OCEAN DRILLING PROGRAM

LEG 180 SCIENTIFIC PROSPECTUS

WOODLARK BASIN

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This Scientific Prospectus is based on pre-cruise 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 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.

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ABSTRACT

The lateral variation from active continental rifting to seafloor spreading within a small region makes the western Woodlark Basin an attractive area to investigate the mechanics of lithospheric extension. Earthquake source parameters and seismic reflection data indicate that low-angle (~25° to 30°) normal faulting is active in the region of incipient continental separation. A low-angle normal fault emerges along the northern flank of Moresby Seamount, a continental crustal block with greenschist metamorphic basement. Asymmetric basement fault blocks overlain by only minor ponded sediments characterize the margin to the south, whereas the margin to the north has a down flexed prerift sedimentary basin and basement sequence unconformably onlapped by synrift sediments.

Leg 180 will drill a transect of three sites just ahead of the spreading tip: ACE-9a on the down flexed northern margin; ACE-8a through the rift basin sediments, the low-angle normal fault zone, and into the footwall; and ACE-3c near the crest of the footwall fault block (Moresby Seamount).

The primary objectives at these sites are (1) to characterize the composition and in situ properties (stress, permeability, temperature, pressure, physical properties, and fluid pressure) of an active low-angle normal fault zone to understand how such faults slip, and (2) to determine the vertical motion history of both the downflexed hanging wall and the unloaded footwall as local groundtruth for input into regional models to determine the timing and amount of extension prior to spreading initiation.

INTRODUCTION

The processes by which continental lithosphere accommodates strain during rifting and the initiation of seafloor spreading are presently known primarily from the study of either (1) passive margins bordering rifted continents, where extensional tectonics have long ceased and evidence for active tectonic processes must be reconstructed from a record that is deeply buried in postrift sediments and thermally equilibrated; or (2) regions of intracontinental extension, such as the U.S. Basin and Range and the Aegean, where extension has occurred recently by comparison to most passive margin examples but has not proceeded to the point of continental breakup.

One particularly controversial conjecture from these studies is that aerially large normal detachment faults dip at low angles and accommodate very large amounts of strain through simple shear of the entire lithosphere. The role of low-angle normal detachment faults has been contested strongly, both on observational and theoretical grounds. It has been suggested that intracontinental detachments are misinterpreted and actually form by rollover of originally high-angle features, or that they occur at the brittle/ductile boundary in a pure shear system. Theoretically, it has been shown that normal faulting on detachment surfaces would require that the fault be extremely weak—almost frictionless—to allow horizontal stresses to cause failure on low-angle planes. The growing evidence for a weak fault and strong crust associated with motion on the San Andreas Transform Fault supports the weak normal detachment fault model, and models abound in the literature in which low-angle detachment faulting is an essential mechanism of large-scale strain accommodation.

Nevertheless, the mechanisms by which friction might be effectively reduced on low-angle normal fault surfaces are not understood. One possibility is that active shearing in the fault zone creates a strong permeability contrast with the surrounding crust (by opening cracks more quickly than precipitation can heal them), allowing pore pressures that are high and near to the fault-normal compressive stress within the fault zone, but that decrease with distance into the adjacent crust (Rice, 1992; Axen, 1992). Others have suggested that fluid-rock reactions form phyllosilicates in the fault zone that are particularly weak because of their well-developed fabrics (Wintsch et al., 1995). Alternatively, principal-stress orientations may be rotated into configurations consistent with low-angle faulting, although it has not been demonstrated that the magnitudes of reoriented stresses are sufficient to initiate and promote such slip (Wills and Buck, 1997). Testing for such fault-proximal high permeability and pore pressures, for the presence of weak phyllosilicates, and/or for local rotation of stress axes requires drilling into an active system. This would also allow determination of the properties of the fault rock at depth (do they exhibit reduced frictional strength at higher slip velocities, consistent with unstable sliding and observed earthquakes?) as well as studies of the mechanisms by which fluid-rock reactions affect deformation (constitutive response, frictional stability, long-term fault strength). See Hickman et al. (1993) and Barton et al. (1995) for extensive discussion of the mechanical involvement of fluids in faulting and Wernicke (1995) for a review of low-angle normal faulting.

The continuum of active extensional processes, laterally varying from continental rifting to seafloor spreading in the western Woodlark Basin-Papuan Peninsula region of Papua New Guinea (Fig. 1) provides the opportunity to test these various models. Seafloor spreading magnetic anomalies indicate that during the last 6 m.y. the formerly contiguous, eastward extensions of the Papuan Peninsula (the Woodlark and Pocklington Rises) were separated as a westward propagating spreading center opened the Woodlark Basin about a pole close to Port Moresby (~9.5°S, 147°E). The current spreading tip is at 9.8°S and 151.7°E. Farther west, extension is accommodated by continental rifting, with associated full and half graben metamorphic core complexes and peralkaline rhyolitic volcanism. Earthquake source parameters and seismic reflection data indicate that low-angle normal faulting is active in the region of incipient continental separation (Figs. 2-5; Abers, 1991; Taylor et al., 1995, 1996; Mutter et al., 1996; Abers et al., 1997). Leg 180 will drill a transect of sites (just ahead of the spreading tip) above, below, and through a low-angle normal fault to determine the vertical motion and horizontal extension history prior to seafloor spreading and to characterize the composition and in situ physical properties of the active fault zone.

BACKGROUND

Recent Research Programs

Several recent research programs have significantly improved our understanding of the regional geological and geophysical setting of rifting into the Papuan Peninsula (Figs. 1-3):

1. Sidescan and underway geophysical surveys have provided bathymetry, acoustic imagery, magnetization, and gravity maps that permit detailed reconstructions of the spreading history

(Taylor et al., 1995, 1996; Goodliffe et al., 1997, and A. Goodliffe, unpubl. data).

2. Multichannel seismic reflection surveys reveal the upper crustal architecture of the rifting region, including the presence of low-angle normal faults (Figs. 3-5; Mutter et al., 1996; Taylor et al., 1996).

3. The PACLARK and SUPACLARK series of cruises in 1986-1991 (Binns et al., 1987, 1989, 1990; Lisitsin et al., 1991; Benes et al., 1994) included dredging, coring, camera and video observations, and seven *Mir* submersible dives. The bottom samples include normal mid-ocean ridge basalt (N-MORB) from the youngest spreading segments, as well as greenschist facies metamorphics from the lower north flank of Moresby Seamount. In contrast, a 1995 site survey dredged late Pliocene (synrift) sedimentary rocks from the upper south flank of Moresby Seamount—apparently precluding a metamorphic core complex origin for this feature (Taylor et al., 1996).

4. Abers (1991) and Abers et al. (1997) determined source parameters and relocated earthquakes in the rifting region. The focal mechanisms are all extensional or strike-slip with northerly tension axes (T-axes; Fig. 2). Several are consistent with slip on shallow-dipping normal faults.

5. Studies of metamorphic core complexes on the Papuan Peninsula, D'Entrecasteaux, and Misima Islands (Fig. 2) show that (A) they are associated with Pliocene/Pleistocene granodiorite intrusions and amphibolite-facies ductile shear zones, (B) they have been rapidly exhumed from ~30 km depth (7-11 kilobar [kb]) in the last 4 m.y., (C) uplift continues (forming topography up to 2.5 km), and (D) they are very three dimensional and regionally discontinuous (or varying in grade) along strike (Davies and Warren, 1988, 1992; Hill, 1987, 1990, 1994, 1995; Hill et al., 1992, 1995; Hill and Baldwin, 1993; Baldwin et al., 1993; Lister and Baldwin, 1993; Baldwin and Ireland, 1995).

6. The Papuan Ultramafic Belt (PUB) is a late Paleocene to early Eocene supra-subduction zone

ophiolite with gabbros and boninites $^{40}Ar/^{39}Ar$ dated at 59 Ma (R. Duncan, pers. comm., 1993; Walker and McDougall, 1982) and P4 (late Paleocene) foraminifer-bearing micrites overlying the basalts with tonalite-diorite-dacite intrusions K/Ar dated at 57-47 Ma (Rogerson et al., 1993). This revision to dating of the Papuan Peninsula basement allows a simplified geological evolution for the region, as outlined below.

Papuan Crustal Evolution

Paleogene Subduction and Collision

Much of the Papuan Peninsula is 1-3 km above sea level and is underlain by crust 25-50 km thick (Finlayson et al., 1976). Major orogenic thickening of the crust occurred following the northeast subduction and partial accretion of a thick sequence of dominantly Cretaceous to Eocene strata beneath a late Paleocene-early Eocene island arc that includes the PUB, Milne Basic Complex, and Cape Vogel boninites (Davies and Jaques, 1984; Davies et al., 1984; Rogerson et al., 1987, 1993). Collision of the Australian (Papuan) continental margin plateau caused subduction to cease and uplifted the accretionary complex (Owen Stanley metamorphics) by the early Miocene (Rogerson et al., 1987). Metabasites in the Emo metamorphics and Suckling-Dayman massif (the latter with a cover of Maastrichtian micrites) have been exhumed from 7-12 kb (25-35 km) and may represent slivers of the subducted Cretaceous oceanic crust (Davies, 1980; Worthing, 1988).

The preMiocene geology of the islands on the Pocklington and Woodlark Rises is similar to that of the Papuan Peninsula, with Owen Stanley metamorphics in the south (Misima, Tagula, and Rossel Islands) and Milne Basic Complex outcrops on Woodlark Island (Davies and Smith, 1971; Ashley and Flood, 1981). Likewise, late Paleocene volcanics occur at the base of the Nubiam 1 well (Stewart et al., 1986), west of the Trobriand Islands, and the metamorphic core complexes on the D'Entrecasteaux Islands have a core of Owen Stanley metamorphics and a cover of unmetamorphosed PUB ultramafics (Davies and Warren, 1988).

Miocene-Quaternary Arc and Forearc

Superimposed on this Paleogene basement is widespread middle Miocene to Holocene calc-alkaline and shoshonitic magmatism (Smith and Milsom, 1984) associated with southwest subduction of the Solomon Sea Basin at the Trobriand Trough. Active arc volcanism and a deforming accretionary prism are compatible with present-day slow subduction at the Trobriand Trough (Hamilton, 1979; Davies and Jaques, 1984; Lock et al., 1987), though this remains controversial given the small number of intermediate-depth earthquakes beneath the region (Abers and Roecker, 1991) and the lack of ^{10}Be in the arc lavas (Gill et al., 1993). The geochemistry of the volcanics reveals melting and mixing of at least three magma sources: (1) subduction-modified mantle supplied the calc-alkaline arc volcanism; (2) this mantle, with the addition of partial melts from upwelling aesthenosphere, produced the comenditic (transitional basalt-peralkaline rhyolites) series around Dawson Strait; and (3) contamination by lower crust of Australian affinity formed minor high-K trachytes (see Smith, 1976; Hegner and Smith, 1992; Stolz et al., 1993; and references therein).

The Cape Vogel (including Trobriand) Basin is a Neogene forearc basin, characterized by middle Miocene subsidence, volcanism, deep-marine sedimentation, late Miocene uplift and erosion (1-2 km) of the margins, and Pliocene coarse clastic (from uplift of the Papuan Peninsula and D'Entrecasteaux Islands to the south) and Quaternary carbonate, shallow-water sedimentation during broad subsidence (Tjhin, 1976; Stewart et al., 1986; Francis et al., 1987; Davies and Warren, 1988). The basin experienced late Miocene/Pliocene inversion in the northwest, but its center continues to subside in the southeast (Pinchin and Bembrick, 1985). The Lusancay-Trobriand-Woodlark Islands sit atop an outer forearc structural high with an associated 150-200 mgal free-air gravity anomaly.

The Trobriand Trough, the outer forearc structural and gravity high, and the Cape Vogel forearc basin terminate near Woodlark Island. Farther east, the Woodlark and Pocklington Rises were not a Pliocene/Pleistocene arc-forearc system. Rather, the northern edge of the eastern Woodlark Rise was a transform margin, and seismicity and sidescan data indicate that it is still an active right-lateral fault. Thus, the Woodlark Basin did not originate as a backarc basin, in that the eastern Woodlark and Pocklington Rises were not active island arcs (Weissel et al., 1982). Nevertheless, the locus of present rifting (see below) bisects an inherited crustal asymmetry, with the Neogene forearc basin to the north and the Paleogene accretionary/collision complex and Neogene backarc to the south.

Pliocene/Pleistocene Rifting

Shallow seismicity, with extensional and strike-slip focal mechanisms having northerly T-axes, is concentrated east of the D'Entrecasteaux Islands and extends westward into the Papuan Peninsula at 9°-10°S to about 148°E (Fig. 2; Weissel et al., 1982; Abers, 1991; Abers et al., 1997). Pliocene/Pleistocene extension has produced three flooded grabens (Mullins Harbor, Milne Bay and Goodenough Bay) on the eastern extremity of the Papuan Peninsula with associated rift-flank subaerial uplift to over 500 m (Smith and Simpson, 1972). Metamorphic core complexes on the D'Entrecasteaux Islands and in the Suckling-Dayman massif on the Papuan Peninsula were also exhumed in the Pliocene/Pleistocene (Davies, 1980; Davies and Warren, 1988; Hill, 1990). The best structural studies, geothermometry, geobarometry, and age dating of these complexes have been done on Goodenough and Fergusson Islands (Davies and Warren, 1992; Hill et al., 1992, 1995; Hill and Baldwin, 1993; Baldwin et al., 1993; Lister and Baldwin, 1993; Hill, 1994; Baldwin and Ireland, 1995). There, normal movement along a 0.3- to 1.5-km-thick ductile mylonitic shear zone resulted in the uplift of deep metamorphic rocks and the juxtaposition of unmetamorphosed cover rocks. Granodioritic intrusion then focused uplift on several domes, offset by strike-slip faults. The ductile shear zones were brecciated and truncated by brittle faults late in their history. These domal structures are juxtaposed along strike with regions of significantly less unroofing, such as the low-grade (greenschist) eastern halves of both Normanby and Misima Islands.

Woodlark Basin Evolution

The oldest magnetic anomalies (An.3R), in the extreme east of the basin, indicate that seafloor spreading began by 6 Ma (Taylor, 1987; Taylor and Exon, 1987). Spreading has sequentially transgressed westward, stepping across Simbo Transform (156.5°E) about 4 Ma and Moresby Transform (154.2°E) about 1.9 Ma to reach its current tip at 151.7°E (Figs. 1, 2). Bruhnes Chron spreading rates decrease from 67 mm/yr at 156.2°E to 36 mm/yr at 152°E (Fig. 1). The 500-km-long spreading axis reoriented synchronously about 80-100 ka (Goodliffe et al., 1997, and unpubl. data).

