OCEAN DRILLING PROGRAM

LEG 181 SCIENTIFIC PROSPECTUS

SOUTHWEST PACIFIC GATEWAYS

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

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ABSTRACT

The circulation of cold, deep Antarctic Bottom Water (AABW) is one of the controlling factors in Earth's climate. Today, 40% of this water enters the world ocean through the Southwest Pacific Gateway as a thermohaline drive Deep Western Boundary Current (DWBC). South of 46°S, the DWBC is coupled with the wind-driven Antarctic Circumpolar Current (ACC). Understanding the evolution of the Pacific DWBC is fundamental to understanding world oceanic and climatic histories. The evolution of the ACC-DWBC system has taken place since the late Oligocene (32-20 Ma), when plate movements created the first deep-water oceanic gaps south of Australia and South America. An excellent stratigraphic record of these events, and of the development of the modern ACC-DWBC, occurs in sediment drifts east of the New Zealand microcontinental plateau. Seven Southwest Pacific drill sites are proposed to reconstruct the stratigraphy, paleohydrography, and dynamics of the DWBC and related water masses. The proposed sites make up a transect of water depths from 315 m to 4460 m, and span a latitudinal range from 39°S to 51°S. Only one previous hydraulic piston core site is located in this large region (Deep Sea Drilling Project [DSDP] Site 594), and earlier DSDP drilling (Sites 275-276) occurred at sites where Neogene sediment is largely missing because of DWBC erosion. Consequently, our knowledge of Southwest Pacific ocean history, and of the development of the ACC-DWBC system, is extremely poor. Leg 181 drilling will provide the sedimentary sequences needed to study a range of high-priority problems in Southern Ocean Neogene paleohydrography, sedimentology, paleoclimatology, and micropaleontology.

INTRODUCTION

Leg 181 will drill sites located in the key Southwest Pacific Gateway because:

1. The Pacific Deep Western Boundary Current (DWBC) is the largest single contributor today to the deep waters of the world's oceans (20 Sverddrups [1 Sv = 10^6 m^3s^{-1}]; Fig. 1), and deciphering its history is, therefore, of fundamental importance to global and Pacific ocean hydrography.

2. The stratigraphic record of the eastern New Zealand Plateau and its abyssal margins is the best one available for deciphering the development history of Pacific Southern Ocean water masses, and of the sediment drifts they deposited. Recent publications (Carter and Carter, 1993, 1996; Lewis, 1994; Carter and McCave, 1994, in press; L. Carter et al., 1996; McCave and Carter, 1997) delineate the region between the Solander Trough and the Kermadec Trench, east of the modern Australian-Pacific plate boundary, as an integrated sediment source-transport-sink area, termed the Eastern New Zealand Oceanic Sedimentary System (ENZOSS). Since ~10 Ma, sediment from mountains along the New Zealand plate boundary has been transported through deep-sea channel/fan systems, delivered into the path of the DWBC, entrained northwards within this current system and finally consumed by subduction at the same plate boundary after a transport path of up to 3500 km. The stratigraphic record from the ENZOSS, and in particular any new high-resolution, Neogene Ocean Drilling Program (ODP) sections from its deep-sea parts, are directly relevant to one of the most important unresolved problems of Cenozoic climatology, namely the timing and precise nature of the development of widespread glaciation on the Antarctic continent (Barrett, in press). In turn, the same glacial events that contribute source water to the DWBC and its companion flow, the Antarctic Circumpolar Current (ACC), force the boundary current south of 49°S.

3. The gateway region includes two major oceanic fronts, the Subtropical Convergence and the

Subantarctic Front, and is proximal to a third, the Antarctic Convergence (Figs. 2, 3). Thus, the region is in a prime position to allow determination of the migration of these boundaries, the forcing processes that cause them to move, and the environmental response to their movement.

BACKGROUND

Tectonic Creation of the Southern Ocean

The origin of the modern thermohaline ocean circulation system must postdate the tectonic creation of a continuous Southern Ocean. Particularly important for the origin of the ACC-DWBC was the opening of the Australian-Antarctic (South Tasman) and South American-Antarctic (Drake Passage) deep-water flow gateways (Lawver et al., 1992). The South Tasman Gateway, including the Balleny Fracture Zone (Lonsdale, 1988), opened to deep water in the early Oligocene (~32 Ma), thereby allowing connection between the Indian and Pacific Oceans for the first time (Kennett, Burns, et al., 1972). Later, at ~20 Ma (earliest Miocene), the opening of Drake Passage (Boltovskoy, 1980) allowed the establishment of the full circum-Antarctic ocean circulation. During the critical late Eocene to Miocene period, the New Zealand Plateau was located downcurrent from the evolving South Tasman Gateway (Watkins and Kennett, 1971), and directly in the path of the evolving ACC-DWBC system.

Modern Regional Oceanography

The supply of deep water to the Pacific Ocean is dominated by a single source, the Deep Western Boundary Current (DWBC) that flows north out of the Southern Ocean along the east side of the Campbell Plateau-Chatham Rise-Hikurangi Plateau, east of New Zealand (Figs. 1-5, Table 1). The volume transport of the DWBC in this region is about 20 Sv, which comprises ~40% of the total input of deep water to the world's oceans (Warren, 1973; 1981). (A secondary, but minor, flow of ~3 Sv of deep water flows north into the Peru-Chile basin; Lonsdale, 1976). The magnitude of DWBC flow, and the low temperature of the water involved, are major determinants of the oceanography of the Pacific Ocean and of the global heat balance. Monitoring the DWBC flow at its entry into the Pacific is a key area where the "global salt conveyor" hypothesis (Broecker et al., 1990; Schmitz, 1995) can be tested, as the flow, thereafter, is believed to spread out to fill the Pacific. Some water upwells and returns at shallower depths to the Atlantic, whereas other waters return south as North Pacific Deep Water (NPDW).

The supply of cold water to the deep Pacific from the main generating regions in the Weddell and Ross Seas is modulated by the ACC, which mixes these waters with North Atlantic Deep Water (NADW) in the South Atlantic to form Circumpolar Deep Water (CDW). Deep-water output to the Pacific, therefore, carries the combined signatures of Southern Ocean processes in the region of deep-water formation, chemical composition related to Southern Ocean gas exchange, and NADW. Despite its turbulent passage around Antarctica, CDW is not completely mixed, and a distinct NADW salinity maximum can be recognized at depths of 2800 m (at 55°S) deepening northwards to 3400 m (at 28°S). In the Southwest Pacific, the DWBC comprises three main divisions (1) lower CDW, a mixture of bottom waters generated around Antarctica, in particular cold Weddell Sea deep water and NADW; (2) salinity-maximum middle CDW, representing the NADW core; and (3) strongly nutrient-enriched and oxygen-depleted upper CDW, mainly derived from Indian Ocean outflow added to Pacific outflow returning through Drake Passage. The DWBC has its upper boundary at depths around 2000-2500 m. On the eastern side, the DWBC is overlain between 2550 and 1450 m depth by south-flowing NPDW, and is marked by an oxygen minimum and high silica. Regionally, both DWBC and NPDW are overlain by low-salinity, Antarctic Intermediate Water (AAIW) (Figs. 4, 6).

The ACC-DWBC enters the Southwest Pacific through gaps in the Macquarie Ridge complex before passing along the 3500-m-high margin of the Campbell Plateau. Near the mouth of the Bounty Trough, the ACC uncouples and continues its eastward path, whereas the DWBC flows north around the eastern end of Chatham Rise and through Valerie Passage, where a small part of the flow diverges through gaps in the Louisville Ridge. Valerie Passage, the 250-km-wide gap between the Chatham Rise and the Louisville seamount chain, therefore marks the gateway to the Pacific for the DWBC.

Sedimentary Record of the ACC-DWBC

Sediments on the eastern New Zealand margin at shelf to upper bathyal depths (100-1000 m) are known to have been strongly affected by currents since at least the late Oligocene (Ward and Lewis, 1975; Carter, 1985; Fulthorpe and Carter, 1991; R. Carter et al., 1996). This evidence for strong paleoflows, together with the confirmation that substantial Antarctic glaciation commenced at least as early as the early Oligocene (Shackleton and Kennett, 1975; Barron, Larsen, et al., 1989), implies that Pacific hydrography has been fundamentally affected by an evolving circumpolar current and western boundary current system since the mid-Cenozoic.

To reconstruct the paleoflow of the DWBC and overlying current system requires drill sites through thick, undisturbed, fine-grained sediment masses constructed under the influence of the current. Seismic records indicate the presence of suitable sedimentary drifts at many points along the eastern edge of the New Zealand Plateau, in water and paleowater depths between 300 m and 5500 m (Carter and McCave, 1994; L. Carter et al., 1996). Three sediment sources are involved in building these drifts: (1) transport into the area via the DWBC itself (e.g., subantarctic diatoms present in the drifts at 40°S; Carter and Mitchell, 1987); (2) pelagic and hemipelagic rain, and airfall rhyolitic ash, which over the last 20 k.y. has been input at a rate of up to one third that of fluvial terrigenous sediment (Carter et al., 1995); and (3) terrigenous muddy sediment from New Zealand, deposited at the shelf edge by slope progradation (Fulthorpe and Carter, 1991) or delivered into the path of the DWBC from turbidity currents travelling down the Solander, Bounty, and Hikurangi channel systems. Each of these sediment sources can be constrained, and the sedimentary dynamics and transport paths of the modern system are moderately well delineated (e.g., Carter and Carter, 1993; Carter and McCave, 1994; Lewis, 1994). In contrast, little is known regarding the earlier Cenozoic record of the DWBC.

The available seismic records show that the DWBC has been active along the eastern New Zealand margin since at least the Miocene, and probably since the mid-Oligocene (32 Ma) (Carter and McCave, 1994). After ~10 Ma, abundant terrigenous material was shed from rising mountains along the Alpine Fault plate boundary (Kennett, von der Borch, et al., 1986) and fed into the Solander, Bounty, and Hikurangi channel systems, especially at times of late Neogene glacial sea-level lowstand. Much of this sediment was then entrained in the DWBC drift system, which carried it northwards to be eventually subducted into the Kermadec Trench.

Sediment is delivered into the DWBC through two newly described transport conduits, the Bounty (Carter and Carter, 1993) and Hikurangi (Lewis, 1994) channel-fan systems. A third feeder channel, Solander, is poorly known, but extends for >450 km before discharging into the DWBC at Emerald Basin between Macquarie Ridge and the western side of Campbell Plateau (Carter et al., 1996; Carter and McCave, in press). The Hikurangi Fan has been termed a "fan-drift" by Carter and McCave (1993) because it apparently represents the extreme case of a fan whose thickness and facies pattern are directly remolded by a deep current into the form of a sediment drift. In contrast, the Bounty Fan, located in a bathymetric embayment, has retained its fan morphology and has developed directly across the path of the DWBC (Carter and Carter, 1993), the only evidence of drift formation being scour of the northern fan and redeposition of material as a series of small, discrete ridges. Compared to Hikurangi Fan Drift, Bounty Fan has formed in a region where the DWBC is slowed because of a gently sloping western boundary and the shelter provided by Bollons Seamount.

The two described abyssal fans are supplied with sediment by turbidites passing through the Bounty and Hikurangi Channels, each of which is over 1000 km long. The Hikurangi Channel heads in the Kaikoura Canyon, only a few hundred meters from shore, and less than 10 km from the rapidly rising, 2.5-km-high Seaward Kaikoura Mountains. The Hikurangi system is therefore active today, in interglacial times. In contrast, the Solander and Bounty Channels head in a number of canyons that indent the edge of the continental shelf. The Bounty and Solander systems are, therefore, strongly sea-level (i.e., climatically) controlled with most sediment being fed into them during glacial lowstands, whereas during interglacials the same sediment stream is diverted along the inner shelf, some of it even reaching the Hikurangi System via the Kaikoura Canyon (Carter and Herzer, 1979).

SCIENTIFIC OBJECTIVES

Leg 181 drill sites are mostly located in sediment drift sites across a depth range of 315-4460 m, and will provide a moderate resolution record (2-5 cm/k.y.) of climatic and paleohydrographic changes since the early Miocene. We aim to recover material that will allow the following scientific problems to be studied.

1. Delineate the Cenozoic development of zonal water masses and the ACC system.

Current understanding of paleoclimate suggests that the earliest major meltwater events from Antarctic glaciation occurred at ~38 Ma (Eocene/Oligocene boundary; Shackleton and Kennett, 1975; Miller et al., 1990). At ~32 Ma (mid-Oligocene), the South Tasman Gateway opened, including the Balleny Fracture Zone (Lonsdale, 1988), thereby connecting the Indian and Pacific Oceans for the first time (Kennett, Burns, et al., 1972). Finally, it was not until ~20 Ma (earliest Miocene) that the opening of Drake Passage (Boltovskoy, 1980) allowed the establishment of the full pattern of circum-Antarctic ocean circulation. The evolution of this system, including periods when the boundary current component may have extended into shallow depths or reversed (Mikolajewicz et al., 1993), is the target of Sites SWPAC-5B and 6B. These sites may also penetrate to the regionally widespread 29 Ma mid-Oligocene unconformity (Marshall Paraconformity; Carter, 1985), the genesis of which may relate to the inception of ACC-DWBC activity as much as to global sea-level change (cf. the postulated large 29 Ma lowstand of Haq et al., 1987). Site SWPAC-1C is targeted on large Miocene-Pliocene platform drifts that grew from a paleowater depth of 1000 m in the head of the Bounty Trough (Fulthorpe and Carter, 1991).

2. Infer the changing paleohydrography of the CDW supply to the Pacific Ocean; in particular, to trace the history of mixing of Weddell Sea Deep Water (WSDW) and NADW components.

Measurement of $\delta^{18}O$, $\delta^{13}C$, and Cd/Ca from microfossil tests will be used to distinguish the relative contribution of nutrient-enriched NADW and $\delta^{13}C$ depleted components (Boyle and Keigwin, 1987; Oppo and Fairbanks, 1987; Charles and Fairbanks, 1992; Bertram et al., 1995).

Sites SWPAC-2B and 5B were selected to maximize the chance of the high-quality carbonate-rich records required for such measurements. For the deeper water sites, should carbonate percentages be low, the bulk carbonate technique of Shackleton et al. (1993) may yield a satisfactory isotope stratigraphy. However, we have obtained monospecific benthic and planktonic oxygen isotope records for mid-Holocene to Stage 3 from a core at 4802 m near Site SWPAC-16A, and McCave and Carter (1997) estimate the carbonate compensation depth (CCD) to lie at ~4750 m. The late Neogene stratigraphy may be strongly supported by a tephrochronology derived from the numerous widespread Cenozoic ash beds deposited east of New Zealand. Global understanding of the history of these water masses will require the comparison of gradients of water composition between sites in the North Atlantic, South Atlantic, North Pacific, and Southern Oceans.

3. Determine the relative paleoflow speeds of deep and intermediate waters, and thereby estimate the changing flux of CDW into the Pacific through time.

The noncohesive sortable silt (10-63 μm) fraction has been shown at widely separated locations to yield coherent indications of flow speed and hence water mass movement (McCave et al., 1995a, b; Manighetti and McCave, 1995; Robinson and McCave, 1994; Haskell et al., 1991). Evaluation of such grain-size signals in the North Chatham Drift (Site SWPAC-5B) and Campbell Drift (Site SWPAC-7B) will permit estimation of the velocity behavior of the DWBC. Sites SWPAC-1C, 2B, and 6B will yield indications of the behavior of low salinity AAIW. Site SWPAC-7B, located a little to the south of the Bounty Trough, will be important for assessing the extent to which the ACC acts as a driving force for CDW inflow, because the site is at the latitude of the mouth of the trough at which the modern ACC veers east into the Pacific, at that point becoming decoupled from the deep boundary flow (cf. Semtner and Chervin, 1992).

4. Establish the history and depth ranges of AAIW across the New Zealand Plateau.

In the North Atlantic, an intermediate water (possibly paleo-Labrador sea water) has been shown to increase both in depth range and speed during glaciations, concomitant with a decrease in NADW production in the Norwegian-Greenland Sea (Boyle and Keigwin, 1987; Manighetti and McCave, 1993). As this change is associated with suppression of NADW, there is little reason to expect the same glacial/interglacial changes to AAIW in the Southern Ocean. However, Pudsey et al. (1988) have argued that AABW production also diminished during glacials as a result of the grounding of ice sheets, in which case the thickness of AAIW may well have increased concomitantly. If the vigor of global deep circulation was decreased by these North Atlantic and Antarctic events, then during glacial times the Indian/Pacific upper CDW should have become even more nutrient enriched and oxygen depleted than it is today. Material from Site SWPAC-5B (depth 3308 m) will be used for $\delta^{13}C$ and trace element analysis (e.g., Cd/Ca in calcite and opal) to allow ocean paleochemistry to be used to determine whether during glaciations the site lay under severely depleted AAIW or enriched CDW.

5. Determine the history of productivity and surface water mass fluctuations in the vicinity of the Subtropical Convergence.

Near zones of upwelling, such as the Subtropical Convergence (STC), it is usually difficult to distinguish between climatically controlled temporal and spatial changes in productivity because the convergence moves. Unusually, however, for at least the last full glacial/interglacial cycle the STC has apparently been topographically trapped over the Chatham Rise (Fenner et al., 1992; Nelson et al., 1993; Weaver et al., in press). This raises the prospect of being able to obtain temporal records of productivity change from faunal, isotopic, and chemical data without the aliassing usually produced by shifts in the position of such convergences. DSDP Site 594, in 1200 m of water just south of the present STC, is a valuable control because it shows that cold water reached there in the last glaciation (Nelson et al., 1993), probably representing waters wind-drifted from the Subantarctic Front (SAF), which itself remained bounded by the Campbell Plateau. Site 594 provides a high-quality record extending to the middle Miocene, and we aim to match it by similar records from beneath the STC and farther north (Site SWPAC-5B) and south (Sites SWPAC-6B, 7B).

