# OCEAN DRILLING PROGRAM

# LEG 189 SCIENTIFIC PROSPECTUS

# THE TASMANIAN SEAWAY

# BETWEEN AUSTRALIA AND ANTARCTICA

## Paleoclimate and Paleoceanography

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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.

Technical Editors: Karen K. Graber and Angeline T. Miller

## ABSTRACT

The Earth has rarely experienced ice age conditions during its long evolution. The Cenozoic Era is thus distinctive in its development of major ice sheets in both polar regions. Progressive cooling at high latitudes during the Cenozoic led to the development of the polar cryosphere, initially on Antarctica and later in the Northern Hemisphere. In the early 1970s, a hypothesis was proposed that climatic cooling and cryospheric development resulted from plate tectonic changes that progressively thermally isolated the Antarctic continent as the Circum-Polar Current developed. The development of circum-polar circulation resulted from the opening of the "gateway" of the Tasmanian Seaway south of Tasmania in the Paleogene and the Drake Passage in the earliest Neogene. Circum-polar circulation continued to expand during the Cenozoic with northward migration of Australia and expansion of Drake Passage.

It is likely that these paleoceanographic changes played a fundamental role in the development of Cenozoic climate evolution, associated paleoenvironmental changes such as sea level, and in terrestrial and biotic evolution. Thus, the opening of the Tasmanian Seaway appears to have been vital to the development of Cenozoic global evolution of the Earth's system. Early ocean drilling in the Tasmanian Seaway (Deep Sea Drilling Project Leg 29) provided a basic framework of paleoenvironmental changes associated with the opening of the seaway. Yet, the information obtained during Leg 29, nearly 25 years ago, is of insufficient quality and resolution to fully test the hypothesis of potential relationships among the development of plate tectonics, circum-polar circulation, and global climate. The timing of events remains insufficiently constrained.

During Leg 189, a suite of sites will be drilled to test the hypothesis that Antarctic cryospheric evolution resulted from the isolation of Antarctica by the Circum-Antarctic current. Five sites, located in water depths from 2475 to 3580 m, will be drilled to document paleoceanographic and paleoclimatic changes associated with the opening of the Tasmanian Gateway as Australia moved northward from Antarctica during the Cenozoic. Most sites are designed to penetrate to middle to upper Eocene strata, recording the middle Eocene-Quaternary climatic development preserved in carbonate sediments. Changes in sedimentation are expected to have resulted from the Eocene Gondwanan rifting, onset of circum-Antarctic surface water circulation (70°S), and the development of deep-water circulation (60°S). In addition, the sites will document meridional variations in geochemistry and water-mass temperatures in high-southern latitudes and environmental and biotic

differences during the Paleogene between the Indian and Pacific Oceans because of isolation by the South Tasman Rise. Three sites (WT-1A, WSTR-1B, WSTR-2A) are located at different latitudes in the Indian Ocean, one site (ETP-2A) is in the Pacific Ocean, and one site (STR-2A) is located between the Indian and Pacific Oceans. Four alternate sites (Table 2) have also been selected.

Leg 189 drilling targets new sites designed to greatly improve understanding of Circum-Polar oceanographic and climatic evolution. For example, the relatively shallow region off Tasmania is one of the few places where well-preserved and almost complete marine middle Eocene to Holocene carbonate-rich sequences can be drilled in present-day latitudes of 40°-50°S, and paleolatitudes of up to 70°S.

## INTRODUCTION

The area between Australia’s southernmost prolongation (Tasmania and the South Tasman Rise) and Antarctica is key to understanding global Cenozoic changes in climate and current patterns, involving

- The breakup of Gondwana between 130 and 30 Ma (Fig. 1);
- The drifting of Australia northward from Antarctica;
- Initiation of the Paleogene to early Neogene Circum-Polar Current and the meridional expansion of the Southern Ocean with concomitant thermal isolation of the Antarctic continent and development of its cryosphere during the Paleogene and Neogene (Kennett, Houtz, et al., 1975b); and
- The role these processes have had on global cooling (Fig. 2) and biotic evolution.

The opening of the Tasmanian Seaway between Australia and Antarctica and the only other important constriction in the establishment of the Circum-Polar Current, the Drake Passage, had enormous consequences for global climate. These consequences came in part by isolating Antarctica from warm gyral surface circulation of the Southern Hemisphere oceans, and also by providing the necessary conduits that eventually led to ocean conveyor circulation between the Atlantic and Pacific Oceans. Both factors, in conjunction with other global changes, have been crucial in the development of the polar cryosphere, initially in Antarctica in the Paleogene and later in the Northern Hemisphere in the late Neogene. The relatively shallow region off Tasmania (mostly above the present carbonate compensation depth [CCD]) is strategically well located for studies of the opening and later expansion of the Tasmanian Seaway. It is also one of the few places where almost complete marine middle Eocene to Holocene carbonate-rich sequences can be drilled in present-day latitudes of 40°-50°S, and paleolatitudes of up to 70°S (Fig. 3).

The geographic position of the Tasmanian offshore region makes this a unique location to study the effects of Eocene-Oligocene Australia-Antarctic separation on global paleoceanography. Australia and Antarctica were still locked together in the Tasmanian area in the late Eocene, preventing the establishment of circum-Antarctic circulation (Fig. 1). At that time, and earlier, the water masses were separated on either side of the barrier in the southern Indian and Pacific Oceans and must have exhibited distinct physical, chemical, and biological properties. An understanding of Cenozoic climate evolution clearly requires better knowledge of the timing, nature, and responses of the opening of the Tasmanian Seaway during the Paleogene (Figs. 1, 2).

Furthermore, the continued expansion of the Southern Ocean during the Cenozoic because of the northward flight of Australia from Antarctica, has clearly led to further evolution of the Earth's environmental system and of oceanic biogeographic patterns. The Tasmanian region is also well suited for the study of post-Eocene development of Southern Ocean climate development, including the formation and variation of high-latitude climate zones. This region is one of the few ideally located in the Pacific sector of the Southern Ocean for comparison with the models of Cenozoic climate development and variation in the Indian Ocean and the South Atlantic.

An outstanding question therefore is whether paleoceanographic variability known from the Atlantic and Indian sectors is characteristic of the entire circum-polar ocean, or whether there are zonal asymmetries in the Southern Ocean and, if so, when these developed. The meridional spread of proposed sites (Fig. 4) on the South Tasman Rise (STR) is well suited to monitoring the migration of frontal zones through time, analogous to transects on the Southeast Indian Ridge (SEIR) (Howard and Prell, 1992). Here the total meridional displacement of fronts is expected to be somewhat less than on the SEIR because the STR is a shallower topographical barrier to the Circum-Antarctic Current. The East Tasman Plateau (ETP) site is ideally located to monitor paleoceanographic changes in the interface between the East Australian Current and the Circum-

Polar Current, since the East Australian Current transports heat into the Southern Ocean, an important "gateway" objective.

The sites cored during Leg 189 will also provide high-quality paleoclimatic and paleoceanographic records of Neogene age. These sequences will be employed to examine the development of surface water productivity, oscillations in subtropical and polar fronts, changing strength of the east Australian Current, and changes related to further expansions of the Antarctic cryosphere during the middle Miocene and late Neogene.

Quaternary records are expected also to be of high value for studies of the southern temperate and subantarctic regions. The Southern Ocean participation in the glaciation cycles of the past 500 k.y. appears to track well-known Northern Hemisphere indicators of cryospheric, atmospheric, and oceanographic variability (Imbrie et al., 1992; Imbrie et al., 1993). The Southern Ocean paleoceanographic record, manifested in its temperature response (Howard and Prell, 1992) and carbon cycling (Howard and Prell, 1994; Oppo et al., 1990) mirrors that of the Northern Hemisphere. However, on the Milankovitch band there appears to be a lead in the Southern Ocean, perhaps reflecting the importance of this region. For example, the potential role of Southern Ocean paleoproductivity changes on global climate remains a topic of considerable debate.

In summary, major questions to be addressed are

- How did the Circum-Antarctic Current develop, and what were the roles of the opening of the Tasmanian Seaway (~30 Ma) and Drake Passage (~20 Ma)?
- When did the Tasmanian Seaway open to shallow water, and how did this affect east-west biogeographic differences, isotopic differences relating to changing climatic regimes, and geochemical differences?
- When did the seaway open to deep waters, and how did this affect surface- and deep-water circulation?
- How is circum-Antarctic circulation related to changes in Antarctic climate?
- How did the East Antarctic cryosphere develop in this part of Antarctica, and how does it compare to other sectors?
- What was the nature of the adjacent Antarctic climate in the Greenhouse period in the middle to late Eocene?

- How did sedimentary facies change as the Tasmanian region moved northward, circum-Antarctic circulation became important, and upwelling commenced?
- How did Antarctic surface waters develop in terms of temperature, the thermocline, and oceanic fronts?
- How did intermediate waters evolve during the Neogene, and how was this evolution tied to Antarctic cryosphere development?
- How did Australia's climate change as the continent moved northward?
- How were changes in the marine biota tied to changes in the oceanographic system?

## BACKGROUND

### General

The Tasmanian offshore region consists of continental crust of the Tasmanian margin (Moore et al., 1992; Hill et al., 1997b), the South Tasman Rise (Exon, et al., 1997b), and the East Tasman Plateau (Exon et al., 1997a) and is bounded on all sides by oceanic abyssal plains (Fig. 4). Oceanic crust to the east was created by the seafloor spreading that formed the Tasman Sea in the Late Cretaceous and early Tertiary. The crust to the south and west was formed during the Cenozoic, and perhaps the latest Cretaceous, by the seafloor spreading that led to the separation of Australia and Antarctica.

The continental shelf around Tasmania (Fig. 4) is mostly nondepositional at present. The continental slope west of Tasmania falls fairly regularly from 200 to 4000 m. The continental rise lies at 4000-4500 m, and the abyssal plain is generally 4500-5000 m deep. Sampling cruises have shown that the slope is underlain by continental basement and that Late Cretaceous and Paleogene shallow-marine sandstone, siltstone, and mudstone are widespread in deep water west of Tasmania, overlain by Neogene pelagic carbonates. Seismic interpretation shows that basement is generally overlain by several kilometers of Sorell Basin sediments (Fig. 5, P1).

The current-swept STR is a large, northwest-trending bathymetric high that rises to less than 1000 m below sea level and is separated from Tasmania by a west-northwest-trending saddle more than 3000 m deep (Fig. 4). It has a continental core, and seismic profiles show it is cut into basement highs and deep basins with several kilometers of sedimentary section (Fig. 5, P2 and P3). The overlying sequences in faulted basins include known Neogene pelagic carbonates and Paleogene marine mudstones, and seismic evidence suggests they also contain Cretaceous sediments. The top of the rise is a gentle dome with low slopes, but slopes are generally steeper between 2000 and 4000 m. The western slope is more gentle to 3000 m, but below that there is a very steep scarp trending 350°, which drops away to 4500 m as part of the Tasman Fracture Zone.

The East Tasman Plateau is a nearly circular feature, 2500-3000 m deep, separated from southeast Tasmania by a saddle 3200 m deep (Fig. 4). Slopes are generally low, but considerably greater on the plateau's flanks. Atop the plateau is the Cascade Seamount guyot, which formed as the result of hot spot volcanism and has yielded Eocene and younger shallow-water sandstone and volcanics. The plateau has up to 1.5 s two-way traveltime (TWT) of sediments in places (Fig. 5, P4) that are believed to comprise mainly Neogene pelagic carbonates and Eocene mudstones. These are underlain by continental basement rocks.

**Deep Sea Drilling Project Results**

Leg 29 of the Deep Sea Drilling Project (DSDP) drilled four partially cored sites in the Tasmanian region (Kennett, Houtz, et al., 1975a) (Table 1). The three sites that are relevant for Leg 189 are Site 281 on the STR, Site 282 on the west Tasmanian margin, and Site 280 on the abyssal plain immediately south of the STR (Figs. 4, 6).

Site 282 was drilled on a basement high west of Tasmania. This sequence includes much of the Cenozoic but contains four major unconformities. The sediments rest on a basalt flow of presumed Tertiary age. The sequences are upper Eocene to middle Oligocene mudstone, lower to middle Oligocene mudstone, lower Miocene marl, upper Miocene ooze, and a veneer of Pleistocene ooze. There is little in these sediments to suggest that the earliest sequence was located in deep water until the margin began to subside in the Oligocene. Calcareous microfossils are present throughout and total core recovery was 20%.

Site 281 was drilled on a basement high of quartz-mica schist of latest Carboniferous age, southwest of the tip of the STR. The sequence drilled includes upper Eocene basement conglomerate and glauconitic sandy mudstone, upper Oligocene glauconite-rich detrital sand, Miocene foraminifer-nannofossil ooze, and Pliocene-Pleistocene foraminifer-nannofossil ooze. Evidence from the recovered intervals suggests that the site subsided into deep water after the Miocene. Calcareous microfossils are present throughout, and total core recovery was relatively high (62%).

Site 280 was drilled on a basement high, in deep water southwest of the STR (Fig. 4), and bottomed in an "intrusive basalt," almost certainly associated with oceanic crust. The site penetrated a veneer of upper Miocene to upper Pleistocene clay and ooze underlain, beneath a sampling gap, by 55 m of siliceous lower Oligocene sandy silt and 428 m of middle Eocene to lower Oligocene sandy silt that contains chert in the upper 100 m and glauconite and manganese micronodules in the lower succession. The lower 200 m is rich in organic carbon (0.6%-2.2 %). The younger part of the lower Oligocene to upper Eocene sequence (Unit 5A) contains abundant diatoms, but the lower part (Units 5B and 5C) is almost completely devoid of pelagic microfossils. All sediments are presumed to have been deposited at abyssal depths. A brown organic staining suggests reducing conditions were present in parts of the upper Oligocene and lower Miocene. Total core recovery was only 19%.

Data from Site 281 assisted with the development of a broad globally significant history of the Cenozoic events in the region. Shackleton and Kennett (1975) produced composite foraminiferal oxygen and carbon isotope curves for the late Paleocene to the Pleistocene for Sites 277, 279, and 281. This record exhibits the now classical general increase in oxygen isotopic values reflecting a decrease in bottom- and surface-water temperatures and/or ice buildup during the Cenozoic. There was a general increase in isotopic values during the Paleogene, a rapid increase in the early Oligocene reflecting cryosphere expansion, and steady oxygen isotopic values until the middle Miocene, when there was another rapid oxygen isotopic increase as the Antarctic cryosphere further expanded. This was followed by further increase in oxygen isotopic values reflecting the development of the West Antarctic ice sheet in the late Miocene and the Northern Hemisphere cryosphere in the late Pliocene (Fig. 2). For Site 281 (STR), the sequence studied isotopically was the lower Miocene to the Pliocene, although the hole bottomed in the upper Eocene. In contrast, at Site 277 (Campbell Plateau) the lowest Miocene to upper Paleocene was studied. Although the isotopic sequence developed by Shackleton and Kennett (1975) was pioneering, it is of relatively low resolution, especially within the context of recent investigations.

## SCIENTIFIC OBJECTIVES

### Paleogene History

Existing stratigraphic and sedimentologic information indicates that middle Eocene sequences are different in the northern sites west of Tasmania (DSDP Site 282; Hill et al., 1997a) and in the south in the STR (DSDP Site 281; Exon, et al., 1997b), although shallow marine and deltaic facies are found in both areas. Northern sequences contain abundant organic matter and calcareous temperate microfossil assemblages. Southern sequences contain siliceous microfossils of colder-water character, and varves in some intervals, suggesting strong seasonality perhaps related to the onset of glacial conditions in the Antarctic region. The middle Eocene to upper Oligocene sequences are crucial to understanding the opening of the Tasmanian Seaway, initially in shallow and later in deep water. Before the Oligocene, sequences on either side of the STR should have distinctive biogeographic characters.

Study of the uppermost Eocene through Oligocene sequences will be of special importance in examining the timing of the development of the circum-polar circulation both across and south of the STR (about 65°S at that time). The opening of this gateway was such a profound event that biotic, sedimentologic, and geochemical parameters would almost certainly have undergone distinct changes. When studied in detail and in unison, changes in these parameters are expected to provide the crucially needed evolutionary information on this gateway. The dating of unconformities or hiatuses will provide critical information on major current activity during the Oligocene, especially in the shallow sequences, although sites have been selected to minimize the effects of sediment erosion. We are especially interested in the timing of initial shallow water linkage across the STR and deep-water linkage south of the STR.

Sites WT-1A, WSTR-1B, and WSTR-2A will provide data about the Indian Ocean paleoenvironment prior to opening (middle to late Eocene), whereas ETP-2A will provide information about South Pacific paleoenvironments prior to opening of the Tasmanian Seaway. All sites will address the initial shallow-water breakthrough (late Eocene) and most will address the deep-water breakthrough to some extent (early-middle Oligocene?).

A sequential appearance of marine microfossils, from dinocysts and arenaceous foraminifers (early Eocene), to calcareous nannofossils (middle Eocene), to calcareous benthic foraminifers (early late

Eocene), and to planktonic foraminifers (late late Eocene), may well be revealed at most of the sites. The order of appearance of major groups is paleoenvironmentally significant and is expected to provide crucial insights about the evolution of the Southern Ocean biota. The upper middle Eocene to the lower Oligocene sequence, where calcareous microfossils are present and sedimentation rates are 1.5 to 3 cm/k.y., should provide excellent documentation of tectonic, climatic, and oceanographic changes. Planktonic foraminiferal and calcareous nannofossil biostratigraphy, in conjunction with strontium and oxygen isotope stratigraphies should provide a chronology of sufficient resolution. Specific stratigraphic boundary events (e.g., Eocene/Oligocene, Miocene/Pliocene) will be analyzed at high resolution.

### Neogene and Quaternary History

Coring in the Tasmanian region will assist in evaluation of the dynamic oceanographic and climate evolution that continued in the Southern Ocean during the Neogene and Quaternary. Information gained will include that related to climate and ocean evolution, oscillations in ocean temperatures, migration of ocean fronts, paleoproductivity, and biotic evolution. This leg is complementary to three recent ODP Neogene paleoceanographic legs:  Leg 182 in the Great Australian Bight to the northwest, Leg 177 in the subantarctic South Atlantic, and Leg 181 east of New Zealand. Leg 189 will fill a key geographic gap. For example, the sites are expected to provide temperate and subantarctic Neogene biostratigraphy of foraminifers and calcareous nannofossils.

