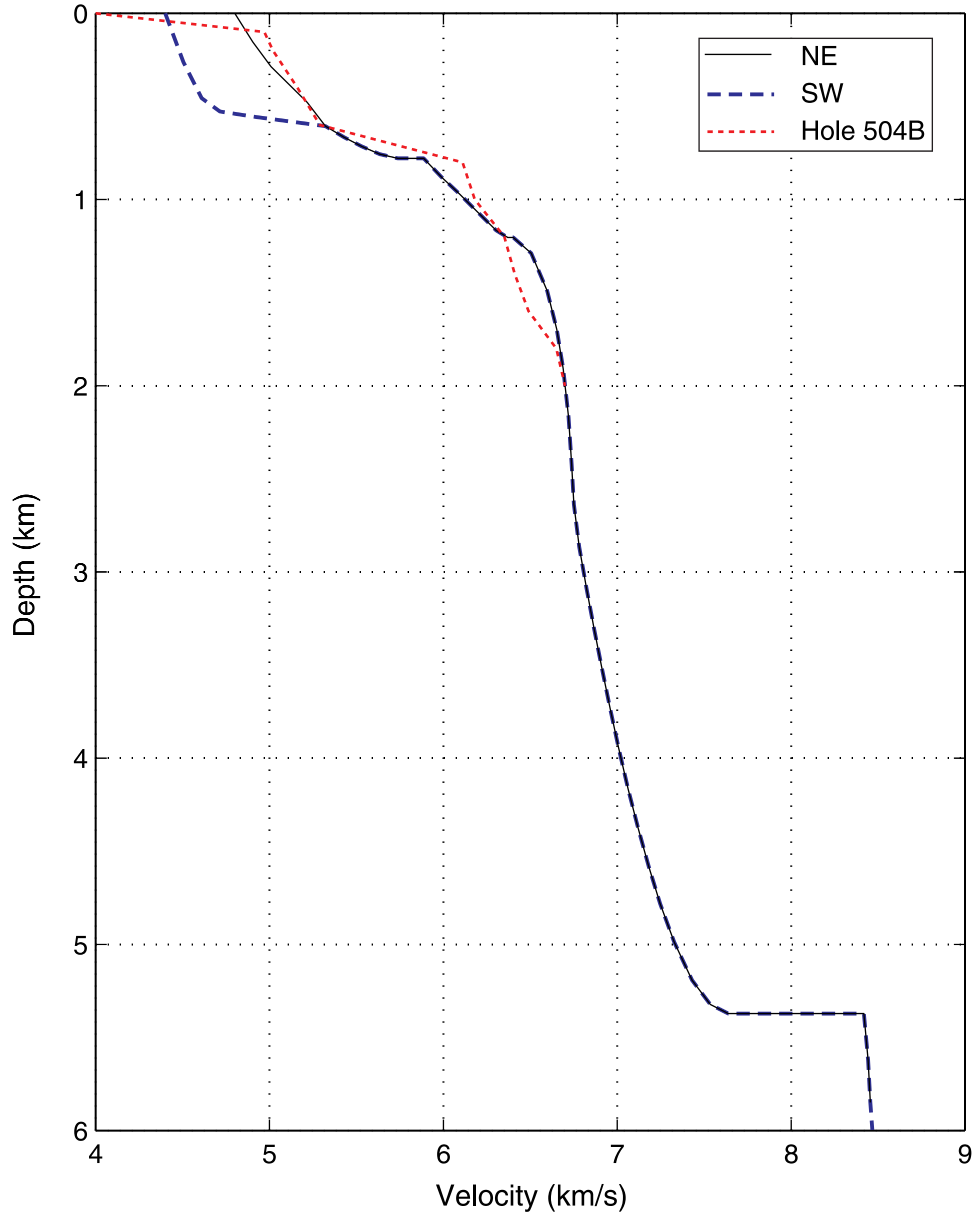


Figure F10

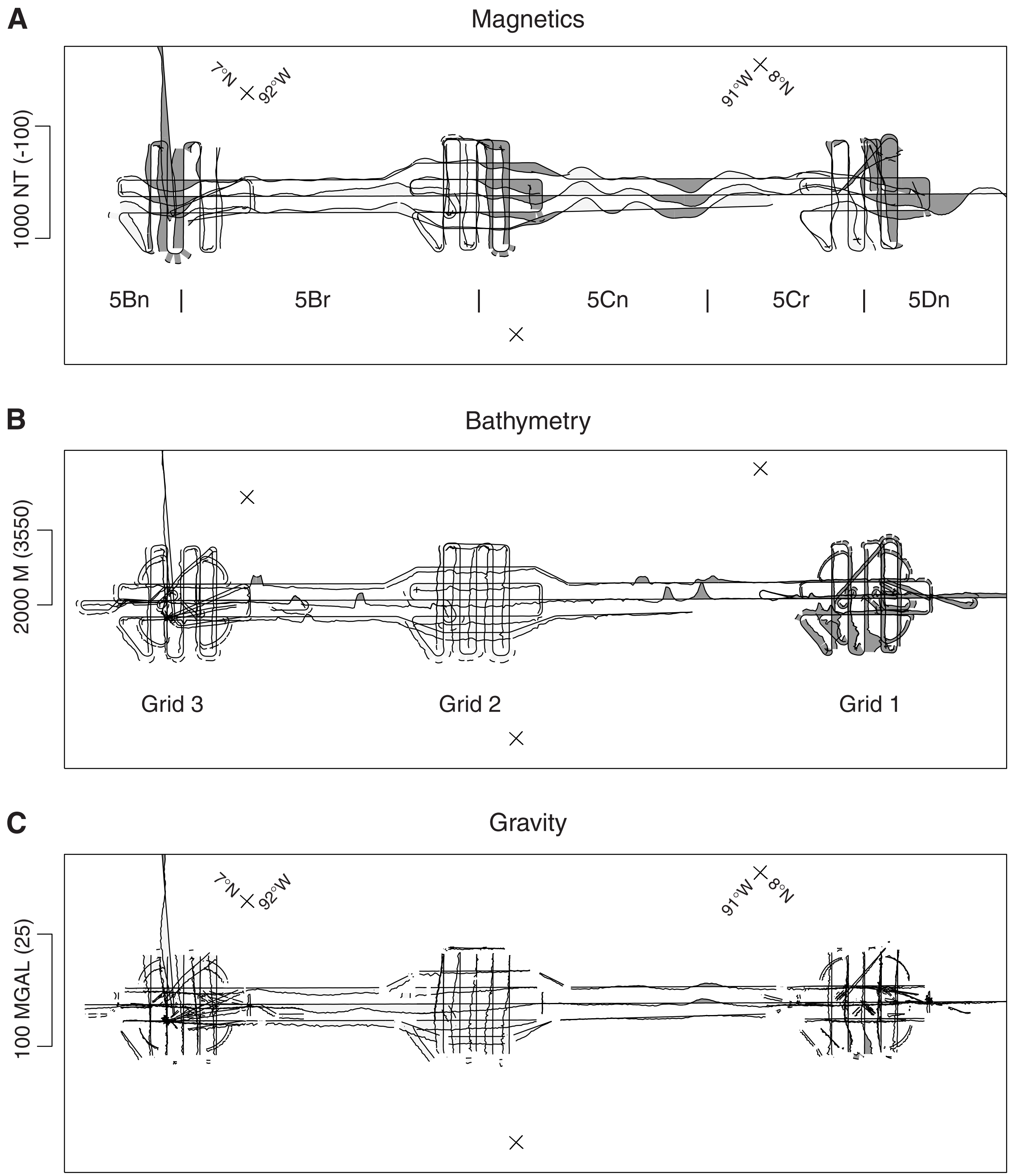

A
Magnetics
1000 NT (-100)
7°N
92°W
91°W
8°N
5Bn
5Br
5Cn
5Cr
5Dn
B
Bathymetry
2000 M (3550)
Grid 3
Grid 2
Grid 1
C
Gravity
100 MGAL (25)
7°N
92°W
91°W
8°N

