

OCEAN DRILLING PROGRAM
LEG 183 SCIENTIFIC PROSPECTUS
KERGUELEN PLATEAU-BROKEN RIDGE:
A Large Igneous Province

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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 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

Earth history is punctuated by massive magmatic events. Resultant mafic large igneous provinces (LIPs) provide the strongest evidence that at certain times in the past, energy transfer from the Earth's interior to its surface has occurred in a manner substantially different from modern plate tectonic processes. Cretaceous time, in particular, is marked by voluminous and episodic basaltic magmatic events generated from the mantle, and these events appear to correlate with extreme states or rapid changes in the oceans, atmosphere, and biosphere. The Kerguelen Plateau/Broken Ridge, one of two giant oceanic plateaus formed in Cretaceous time, is a prime target for investigating (1) mantle processes resulting in LIPs; (2) mechanisms of growth, emplacement, and post-constructional deformation of LIPs; and (3) environmental consequences of voluminous mafic magmatism.

Ocean Drilling Program (ODP) Leg 183 will penetrate igneous basement to depths of ~150 to 200 m at several morphologically and tectonically diverse locations on the $\sim 2 \times 10^6$ km² LIP formed by the Kerguelen Plateau/Broken Ridge in the Southeast Indian Ocean. This leg will build on results obtained by basement drilling at four ODP sites on the Central and Southern Kerguelen Plateau during Legs 119 and 120. A major objective of Leg 183 is to determine the magmatic chronology of the Kerguelen Plateau/Broken Ridge LIP by determining the eruption ages of the uppermost igneous crust at several locations. Studies of basement basalt obtained from dredges and drill cores from Legs 119 and 120 show that much of the Southern Kerguelen Plateau formed at 110 to 115 Ma, whereas the Central Kerguelen Plateau and parts of Broken Ridge are younger (~85 Ma). However, ages of basement from major morphological features, such as Elan Bank and the submarine Northern Kerguelen Plateau, are unknown because they have not been previously sampled.

During evolution of a LIP, it is likely that hydrothermal and metamorphic processes differ from those occurring in a spreading ridge environment. Therefore, another objective is to use cores of the basement and overlying sediments to assess the interaction between LIP magmatism and the surficial environment. Episodes of high magma flux during formation of a LIP may have significant impact on the Earth's hydrosphere, atmosphere, and biosphere. Additional goals of Leg 183 are to determine the mechanism of LIP growth and the tectonic history of the plateau by integrating seismic data with studies of the sedimentary and igneous cores (i.e., seismic volcanostratigraphy). Specifically, these cores will be used to address the following issues: the timing and extent of initial uplift, the relative roles of subaerial and submarine volcanism, the

cooling and subsidence into a submarine environment, and the multiple episodes of post-emplacement deformation.

A unique aspect of this LIP is its clear association with a long linear volcanic ridge, i.e., the Ninetyeast Ridge. Dating of basement basalt from the seven Deep Sea Drilling Project (DSDP) and ODP drill holes that penetrated the igneous basement of the Ninetyeast Ridge established a systematic south to north progression of ages from 38 to ~82 Ma along this hot spot track. In addition, the Kerguelen Archipelago and Heard Island, constructed on the Northern and Central Kerguelen Plateau, respectively, have a volcanic record from ~38 Ma to the present. Studies of subaerial lavas from these islands and submarine lavas recovered by drilling provide a 115 m.y. record of volcanism that can be used to evaluate the hypothesis that the Kerguelen Plateau/Broken Ridge system is related to decompression melting of a plume head and that the subsequent Ninetyeast Ridge and oceanic island volcanism are related to partial melting of the following plume tail. The Kerguelen plume is particularly important because it is a source of an "enriched isotopic component" that forms an end-member in the isotopic arrays defined by ocean island basalts, and it may have been important in creating the distinctive isotopic characteristics of Indian Ocean ridge basalts. Determination of spatial and temporal variations in geochemical characteristics of the basalts forming the Kerguelen Plateau and Broken Ridge are essential for understanding the early history of the Kerguelen plume.

INTRODUCTION

LIPs are a significant type of planetary volcanism found on the Earth, Moon, Venus, and Mars (Coffin and Eldholm, 1994; Head and Coffin, 1997). They represent voluminous fluxes of magma emplaced over relatively short time periods, as would be expected from decompression melting of an ascending, relatively hot, mantle plume. Terrestrial LIPs are dominantly mafic rocks formed during several distinct episodes in Earth history, perhaps in response to fundamental changes in the processes that control energy and mass transfer from the Earth's interior to its surface. The ocean basins contain two very large Cretaceous LIPs, the Kerguelen Plateau/Broken Ridge in the Indian Ocean (Fig. 1) and the Ontong Java Plateau in the Pacific Ocean. Both are elevated regions of the ocean floor encompassing areas of $\sim 2 \times 10^6 \text{ km}^2$ (Coffin and Eldholm, 1994). These LIPs are important for several reasons. First, they provide information about mantle compositions and dynamics that are not reflected by volcanism at spreading ridges. For example, today LIPs account for only 5% to 10% of the heat and magma expelled from the Earth's mantle, but the giant LIPs may have contributed as much as 50% in Early Cretaceous time (Coffin and Eldholm, 1994), thereby indicating a substantial change in mantle dynamics from the Cretaceous to the present (e.g., Stein and Hofmann, 1994). Also, because magma fluxes represented by oceanic plateaus are not evenly distributed in space and time, their episodicity punctuates the relatively steady-state production of crust at seafloor spreading centers. These intense episodes of igneous activity temporarily alter the flux of magma and heat from the mantle to the crust, hydrosphere, and atmosphere, possibly resulting in global environmental change, such as excursions in the chemical and isotopic composition of seawater (e.g., Larson, 1991; Ingram et al., 1994; Jones et al., 1994; Bralower et al., 1997). Finally, because oceanic LIPs may be resistant to subduction, they may be future building blocks of continental crust.

Despite their huge size and distinctive morphology, oceanic plateaus remain among the least understood features in the ocean basins. This drilling leg is focused on sampling the Kerguelen Plateau/Broken Ridge LIP with the objectives of determining the age and composition of the basement volcanic rocks in all major parts of the LIP, mass transfer and chemical fluxes between the volcanic crust and the atmosphere-hydrosphere-biosphere system, and the tectonic history of the LIP beginning with the mechanisms of growth and emplacement and continuing with the multiple episodes of post-constructional deformation that created the present complex bathymetry (Figs. 2-4).

STUDY AREA

Physical Description

The Kerguelen Plateau is a broad topographic high in the southern Indian Ocean surrounded by deep ocean basins: to the northeast lies the Australian-Antarctic Basin; to the south, the 3500-m-deep Princess Elizabeth Trough; to the southwest, the Enderby Basin; and to the northwest, the Crozet Basin (Fig. 2). The plateau stretches ~2300 km between 46°S and 64°S in a southeast-trending direction toward the Antarctic continental margin. It is between 200 and 600 km wide and stands 2-4 km above the adjacent ocean basins. The age of the oceanic crust abutting the Kerguelen Plateau is variable (Fig. 2). As summarized by Schlich and Wise (1992), the oldest magnetic anomalies range from Anomaly 11 (~32 Ma) in the northeast to Anomaly 18 (~43 Ma) off the central part of the eastern plateau. Farther south, the east flank of the Southern Kerguelen Plateau is bounded by the Labuan Basin. Basement of the Labuan Basin has not been sampled, but its age and structure appear to be similar to the main Kerguelen Plateau (Rotstein et al., 1991; Munsch et al., 1992). To the northwest, magnetic anomaly sequences from 23 to 34 have been identified in the Crozet Basin, but on the southwest flank no convincing anomalies have been identified in the Enderby Basin, although Mesozoic anomalies have been suggested (Li, 1988; Nogi et al., 1996). An Early Cretaceous age for the Enderby Basin is assumed in most plate reconstructions (e.g., Royer and Coffin, 1992).

Beginning with early studies (Schlich, 1975; Houtz et al., 1977), the Kerguelen Plateau province has been divided into distinct domains that currently total five: northern, central, and southern portions; Elan Bank; and the Labuan Basin (Figs. 2, 4; Coffin et al., 1986; in prep.). The Northern Kerguelen Plateau (NKP), ~46°S to 50°S, has shallow water depths, <1000 m, and basement elevations 3000-4000 m above adjacent seafloor with maximum elevations forming the Kerguelen Archipelago. A lack of any rocks older than ~40 Ma from the Kerguelen Archipelago and the submarine NKP, as well as plate reconstructions (Royer and Sandwell, 1989; Royer and Coffin, 1992) suggest that the NKP is ≤40 Ma in age, whereas the remainder of the Kerguelen Plateau province appears to be of Cretaceous age. The Central Kerguelen Plateau (CKP), ~50°S to 55°S, is also relatively shallow, contains a major sedimentary basin (Kerguelen-Heard basin), and includes Heard and McDonald Islands, which are dominated by active volcanoes (P. Quilty, pers. comm., 1998). Broken Ridge and the CKP are conjugate Late Cretaceous (see below) provinces (Fig. 1) that were separated by seafloor spreading along the Southeast Indian Ridge (SEIR) during Eocene time (Mutter and Cande, 1983).

The Southern Kerguelen Plateau (SKP) is generally characterized by deeper water, 1500 to 2500 m, and is tectonically more complex (Figs. 2, 4). Of Early Cretaceous age (see below), it is characterized by several large basement uplifts and has experienced multiple stages of normal faulting, graben formation, and strike-slip faulting (e.g., Coffin et al., 1986; Fritsch et al., 1992; Rotstein et al., 1992; Royer and Coffin, 1992; Angoulvant-Coulon and Schlich, 1994; Könnecke and Coffin, 1994; Gladchenko et al., 1997). Elan Bank, a salient extending westward from the boundary between the CKP and SKP, is characterized by water depths of <1000-2000 m. Basement has not been sampled from Elan Bank, and consequently, its age is unknown. Labuan Basin, east of and adjacent to the CKP and SKP, is an extensively faulted, thickly sedimented (>2 s two-way traveltime [TWT] in places) deep ocean basin. Its crust has not been sampled by drilling, but dredging has recovered metamorphic and granitic rock (Montigny et al., 1993). The basin's crustal origin and age are uncertain.

As noted above, Broken Ridge and the Kerguelen Plateau formed as one entity in Cretaceous time and began separating at ~40 Ma. Broken Ridge currently lies ~1800 km north of Kerguelen and forms a narrow and elongated oceanic plateau (100-200 km by ~1000 km at ~2000 m water depth) that trends west-northwest (Fig. 3). It is markedly asymmetric in cross-section, dipping gently (<2°) toward the north but with a steeply dipping (>10°) southern face (Fig. 3). This southern flank was uplifted, perhaps >2 km, by flexural rebound following rift-related Early Tertiary extension (Weissel and Karner, 1989; Peirce et al., 1989).

Crustal Structure

On the basis of drilling results from ODP Legs 119 and 120 (Barron, Larsen, et al., 1989; Schlich, Wise, et al., 1989), together with multichannel seismic reflection data (Coffin et al., 1990; Schaming and Rotstein, 1990; Schlich et al., 1993), the crust of the Kerguelen Plateau and conjugate Broken Ridge is believed to be overwhelmingly basaltic. Numerous dipping basement reflections that are interpreted as flood basalts have been identified in the crust of the CKP and SKP and on Elan Bank (Könnecke et al., 1997). Wide-angle seismic data from the Kerguelen Archipelago, on the NKP, show an upper igneous crust ~10 km thick and a lower crust 7-9 km thick (Recq et al., 1990, 1994; Charvis et al., 1995). Ocean-bottom seismometer wide-angle reflection and refraction experiments have been undertaken recently on both the CKP and SKP (Charvis et al., 1993, 1995; Operto and Charvis, 1995, 1996; Könnecke et al., in press; Charvis and Operto, in press). Crustal structure beneath the Kerguelen Archipelago differs significantly from that of the CKP. Igneous crust of the CKP is 19-21 km thick and is composed of three layers. The upper layer is 1.2- to 2.3-km thick, and velocities range from 3.8 to 4.9 km/s. It could

be composed of either lava flows or interlayered volcanic and sedimentary beds. The second layer is 2.3 to 3.3 km thick, with velocities ranging from 4.7 to 6.7 km downward. In the lower crust, velocities increase from 6.6 km/s at ~8.0 km depth (near the top of the layer) to 7.4 km/s at the base of the crust, with no internal discontinuity. On the southern plateau, igneous crust can be divided into three layers: (1) an upper crustal layer ~5.3 km thick with velocities ranging from 3.8 to 6.5 km/s; (2) a lower crustal layer ~11 km thick with velocities of 6.6 to 6.9 km/s; and (3) a 4 to 6-km thick transition zone at the base of the crust characterized by an average velocity of 6.7 km/s (Operto and Charvis, 1995, 1996). This low-velocity, seismically reflective transition zone at the crust-mantle interface has not been imaged on the NKP or CKP, and it is the basis for the hypothesis that parts of the SKP are fragments of a volcanic passive margin, similar to the Rockall Plateau in the North Atlantic Volcanic Province (Schlich et al., 1993; Operto and Charvis, 1995, 1996).

Previous Sampling of Igneous Basement

What has been learned from previous sampling (ODP Legs 119 and 120 and dredging) of the Kerguelen Plateau/Broken Ridge LIP? Based in large part on ODP-related studies, there is a consensus that decompression melting of the Kerguelen plume was a major magma source for the Kerguelen Plateau/Broken Ridge system. Although sampling and age dating for the entire LIP are grossly insufficient, sampling of the southern Kerguelen Plateau at four spatially diverse locations (ODP Sites 738, 749, and 750 and dredge site MD 48-05 [Fig. 4]) shows that the uppermost parts of the SKP formed over a relatively short interval at ~110 Ma (Leclaire et al., 1987; Whitechurch et al., 1992). This is corroborated by recent $^{40}\text{Ar}/^{39}\text{Ar}$ studies (Pringle et al., 1994; Pringle et al., 1997; Coffin et al., in prep.), which report ages ranging from 108.6 Ma to 112.7 Ma for basement basalts from Sites 738, 749, and 750. Therefore, south of 57°S the uppermost Kerguelen Plateau formed at ~110 Ma. In contrast, basalts from Site 747 on the Central Kerguelen Plateau are much younger, ~85 Ma. This age is similar to the 83-88 Ma age for lavas from Broken Ridge dredge sites 8 and 10 (Fig. 3; Duncan, 1991), which is consistent with the pre-rifting position of Site 747 relative to these Broken Ridge dredge sites. Also, piston coring of sediments on the northeast flank of the plateau between the Kerguelen Archipelago and Heard Island (Fig. 4) recovered Upper Cretaceous cherts and calcareous oozes of probable Santonian age (Fröhlich and Wicquart, 1989). In summary, we have very few high-quality age data for the $2.3 \times 10^6 \text{ km}^2$ (equivalent to approximately eight Icelandic plateaus) of the Kerguelen Plateau/Broken Ridge LIP. Nevertheless, the available data show that large magma volumes erupted over short time intervals, possibly as two or even three pulses (Coffin et al., in prep.): the SKP at ~110 Ma; the CKP, Broken Ridge, and Elan Bank at ~85 Ma; and much of the Kerguelen Archipelago and perhaps the northernmost

portion of the Kerguelen Plateau at ~40-23 Ma (Nicolaysen et al., 1996). Sampling by drilling at other sites throughout the plateau is required to determine if formation of this LIP was truly episodic or if there was a continuous south to north decrease in age of volcanism.