6. Examine the shifting positions of the Subantarctic Front and Antarctic Convergence.

The zone of cold water between the STC and the Antarctic Convergence (AAC) at 60°S is divided by the SAF at about 51°S. Nelson et al. (1993) found a sharp cooling of waters at glacial levels in

Site 594 (latitude near 45°S), suggesting that the SAF lay nearby. Our most southerly drift sites (Sites SWPAC-6B, 7B) and Site SWPAC-8A on the levee of the Bounty Channel will allow us to assess the shift in position of these climatically important fronts, using faunal and coarse fraction analysis, stable isotopes, and magnetic susceptibility measurements to trace ice-rafted detritus.

7. Test the record of circum-Antarctic flow against the Milankovitch orbital model, including estimates of simultaneity with Northern Hemisphere records.

Achieving this objective requires the retrieval of high-quality, long-term faunal and isotopic records from Southern Ocean sites to assess changes in temperature, salinity, and CO_2 as components of the climate system. The relative timing of events between the Northern and Southern Hemisphere will be evaluated (cf. Nelson et al., 1985). We anticipate the best long-term records will come from Sites SWPAC-2B and 5B on the north flank of Chatham Rise, where the North Chatham Drift is up to 1000 m thick and probably extends back to the late Oligocene. The earlier period of drift formation will be principally examined farther north (Site SWPAC-9B), where the thickness is reduced, although obviously with less stratigraphic resolution.

8. Study the effect of an oscillating sediment source controlled by Pleistocene sea-level cyclicity on fan overbank turbidite deposition and sediment supply to the DWBC.

The Bounty Channel and Fan are fed with terrigenous sediment through a number of submarine canyons, which cut the eastern South Island shelf edge. Located about 30-60 km offshore, these canyons were alternately supplied directly with sediment during Pliocene-Pleistocene glacial lowstands, and cut off during interglacial highstands when sediment was moved directly north along the inner shelf (Carter and Carter, 1993). Consequently, the Bounty Fan was supplied with terrigenous sediment mostly during glacial periods, and the levees of the Bounty Channel comprise a regular sequence of 5- to 8-m-thick packets of glacial silt-mud turbidites alternating with interglacial biopelagic, calcareous ooze (Carter et al., 1990). The regularity of these cycles is such that they can be matched *prima facie* with the oxygen isotopic record back to Stage 100, and viewed as the deep-sea record of continental shelf stratigraphic sequences (Carter and Carter, 1992). Site SWPAC-8A will penetrate about 50 of the cycles identified on seismic records, providing (1) a high-quality record of turbidity current activity through the Bounty Channel since the early Pleistocene; (2) a test of the correlation between the observed seismic cyclothems and the oxygen isotopic stages; and (3) a quantitative model of rates of sediment supply to the DWBC and deep sea during a time of glacio-eustatic oscillation of sea level.

9. Estimate the quantities of sediment fed into the DWBC from all sources, including terrigenous sediment delivered through the Solander, Bounty, and Hikurangi Channels; to understand the relative importance of tectonic, climatic, sea-level, and water-mass controls and to derive a sedimentary budget for the ENZOSS.

Since the Pliocene, the three largest sources of sediment for the DWBC drifts have been turbidity currents travelling the length of the Solander, Bounty, and Hikurangi channel systems (Carter et al., 1990; 1994; 1996; Lewis, 1994). Other major sediment sources are direct transport into the region by the DWBC, and pelagic, hemipelagic, and volcanic fallout. In addition to the differing primary targets at each site, all SWPAC sites will contribute data towards the development of a quantitative sedimentary model and budget for the ENZOSS.

10. Examine the history of large volcanic eruptions from the Taupo Volcanic Zone.

Some of the drift sequences targeted for drilling, particularly those nearer North Island, will contain Pliocene-Pleistocene volcanic ash layers of potential value for correlation. Several very large explosive eruptions have occurred in the Taupo Volcanic Zone (TVZ) of New Zealand in the last few million years (Shane et al., 1996). The largest in the last 50 k.y. have exceeded 100 km^2 in volume. These ashes are generally distributed to the east of New Zealand (Stewart and Neall, 1984) and occur widely in marine cores (Ninkovitch, 1968; Lewis and Kohn, 1973; Watkins and Huang, 1977; Kyle and Seward, 1984; Nelson, 1988; Carter et al., 1995). Volcanic ash horizons may also provide useful stratigraphic markers at horizons as old as late Miocene (van der Lingen, 1968), and perhaps earlier. We will investigate possible climatic links between ash eruptions and sea surface temperature (SST), through oxygen isotope analysis and transfer function paleoecology.

The application of combined isothermal plateau fission-track (ITPFT) for dating and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) for fingerprinting has revolutionized the ash chronostratigraphy of the Pliocene-Pleistocene Wanganui Basin (e.g., Naish et al., 1996), and holds great promise for application to any ash layers that are recovered from Leg 181 sites.

PROPOSED SITES

Site SWPAC-1C

The eastern New Zealand continental shelf is underlain by a seaward-dipping, clinoform sequence of early Miocene to Holocene age. Under wide areas of the middle and outer shelf, the simple clinoforms are replaced by major sediment drifts, which were deposited in water depths between ~200 and 1200 m. Individual drifts are 200-800 m thick, 10-15 km wide, and up to several tens of km long (Fulthorpe and Carter, 1991) and contain a record of upper AAIW and thermocline water masses through the Neogene.

SWPAC-1C is targeted to pass through a Pliocene-Pleistocene drape of upper slope mud, and penetrate the main Miocene-Pliocene drift sequence below. The sedimentary record will date the cessation of drift deposition and provide estimates of the paleohydrography of the later parts of the drift sequence. Information on fluctuations in current strength will be compared with the deeper water record available from DSDP Site 594 nearby.

Alternative Site SWPAC-1D (pending approval) is located at 650 m depth, immediately downslope from Site SWPAC-1C. The site is provided as an alternative to Site SWPAC-1C in case adverse weather conditions preclude drilling at Site SWPAC-1C.

Site SWPAC-2B

The Chatham Rise is eroded and current swept to the degree that phosphatized Miocene chalks are exposed along its crest. Gently northward-dipping sediments of Paleogene and early Neogene age occur north and south of the crest of the rise in about 600 m of water. A thin (<0.05-s thick, Unit A) sequence of Pliocene-Pleistocene sediment is lost in the airgun bubble pulse. 3.5 kHz records show these surficial sediments to comprise a pelagic drape with continuous reflectors that probably represent glacial and interglacial cycles. Below this drape, a 0.04-s-thick transparent interval (Unit B) of probable late Miocene age is separated across Unconformity Y from a 0.1-s-thick sequence with strong parallel reflectors (Unit C; early Miocene). Unit C is separated from the probable Paleogene sediment of Unit D across Unconformity X and tentatively correlated with the mid-Oligocene Marshall Paraconformity. Overall the section is expected to comprise a sequence of largely carbonate biopelagic sediments that have never been buried much below the seafloor.

The major targets of Site SWPAC-2B are to retrieve an unaltered sequence of lower Neogene and perhaps Paleogene sediments that encompass the commencement of ACC-AAIW activity on the margin, i.e., penetrate back to the Oligocene. This sequence will provide a record of AAIW paleohydrography, changing paleoproductivity, and variability or stasis in the position of the Subtropical Convergence. A particular attraction of Site SWPAC-2B is the possibility of achieving a high-quality oxygen isotopic record that spans the Oligocene and early Miocene (i.e., the period of probable inception of both Antarctic glaciation and the consequent delivery of cold water into the ACC-DWBC system).

Site SWPAC-5B

A major sediment drift occurs between 169°W and 175°W and at depths of 2200-4500 m on the northeastern slopes of the Chatham Rise. A drift thicker than 0.6 s lies above 3500 m depth, and has been deposited where the DWBC decelerates after passing through Valerie Passage (Carter and McCave, 1994). The drift (Unit B) is well delimited between Unconformities Y and X. A probable paleodrift is delimited by Reflector X' (early Miocene, ~20 Ma) within the base of the unit, which is interpreted to be of mid-Oligocene age. The upper sediments at this site (Unit A) comprise a 0.2-s-thick sequence of Pliocene-Pleistocene pelagic drape, which has been modified by the DWBC as attested by the widespread occurrence of sediment waves. Closely spaced parallel reflectors within this drape probably represent muddy calcareous pelagites and purer calcareous pelagites.

The anticipated presence of a substantial carbonate record back to the middle Oligocene

(Unconformity X) makes Site SWPAC-5B a prime site at which to evaluate the evolution of the AAC-DWBC system, including information on the NADW component of flow. It is anticipated that the upper part of the sequence will contain a record of volcanic ashes derived from North Island, New Zealand.

Site SWPAC-6B

This site is located at a 0.7-s-thick sediment sequence near the eastern edge of the Campbell Plateau. Earlier DSDP drilling at nearby Site 275 revealed a lack of Cenozoic sediment and yielded Late Cretaceous ages at shallow subseafloor depths, beneath a veneer of modern ooze and a manganese pavement. The substantial accumulation of Cenozoic sediment targeted by Site SWPAC-6B has been deposited in an ideal position to record changes in the position of the nearby Subantarctic Front and possibly the Antarctic Convergence. These fronts form, respectively, the northern and southern limits of the ACC. The site is also located at an appropriate depth to monitor changes in AAIW activity and should yield a carbonate record throughout.

Site SWPAC-7B

The Campbell Drift is an extensive sediment accumulation up to 170 km wide, 850 km long, and a maximum of 1.1-s thick, which occurs along the margin of the Campbell Plateau under the path of the DWBC, at depths of 4000-4500 m. DSDP Site 276 was located in the erosional moat between the western edge of the drift and the Campbell Plateau escarpment, and penetrated directly into Oligocene and Eocene siliceous sediment. Thus, DWBC erosion has apparently cut down to the Paleogene in the moat, which means there is an excellent chance of obtaining a continuous Neogene-Paleogene section by drilling through the crest of the drift at Site SWPAC-7B.

Site SWPAC-7B should record the history of the ACC-DWBC and associated water masses as they approach the Pacific gateway. It will be of special interest to compare paleocurrent speeds at this site with sites farther north, as Site SWPAC-7B is located where the DWBC is presently forced by the ACC, which may affect boundary flow to 4000 m or deeper depth.

Site SWPAC-8A

The outer Bounty Trough is a major injection point of New Zealand derived sediment into the path of the DWBC. During the late Neogene, an abyssal fan developed on an unconformity that is correlated with regional Reflector Y (late Miocene, ~8 Ma; Carter et al., 1994). The fan comprises well stratified Pliocene-Pleistocene sediments which, on the north bank, were deposited in the form of deep-sea sediment waves. These waves probably correspond largely to the hydraulics of overspilling turbidity currents, but with influence also from the DWBC. Nearby surface cores demonstrate that the alternating reflecting and nonreflecting units correspond respectively to glacial periods of turbidity current activity and interglacial biopelagic deposition, that is, that a close relationship exists between seismic stratigraphy and oxygen isotopic stratigraphy (Carter and Carter, 1992). A core near the base of the north channel wall contains a well-preserved late Pliocene calcareous planktonic fauna, indicating excellent preservation of carbonate for the interglacial intervals. An additional attraction to this site is the high average sedimentation rate (glacials and interglacials) of ~15 cm/k.y., implied by the deposition of 350 m of levee sediment over ~2.4 m.y.

Site SWPAC-8A will provide high-resolution information on (1) estimates of the turbidity current speeds of deposition and rates of bedform accumulation and migration of deep-sea mud waves; (2) the record of terrigenous vs. biopelagic input into the DWBC and ENZOSS system over the last 3 m.y.; and (3) the correlation between seismic reflectors and oxygen isotopic stratigraphy.

Site SWPAC-9B

The 250-km-long, ridge-like Rekohu Drift consists mainly of inferred Miocene drift sediments. The main Rekohu sequence overlies older sediments across Unconformity X and is onlapped by overbank turbidites of the Hikurangi Channel across Unconformity Y. By correlation with other sections, the Unit B sediments at this site are probably calcareous pelagites. Unravelling the evolution of the Rekohu Drift is critical to understanding the development of Hikurangi Channel, and the injection of sediment into the DWBC north of the drift. The Rekohu Drift has clearly acted as an effective barrier to eastward dispersal of terrigenous sediment from the Hikurangi Channel during the Pliocene-Pleistocene.

Site SWPAC-9B should yield a mainly carbonate record of the Miocene paleohydrography of the DWBC, and (if it penetrates unconformity X) important information on the mid-Cenozoic initiation of the system.

Alternate Site SWPAC-10B

The northern platform flank of the Bounty Trough encompasses a full seismic sequence of Units A through D together with the prominent regional unconformities represented by Reflectors Y (late Miocene, ~6.5 Ma) and X (late Oligocene, ~30 Ma). Thus, in contrast to the late Neogene nature of the Bounty Fan site (Site SWPAC-8A), Site SWPAC-10B will only drill through a thin upper Cenozoic record before penetrating the inferred Miocene sediment that underlies regional unconformity Reflector X. Of key interest is the nature of basal Unit B sediments, their record (if any) of DWBC activity and the character and age of the bounding unconformity below.

The gentle folding that affects all units up to Unconformity Y marks a regional event of probable late middle Miocene age that may correlate the known change in motion of the New Zealand plate boundary at about 10 Ma, from a strike slip to strongly transpressional phase. Site SWPAC-10B would provide direct dating for this important regional event.

Alternate Site SWPAC-16A

The East Chatham deep drift is located at the northeastern end of the rise, at the narrowest point of Valerie Passage. The drift, therefore, lies adjacent to the gateway into the Pacific for the DWBC and was deposited from LCDW, which originated in the Weddell Sea. Core from Site SWPAC-16A is therefore anticipated to contain a record of variations in the source material and strength of depositional current of the DWBC. Kasten Core Chat-3K from this locality contains an excellent benthic and planktonic oxygen and carbon isotope record.

DRILLING STRATEGY

Sites have been selected along two depth transects and one linking latitudinal transect 12° longitude. The latitudinal transect extends from near the estimated glacial position of the SAF (51°S) to north of the modern position of the STC (39°S). Within a single leg of drilling, a tradeoff is required between providing either (1) fewer and shorter extremely high-quality (triple advanced hydraulic piston corer [APC]) records through mainly younger Neogene sediment; or (2) a greater number of high-quality (double APC) records that cover a wider geographic range, and some of which penetrate back to the critical 35-20 Ma interval over which the South Tasman and Drake Passage gateways opened. We have approached this tradeoff by scheduling triple-APC coring on the primary Chatham Rise transect, and double APC at most other sites.

1. The Chatham Rise Transect (Sites SWPAC-2B, 5B, 9B)

This transect comprises three holes in water depths between 615 m and 3308 m located in a northeast band across major sediment drifts of the Chatham Rise. All sites are above the modern CCD, recently determined to be at ~4750 m in this area (McCave and Carter, 1997). Sections span an inferred age of early Miocene to Holocene, within a thickness of 400-750 m. Two sites (Sites SWPAC-2B and 4A) terminate in presumed Oligocene sediment, which marks the regional inception of strong bottom-water flow into the Pacific.

2. Campbell Plateau Transect (Sites SWPAC-1C, DSDP 594, SWPAC-6B, 7B)

This transect commences with Site SWPAC-1C in 315 m of water on the eastern South Island shelf (Canterbury Drifts; to sample upper AAIW and basal thermocline water), then passes southeast close to DSDP 594 to link to two sites near the eastern edge of the Campbell Plateau, Sites SWPAC-6B and 7B. Site SWPAC-6B (543 m water depth) is targeted to sample AAIW. Biopelagite is present at the surface and expected to extend downhole to the target depth. Sedimentation rate in a nearby core (F-121) is <1 cm/k.y., but from the thickening of seismic intervals toward Site SWPAC-6B, significantly higher rates are expected there. Site SWPAC-7B is situated on the crest of the large Campbell Drift, and at 4505 m lies close to the regional CCD. However, monospecific benthic and planktonic isotope records from a site to the north at 4802 m and pilot studies of bulk carbonates (Shackleton et al., 1993) suggest that an isotope record may be determinable with paleomagnetics and perhaps tephrochonology as additional means of age control.

The Campbell Plateau transect will yield a terrigenous silt record of late Miocene to Holocene fluctuations in current strength near the AAIW/thermocline transition (Site SWPAC-1C), a mainly carbonate record of the Neogene AAIW paleohydrography of the Campbell Plateau (Site SWPAC-6B), and a mixed carbonate-abyssal mud record of Neogene paleohydrography of the DWBC (Site SWPAC-7B).

3. Linking Latitudinal Transect (Sites SWPAC-7B, 8A, 2B, 9B)

This transect spans a latitudinal range from 51°S to 39°S, commencing on the Campbell Drift (Site SWPAC-7B, Campbell Plateau transect) and passing through the North Chatham Drift (Site SWPAC-2B, Chatham Rise transect). The addition of two other sites makes up the transect: Site SWPAC-8A near 47°S on the north levee of the Bounty Fan, and Site SWPAC-9B at 39°S on the Rekohu Drift.

The latitudinal transect has been inserted to better track movements of fronts (STC, SAF, and possibly the AAC) during glacial and interglacial cycles. Penetration is therefore limited to the Pliocene-Pleistocene (last 3 m.y.) at Site SWPAC-8A. This site is also deliberately located on a fan levee to retrieve sedimentary process information, particularly on the frequency of turbidity currents and their potential as a proxy for paleoseismic events and the glacial/interglacial switching of sediment supply into the DWBC system.