Figure F11

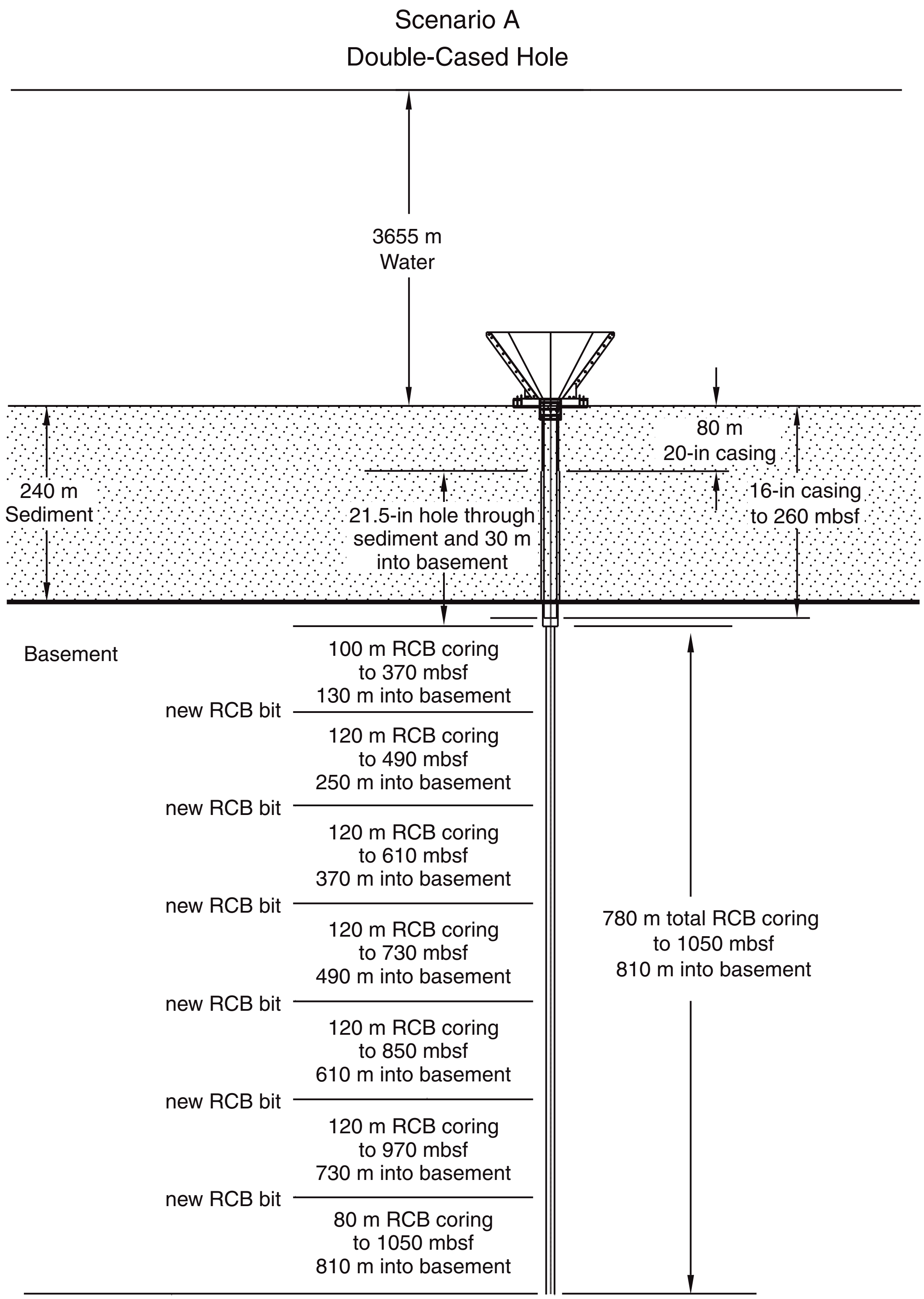

Scenario A
Double-Cased Hole
3655 m
Water
80 m
20-in casing
240 m
Sediment
16-in casing
to 260 mbsf
21.5-in hole through
sediment and 30 m
into basement
Basement
100 m RCB coring
to 370 mbsf
130 m into basement
new RCB bit
120 m RCB coring
to 490 mbsf
250 m into basement
new RCB bit
120 m RCB coring
to 610 mbsf
370 m into basement
new RCB bit
120 m RCB coring
to 730 mbsf
490 m into basement
new RCB bit
120 m RCB coring
to 850 mbsf
610 m into basement
new RCB bit
120 m RCB coring
to 970 mbsf
730 m into basement
new RCB bit
80 m RCB coring
to 1050 mbsf
810 m into basement
780 m total RCB coring
to 1050 mbsf
810 m into basement