Although the Kerguelen Plateau is a volcanic construction formed in a young oceanic basin (Royer and Coffin, 1992; Munsch et al., 1994; Coffin et al., in prep.), evidence is equivocal as to whether it was emplaced at a spreading center (e.g., Iceland) or off-ridge (e.g., Hawaii) (Coffin and Gahagan, 1995). In contrast, there is unambiguous evidence that much of the uppermost basement of the southern and central Kerguelen Plateau was emplaced in a subaerial environment. The evidence includes: (1) oxidized flow tops and the vesicularity of lava flows at ODP Sites 738 and 747, (2) nonmarine, organic-rich sediments (containing up to 5-cm pieces of charcoal) overlying the basement at Site 750, and (3) claystone topped by a basalt cobble conglomerate and glauconitic sediment with wood fragments in the lowermost core at Site 748 (Schlich et al., 1989). Coffin (1992) concluded that the drill sites in the SKP had long (>10 to ≤50 m.y.) histories of subaerial volcanism and erosion followed by subsidence caused by cooling. Higher temperature metamorphism, based on zeolite mineralogy, of the basaltic basement at Site 749 compared to Sites 747 and 750 may indicate erosion to deeper levels at Site 749 (Sevigny et al., 1992).

The islands on the NKP are dominantly formed of <40 Ma transitional and alkaline lavas (e.g., Barling et al., 1994; Yang et al., 1998). In contrast, dredging along the 77°E graben of the Kerguelen Plateau and from Broken Ridge (Figs. 3 and 4) recovered basaltic rocks whose compositions are tholeiitic; however, their incompatible element abundances are similar to those of ocean island tholeiitic basalts rather than typical mid-ocean-ridge basalt (MORB) (e.g., Davies et al., 1989; Weis et al., 1989; Mahoney et al., 1995). Tholeiitic basalts also form the igneous basement of the Kerguelen Plateau at drill Sites 738, 747, 749, and 750 (Fig. 5A). Except for an alkaline basalt flow 200 m above basement at Site 748, all samples derived from the Kerguelen plume (i.e., the Kerguelen Plateau and Ninetyeast Ridge) over the interval from ~110 to 38 Ma are tholeiitic basalt (e.g., Frey et al., 1991; Saunders et al., 1991; Storey et al., 1992; Frey and Weis, 1995). The significance of this result is that tholeiitic compositions are derived by relatively high extents of melting (e.g., Kent and McKenzie, 1994), which suggests that the Kerguelen plume was a high-flux magma source for a long time. However, the MgO-rich melts (picrites) expected from unusually large extents of melting of high-temperature plumes (Storey et al., 1991) have not been recovered. In fact, in contrast to tholeiitic lavas forming the Hawaiian shields, there is no evidence in lavas associated with the Kerguelen plume for melt segregation at relatively high pressures within the garnet stability field (Frey et al., 1991).

Most lavas from the Kerguelen Plateau and Broken Ridge have Sr and Nd isotopic ratios that range from those typical of enriched MORB from the SEIR to those proposed for the Kerguelen plume (Fig. 5B). In Pb-Pb isotopic ratios, most Kerguelen Plateau lavas define an elongated field that is subparallel to that for SEIR MORB. However, like lavas forming the Kerguelen Archipelago, the Kerguelen Plateau lavas are offset from the MORB field to higher $^{208}\text{Pb}/^{204}\text{Pb}$ at a given $^{206}\text{Pb}/^{204}\text{Pb}$ ratio (Fig. 5C). These Sr, Nd, and Pb isotopic data have been interpreted as resulting from mixing of the Kerguelen plume with entrained depleted asthenosphere (e.g., Weis et al., 1992). In contrast, basalts from ODP Site 738 on the southernmost SKP and dredge site 8 from eastern Broken Ridge (Fig. 1) have atypical geochemical characteristics for oceanic lavas. These lavas have very high $^{87}\text{Sr}/^{86}\text{Sr}$, low $^{143}\text{Nd}/^{144}\text{Nd}$, and high $^{207}\text{Pb}/^{204}\text{Pb}$ ratios, which accompany relatively low $^{206}\text{Pb}/^{204}\text{Pb}$ compositions (Fig. 5B, C). Although sampling is sparse, Mahoney et al. (1995) have shown that lavas from plateau locations closest to continental margins (e.g., Site 738 in the far south, dredge site 8 from eastern Broken Ridge, and lavas from the Naturaliste Plateau [Fig. 1]) have the most extreme isotopic characteristics (e.g., $^{87}\text{Sr}/^{86}\text{Sr} > 0.7090$), which are accompanied by relative depletions in Nb and Ta and relatively high $^{207}\text{Pb}/^{204}\text{Pb}$ ratios. They conclude that these geochemical features arose from a continental lithosphere component (e.g., Storey et al., 1989) that contributed to magmatism near the edges of the Kerguelen Plateau/Broken Ridge system. The geochemical evidence for this continental component is consistent with geophysical evidence suggesting the SKP contains a passive margin fragment (Schlich et al., 1993; Operto and Charvis, 1995, 1996).

SCIENTIFIC OBJECTIVES

Leg 183 will address four first-order problems related to the characterization and quantification of mafic igneous crustal production and its effects during the Cretaceous and Cenozoic. Our objectives are to

1. determine the chronology of Kerguelen/Broken Ridge magmatism;
2. constrain mineralogy and composition of mantle sources, melting processes, and post-melting magmatic evolution;
3. evaluate the effects of LIP formation on the environment; and
4. identify and interpret relationships between LIP development and tectonism.

Perhaps the most significant question is how much magma was erupted over what time interval? More specifically, (1) what time interval is represented by the uppermost volcanic basement of this LIP? (2) Do eruption ages vary systematically with location on the plateau? (3) Was the growth episodic or continuous? (4) Did the plateau grow by lateral accretion (i.e., similar to Iceland) or by vertical accretion and underplating? Answers to these questions, to be provisionally provided by dating the oldest sediment above basaltic basement and later more definitively by $^{40}\text{Ar}/^{39}\text{Ar}$ dating of the basalts, are required to understand the generation of voluminous magma, the physical processes of magma intrusion and extrusion, and to assess the impact of Cretaceous volcanism on the surficial environment by estimating fluxes into the ocean-atmosphere system. An aspect of oceanic plateau volcanism that has been explored in only cursory detail (e.g., Sevigny et al., 1992) is the role of hydrothermal alteration in controlling elemental and isotopic fluxes. The extent, nature, and duration of hydrothermal processes on the plateau can be determined by drilling several holes with 150-200 m basement penetration.

We expect to recover basement rocks consisting of variably altered and metamorphosed basalt. To accomplish objective 2, concerning mantle sources and magmatic processes, and objective 3, concerning environmental effects of LIP formation, we will determine

- a. Composition (major and trace elements) and isotopic ratios (Sr, Nd, and perhaps others) of unaltered phenocrysts (typically olivine, plagioclase, and clinopyroxene). Such data will provide information on parental magma composition and the role of crustal processes such as fractional crystallization, magma mixing, and assimilation.

- b. Composition (major and trace element) isotopic ratios (O, Sr, Nd, Pb, Hf, and Os) of whole rocks. Different subsets of these geochemical data will be used to understand both magmatic and post-magmatic processes and the role of geochemically distinct mantle and crustal components in these rocks.

Several lines of evidence support the interpretation that the Kerguelen plume has been a long-term source of magma for major bathymetric features in the eastern Indian Ocean. For example, the systematic south-north age progression on Ninetyeast Ridge is consistent with a hot spot track formed as the Indian plate migrated northward over the Kerguelen plume (Mahoney et al., 1983; Duncan, 1991). Also, isotopic similarities between lavas from the Ninetyeast Ridge, the younger lavas forming the Kerguelen Archipelago and Heard Island, and the older lavas forming the Kerguelen Plateau and Broken Ridge (Fig. 5B, C) indicate that the Kerguelen plume played an important role (Weis et al., 1992; Frey and Weis, 1995, 1996). The presence of a LIP, perhaps resulting from decompression of a plume head, and an associated long-lived hot-spot track present an excellent opportunity to understand a long-lived mantle plume.

Many studies of ocean island volcanoes have demonstrated that geochemically distinct sources (e.g., the plume, entrained mantle, and overlying lithosphere) contribute to plume-related volcanism. Because isotopic characteristics of plume, asthenosphere, and lithosphere sources are usually quite different, temporal geochemical variations in stratigraphic sequences of lavas can be used to determine the relative roles of plume, asthenosphere, and lithosphere sources in plume-related volcanism. Establishing how the proportion of these sources changes with time and location provides an understanding of how plumes "work" (e.g., Chen and Frey, 1985; Gautier et al., 1990; White et al., 1993; Peng and Mahoney, 1995). A continental lithosphere source component has also been recognized in some lavas from the SKP and eastern Broken Ridge (Mahoney et al., 1995). Also, wide-angle seismic data collected by ocean-bottom seismometers in the Raggatt Basin of the SKP have defined a reflective zone at the base of the crust, which has been interpreted to be stretched continental lithosphere (Operto and Charvis, 1995, 1996). The present geochemical data set shows that a continental lithosphere component is obvious in lavas at only two sites (dredge site 8 on Broken Ridge and Site 738 in the SKP [Fig. 5B, C]). There is no evidence for a continental component in lavas from the Central Kerguelen Plateau, the Ninetyeast Ridge, and the Kerguelen Archipelago (Frey et al., 1991; Yang et al., 1998). Determining the spatial and temporal role of this lithosphere component is required to evaluate whether this continental component is a piece of Gondwana lithosphere that was incorporated into the plume.

In addition to answering questions about plume-lithosphere interactions, geochemical data for plateau lavas will define the role of depleted asthenosphere in creating this plateau. A MORB-related asthenosphere is apparent in some of the Ninetyeast Ridge drill sites (e.g., as reflected by the Sr and Nd isotopic ratios of lavas from Site 756; Weis and Frey, 1991) and is an expected consequence of the plume being close to a spreading ridge axis during formation of the Ninetyeast Ridge. Relatively shallow basement holes (150-200 m) in the Kerguelen Plateau can be used to define spatial and short-term variability during the waning phase of plateau volcanism. A surprising result of the shallow penetrations of the Kerguelen Plateau is that sampling of 35-50 m of igneous basement at several plateau sites shows that lavas at each site have a suite of distinctive geochemical characteristics: each site has a distinctive combination of Sr and Nd isotopic ratios (Fig. 5B). Does this heterogeneity reflect spatial heterogeneities in a plume or localized differences in mixing proportions of components derived from asthenosphere, plume, and slivers of continental lithosphere? Interpretation requires knowledge of temporal variations in geochemical characteristics at several locations.

Leg 183 will address the environmental impact of the formation of Kerguelen and Broken Ridge. Important goals for this assessment are to (1) define the post-magmatic compositional changes resulting from interaction of magmas with the surficial environment, (2) determine the relative roles of submarine and subaerial volcanism in constructing the upper part of the plateau, and (3) estimate volatile contents of magmas from compositional studies of phenocrysts and their inclusions. The study of altered and metamorphosed basement rocks will be a major source for this information, but important information will also be provided by overlying sediments. From these data, fluxes of elements, including volatiles, particulates, and heat from Kerguelen/Broken Ridge into the atmosphere-hydrosphere-biosphere system, can be estimated and their environmental impact assessed.

To understand the relationships between LIP magmatism and tectonic events, we will study Kerguelen and Broken Ridge's seismic volcanostratigraphy i.e., seismic facies analysis linked with petrophysics and borehole data with various aspects integrated by synthetic seismic modeling. We seek to determine stratigraphic and structural relationships, both within the various Kerguelen domains and Broken Ridge and between these features and adjacent oceanic crust. Seismic volcanostratigraphic studies can reveal temporal and spatial patterns of LIP extrusion in a regional tectonic framework as well as test for synchronous or asynchronous post-emplacement tectonism of the Kerguelen Plateau, Broken Ridge, and adjacent ocean basins. Increased knowledge of the vertical and tectonic histories of the Kerguelen Plateau and Broken Ridge will provide insights into

and much-needed boundary conditions for models of mantle upwelling, crustal thinning, lithospheric thermal histories, crustal growth histories, and post-constructional subsidence and faulting.

Observations of physical volcanology (e.g., flow thicknesses and directions, morphology, vesicle distribution, presence and nature of interbeds, and subaerial vs. submarine extrusion) will provide important information on the distribution of melt conduits and fluxes. Physical volcanology provides ground truth for seismic volcanostratigraphy. We seek to understand how the uppermost crust of Kerguelen and Broken Ridge formed, to locate surficial or shallow subsurficial sources for the basalts (discrete volcanoes or feeder dikes), to document environments of basalt extrusion, and to assess effects of pre-existing bathymetry and topography on flow distribution.

DRILLING STRATEGY

LIPs are enormous igneous constructions that present considerable challenges for adequate sampling to address our first-order questions. Our knowledge of LIPs is rudimentary, similar, perhaps, to that of mid-ocean ridges before general acceptance of the plate tectonics paradigm in the late 1960s. Considerable shallow basement drilling and significant geophysical surveying are necessary to begin to address issues of Cretaceous mantle dynamics and environmental consequences. Understanding the complete temporal and compositional history of the Kerguelen Plateau and Broken Ridge will require several approaches, including (1) transects of shallow (~200 m) basement holes across the surface of the LIP; (2) offset drilling in tectonic windows that expose deeper levels of the LIP that are otherwise inaccessible; (3) intermediate (1000-2000 m) and deep (>2000 m) basement holes at carefully chosen locations; and (4) reference holes on older adjacent oceanic crust. Leg 183 utilizes approach 1 and should complete the fundamental and necessary reconnaissance phase of Kerguelen sampling, which has included Legs 119 and 120. To obtain a comprehensive database of eruption ages and lava compositions for the entire LIP, Leg 183 will sample igneous basement to depths of ≥ 150 -200 m using single rotary core barrel (RCB) holes at as many morphologically and tectonically distinct regions of the Kerguelen Plateau/Broken Ridge LIP as possible on one leg (Tables 1, 2; Figs. 2, 3, 4). In addition, the sedimentary section immediately overlying the basement will provide estimates of minimum ages for extrusive basement, important information regarding eruption and weathering in a subaerial vs. submarine environment, and possibly evidence for tectonic events in the plateau's history.

Leg 183 is scheduled to start and finish in Fremantle, Australia. Transit time from Fremantle to the first site on the southern Kerguelen Plateau, KIP-13B, is projected at 8.1 days (Table 1). KIP-13B is the only Leg 183 site located where icebergs may present an operational hazard; completing our drilling objectives at the site may or may not be possible depending on ice conditions. Drilling (RCB) and logging time at the site is estimated at 7.7 days. Transit from KIP-13B to the next site, KIP-6C on Elan Bank, will require 2.2 days; drilling (RCB) and logging time at KIP-6C is expected to be 4.7 days. KIP-7B on the central Kerguelen Plateau is a 1.1-day transit from KIP-6C; drilling (RCB) and logging time is estimated at 7.5 days. Transit to the next site, KIP-3F on the central Kerguelen Plateau, will take 0.8 days. RCB drilling and logging time at KIP-3F is estimated at 5.0 days. KIP-2E, on the northernmost Kerguelen Plateau, is a 1.3-day transit from KIP-3F; drilling (RCB) and logging time is estimated at 6.7 days. Transit time to the final primary site, KIP-9B on Broken Ridge, is projected at 6.3 days, and 4.8 days have been estimated to drill and log the site. Fremantle is a 3.8-day transit from KIP-9B.