Alternate Sites

Drilling plans for the alternate sites are discussed in the Site Summary Section (pages 62 and 65).

LOGGING PLAN

Sediments encountered at the seven primary sites will consist of periodically alternating layers of biopelagic carbonate and silica-rich sediment with varying amounts of fine-grained terrigenous detritus. Some terrigenous sand may be encountered. Because of the strong density and porosity variations associated with such lithologies, core and log physical property measurements are likely to be extremely important proxy indicators for reconstructing time series of sediment composition. Some sites may have high sediment accumulation rates, generating great potential for the achievement of very high-resolution records of paleoclimatic and paleoceanographic variability.

All proposed sites have penetration depths exceeding 300 m, and will be logged with the triple-combo and formation microscanner (FMS) tools. It is anticipated that most sites will also be logged using the geological high-resolution magnetometer (GHMT) tool string.

SAMPLING STRATEGY

General

Most of the core material to be recovered during Leg 181 will be retrieved by APC and extended core barrel (XCB) coring, generally by triple coring for the first priority sites and by double coring for any secondary sites drilled. One half of one hole at each site will be the permanent archive half. Micropaleontology and sedimentology samples will be taken after a composite sampling splice is constructed from the two or more holes drilled at that site. High-resolution sampling is anticipated for most sites (2-5 cm interval), with 10 to 20 cm^3 needed for each sample, depending on the abundance of fossils (especially benthic foraminifers). Sampling schedules will be worked out between the parties involved to optimize stratigraphic coverage and to minimize duplication. Geochemical sampling, which calls for larger volumes, will be done on material from the third hole if it would otherwise interfere with first-pass micropaleontology and sedimentology sampling. Whole-round samples may be available for pore-water studies from the third copy, as long as a sample's position is not crucial to filling gaps in the continuous stratigraphic record. If there is a need for a rapid decision on the location of a whole-round sample, but information is insufficient to identify critical intervals for continuous stratigraphy, only short whole-round sections (up to 15 cm long) will be permitted. Such sections should be separated by at least 1 m. Sampling for microbiological studies will also follow this strategy.

Sampling for physical properties will be undertaken so as not to interfere with stratigraphically sensitive sampling sequences and to take advantage of available continuous nondestructive measurements.

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 Time Table

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.

General Sampling Procedure

Investigators should avoid sampling the center of core halves. Sample plugs should be taken as close to the edges of a split core as feasible, given the purpose of sampling. Samples may also be taken with the "scoop" tool, which includes material from the edges of the split core. Large samples taken with the "cookie-cutter" tool, for example for lamina-scale studies, will be shared among interested scientific party members.

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. Sampling for high-resolution isotopic, sedimentologic, and micropaleontologic studies will be conducted after construction of the spliced composite section. Most of the high-resolution sampling will, therefore, be deferred until after the cruise; however, the upper few cores in each hole that contain high-porosity sediments that may be disturbed during transport to the Texas A&M University (TAMU) repository will be sampled on board ship. High-resolution sampling is anticipated for most of the upper APC and XCB cores (2- to 5-cm intervals), depending on the abundance of microfossils (especially benthic foraminifers). U-channel sampling for high-resolution paleomagnetic and rock-magnetic studies will be conducted postcruise in the temporary archive half along the composite sampling splice, where appropriate.

Special Core Handling

Samples for organic geochemical analysis may need to be frozen, and therefore, must be taken on board. Facilities will be available for this.

Final Comment

All sampling for Leg 181, and the final sampling plan, will be approved by the SAC, consisting of the Co-chief Scientists (Carter, McCave), Staff Scientist (Richter), and Curatorial representative (McCarty). 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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FIGURE CAPTIONS

Figure 1. Regional bathymetry, sediment bodies, sediment pathways, and SWPAC transects and sites within the ENZOSS system, Southwest Pacific Ocean. STSC = Solander trough submarine channel.

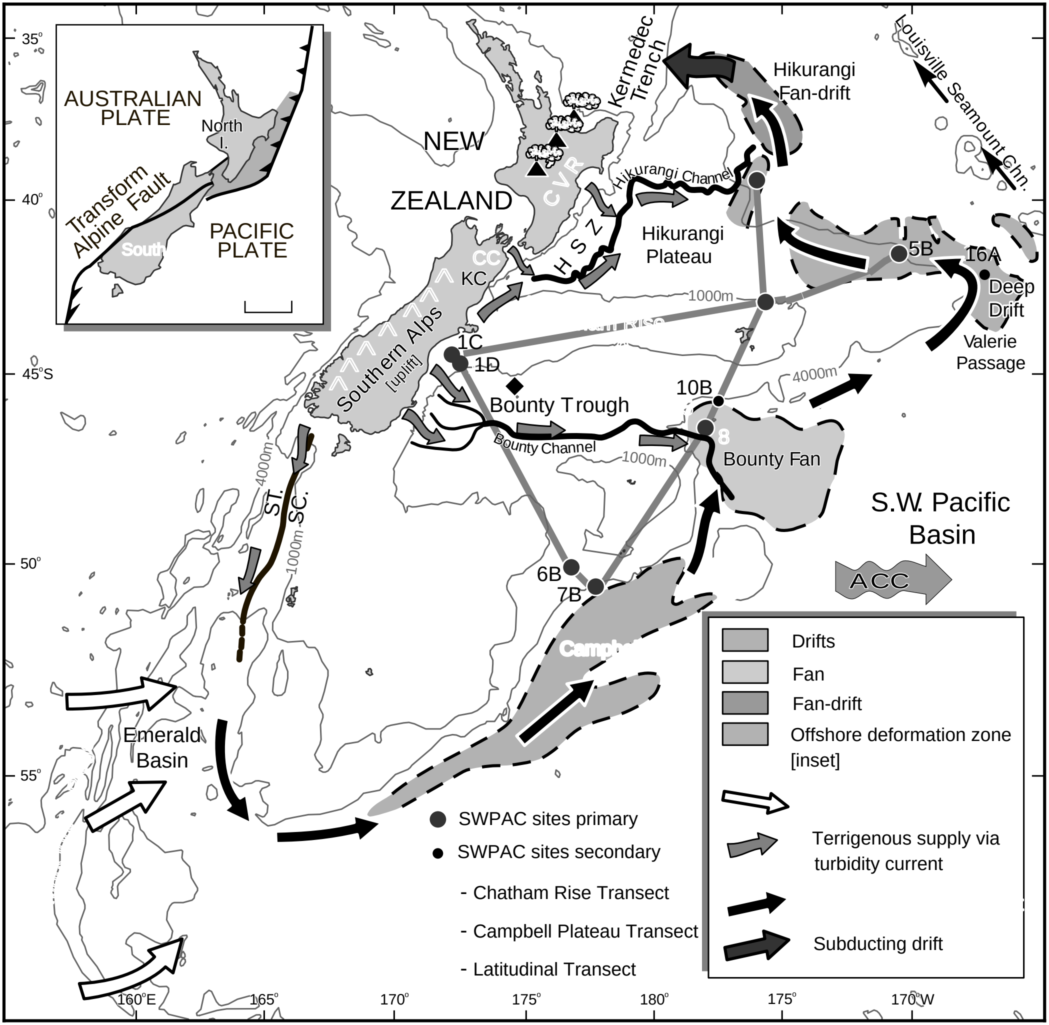
Figure 2. Location map of the proposed Leg 181 drill sites east of New Zealand in the Southwest Pacific Ocean.

Figure 3. Location of SWPAC sites (numbered black squares) projected onto a meridional section through the major water masses of the Pacific Ocean basin. Lines show salinity values.

Figure 4. Major water masses, fronts, and current systems of the Southwest Pacific. The ACC reenters the region from the west with DWBC flow commencing east of the Macquarie Ridge complex. Near latitude 50°S, the ACC resumes its eastward path with 20 Sv of DWBC flow continuing northward around the east end of Chatham Rise. SSW = subtropical surface water, STC = subtropical convergence, ASW = Australasian subantarctic water, SAF = subantarctic front, CSW = circumpolar subantarctic water, and AAC = Antarctic convergence.

Figure 5. Southwest-northeast section across the DWBC system and related water masses, from north Chatham Rise to the Louisville seamount chain and beyond. Abbreviations defined in Table 1.

Figure 6. West-east section through the eastern New Zealand continental margin, showing location of proposed SWPAC drilling sites in relation to bathymetry and major water masses. Abbreviations are defined in Table 1. Site SWPAC-16 is an alternative site.



AUSTRALIAN PLATE
North I.
Transform Alpine Fault
South
PACIFIC PLATE
NEW ZEALAND
CVR
Kermedec Trench
Hikurangi Fan-drift
Louisville Seamount Chn.
Hikurangi Channel
HSZ
Hikurangi Plateau
CC
KC
Southern Alps [uplift]
1000m
5B
16A
Deep Drift
Valerie Passage
1C
1D
Bounty Trough
10B
4000m
Bounty Channel
Bounty Fan
ST.
SC.
S.W. Pacific Basin
6B
7B
ACC
Emerald Basin
Drifts
Fan
Fan-drift
Offshore deformation zone [inset]
Terrigenous supply via turbidity current
Subducting drift
SWPAC sites primary
SWPAC sites secondary
- Chatham Rise Transect
- Campbell Plateau Transect
- Latitudinal Transect
35°
40°
45°S
50°
55°
160°E
165°
170°
175°
180°
175°
170°W

Figure 1

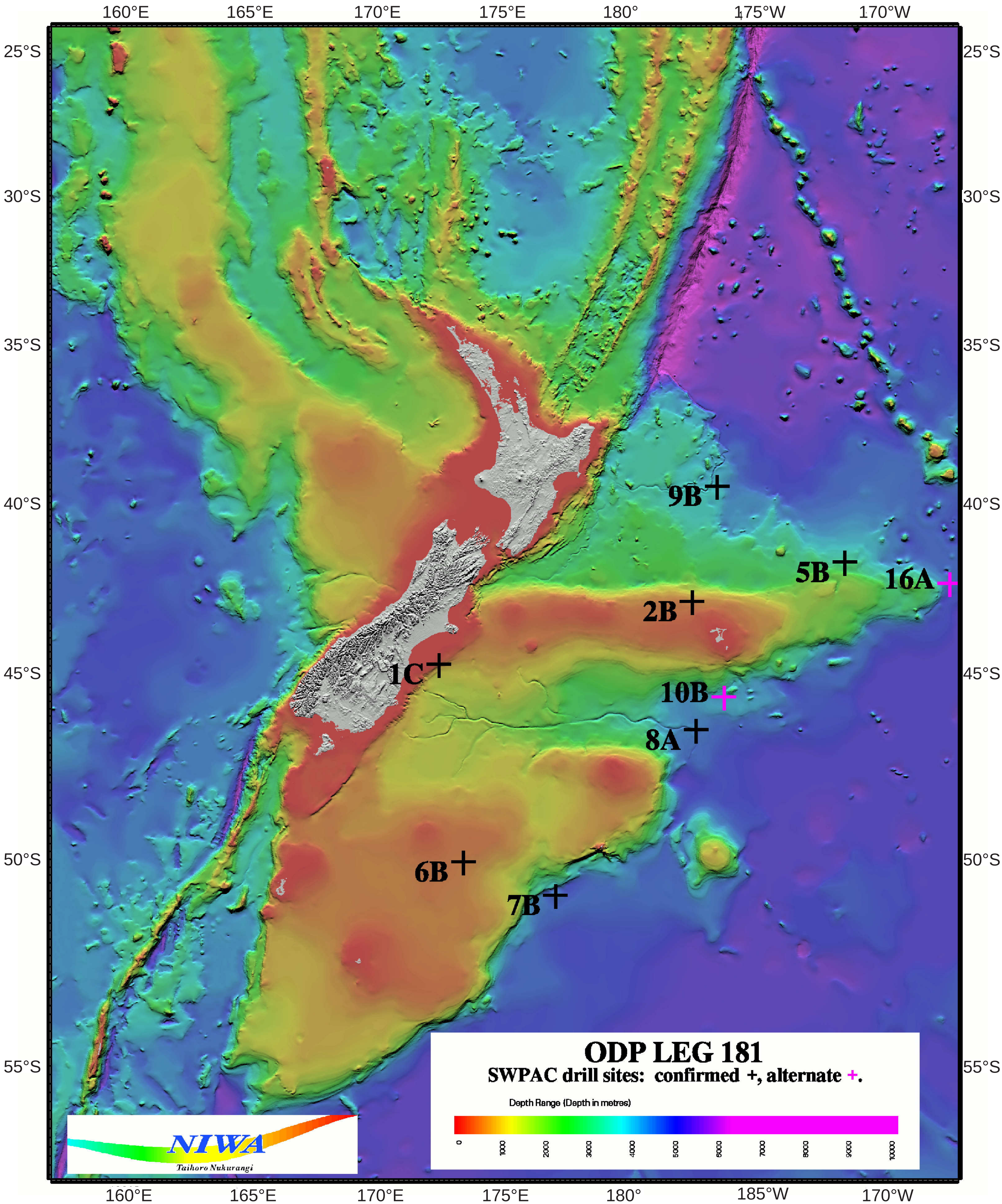
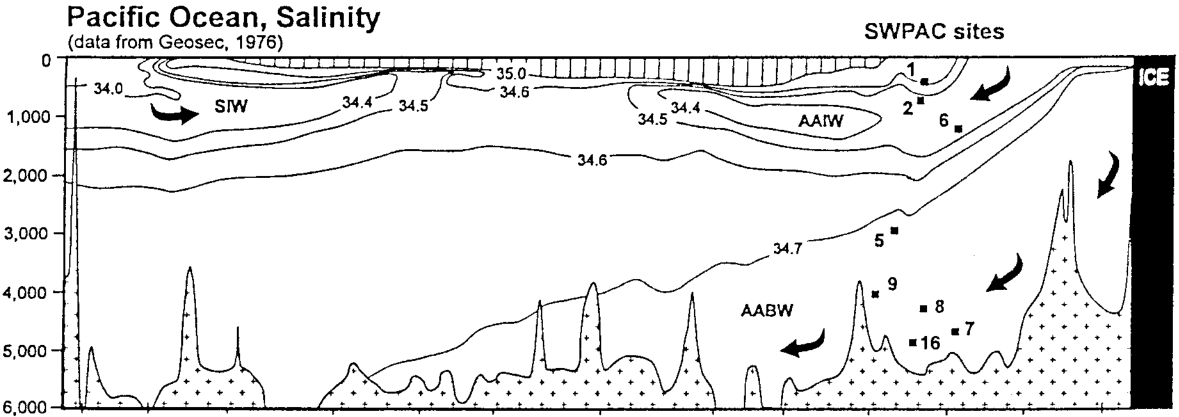
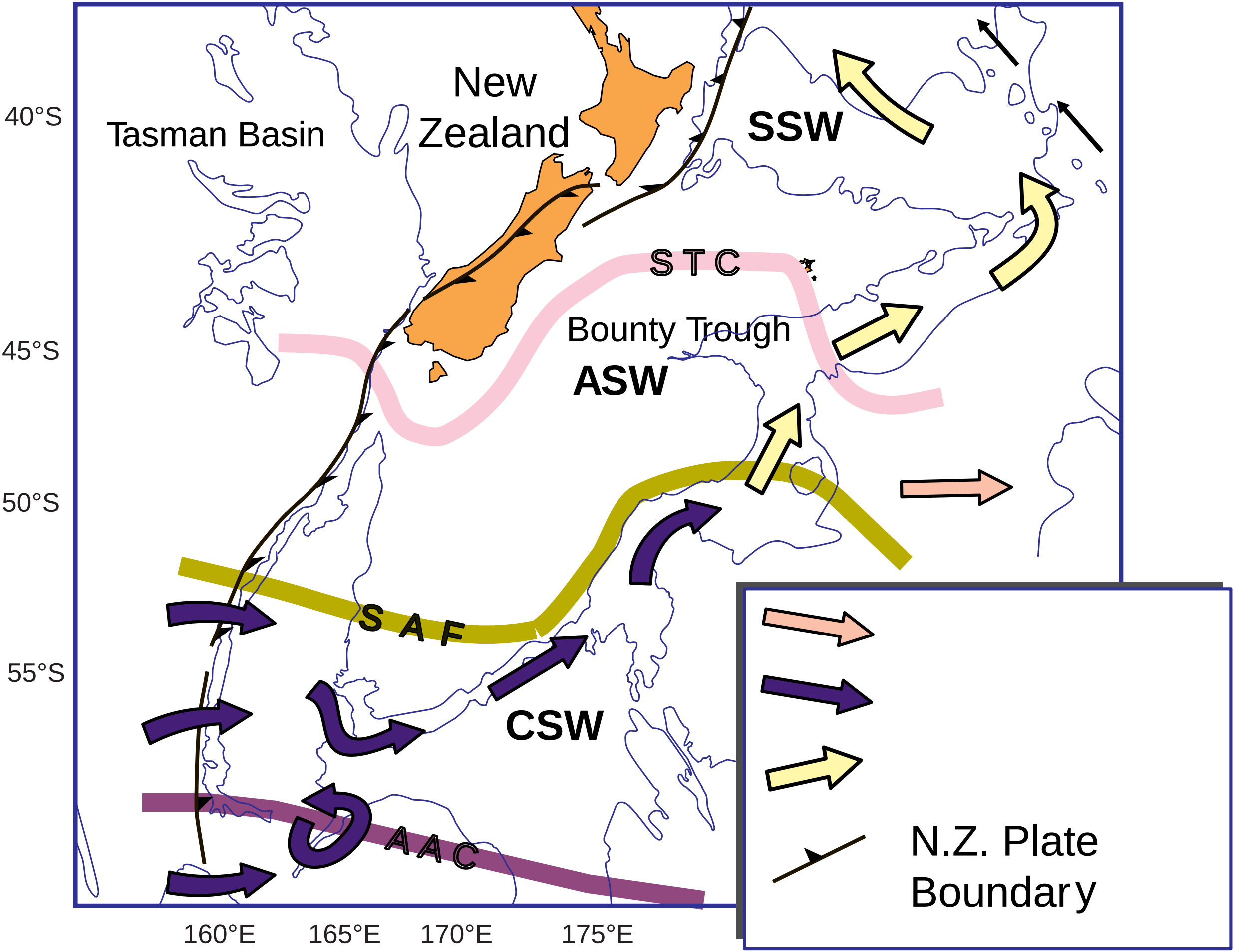