The sidescan and geophysical data show that the rifting-to-spreading transition involves both nucleation of discrete spreading cells and organized ridge propagation (Taylor et al., 1995). Two ridge propagation events into the margin at 153°E formed continental slivers surrounded by oceanic crust. Spreading is about to propagate into this margin again. Rifting of the conjugate margins continues for ~1 m.y. after spreading has separated them. Extension does not immediately localize to the ridge axis, as shown by the present overlap between spreading and seismogenic margin faulting, and by inwardly curved seafloor fabric and magnetic anomalies that require nonrigid margin reconstructions. The initial spreading system lacks transform faults and has both overlapping and orthogonally offset segments (Figs. 1, 2). The 50-km-offset Moresby Transform Fault formed by cutting through rifted crust to join overlapping spreading segments of initial oceanic crust. It is not contiguous with transfer faults in the rifted margins. The initial spreading system evolves by ridge propagation, transform development, and ridge jumping/rotation.

Seismic reflection data indicate a very sharp (1 to 2 km wide at the surface) transition from rifted crust to oceanic crust. There are no dipping reflector sequences indicative of excessive lava production and high degrees of mantle partial melting, but there are small volcanoes a few kilometers in diameter that are often erupted along margin faults. Indeed, the initial seafloor spreading lavas indicate low degrees of partial melting: basalts from the youngest spreading segment, just east of Moresby Seamount, have Na_8 = 3.1 (Binns and Whitford, 1987). Other young axial lavas include FeTi basalts and low- and high-Si andesites with evidence for both mantle heterogeneity and crustal contamination.

Secondary convection in the mantle, induced by higher horizontal temperature gradients created during rifting of the thicker continental margins in the west, may explain the contrast in geophysical characteristics of the oceanic basins to either side of Moresby Tranform (Martinez et al., submitted 1998). With respect to the eastern basin, the western basin (1) is ~500 m shallower; (2) has Bouguer gravity anomalies that are >30 mgals lower; (3) has magnetic anomaly and modeled seafloor magnetization amplitudes that are respectively 100% and 50% higher; (4) has spreading centers with rifted axial highs as against axial valleys; (5) has smoother seafloor fabric; and (6) has exclusively nontransform spreading center offsets in contrast to transform faults and fracture zones that extend to the basin edges, all despite having lower spreading rates.

Drilling Area

The rifting region just ahead of the apex of spreading has been imaged by several seismic reflection surveys (Figs. 3-5; Mutter et al., 1993, 1996; Goodliffe et al., 1993; Taylor et al., 1996). North of Moresby Seamount, a low-angle (25°-30°) normal fault dips north beneath a down-flexed prerift sedimentary basin and basement sequence, unconformably onlapped by synrift sediments that are cut by higher angle normal faults with a zigzag pattern in plan view (Figs. 2-5). The seismic stratigraphy can be reasonably jump-correlated to that in the Trobriand Basin and is interpreted to be a Pliocene to Quaternary synrift sequence lying unconformably above a Miocene forearc basin sequence on Paleogene volcanic and metamorphic basement (Fig. 5). To the south of Moresby Seamount, high-relief rotated fault blocks are commonly overlain by only minor ponded sediments.

Shallow (2-10 km) normal and strike-slip faults, with northerly T-axes, bound the north side of the rifting-spreading transition (Fig. 2; Abers, 1991; Taylor et al., 1995; Abers et al., 1997). All of the earthquake hypocenters occur within or north of the rift graben, and there are no major extensional structures north of the graben-bounding antithetic fault. Without local seismometers, the teleseismicity cannot be definitively associated with the low-angle reflector, but there is no more likely candidate structure. Furthermore, the seismic stratigraphy of the profiles in Figure 3 cannot be matched without recent faulting on the low-angle reflector.

Two dredges of the northern flank of Moresby Seamount recovered metabasic greenschists, metagabbro, pelitic schist, and minor siliceous phyllite and microgranite that is material similar to the low-grade (greenschist) metamorphics on eastern Normanby and Misima Islands, not the core complex amphibolite metamorphics on Goodenough, Fergusson, and northwest Normanby (H. Craig, 1986, unpubl. SIO cruise report; Binns et al., 1987; J. Hill, pers. comm., 1996). In contrast, a dredge from 541 to 1211 m (~0.7-1.6 s two-way traveltime [TWT]) on the upper southern flank of the seamount recovered late Pliocene (N21 = 1.9-3.1 Ma) clastic sedimentary rocks of equivalent facies to the Awaitapu Formation of the Trobriand region in the Cape Vogel Basin (Francis et al., 1987). Benthic foraminifers indicate sediment deposition in water depths of 340-800 m (J. Resig, pers. comm., 1995). These rocks are equivalent to those that we infer lie near the base of the synrift cover sequence in the rift basin and on the northern margin.

A cross section consistent with the available seismic and dredge data is shown in Figure 5 (Taylor et al., 1996). At the end of the Miocene, the Paleogene basement and a forearc basin filled with Miocene sediment were being eroded at or near sea level. Pliocene rifting formed sediment-filled grabens in the southern orogenically thickened arc province, accompanied by gradual subsidence of the thinner, colder (and therefore stronger) forearc to the north (inferred Pliocene sediments are dotted in Fig. 5). Quaternary stretching localized on a low-angle normal fault (the antithetic hanging-wall fault accommodated little additional extension). The northern margin flexed down southward and was onlapped by sediments delivered via submarine channels incising northward. Recently, continued extension on the low-angle fault variably collapsed the hanging-wall graben, into which sediments are now prograding from the north.

This interpretation predicts about 12 km of heave on the low-angle fault. This compares with at least 130 km of total extension in the 4 m.y. prior to spreading at this longitude, calculated from the pole of opening derived from seafloor spreading magnetic anomalies, and probably greater amounts back to the beginning of spreading at >6 Ma (Taylor et al., 1996). Given only minor extension of the northern, flexed margin, we infer that the locus of current extension must be the northernmost of a series of similar structures that extended weak crust to the south, forming the block-faulted Pocklington Rise. The regional estimates predict that this rugged province of mainly inactive faults accommodated >120 km of total strain as it collapsed from heights comparable to the 3-km-high Owen Stanley Ranges that form the backbone of the Papuan Peninsula. We do not know where to locate so much extension given a current total width of 200 km for this province.

SCIENTIFIC OBJECTIVES

The western Woodlark Basin is arguably the best characterized region of active continental breakup. The proximity of a seismogenic low-angle normal fault that has been imaged by seismic reflection data and zero-offset conjugate margins that are about to be penetrated by seafloor spreading is unique. There are two major objectives for drilling in this region. Both are within the broader context of understanding the physical processes and mechanics of lithospheric extension:

1. Characterize the composition and in situ properties (stress, temperature, physical properties, and fluid pressure) of an active low-angle normal-fault zone to understand how such faults slip. Questions to be answered include the following: What are the differences in properties of the active fault compared to the surrounding crust? How is friction effectively reduced? Is there a strong permeability and fluid pressure contrast between the fault zone and its surroundings? Do the fault zone materials exhibit reduced frictional strength at higher slip velocities, consistent with unstable sliding? How do fluid/rock reactions affect the deformation mechanisms and rock fabrics?

2. Determine the vertical motion history of both the down-flexed hanging wall and the unloaded footwall (by backstripping the biostratigraphy, regionalizing the well data using seismic stratigraphy, and by Pressure-Temperature-time [P-T-t] data and petrofabric studies of metamorphic basement), as local groundtruth for input into regional models to determine the timing and amount of extension prior to spreading initiation.

Drilling a very deep hole (>2.5 km) through the low-angle normal fault in the seismogenic zone, where both the footwall and hanging wall are composed of basement, remains our long-term objective. However, as Leg 180 may penetrate only ~1200 m across the fault zone, this and further fault zone experiments and monitoring (e.g., CORK) will require a future leg.

DRILLING STRATEGY

Leg 180 will drill a transect of three sites across an asymmetric incipient conjugate margin pair (4-5 km ahead of the spreading tip): Site ACE-9a on the down-flexed northern margin; Site ACE-8a through the rift basin sediments, the active low-angle normal fault zone, and into the footwall; and Site ACE-3c near the crest of the metamorphic footwall fault block (Moresby Seamount). Water depths at the drill sites range from 420 m to 3180 m.

The sites are located within a grid of multichannel seismic (MCS) lines and multibeam bathymetry (Fig. 3). The northern site (ACE-9a) is designed to penetrate the Pliocene-Quaternary hemipelagic cover sequence into the prerift section of Miocene forearc clastics. Penetration into greenschist facies metamorphic basement beneath the 300-m-thick Pliocene-Quaternary section at Site ACE-3c is planned to be 100+ m or until bit destruction. Site ACE-8a includes a triple-casing reentry hole (Fig. 6) that will also sample basement.

The plan is to start with a jet-in test at Site 8a to determine how much initial casing can be washed in with the reentry cone at the Site 8a reentry hole. We will then core and log, to the maximum depth possible, at the Site ACE-8a pilot holes. This will be followed by coring and logging at Site ACE-9a before returning to Site ACE-8a for operations at the cased Site ACE-8a reentry hole. Site ACE-3c will be the final hole of the leg.

Casing at the Site ACE-8a reentry hole is needed in anticipation of possibly unstable sediments (resulting from rapid deposition and faulting), an active fault zone (probably overpressured), and anisotropic basement (probably sheared and altered). We expect that this will be the most challenging drilling operation during Leg 180. Uncertainties regarding the degree of consolidation of the seafloor sediments may have considerable impact on our ability to install the reentry cone and attached conductor pipe (20-in. casing). The jet-in test at the begining of the leg will provide information to determine the appropriate type of seafloor structure and deployment technique. Our plan is to wash the reentry cone and casing into the seafloor. If the jet-in test indicates this is not possible, the installation process could become more complex and time consuming, potentially impacting other cruise activities.

The vertical seismic profile (VSP) and packer experiments are dependent upon successfully cementing around the long casing strings. The cement characteristics are dependent on the local temperature gradient, which is unknown. Therefore, we plan to have specially blended cement and additives on board to allow shipboard adjustment of the cement characteristics.

The deepest casing string was designed to use liner (10 $^3/_4$ in.) hanger technology instead of conventional casing hanger hardware. Installing a very long casing string through a potentially unstable detachment fault is problematic. Use of the liner hanger allows us to install the casing at the deepest possible point that the formation will allow without requiring that a predetermined length of hole remain open.

Alternative Sites ACE-1c and ACE-7b exist to increase the stratigraphic resolution of the onlap sequences on the northern margin, if they are drilled.

LOGGING PLAN

All sites will be logged with the triple-combo geophysical and formation microscanner (FMS)/sonic (sonic digital tool [SDT]) combination tools to which the temperature tool (TLT) will be added. The triple-combo (DIT-HLDS-APS) will provide three independent porosity estimates by measuring the electronic density (hostile environment lithodensity sonde [HLDS]), the hydrogen density (accelator porosity sonde [APS]), and the electrical resistivity (phasor dual induction tool [DIT]). The dual laterolog (DLL) may be required to measure electrical resistivity in the basement if the basement turns out to be very resistive. The FMS will provide oriented images of drilling induced tensile fractures and natural fractures for stress analysis, for structural analysis, and core/log integration.

The geological high-sensitivity magnetometer (GHMT), if on board, may be used at Site ACE-9a to aid core/log integration via magnetic susceptibility. The borehole televiewer (BHTV) will be run in the deeper section of Sites ACE-3c and 8a to ultrasonically image lithostratigraphy, fracture orientation, and the presence and extent of borehole breakouts.

At Site ACE-8a, the Schlumberger five-element array seismic imager (ASI) will be used in the cased hole for a VSP to accurately tie the well to the MCS data. In addition, a drill-string straddle packer will be used to isolate two perforated intervals within the cemented casing and, perhaps, one interval within the open borehole below the casing. The three isolated intervals will be above, within, and below the fault zone. Once the packers are set, the isolated interval will be allowed to equilibrate to obtain the best possible estimate of formation pore pressures. Subsequently, pulse tests will be conducted to estimate formation permeabilities. If injected pulses decay very rapidly, indicating high formation permeability, constant-rate flow tests will be conducted. The longer duration tests allow for greater radius of influence and more reliable permeability estimates. Following the hydrogeologic tests in Site ACE-8a, the interval will be hydraulically fractured for the purpose of measuring the least principal stress magnitude (Sh_{min}). These tests will consist of at least two cycles of fluid injection and shut-in, followed by bleeding off excess pressure.

Details of the complete stress tensor will be inferred from hydraulic fracture experiment (Sh_{min}), pore pressure estimates, and images (BHTV and FMS) of tensional (tensile cracking) and compressive (wellbore breakouts) failures. Repeated temperature profiles from logging may provide evidence for fluid flow associated with critically stressed fractures and faults. These temperature profiles will also help constrain the thermal perturbations, enabling the development of drilling-induced tensile cracking. Interactions between breakouts and fractures/faults may also be used to constrain the extent of stress perturbation associated with active faulting (Barton and Zoback, 1994).

SAMPLING STRATEGY

Sampling guidelines and policy are available at the following web site URL: http://www-odp.tamu.edu/curation/forms.htm. The Sample Allocation Committee (co-chiefs, staff scientist, and ODP curator onshore and curatorial representative on board ship) will work with the entire scientific party to formulate a formal leg-specific sampling plan for shipboard and postcruise sampling. Modification of the strategy during the leg must be approved by the co-chiefs, staff scientist, and curatorial representative on board ship.

The minimum permanent archive will be the standard archive half of each core. All sample frequencies and sizes must be justified on a scientific basis and will be dependent on core recovery, the full spectrum of other requests, and the cruise objectives. Some redundancy of measurement is unavoidable, but minimizing the redundance of measurements among the shipboard party and identified shore-based collaborators will be a factor in evaluating sample requests.

In some critical intervals (e.g., fault gouge, ash layers, basement, veins, etc.), there may be considerable demand for samples from a limited amount of core material. These intervals may require special handling, a higher sampling density, reduced sample size, or continuous core sampling by a single investigator. A coordinated sampling plan may be required before critical intervals are sampled.

PROPOSED SITES

Site ACE-3c

This proposed site is situated on a small bench just north of the crest of Moresby Seamount near where the basement reflector is shallowest (Figs. 3-5). The site is positioned in 420 m of water to avoid the possible safety and logistical constraints of shallower water drilling. However, 12-kHz records indicate the presence of only 6 m of ponded sediments above the northeast-dipping sediments seen on seismic records. Approximately 300 m of lithified sediments and 100+ m of metamorphic basement may be drilled at this site.

The primary objective at this site is to determine the internal structure and composition of Moresby Seamount, including the nature of the basement (rock type, P-T-t, structural fabric, and deformation history). By comparison with the stratigraphy and basement at the other sites, this will constrain the offset on the inferred low-angle normal fault. If Moresby Seamount is not a core complex, it should comprise sedimentary rocks above upper crustal rocks (presumably prerift metamorphic basement) without evidence of intense ductile deformation and rapid decompression.