Figure F12

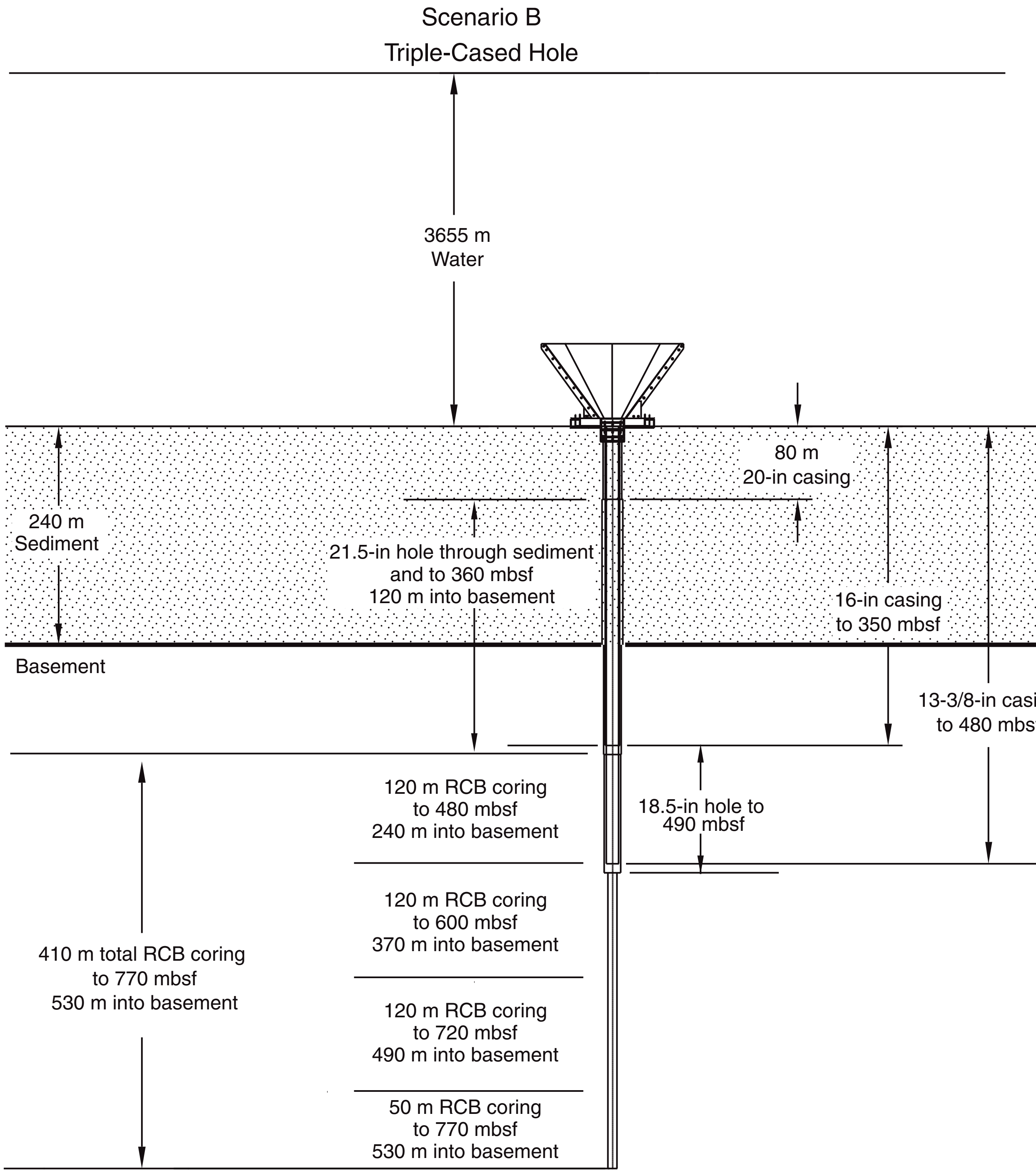

Scenario B
Triple-Cased Hole
3655 m
Water
240 m
Sediment
80 m
20-in casing
21.5-in hole through sediment
and to 360 mbsf
120 m into basement
16-in casing
to 350 mbsf
Basement
13-3/8-in casing
to 480 mbsf
18.5-in hole to
490 mbsf
120 m RCB coring
to 480 mbsf
240 m into basement
120 m RCB coring
to 600 mbsf
370 m into basement
120 m RCB coring
to 720 mbsf
490 m into basement
50 m RCB coring
to 770 mbsf
530 m into basement
410 m total RCB coring
to 770 mbsf
530 m into basement