160°E
165°E
170°E
175°E
180°
175°W
170°W
25°S
30°S
35°S
40°S
45°S
50°S
55°S
9B
5B
16A
2B
1C
10B
8A
6B
7B
ODP LEG 181
SWPAC drill sites: confirmed +, alternate +.
Depth Range (Depth in metres)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
NIWA
Taihoro Nukurangi
185°W

Figure 2



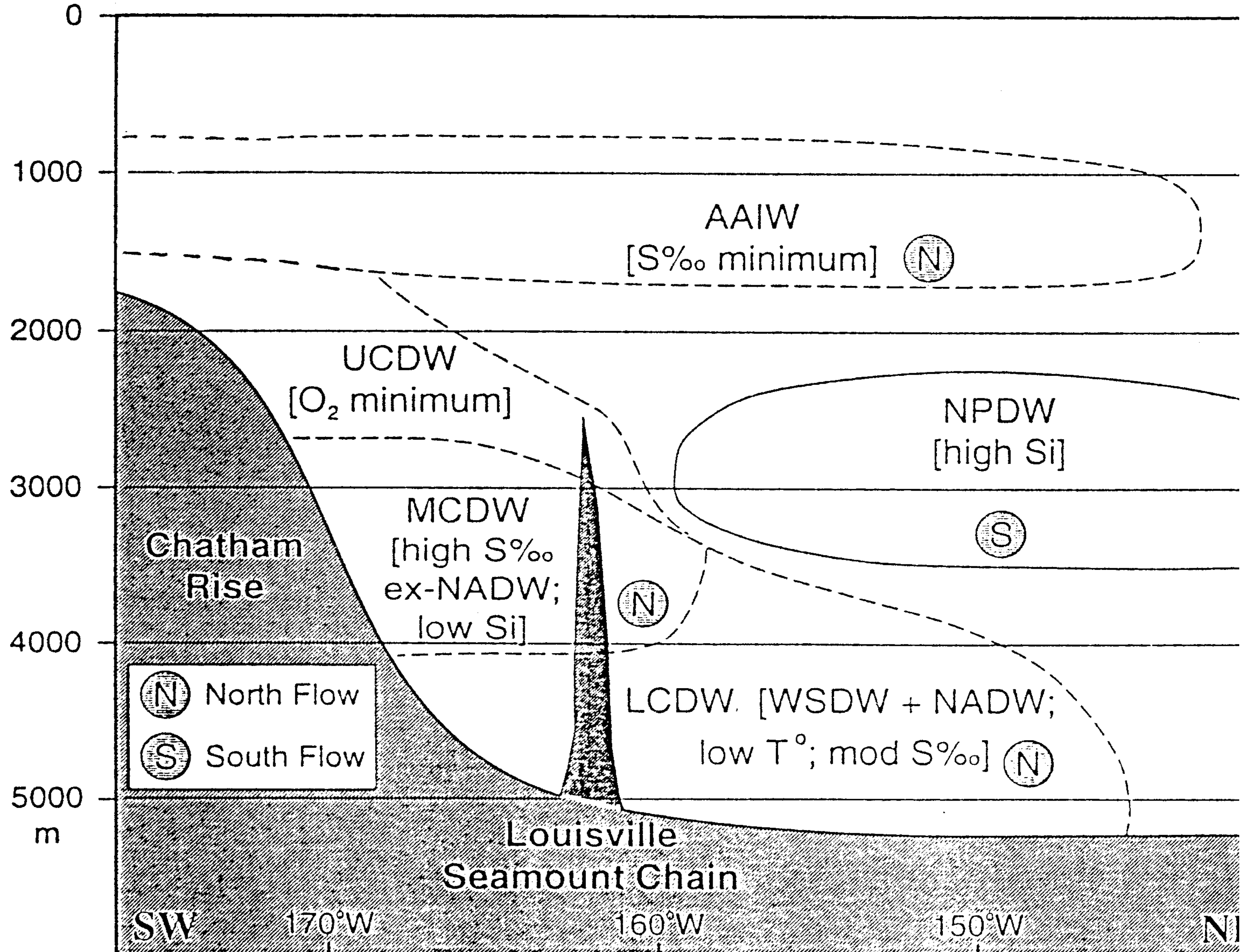
Pacific Ocean, Salinity
(data from Geosec, 1976)
SWPAC sites
ICE
SIW
AAIW
AABW
34.0
34.4
34.5
35.0
34.6
34.7
1
2
5
6
7
8
9
16
0
1,000
2,000
3,000
4,000
5,000
6,000
m
N 50
40
30
20
10
0
10
20
30
40
50
60
70 S

Figure 3



40°S
45°S
50°S
55°S
160°E
165°E
170°E
175°E
Tasman Basin
New Zealand
SSW
STC
Bounty Trough
ASW
SAF
CSW
AAC
N.Z. Plate Boundary

Figure 4



0
1000
2000
3000
4000
5000
m
AAIW
[S‰ minimum]
N
UCDW
[O2 minimum]
NPDW
[high Si]
MCDW
[high S‰
ex-NADW;
low Si]
S
N
Chatham
Rise
LCDW [WSDW + NADW;
low T°; mod S‰]
N
N North Flow
S South Flow
Louisville
Seamount Chain
SW
170°W
160°W
150°W
NE

Figure 5

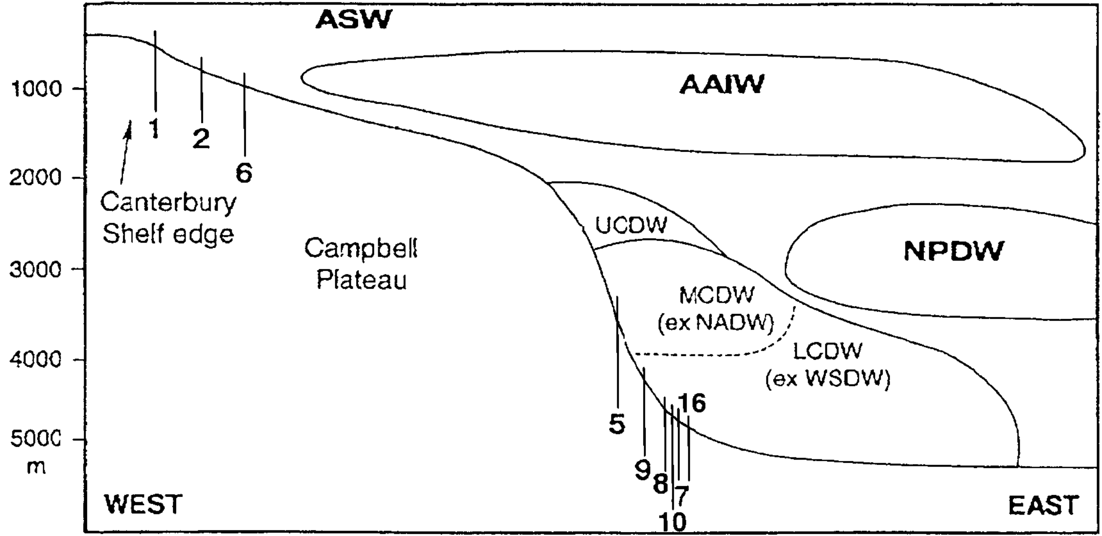

ASW
AAIW
1000
2000
3000
4000
5000
m
1
2
6
Canterbury
Shelf edge
Campbell
Plateau
UCDW
NPDW
MCDW
(ex NADW)
LCDW
(ex WSDW)
5
9
8
7
10
16
WEST
EAST

Figure 6

Table 1. Tabulated Data for the Major Water Masses and Fronts of the Southwest Pacific

Water Mass	Abbr.	Depth (m)	Density	Salinity	Temp. (°C)	Oxygen	Silica
Subtropical Surface Water	SSW	Surface	>15				
Subtropical Convergence	STC		*Separates CSW from ASW at 15 degree summer surface isotherm*				
Australasian Subantarctic Water	ASW	Surface	8-15				
Subantarctic Front	SAF		*Separates ASW from CSW at 8 degree summer surface isotherm*				
Circumpolar Surface Water	CSW	Surface	5-8				
Antarctic Convergence (Polar Front)	AAC		*Separates CSW from Antarctic Water (AAW), with icebergs (<5 °C)*				
Thermocline water		0-400		34.42-34.90	7.00-11.00	4.40-5.00	
Subantarctic Mode Water	SAMW	400-600	(26.80-27.20)	(34.0-34.2)	(6-10)	(very high)	(very low)
Antarctic Intermediate Water (S min)	AAIW	600-1450	27.20-27.35	34.50-34.36	3.20-7.00	3.20-4.70	
North Pacific Deep Water (O min)	NPDW	1450-2550		34.67-34.50	1.80-3.20	2.80-3.20	
	UCDW	2550-2900	36.50-37.00	34.67-34.71	1.60-1.80	3.03-3.45	high
Circumpolar Deep Water (upper)	MCDW	2900-3800	37.00-45.93	34.71-34.73	0.90-1.60	3.45-3.63	high
Circumpolar Deep Water (middle) (S max)	LCDW	>3800	45.93-46.00	<34.71	0.55-0.90	4.70-4.80	high
Antarctic Circumpolar Current	ACC	0-seafloor	Various	-------------------	-------------	--------------	-------------
Weddell Sea Deep Water	WSDW				-0.30-0.00		
North Atlantic Deep Water	NADW		As for MCDW	-------------------	-------------	--------------	-------------
Antarctic Bottom Water*	AABW						

*General term for cold water of Antarctic origin that spreads north into the major ocean basins

Site No.	Location Lat/Long	Water Depth	Projected Operations Plan	Transit (days)	Drilling (days)	Logging (days)	Total On-site
PRIMARY SITES							
Sydney			Transit 1440 nmi from beginning port to Site SWPAC-1C @ 10.5 kt	5.7			
SWPAC-1C	44°45.33' S	315	APC to 150 mbsf, APC/XCB to 500 mbsf, Log		2.4	0.7	3.1
	172°23.60' E						
			Transit 404 nmi from SWPAC-1C to SWPAC-6B @ 10.5 kt	1.6			
SWPAC-6B	50°03.80' S	543	APC to 150 mbsf, APC to 150 mbsf, APC/XCB to 750 mbsf, Log		4.1	0.7	4.8
	173°22.30' E						
			Transit 105 nmi from SWPAC-6B to SWPAC-7B @ 10.5 kt	0.4			
SWPAC-7B	50°53.88' S	4505	APC to 150 mbsf, APC/XCB to 410 mbsf, Log		5.0	1.0	6.0
	176°59.81' E						
			Transit 380 nmi from SWPAC-7B to SWPAC-8A @ 10.5 kt	1.5			
SWPAC-8A	46°34.78' S	4425	APC to 150 mbsf, APC/XCB to 700 mbsf, Log		7.1	1.2	8.3
	177°23.63' W						
			Transit 262. nmi from SWPAC-8A to SWPAC-2B @ 10.5 kt	1.0			
SWPAC-2B	42°55.87' S	615	APC to 150 mbsf, APC to 150 mbsf, APC/XCB to 520 mbsf, Log		3.3	0.8	4.1
	177°33.97' W						
			Transit 281 nmi from SWPAC-2B to SWPAC-5B @ 10.5 kt	1.1			
SWPAC-5B	41°47.18' S	3308	APC to 150 mbsf, APC to 150 mbsf, APC/XCB to 700 mbsf, Log		7.0	1.1	8.1
	171°29.95' W						
			Transit 255 nmi from SWPAC-5B to SWPAC-9B @ 10.5 kt	1.0			
SWPAC-9B	39°29.90' S	4001	APC to 150 mbsf, APC/XCB to 510 mbsf, Log		5.4	1.0	6.3
	176°31.90' W						
			Transit 458 nmi from SWPAC-9A to Wellington @ 10.5 kt	1.8			
Wellington							
				14.2	**34.2**	**6.5**	**40.7**
			TOTAL DAYS:			**54.9**	
ALTERNATE SITES							
SWPAC-10B	46° 14.80' S	4542	APC to 150 mbsf, APC to 150 mbsf, APC/XCB to 700 mbsf, Log		8.5	1.2	9.7
	176° 56.90' W						
SWPAC-16A	42° 25.22' S	4616	APC to 150 mbsf, APC/XCB to 510 mbsf, Log		5.1	1.0	6.1
	167° 30.58' W						

Table 2. Leg 181 Operations Plan and Time Estimate

SITE SUMMARIES

Site: SWPAC-1C

Priority: 1

Position: 44°45.33'S, 172°23.6'E

Water Depth: 315 m

Sediment Thickness: >2000 m

Target Drilling Depth: 500 m

Approved Maximum Penetration: 600 m

Seismic Coverage: BP Line CB-82-22, CB82-43/7, Ewing Lines 1b, 2e

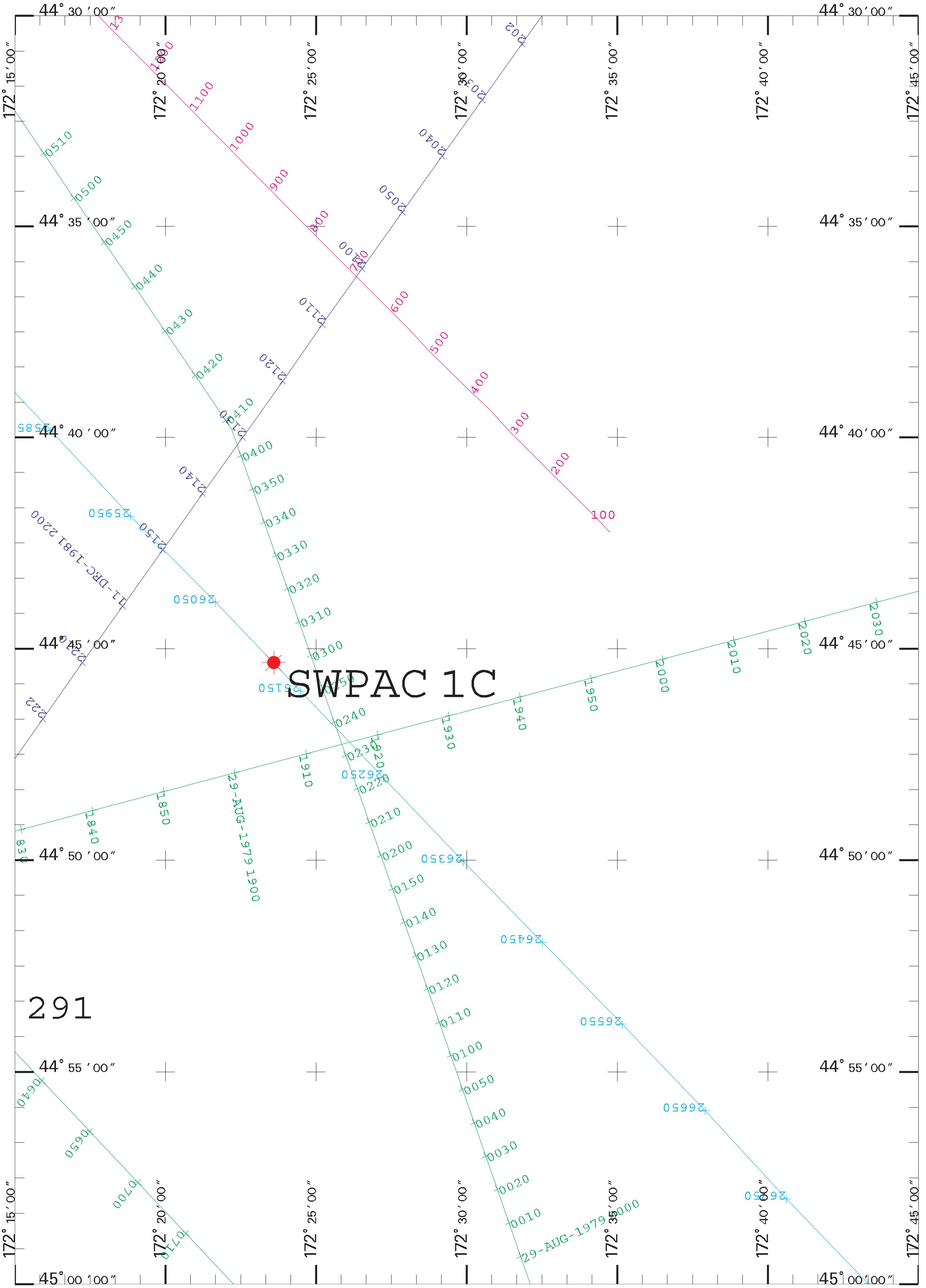
Objectives: The objectives of SWPAC-1C are to:

1. Determine the Cenozoic history of shallow WBC and associated drift formation.
2. Evaluate late Miocene changes in sea level.