In particular, the history of water-mass formation and mixing among Antarctic, Indian, and Pacific sources can be monitored in this area through isotopic and trace-metal proxies measured in the abundant planktonic and benthic foraminifers. These sites will complement the Leg 177 South Atlantic subantarctic transect sites in answering questions about the circumpolar symmetry of Southern Ocean paleoclimate change and interbasin circulation patterns that influence the ocean’s dissolved carbon and alkalinity budgets.

## PROPOSED SITES

### West Tasmania: WT-1A and WT-2A

Proposed Site WT-1A is designed to penetrate through 880 m of Cenozoic sediments to the middle Eocene on the midslope west of Tasmania and southeast of DSDP Site 282. Site 282 was located on a structural high with 192 m of Neogene sediments interrupted by three unconformities. The proposed site will be drilled through a single conformable Cenozoic sequence dipping toward the ocean. Cretaceous sequences dip toward Tasmania, so that any hydrocarbons would have migrated freely out of the area. The Neogene sequence at WT-1A is estimated to be ~700 m thick.

The proposed site is at the crossing of seismic lines *Tasmante* 125-52 and *Sonne* SO36B-47 in a present water depth of 2475 m. The evidence from DSDP Site 282 suggests that the Paleogene sequence is mud dominated, and the seismic profiles suggest a deltaic origin in both the Paleogene and the Cretaceous, with the possibility of some porous beds. The Eocene sequence of shallow marine mudstone (200 m thick) at Site 282 consisted of dark organic-rich uppermost middle to upper Eocene nannofossil-bearing mudstone that is believed to have been deposited in a deep basin with restricted circulation. Thus, there is a chance that anoxic sediments will have accumulated in a silled basin on the margins of the opening Southern Ocean. Total nearby sediment thickness is 3500 m.

At WT-1A, the section to 0.8 s (680 m) is moderately transparent on most seismic profiles and unconformably overlies a sequence that is finely cross-bedded on high-resolution profiles. Two cores indicate that the cross-bedded section consists of shallow marine Eocene mudstone. An inferred Oligocene unconformity appears to form the base of the overlying transparent sequence. Within the Neogene sequence, there is some downlap onto a reflector at 0.45 s. We propose to drill through 0.17 s (200 m) of cross-bedded Eocene sequence. The approximate total depth is 880 m and may require reentry. The site lacks any structure and is believed to be safe with respect to potential petroleum entrapment.

Alternate Site WT-2A is designed to penetrate 855 m into Eocene sediments. This site is in an area with little structure, where all sequences dip toward the ocean, so that any hydrocarbons could migrate freely out of the area. The seismic profiles again suggest a deltaic origin, with the possibility of some porous beds, in the Paleogene. Total sediment thickness nearby exceeds 3000 m.

**West South Tasman Rise: WSTR-1B**

This shallow-penetration (250 m) site is close to the western margin of the STR and is designed to retrieve a thick young Neogene section. The younger part of the Neogene section is seismically transparent and has accumulated in the lee of the Tasman Fracture Zone, which forms a ridge to the west.

Site WSTR-1B is in a gentle structural low with thick, almost flat-lying, sediments. The older Neogene section is well bedded but hummocky in character and probably consists of chalks with some hiatuses. The seismically similar underlying Eocene sequence is probably largely mudstone. The lowest part of the Neogene section appears to be absent at this site.

The proposed site is at the intersection of multichannel seismic profiles *Tasmante* 125-4 and 9 in a present-day water depth of 3580 m. The site is designed to penetrate 0.23 s (195 m) of Pliocene to Holocene transparent ooze that onlaps 0.22 s (185 m) of upper Oligocene to Miocene ooze and chalk above the Oligocene unconformity. Below the Oligocene unconformity is 0.1 s (110 m) of upper Eocene to lower Oligocene marine mudstone, marl, and chalk, above 0.08 s (90 m) of middle Eocene mudstone. The site is in a local low in the Cretaceous surface and is believed to be safe as regards possible hydrocarbon entrapment.

**West South Tasman Rise: WSTR-2A**

Proposed Site WSTR-2A is about 60 km east of Site WSTR-1B on the western slope of the culmination of the STR and is designed to penetrate a thicker (and older) lower Neogene sequence than Site WSTR-1B (470 m compared to 185 m). The young transparent ooze sequence of Site WSTR-1B is absent, but the underlying well-bedded sequence is well developed.

Site WSTR-2A consists largely of a sequence of Neogene ooze and is thus unlikely to contain any potential reservoir rocks. The site is located in an area of flat-lying Cenozoic sediments, overlying a structural low in the Cretaceous sequence. The Eocene sequence does contain some bedding, but little evidence of progradation. Although total sediment thickness nearby may reach 2000 m, the site is believed to be without hydrocarbons.

This site is located at the intersection of multichannel seismic profiles SO36B-58 and *Tasmante* 125-14. The site is designed to penetrate 0.55 s (470 m) of upper Oligocene to Miocene ooze and chalk above the Oligocene unconformity. Below the unconformity, we intend to drill 0.3 s (310 m) of upper Eocene to lower Oligocene sediments. Seismic profiles show that the calcareous sediments below the Oligocene unconformity are well bedded.

**South Tasman Rise: STR-2A, STR-1A, SET-1A**

Proposed Site STR-2A is designed to penetrate 940 m, well down into the Eocene, in an area where maximum sediment thickness is 3000 m. It may possibly enter the uppermost Paleocene. The site should penetrate 0.30 s (255 m) of Neogene ooze and chalk above the Oligocene unconformity and 0.65 s (685 m) of Eocene mudstone. The assumed top of the Cretaceous is at 1.2 s (~1250 m) below seafloor, and another prominent Cretaceous reflector is at 1.5 s (~1600 m). The site is on the intersection of multichannel seismic profiles AGSO 202-05 and -06. A 20-m core taken by the *Marion Dufresne* provides a continuous section back to ~900 ka. *Sonne* coring, *Rig Seismic* dredging, and data from DSDP Site 281 suggest that the facies is greatly different to that on the Tasmanian margin (DSDP Site 282, *Sonne* cores, and WT-2A). On the STR, the facies is olive to gray upper Eocene shelf to upper slope mudstone with abundant microfossils, both siliceous and calcareous in places. The site is in a depression from which any hydrocarbons generated in the Cretaceous sequence (about half the section) should migrate updip to the east.

The Neogene section, ~255 m thick, is transparent and virtually flat lying. The assumed Oligocene sequence, about 100 m thick, is strongly bedded and rather hummocky. The underlying well-bedded and virtually flat-lying sequence, about 200 m thick, is not very reflective. Beneath this is a poorly reflective and somewhat disturbed section, about 300 m thick, that onlaps a gently dipping, poorly reflective sequence. The site is designed to terminate in the upper part of the dipping sequence.

Alternate proposed Site STR-1A is on the southern slope of the STR and lies about 20 km north-northeast of DSDP Site 281, which was drilled on a basement high and is tied through seismic profile SO36B-51 to Site STR-1A. Basement is at about 1.3 s (1500 m), and there is a wedge of Cenozoic and possibly older sediments, reaching a maximum of a little less than 2000 m to the northeast, against a northwest trending fault. Site STR-1A would penetrate ~200 m of Neogene carbonates and 400 m of middle Eocene to lower Oligocene shallow-marine mudstone.

The maximum sediment thickness is about 2500 m. The Cenozoic sediments dip south and there is little chance of up-dip pinchouts. The DSDP evidence shows that the Eocene sequence is mud dominated, but the seismic profiles suggest a deltaic origin, with some possibility of porous beds. Whether the total sequence is Eocene or includes the Paleocene is unknown. The site is in a structural low over shallow basement, and there was no problem with hydrocarbons at DSDP Site 281 on a nearby structural high, so there is little danger of hydrocarbon entrapment.

The site is at the intersection of multichannel seismic profiles *Tasmante* 125-31 and SO36B-51. The site is designed to penetrate 0.21 s (180 m) of Neogene ooze and chalk above the Oligocene unconformity, 0.32 s (350 m) of upper Eocene to lower Oligocene marls below the Oligocene unconformity, and 0.07 s (70 m) of older Eocene mudstone. The presumed Cretaceous/Tertiary boundary lies 1.06 s (1110 m) below the seafloor.

Alternate Site SET-1A lies in 4060 m of water in the L'Atalante depression on *Tasmante* profile 125-4, between the STR and ETP. The site is designed to penetrate 400 m of Neogene drift sediments and 100 m of Paleogene clays. Total sediment thickness is about 1500 m.

**East Tasman Plateau: ETP-2A and ETP-1A**

Proposed Site ETP-2A is designed primarily to penetrate high-resolution carbonate-rich Neogene and Quaternary sequences in an area where the East Australian Current will have had variable influence through time, and it is located at a latitude comparable to the sites west of Tasmania. Secondly, it should penetrate a lower Oligocene and upper Eocene marine sequence whose character is poorly known. The sediments rest on continental or volcanic basement at 1.4 s (about 1400 m). There is little angular break apparent at the Oligocene unconformity.

The present water depth is 2630 m. The site should penetrate 640 m through Cenozoic sediments in an area of almost flat-lying sediments about 1400 m thick. Basement is believed to be Eocene volcanics above cratonic basement. The seismic profiles suggest that there is a Neogene pelagic carbonate sequence overlying a tight Paleogene sequence of volcaniclastic mudstone or muddy sandstone. Given the sediment thickness, there is almost no chance of hydrocarbon generation, and there are no conceivable traps.

The proposed site is on multichannel seismic profiles *Tasmante* 125-4 and AGSO 202-01 and 13. The site is designed to penetrate 0.58 s (495 m) of Neogene-Quaternary ooze and chalk above the Oligocene unconformity, 0.22 s (240 m) of thickly bedded upper Eocene to lower Oligocene chalk and mudstone below the unconformity, and finish well above volcanic basement (probably Eocene sills or flows).

This site will reveal much of the postbreakup history of the enigmatic ETP. The site is in a depression in the basement and should be safe from possible hydrocarbon entrapment.

Alternate Site ETP-1A is very like ETP-2A. It is on *Tasmante* profile 125-3 and is designed to penetrate 615 m through Cenozoic sediments in an area of almost flat-lying sediments about 1150 m thick. Basement is again believed to be Eocene volcanics above cratonic basement.

## DRILLING STRATEGY

The five high priority sites summarized in Table 2 and shown in Figure 4 are planned to be drilled in an arc from west to east (i.e., from the Indian to Pacific Oceans).

### North-South Transect

Proposed Sites WT-1A, ETP-2A, WSTR-1B, WSTR-2A, and STR-2A will extend from well north of the Subtropical Convergence to almost as far south as the present-day Polar Front. This transect will provide constraints on glacial-interglacial meridional oscillations in the Southern Ocean surface waters. The sites are near or above the regional lysocline and should provide continuous Neogene stable isotope and foraminiferal records. The transect will also aid the integration of cold-water siliceous biostratigraphy with temperate carbonate microfossil biostratigraphy.

Site ETP-2A has the additional advantage of being in position to monitor paleoceanographic changes at the confluence of the East Australia Current and the Subtropical Convergence, one of the areas of Western Boundary Current heat transport into the Southern Ocean.

### East-West Transect

Proposed Sites WT-1A, WSTR-1B, WSTR-2A, and ETP-2A will provide information on the Cenozoic reduction of microfossil provinciality between the Indian and Pacific Oceans as the barrier of the STR diminished with time.

**Coring**

Most of the sites will be triple cored with the advanced hydraulic piston corer/extended core barrel (APC/XCB) systems to about 200 m (refusal) in the Neogene. XCB coring will continue to ~500 m in the first APC hole. The remainder of each site will be cored in a fourth hole with the rotary core barrel (RCB) after washing to within 10 m of the XCB depth. Reentry with a free-fall funnel (mini cone) may be unavoidable at Sites WT-1A and STR-2A.

## LOGGING PLAN

The proposed leg aims to investigate the development of the Antarctic Circum-Polar Current (ACC) by coring five sites near Tasmania. Downhole measurements provide a means of investigating the compositional and physical variability in situ, thereby providing continuous records of climate driven cyclicity.

The triple combo and Formation MicroScanner (FMS)/Sonic tool strings as well as the geological high-resolution magnetometer (GHMT) will be run at all sites drilled deeper than 250 m and will be particularly important when dealing with cyclic changes in sediment lithology. The sedimentation rates are high enough at most sites for standard logs such as density and gamma ray to continuously resolve climate-related changes in sediment lithology (e.g., percent $CaCO_3$) on orbital timescales. The addition of the new high-resolution gamma tool will allow approximately three times better vertical resolution than the current tool for minimal time costs. The FMS images will allow suborbital variability to be resolved in addition to allowing observation of bedding, turbidites, faults, clasts, nodules, and bioturbated beds. The extremely high resolution of the FMS tool provides the potential for fine-scale (centimeter) core-log integration. In addition, ice-rafted detritus-rich intervals are identifiable by their physical properties, notably gamma ray and magnetic susceptibility. Logs also provide a key link between core and seismic data: sonic velocity logs and synthetic seismograms may be directly compared to the seismic section.

The total magnetic field, in tandem with the magnetic susceptibility, provides a downhole magnetic polarity stratigraphy. The present Earth's field at the sites will be strong enough to be in the range of the magnetic field sensor, and there should be a strong borehole anomaly (sites are well clear of the $\pm35°$ inclination zone). The sites have moved about 20° northward since the middle Eocene, but this should not prevent a full polarity stratigraphy from being obtained using the GHMT. In addition, previous logging in the high-latitude Southern Ocean (Leg 177) and the North Atlantic (Leg 162) shows that magnetic susceptibility is particularly useful for core-log integration, allowing the recovered core to be mapped back to its true stratigraphic depth.

## SAMPLING STRATEGY

### General

Much of the Neogene core material to be recovered during Leg 189 will be retrieved by APC and XCB coring, generally by triple coring. Sampling of the recovered cores will be subject to the rules described in the ODP Sample Distribution Policy (http://www-odp.tamu.edu/publications policy.html). Sampling for high-resolution isotopic, sedimentologic, and micropaleontologic studies will be conducted after construction of the spliced composite section. High-resolution sampling is anticipated for most sites. Sampling schedules will be worked out to optimize stratigraphic coverage and to minimize duplication. Geochemical sampling, which calls for larger volumes, will be conducted on material from the third hole if it would otherwise interfere with first-pass micropaleontology and sedimentology sampling.

Most high-resolution sampling will be deferred until after the cruise; however, the upper few cores in each hole that contain high-porosity sediments, which may be disturbed during transport to the Gulf Coast Repository (Texas A&M University), will be sampled on board ship. High-resolution sampling is anticipated for most of the upper APC and XCB cores, depending on the abundance of microfossils (especially benthic foraminifers). Where appropriate, U-channel sampling for high-resolution paleomagnetic studies will be conducted postcruise in the temporary archive half along the composite sampling splice.

Sampling for whole-round samples (e.g., physical properties, interstitial waters, etc.) will be undertaken so as not to interfere with stratigraphically sensitive sampling sequences and to take advantage of available continuous nondestructive measurements where possible.

The large amount of material to be rotary cored will largely be Eocene and lower Oligocene detrital sediments, but will also probably include the older Neogene sequences in places. The sampling density will be much lower in the detrital sequences.

**Ultra-High-Resolution Sites**

Should particularly thinly laminated sediments be encountered, or some other factor necessitate it, detailed very high-resolution sampling may be approved. The sampling allocation committee (SAC) will determine details of the sampling pattern in such instances.

**Sampling Timetable**

Detailed sampling of cores from a given site will proceed only after a composite stratigraphy is constructed from cores from the two or more holes drilled at the site. The splice will be constructed, and the stratigraphic information will be distributed to the scientific party, in advance of postcruise sampling to facilitate planning and scientific collaboration. Requests to sample on board, for pilot studies or for projects requiring lower stratigraphic resolution, will be considered by the SAC.

**Archives**

The permanent archive will be the ODP-defined "minimum permanent archive." Once the working half of a core section is depleted, the temporary archives for that section will be accessible for sampling. Wherever possible, one-quarter of such temporary archives should be preserved by sampling off-center. The archive-half cores (permanent and temporary) for all holes will not be sampled aboard ship, and the permanent archive will be designated postcruise.

**Final Comment**

All sampling for Leg 189, and the final sampling plan, will be approved by the SAC, consisting of the Co-Chief Scientists (Exon and Kennett), Staff Scientist (Malone), and the Curator (or his representative). The initial sampling plan will be preliminary and may be modified during the cruise, depending upon actual material recovered and collaborations that may evolve between scientists.

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# FIGURES

**Figure 1**. Antarctica and surrounding continents at the Cretaceous/Tertiary boundary, in early Oligocene and earliest Miocene times, showing the change from meridional to circum-Antarctic Current circulation that brought about the thermal isolation of Antarctica (Kennett, 1978).

**Figure 2.** Global sea level, tectonism, and ice volume (after Barrett, 1994). Left curve from Atlantic benthic foraminifers (Miller et al., 1987); right curve from seismic sequence analysis (Haq et al., 1987).

**Figure 3.** Trajectory of the South Tasman Rise with respect to Antarctica (J.-Y. Royer, unpubl. data). Because Antarctica has remained stable relative to the South Pole since the Cretaceous (e.g., Muller et al. 1993; DiVenere et al., 1994), it also shows the paleolatitudes of the STR. The close correspondence between the hot spot trace (dashed line) and the trace with Antarctica fixed (solid line) adds confidence to the interpretation (ages after Cande and Kent [1995] magnetic reversal time scale; magnetic chrons in parentheses).

**Figure 4**. Bathymetry of the offshore Tasmanian region, making use of *Tasmante* swath bathymetry. Solid lines = seismic profiles shown in Figure 5. Contours in meters.

**Figure 5.** Cross-sections from seismic profiles across the region showing DSDP and proposed high-priority ODP sites. P1 = west Tasmania, P2 and 3 = South Tasman Rise, P4 = East Tasman Plateau. Site locations are shown in Figure 4.

**Figure 6.** Map of the offshore Tasmanian region showing location of multichannel seismic tracks. Locations of DSDP sites and proposed ODP sites are also shown.