Figure F13

SITE SUMMARIES

Site: GUATB-03C

Priority: 1
Position: 6°44.19′N, 91°56.06′W
Water Depth: 3655 m
Sediment Thickness: 240 m
Target Drilling Depth: 1050 mbsf
Approved Maximum Penetration: Unlimited

Seismic Coverage: MCS with 480 channels, 10 air guns; refraction shooting 20 air guns recorded on ocean-bottom hydrophones; 3.5-kHz reflection, Hydrosweep multibeam bathymetry: all acquired on *Ewing* cruise EW9903 (March–April, 1999). Site GUATB-03C is at the crossing of EW9903 lines 22 and 27.

Objectives:

1. Provide a reference with in situ samples of most or all of the extrusive section and possibly the upper dike section in normal, intact oceanic crust formed at very fast spreading rate at 15 Ma to constrain models of formation and alteration of oceanic crust.
2. Provide a "legacy hole" available for future deepening, possibly reaching the dike–gabbro transition in a single-leg return.

Drilling Program:

Hole A: APC/XCB core to top of basement. Jet-in test.
Hole B: RCB drill ahead to near basement, core to ~120 m into basement, log with triple combo, FMS/sonic, and if hole conditions permit, the BGR borehole magnetometer and UBI.
Hole C: Set a reentry cone with 20-in casing to ~80 m, set 16-in casing 20–110 m into basement, depending on observations made in Hole B. RCB core as deep as possible. If conditions require, log, set 13⅜-in casing at intermediate depth, and then continue RCB coring. Log with triple combo, FMS/sonic, BGR borehole magnetometer, UBI, and WST-3.

Logging and Downhole: Triple-combo, FMS/sonic, BGR borehole magnetometer for oriented magnetic field measurements, UBI for acoustic borehole image, and WST for normal-incidence vertical seismic profiling.

Nature of Rock Anticipated: Pelagic sediment overlying basalt, dikes, and gabbro.

The seismic data for this site can be seen on Figures F8 and F9.

Site: GUATB-03B

Priority: 2 (Alternate site)
Position: 6° 43.64′N, 91° 56.66′W
Water Depth: 3650 m
Sediment Thickness: 240 m
Target Drilling Depth: 1050 mbsf
Approved Maximum Penetration: Unlimited
Seismic Coverage: MCS with 480 channels, 10 air guns; refraction shooting 20 air guns recorded on ocean bottom hydrophones; 3.5-kHz reflection, Hydrosweep multibeam bathymetry: all acquired on Ewing cruise EW9903 (March–April, 1999). Site GUATB-03B is on EW9903 line 22, between lines 26 and 27.

Objectives, Drilling Program, Logging and Downhole operations, and Nature of Rock Anticipated are the same as for the primary site (GUATB-03C).

The seismic data for this site can be seen on Figure F8.

Site: GUATB-03A

Priority: 2 (Alternate site)