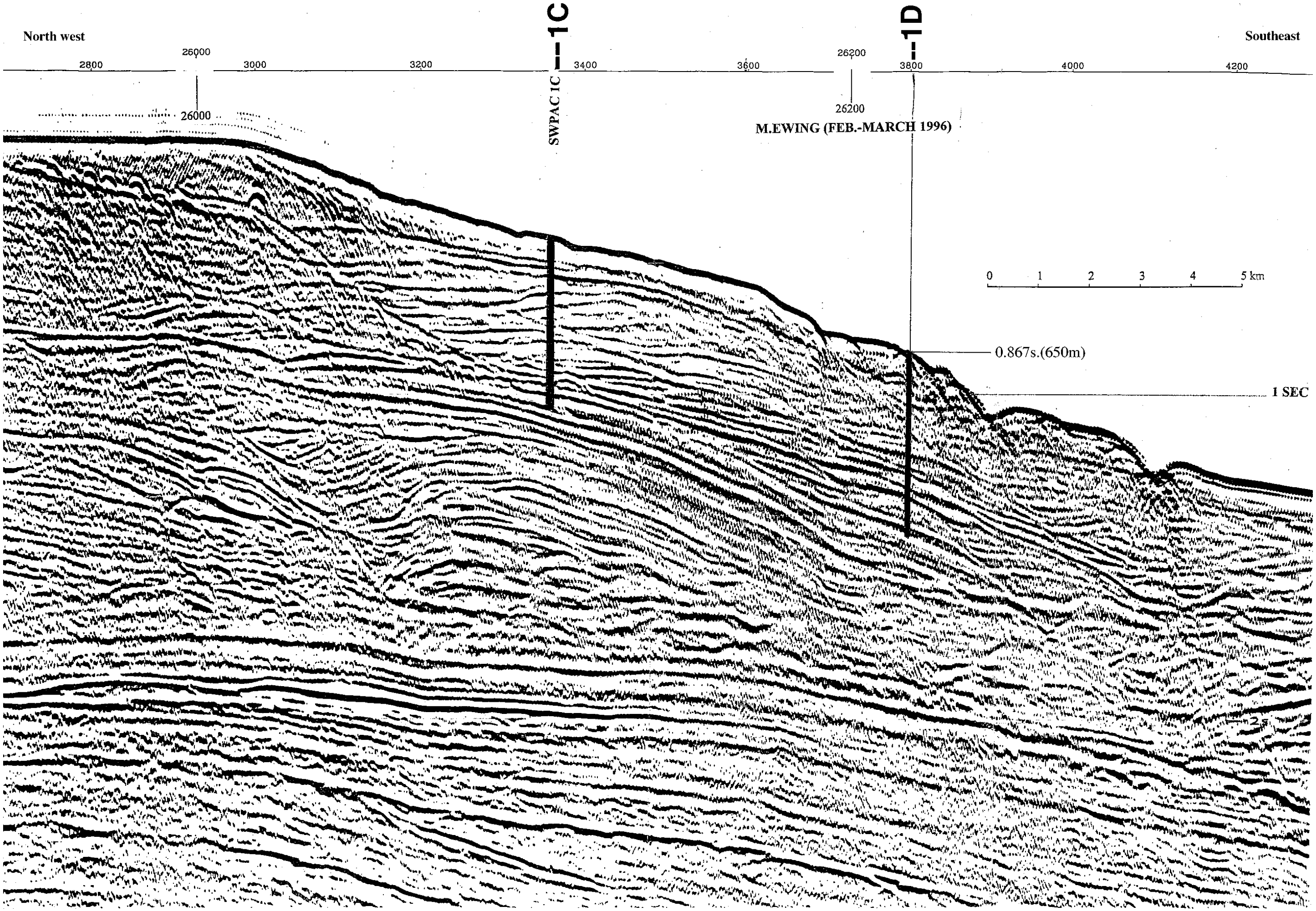
Drilling Program: Double APC, XCB

Logging and Downhole Operations: Triple combo, FMS/Sonic, GHMT

Nature of Rock Anticipated: Terrigenous silts, muds, and minor sands



Track Lines SWPAC-1C



Seismic Line SWPAC-1C

Site: SWPAC-2B

Priority: 1

Position: 42°55.87'S, 177°33.97'W

Water Depth: 615 m

Sediment Thickness: ~1200 m

Target Drilling Depth: 628 m

Approved Maximum Penetration: 660 m

Seismic Coverage: SCS high-resolution seismic Mobil 72-21; NIWAR 3034 Lines 3 and 4

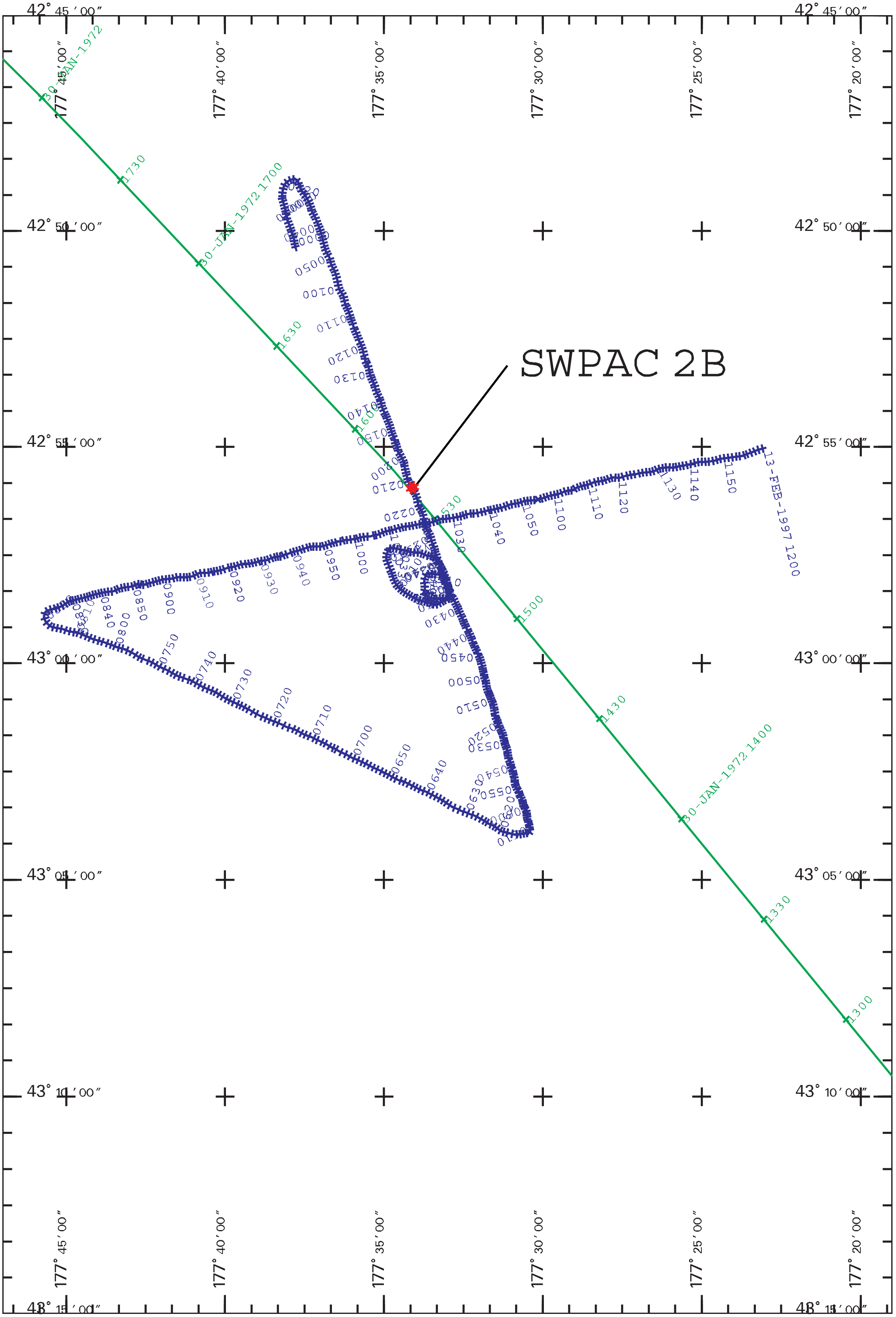
Objectives: The objectives of SWPAC-2B are to:

1. Test the record of circum-Antarctic flow against the Milankovitch orbital model, including estimates of simultaneity with Northern Hemisphere records.
2. Obtain high-resolution oxygen isotope record of Eocene/Oligocene.
3. Determine paleoproductivity and location of STC and paleohydrography of AAIW.

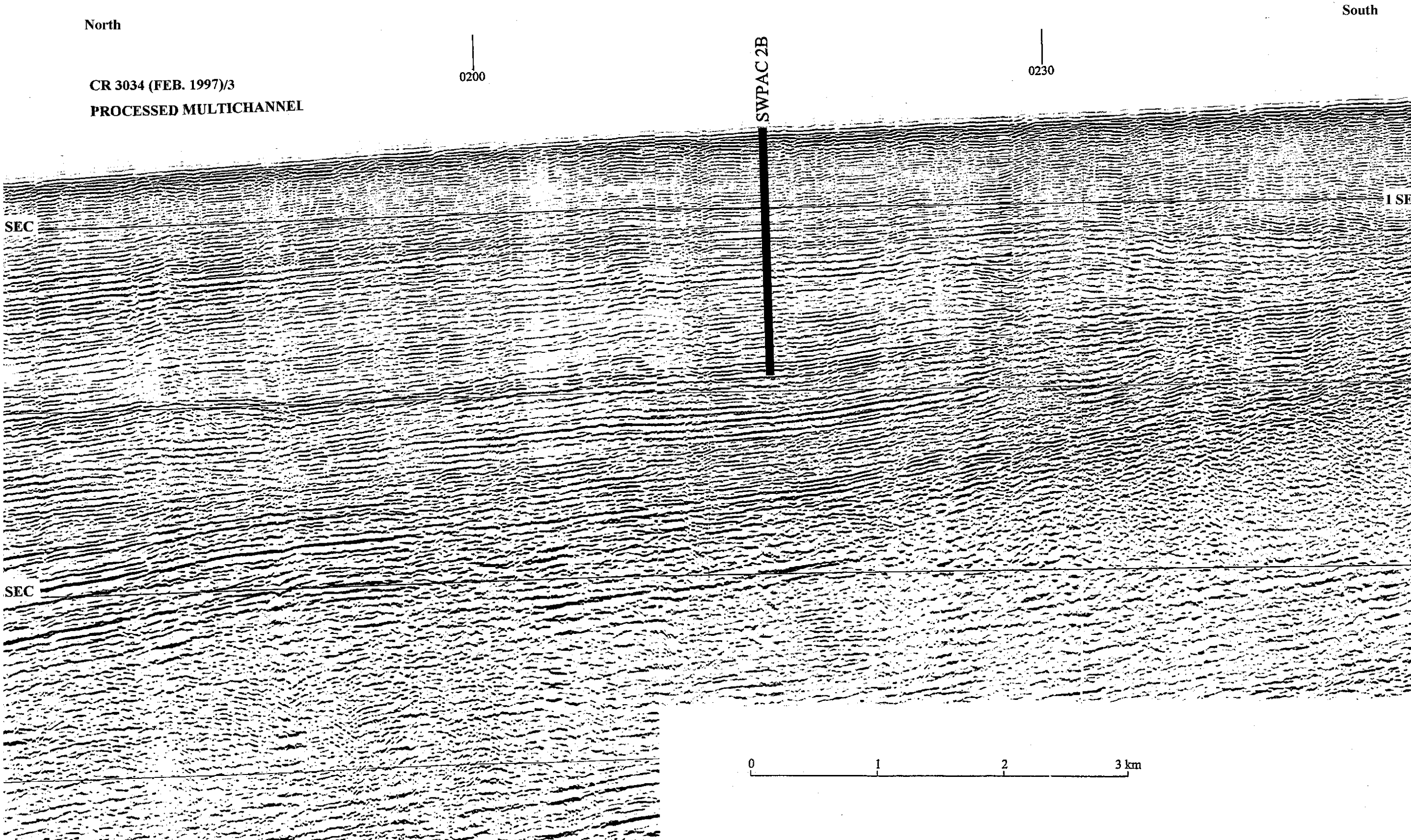
Drilling Program: Triple APC, XCB

Logging and Downhole Operations: Triple combo, FMS/Sonic, GHMT

Nature of Rock Anticipated: Surface sand and phosphate nodules, hemipelagites, carbonate pelagites



Track Line SWPAC-2B



Seismic Line SWPAC-2B

Site: SWPAC-5B

Priority: 1

Position: 41°47.18'S, 171°29.95'W

Water Depth: 3308 m

Sediment Thickness: ~860 m

Target Drilling Depth: 700 m

Approved Maximum Penetration: 750 m

Seismic Coverage: SCS high-resolution seismic, NZOI CR2050, Lines C and D, NIWSAR 3034 Lines 7 and 8

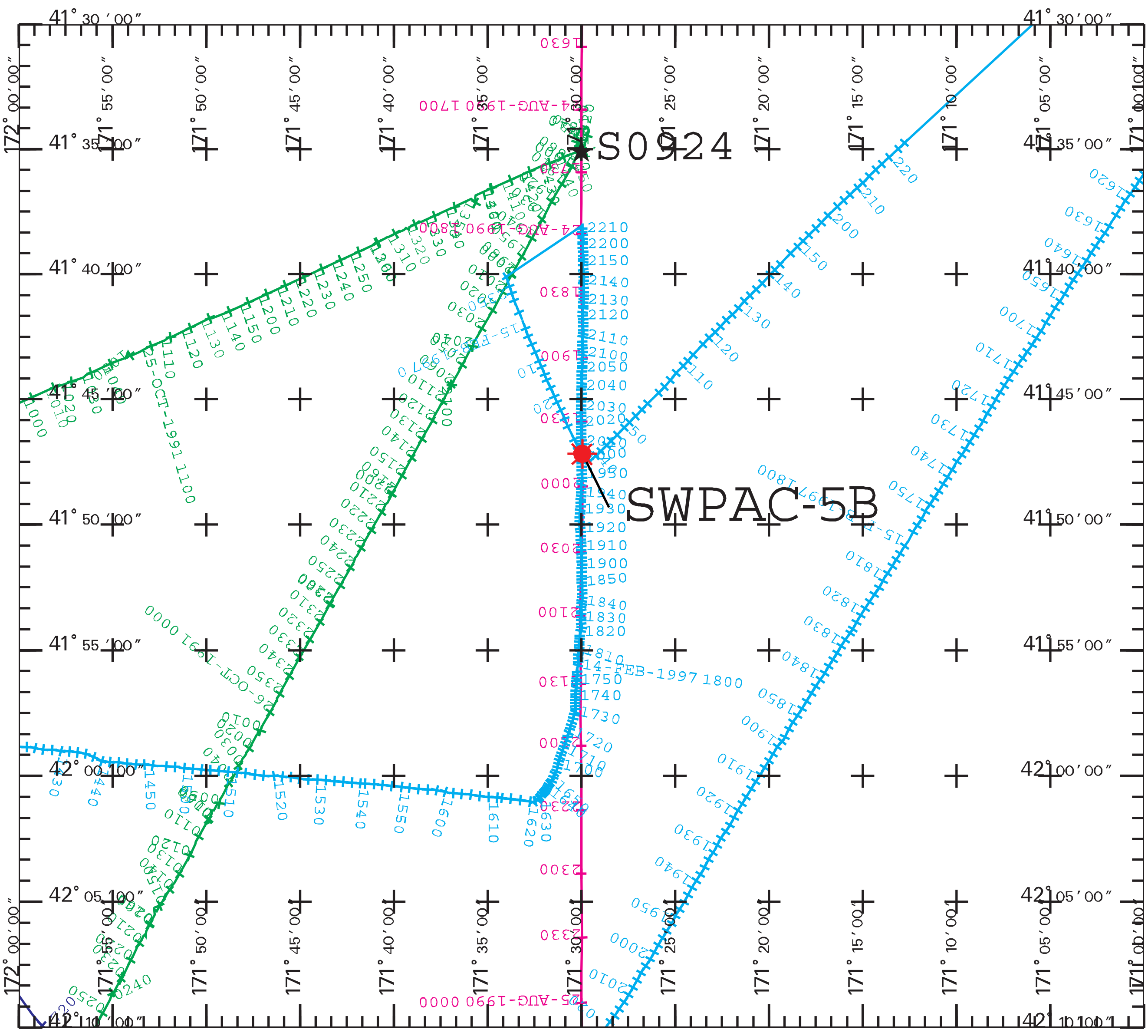
Objectives: The objectives of SWPAC-5B are to:

1. Test coherence of paleoclimatic record with Milankovitch cycles.
2. Determine the evolution of circum-Antarctic ocean circulation, including periods when the boundary current component may have extended into shallow depths or reversed.
3. Evaluate grain-size signals (flow speed) to determine water-mass movement to estimate the velocity behavior of the DWBC.
4. Determine paleoproductivity and location of STC and paleohydrography of CDW (including NADW component).