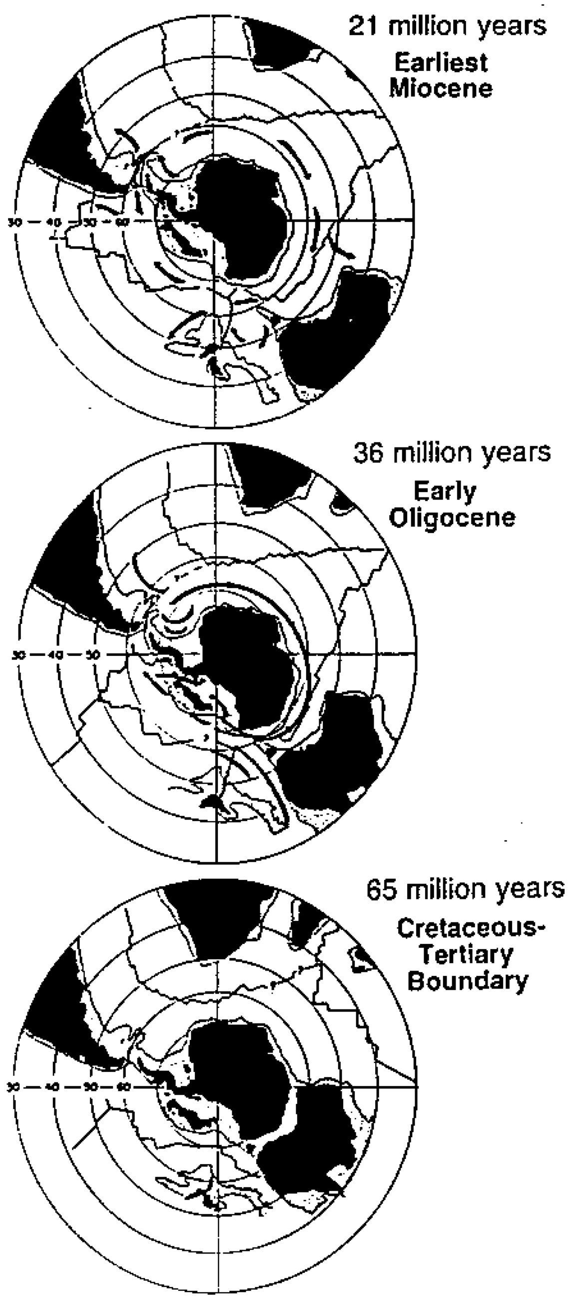
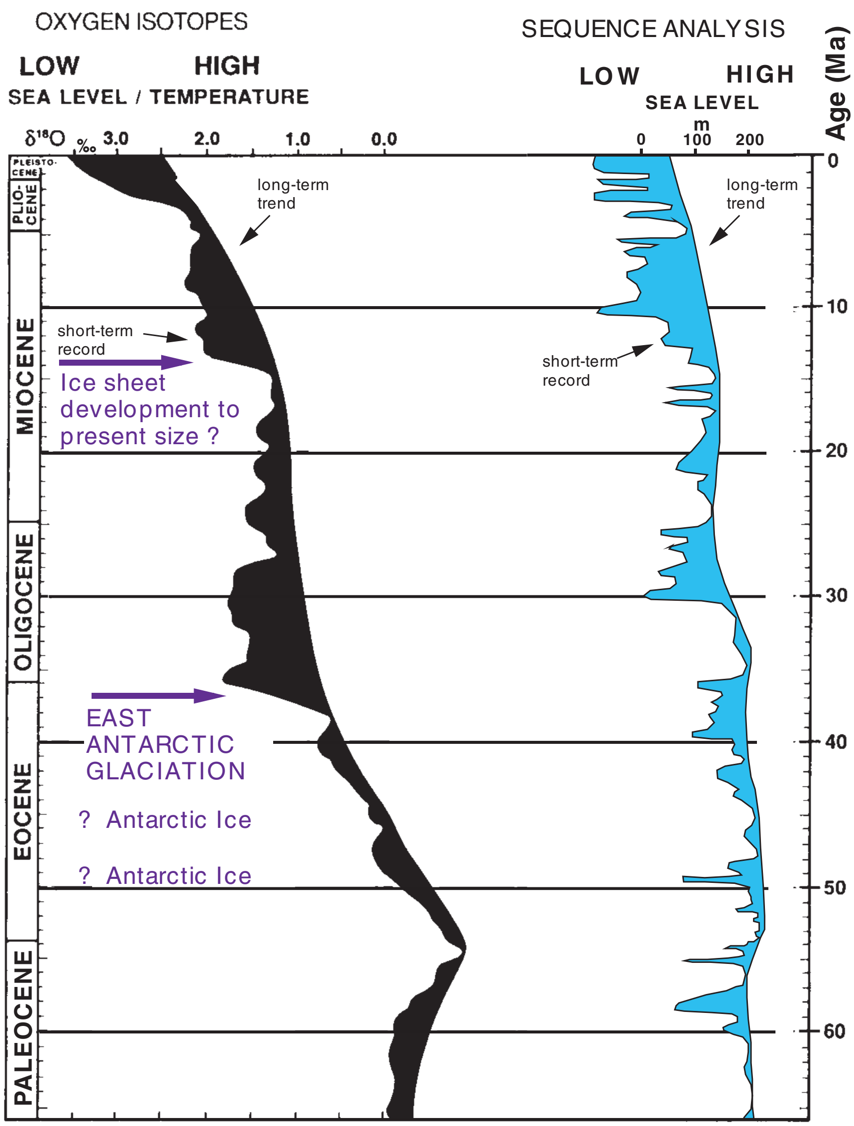

21 million years
Earliest
Miocene
36 million years
Early
Oligocene
65 million years
Cretaceous-
Tertiary
Boundary

**Figure 1**

## Oxygen isotope and sea-level records




1‰ $^{18}O$ = 110 m sea-level or 4°C water-temperature change
(modified from Barrett, 1994)

**Figure 2**

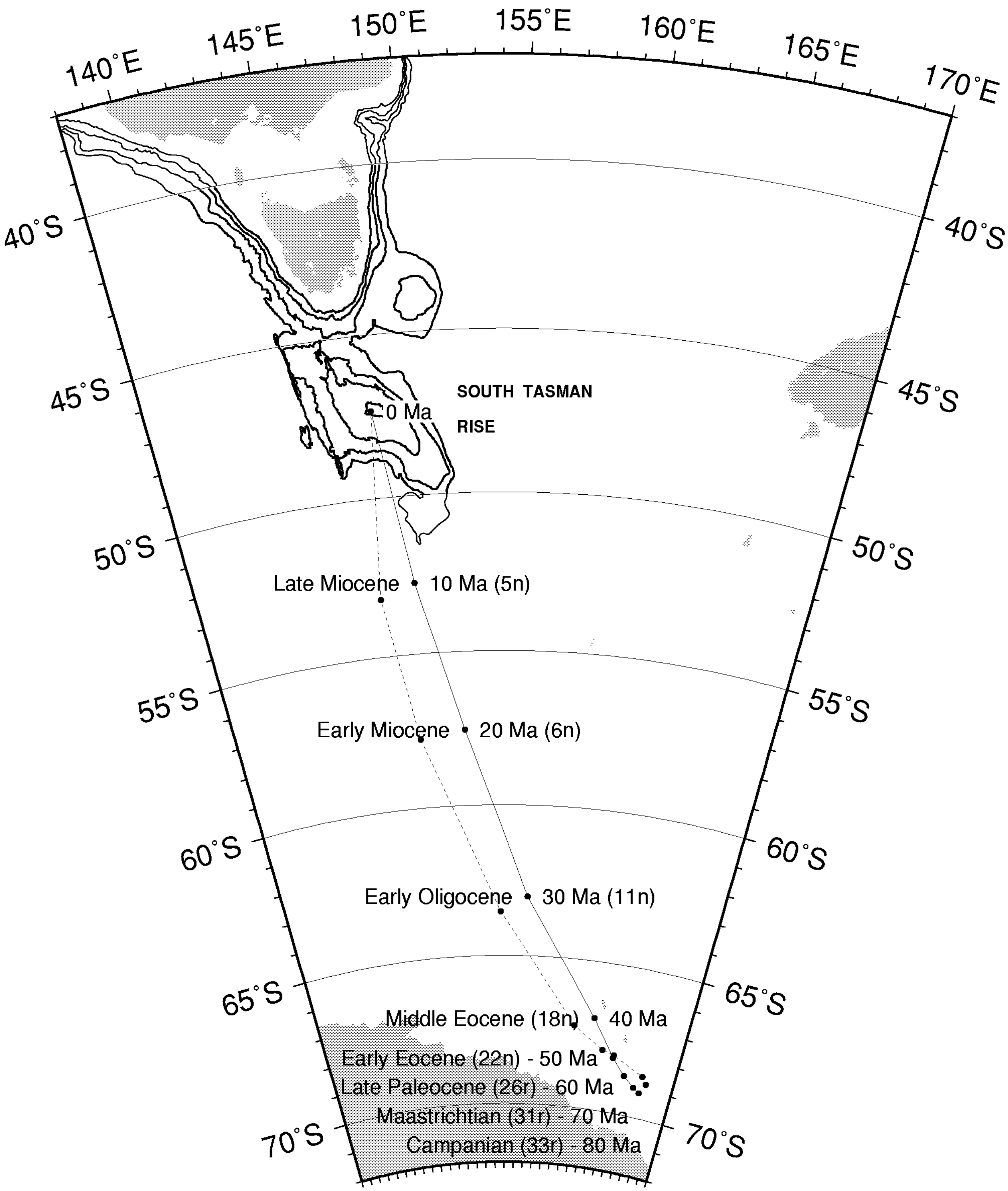

140°E
145°E
150°E
155°E
160°E
165°E
170°E
40°S
45°S
50°S
55°S
60°S
65°S
70°S
SOUTH TASMAN
RISE
0 Ma
Late Miocene
10 Ma (5n)
Early Miocene
20 Ma (6n)
Early Oligocene
30 Ma (11n)
Middle Eocene (18n)
40 Ma
Early Eocene (22n) - 50 Ma
Late Paleocene (26r) - 60 Ma
Maastrichtian (31r) - 70 Ma
Campanian (33r) - 80 Ma

**Figure 3**

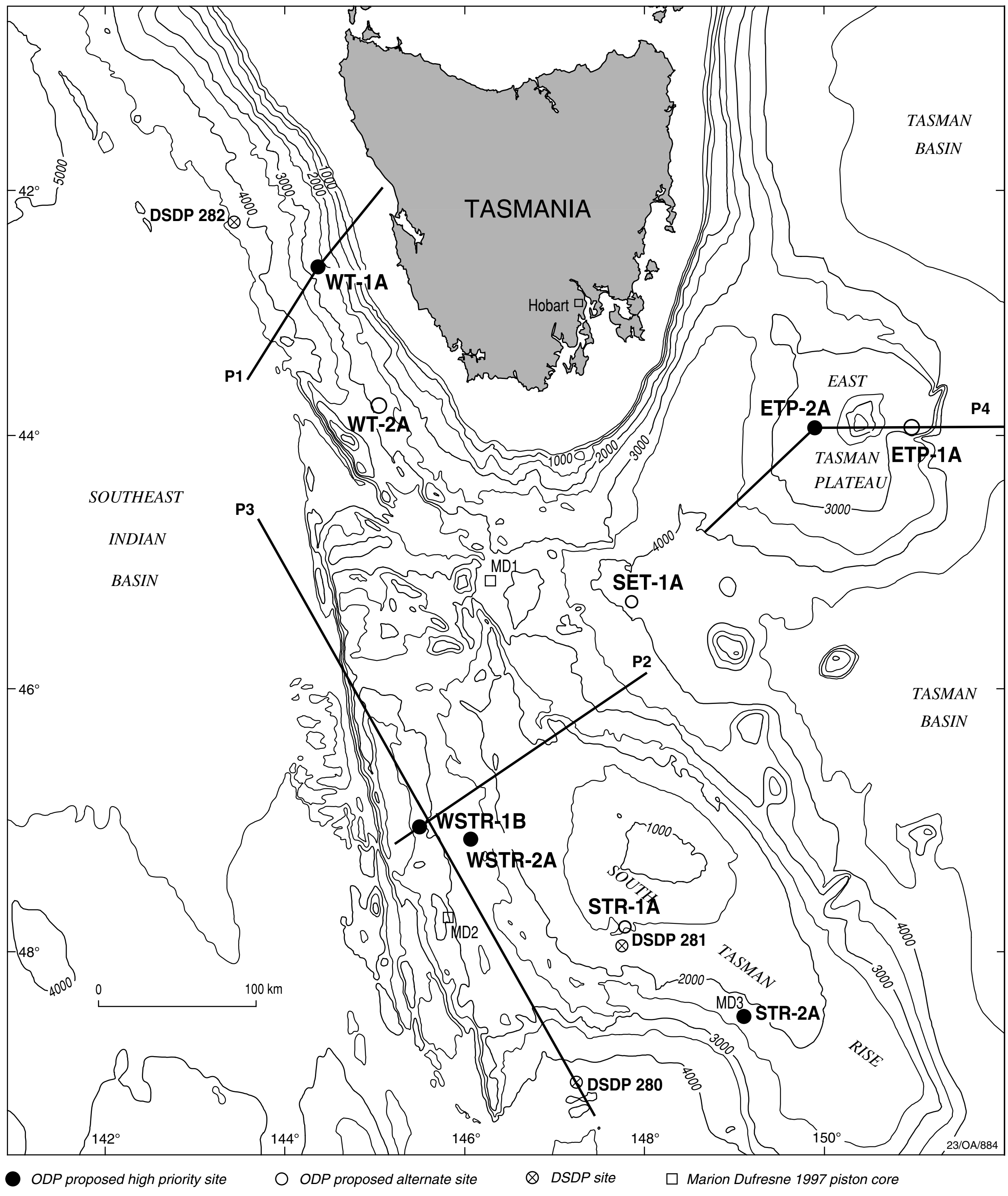

TASMAN
BASIN
TASMANIA
Hobart
42°
44°
46°
48°
5000
4000
3000
2000
1000
DSDP 282
WT-1A
P1
WT-2A
ETP-2A
P4
EAST
TASMAN
PLATEAU
ETP-1A
3000
SOUTHEAST
INDIAN
BASIN
P3
4000
MD1
SET-1A
P2
TASMAN
BASIN
WSTR-1B
WSTR-2A
1000
SOUTH
STR-1A
DSDP 281
TASMAN
MD2
2000
MD3
STR-2A
RISE
3000
4000
0
100 km
DSDP 280
142°
144°
146°
148°
150°
23/OA/884
ODP proposed high priority site
ODP proposed alternate site
DSDP site
Marion Dufresne 1997 piston core

**Figure 4**

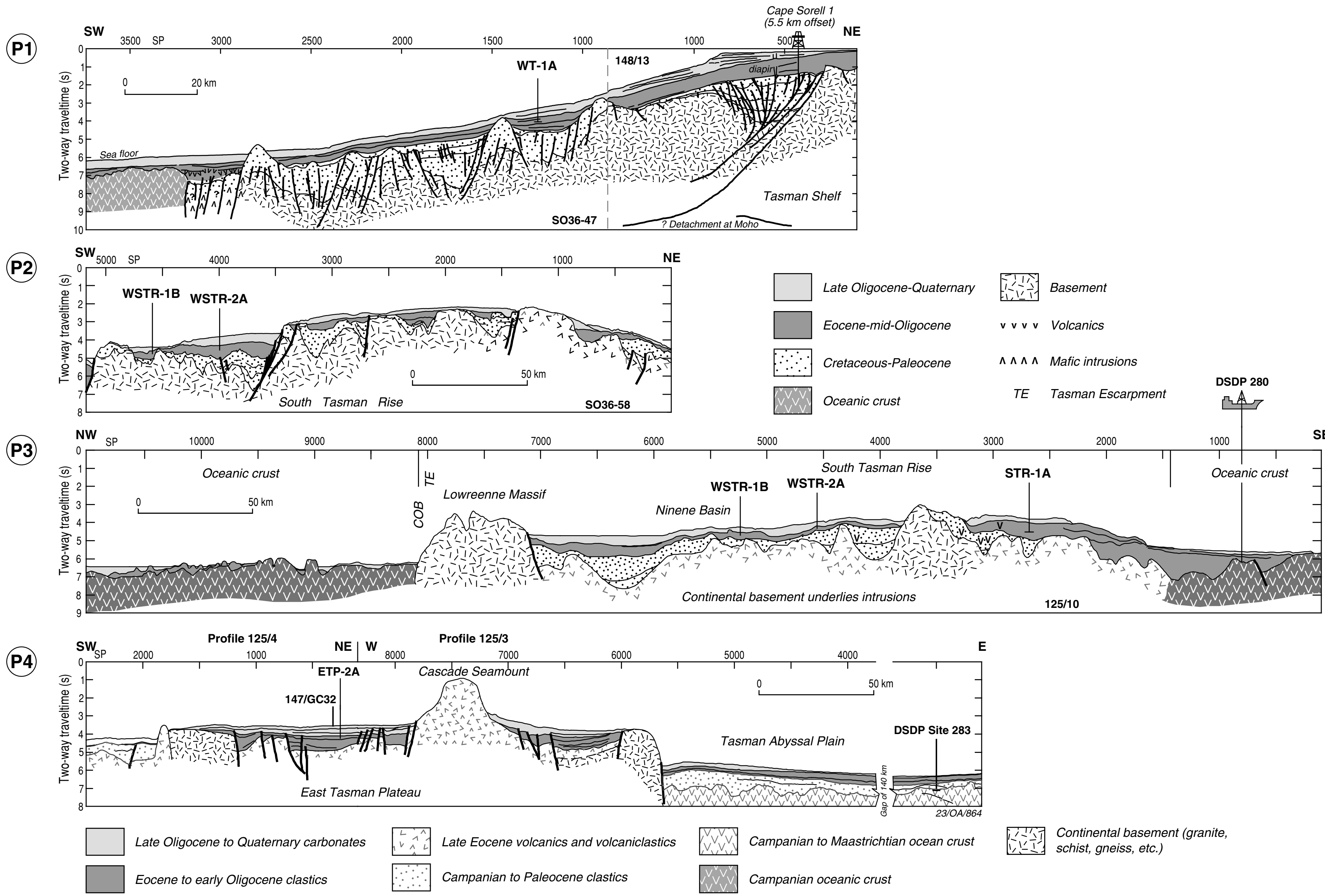

P1
SW
NE
SP
3500
3000
2500
2000
1500
1000
1000
500
Cape Sorell 1
(5.5 km offset)
Two-way traveltime (s)
0
20 km
WT-1A
148/13
diapir
Sea floor
Tasman Shelf
SO36-47
? Detachment at Moho
P2
SW
NE
5000
4000
3000
2000
1000
WSTR-1B
WSTR-2A
50 km
South Tasman Rise
SO36-58
Late Oligocene-Quaternary
Eocene-mid-Oligocene
Cretaceous-Paleocene
Oceanic crust
Basement
v v v v
Volcanics
Λ Λ Λ Λ
Mafic intrusions
TE
Tasman Escarpment
DSDP 280
P3
NW
SE
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
Oceanic crust
TE
COB
Lowreenne Massif
South Tasman Rise
Ninene Basin
WSTR-1B
WSTR-2A
STR-1A
Oceanic crust
Continental basement underlies intrusions
125/10
P4
SW
Profile 125/4
NE
W
Profile 125/3
E
2000
1000
8000
7000
6000
5000
4000
ETP-2A
Cascade Seamount
147/GC32
Tasman Abyssal Plain
DSDP Site 283
Gap of 140 km
East Tasman Plateau
23/OA/864
Late Oligocene to Quaternary carbonates
Eocene to early Oligocene clastics
Late Eocene volcanics and volcaniclastics
Campanian to Paleocene clastics
Campanian to Maastrichtian ocean crust
Campanian oceanic crust
Continental basement (granite, schist, gneiss, etc.)