PROPOSED SITES

Five of the primary proposed sites are located on the Kerguelen Plateau and one is on Broken Ridge (Tables 1, 2; Figs. 2, 3, 4). Site surveys for all of the primary sites on the Kerguelen Plateau were undertaken by Australia (Australian Geological Survey Organisation) in 1997 and by France (École et Observatoire des Sciences de la Terre, Université Louis Pasteur, Strasbourg) in 1998. The high-quality multichannel seismic data acquired during the site surveys have been critical to candidate site selection. On behalf of the entire Leg 183 shipboard scientific party, the designated co-chief scientists wish to acknowledge and commend France and Australia for their allocation of significant resources in support of ODP objectives on the Kerguelen Plateau.

The Pollution Prevention and Safety Panel (PPSP) has approved six primary sites (KIP-2E, KIP-3F, KIP-6C, KIP-7B, KIP-9B, and KIP-13B) and alternates for each (KIP-2C, KIP-3C, KIP-6D, KIP-7C, KIP-9C, and KIP-13A). PPSP has also approved three secondary sites (KIP-1D, KIP-10C, and KIP-14C) and alternates (KIP-1E and KIP-10D). In case drilling objectives at the six primary sites are met ahead of schedule, or conditions do not permit reaching our objectives at the primary sites and their alternates, the highest priority secondary site, KIP-1D, will be targeted.

Primary Sites (Alternate Sites)

KIP-2E (KIP-2C)

Igneous basement of the NKP has never been sampled apart from the Kerguelen Isles. A site north of the Kerguelen Archipelago is required to establish the age, composition, and construction environment of the NKP (presumed to be Cenozoic in age), as well as to document tectonic events and to test plate reconstructions.

KIP-3F (KIP-3C)

Several distinct, roughly circular bathymetric and gravity highs form a linear trend between the Kerguelen Archipelago on the NKP and the active Heard and McDonald Islands on the CKP (Figs. 2, 4). This site was selected because it is on one of several aligned gravity highs that may reflect a hot-spot track between Heard/McDonald and Kerguelen Islands. Drilling is necessary to determine the age, composition, and extrusion environment of one of the presumed volcanoes.

KIP-6C (KIP-6D)

This site is on Elan Bank, which is a prominent east-west-oriented bathymetric and gravity high west of the CKP (Figs. 2, 4). This major morphotectonic component of the Kerguelen Plateau province is unsampled; drilling at this site will constrain its age, composition, construction environment, and tectonic history.

KIP-7B (KIP-7C)

This site in the CKP is ~100 km north of ODP Site 747. The radioisotopic age of basalts at Site 747 is ~85 Ma, which represents the only sampled basement of Late Cretaceous age found on the Kerguelen Plateau. Drilling at Site KIP-7B will evaluate the areal extent of Late Cretaceous crust, its composition, and extrusion environment. In addition, the sedimentary section will help constrain the post-constructional tectonic history.

KIP-13B (KIP-13A)

This site on the Southern Kerguelen Plateau is located on a bathymetric and gravity high (Figs. 2, 4). The location was selected to evaluate the areal extent of continental crustal contamination north of Site 738 (Figs. 2, 5), as well as the age and formation environment of this part of the plateau. Several hundred meters of sediment will help to constrain the tectonic history.

KIP-9B (KIP-9C)

This site on the Eastern Broken Ridge will provide the first in situ basement samples from the entire Broken Ridge (Fig. 3). It is located near Dredge 8, whose lavas are similar in age (88 Ma) to lavas from Site 747. Unlike lavas from the central part of the Kerguelen plateau, dredge site 8 lavas contain a continental lithosphere component (Fig. 5). This site will define the spatial extent of this component as well as the age, extrusion environment, and tectonic history of this part of Broken Ridge.

Primary Secondary Site (Alternate)

KIP-1D (KIP-1E)

This site is on Leclaire Rise (aka Skiff Bank), which has been proposed as the current site of the Kerguelen hot spot but has never been sampled. A site here is required to establish the age, composition, and construction environment of Skiff Bank as well as to test plate reconstructions and ideas of hot-spot fixity.

Ancillary Secondary Sites (Alternates)

KIP-10C (KIP-10D)

This site lies in the Enderby Basin, presumed oceanic crust southwest of Kerguelen that has never been sampled. This reference site will establish the age and composition of the Enderby Basin, and may record the history of Kerguelen plume activity in its sediment. The site will help to constrain plate tectonic reconstructions.

KIP-14C

This site is in the Labuan Basin, a deep-water portion of the Kerguelen Plateau province that has yielded dredges of metamorphic and granitic rock but has never been drilled. This site will establish the age and composition of the Labuan Basin and may contain a sedimentary record of Kerguelen plume activity. The site will also help to constrain plate tectonic models.

SAMPLING STRATEGY

Shipboard Samples and Data Acquisition

Following core labeling, measurement of nondestructive properties, and core splitting, samples will be selected from core working halves (~1 to 2 samples per 9.5 m of core) by members of the shipboard party for routine measurement of physical and magnetic properties, bulk chemical analyses by X-ray fluorescence, carbon-nitrogen-sulfur (CNS) analyzer, and X-ray diffraction, as necessary. Polished thin sections of these samples will be prepared for identification of minerals, determination of mineral modes by point counting, and studies of texture and fabric.

Sampling for Shore-Based Studies

Shipboard scientists may usually expect to obtain ~100 samples up to 15 cm³ in size. In special cases, additional or larger samples may be obtained with the approval of the Sample Allocation Committee (SAC), which is composed of the co-chiefs, the staff scientist, the shipboard curatorial representative, and the ODP curator. Additional samples may be obtained upon written request onshore soon after the cores return to the ODP repository. Short intervals of unusual scientific interest (e.g., veins, ores, and dikes) may require a higher sampling density, reduced sample size, continuous core sampling by a single investigator, or sampling techniques not available on board ship. These will be identified during the core description process, and the sampling protocol will be established by the interested scientists and shipboard SAC.

To minimize the time and effort required for sampling for shore-based studies, we encourage sampling consortia involving researchers with complementary expertise. Sample size will depend on the number of investigators in the group.

Redundancy of Studies

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

LOGGING PLAN

Downhole tools deployed during Leg 183 will enable accurate mapping of the volcanostratigraphy, volcanic facies variations, and structural features, as well as interpretation of tectonic stresses and correlation between core data and regional seismic reflection profiles. The downhole measurement tools planned for use at all sites during Leg 183 include the full set of Schlumberger logging tools: the triple combo with natural gamma-ray sonde (NGS); porosity (accelerator porosity sonde [APS]), density (hostile environment lithodensity sonde [HLDS]), resistivity (dual induction tool [DIT-E]), caliper and temperature (Lamont temperature tool [TLT]) probes; the Formation MicroScanner (FMS)/sonic (dipole shear sonic imager [DSI]) combination; and the Dual LateroLog (DLL)/NGS combination. Pending funding, the well seismic tool (WST) will be run at all sites.

The geophysical tool string (triple-combo) provides measurements of the porosity-dependent density, porosity, velocity, and resistivity logs, in addition to variations in natural gamma radiation. These logs are useful for determining petrophysical and lithologic variations in both volcanic and sedimentary intervals (e.g., Broglia and Moos, 1988; Planke, 1994).

The FMS provides a detailed resistivity image of the borehole wall. It has previously been used successfully in a volcanic setting on Leg 152 (Cambray, 1998; Planke and Cambray, 1998). The log provides a detailed volcano stratigraphy and is particularly useful to image altered, fractured, and highly vesiculated zones that may be poorly sampled during coring. It also has the potential to provide important structural and stress field information and can be used for core-log integration.

Seismic reflection data are essential to extrapolate the drilling results away from and between the drill sites. The dipole shear sonic imager (DSI) will produce a full set of waveforms (P -, S -, and Stoneley-waves). Synthetic seismograms constructed from the compressional velocity and density logs provide a link between the core and the reflection data. For accurate time-depth conversions, synthetic seismograms require calibration with downhole seismic data. These calibration data will be obtained by the check-shot survey (WST). The shear-wave velocity provides information in both the relatively slow lava flow margins and relatively fast flow interiors. Such data are important as inputs for modeling seismic wave-propagation in volcanic sequences.

Approximate time estimates for logging operations (hole conditioning not included) during Leg 183 are 148.8 hr (6.2 days), including use of the WST.

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FIGURE CAPTIONS

Figure 1. Map of the eastern Indian Ocean showing major physiographic features. Large black dots = DSDP and ODP drill sites, from which igneous basement was obtained on the Ninetyeast Ridge and Kerguelen Plateau; small black dots = dredge sites. Igneous basement was not obtained at ODP Sites 748 (gray shaded circle) and 752 (open circle).

Figure 2. Bathymetry of the Kerguelen Plateau (Fisher et al., pers. comm., 1996). Filled stars = previous ODP drill sites that recovered igneous basement; open stars = sites that bottomed in sediment. Closed circles = primary proposed drill sites (KIP) for Leg 183; open circles = alternate proposed drill sites. Seismic lines used to select the sites = black lines with cruise identifiers (GA = *Gallieni*; MD = *Marion Dufresne*; RS = rig seismic). Contour interval is 500 m.

Figure 3. Bathymetry of Broken Ridge (GEBCO, 1984). Filled stars = previous DSDP and ODP drill sites that recovered igneous basement; open stars = sites that bottomed in sediment. Black squares = dredge locations (DR-X) that recovered igneous basement. Open and closed circles = proposed drill sites (KIP-9B and 9C) for Leg 183 as in Figure 2. The seismic line used to select these sites = a black line with cruise identifier (C = *Robert Conrad*). Contour interval is 500 m.

Figure 4. Satellite-derived gravity field for the Kerguelen Plateau (Sandwell and Smith, 1997) showing important morphotectonic components of the plateau, location of previous ODP drill sites (black stars = sites where igneous basement was recovered), locations of the MD dredge sites (black squares) that recovered basaltic basement, and the proposed drill sites (KIP) for Leg 183. Bathymetric contours (1000 m interval) are from Fisher (pers. comm., 1996). To examine the color version, see Technical Note 20/6 on the ODP web page (<http://www-odp.tamu.edu/publications/TECHREP.HTML>).

Figure 5. A. Total alkalis vs. SiO₂ plot (wt% with FeO adjusted to 85% of total iron) for classifying tholeiitic and alkalic basalts. Lavas from Kerguelen Plateau ODP Sites 747, 749, and 750 are tholeiitic basalts. Lavas from ODP Site 748 are alkalic basalts that were recovered 200 m above basement. The lavas dredged from the central Kerguelen Plateau (open circles) and ODP Site 738 straddle the boundary line, largely because the alkali contents of these lavas were increased during postmagmatic alteration. As an extreme example, the solid triangle = a highly altered sample (Hole 750B-19R-1, 47-50 cm) from ODP Site 750. Lavas from Dredges 9 and 10 on Broken Ridge are also tholeiitic, whereas lavas from Dredge 8 overlap with the field for Site

738. Data from Davies et al. (1989), Storey et al. (1992), and Mahoney et al. (1995). **B.** $^{143}\text{Nd}/^{144}\text{Nd}$ vs. $^{87}\text{Sr}/^{86}\text{Sr}$ showing data points for basalts recovered from the Kerguelen Plateau and Broken Ridge. The Broken Ridge samples are measured data corrected to an eruption age of 88 Ma, the dredged Kerguelen Plateau samples are measured data corrected to an eruption age of 115 Ma. The effects of age correction are shown by the two fields (measured and age corrected) for Site 738 on the southern Kerguelen Plateau. Data for other ODP sites are not age corrected because parent/daughter abundance ratios are not available. Data for Kerguelen Plateau and Broken Ridge samples are from Weis et al. (1989), Salters et al. (1992), and Mahoney et al. (1995). Shown for comparison are fields for SEIR MORB, St. Paul and Heard Islands (Heard data = trajectory of solid line from Barling et al., 1994), and Ninetyeast Ridge (gray-shaded fields labeled NER and NER 216), the entire Kerguelen Archipelago with subfields indicated for the youngest archipelago lavas (Mt. Ross and Southeast UMS), which Weis et al. (1993, 1997) interpret as representative of the Kerguelen Plume. **C.** $^{208}\text{Pb}/^{204}\text{Pb}$ vs. $^{206}\text{Pb}/^{204}\text{Pb}$ showing measured data points for basalts recovered from the Kerguelen Plateau and Broken Ridge. Shown for comparison are measured fields for SEIR MORB, and lavas from St. Paul and Amsterdam Islands, and initial ratios for lavas from the Kerguelen Archipelago and the Ninetyeast Ridge. The proposed field (Weis et al., 1993) for the plume is labeled "Southeast UMS." Data sources are as in Figure 5B.