Site ACE-8a

This proposed site is situated on the southern edge of the graben north of Moresby Seamount and will be drilled though the hanging wall, across the fault zone, and into the footwall of the inferred low-angle fault (Figs. 3-5). The expected section at Site ACE-8a includes up to 900 m of Quaternary hemipelagic sediments (only 0.7 s TWT, but are apparently fast-interval velocities averaging 2.6 km/s) overlying 250-300 m of fault zone and metamorphic basement rocks.

The primary objectives at this site are to determine the (1) sedimentology, biostratigraphy, structural fabric, and vertical motion history in the graben; (2) in situ stress, temperature, physical properties, and fluid pressures in and around the fault zone; and (3) nature of the basement (rock type, P-T-t, structural fabric, deformation history) in and below the fault zone.

Site ACE-9a

Proposed Site ACE-9a is north of a major south-dipping normal-fault system that is antithetic to the low-angle fault dipping north from Moresby Seamount (Fig. 4). The site is positioned to cross two angular unconformities (Fig. 4). Beneath the lower angular unconformity, a stratified sequence, interpreted to be prerift forearc basin sediments, dips north. The expected sequence at Site ACE-9a includes 780 m of Holocene to Pliocene hemipelagic, synrift sediments unconformably overlying 220 m of consolidated Miocene forearc basin sediments.

The primary objectives at this site are to determine the (1) sedimentology, biostratigraphy, and vertical motion history of the synrift sediments on the northern margin and (2) nature of the forearc basin sequence and, hence, the prerift history.

Alternate Sites ACE-1c and ACE-7b

These are alternate sites located on the northern margin (Figs. 3-5). The stratal geometry, including two angular unconformities, requires that at least two sites be drilled to best characterize this region. Site ACE-9a is a compromise site between these two.

Proposed Site ACE-1c is just north of a major south-dipping normal-fault system that is antithetic to the low-angle fault dipping north from Moresby Seamount (Fig. 4). It is also located above north-dipping reflectors at the base of the interpreted prerift forearc basin sequence. The expected sequence at Site ACE-1c includes 950 m of Quaternary hemipelagic, synrift sediments unconformably overlying 50 m of Paleogene volcanic or metamorphic basement.

Proposed Site ACE-7b is 15 km farther north on the margin and is positioned to cross two angular unconformities (Fig. 4). Beneath the lower angular unconformity, a stratified sequence dips north. The expected section at Site ACE-7b includes 640 m of Pliocene to Quaternary hemipelagic sediments unconformably overlying 110 m of consolidated Miocene forearc basin sediments.

The primary objectives at these sites are to determine the (1) sedimentology, biostratigraphy, and vertical motion history of the northern margin; (2) nature of the forearc basin and basement sequence and, hence, the prerift history; and (3) in situ stress orientation, permeability, temperature, physical properties, and fluid composition in the basement for comparison with the same parameters in the active low-angle fault zone.

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FIGURE CAPTIONS

Figure 1. Major physiographic features and active plate boundaries of the Woodlark Basin region. The stippled area encloses oceanic crust formed during the Brunhes Chron at spreading rates labeled in mm/yr. MT and ST = Moresby and Simbo Transform Faults, respectively; DE = D'Entrecasteaux Islands. Top inset: geographical location of the Woodlark Basin. Bottom inset: depth profile along the axis of the spreading center with the five spreading segments numbered.

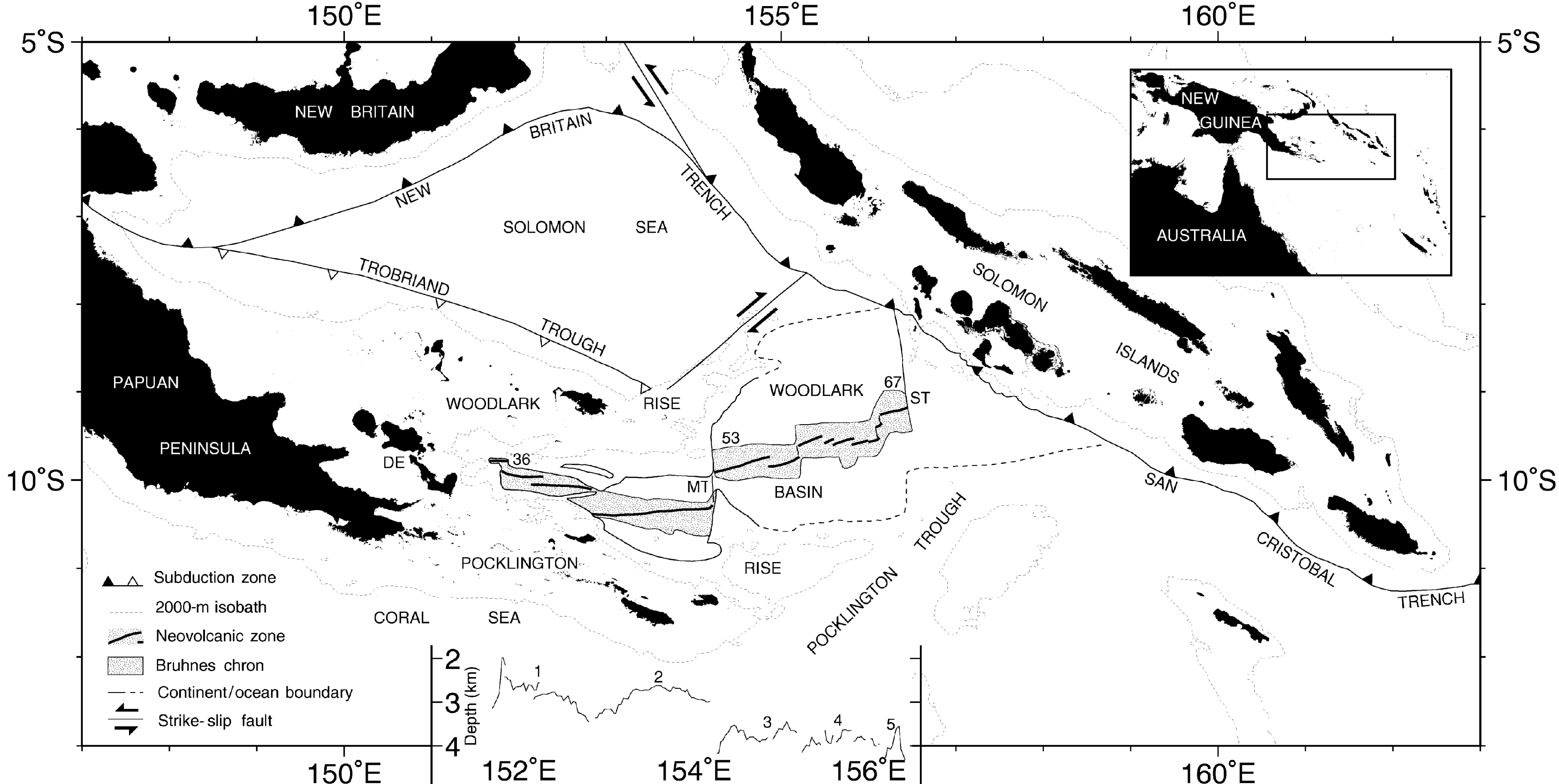
Figure 2. HAWAII MR1 bathymetric texture and acoustic imagery. Relocated epicenters (black circles) and earthquake focal mechanisms are from Abers et al. (1997). PP = Papuan Peninsula, G = Goodenough Island, F = Fergusson Island, N = Normanby Island, R = Rossel Island, T = Tagula Island, MS = Moresby Seamount, MT = Moresby Transform Fault, M = Misima Island, W = Woodlark Island. The solid line is the landward boundary of oceanic crust, and the dashed line marks the boundary of crust formed during the Brunhes Chron.

Figure 3. Location of the proposed drill sites (Sites ACE-1c, 3c, 7b, 8a, and 9a) and multichannel seismic track data plotted on a base map with 100-m bathymetric contours (thicker contours labeled every km). Relocated earthquake epicenters (open black circles) together with the focal mechanisms (beach balls) are from Abers et al. (1997). The western limit of the Woodlark spreading system is marked by the closed black line, the major rift-bounding normal faults by the ticked lines.

Figure 4. Migrated seismic profiles showing the location of the proposed drill sites, Sites ACE-1c, 3c, 7b, 8a, and 9a.

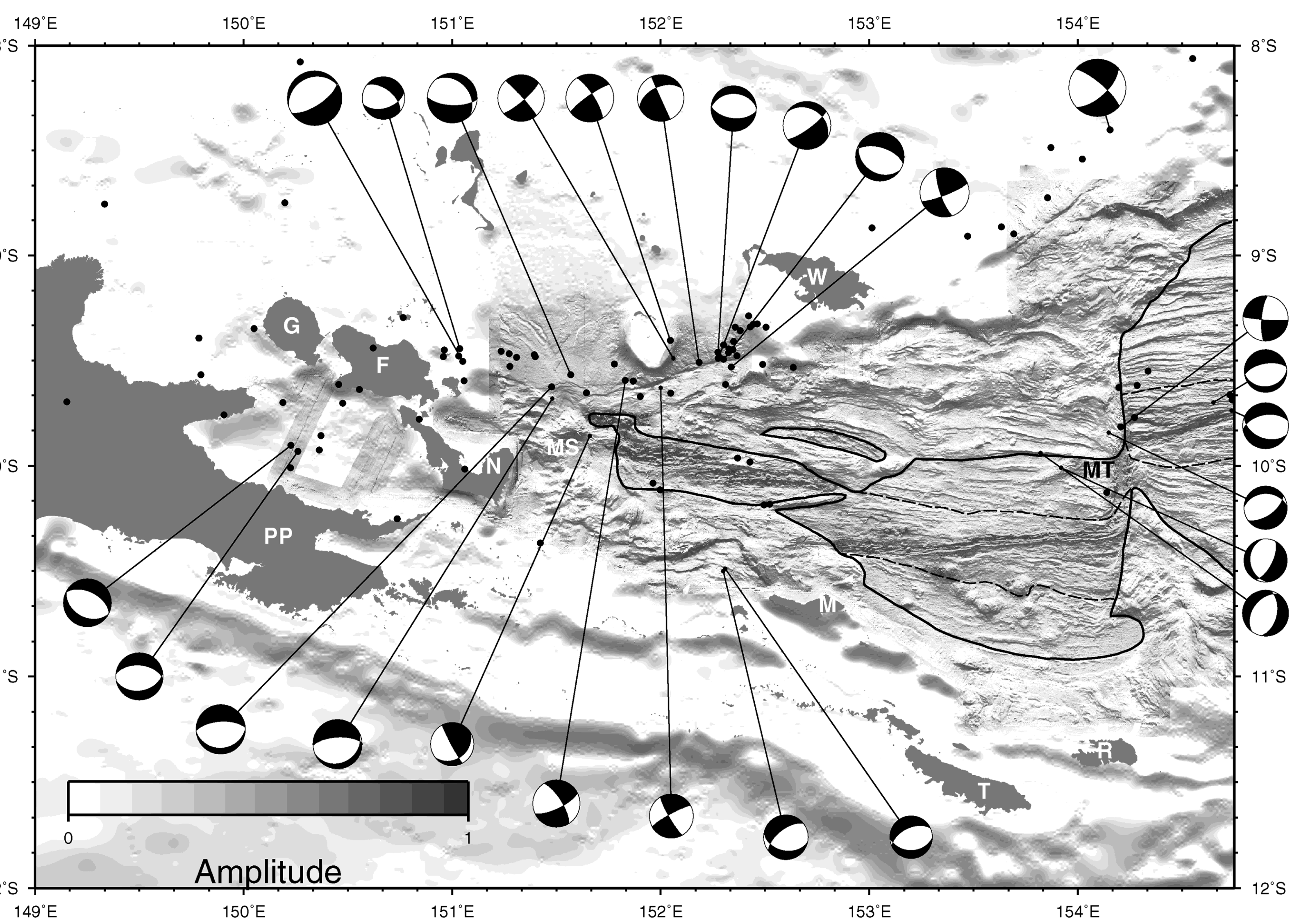
Figure 5. Nested meridional sections showing the regional and local structures across the incipient conjugate margins. The proposed drill sites are Sites ACE-3c, 8a, and 9a, with alternate Sites ACE-1c and 7b. VE = vertical exaggeration.

Figure 6. Planned reentry cone and casing installation at Site ACE-8a.



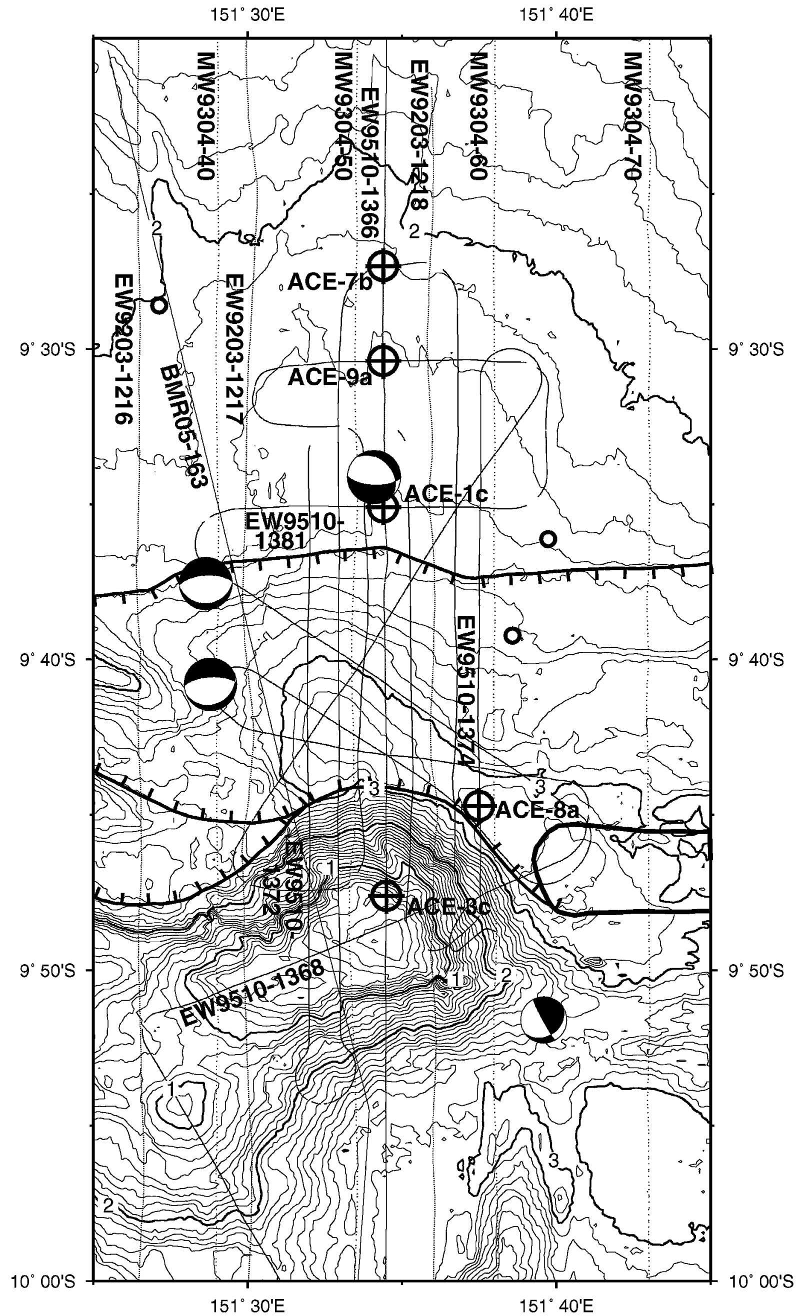
150°E
155°E
160°E
5°S
10°S
NEW BRITAIN
NEW BRITAIN TRENCH
SOLOMON SEA
TROBRIAND TROUGH
PAPUAN PENINSULA
WOODLARK RISE
DE
36
53
67
ST
MT
WOODLARK BASIN
SOLOMON ISLANDS
SAN CRISTOBAL TRENCH
POCKLINGTON TROUGH
POCKLINGTON RISE
CORAL SEA
NEW GUINEA
AUSTRALIA
Subduction zone
2000-m isobath
Neovolcanic zone
Bruhnes chron
Continent/ocean boundary
Strike-slip fault
Depth (km)
2
3
4
1
2
3
4
5
152°E
154°E
156°E