**Figure 5**

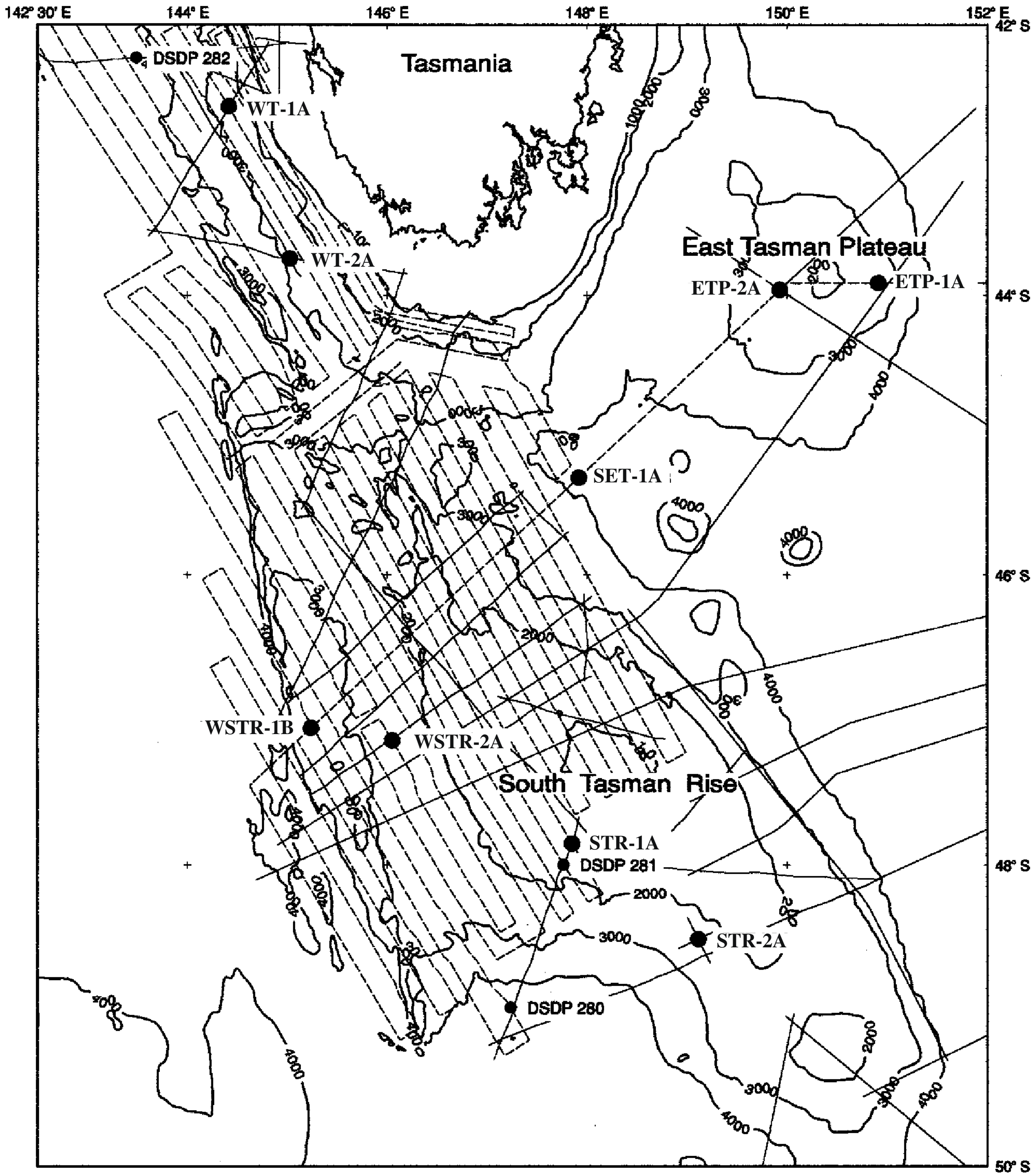

142° 30' E
144° E
146° E
148° E
150° E
152° E
42° S
44° S
46° S
48° S
50° S
Tasmania
East Tasman Plateau
South Tasman Rise
DSDP 282
WT-1A
WT-2A
ETP-2A
ETP-1A
SET-1A
WSTR-1B
WSTR-2A
STR-1A
DSDP 281
STR-2A
DSDP 280

**Figure 6**

## TABLES

**Table 1. DSDP Leg 29 sites in Leg 189 operational area.**

| Site | Lat (S) Long (E) | Water depth (m) | Penet-ration (m) | Total recov-ery* (%) | Maximum age of sediments | Basement type |
|---|---|---|---|---|---|---|
| 280 | 48°57.44´ 147°14.08´ | 4176 | 524 | 19% | Early to mid-Eocene | Intrusive basalt |
| 281 | 47°59.84´ 147°45.85´ | 1591 | 169 | 62% | Late Eocene | Late Carboniferous Paleozoic schist |
| 282 | 42°14.76´ 143°29.18´ | 4202 | 310 | 20% | Late Eocene | Pillow basalt |
| 283 | 43°54.60´ 154°16.96´ | 4729 | 592 | 10% | Paleocene | Altered basalt |

** Total recovery = core recovered divided by depth of maximum penetration*

**Table 2. Proposed Leg 189 Sites**

Five high-priority sites in **bold**, alternates in normal text

| Site Name | Lat (S) Long (E) | Water depth (m) | Penetr-ation (m) | Neogene/ Paleogene Thickness (m) | Brief site-specific objectives |
|---|---|---|---|---|---|
| **WT-1A** | 42°36.58´ 144°24.76´ | 2475 | 880 | 680/ 200 | Eocene-Holocene Indian Ocean section, for high-resolution biostratigraphy |
| WT-2A | 43°43.84´ 145°01.49´E | 2910 | 855 | 255/ 600 | Nearly complete Cenozoic Indian Ocean section |
| **WSTR-1B** | 47°03.93´ 145°14.21´ | 3580 | 250 | 250/ 0 | Upper Neogene Indian Ocean section, for high resolution biostratigraphy, with complete Quaternary |
| **WSTR-2A** | 47°09.06´ 146°02.98´ | 2710 | 780 | 470/ 310 | Eocene-Holocene Indian Ocean section, for high-resolution biostratigraphy, with complete lower Neogene |
| STR-1A | 47°51.22´ 147°51.05´ | 1465 | 600 | 180/ 420 | Complete middle Eocene to lower Oligocene section for high-resolution biostratigraphy |
| **STR-2A** | 48°30.00´ 149°07.00´ | 2150 | 940 | 255/ 685 | Eocene to lower Oligocene, and upper Oligocene to Holocene section |
| SET-1A | 45°18.62´ 147°55.16´ | 4060 | 500 | 400/ 100 | Complete Neogene Pacific Ocean drift section |
| **ETP-2A** | 43°57.60´ 149°55.70´ | 2630 | 640 | 495/ 145 | Eocene-Holocene Pacific Ocean section for high resolution biostratigraphy |
| ETP-01A | 43°54.60´ 150°54.60´ | 2790 | 615 | 365/ 250 | Complete Neogene Pacific Ocean section; complete Eocene-lower Oligocene marine section |

TABLE 3. Site Time Estimate

| Site No. | Location Lat/Long | Water Depth | Preliminary Operations Plan | Transit (days) | Drilling (days) | Logging (days) | Total On-site |
|---|---|---|---|---|---|---|---|
| **PRIMARY SITES** | | | | | | | |
| Hobart | | | Transit 200 nmi from Hobart to WT-1A @ 9.0 kt | 0.9 | | | |
| WT-1A | 42°36.58' S | 2475m | Triple APC to 200 mbsf, ADARA, XCB first hole to 500 mbsf | | 9.7 | 1.4 | 11.1 |
| | 144°24.76' E | | Drill to 500 mbsf, RCB to 880 mbsf | | | | |
| | | | Wireline log | | | | |
| | | | Transit 270 nmi from WT-1A to WSTR-1B @ 9.0 kt | 1.3 | | | |
| WSTR-1B | 47°03.93' S | 3580m | Triple APC/XCB to 250 mbsf | | 5.3 | 0.0 | 5.3 |
| | 145°14.21' E | | | | | | |
| | | | Transit 34 nmi from WSTR-1B to WSTR-2A @ 9.0 kt | 0.2 | | | |
| WSTR-2A | 47°09.06' S | 2710m | Triple APC to 200 mbsf, ADARA, XCB first hole to 500 mbsf | | 9.3 | 1.3 | 10.6 |
| | 146°02.98' E | | Drill to 500 mbsf, RCB to 780 mbsf | | | | |
| | | | Wireline log | | | | |
| | | | Transit 148 nmi from WSTR-2A to STR-2A @ 9.0 kt | 0.7 | | | |
| STR-2A | 48°30.00' S | 2150m | Triple APC to 200 mbsf, ADARA, XCB first hole to 500 mbsf | | 9.2 | 1.4 | 10.6 |
| | 149°07.00' E | | Drill to 500 mbsf, RCB to 940 mbsf | | | | |
| | | | Wireline log | | | | |
| | | | Transit 275 nmi from STR-2A to ETP-2A @ 9.0 kt | 1.3 | | | |
| ETP-2A | 43°57.60' S | 2630m | Double APC to 200 mbsf, ADARA, XCB first hole to 500 mbsf | | 6.8 | 1.2 | 8.0 |
| | 149°55.70' E | | Drill to 500 mbsf, RCB to 640 mbsf | | | | |
| | | | Wireline log | | | | |
| Townsville | | | Transit 1750 nmi from ETP-2A to Townsville @ 9.0 kt | 8.1 | | | |
| | | | | **12.4** | **40.3** | **5.3** | **45.6** |
| | | | | **TOTAL DAYS:** | **58.0** | | |
| **ALTERNATE SITES** | | | | | | | |
| WT-2A | 43° 43.84' S | 2910m | Triple APC to 200 mbsf, ADARA, XCB first hole to 500 mbsf | | 10.3 | 1.4 | 11.7 |
| | 145° 01.49' E | | Drill to 450 mbsf, RCB to 855 mbsf | | | | |
| | | | Wireline log | | | | |
| SET-1A | 45° 18.62' S | 4060m | Triple APC to 200 mbsf, ADARA, XCB first hole to 500 mbsf | | 7.1 | 1.2 | 8.3 |
| | 147° 55.16' E | | Wireline log | | | | |
| ETP-1A | 43° 54.60' S | 2790m | Triple APC to 200 mbsf, ADARA, XCB first to 500 mbsf | | 8.1 | 1.2 | 9.3 |
| | 150° 54.60' E | | Drill to 450 mbsf, RCB to 615 mbsf | | | | |
| | | | Wireline log | | | | |
| STR-1A | 47° 51.22' S | 1465m | Triple APC to 200 mbsf, ADARA, XCB first hole to 500 mbsf | | 6.7 | 1.0 | 7.7 |
| | 147° 51.05' E | | Drill to 450 mbsf, RCB to 600 mbsf | | | | |
| | | | Wireline log | | | | |

**DATE: 29 June 1999** **FILE: I:\ DATA \ DSD_INFO \ LEGS\189\Prop485.xls** **BY: Ron Grout**

## SITE SUMMARIES

**Site:** ETP-1A

**Priority:** 2
**Position**: 43°54.60´S, 150°54.60´E
**Water Depth:** 2790 m
**Sediment Thickness:** 1200 m
**Target Drilling Depth:** 615 m
**Approved Maximum Penetration:** 615 m
**Seismic Coverage:** *Tasmante* (*L'Atalante*) 125-3

**Objectives:** The objectives of ETP-1A include

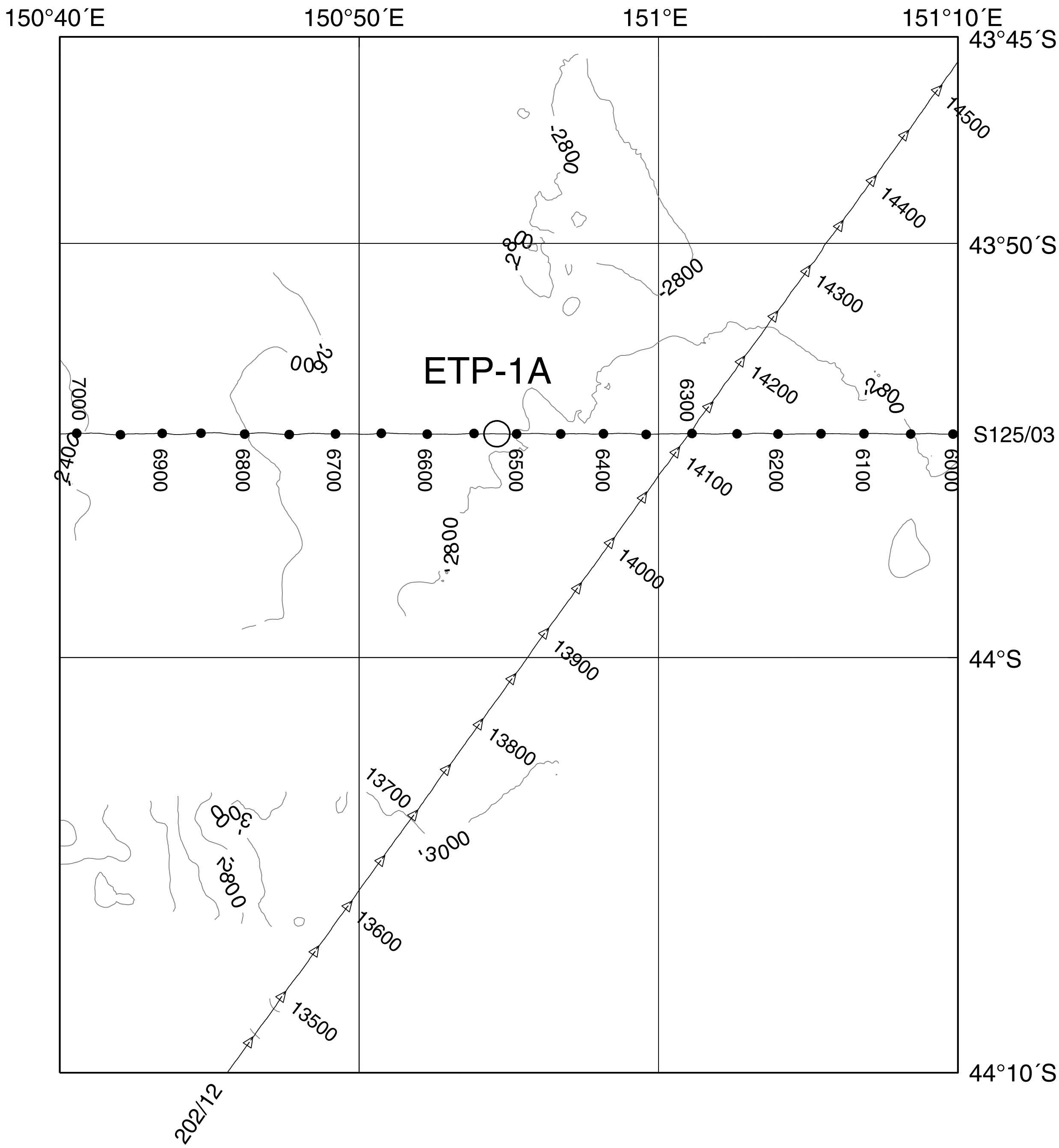
1. Coring and logging a complete Neogene Pacific Ocean pelagic carbonate section

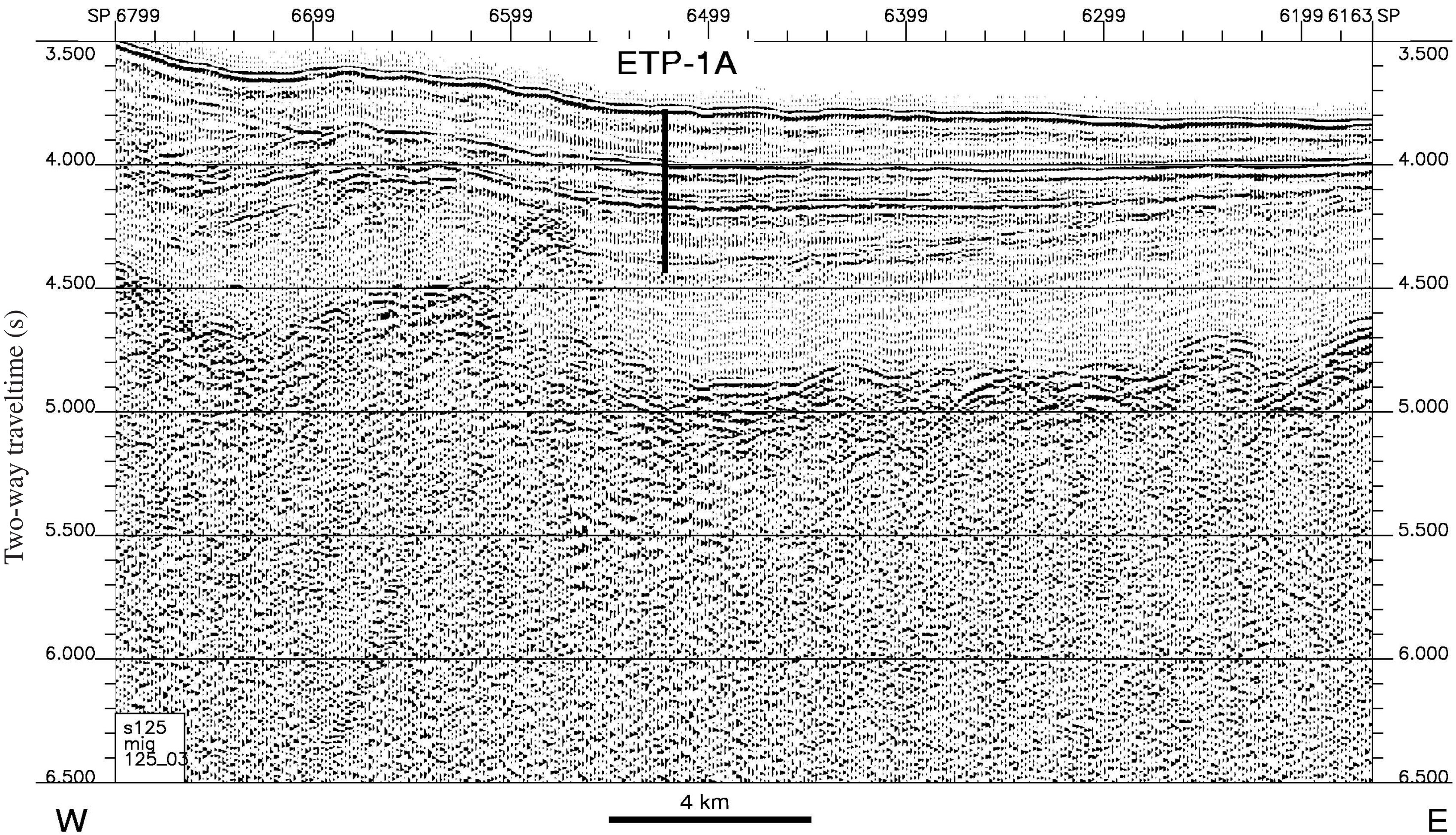
2. Coring and logging a complete Eocene-lower Oligocene detrital(?) section