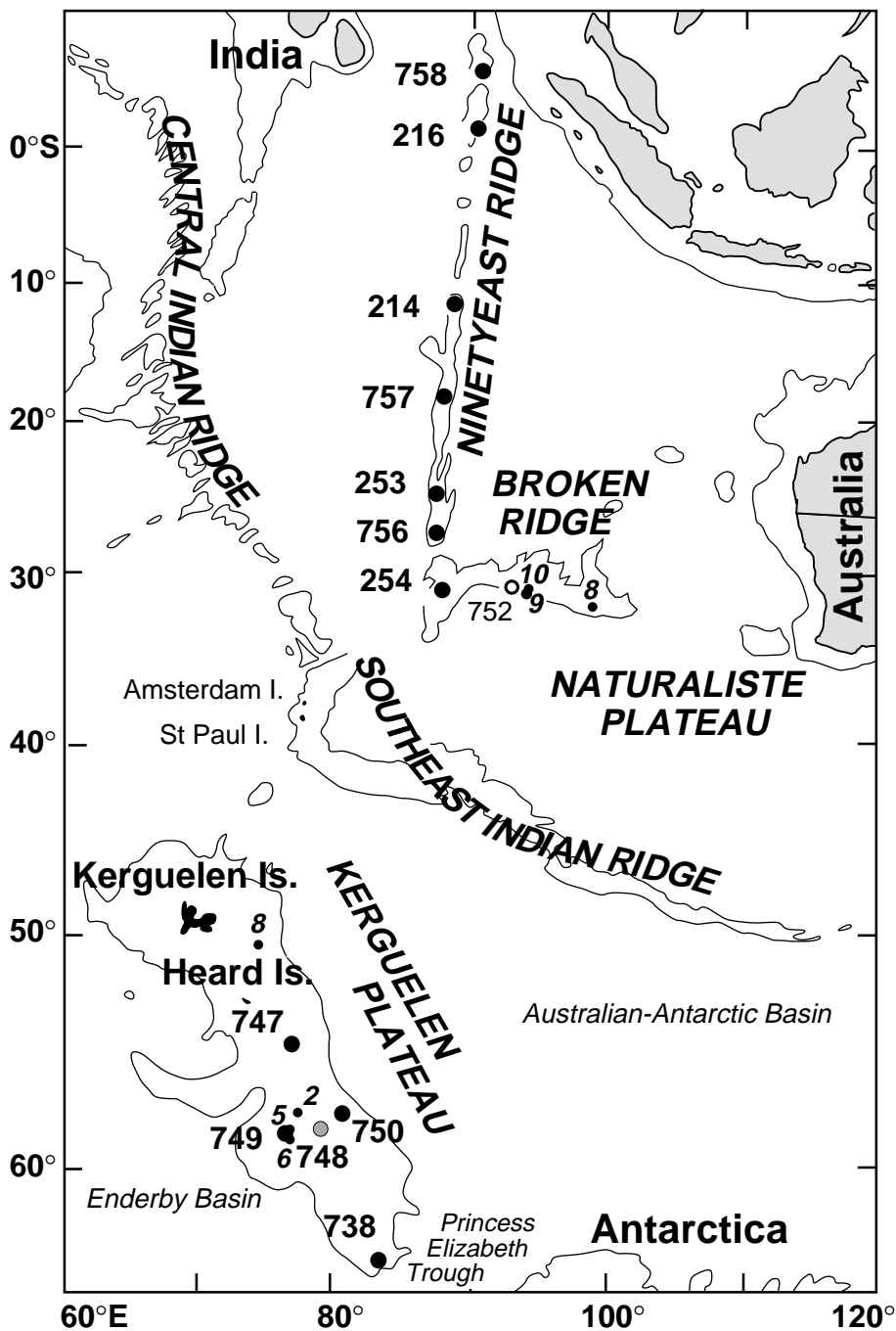


Figure 1

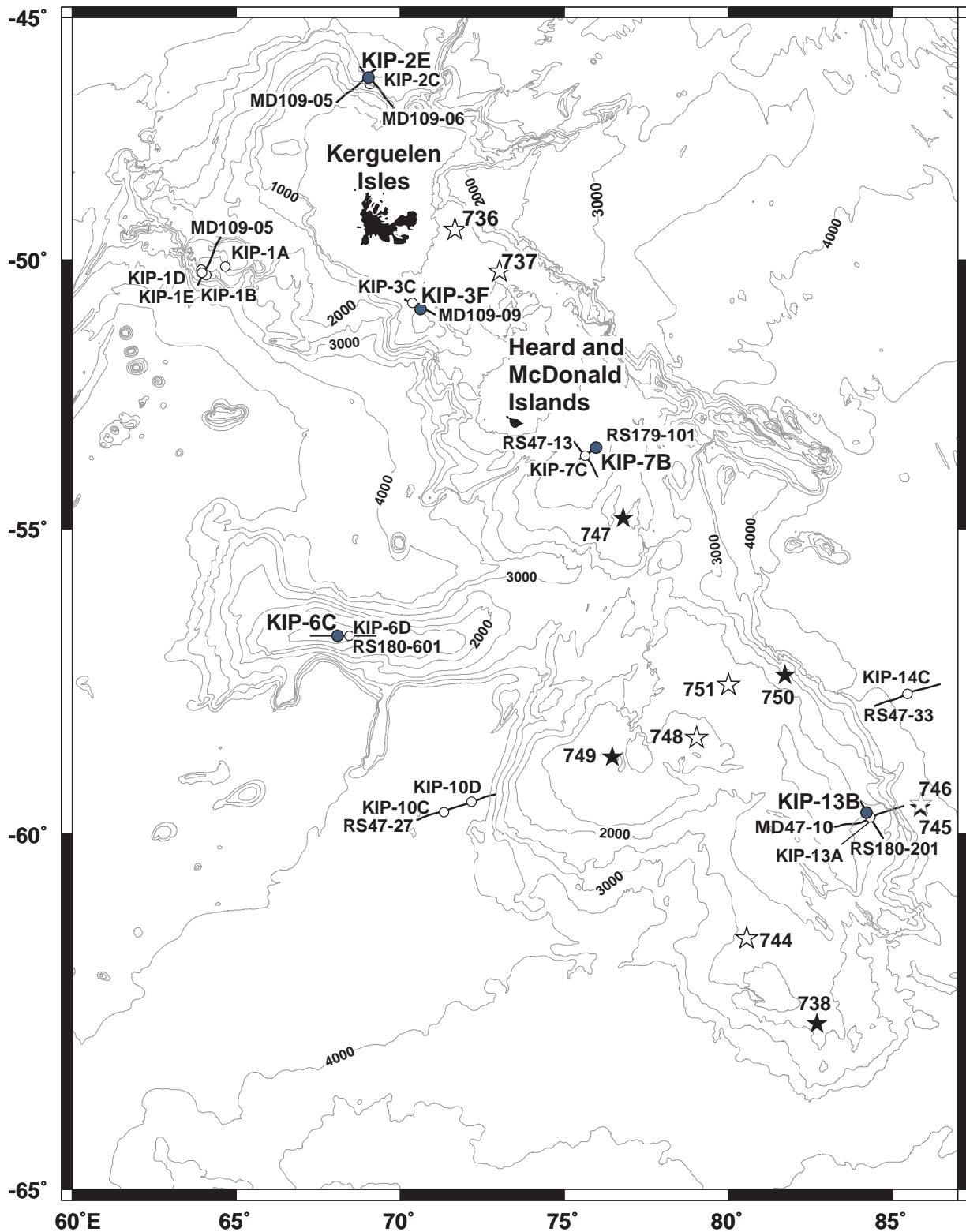
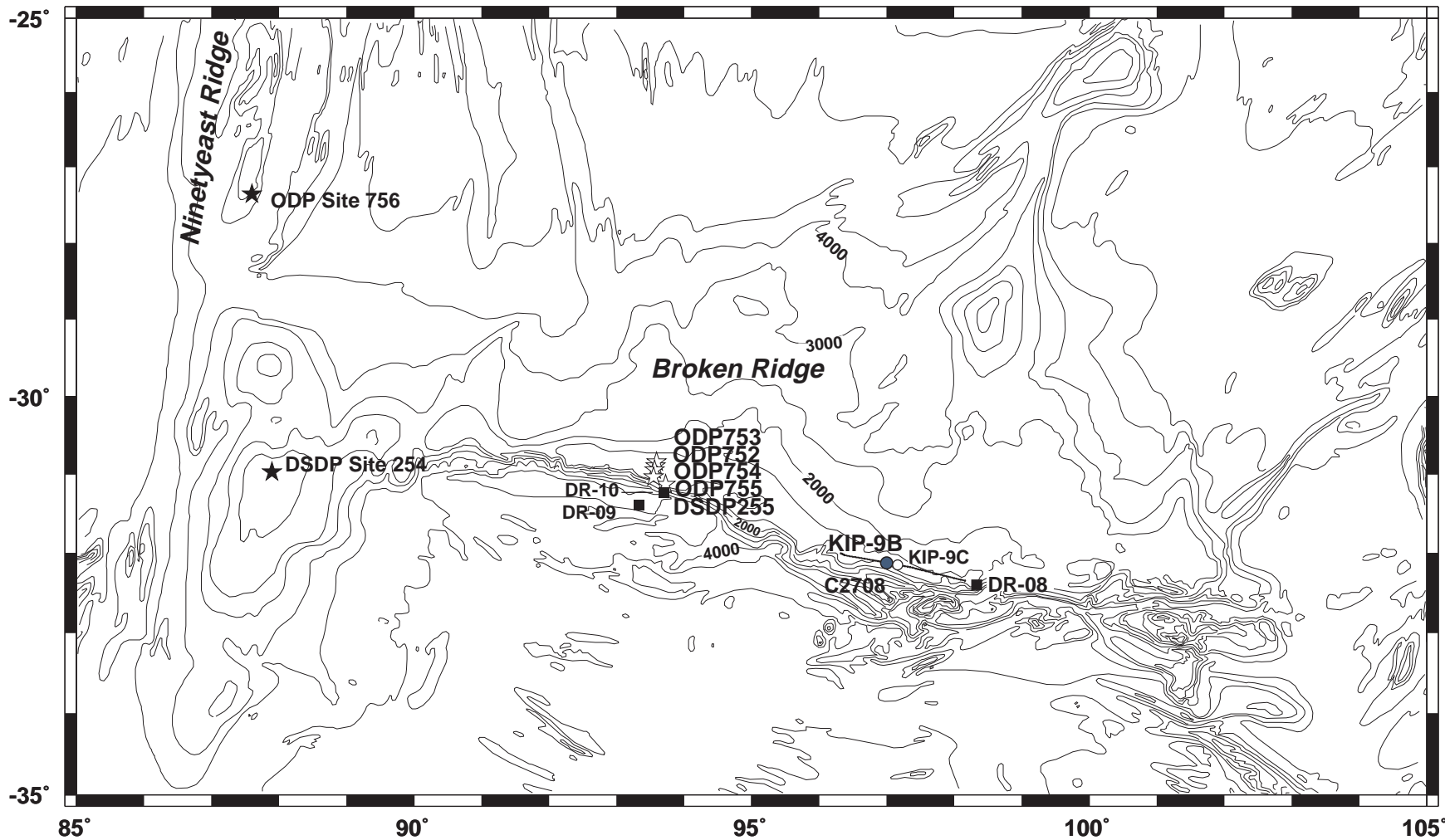


Figure 2



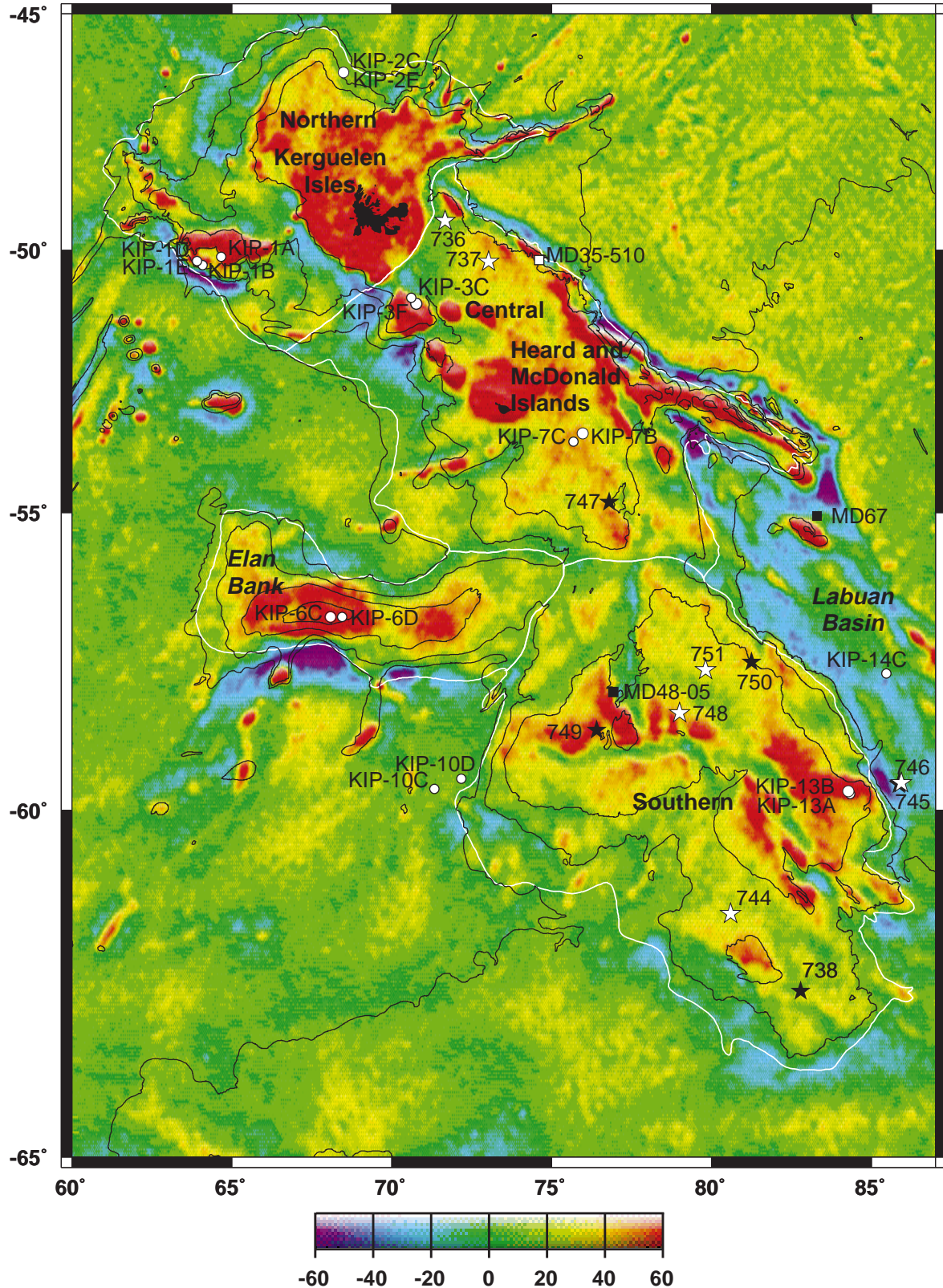


Figure 4

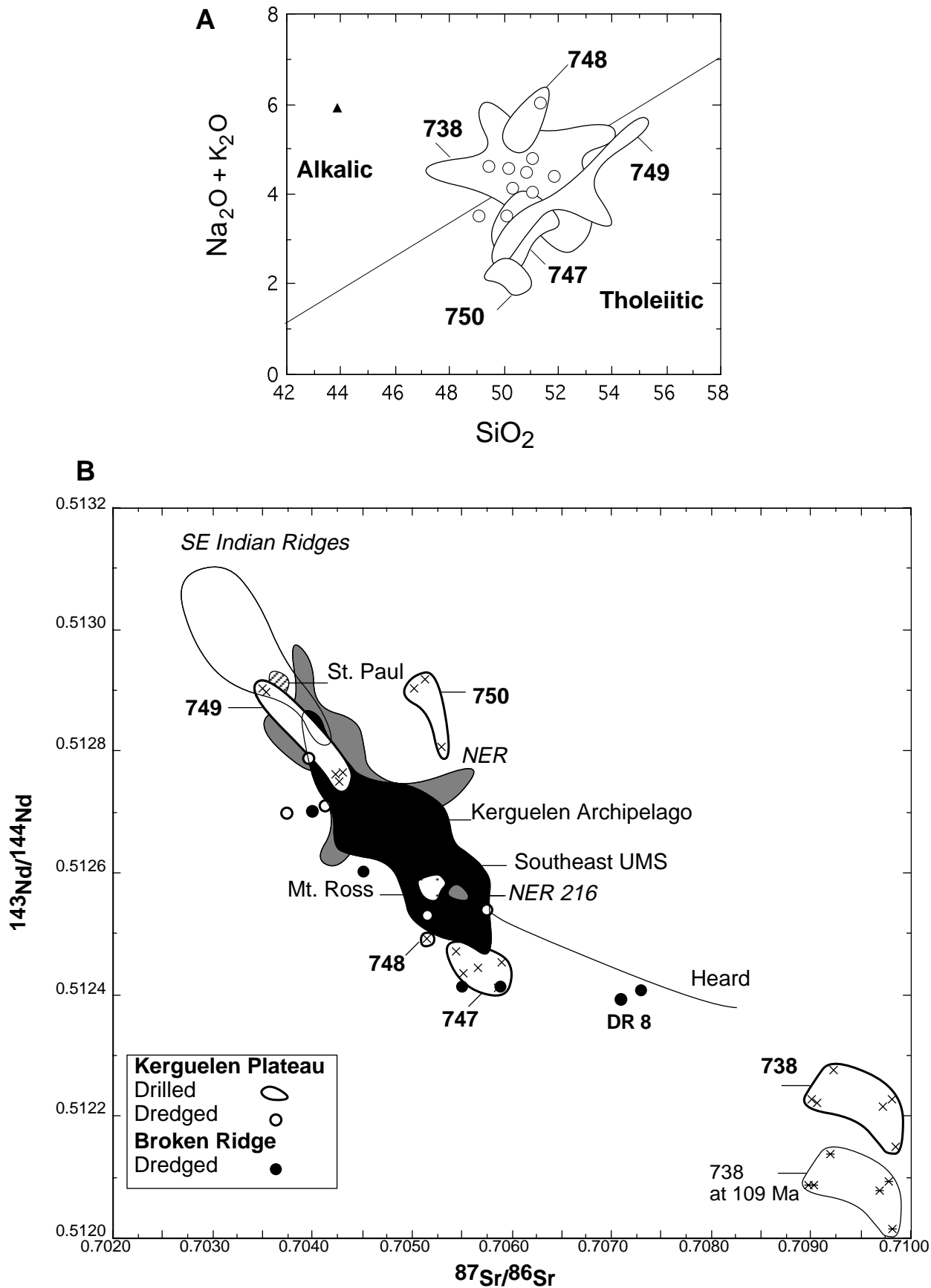


Figure 5 (continued on next page)

