Integrated Ocean Drilling Program
Expedition 318 Scientific Prospectus

Cenozoic East Antarctic Ice Sheet Evolution from Wilkes Land Margin Sediments

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Abstract

Understanding the evolution and dynamics of the Antarctic cryosphere, from its inception during the Eocene–Oligocene transition (~33 Ma) through the significant periods of climate change during the Cenozoic, is not only of major scientific interest but also is of great importance for society. The transition from Greenhouse to Icehouse Earth conceivably was the most significant step in large-scale planetary change, impacting global sea level, albedo, and oceanographic and biotic evolution, among other changes. State-of-the-art climate models combined with paleoclimatic proxy data suggest that the main triggering mechanism for initial inception and development of the Antarctic glaciation was the decreasing levels of CO_2 concentration in the atmosphere. With current rising atmospheric greenhouse gases resulting in rapidly rising global temperatures, studies of polar climates, and the Antarctic cryosphere behavior in particular, are prominent on the research agenda.

Drilling the Antarctic Wilkes Land margin is designed to provide a long-term record, obtained from sedimentary archives along an inshore to offshore transect, of Antarctic glaciation and its intimate relationships with global climatic and oceanographic change. Stratigraphic interpretations indicate that the Wilkes Land record will include the critical periods in Cenozoic Earth climate evolution when the cryosphere formed, likely in step-wise fashion, and subsequently evolved to assume its present-day configuration. The principal goals are

1. To obtain the timing and nature of the first arrival of ice at the Wilkes Land margin (referred to as the “onset of glaciation”) inferred to have occurred during the earliest Oligocene (Oligocene isotope event-1),
2. To obtain the nature and age of the changes in the geometry of the progradational wedge interpreted to correspond with large fluctuations in the extent of the East Antarctic Ice Sheet (EAIS) and possibly coinciding with the transition from a wet-based to a cold-based glacial regime (late Miocene–Pliocene?),
3. To obtain a high-resolution record of Antarctic climate variability during the late Neogene and Quaternary, and
4. To obtain an unprecedented, ultrahigh resolution (i.e., annual to decadal) Holocene record of climate variability.

The Wilkes Land drilling program is designed to constrain the age, nature, and paleoenvironment of deposition of the previously only seismically inferred glacial sequences. Determining the chronostratigraphy of the Wilkes Land sediments, which

is at present nonexistent, is critical to ground-truth the existing glacial-stratigraphic and ice sheet volume models for this margin. Ice sheet models suggest that the Wilkes Land margin became glaciated in the later stages of East Antarctic glaciation, after Prydz Bay and the Weddell Sea; therefore, it is presumed to be more sensitive to future temperature changes. Drilling the Wilkes Land margin has a unique advantage in that Unconformity WL-U3, inferred to separate preglacial strata below from glacial strata above in the continental shelf, can be traced to the continental rise deposits, allowing sequences to be linked from shelf to rise. Because strata below and above the “glacial onset” unconformity can be sampled at relatively shallow penetration depths, the record of the onset of glaciation can be obtained during a single drilling expedition from two depositional environments, the shelf foreset (proposed Sites WLSHE-07, WLSHE-09, WLSHE-10, and WLSHE-11) and the abyssal plain hemipelagic (proposed Site WLRIS-02A) strata. The shelf foreset section provides a direct record of first occurrence of grounded ice but one that is less continuous and harder to date. The rise hemipelagic section provides an indirect record of glaciation but one that is more continuous and easier to date. Constraints on the age and nature of the Wilkes Land glacial sequences is essential to provide age constraints for models of Antarctic ice sheet development.

The EAIS in the Wilkes subglacial basin is grounded below sea level and therefore may have been more sensitive to climate changes in the late Neogene. The sedimentary sections on the Wilkes Land margin may therefore not only hold the record of the time when the EAIS first reached this margin, but also the record of ice sheet fluctuations during times when the EAIS is thought to be more stable (15 Ma–recent). This information is critical for developing reliable models of future Antarctic ice sheet behavior.