**Drilling Program:** Triple APC, XCB, RCB

**Logging and Downhole Operations:** Triple combo, FMS-Sonic, GHMT

**Nature of Sediment Anticipated:** Neogene ooze and chalk (365 m); Eocene mudstone(?)


150°40´E
150°50´E
151°E
151°10´E
43°45´S
43°50´S
44°S
44°10´S
ETP-1A
S125/03
202/12
7000
6900
6800
6700
6600
6500
6400
6300
6200
6100
6000
14500
14400
14300
14200
14100
14000
13900
13800
13700
13600
13500
-2800
-2600
-3000
-2400


SP 6799
6699
6599
6499
6399
6299
6199 6163 SP
ETP-1A
3.500
4.000
4.500
5.000
5.500
6.000
6.500
Two-way traveltime (s)
s125
mig
125_03
4 km
W
E

**Site:** ETP-2A

**Priority:** 1
**Position:** 43°57.60´S, 149°55.70´E
**Water Depth:** 2630 m
**Sediment Thickness:** At least 1400 m
**Target Drilling Depth:** 640 m
**Approved Maximum Penetration:** 735 m
**Seismic Coverage:** *Tasmante* (*L'Atalante*) 125-4, AGSO *Rig Seismic* 202-1 and 202-13

**Objectives:** The objectives of ETP-2A include

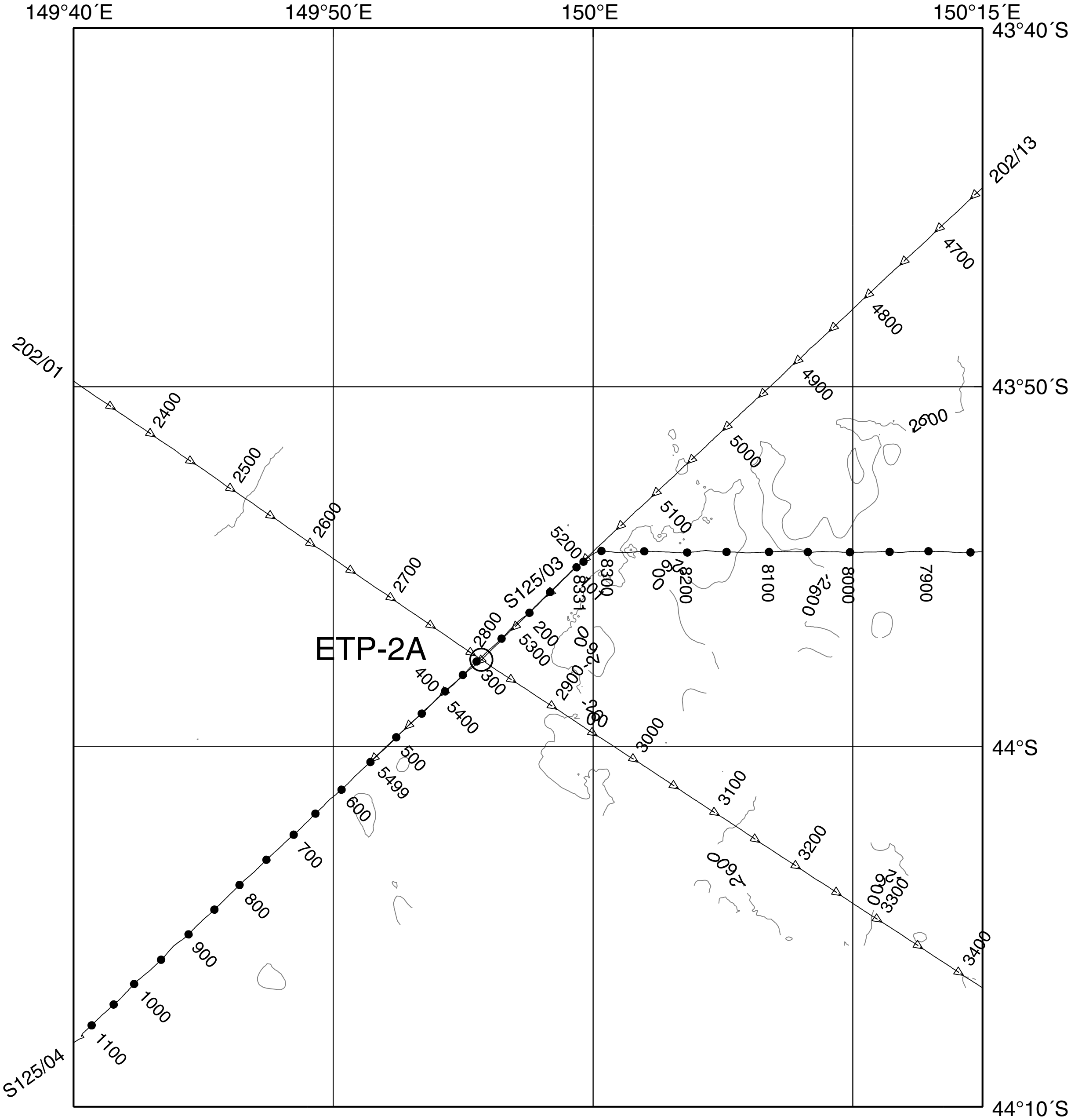
1. Coring and logging an Oligocene-Holocene Pacific Ocean pelagic carbonate section for high-resolution biostratigraphy and paleoceanography (effects of East Australian Current)

2. Coring and logging an Eocene mudstone(?) section for paleoceanographic and paleoclimatologic study

**Drilling Program:** Double APC, XCB, RCB

**Logging and Downhole Operations:** Triple combo, FMS-Sonic, GHMT

**Nature of Sediment Anticipated:** Neogene ooze and chalk (495 m); Eocene mudstone


149°40´E
149°50´E
150°E
150°15´E
43°40´S
43°50´S
44°S
44°10´S
202/13
202/01
S125/03
S125/04
ETP-2A
2400
2500
2600
2700
2800
2900
3000
3100
3200
3300
3400
4700
4800
4900
5000
5100
5200
5300
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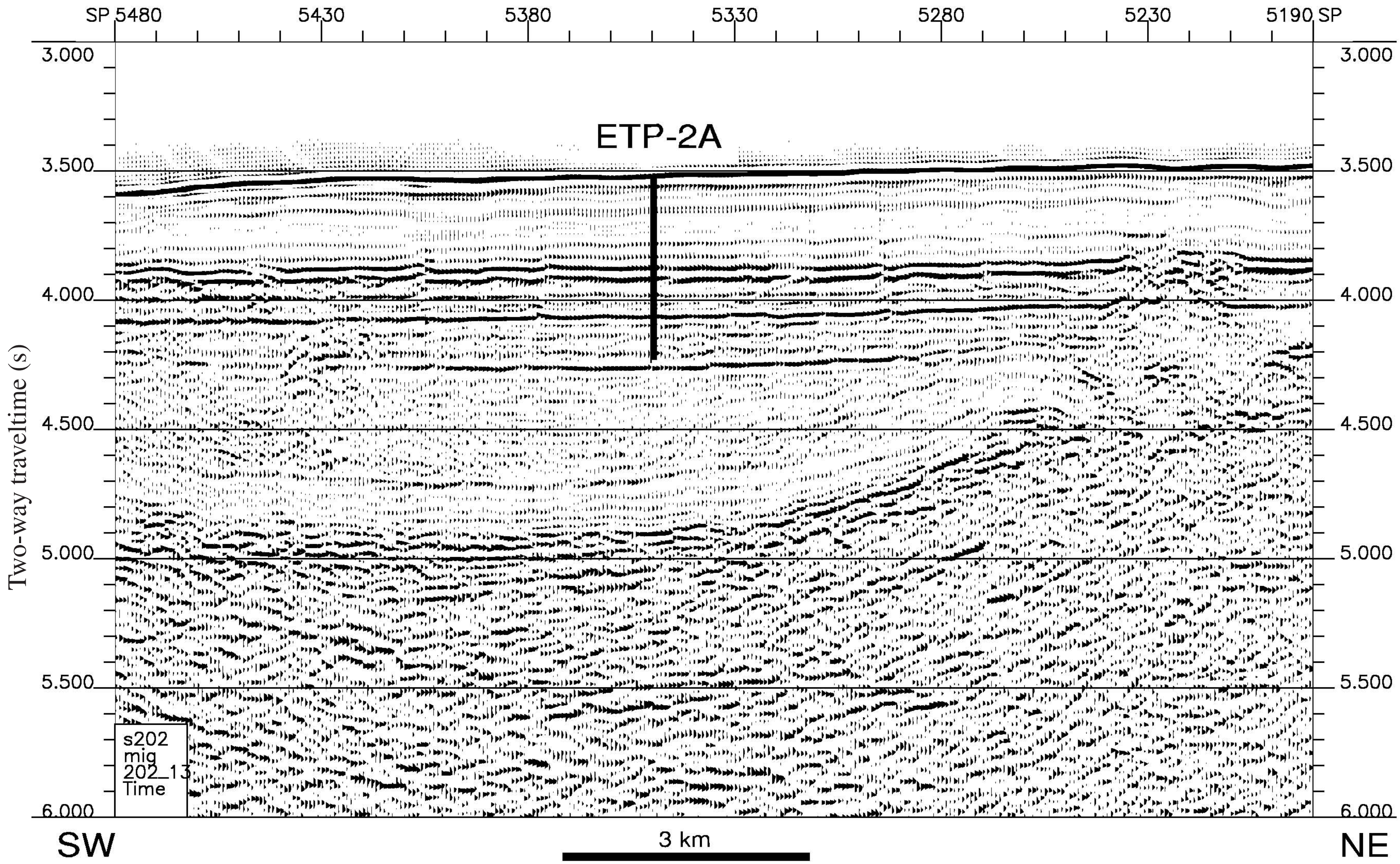
700
800
900
1000
1100


SP 5480
5430
5380
5330
5280
5230
5190 SP
ETP-2A
Two-way traveltime (s)
3.000
3.500
4.000
4.500
5.000
5.500
6.000
s202
mig
202_13
Time
SW
3 km
NE

**Site:** SET-1A

**Priority:** 2
**Position**: 45°18.62´S, 147°55.16´E
**Water Depth:** 4060 m
**Sediment Thickness:** 1800 m
**Target drilling Depth:** 500 m
**Approved Maximum Penetration:** 500 m
**Seismic Coverage:** *Tasmante* (*L'Atalante*) 125-4

**Objectives**: The objectives of SET-1A include

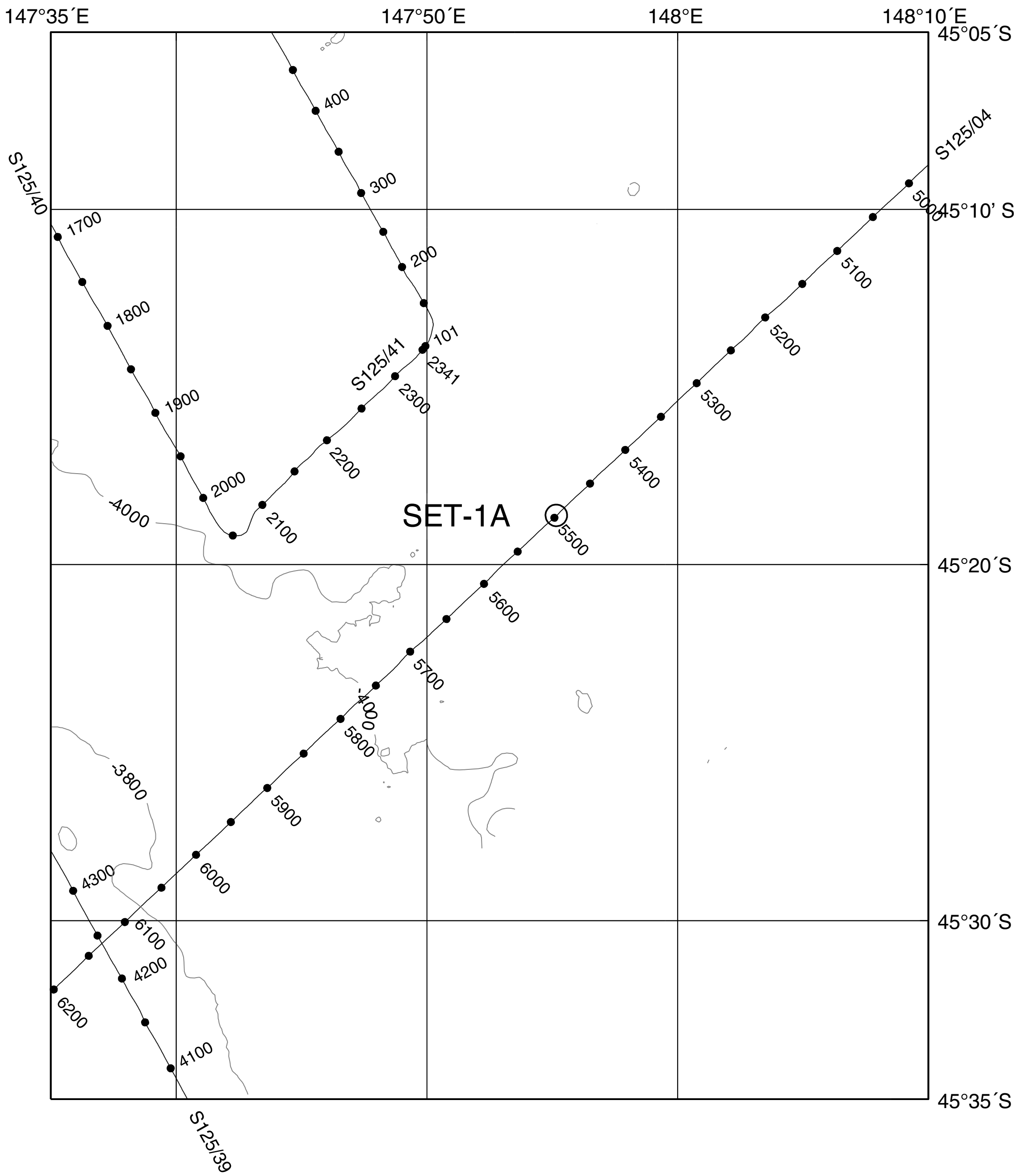
1. Coring and logging a complete Eocene-Neogene Pacific Ocean drift section

2. Determining climate, sea-level, and tectonic controls on abyssal sediment supply

**Drilling Program:** Triple APC, XCB, RCB

**Logging and Downhole Operations:** Triple combo, FMS-Sonic, GHMT

**Nature of Sediment Anticipated:** Neogene ooze and chalk (400 m); Eocene mudstone or chalk


147°35´E
147°50´E
148°E
148°10´E
45°05´S
45°10' S
45°20´S
45°30´S
45°35´S
SET-1A
S125/04
S125/40
S125/41
S125/39
-4000
-3800
-4000
400
300
200
101
2341
2300
2200
2100
2000
1900
1800
1700
5000
5100
5200
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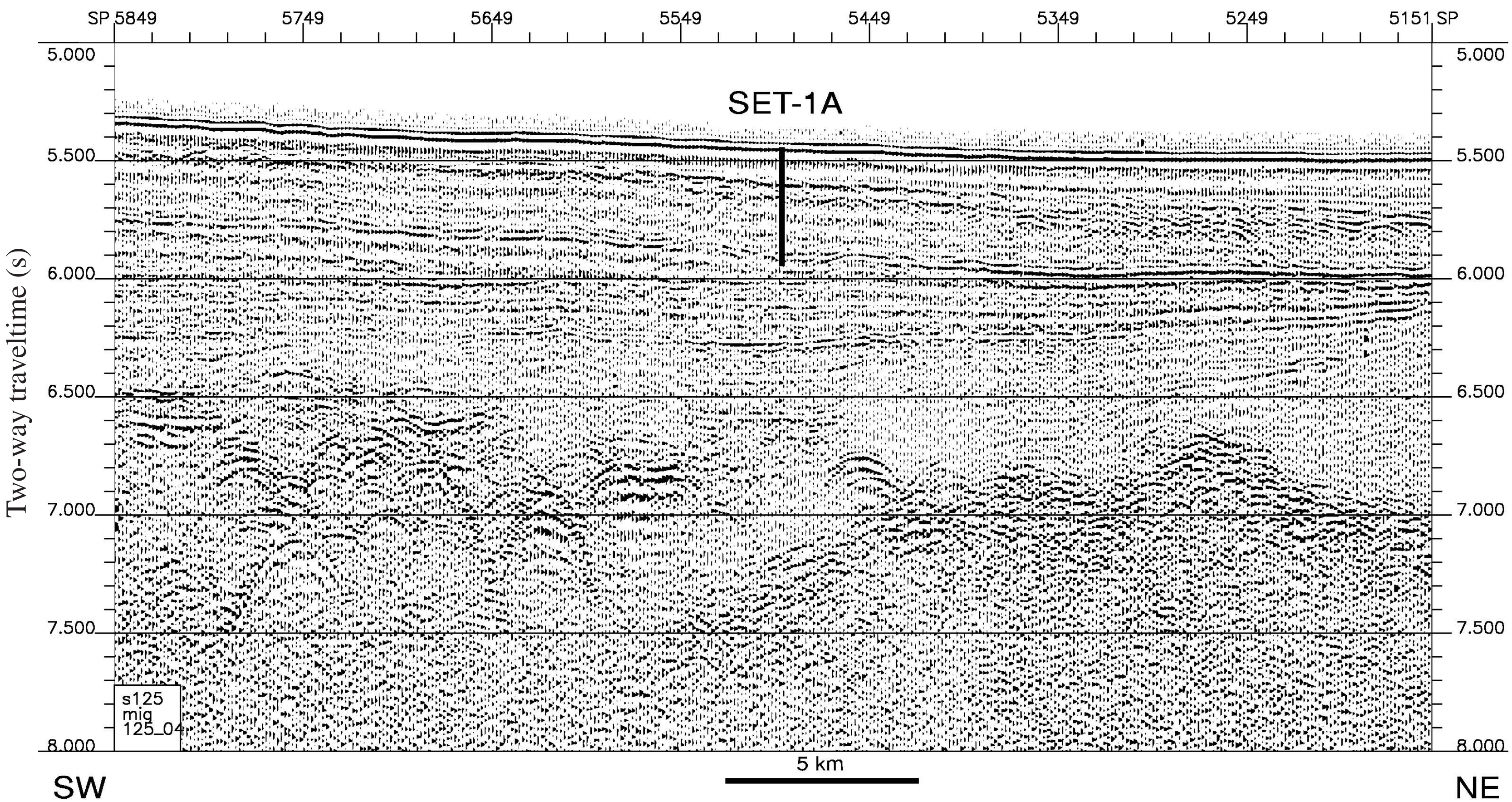
5400
5500
5600
5700
5800
5900
6000
6100
6200
4300
4200
4100