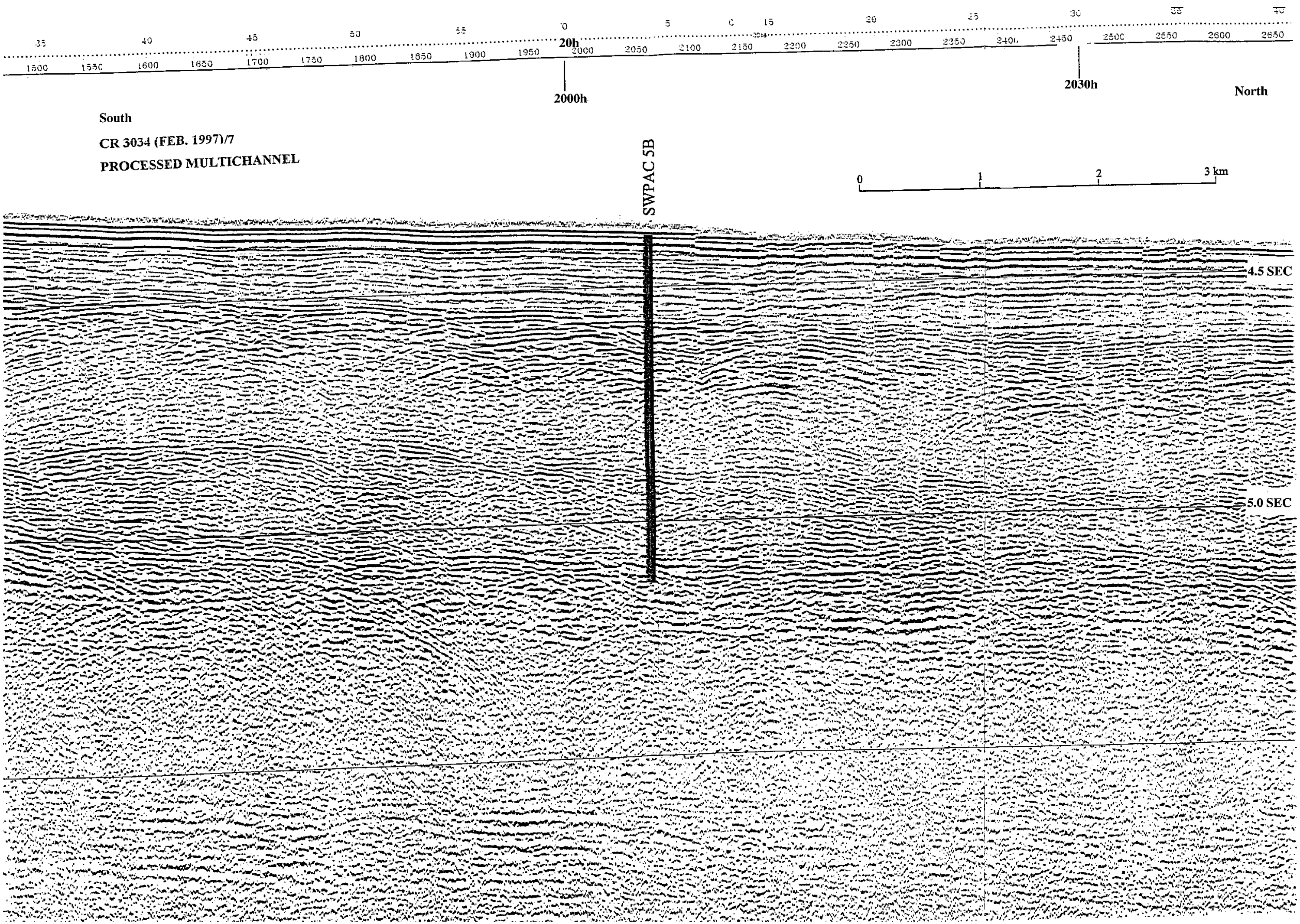
Drilling Program: Triple APC, XCB

Logging and Downhole Operations: Triple combo, FMS/Sonic, GHMT

Nature of Rock Anticipated: Hemipelagites, carbonate pelagites



Track Line SWPAC-5B



Seismic Line SWPAC-5B

Site: SWPAC-6B

Priority: 1

Position: 50°03.80'S, 173°22.30'E

Water Depth: 543 m

Sediment Thickness: ~960 m

Target Drilling Depth: 750 m

Approved Maximum Penetration: 764 m

Seismic Coverage: Eltanin 52, NIWAR 3034 Lines 20 and 21

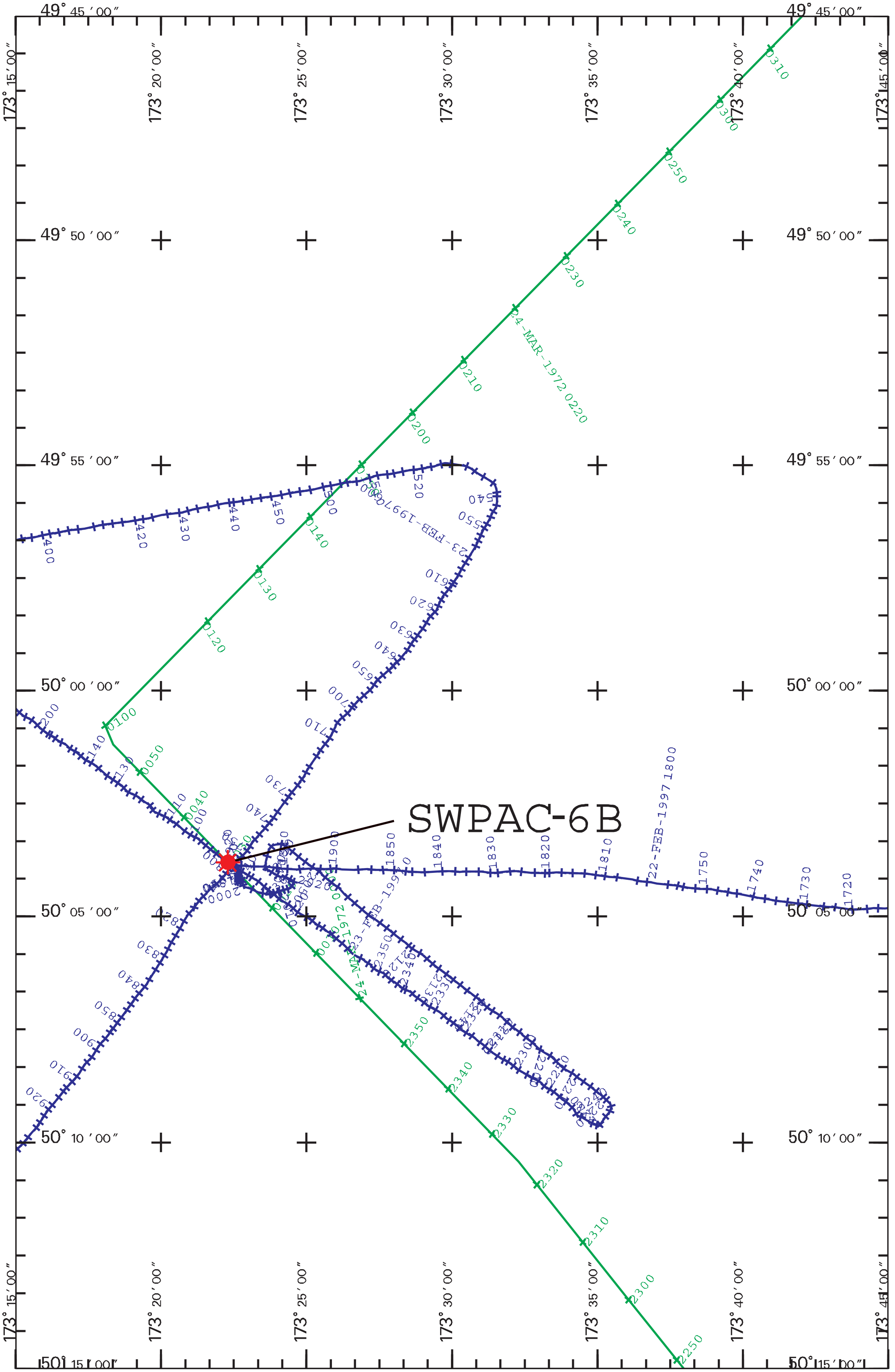
Objectives: The objectives of SWPAC-6B are to:

1. Determine the evolution of circum-Antarctic ocean circulation, including periods when the boundary current component may have extended into shallow depths or reversed.
2. Determine the behavior of low salinity AAIW.
3. Stable isotope analyses to outline water mass and productivity variability through mid-Oligocene.

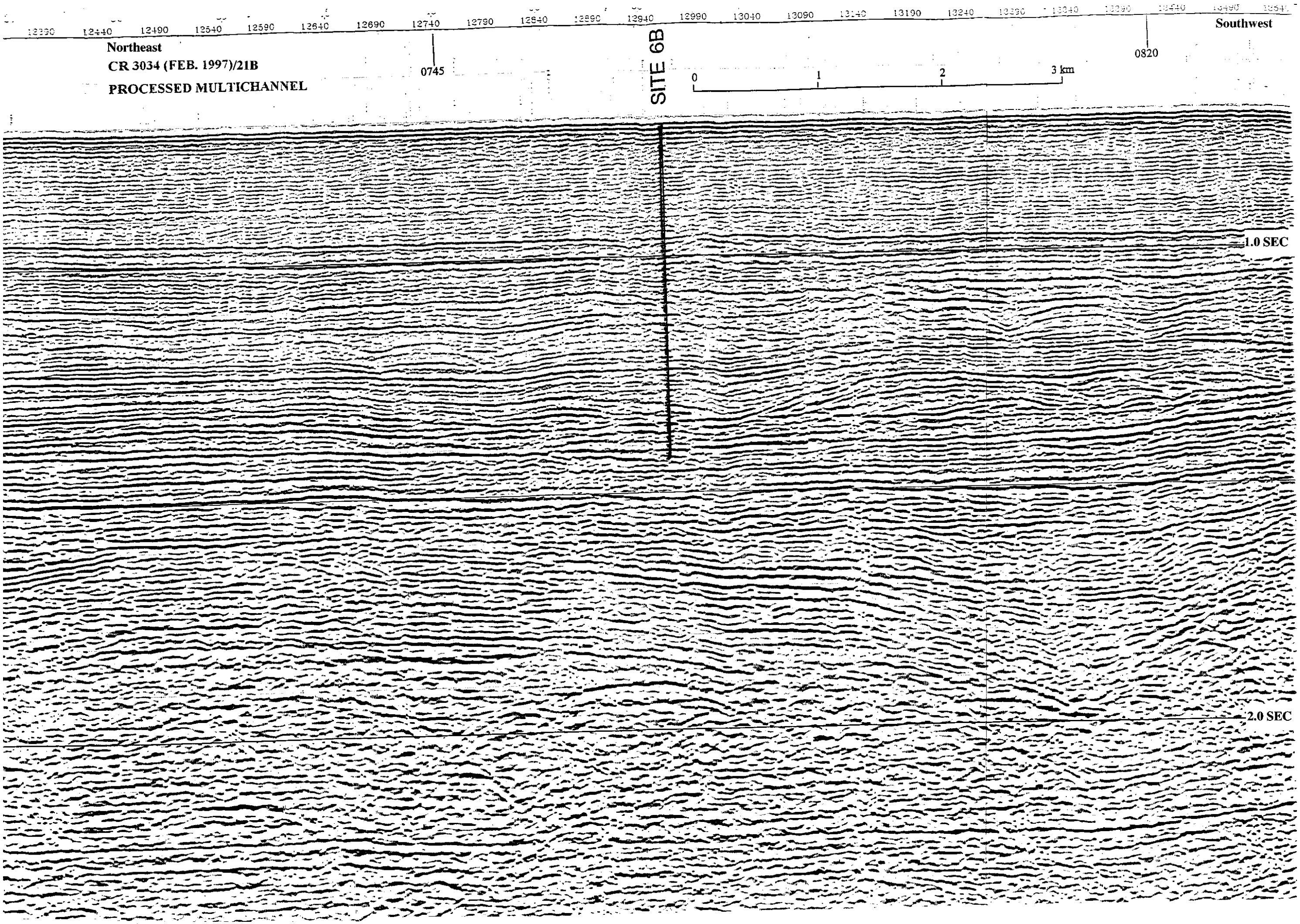
Drilling Program: Triple APC, XCB

Logging and Downhole Operations: Triple combo, FMS/Sonic, GHMT

Nature of Rock Anticipated: Calcareous biopelagites



Track Line SWPAC-6B



Seismic Line SWPAC-6B

Site: SWPAC-7B

Priority: 1

Position: 50°53.88'S, 176°59.81'E

Water Depth: 4505 m

Sediment Thickness: 776 m

Target Drilling Depth: 410 m

Approved Maximum Penetration: 510 m

Seismic Coverage: Eltanin 43, NIWAR 3034 Lines 16 and 17

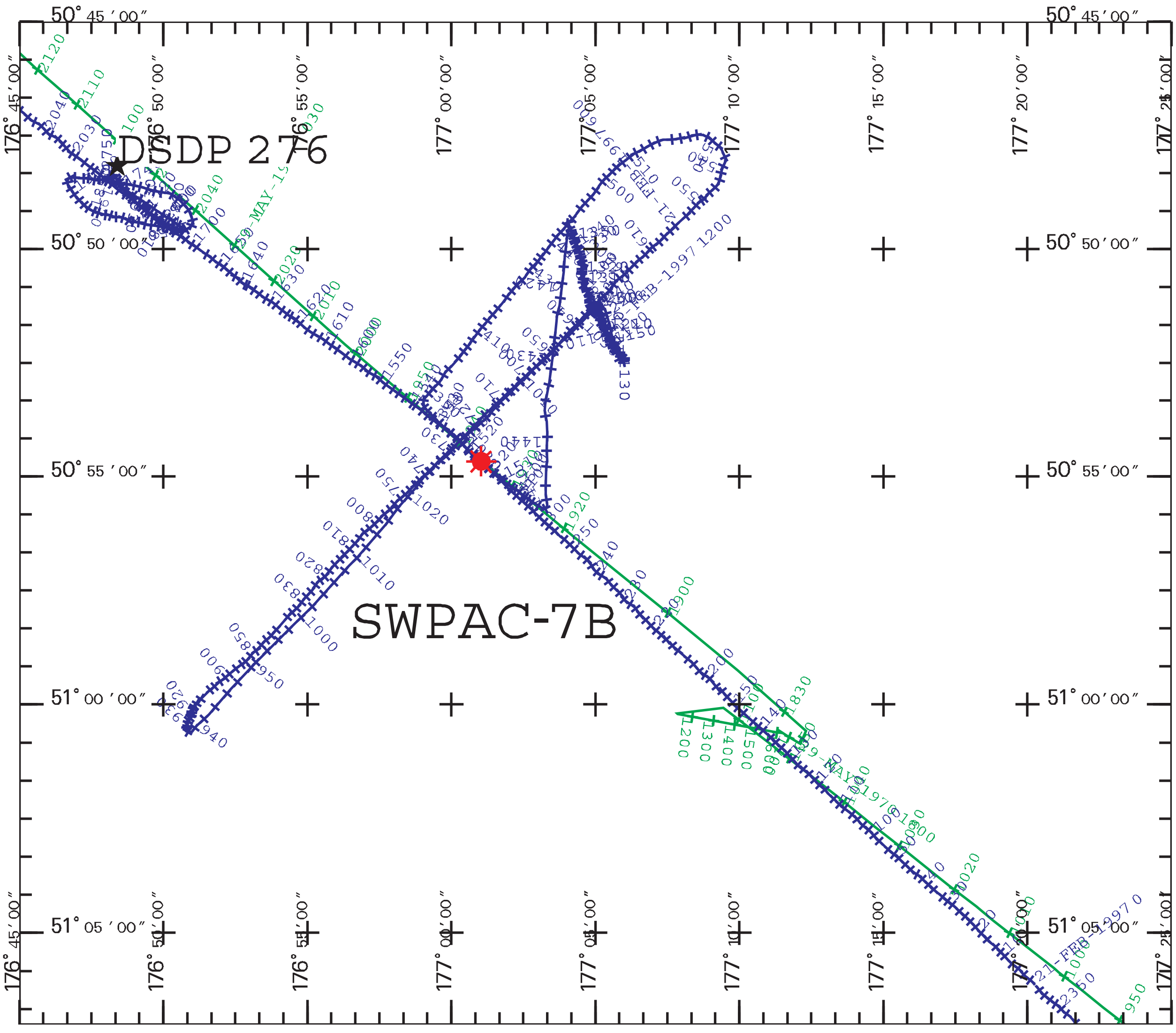
Objectives: The objectives of SWPAC-7B are to:

1. Determine history of CDW incursions into SW Pacific.
2. Evaluate grain-size signals (flow speed) to determine water mass movement at this site to estimate the velocity behavior of the DWBC.
3. This site will be important for assessing the extent to which the ACC acts as a driving force for CDW inflow.