Schedule for Expedition 318

Expedition 318 to the Wilkes Land margin of Antarctica is derived from the original Integrated Ocean Drilling Program (IODP) drilling Proposal 482 as well as Ancillary Project Letter 638 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) and planned for the *JOIDES Resolution,* operating under contract with the U.S. Implementing Organization (USIO). The expedition is currently scheduled to begin in Wellington, New Zealand, in January 2009 and end in Wellington in March 2009. The exact dates of the USIO expedition schedule may be adjusted depending on the completion date of the conversion of the drillship. For the current

JOIDES Resolution schedule, see **iodp.tamu.edu/scienceops.** Supporting site survey data for Expedition 318 are archived at the IODP-Management International Site Survey Data Bank (**ssdb.iodp.org**). Details on the facilities aboard the *JOIDES Resolution* can be found at **iodp.tamu.edu/publicinfo/drillship.html.**

Introduction

Polar ice is an important component of the modern climate system, affecting global sea level, ocean circulation and heat transport, marine productivity, and planetary albedo, among other things. The modern semipermanent ice caps are, geologically speaking, a relatively young phenomenon. Since mid-Permian (~270 Ma) times, parts of Antarctica became (re)glaciated only ~34 m.y. ago, whereas episodes of major Northern Hemisphere continental ice began ~3 m.y. ago (e.g., Zachos et al., 2001) (Fig. **F1**). In a broad sense, the record of Antarctic glaciation from the time of first ice sheet inception (around the Eocene/Oligocene boundary; Oligocene isotope event 1 [Oi-1] glaciation) through the significant periods of climate change during the Cenozoic, such as the Oligocene/Miocene boundary, the Miocene isotope event 1 [Mi-1], the mid-Miocene climatic optimum, late Neogene cooling, early Pliocene warming events, the Quaternary glacial–interglacial cycles, and the concomitant biotic and paleocenographic evolution, is not only of scientific interest but also is of great importance for society. State-of-the-art climate models (e.g., DeConto and Pollard, 2003a, 2003b; Huber et al., 2004; DeConto et al., 2007) combined with paleoclimatic proxy data (e.g., Pagani et al., 2005) suggest that the main triggering mechanism for initial inception and development of the Antarctic ice sheet were the decreasing levels of CO_2 concentration in the atmosphere (Fig. **F2**), and that the opening of critical Southern Ocean gateways (e.g., Kennett, 1977; DeConto and Pollard, 2003a, 2003b; Huber et al., 2004; Barker and Thomas, 2004) played only a secondary role. With current rising atmospheric greenhouse gases resulting in rapidly rising global temperatures (Intergovernmental Panel on Climate Change [IPCC], 2007), studies of polar climates are prominent on the research agenda. Understanding Antarctic ice sheet dynamics and stability is of special relevance because, based on IPCC 2007 forecasts, CO_2 doubling or 1.8°–4°C equivalent for the end of this century is expected. These conditions were not experienced in our planet since 10–15 Ma, when only the Antarctic ice sheet existed (Fig. **F3**).

Since their inception, like the Northern Hemisphere ice sheets, the Antarctic ice sheets appear to have been very dynamic; waxing and waning in response to global climate change over intermediate and even short (orbital) timescales (e.g., Wise et al., 1991; Zachos et al., 1997; Barker, Camerlenghi, Acton, et al., 1999; DeConto and Pollard, 2003a, 2003b). Yet, not much is known about the nature, cause, timing, and rate of processes involved, notably of Antarctic glaciation. Past ocean drilling into the Antarctic continental shelf and basins in Prydz Bay and the Ross Sea (i.e., Ocean Drilling Program [ODP] Legs 119 and 188, Deep Sea Drilling Program [DSDP] Leg 28, and Cape Roberts Project) indicates two basic states of the Antarctic ice sheet(s): (1) an early phase lasting ~20 m.y. with a less stable ice cover characterized by strong cyclic waxing and waning (Zachos et al., 1997; Wade and Pälike, 2004; Pälike et al., 2006), and (2) a later (from ~14 Ma to recent) phase when deep-sea isotope records (e.g., Miller et al., 1985; Flower and Kennett, 1994) indicate that the Antarctic ice sheet(s) became a quasipermanent, and more stable, feature sustaining polar climates. However, even the "stable" ice sheets may have varied considerably in size, perhaps by as much as 25 m of sea level equivalent (SLE) (Kennett and Hodell, 1993). Of the two main ice sheets, the West Antarctic Ice Sheet (WAIS) (Fig. **F4**) is mainly marine based and is considered less stable. The EAIS, which overlies continental terranes that are largely above sea level, is considered stable and is believed to respond only slowly to changes in climate. However, reports of beach gravel deposited 20 m above sea level in Bermuda and the Bahamas from 420 to 360 ka indicate the collapse of not only the WAIS (6 m of SLE), and the Greenland ice sheet (6 m of SLE), but possibly also 8 m of SLE from East Antarctic ice sources (Hearty et al., 1999). Therefore, it is indicated that during episodes of global warmth, with likely elevated atmospheric CO_2 conditions, the EAIS may contribute just as much or more to rising global sea level as the proverbial unstable Greenland ice sheet. In the face of rising CO_2 levels (IPCC, 2007) a better understanding of the EAIS dynamics is therefore urgently needed from both an academic as well as a societal point of view.