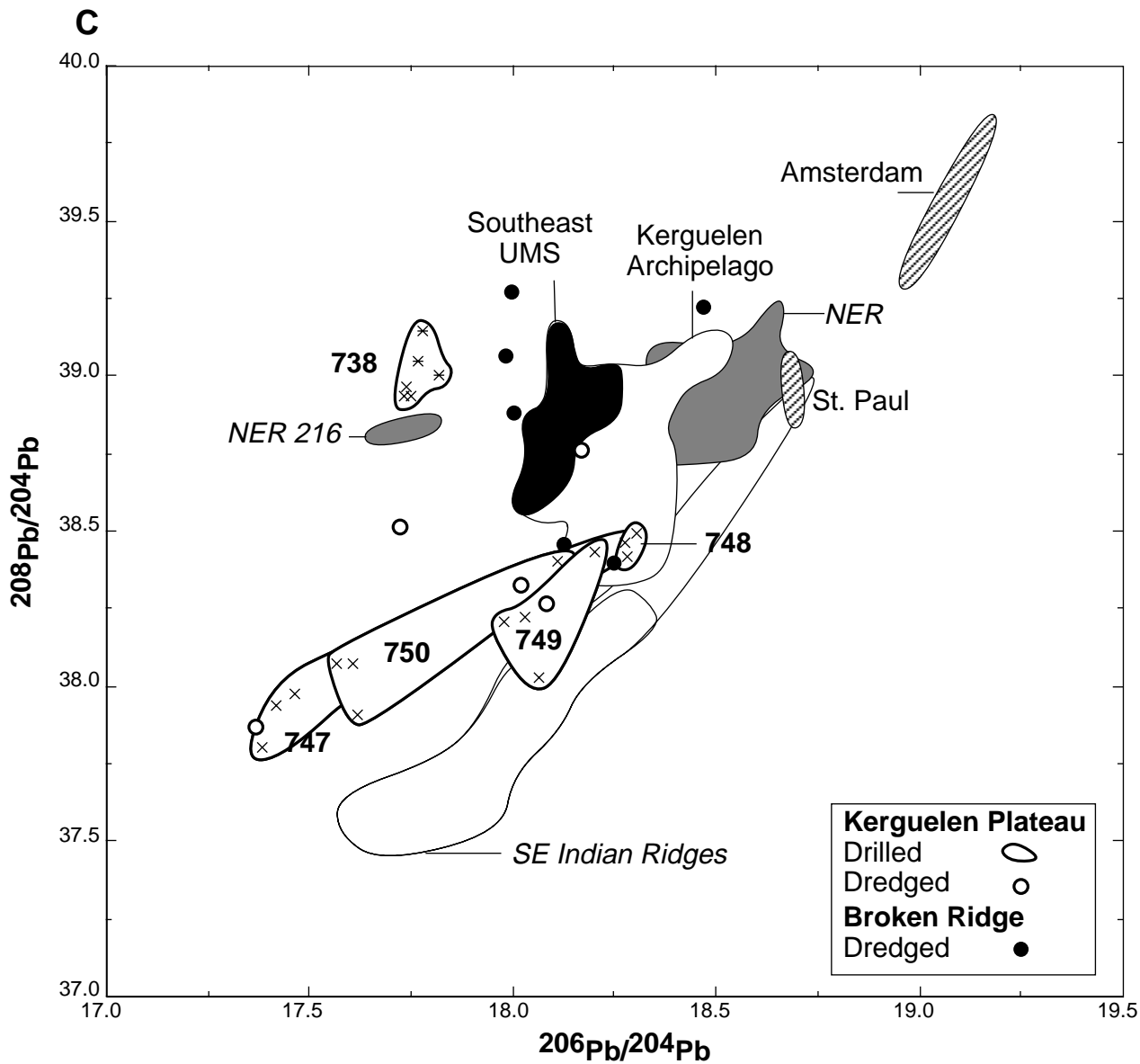


Figure 5 (continued)

Table 1: Primary Site Time Estimates

Site No.	Location Lat/Long	Water Depth	Operations Description	PPSP Depth	Transit	Drilling	Logging	Total
					(days)	(days)	(days)	On-site
Fremantle	32.07°S		Transit 2031 nmi from Fremantle to KIP-13B @ 10.5 kt		8.1			
	115.44°E							
KIP-13B	59°42.0'S	1600m	RCB coring 595m sediment + 160m basement = 755 mbsf TD	995mbsf		6.5	1.2	7.7
	84°16.4'E		Wireline Logs: Triple combo, FMS/DSI, DLL, WST					
			Note: Estimated bit rotating hours = 70.6					
			Transit 552 nmi from KIP-13B to KIP-6C @ 10.5 kt		2.2			
KIP-6C	56°50.0'S	1027m	RCB coring 215m sediment + 160m basement = 375 mbsf TD	615mbsf		3.8	0.9	4.7
	68°05.6'E		Wireline Logs: Triple combo, FMS/DSI, DLL, WST					
			Note: Estimated bit rotating hours = 54.7					
			Transit 271 nmi from KIP-6C to KIP-7B @ 10.5 kt		1.1			
KIP-7B	53°33.1'S	1168m	RCB coring 685m sediment + 160m basement = 845 mbsf TD	1085mbsf		6.3	1.2	7.5
	75°58.5'E		Wireline Logs: Triple combo, FMS/DSI, DLL, WST					
			Note: Estimated bit rotating hours = 76.3					
			Transit 200 nmi from KIP-7B to KIP-3F @ 10.5 kt		0.8			
KIP-3F	51°04.0'S	740m	RCB coring 350m sediment + 160m basement = 510m TD	750 mbsf		4.1	0.9	5.0
	70°46.2'E		Wireline Logs: Triple combo, FMS/DSI, DLL, WST					
			Note: Estimated bit rotating hours = 56.5					
			Transit 320 nmi from KIP-3F to KIP-2E @ 10.5 kt		1.3			
KIP-2E	46°16.6'S	2450m	RCB coring 350m sediment + 160m basement = 510 mbsf TD	750 mbsf		5.6	1.1	6.7
	68°29.5'E		Wireline Logs: Triple combo, FMS/DSI, DLL, WST					
			Note: Estimated bit rotating hours = 56.5					
			Transit 1596 nmi from KIP-2E to KIP-9B @ 10.5 kt		6.3			
KIP-9B	32°07.3'S	1240m	RCB coring 160m sediment + 160m basement = 320 mbsf TD	560mbsf		3.9	0.9	4.8
	97°00.4'E		Wireline Logs: Triple combo, FMS/DSI, DLL, WST					
			Note: Estimated bit rotating hours = 53.0					
Fremantle	32.07°S		Transit 938 nmi from KIP-9B to Fremantle @ 10.5 kt		3.8			
	115.44°E							
Note 1: This leg has been scheduled for 60 days at sea.					23.6	30.2	6.2	36.4
					TOTAL DAYS:		60.0	¹

Table 2: Alternate Site Time Estimates

Site No.	Location Lat/Long	Water Depth	Operations Description	PPSP Depth	Priority	Drilling	Logging	Total
					Alt. For	(days)	(days)	On-site
KIP-1D	50°11.1'S 63°56.2'E	1460m	RCB coring 480m sediment + 160m basement = 640 mbsf TD Wireline Logs: Triple combo, FMS/DSI, DLL, WST	880mbsf	1 n/a	5.3	1.1	6.4
KIP-13A	59°44.9'S 84°19.9'E	1646m	RCB coring 540m sediment + 160m basement = 700 mbsf TD Wireline Logs: Triple combo, FMS/DSI, DLL, WST	940mbsf	2 13B	6.2	1.2	7.4
KIP-6D	56°50.0'S 68°26.8'E	1162m	RCB coring 450m sediment + 160m basement = 610 mbsf TD Wireline Logs: Triple combo, FMS/DSI, DLL, WST	850mbsf	2 6C	5.0	1.1	6.1
KIP-7C	53°41.6'S 75°38.0'E	1109m	RCB coring 700m sediment + 160m basement = 860 mbsf TD Wireline Logs: Triple combo, FMS/DSI, DLL, WST	1100mbsf	2 7B	6.3	1.2	7.5
KIP-3C	50°57.3'S 70°37.2'E	840m	RCB coring 460m sediment + 160m basement = 620 mbsf TD Wireline Logs: Triple combo, FMS/DSI, DLL, WST	860 mbsf	2 3F	4.6	0.7	5.3
KIP-2C	46°17.0'S 68°30.0'E	2450m	RCB coring 370m sediment + 160m basement = 530 mbsf TD Wireline Logs: Triple combo, FMS/DSI, DLL, WST	770mbsf	2 2E	5.7	0.9	6.6
KIP-9C	32°08.8'S 97°09.9'E	1215m	RCB coring 160m sediment + 160m basement = 320 mbsf TD Wireline Logs: Triple combo, FMS/DSI, DLL, WST	560mbsf	2 9B	3.9	0.9	4.8
KIP-1A	50°08'S 64°40.0'E	1050m	RCB coring 400m sediment + 160m basement = 560 mbsf TD Wireline Logs: Triple combo, FMS/DSI, DLL, WST	800mbsf	3 n/a	4.6	0.7	5.3
KIP-1B	50°18'S 64°05.0'E	2000m	RCB coring 360m sediment + 160m basement = 520 mbsf TD Wireline Logs: Triple combo, FMS/DSI, DLL, WST	760mbsf	3 1A	5.5	0.8	6.3
KIP-1E	50°13.0'S 63°54.5'E	1550m	RCB coring 420m sediment + 160m basement = 580 mbsf TD Wireline Logs: Triple combo, FMS/DSI, DLL, WST	820mbsf	3 1D	5.3	1.1	6.4
KIP-10C	59°38.3'E 71°26.3'E	4300m	RCB coring 780m sediment + 160m basement = 940 mbsf TD Wireline Logs: Triple combo, FMS/DSI, DLL, WST	1180mbsf	3 n/a	11.5	2.4	13.9
KIP-10D	59°31.9'S 72°06.7'E	4300m	RCB coring 700m sediment + 160m basement = 860 mbsf TD Wireline Logs: Triple combo, FMS/DSI, DLL, WST	1100mbsf	3 10C	10.8	2.2	13.0
KIP-14C	57°47.5'S 85°28.2'E	4600m	RCB coring 485m sediment + 160m basement = 645 mbsf TD Wireline Logs: Triple combo, FMS/DSI, DLL, WST	885mbsf	3 n/a	11.7	2.5	14.2
Note 1: Time estimates are preliminary only and will require later refinement if drilled.								

PRIMARY SITE SUMMARIES

Site: KIP-2E

Priority: 1

Position: 46°16.6'S, 68°29.5'E

Water Depth: 2450 m

Sediment Thickness: 350 m

Target Drilling Depth: 550 mbsf

Approved Maximum Penetration: 750 mbsf

Seismic Coverage: 1998 multichannel seismic line *Marion Dufresne* 109-06

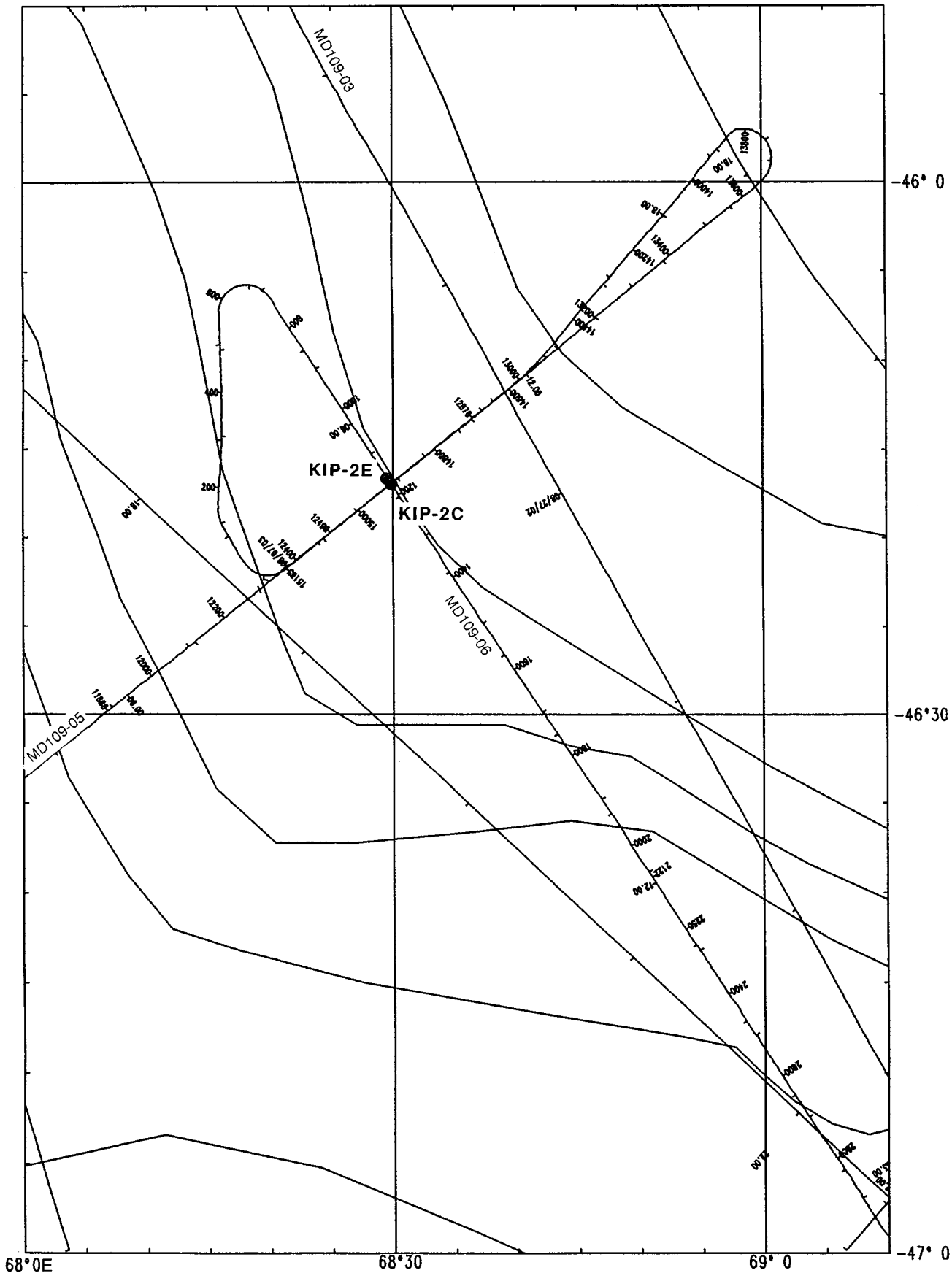
Objectives: The objectives of KIP-2E are to

1. obtain 200 m of igneous basement to characterize petrography and lava compositions,
2. determine basalt flow thicknesses,
3. obtain sedimentary record and determine sequence facies,
4. determine a minimum basement age using overlying sediment and possible sediment interbeds,
5. define the ages of seismic sequence boundaries, and
6. estimate duration of possible subaerial and shallow-water environments.