SP 5849
5749
5649
5549
5449
5349
5249
5151 SP
SET-1A
Two-way traveltime (s)
5.000
5.500
6.000
6.500
7.000
7.500
8.000
s125
mig
125_04
5 km
SW
NE

**Site:** STR-1A

**Priority:** 2
**Position**: 47°51.22´S, 147°51.05´E
**Water Depth:** 1465 m
**Sediment Thickness:** At least 1300 m
**Target Drilling Depth:** 600 m
**Approved Maximum Penetration:** 600 m
**Seismic Coverage:** *Tasmante* (*L'Atalante*) 125-31, *Sonne* SO36B-51

**Objectives:** The objectives of STR-1A are to sample

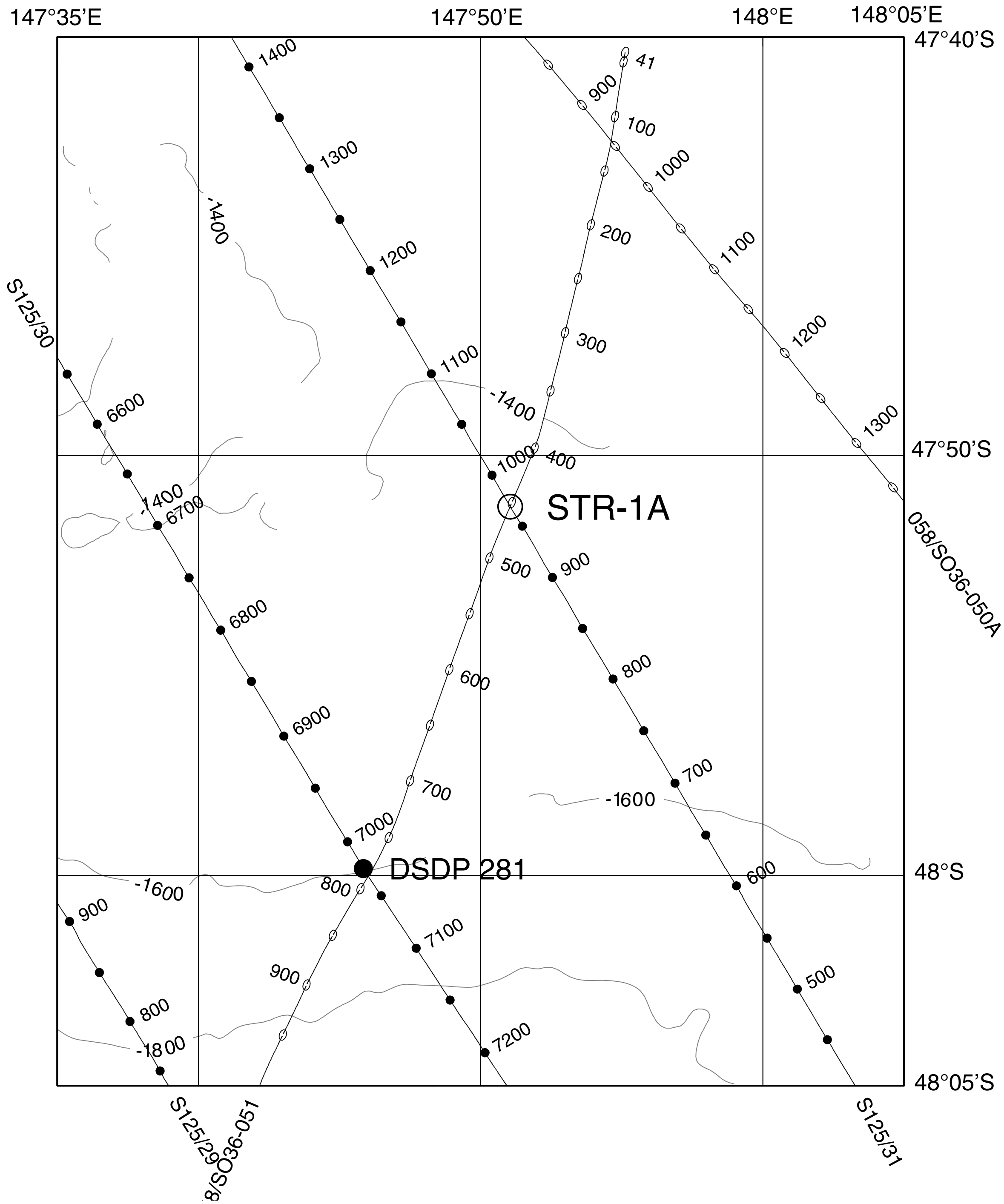
1. Complete middle Eocene to lower Oligocene section for paleoceanographic/paleoclimatologic study

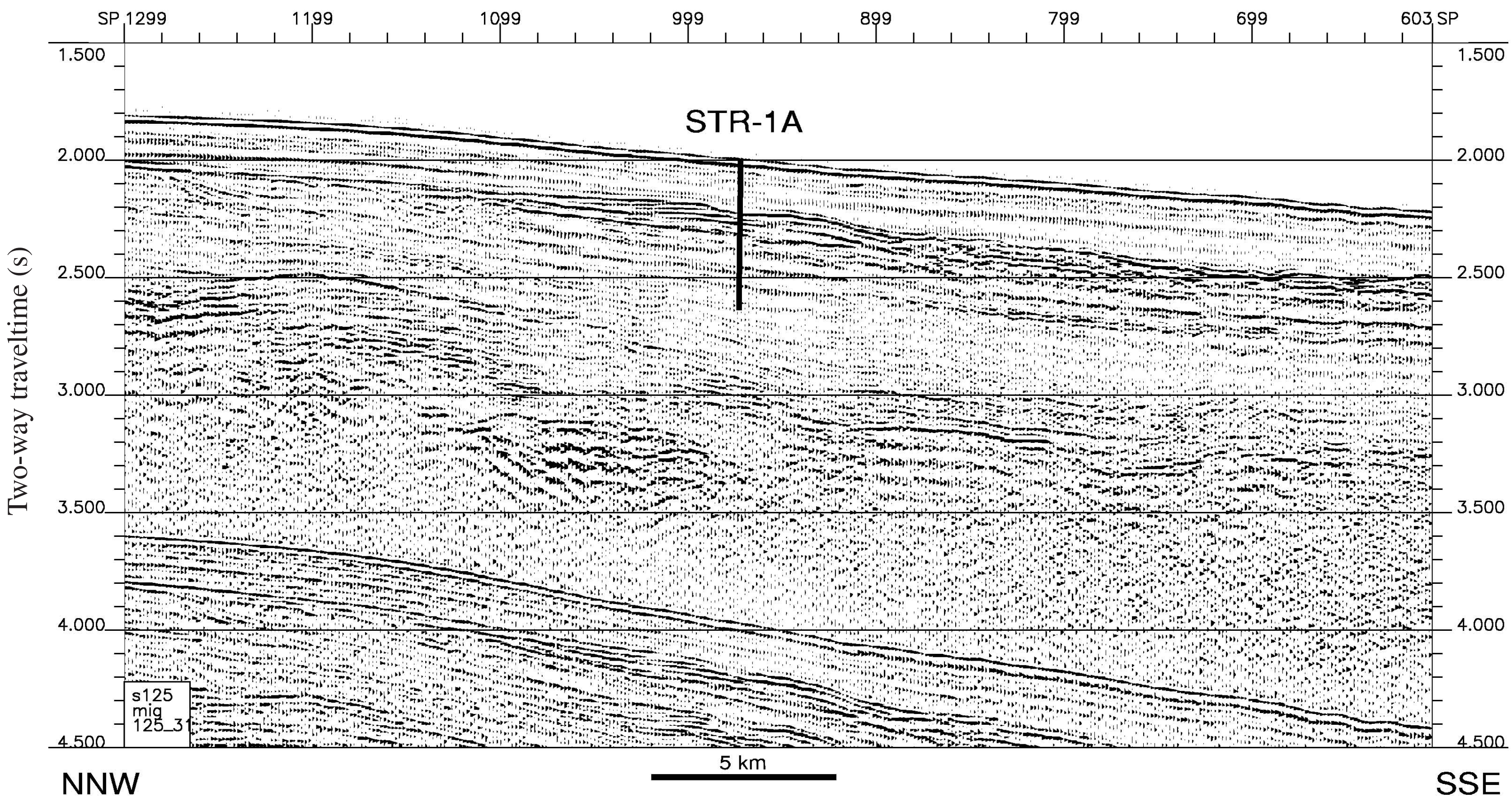
2. Neogene pelagic carbonates for stratigraphic/paleoceanographic study

**Drilling Program:** Triple APC, XCB, RCB

**Logging and Downhole Operations:** Triple combo, FMS-Sonic, GHMT

**Nature of Sediment Anticipated:** Neogene ooze and chalk (180 m); Paleogene mudstone


147°35'E
147°50'E
148°E
148°05'E
47°40'S
47°50'S
48°S
48°05'S
STR-1A
DSDP 281
S125/30
S125/29
S125/31
058/SO36-050A
8/SO36-051
-1400
-1600
-1800


SP 1299
1199
1099
999
899
799
699
603 SP
STR-1A
1.500
2.000
2.500
3.000
3.500
4.000
4.500
Two-way traveltime (s)
s125
mig
125_31
5 km
NNW
SSE

**Site:** STR-2A

**Priority:** 1
**Position**: 48°30.00´S, 149°07.00´E
**Water Depth:** 2150 m
**Sediment Thickness:** At least 2500 m
**Target Drilling Depth:** 940 m
**Approved Maximum Penetration:** 640 m (changed to 1000 m pending PPSP approval)
**Seismic Coverage:** AGSO *Rig Seismic* 202-05, 202-06

**Objectives:** The objectives of STR-2A include

1. Coring and logging an Eocene to early Oligocene prograding rift section

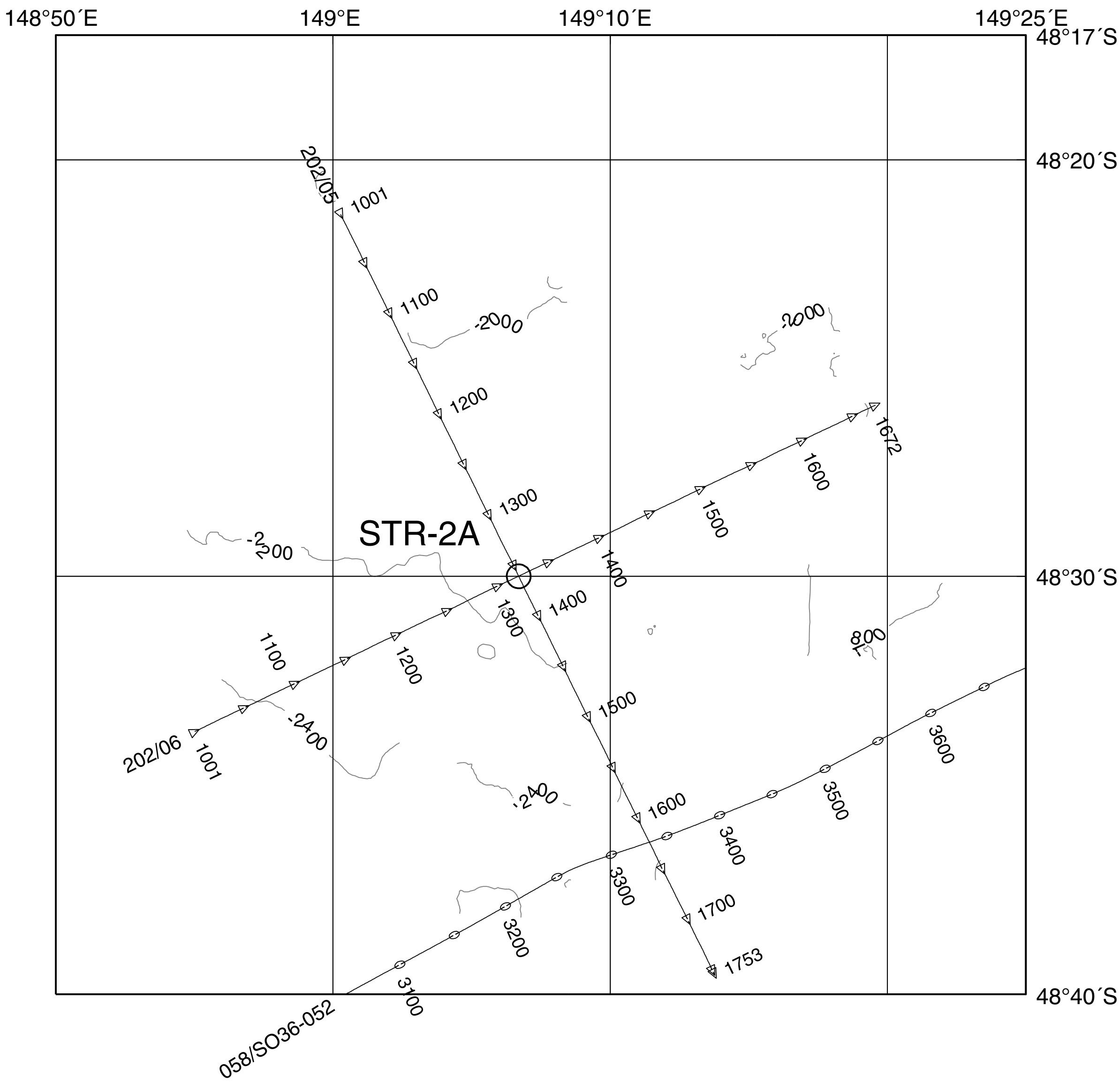
2. Coring and logging a late Oligocene to Holocene section to study paleoceanography and paleoclimate in an area where the early effects of the deep-water Circum-Antarctic Current should be apparent

3. Testing the record of Circum-Antarctic flow against the Milankovitch orbital model

**Drilling Program:** Triple APC, XCB, RCB

**Logging and Downhole Operations:** Triple combo, FMS-Sonic, GHMT

**Nature of Sediment Anticipated:** Neogene ooze and chalk (255 m); Eocene mudstone


148°50´E
149°E
149°10´E
149°25´E
48°17´S
48°20´S
48°30´S
48°40´S
STR-2A
202/05
202/06
058/SO36-052
1001
1100
1200
1300
1400
1500
1600
1672
1700
1753
3100
3200
3300
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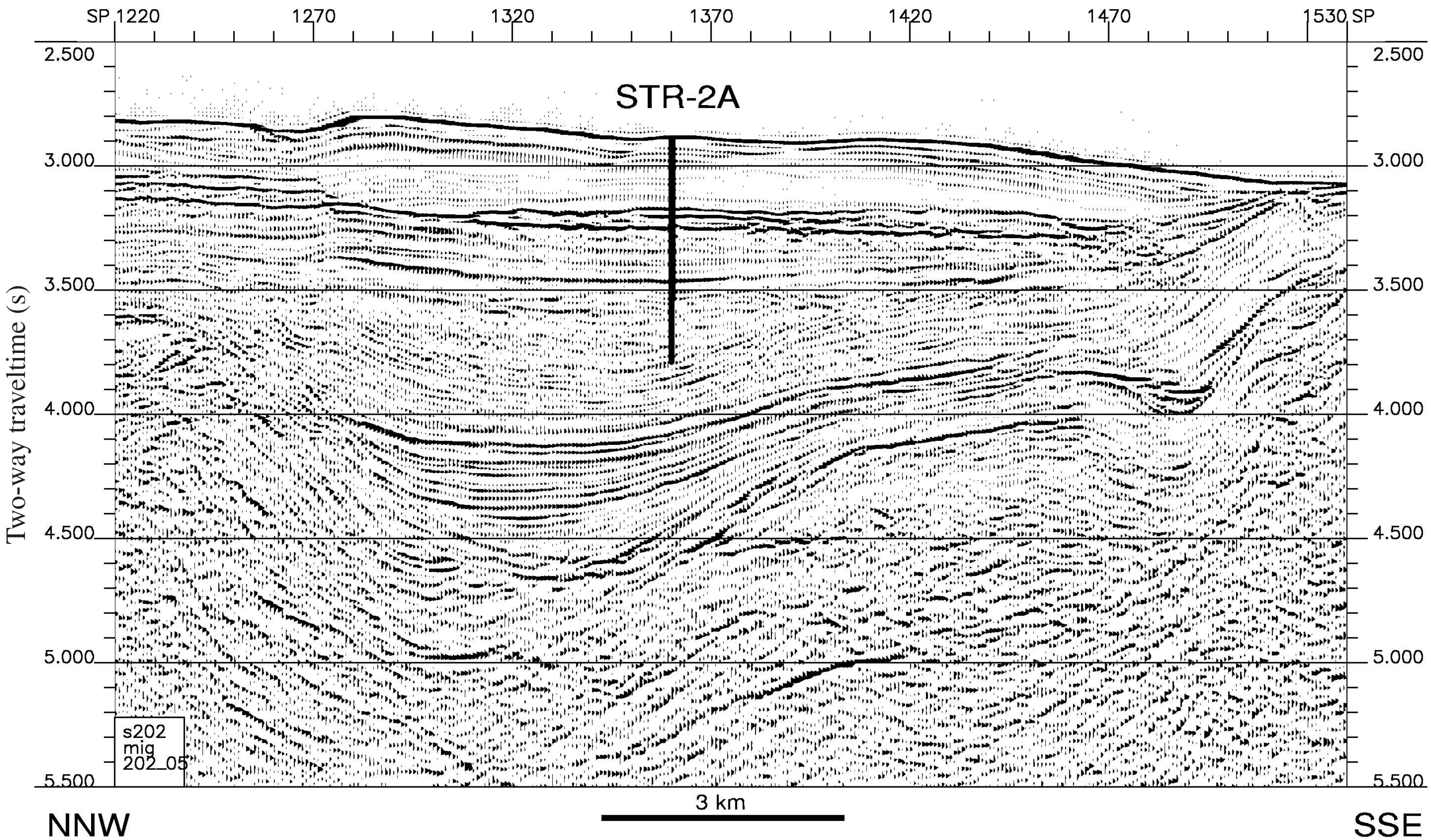
3500
3600
-2000
-2200
-2400
-1800