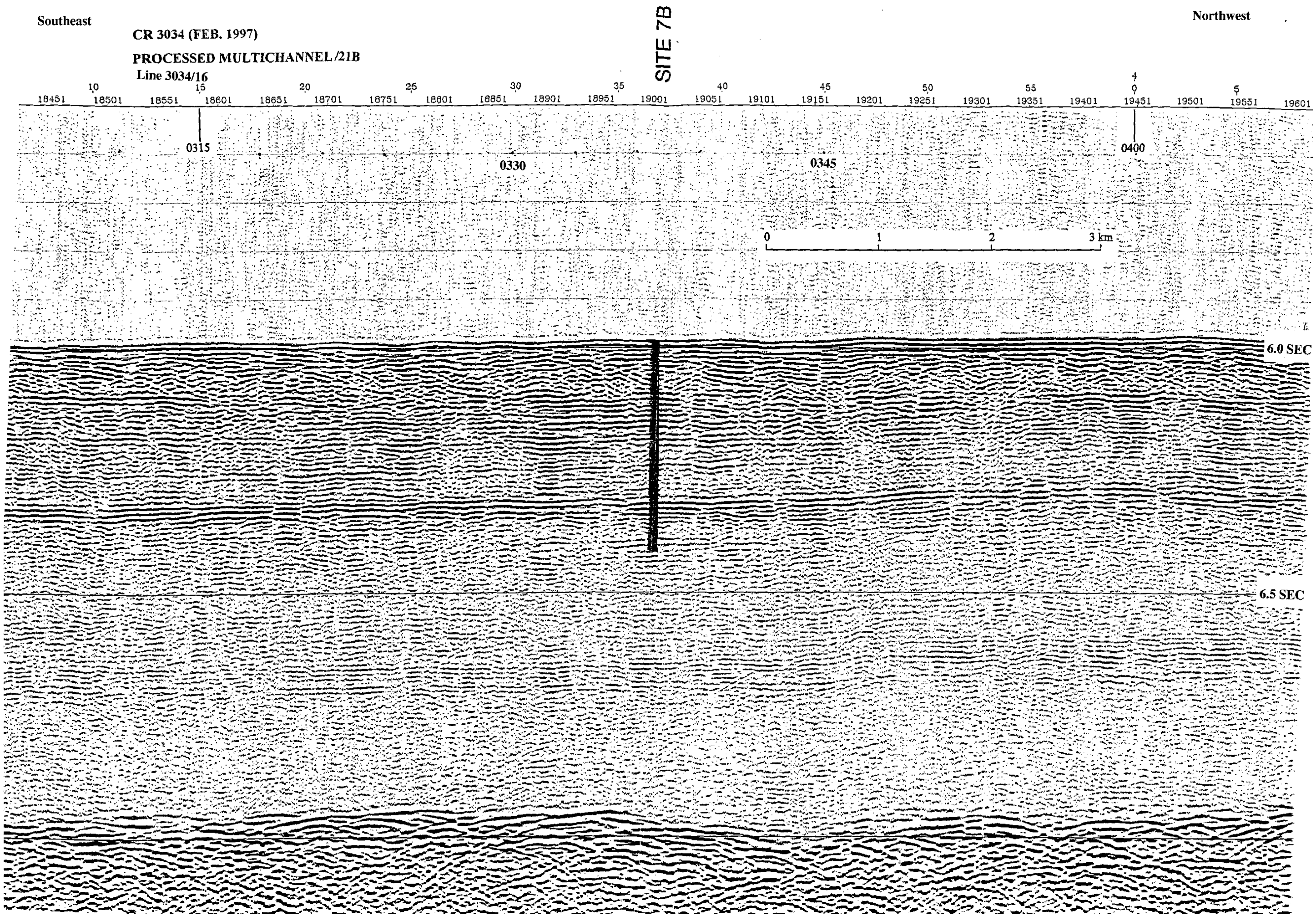
Drilling Program: Double APC, XCB

Logging and Downhole Operations: Triple combo, FMS/Sonic, GHMT

Nature of Rock Anticipated: Sand and Mn nodules on surface; foraminiferal ooze and terrigenous mud



Track Line SWPAC-7B



Seismic Line SWPAC-7B

Site: SWPAC-8A

Priority: 1

Position: 46°34.78'S, 177°23.63'W

Water Depth: 4425 m

Sediment Thickness: 1160 m

Target Drilling Depth: 710 m

Approved Maximum Penetration: 800 m

Seismic Coverage: NZOI Lines CR2023, CR2040, and CR1151; NIWAR 3034 Lines 11 and 12

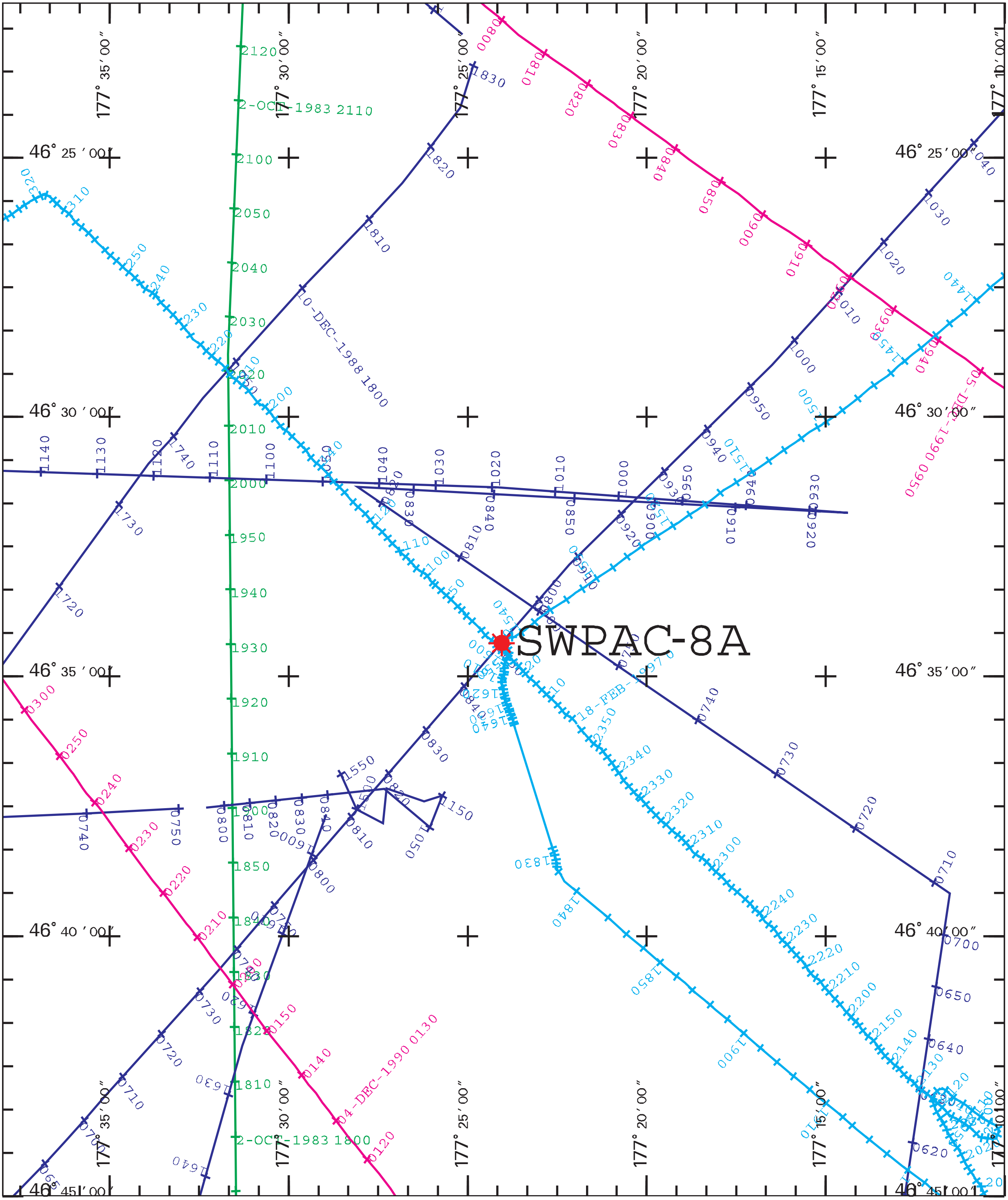
Objectives: The objectives of SWPAC-8A are to:

1. Determine climate, sea level, and tectonic controls on abyssal sediment supply.
2. Test the deep-sea cyclotherm model.
3. Evaluate late Miocene to Holocene sediment injection into DWBC.
4. This site in combination with the most southerly drift sites (Sites SWPAC-6B, 7B) will allow us to assess the shift in position of the climatically important AAC and SAF fronts using faunal and coarse-fraction analysis and stable isotopic and magnetic susceptibility measurements to trace ice-rafted detritus.

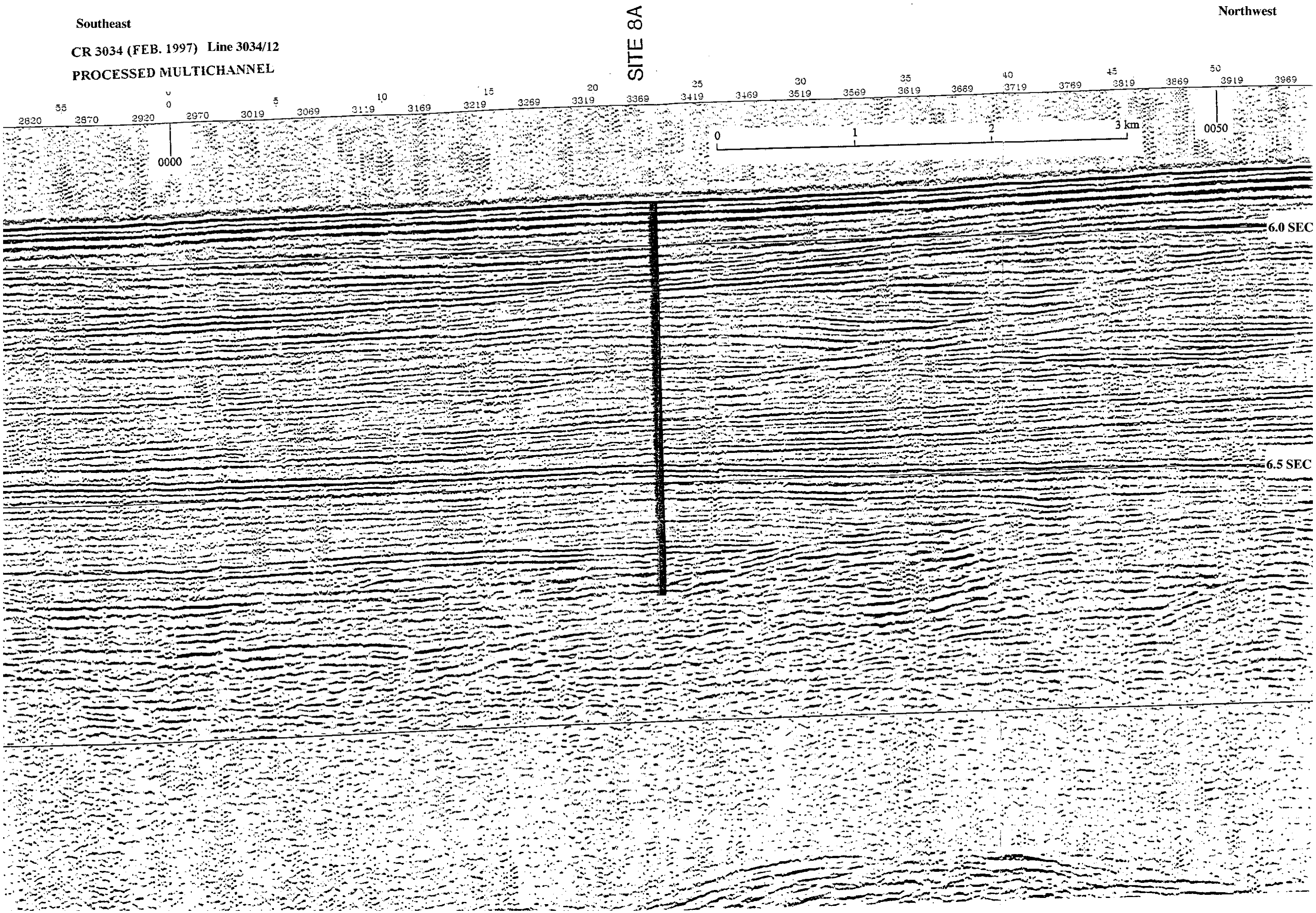
Drilling Program: Double APC, XCB

Logging and Downhole Operations: Triple combo, FMS/Sonic, GHMT

Nature of Rock Anticipated: Terrigenous silt/mud turbidites, hemipelagites



Track Line SWPAC-8A



Seismic Line SWPAC-8A

Site: SWPAC-9B

Priority: 1

Position: 39°29.90'S, 176°31.90'W

Water Depth: 4001 m

Sediment Thickness: 564 m

Target Drilling Depth: 510 m

Approved Maximum Penetration: 600 m

Seismic Coverage: NZO1 2050 Lines A and B

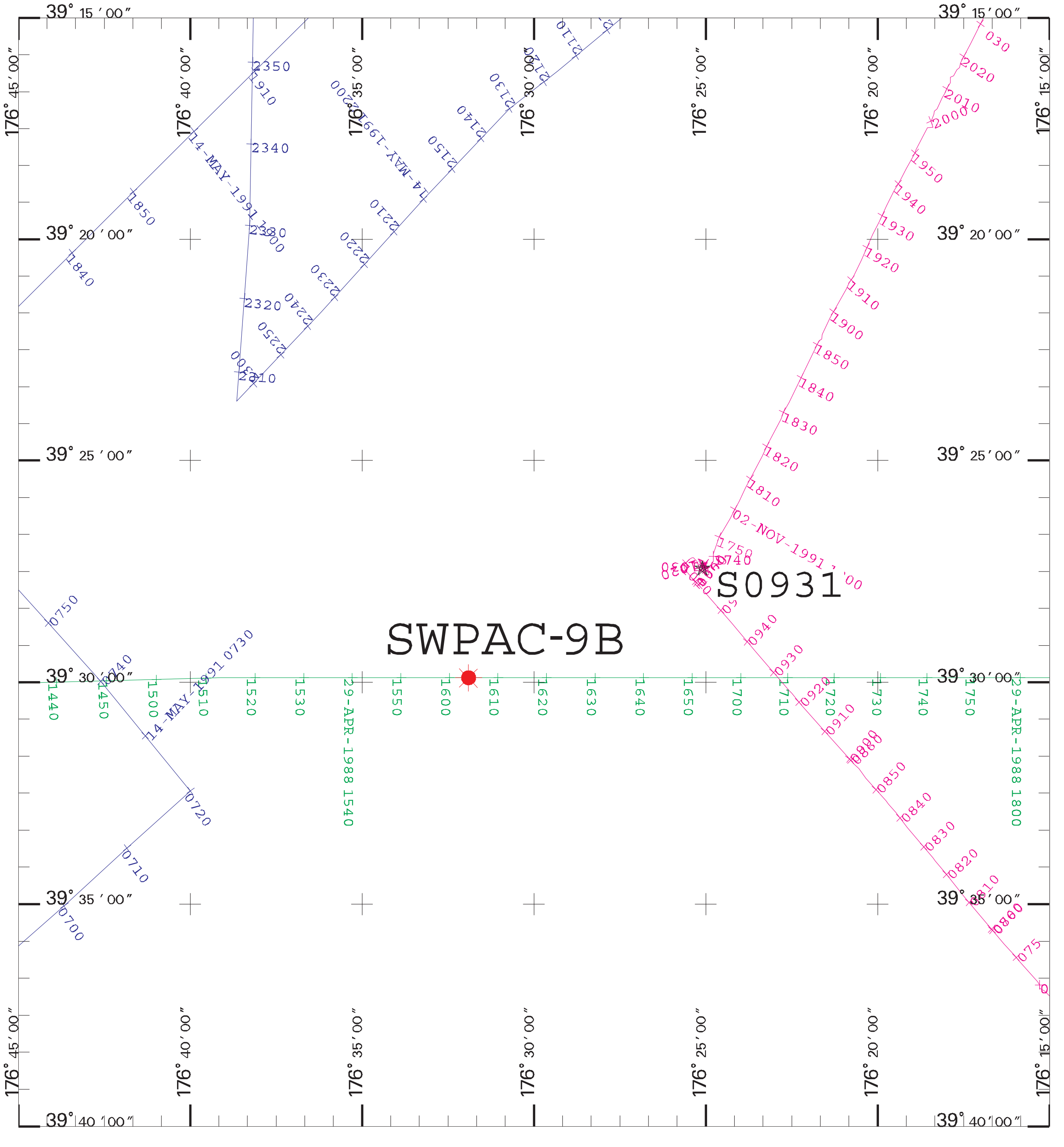
Objectives: The objectives of SWPAC-9B are to determine:

1. Miocene evolution of DWBC and associated water masses.
2. Abyssal sediment budget.
3. Paleovolcanic history of the Neogene.