Figure 1



149°E
150°E
151°E
152°E
153°E
154°E
8°S
9°S
10°S
11°S
12°S
W
G
F
N
MS
PP
M
MT
R
T
0
1
Amplitude

Figure 2



151° 30'E
151° 40'E
MW9304-40
MW9304-50
EW9510-1366
EW9203-1218
MW9304-60
MW9304-70
EW9203-1216
EW9203-1217
BMR05-163
ACE-7b
ACE-9a
ACE-1c
EW9510-
1381
EW9510-1374
ACE-8a
EW9510-
1372
ACE-3c
EW9510-1368
9° 30'S
9° 40'S
9° 50'S
10° 00'S

Figure 3

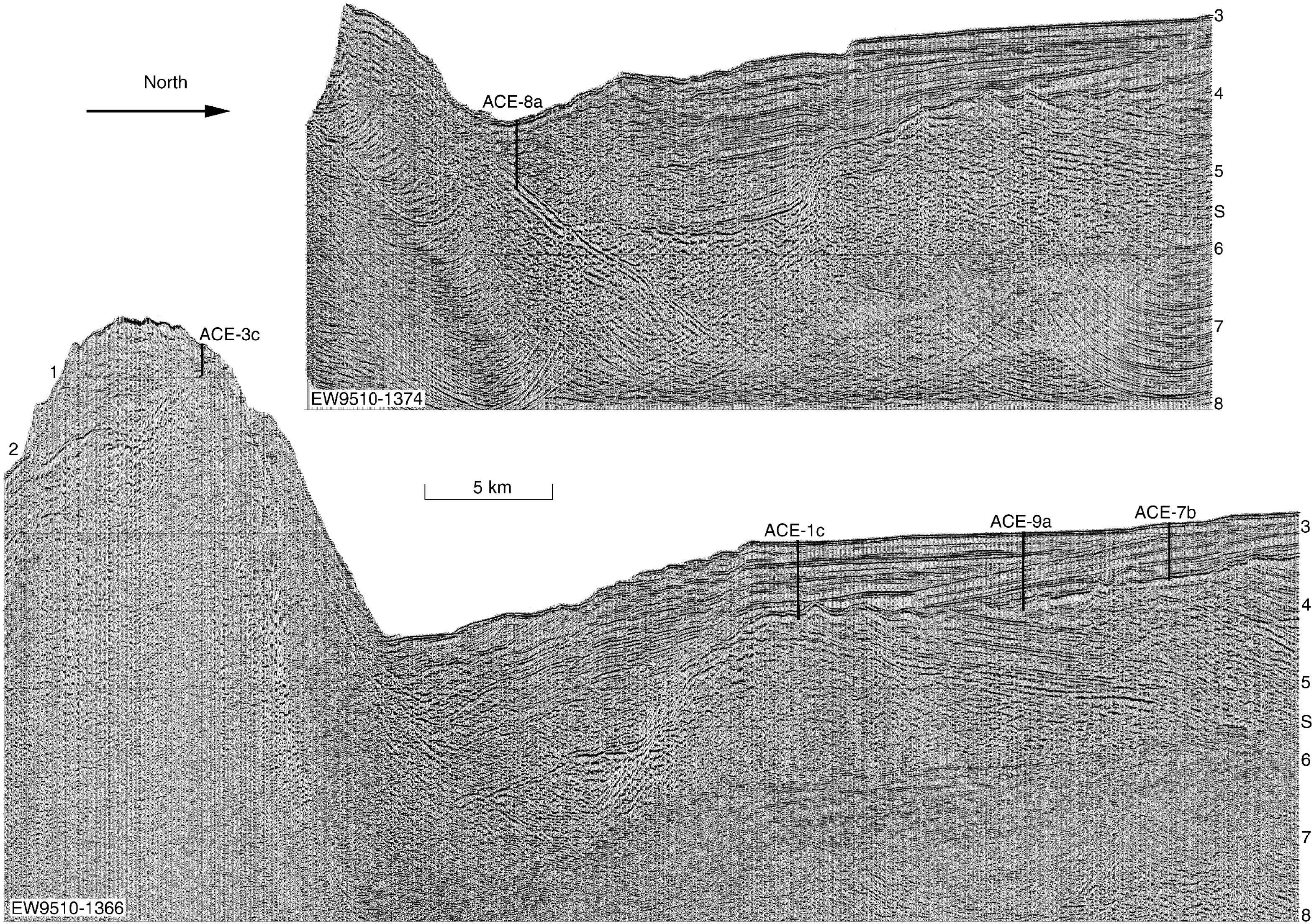
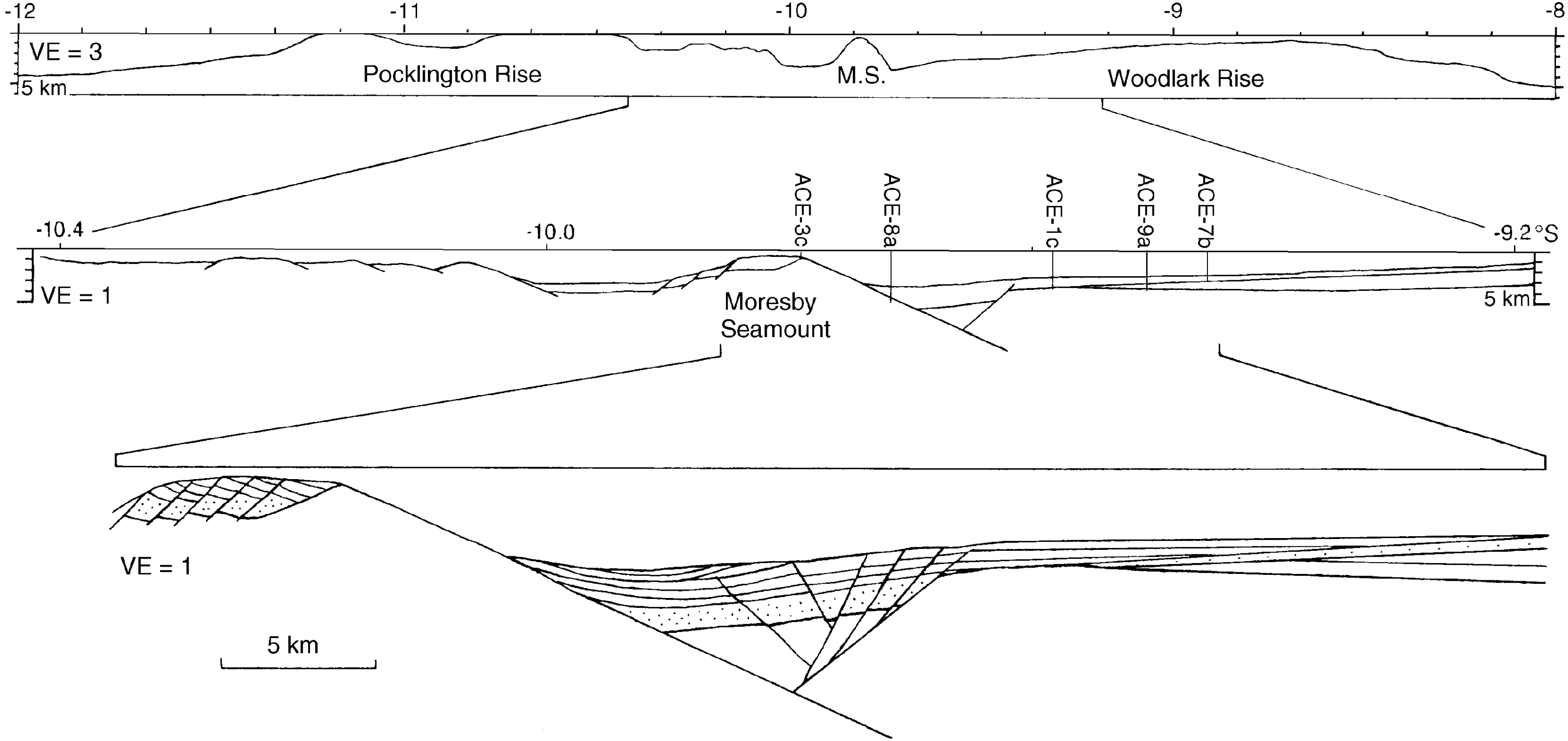

North
ACE-8a
EW9510-1374
ACE-3c
1
2
5 km
ACE-1c
ACE-9a
ACE-7b
EW9510-1366
3
4
5
S
6
7
8
3
4
5
S
6
7
8

Figure 4



-12
-11
-10
-9
-8
VE = 3
Pocklington Rise
M.S.
Woodlark Rise
5 km
-10.4
-10.0
-9.2°S
ACE-3c
ACE-8a
ACE-1c
ACE-9a
ACE-7b
VE = 1
Moresby
Seamount
5 km
VE = 1
5 km

Figure 5

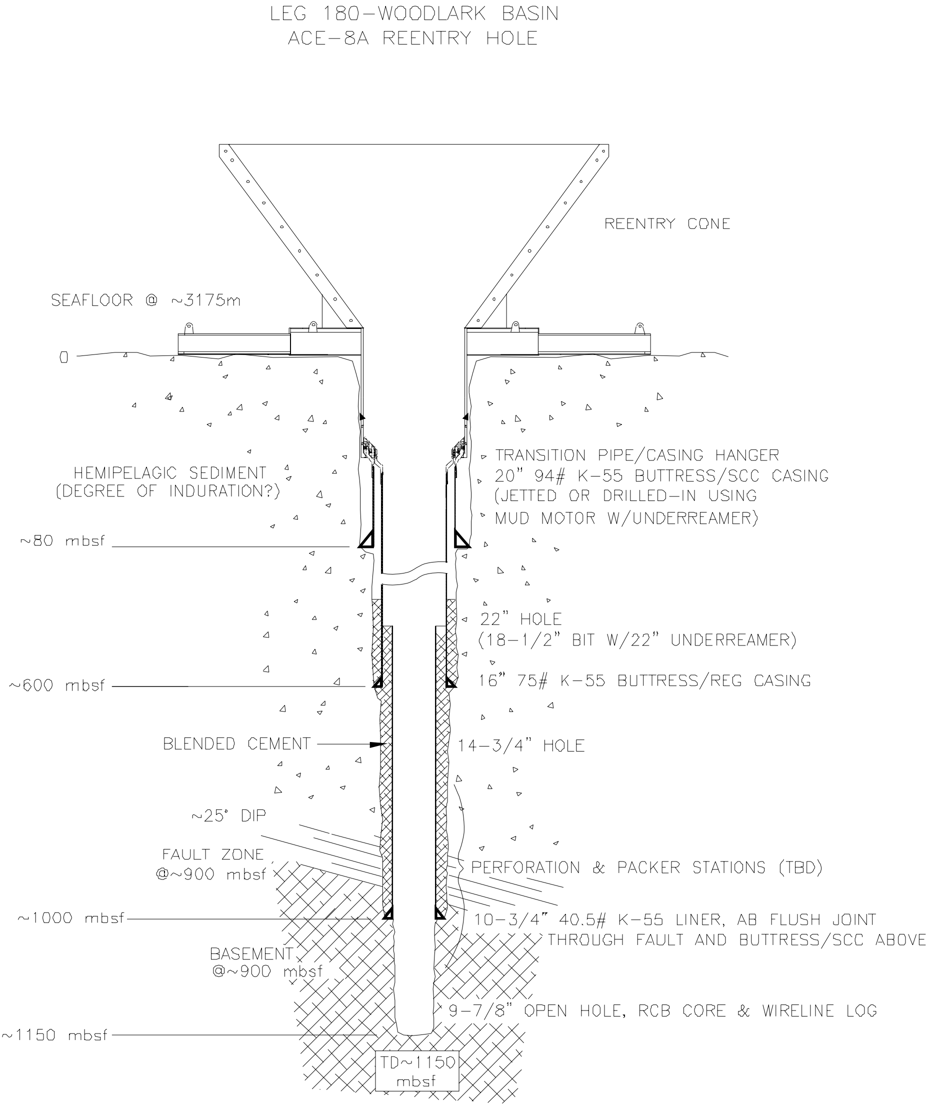

LEG 180–WOODLARK BASIN
ACE–8A REENTRY HOLE
REENTRY CONE
SEAFLOOR @ ~3175m
0
TRANSITION PIPE/CASING HANGER
20" 94# K–55 BUTTRESS/SCC CASING
(JETTED OR DRILLED–IN USING
MUD MOTOR W/UNDERREAMER)
HEMIPELAGIC SEDIMENT
(DEGREE OF INDURATION?)
~80 mbsf
22" HOLE
(18–1/2" BIT W/22" UNDERREAMER)
~600 mbsf
16" 75# K–55 BUTTRESS/REG CASING
BLENDED CEMENT
14–3/4" HOLE
~25° DIP
FAULT ZONE
@~900 mbsf
PERFORATION & PACKER STATIONS (TBD)
~1000 mbsf
10–3/4" 40.5# K–55 LINER, AB FLUSH JOINT
THROUGH FAULT AND BUTTRESS/SCC ABOVE
BASEMENT
@~900 mbsf
9–7/8" OPEN HOLE, RCB CORE & WIRELINE LOG
~1150 mbsf
TD~1150
mbsf