Position: 6°40.64′N, 91°55.94′W

Water Depth: 3621 m

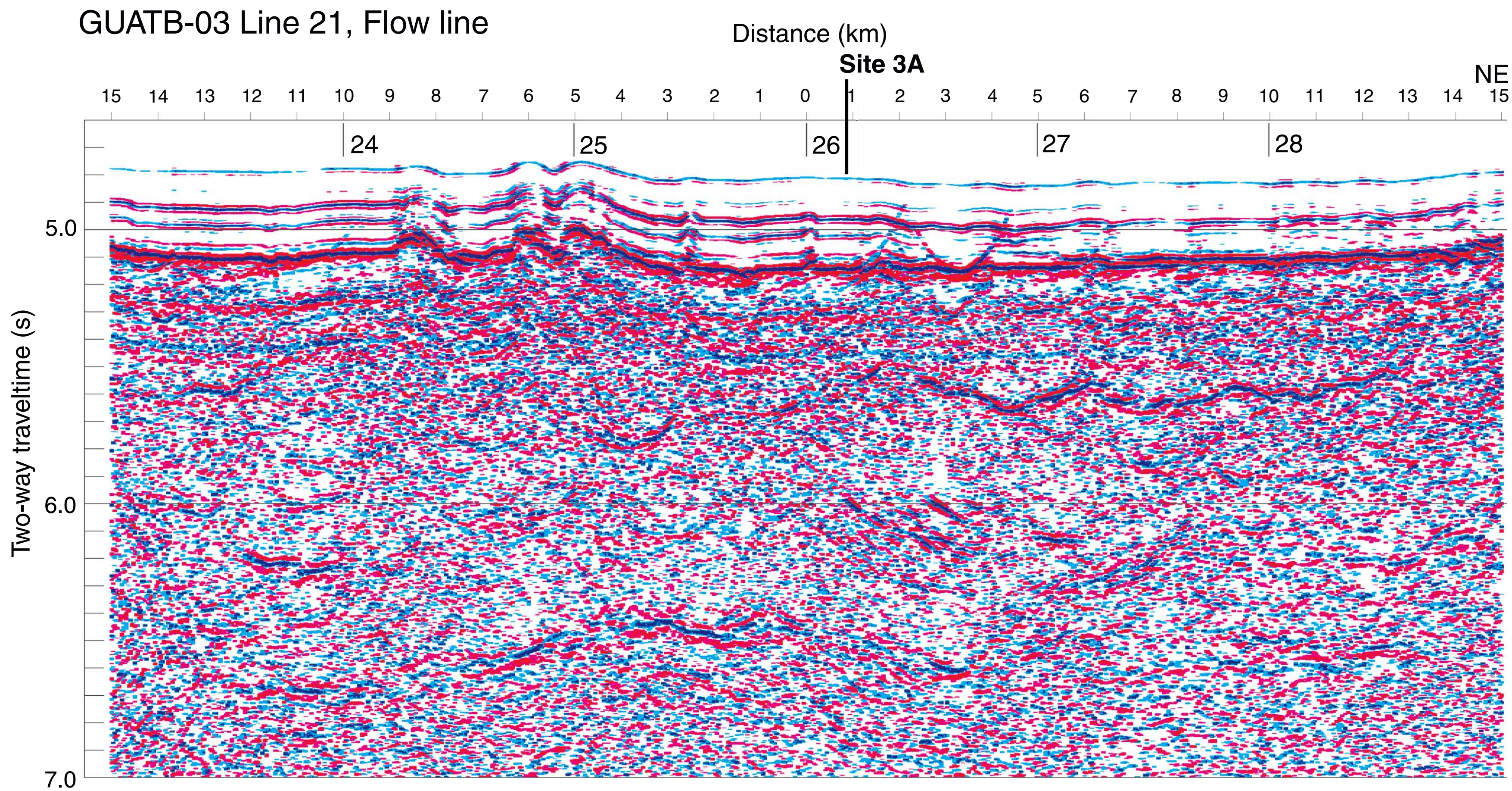
Sediment Thickness: 240 m

Target Drilling Depth: 1050 mbsf

Approved Maximum Penetration: Unlimited

Seismic Coverage: MCS with 480 channels, 10 air guns; refraction shooting 20 air guns recorded on ocean-bottom hydrophones; 3.5-kHz reflection, Hydrosweep multibeam bathymetry: all acquired on *Ewing* cruise EW9903 (March–April, 1999). Site GUATB-03A is on EW9903 line 21, between lines 26 and 27.