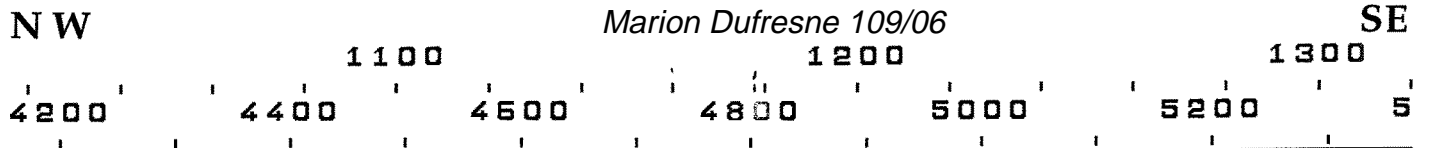
Drilling Program: RCB

Logging and Downhole Operations: Triple combo, FMS/DSI, WST, DLL/NGT

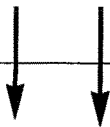
Nature of Rock Anticipated: Calcareous and siliceous ooze, chalk, basalt



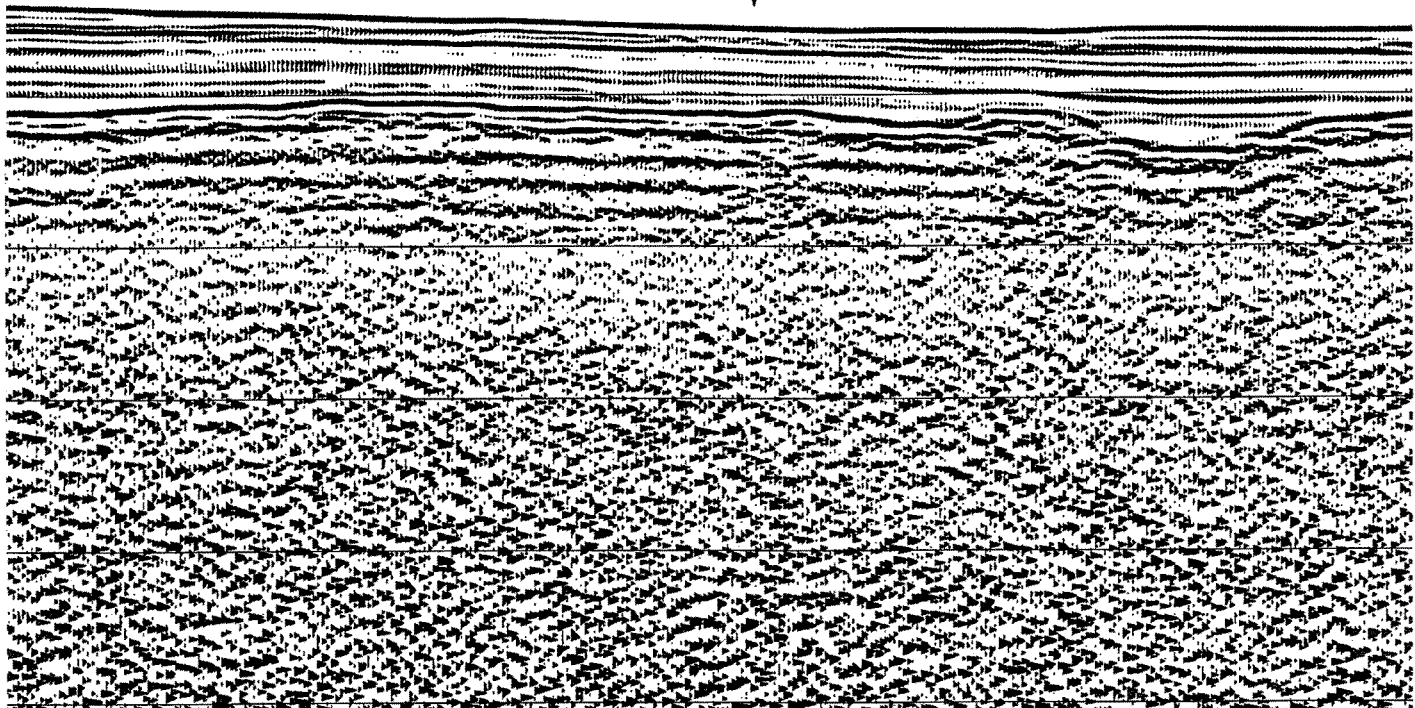
Track Line for KIP-2E



KIP-2E KIP-2C



3



Two-way traveltime (s)

4

5



5 km

Marion Dufresne 109/06

Seismic for KIP-2E

Site: KIP-3F

Priority: 1

Position: 51°04.0'S, 70°46.2'E

Water Depth: 740 m

Sediment Thickness: 350 m

Target Drilling Depth: 550 mbsf

Approved Maximum Penetration: 750 mbsf

Seismic Coverage: 1998 multichannel seismic line *Marion Dufresne* 109-09

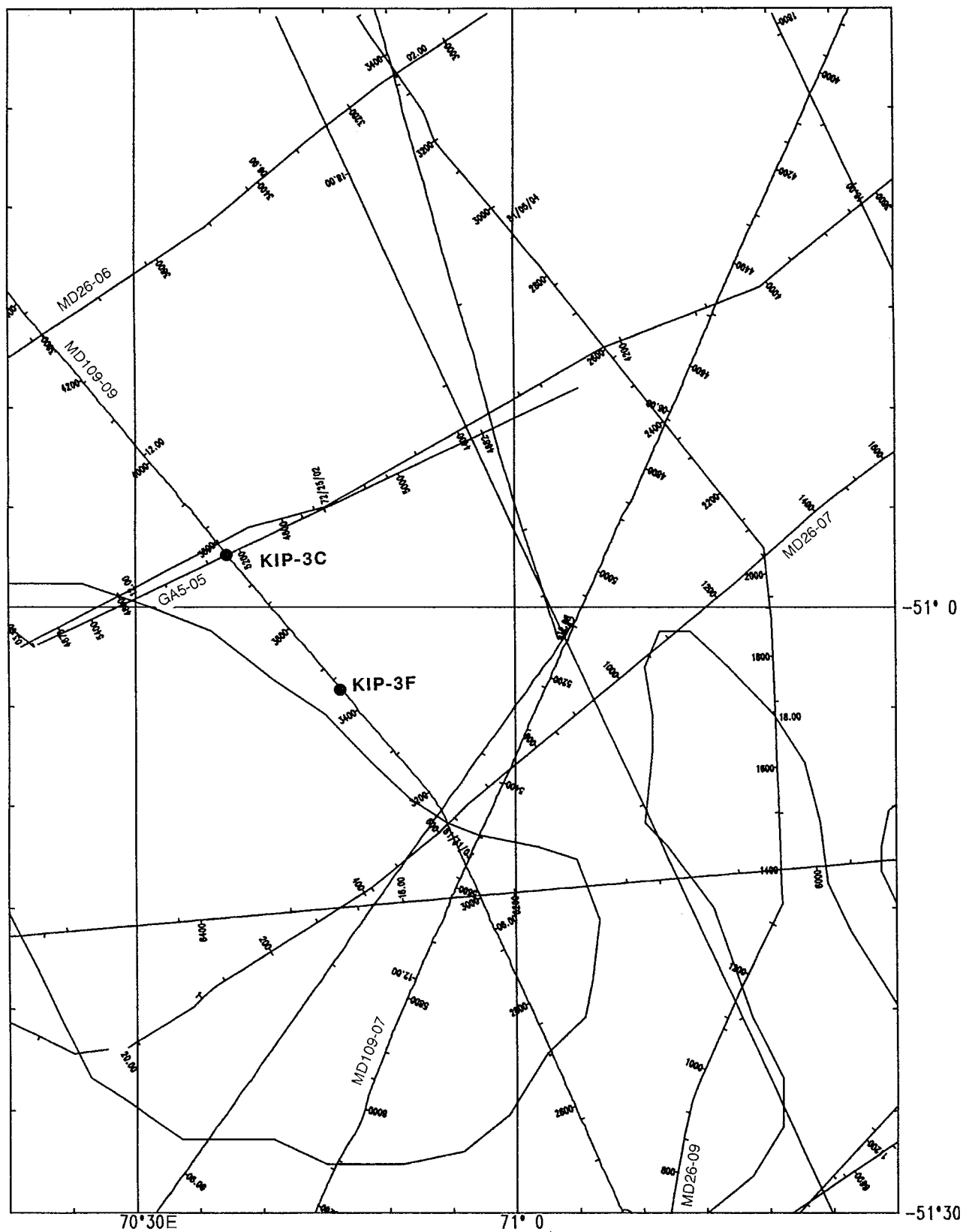
Objectives: The objectives of KIP-3F are to

1. obtain 200 m of igneous basement to characterize petrography and lava compositions,
2. determine basalt flow thicknesses,
3. obtain sedimentary record and determine sequence facies,
4. determine a minimum basement age using overlying sediment and possible sediment interbeds,
5. define the ages of seismic sequence boundaries, and
6. estimate duration of possible subaerial and shallow-water environments.

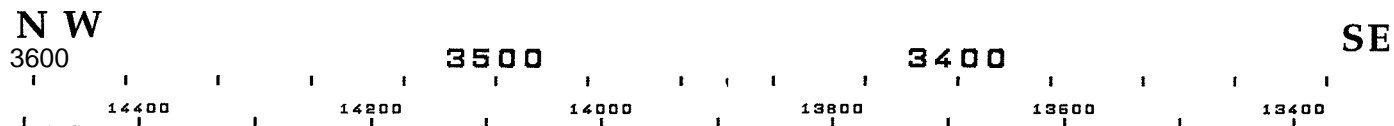
Drilling Program: RCB

Logging and Downhole Operations: Triple combo, FMS/DSI, WST, DLL/NGT

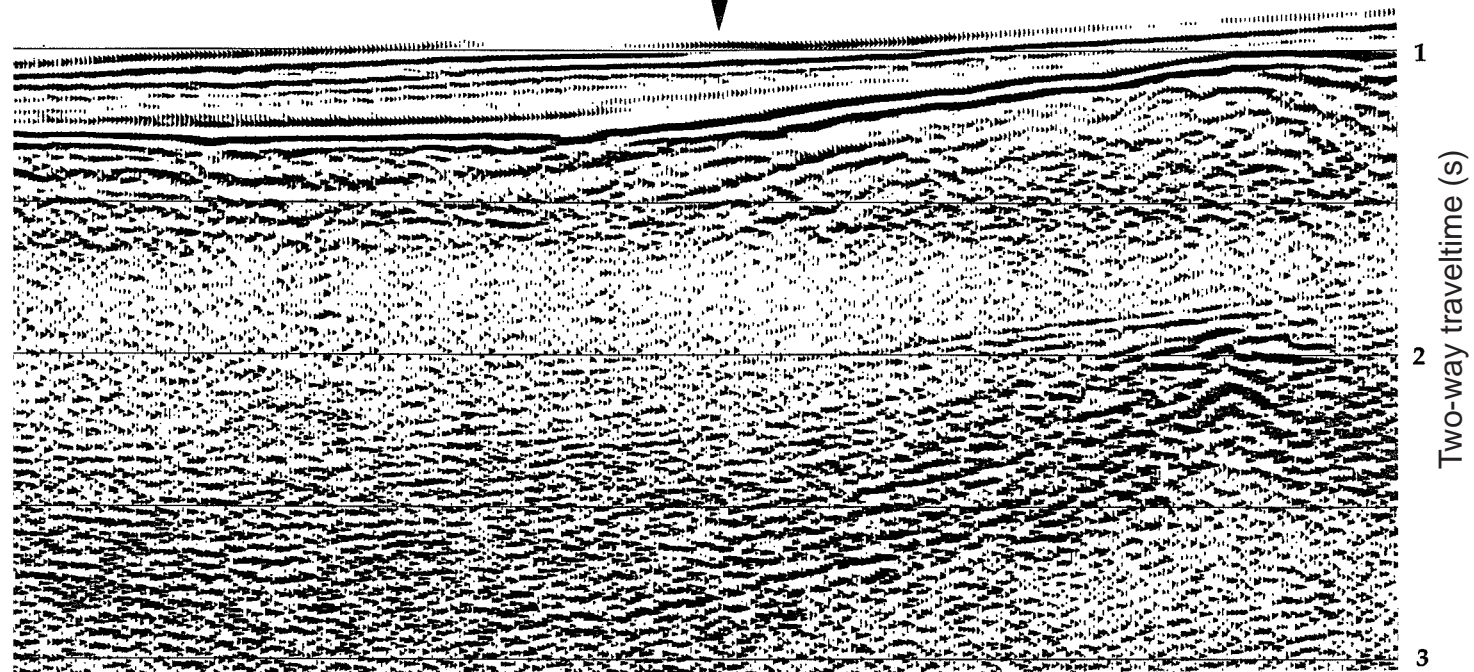
Nature of Rock Anticipated: Calcareous and siliceous ooze, chalk, basalt