Figure 6

Leg No. 180 - Woodlark Basin

Prospectus Operations Plan for Primary Drill Sites

Site No.	Location Lat/Long	Water Depth	Projected Operations Plan		Transit (days)	Drilling (days)	Logging (days)	Total On-site
Darwin	12.23° S		Transit 1464 nmi from Darwin to Site ACE-8A @ 10.5 kt	139.4hr	5.8			
	130.44° E							
ACE-8A	9° 44.71' S	3175m	A: Jet-in test with 18-1/2" tricone drill bit/trip out	26.4hr		12.4	1.8	14.2
Pilot	151° 37.52' E		APC/XCB w/LFV to 400 mbsf, temperature measurements	79.8hr				
Hole			Triple combo/FMS-Sonic wireline log, plug w/heavy mud	13.8hr				
			B: Drill to ~380 mbsf, RCB w/MBR to ~1020 mbsf	192.3hr				
			Triple combo/FMS-Sonic/BHTV wireline logs, plug w/mud & cement	28.2hr				
			'DP offset 14.6 nmi from Site ACE-8A to Site ACE-9A (while tripping pipe)		0.0			
ACE-9A	9° 30.387' S	2211m	A: APC/XCB w/LFV to 500 mbsf, temperature measurements	75.6hr		8.0	0.9	8.9
	151° 34.393' E		B: Drill to 490 mbsf, RCB w/MBR to 1000 mbsf (no basement)	115.7hr				
			Triple Combo/FMS-Sonic wireline logs	20.9hr				
			DP offset 14.6 nmi from Site ACE-9A to Site ACE-8A (while tripping pipe)		0.0			
ACE-8A	9° 44.71' S	3175m	C: Jet or drill-in reentry cone with 20" casing to ~80 mbsf	34.8hr		18.8	1.6	20.4
Reentry	151° 37.52' E		Drill 18-1/2" hole with 22" underreamer to ~620 mbsf	54.2hr				
Hole			Set/cement 16"-75 lb/ft K-55 buttress/SCC casing to ~600 mbsf	33.1hr				
			Drill 14-3/4" hole w/tricone bit to ~1020 mbsf	110.4hr				
			Set/cement 10-3/4"-40.5 lb/ft K-55 flush joint liner to ~1000 mbsf.	37.4hr				
			RCB to ~1150 mbsf (~150 m into basement)	92.3hr				
			Run in hole w/DP, prepare for wireline logging	12.4hr				
			SDT cement/triple combo/FMS-sonic/BHTV/VSP-ASI wireline logs	37.2hr				
			Round trip drill string for TAM straddle packer BHA	22.4hr				
			Two WL perforation runs - 4 shots/ft, .33" dia, 10-20 ft. interval	6.0hr				
			Conduct packer experiments w/TAM straddle packer	34.0hr				
			(packer set inside 10-3/4" casing f/2 sets, open hole f/3rd set)					
			Recover drill string, NDT BHA, and secure for transit	14.8hr				
			DP offset 4.1 nmi from Site ACE-8A to Site ACE-3C (while tripping pipe)		0.0			
ACE-3C	9° 47.61' S	420m	Hole A: RCB w/MBR to 400 mbsf (300m sed/100 m base), temperature	80.2hr		3.3	0.6	3.9
	151° 34.50' E		Triple Combo/FMS-Sonic/BHTV wireline logs	14.4hr				
Townsville	19.13° S		Transit 700 nmi from Site ACE-3C to Townsville @ 10.5 kt	66.7hr	2.8			
	146.48° E							
					8.6	**42.5**	**4.9**	**47.4**

TOTAL DAYS: 56.0

Leg No. 180 - Woodlark Basin

Prospectus Operations Plan for Alternate Drill Sites

Site No.	Location Lat/Long	Water Depth	Projected Operations Plan		Transit (days)	Drilling (days)	Logging (days)	Total On-site
ACE-1C	9° 35.117' S	2307m	A: APC/XCB to 500 mbsf, temperature measurements	77.0hr		9.5		9.5
	151° 34.424' E		B: Drill to 480 mbsf, RCB w/MBR to 1030 mbsf (~80m of basement)	150.8hr				
			Triple Combo/FMS-sonic, GHMT, and BHTV (basement) wireline logs					
ACE-7B	9° 27.327' S	2115m	A: APC/XCB to 500 mbsf, temperature measurements	73.9hr		6.1		6.1
	151° 34.396' E		B: Drill to 490 mbsf, RCB w/MBR to 750 mbsf	72.4hr				
			Triple Combo/FMS-sonic, and GHMT wireline logs					
					0.0	**15.6**	**0.0**	**15.6**

SITE SUMMARIES

Site: ACE-1c

Priority: 2
Position: 9°35.117'S, 151°34.424'E
Water Depth: 2307 m
Sediment Thickness: 950 m
Approved Maximum Penetration: 1030 mbsf
Seismic Coverage: EW9510-1366 (WW01 CMP 4547) and 1381 (WW13 CMP 1681)

Objectives: The objectives of Site ACE-1c are to determine the:

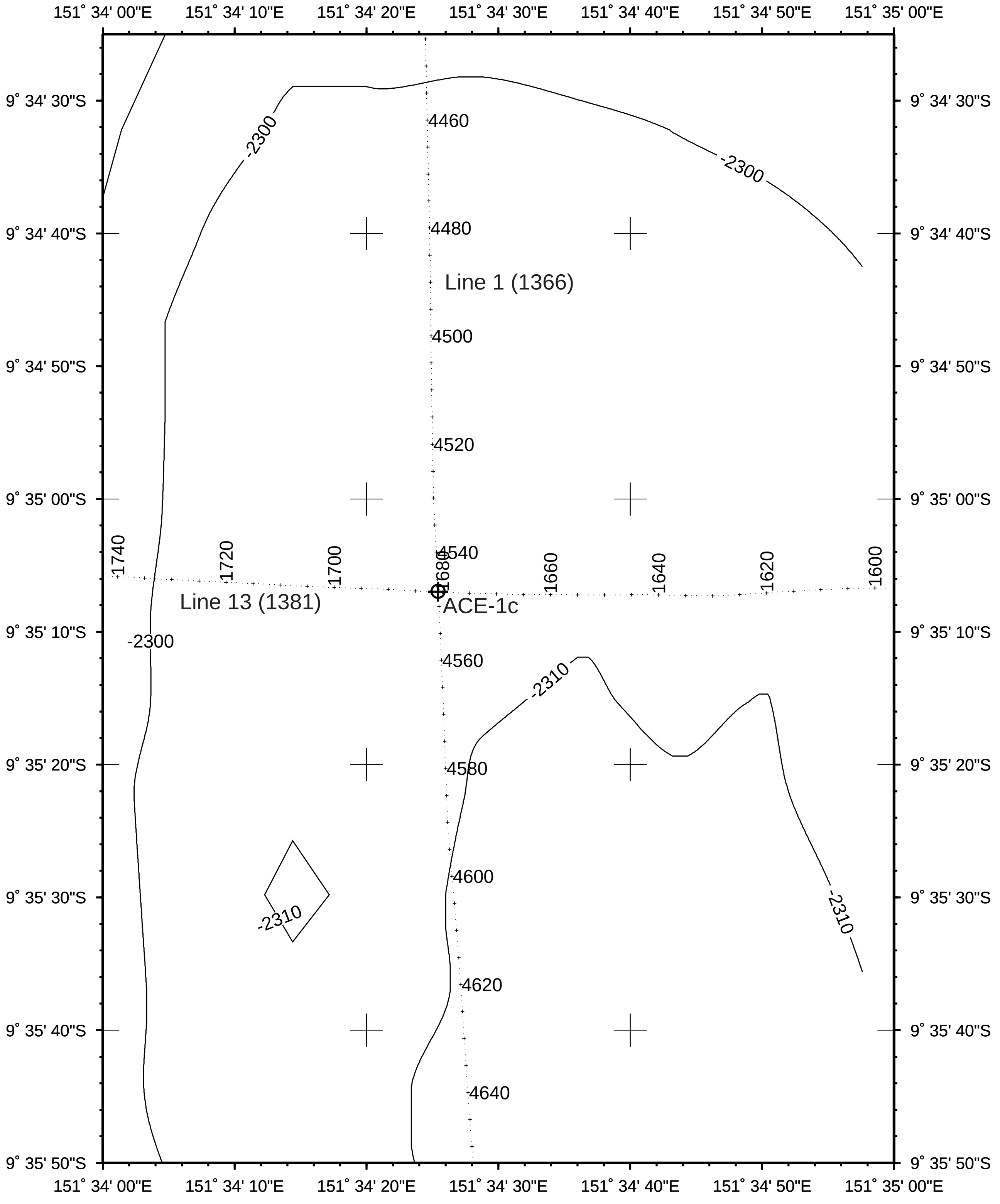
1. sedimentology, biostratigraphy, and vertical motion history of the northern margin;
2. nature of basement and the pre-rift history; and
3. basement stress orientation, permeability, temperature, physical properties, and fluid composition.

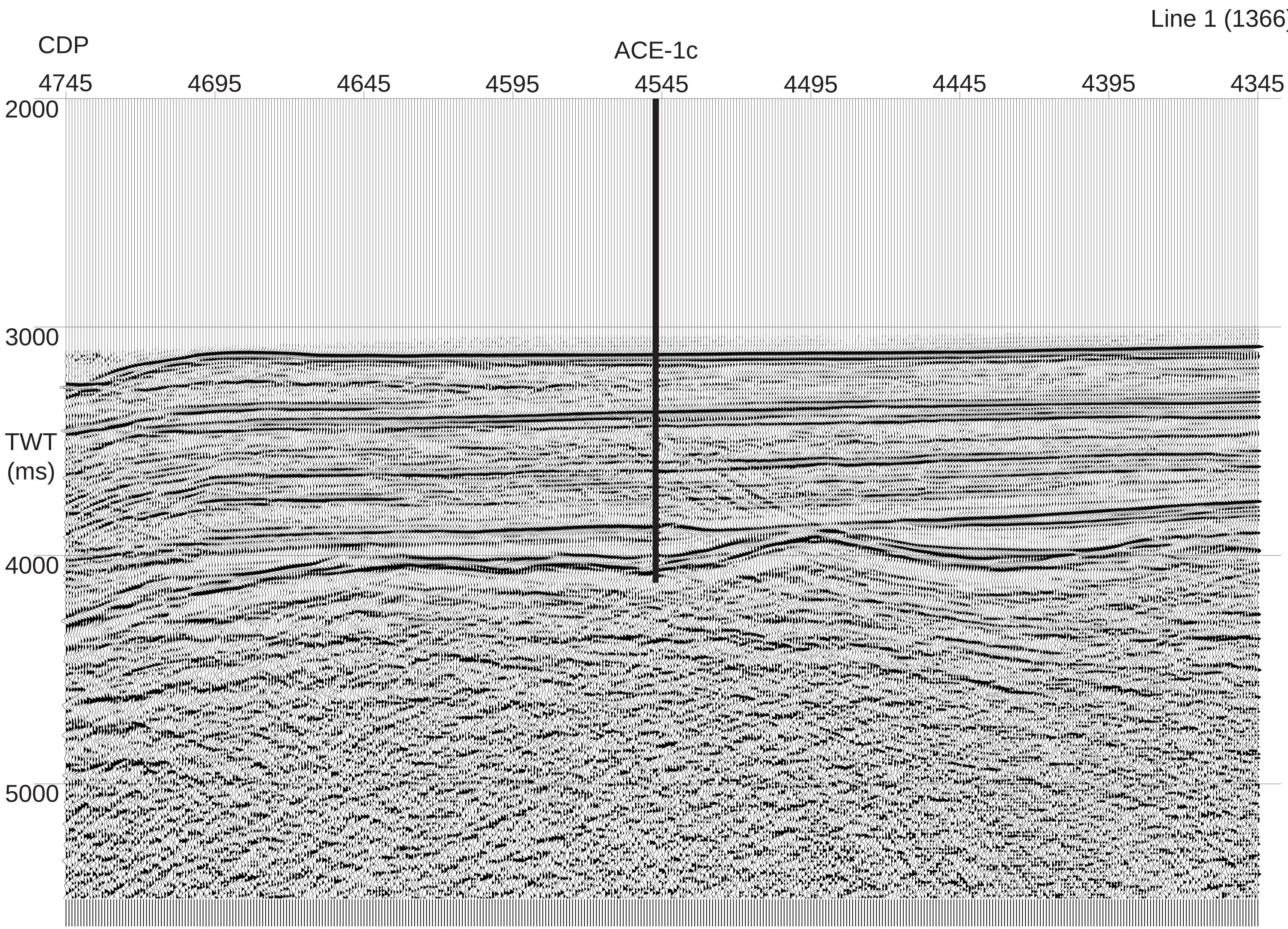
Drilling Program: APC, XCB, RCB.

Logging and Downhole Operations: Triple-combo Geophysics, FMS-sonic, GHMT (if on board), BHTV in basement, temperature (Adara, DVTP/WSTP).