SP 1220
1270
1320
1370
1420
1470
1530 SP
STR-2A
Two-way traveltime (s)
2.500
3.000
3.500
4.000
4.500
5.000
5.500
s202
mig
202_05
3 km
NNW
SSE

**Site:** WSTR-1B

**Priority:** 1
**Position**: 47°03.93´S, 145°14.21´E
**Water Depth:** 3580 m
**Sediment Thickness:** At least 1600 m
**Target Drilling Depth:** 250 m
**Approved Maximum Penetration:** 680 m
**Seismic Coverage:** *Tasmante* (*L'Atalante*) 125-4, 125-9

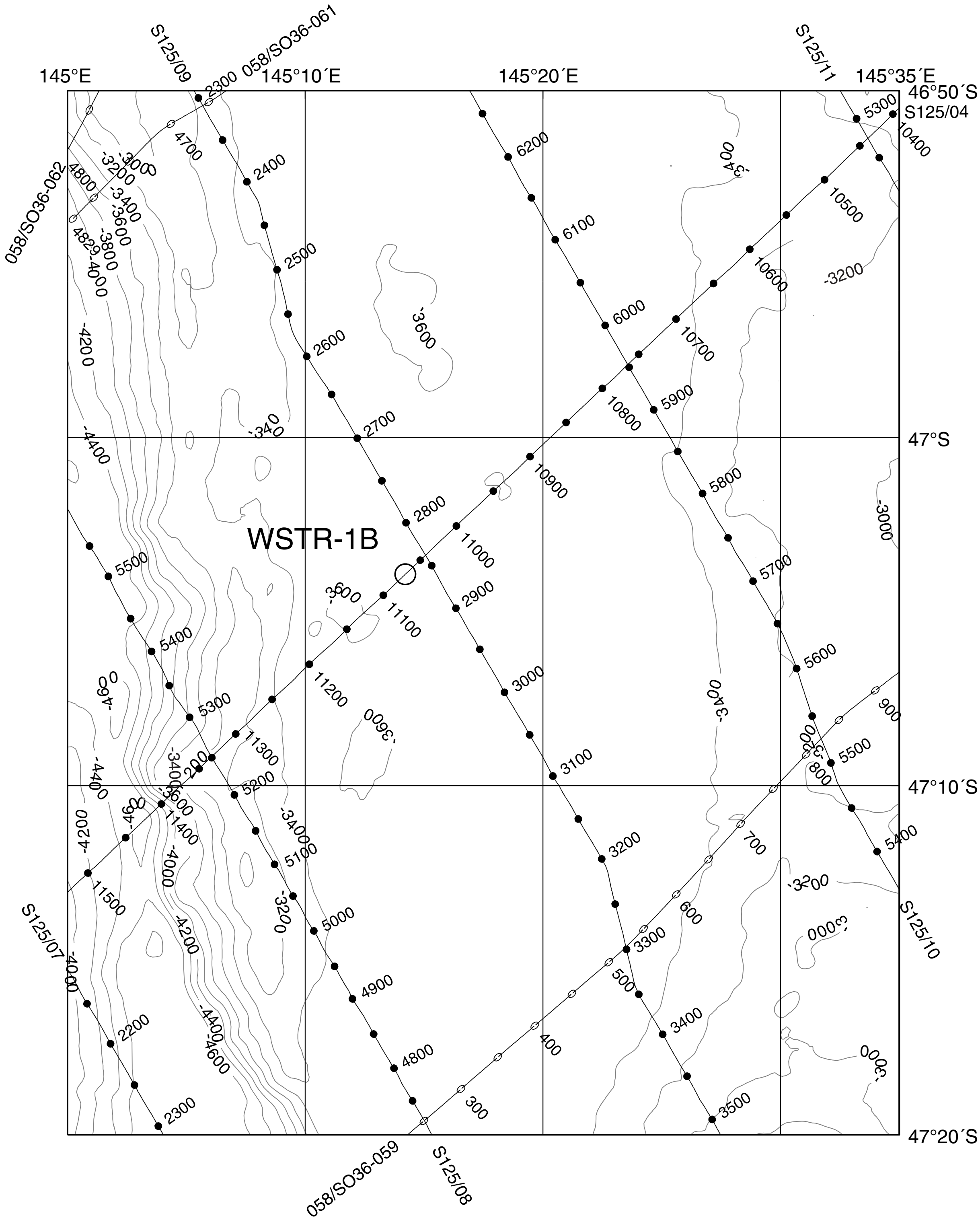
**Objectives**:

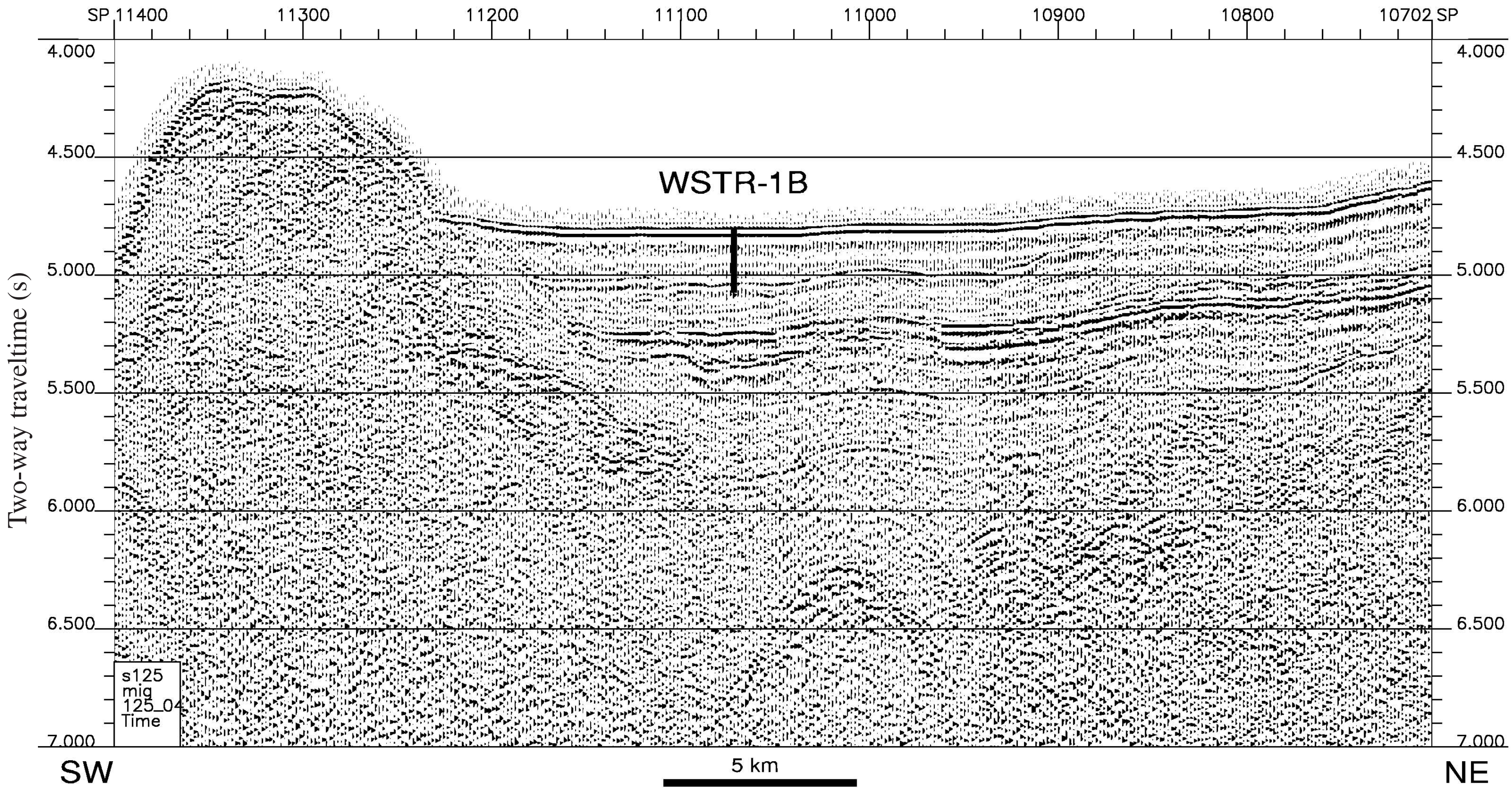
The objective of WSTR-1B is to core and log a late Neogene and a complete Quaternary Indian Ocean section for high-resolution biostratigraphic study.

**Drilling Program:** Triple APC

**Logging and Downhole Operations:** None

**Nature of Sediment Anticipated:** upper Neogene ooze and chalk


145°E
145°10´E
145°20´E
145°35´E
46°50´S
47°S
47°10´S
47°20´S
WSTR-1B
S125/09
058/SO36-061
058/SO36-062
S125/11
S125/04
S125/07
S125/08
058/SO36-059
S125/10


SP 11400
11300
11200
11100
11000
10900
10800
10702 SP
4.000
4.500
5.000
5.500
6.000
6.500
7.000
Two-way traveltime (s)
WSTR-1B
s125
mig
125_04
Time
SW
5 km
NE

**Site:** WSTR-2A

**Priority:** 1
**Position**: 47°09.06´S, 146°02.98´E
**Water Depth:** 2710 m
**Sediment Thickness:** At least 2200 m
**Target drilling Depth:** 780 m
**Approved Maximum Penetration:** 580 m (changed to 900 m pending PPSP approval)
**Seismic Coverage:** *Tasmante* (*L'Atalante*) 125-14, *Sonne* SO36B-58

**Objectives:** The objectives of WSTR-2A include

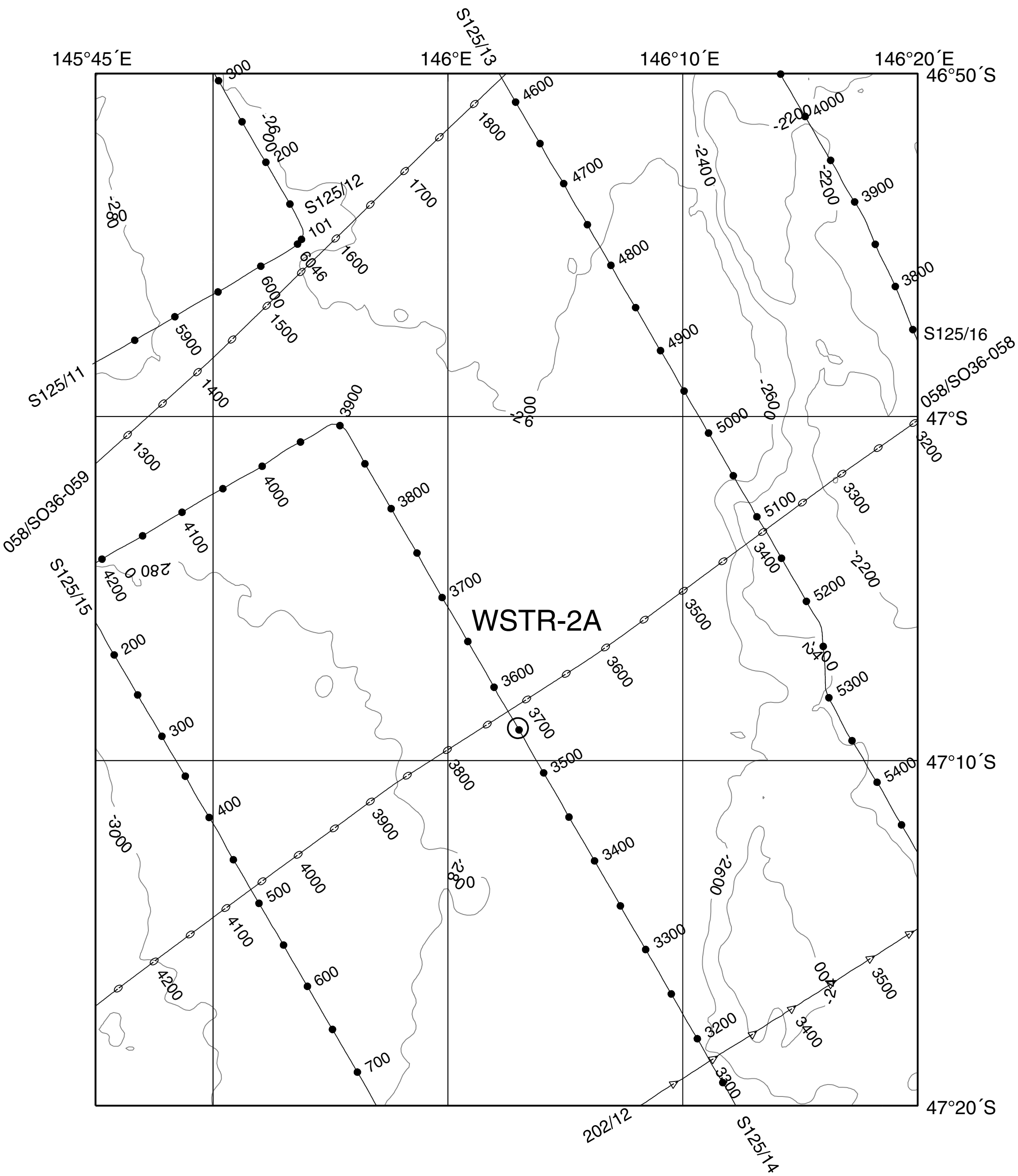
1. Coring and logging Oligocene to Holocene and complete lower Neogene Indian Ocean pelagic carbonate section for high-resolution biostratigraphic study

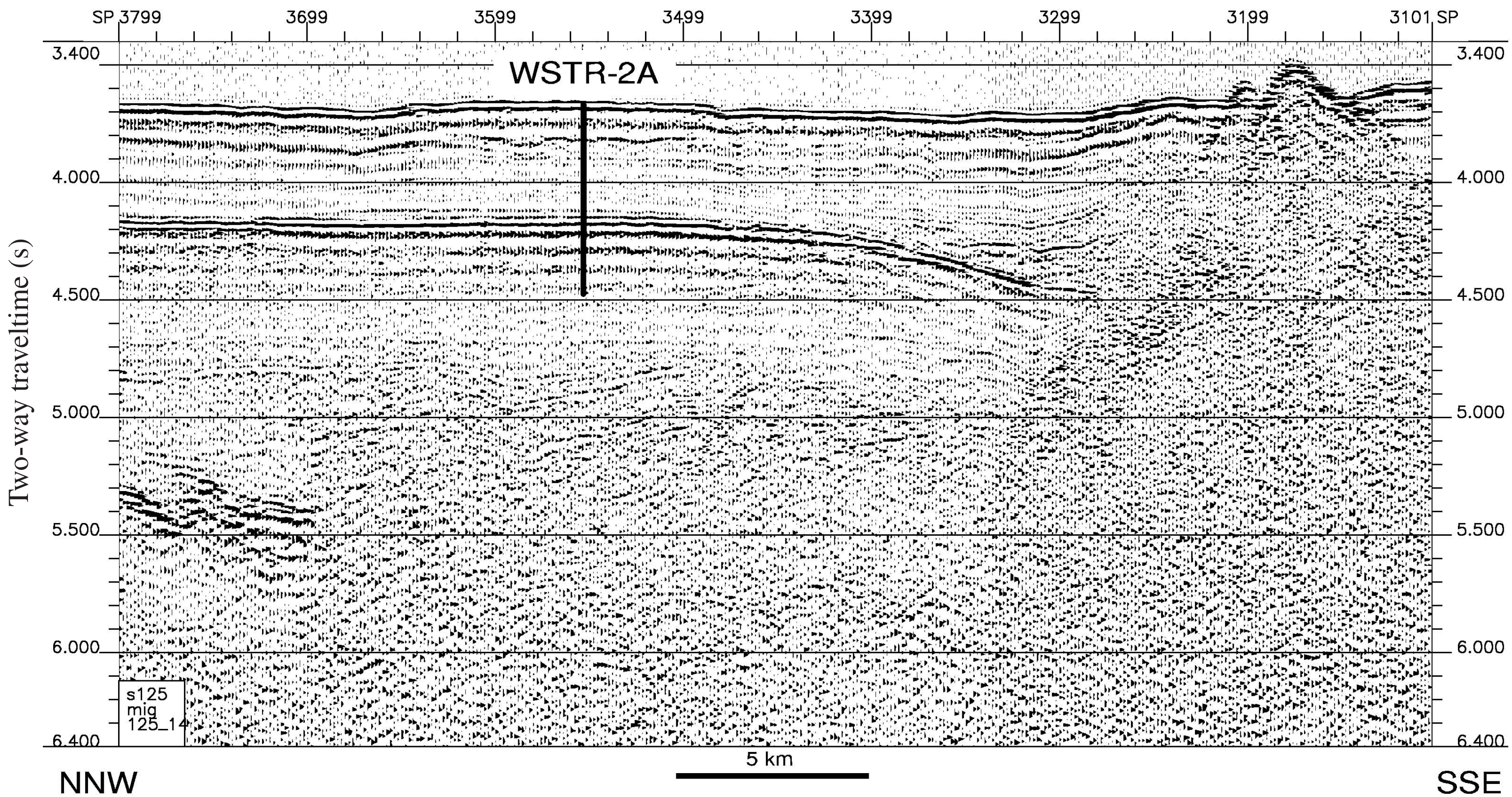
2. Coring and logging Eocene prograding detrital rift sequence for paleoceanographic/paleoclimatic study