Track Line for KIP-3F



KIP-3F



Marion Dufresne 109/09

5 km

Seismic for KIP-3F

Site: KIP-6C

Priority: 1

Position: 56°50.0'S, 68°05.6'E

Water Depth: 1027 m

Sediment Thickness: 215 m

Target Drilling Depth: 415 mbsf

Approved Maximum Penetration: 615 mbsf

Seismic Coverage: 1997 multichannel seismic line *Rig Seismic* 179-601

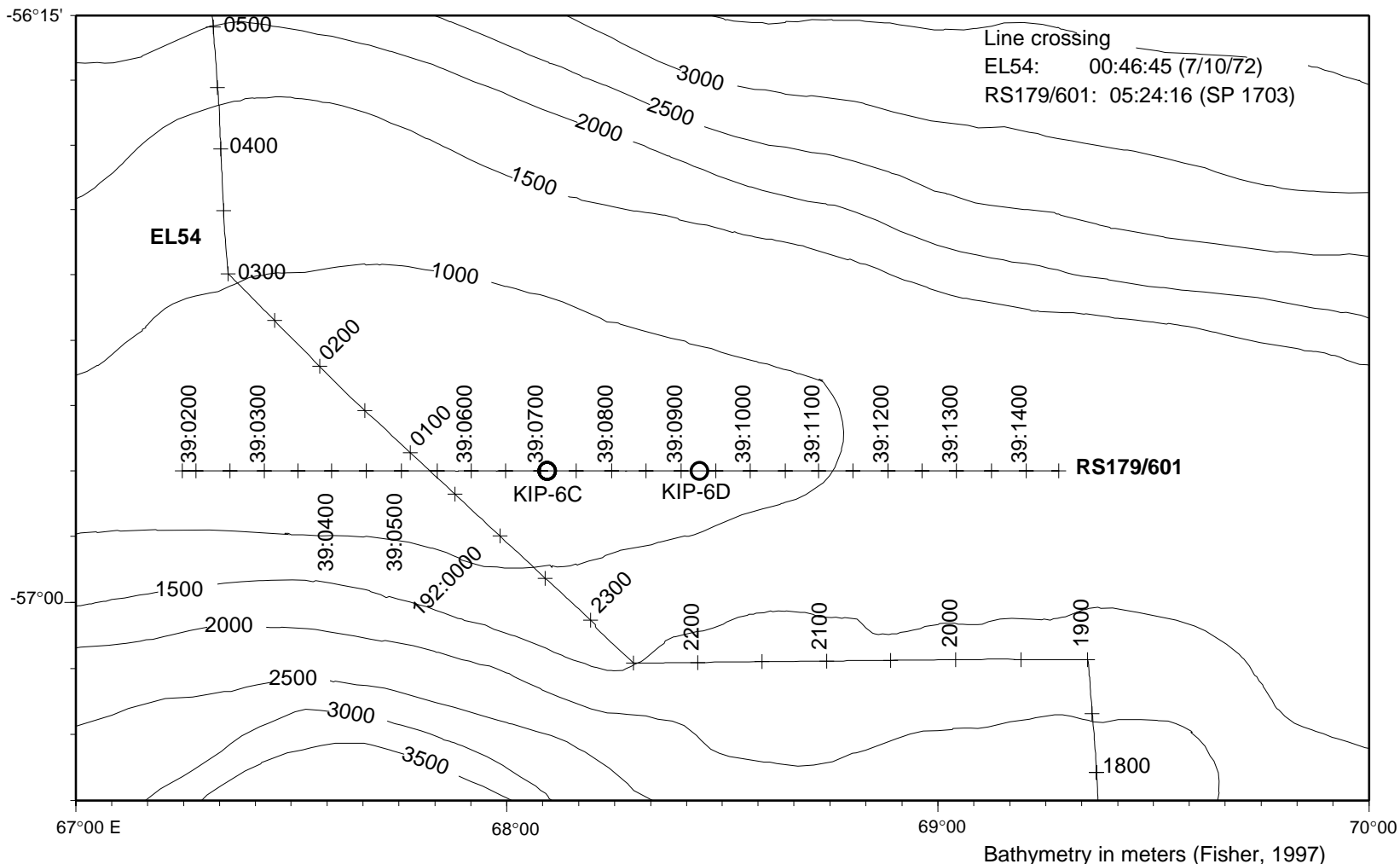
Objectives: The objectives of KIP-6C are to

1. obtain 200 m of igneous basement to characterize petrography and lava compositions,
2. determine basalt flow thicknesses,
3. obtain sedimentary record and determine sequence facies,
4. determine a minimum basement age using overlying sediment and possible sediment interbeds,
5. define the ages of seismic sequence boundaries, and
6. estimate duration of possible subaerial and shallow-water environments.

Drilling Program: RCB

Logging and Downhole Operations: Triple combo, FMS/DSI, WST, DLL/NGT

Nature of Rock Anticipated: Calcareous and siliceous ooze, chalk, basalt



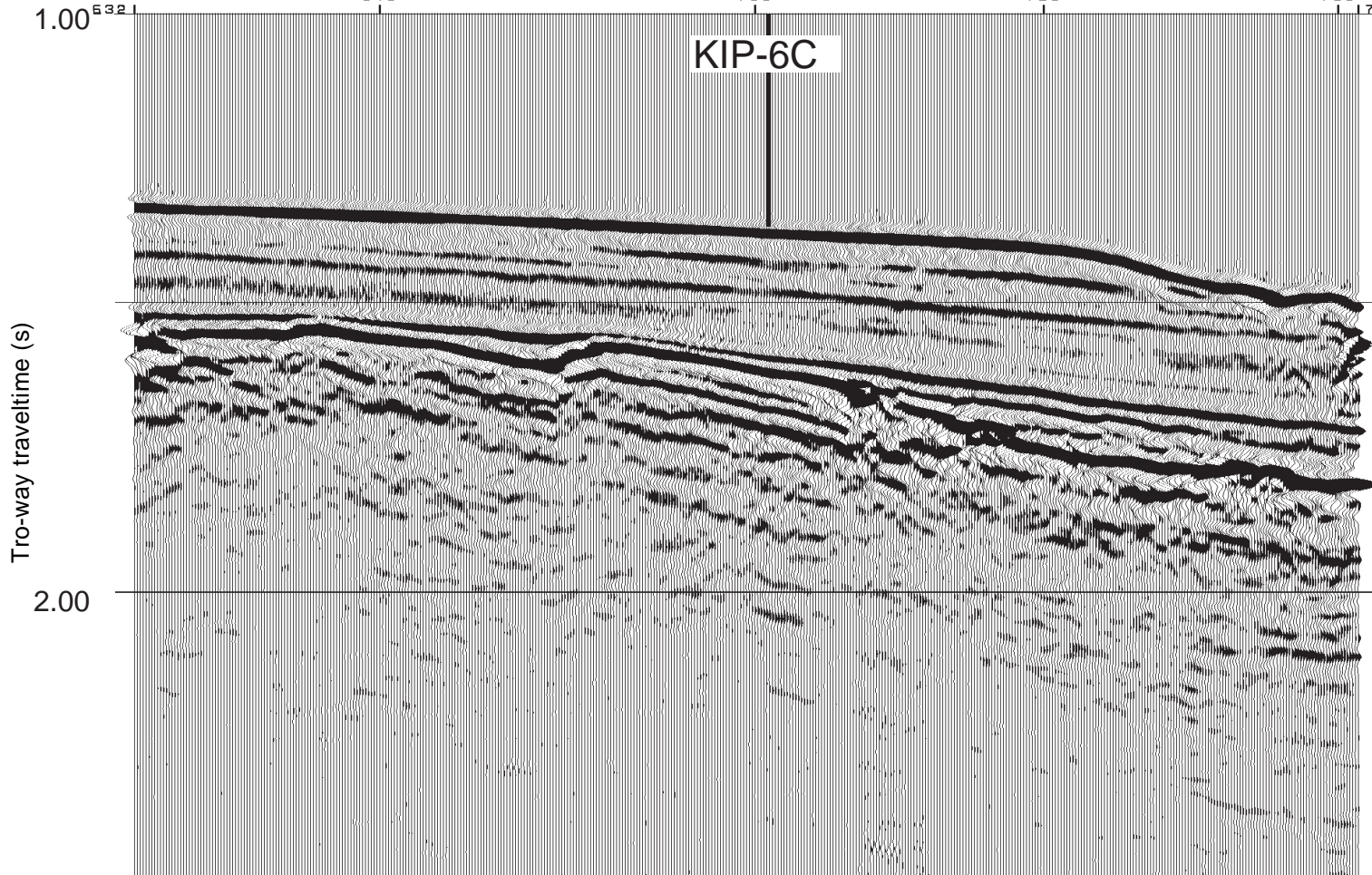
Track line 6C

Rig Seismic 179/601

W

E

SHOTPOINT	1919	1925	1950	1975	2000	2025	2050	2075	2100	2125	12131									
CDP	7801	7825	7875	7925	7975	8025	8075	8125	8175	8225	8275	8325	8375	8425	8475	8525	8575	8625	18649	
GMT	632				645					705				720					735	1736



5 km

Seismic for KIP-6C

Site: KIP-7B

Priority: 1

Position: 53°33.1'S, 75°58.5'E

Water Depth: 1168 m

Sediment Thickness: 685 m

Target Drilling Depth: 885 mbsf

Approved Maximum Penetration: 1085 mbsf

Seismic Coverage: 1997 multichannel seismic line *Rig Seismic* 179-101

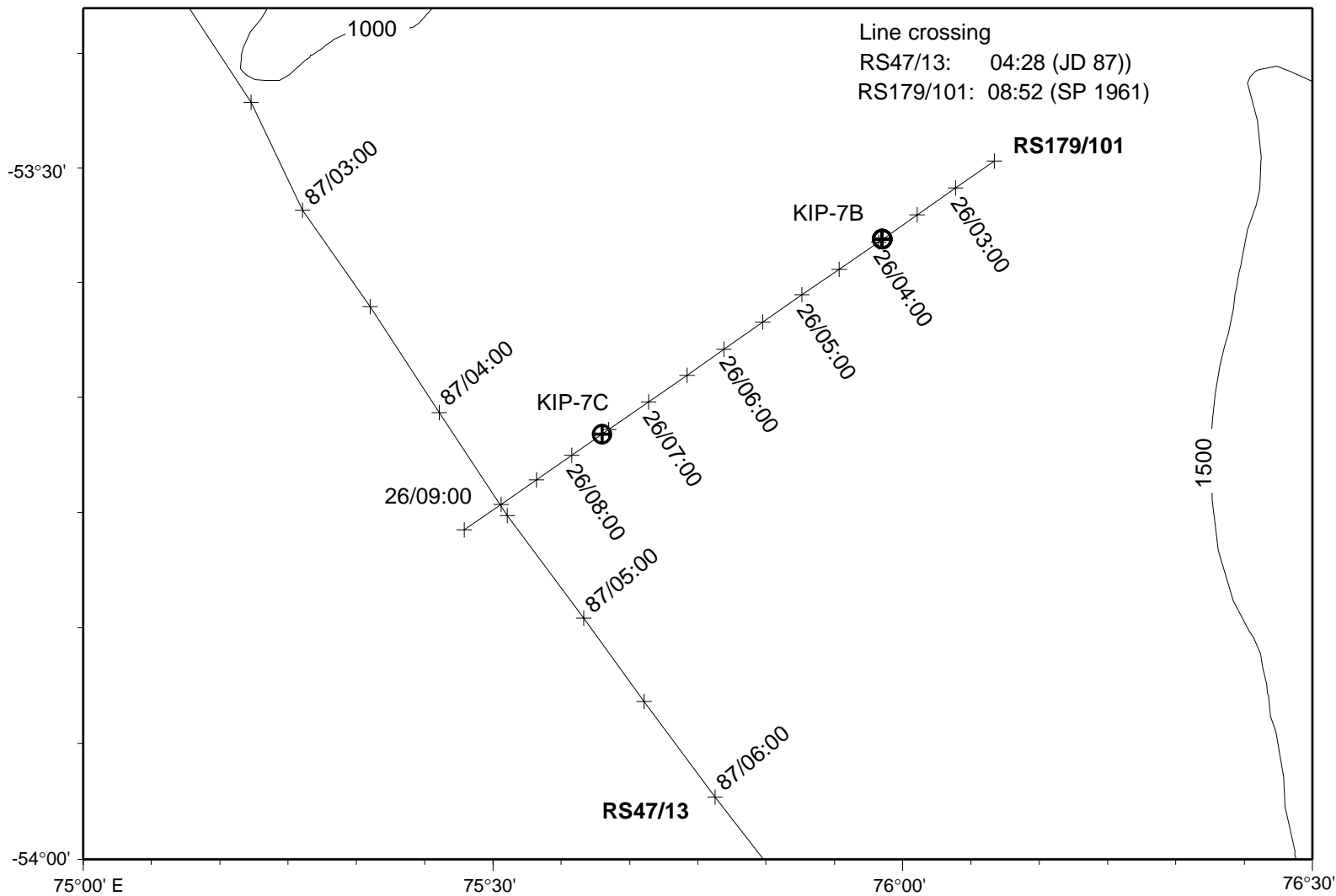
Objectives: The objectives of KIP-7B are to

1. obtain 200 m of igneous basement to characterize petrography and lava compositions,
2. determine basalt flow thicknesses,
3. obtain sedimentary record and determine sequence facies,
4. determine a minimum basement age using overlying sediment and possible sediment interbeds,
5. define the ages of seismic sequence boundaries, and
6. estimate duration of possible subaerial and shallow-water environments.

Drilling Program: RCB

Logging and Downhole Operations: Triple combo, FMS/DSI, WST, DLL/NGT

Nature of Rock Anticipated: Calcareous and siliceous ooze, chalk, basalt



Track line 7B

Rig Seismic 179/101

SW

NE

SHOTPOINT	13931	1375	1350	1325	1300	1275	1250	1225	1200	1175	1150	1125	1100	1075	1069													
CDP	56991	5675	5625	5575	5525	5475	5425	5375	5325	5275	5225	5175	5125	5075	5025	4975	4925	4875	4825	4775	4725	4675	4625	4575	4525	4475	4425	4401
GHT	5041			450		435		420		405							345				330			315			300	255

Two-way traveltime (s)