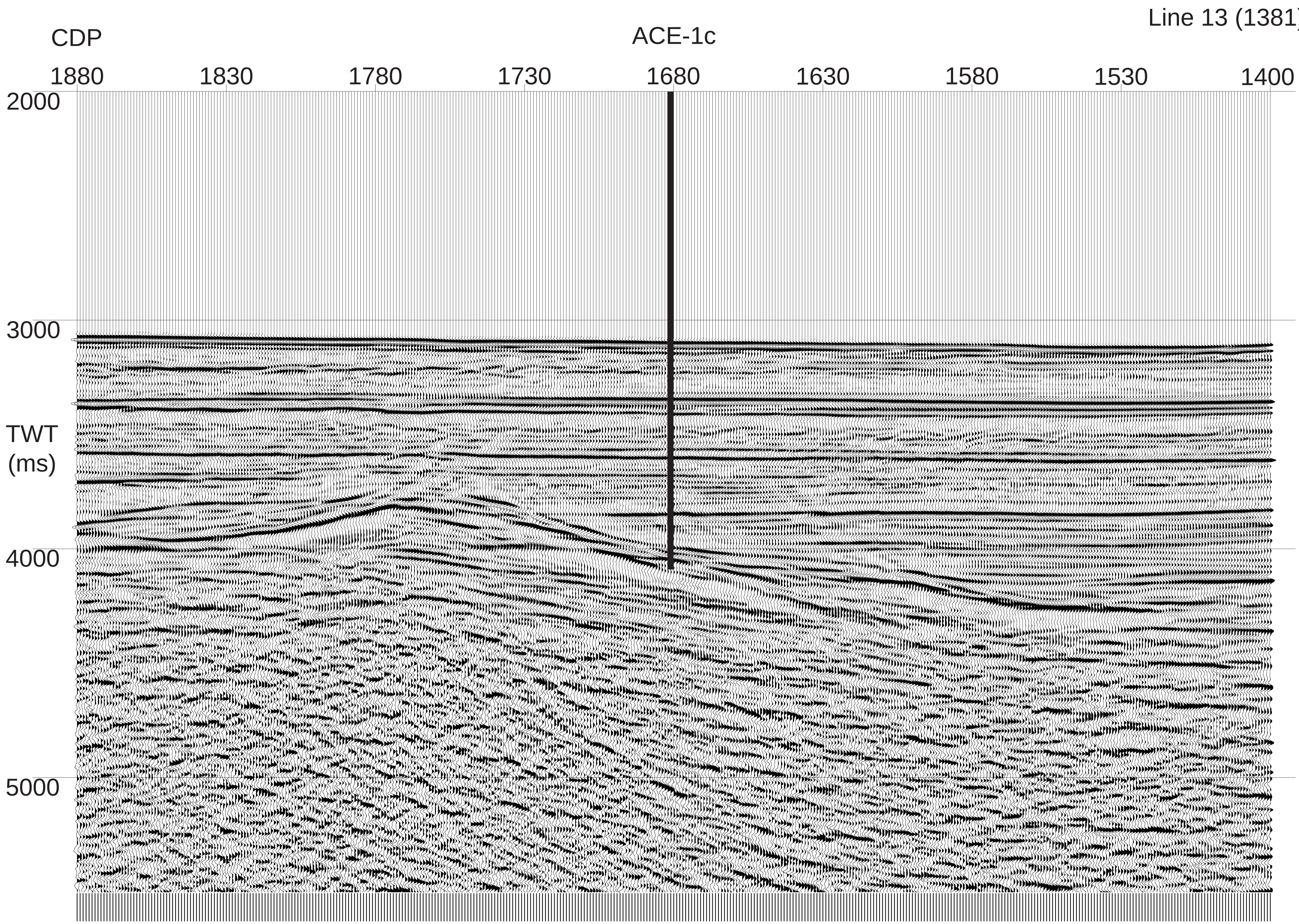
Nature of Rock Anticipated: Quaternary hemipelagic sediments, Paleogene volcanics and volcaniclastics.

Site ACE-1c: Crossing of Lines 1 and 13





Line 1 (1366)
CDP
ACE-1c
4745
4695
4645
4595
4545
4495
4445
4395
4345
2000
3000
TWT
(ms)
4000
5000


Line 13 (1381)
CDP
ACE-1c
1880
1830
1780
1730
1680
1630
1580
1530
1400
2000
3000
TWT
(ms)
4000
5000

Site: ACE-3c

Priority: 1
Position: 9°47.61'S, 151°34.50'E
Water Depth: 420 m
Sediment Thickness: 300 m
Approved Maximum Penetration: 1000 mbsf
Seismic Coverage: EW9510-1366 (WW01 CMP 6390)

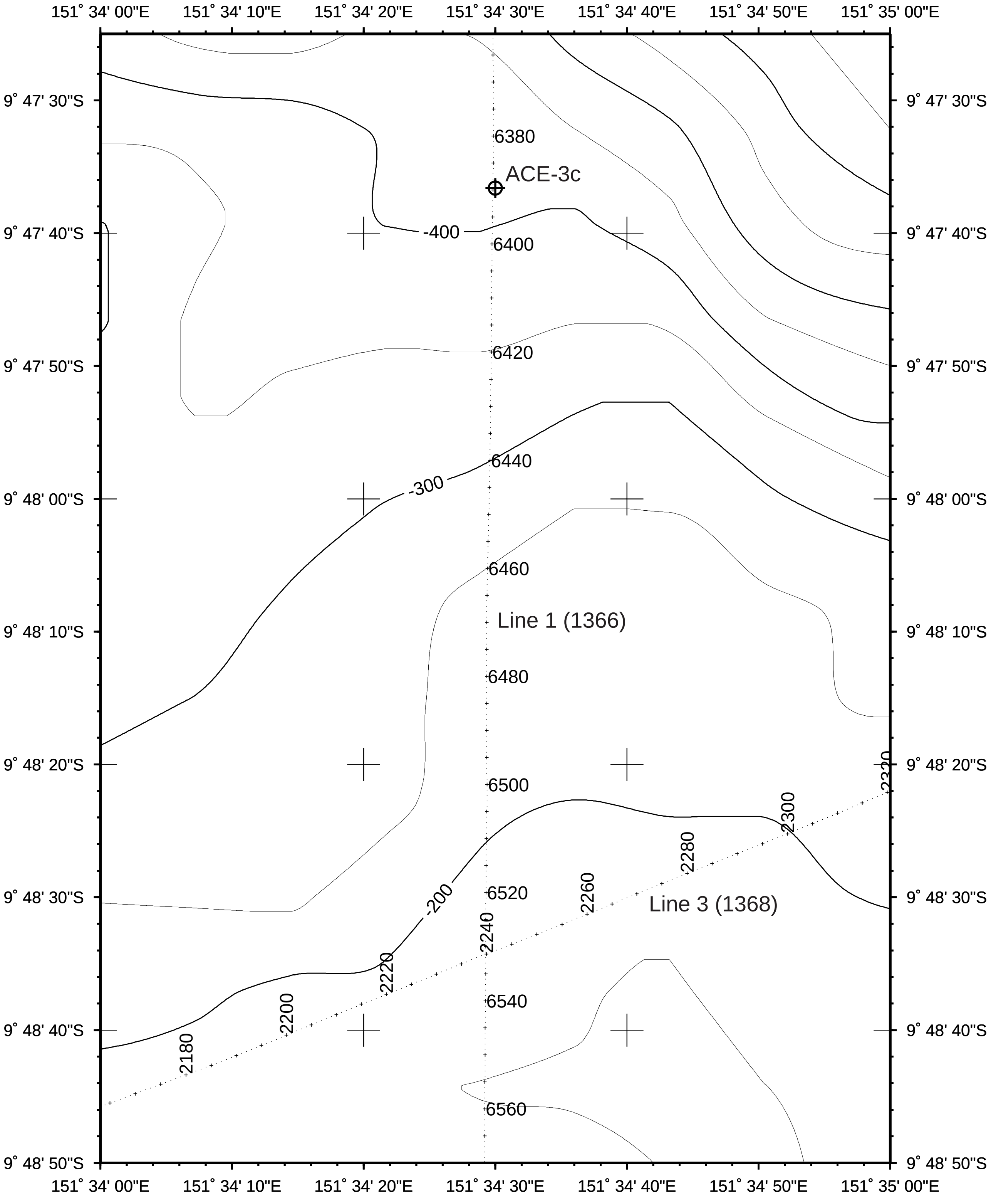
Objective: The objective of Site ACE-3c is to determine the internal structure and composition of Moresby Seamount including the nature of basement (rock type, P-T-t, structural fabric, and deformation history).

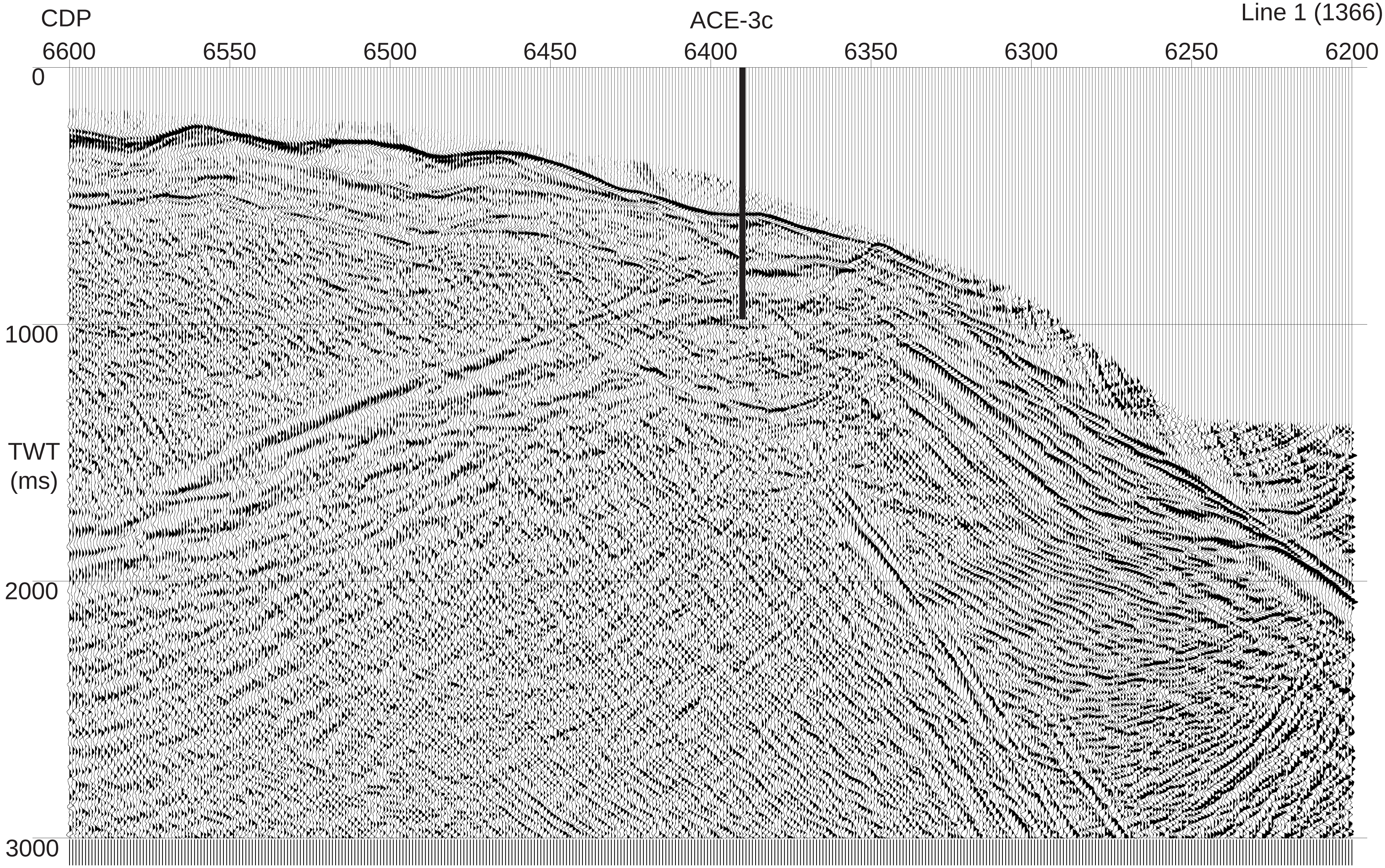
Drilling Program: RCB.

Logging and Downhole Operations: Triple-combo Geophysics, FMS-sonic, BHTV in basement.

Nature of Rock Anticipated: 6 m Holocene carbonate sand; Quaternary sandstone, siltstone and mudstone; Paleogene greenschist facies metamorphics.

Site ACE-3c: Line 1




CDP
ACE-3c
Line 1 (1366)
6600
6550
6500
6450
6400
6350
6300
6250
6200
0
1000
TWT
(ms)
2000
3000

Site: ACE-7b

Priority: 2
Position: 9°27.327'S, 151°34.396'E
Water Depth: 2115 m
Sediment Thickness: 750 m
Approved Maximum Penetration: 750 mbsf
Seismic Coverage: EW9510-1366 (WW01 CMP 3399) and 1369a (WW4a CMP 1208)

Objectives: The objectives of Site ACE-7b are to determine:

1. sedimentology, biostratigraphy, and vertical motion history of the northern margin, and

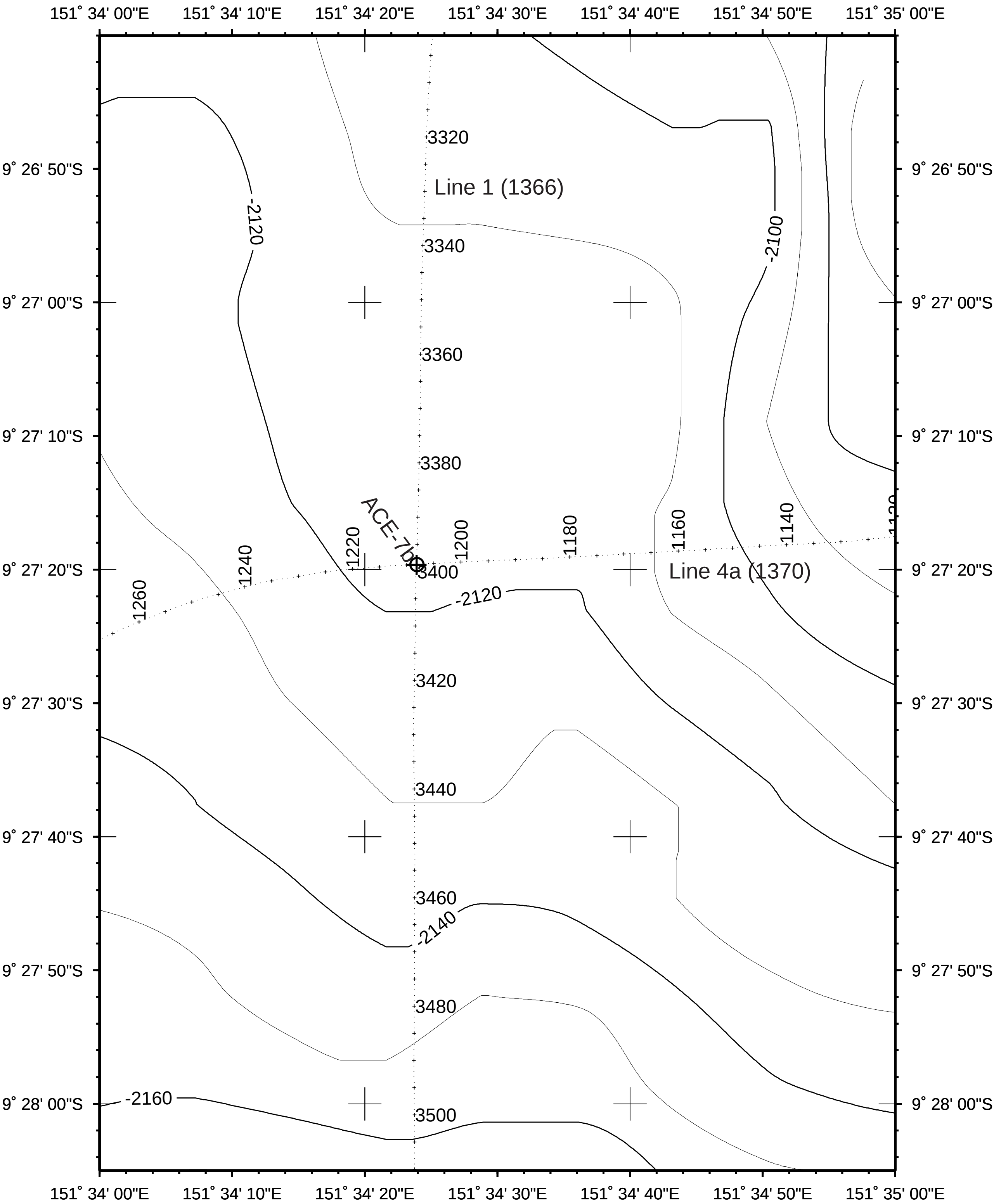
2. nature of the forearc basin sequence and the pre-rift history.