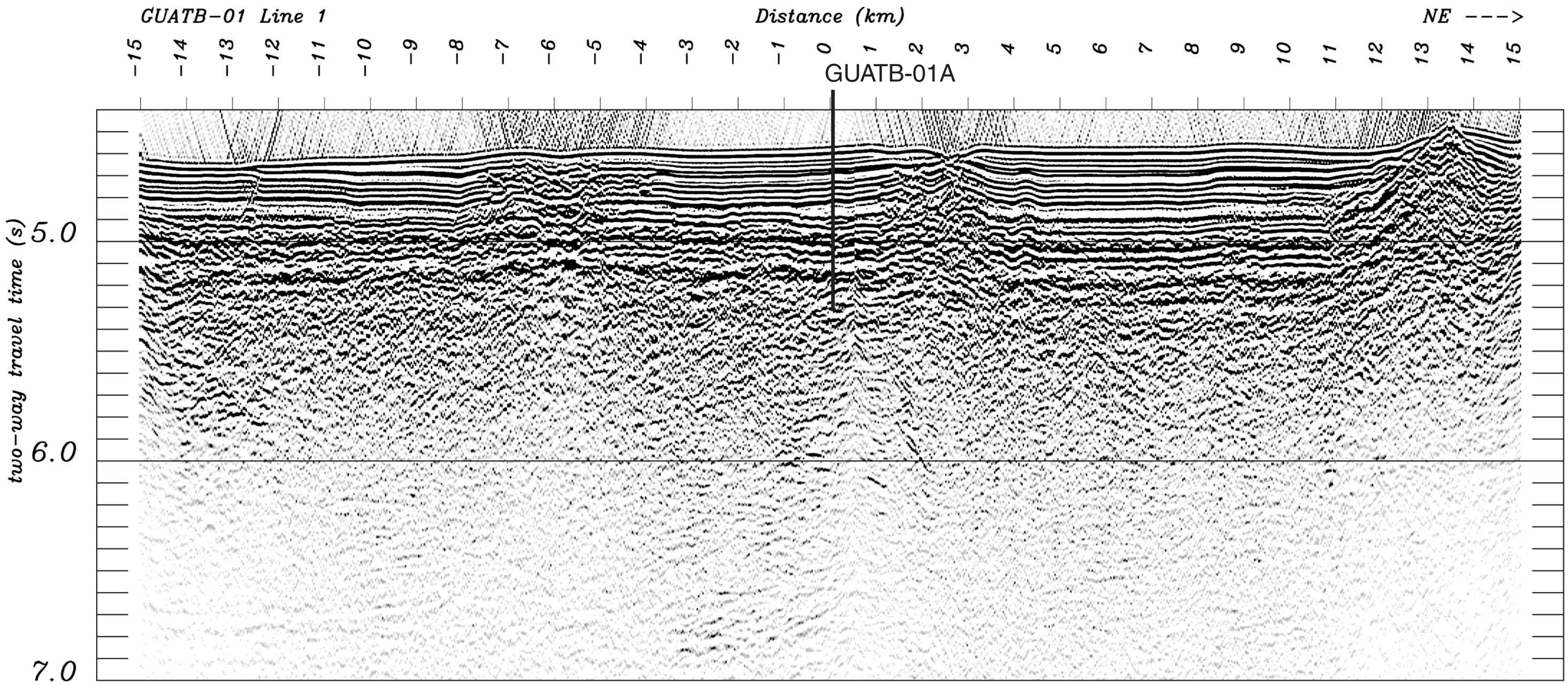
Objectives, Drilling Program, Logging and Downhole operations, and Nature of Rock Anticipated are the same as for the primary site (GUATB-03C).


GUATB-03 Line 21, Flow line
Distance (km)
Site 3A
NE
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
24
25
26
27
28
Two-way traveltime (s)
5.0
6.0
7.0

Site: GUATB-01A

Priority: 2 (Alternate site)
Position: 7°55.50′N, 90°32.64′W
Water Depth: 3454 m
Sediment Thickness: 290 m
Target Drilling Depth: 1050 mbsf
Approved Maximum Penetration: Unlimited
Seismic Coverage: MCS with 480 channels, 10 air guns; refraction shooting 20 air guns recorded on ocean-bottom hydrophones; 3.5-kHz reflection, Hydrosweep multibeam bathymetry: all acquired on *Ewing* cruise EW9903 (March–April, 1999). Site GUATB-01A is at the crossing of EW9903 lines 1 and 6.

Objectives, Drilling Program, Logging and Downhole operations, and Nature of Rock Anticipated are the same as for the primary site (GUATB-03C).


GUATB-01 Line 1
Distance (km)
NE --->
-15 -14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
GUATB-01A
two-way travel time (s)
5.0
6.0
7.0

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