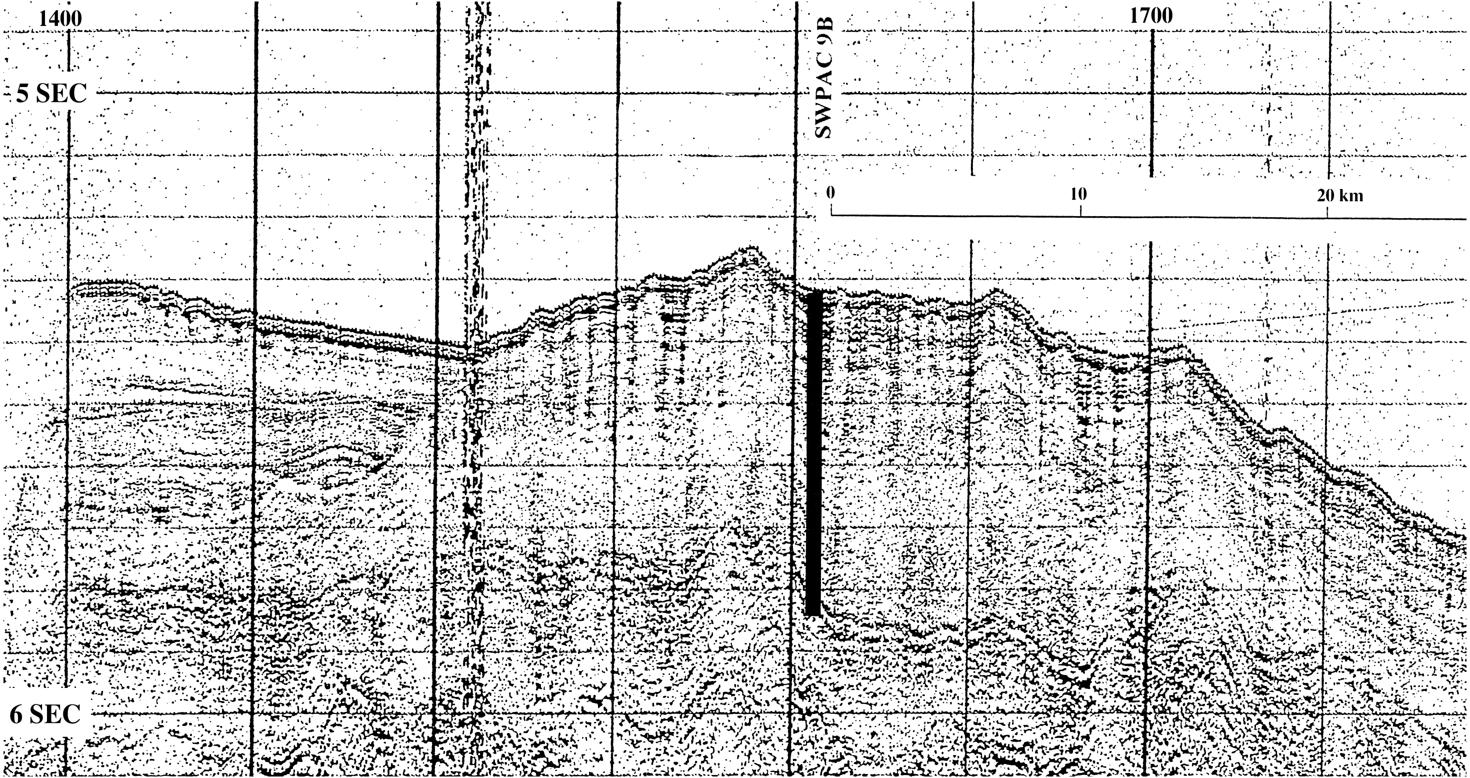
Drilling Program: Double APC, XCB

Logging and Downhole Operations: Triple combo, FMS/Sonic, GHMT

Nature of Rock Anticipated: Terrigenous and carbonate/siliceous mud, tephra



Track Lines SWPAC-9B



Seismic Line SWPAC-9B

Site: SWPAC-10B

Priority: 2

Position: 46°14.8'S, 176°56.9'W

Water Depth: 4542 m

Sediment Thickness: ~2000 m

Target Drilling Depth: 400 m

Approved Maximum Penetration: 400 m

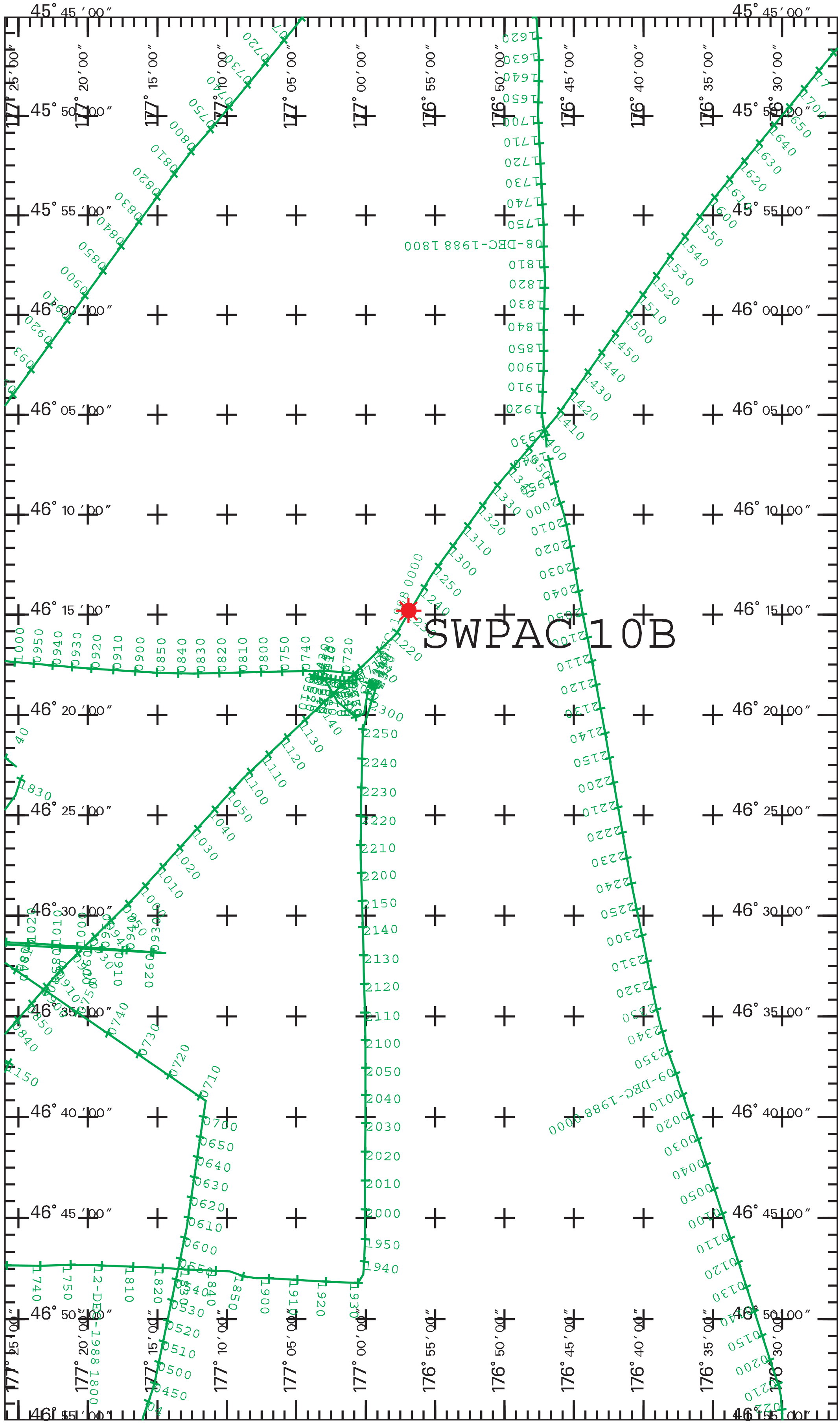
Seismic Coverage:

Objectives: The objectives of SWPAC-10B are the same as for SWPAC-8A

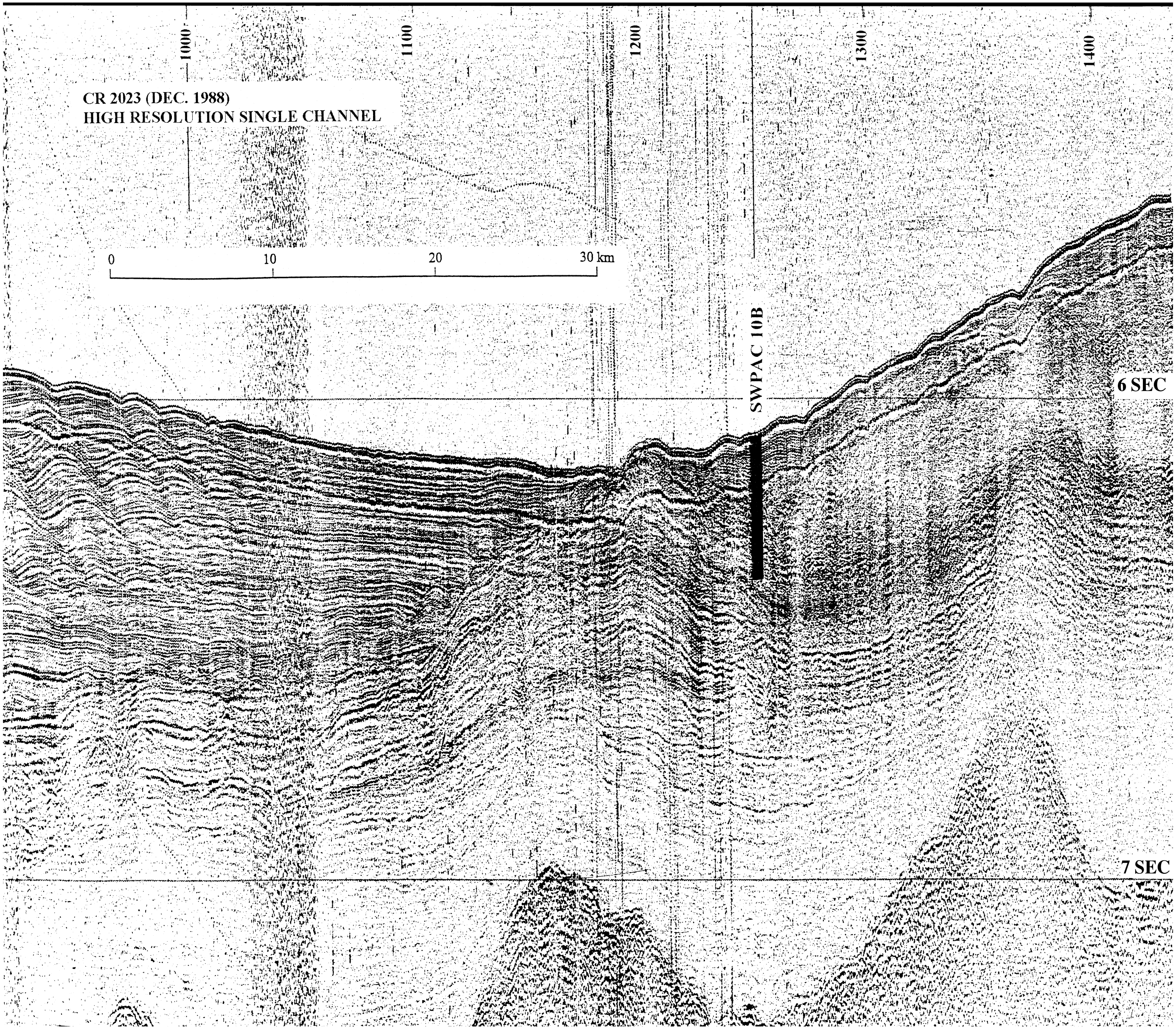
Drilling Program: Double APC, XCB

Logging and Downhole Operations: Triple combo, FMS/Sonic, GHMT

Nature of Rock Anticipated: Terrigenous, biosiliceous and carbonate sediments.



Track Line SWPAC-10B



Seismic Line SWPAC-10B

Site: SWPAC-16A

Priority: 2

Position: 42°25.22'S, 167°30.58'W

Water Depth: 4616 m

Sediment Thickness: ~2000 m

Target Drilling Depth: 480 m

Approved Maximum Penetration: 480 m

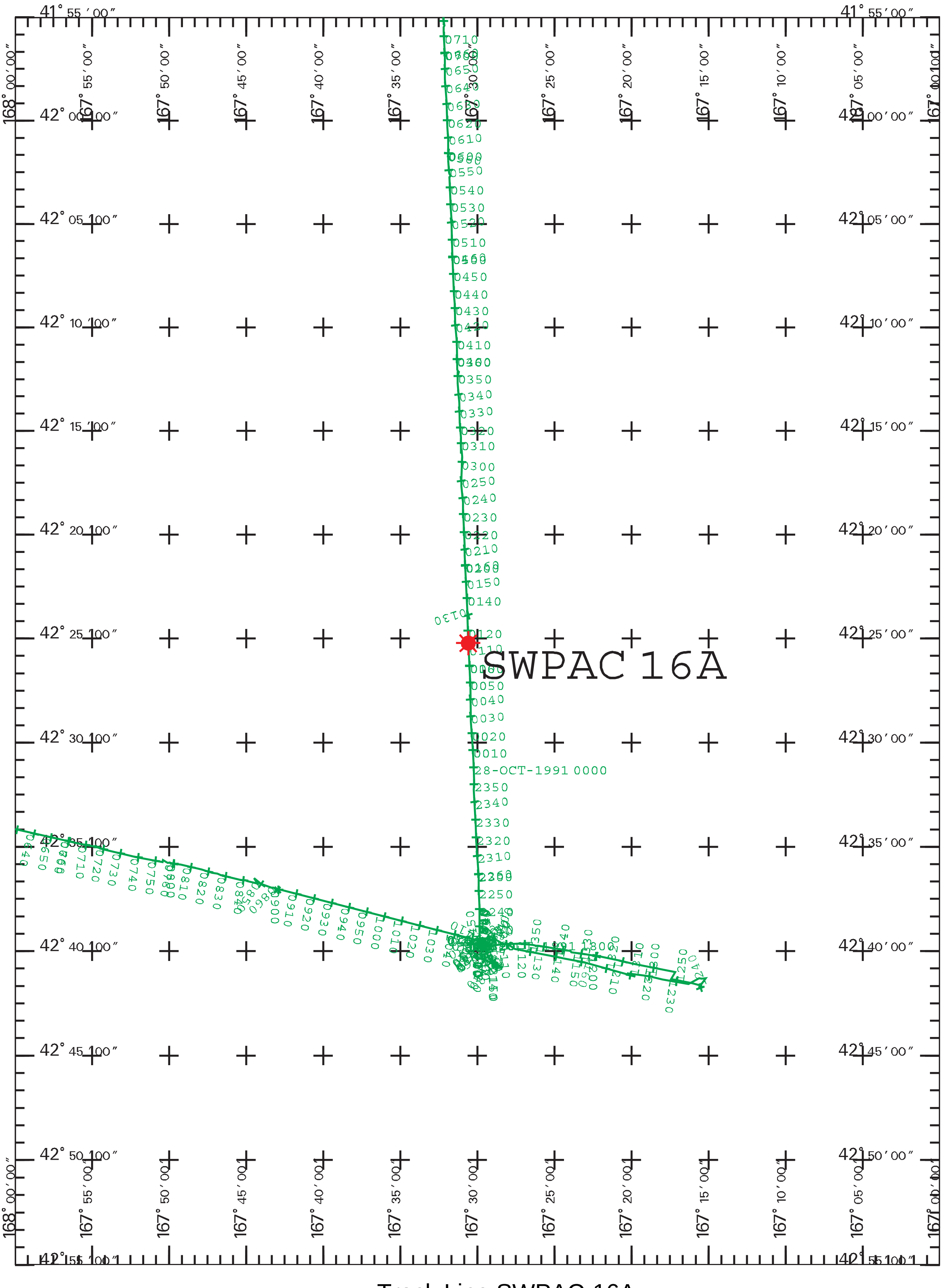
Seismic Coverage:

Objectives: The objectives of SWPAC-16A are the same as for SWPAC-9B and 5B

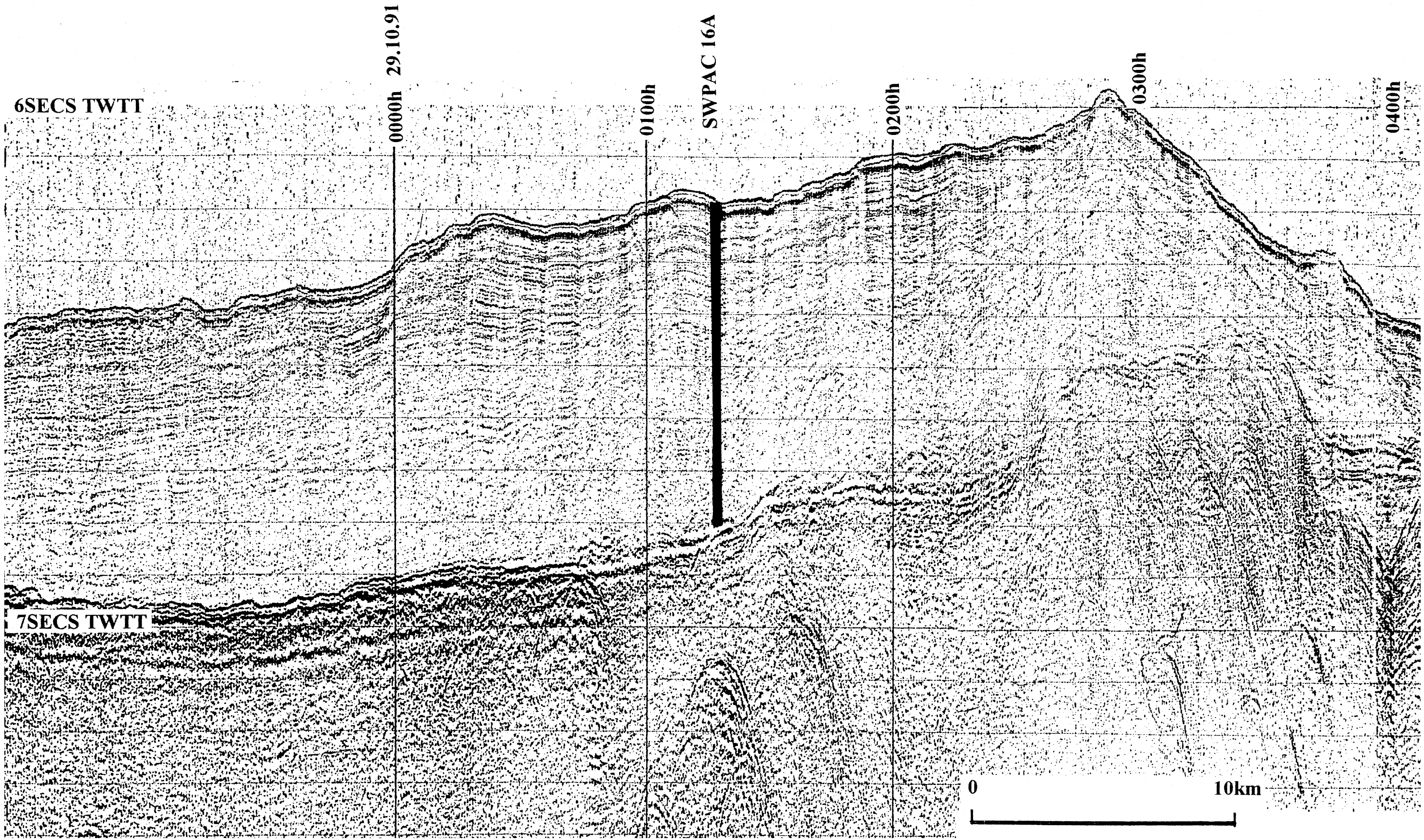
Drilling Program: Double APC, XCB

Logging and Downhole Operations: Triple combo, FMS/Sonic, GHMT

Nature of Rock Anticipated: Terrigenous mud with variable carbonate and biosiliceous content



Track Line SWPAC-16A



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*Scientific Party is subject to change.