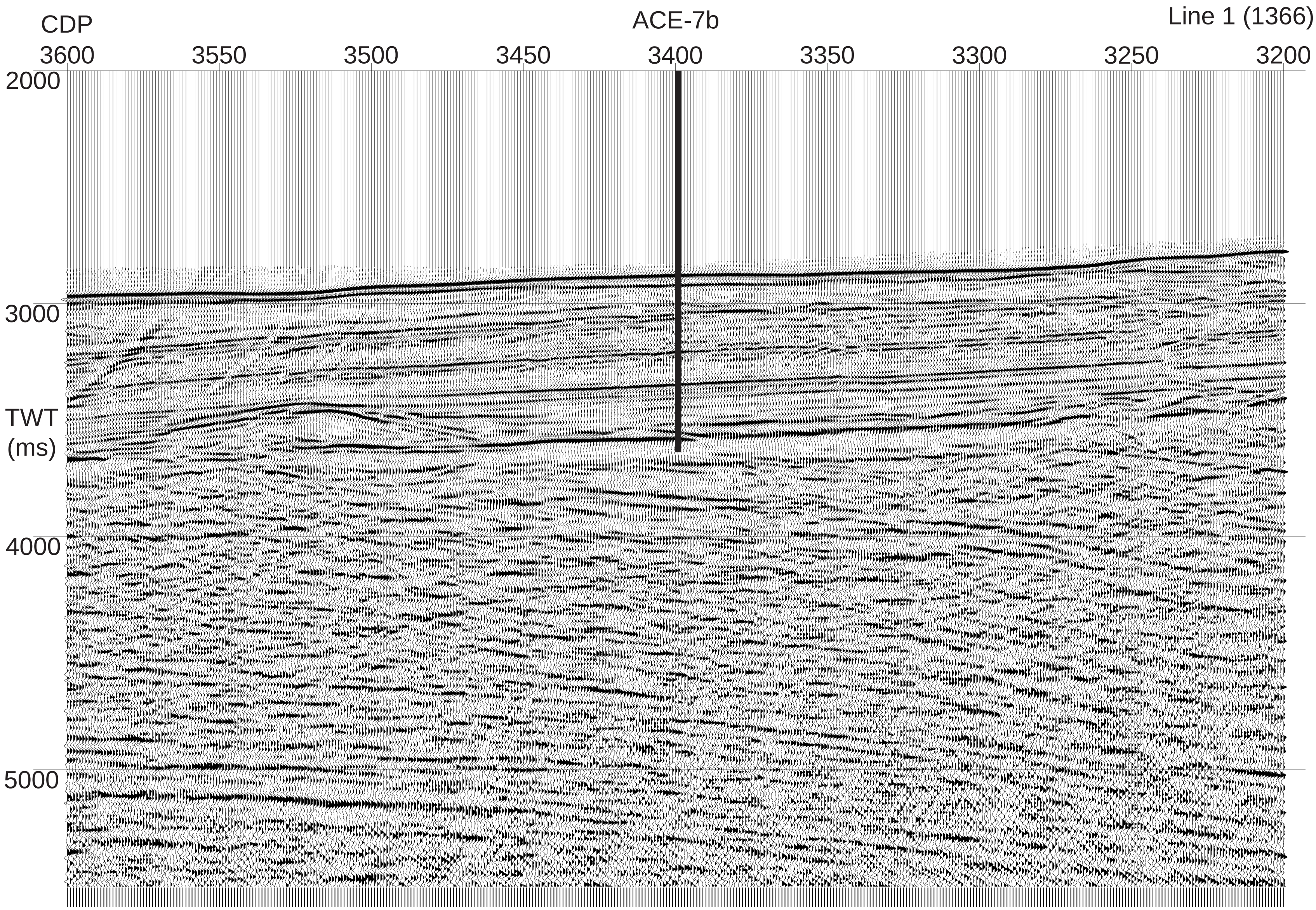
Drilling Program: APC, XCB, RCB.

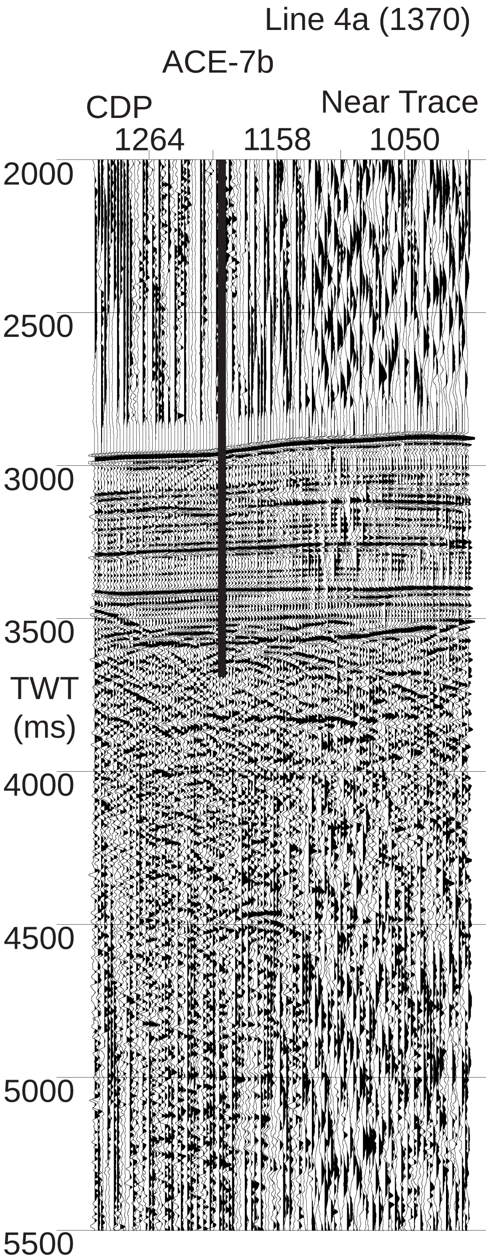
Logging and Downhole Operations: Triple-combo Geophysics, FMS-sonic, GHMT (if on board), temperature (Adara, DVTP/WSTP).

Nature of Rock Anticipated: 640 m Pliocene-Quaternary hemipelagic sediments above 110 m Miocene forearc basin sediments (sandstone, siltstone, and mudstone).

Site ACE-7b: Crossing of Lines 1 and 4a




CDP
ACE-7b
Line 1 (1366)
3600
3550
3500
3450
3400
3350
3300
3250
3200
2000
3000
TWT
(ms)
4000
5000



Line 4a (1370)
ACE-7b
CDP
Near Trace
1264
1158
1050
2000
2500
3000
3500
TWT
(ms)
4000
4500
5000
5500

Site: ACE-8a

Priority: 1
Position: 9°44.71'S, 151°37.52'E
Water Depth: 3175 m
Sediment Thickness: 900 m
Approved Maximum Penetration: 1500 mbsf
Seismic Coverage: EW9510-1374 (WW08 CMP 1500)

Objectives: The objectives of Site ACE-8a are to determine the:

1. sedimentology, biostratigraphy, structural fabric, and vertical motion history in the rift graben,

2. nature of basement (P-T-t, structural fabric, deformation history) in and below fault zone, and

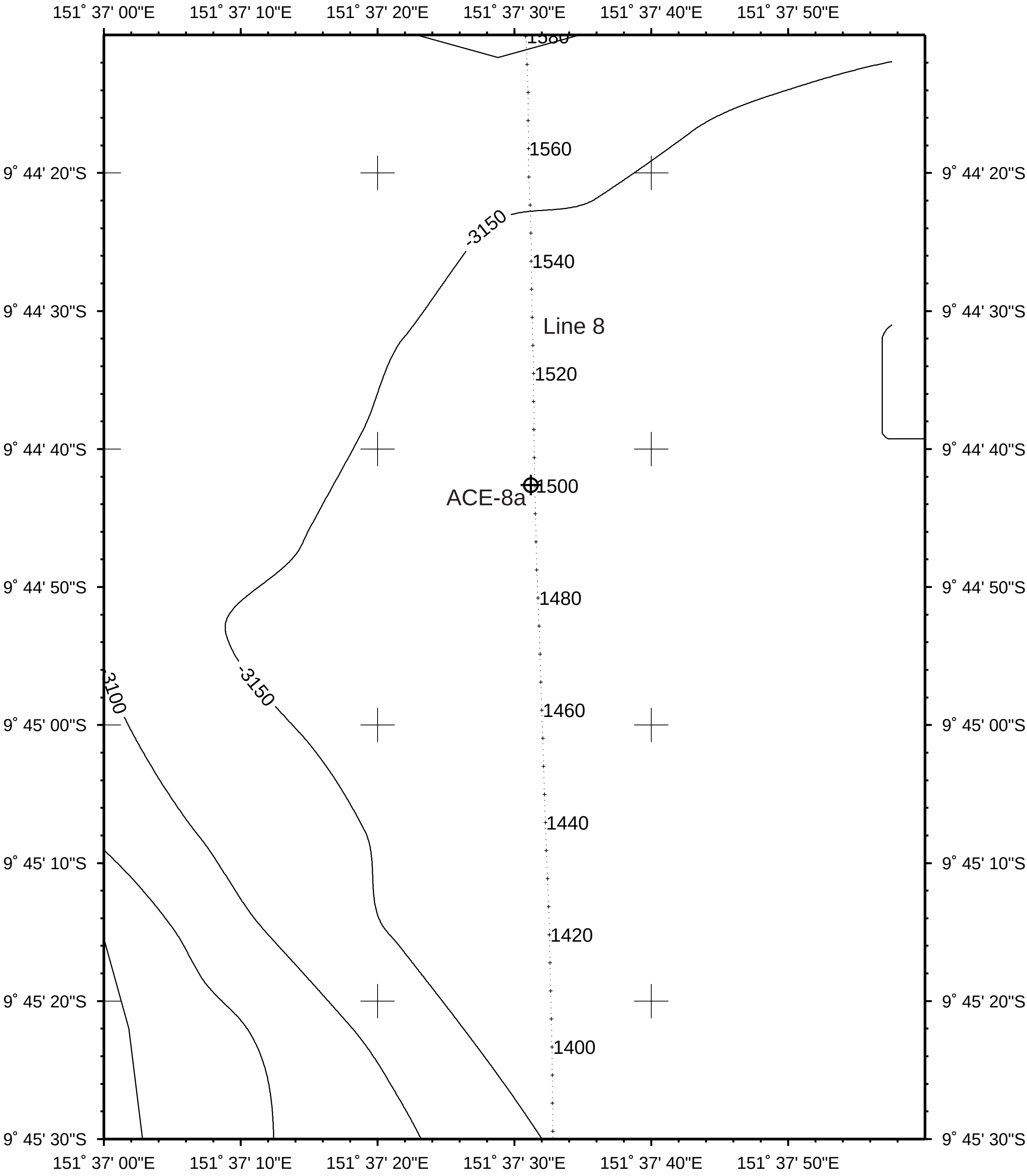
3. in situ stress, temperature, physical properties, fluid pressure, and composition.

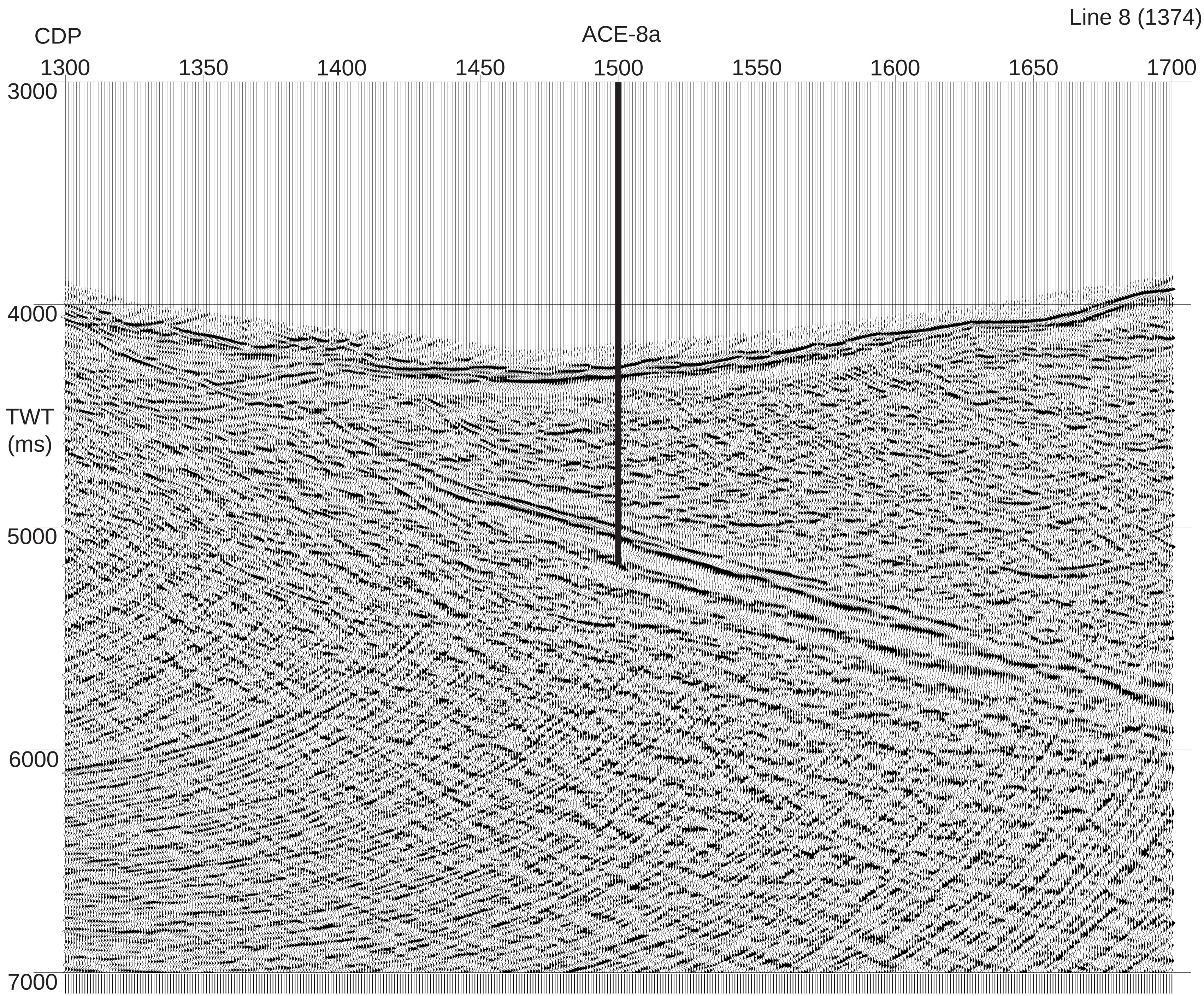
Drilling Program: ACE-8a Pilot hole: APC, XCB, RCB, logging. ACE-8a Reentry hole: Reentry cone and triple casing, basement coring and logging, basement logging, casing perforation, packer hydrologic testing.