1.00

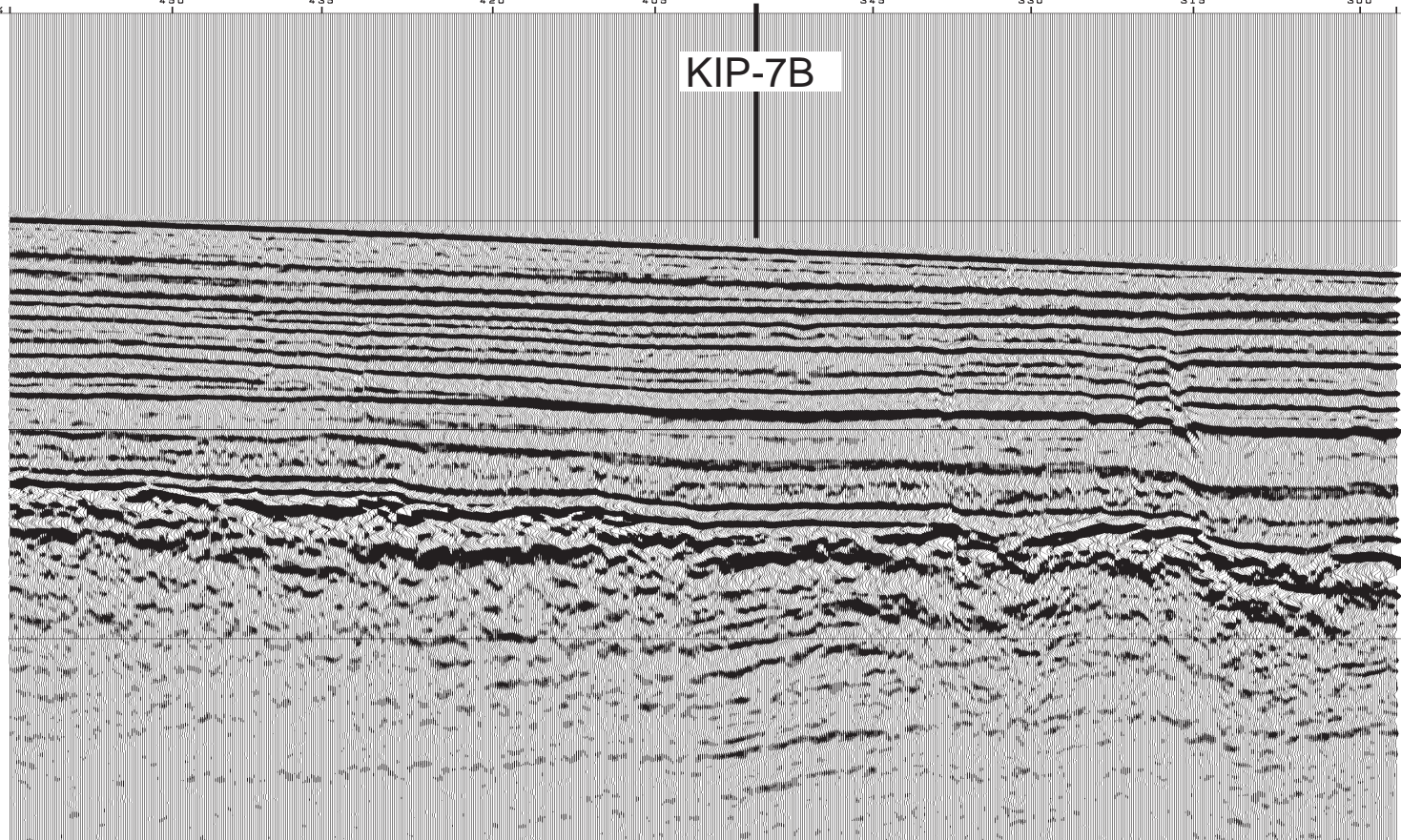
2.00

3.00

KIP-7B

5 km

Seismic for KIP-7B



Site: KIP-9B

Priority: 1

Position: 32°07.3'S, 97°00.4'E

Water Depth: 1240 m

Sediment Thickness: 160 m

Target Drilling Depth: 360 mbsf

Approved Maximum Penetration: 560 mbsf

Seismic Coverage: 1986 single-channel seismic line *Robert Conrad* 2708

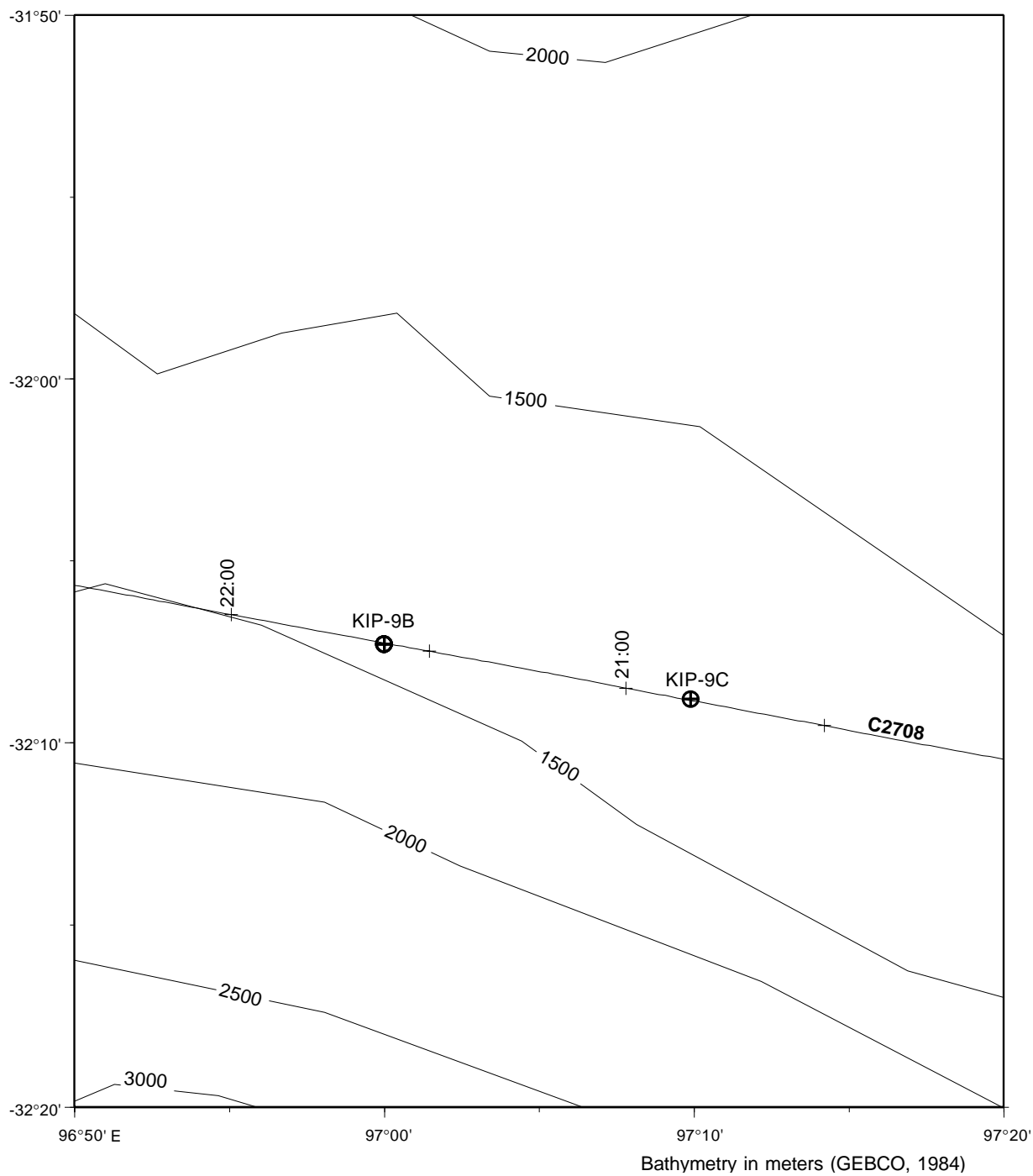
Objectives: The objectives of KIP-9B are to

1. obtain 200 m of igneous basement to characterize petrography and lava compositions,
2. determine basalt flow thicknesses,
3. obtain sedimentary record and determine sequence facies,
4. determine a minimum basement age using overlying sediment and possible sediment interbeds,
5. define the ages of seismic sequence boundaries, and
6. estimate duration of possible subaerial and shallow-water environments.

Drilling Program: RCB

Logging and Downhole Operations: Triple combo, FMS/DSI, WST, DLL/NGT

Nature of Rock Anticipated: Calcareous ooze, basalt



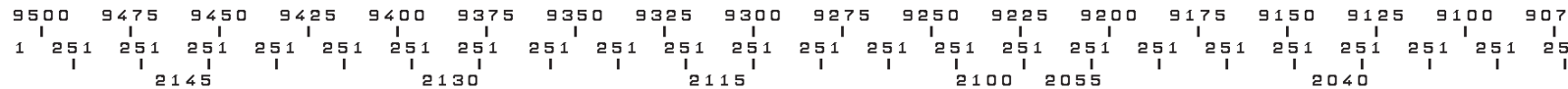
Track line 9B

ENE

ROBERT CONRAD 2708

WSW

Shotpoint
CDP
GMT



1.5

KIP-9B

KI-9C

Two-way traveltimes (s)

2

2.5

10 km

Seismic for KIP-9B

Site: KIP-13B

Priority: 1

Position: 59°42.0'S, 84°16.4'E

Water Depth: 1600 m

Sediment Thickness: 595 m

Target Drilling Depth: 795 mbsf

Approved Maximum Penetration: 995 mbsf

Seismic Coverage: 1997 multichannel seismic line *Rig Seismic* 180-201

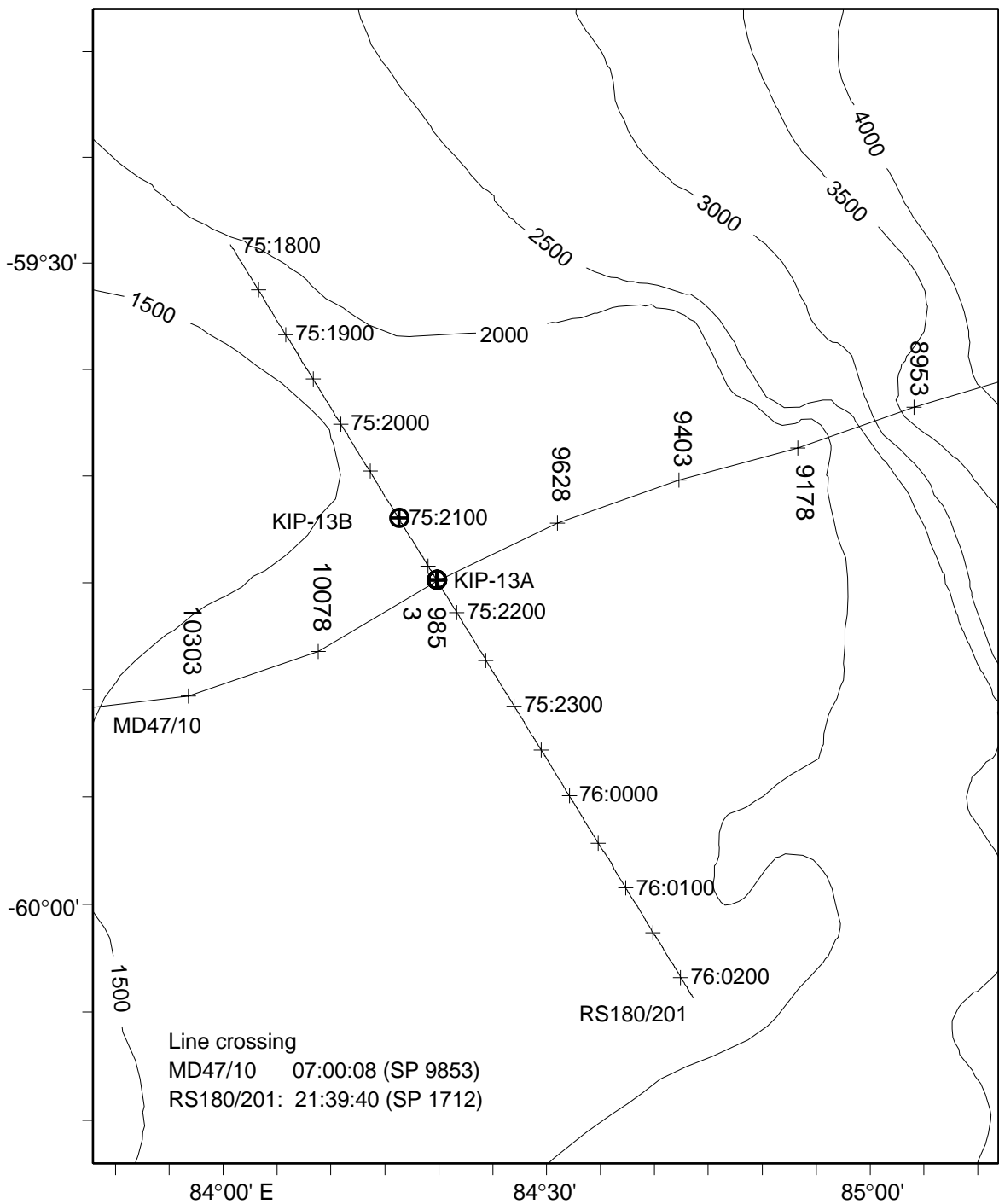
Objectives: The objectives of KIP-13B are to

1. obtain 200 m of igneous basement to characterize petrography and lava compositions,
2. determine basalt flow thicknesses,
3. obtain sedimentary record and determine sequence facies,
4. determine a minimum basement age using overlying sediment and possible sediment interbeds,
5. define the ages of seismic sequence boundaries, and
6. estimate duration of possible subaerial and shallow-water environments.

Drilling Program: RCB

Logging and Downhole Operations: Triple combo, FMS/DSI, WST, DLL/NGT

Nature of Rock Anticipated: Calcareous and siliceous ooze, chalk, basalt



Bathymetry in meters (Fisher, 1997)

Track Line KIP-13B

NW

Rig Seismic 180/201

SE

Two-way traveltime (s)

1.00

2.00

3.00

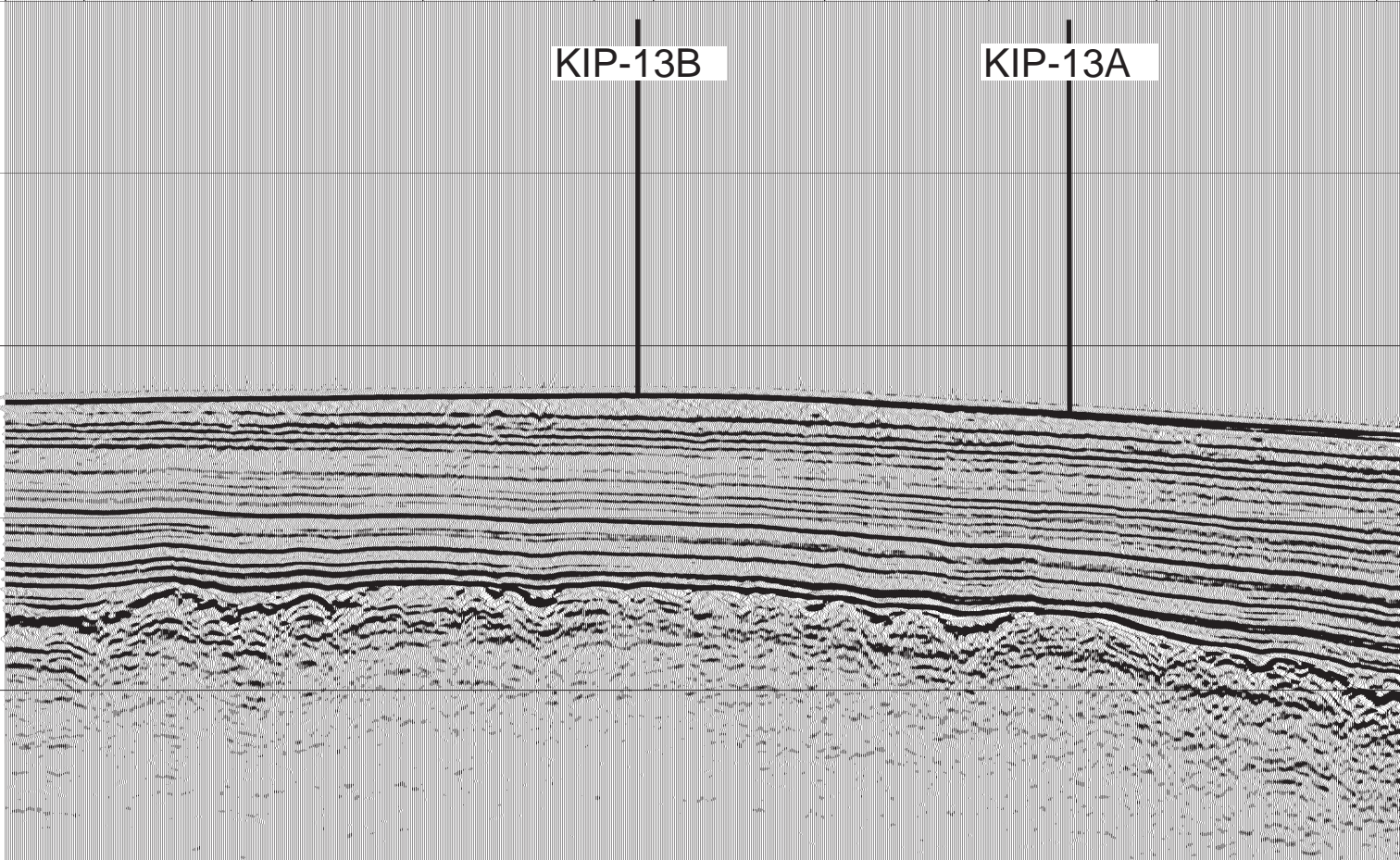
KIP-13B

KIP-13A

Seismic for KIP-13B

5 km

1394 1400 1425 1450 1475 1500 1525 1550 1575 1600 1625 1650 1675 1700 1725 1750 1775 1793
5701 5725 5775 5825 5875 5925 5975 6025 6075 6125 6175 6225 6275 6325 6375 6425 6475 6525 6575 6625 6675 6725 6775 6825 6875 6925 6975 7025 7075 7125 7175 7225 7275 7299
2002 2010 2025 2040 2055 2100 2115 2130 2145 2205 2207



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