**Drilling Program:** Triple APC, XCB, RCB

**Logging and Downhole Operations:** Triple combo, FMS-Sonic, GHMT

**Nature of Sediment Anticipated:** Neogene-Oligocene ooze and chalk (470 m); Eocene mudstone


145°45´E
146°E
146°10´E
146°20´E
46°50´S
47°S
47°10´S
47°20´S
WSTR-2A
S125/11
S125/12
S125/13
S125/14
S125/15
S125/16
058/SO36-058
058/SO36-059
202/12



SP 3799
3699
3599
3499
3399
3299
3199
3101 SP
WSTR-2A
3.400
4.000
4.500
5.000
5.500
6.000
6.400
Two-way traveltime (s)
s125
mig
125_14
5 km
NNW
SSE

**Site:** WT-1A

**Priority:** 1
**Position**: 42°36.58´S, 144°24.76´E
**Water Depth:** 2475 m
**Sediment Thickness:** At least 1200 m
**Target drilling Depth**: 880 m
**Approved Maximum Penetration:** 880 m
**Seismic Coverage:** *Sonne* SO36B-47, *Tasmante* (*L'Atalante*) 125-52

**Objectives:** The objectives of WT-1A include

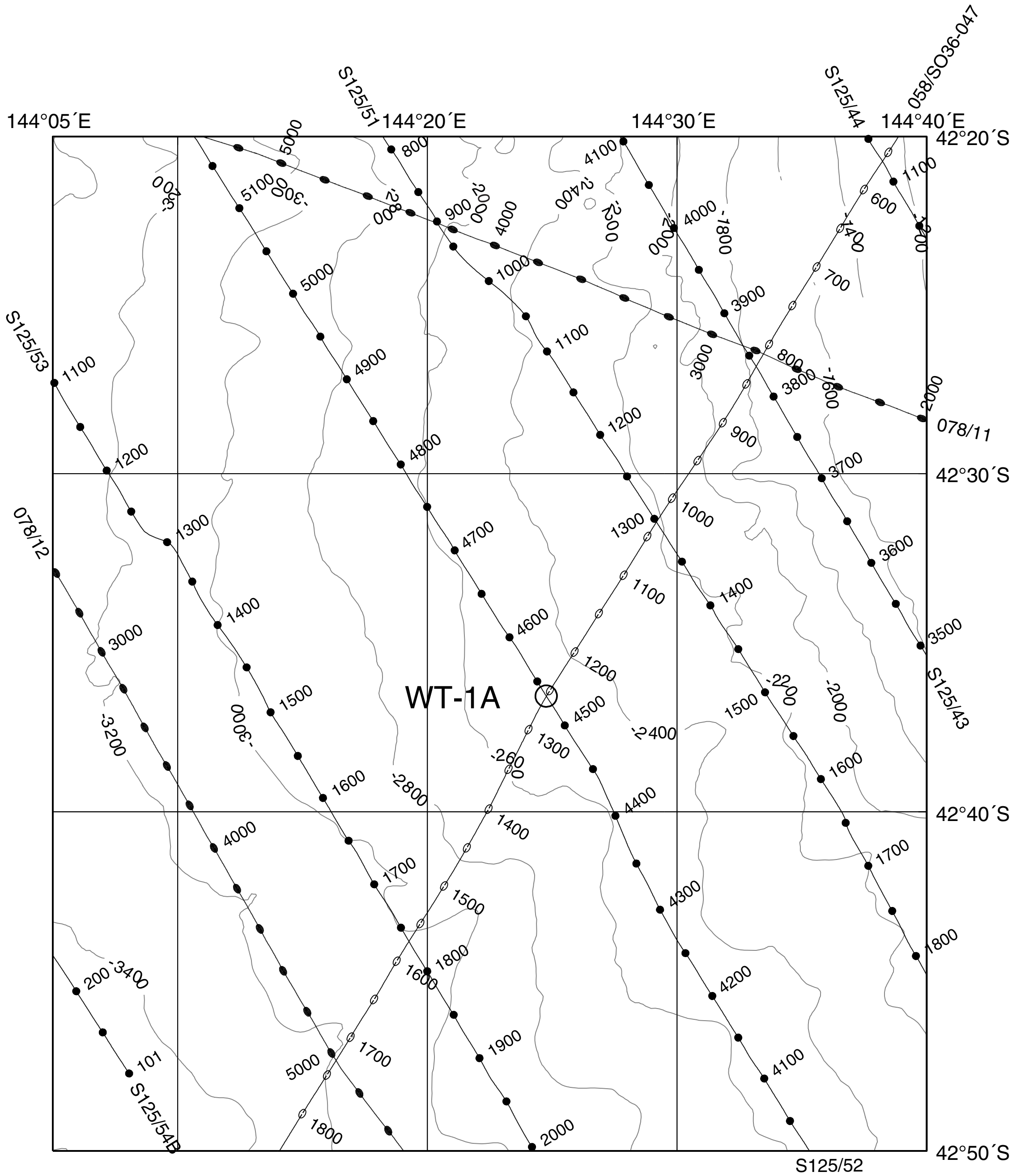
1. Coring and logging an Oligocene-Holocene Indian Ocean pelagic carbonate section for high-resolution biostratigraphic study

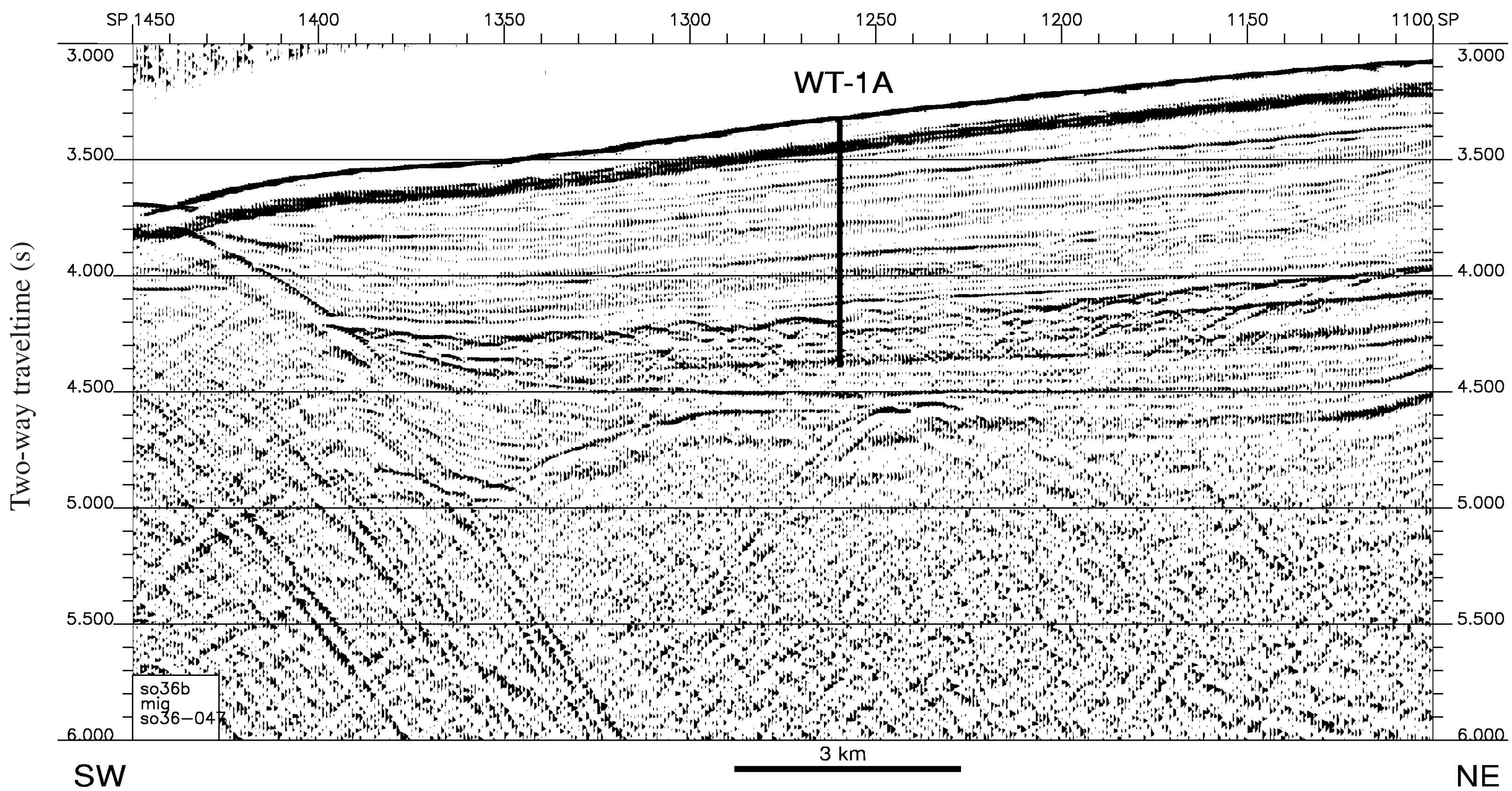
2. Coring and logging an Eocene prograding detrital section formed in early rifting for paleoceanographic and paleoclimatic history

**Drilling Program:** Triple APC, XCB, RCB

**Logging and Downhole Operations:** Triple combo, FMS-Sonic, GHMT

**Nature of Sediment Anticipated:** Neogene ooze and chalk (680 m); Eocene mudstone


144°05´E
144°20´E
144°30´E
144°40´E
42°20´S
42°30´S
42°40´S
42°50´S
WT-1A
S125/51
S125/44
058/SO36-047
S125/53
078/12
078/11
S125/43
S125/52
S125/54B


SP 1450
1400
1350
1300
1250
1200
1150
1100 SP
WT-1A
Two-way traveltime (s)
3.000
3.500
4.000
4.500
5.000
5.500
6.000
so36b
mig
so36–047
3 km
SW
NE

**Site:** WT-2A

**Priority:** 2
**Position**: 43°43.84´S, 145 01.49´E
**Water Depth:** 2910 m
**Sediment Thickness:** At least 1200 m
**Target Drilling Depth:** 855 m
**Approved Maximum Penetration:** 855 m
**Seismic Coverage:** *Sonne* SO36B-48, BMR 78/12 (*Rig Seismic*)

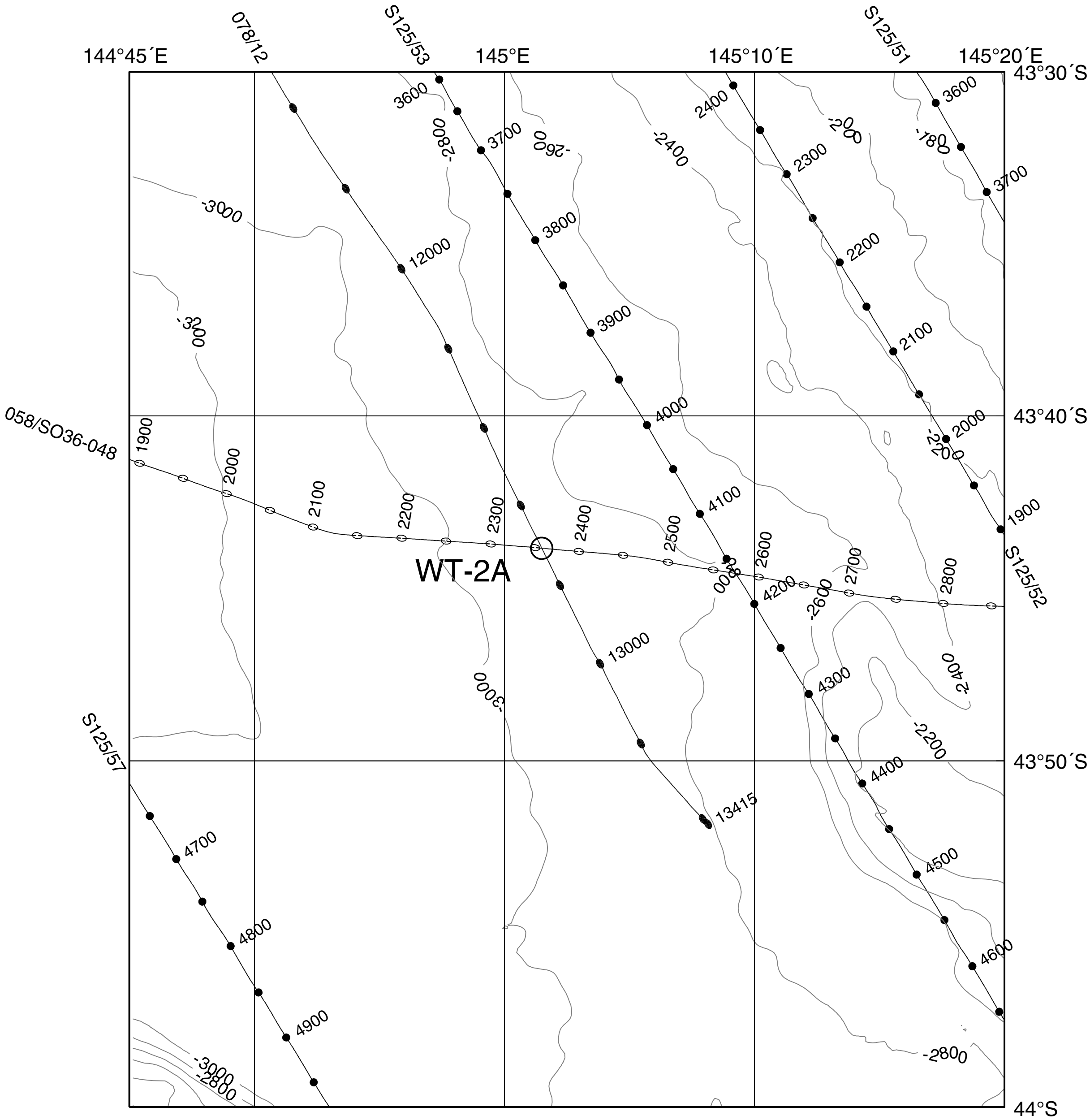
**Objectives**:

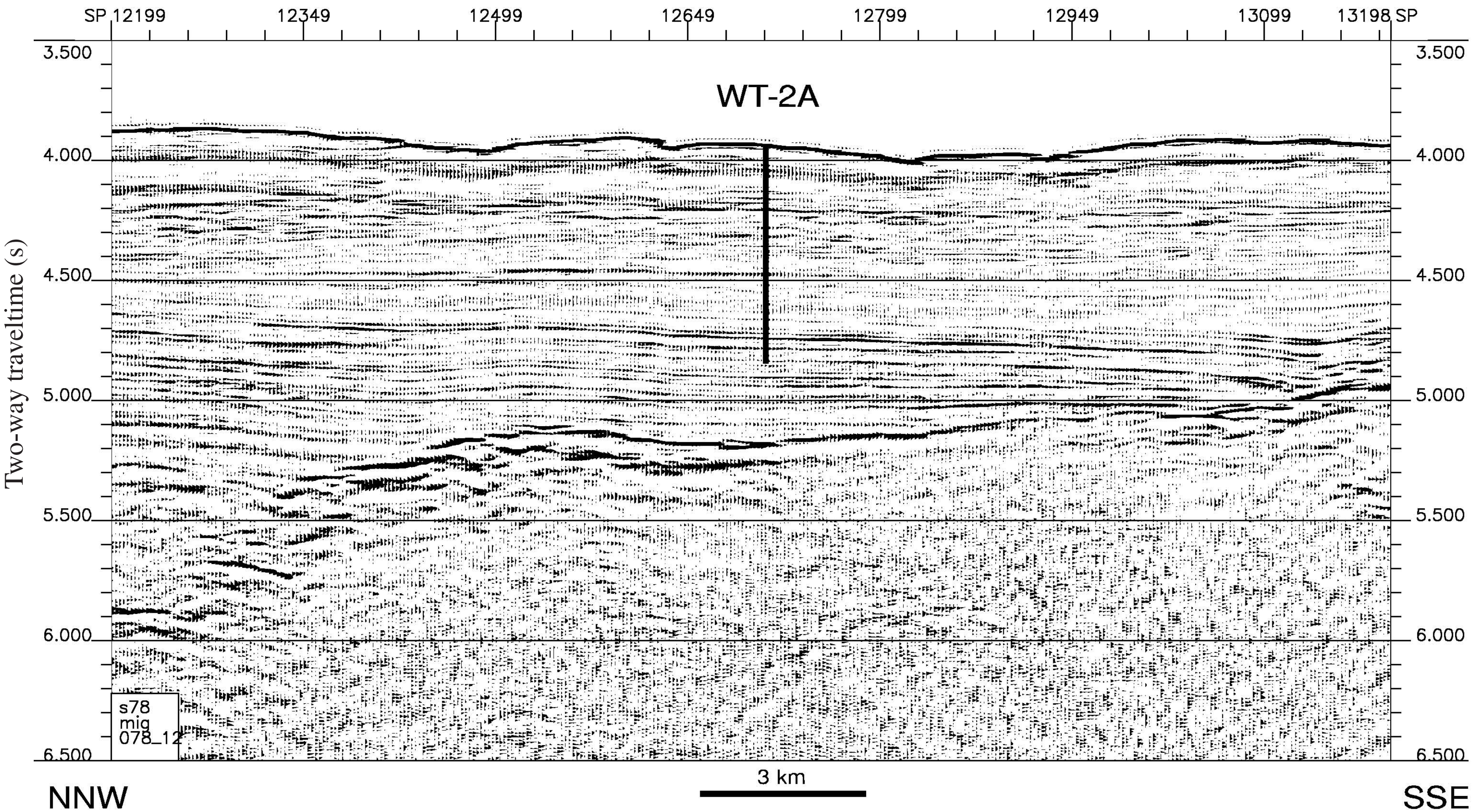
The objective of WT-2A is to core and log a nearly complete Cenozoic Indian Ocean section, which includes an Eocene detrital rift sequence and an Oligocene-Holocene pelagic sequence

**Drilling Program:** Triple APC, XCB, RCB

**Logging and Downhole Operations:** Triple combo, FMS-Sonic, GHMT

**Nature of Sediment Anticipated:** Neogene ooze and chalk (255 m); Eocene mudstone


144°45´E
145°E
145°10´E
145°20´E
43°30´S
43°40´S
43°50´S
44°S
078/12
S125/53
S125/51
S125/52
S125/57
058/SO36-048
WT-2A


SP 12199
12349
12499
12649
12799
12949
13099
13198 SP
WT-2A
3.500
4.000
4.500
5.000
5.500
6.000
6.500
Two-way traveltime (s)
s78
mig
078_12
3 km
NNW
SSE

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