Logging and Downhole Operations: Triple-combo Geophysics, FMS-sonic, BHTV, vertical seismic profile (ASI-VSP), packer experiments, temperature (Adara, DVTP/WSTP).

Nature of Rock Anticipated: Quaternary hemipelagic sediments, sheared fault zone rocks, metamorphics.

Site ACE-8a: Line 8





Line 8 (1374)
CDP
ACE-8a
1300
1350
1400
1450
1500
1550
1600
1650
1700
3000
4000
TWT
(ms)
5000
6000
7000

Site: ACE-9a

Priority: 1
Position: 9°30.387'S, 151°34.393'E
Water Depth: 2211 m
Sediment Thickness: 1000 m
Approved Maximum Penetration: 1000 mbsf
Seismic Coverage: EW9510-1366 (WW01 CMP 3850) and 1379 (WW11 CMP 1624)

Objectives: The objectives of Site ACE-9a are to determine:

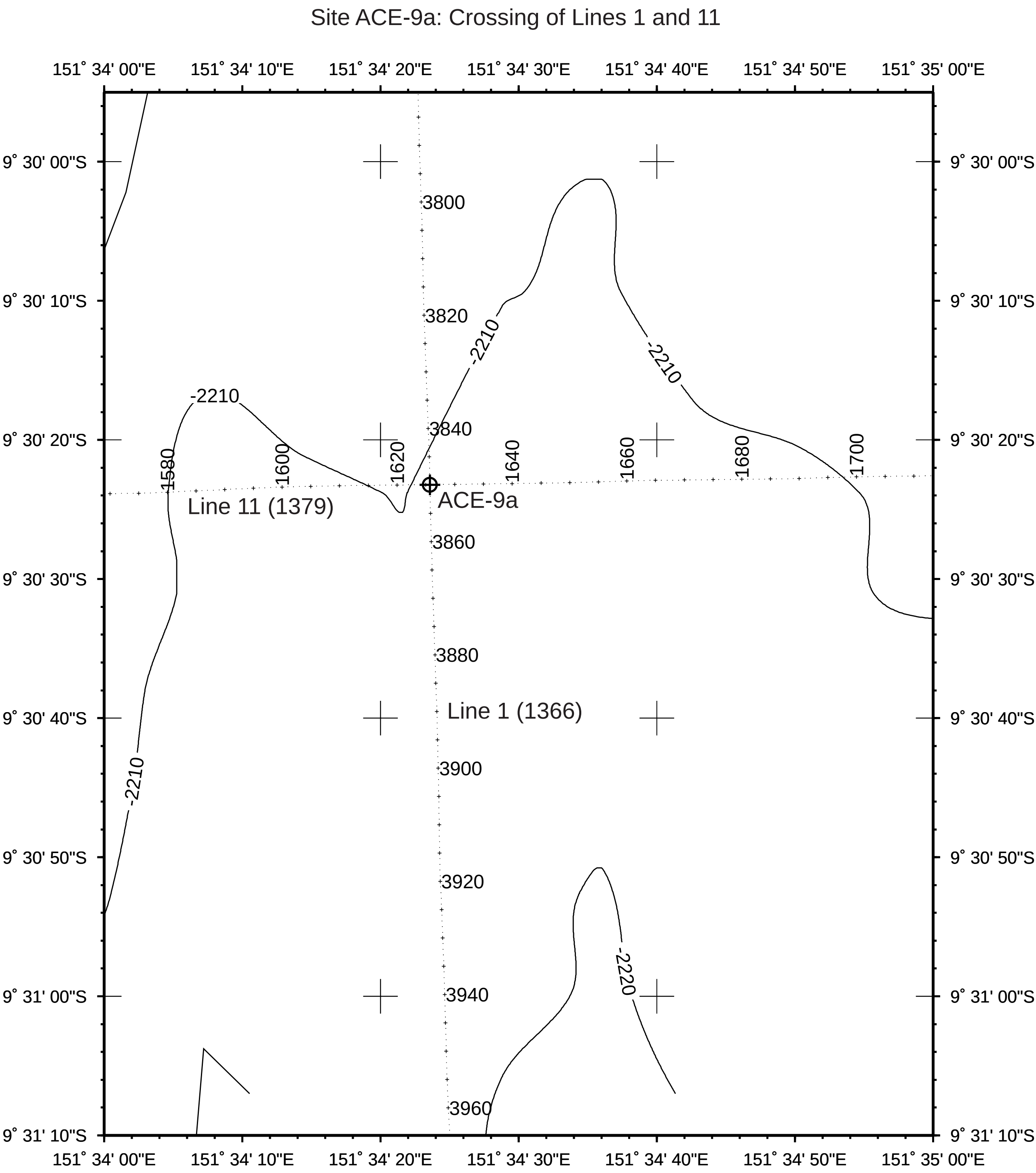
1. sedimentology, biostratigraphy, and vertical motion history of the northern margin, and

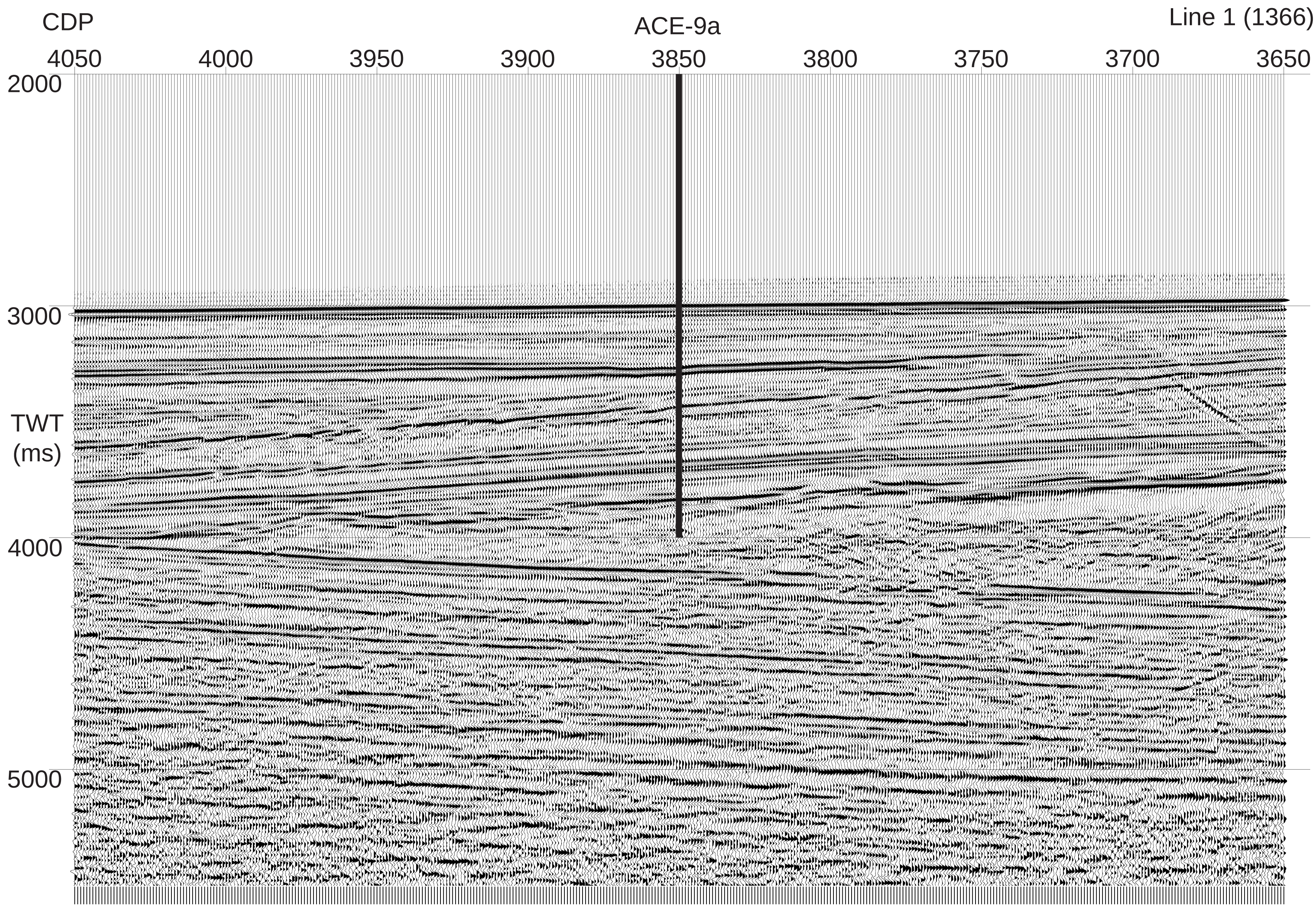
2. nature of the forearc basin sequence and the pre-rift history.

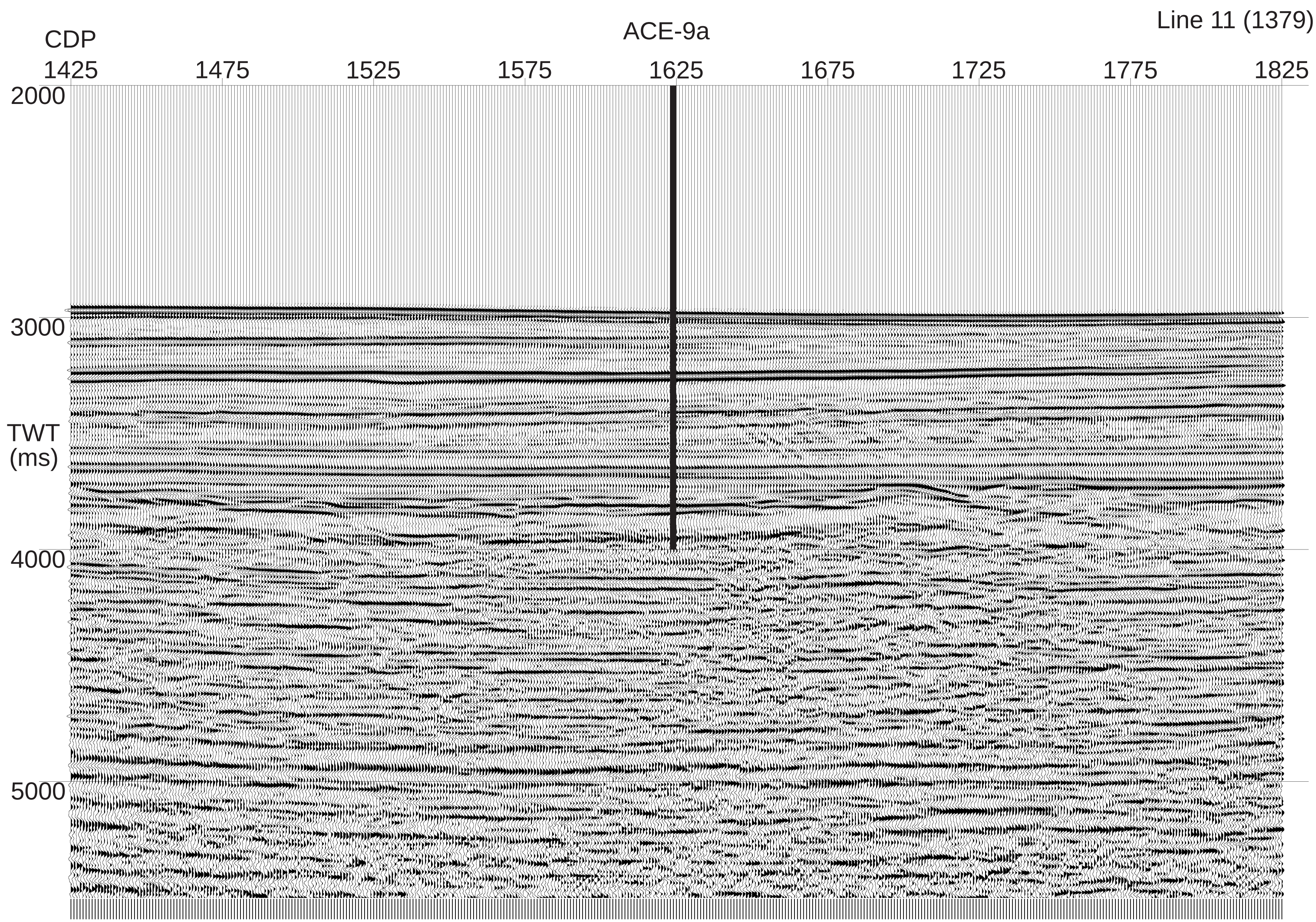
Drilling Program: APC, XCB, RCB.

Logging and Downhole Operations: Triple-combo Geophysics, FMS-sonic, GHMT (if on board), temperature (Adara, DVTP/WSTP).

Nature of Rock Anticipated: 780 m Pliocene-Quaternary hemipelagic sediments above 220 m Miocene forearc basin sediments (sandstone, siltstone, and mudstone).


Site ACE-9a: Crossing of Lines 1 and 11
151° 34' 00"E
151° 34' 10"E
151° 34' 20"E
151° 34' 30"E
151° 34' 40"E
151° 34' 50"E
151° 35' 00"E
9° 30' 00"S
9° 30' 10"S
9° 30' 20"S
9° 30' 30"S
9° 30' 40"S
9° 30' 50"S
9° 31' 00"S
9° 31' 10"S
3800
3820
3840
3860
3880
3900
3920
3940
3960
1580
1600
1620
1640
1660
1680
1700
-2210
-2220
ACE-9a
Line 11 (1379)
Line 1 (1366)


CDP
ACE-9a
Line 1 (1366)
4050
4000
3950
3900
3850
3800
3750
3700
3650
2000
3000
TWT
(ms)
4000
5000


Line 11 (1379)
ACE-9a
CDP
1425
1475
1525
1575
1625
1675
1725
1775
1825
2000
3000
TWT
(ms)
4000
5000

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