A key region for analysis of the long- and short-term behavior of the EAIS is the eastern sector of the Wilkes Land margin, located at the seaward termination of the largest East Antarctic subglacial basin, the Wilkes subglacial basin (Figs. **F5, F6**) (Drewry, 1983; Ferraccioli et al., 2001, 2007). The base of the portion of the EAIS draining through the Wilkes subglacial basin is largely below sea level, suggesting that this portion of the EAIS is potentially less stable than the rest of the EAIS. Numerical models of ice sheet behavior (e.g., Huybrechts, 1993; DeConto and Pollard, 2003a, 2003b) (Fig. **F2**) provide a basic understanding of the climatic sensitivity of particular Antarctic regions for early ice sheet formation, connection and expansion, and eventual formation of the entire ice sheet. For example, in these models glaciation is shown to have begun in the East Antarctic interior, discharging mainly through the Lambert

Graben to Prydz Bay. These models imply that the EAIS did not reach sea level in the Wilkes Land margin until a later stage. These models must now be validated through drilling and obtaining concrete evidence found in the sedimentary record. Sediments from Prydz Bay cores drilled during Leg 188 (O'Brien, Cooper, Richter, et al., 2001; Cooper, O'Brien, and Richter, 2004) contained the record of the first arrival of ice sheets to that margin. There, the onset of glaciation is dated to the latest Eocene–earliest Oligocene (~34 Ma). The timing and mode of the onset of glaciation at the Wilkes Land continental margin is still unknown but is essential for providing age constraints for the models of EAIS development and changes in its volume. Moreover, detailed portrayal of the subsequent Cenozoic history and dynamics of the Antarctic glacial cycles at Wilkes Land will provide further constraints for model experiments and future predictions about EAIS stability.

Conceivably even more important than the history of the Antarctic glaciations are past lessons of deglaciations. Seismic surveys and pilot studies indicate that the Wilkes Land margin also includes sites of ultrahigh accumulation rates of sediments recording the Holocene deglaciation. Recovery and analysis of these unique ~200 m thick series of "tree ring" type, annually layered sediments predominantly consisting of phytoplankton remains constituting one of the worlds most expanded archives of recent environmental change is one of the tasks ahead to ensure palaeoenvironmental reconstruction with unprecedented detail.

During Expedition 318, we will drill key sites along a shelf-rise-abyssal plain transect at Wilkes Land, Antarctica (Figs. **F5, F6;** Table **T1**), to determine the timing and mode of the onset of Antarctic glaciation at the Wilkes Land continental margin, to determine the subsequent Cenozoic history and dynamics of the Antarctic glacial cycles, and to recover and reconstruct the dynamics of the youngest deglaciation in detail.

Background

Physiographic and geologic setting

The Adélie and George V Coasts of the eastern Wilkes Land margin drain the EAIS with a mostly divergent flow pattern (Fig. **F4**). Ice cliffs and two prominent outlet glaciers, the Mertz and the Ninnis, characterize the present coastline (Figs. **F5, F6**). These outlet glaciers extend seaward as ice tongues and have an important role in ice drainage and sediment delivery to the ocean (Anderson et al., 1980; Drewry and Cooper, 1981). Drainage velocities in outlet glaciers range from >0.5 km/y to ~3.7 km/y (Fig.

F4) (Lindstrom and Tyler, 1984; MacDonald et al., 1989), whereas drainage in the areas between outlet glaciers, occupied by sea cliffs, may range from a few meters to tens of meters every year (Anderson, 1999).

The eastern Wilkes Land continental margin formed during the Cretaceous separation of Australia and Antarctica (Cande and Mutter, 1982; Sayers et al., 2001; Veevers, 1987; Colwell et al., 2006; O'Brien and Stagg, 2007; Leitchenkov et al., 2007). The acoustic basement across the margin consists of block-faulted continental crust, thinned and intruded transitional crust, and oceanic crust (Eittreim and Smith, 1987; Eittreim, 1994). Deep marginal rift basins generally characterize the transition zone from continental to oceanic crust (Eittreim, 1994). Maximum sedimentary thickness (~8 km) has been reported from these marginal rift basins.

The stratigraphy of the eastern Wilkes Land margin is known mainly from the seismic stratigraphic analyses of numerous multichannel seismic reflection surveys in the eastern Wilkes Land margin (Sato et al., 1984; Wannesson et al., 1985; Tsumuraya et al., 1985; Eittreim and Hampton, 1987; Ishihara et al., 1996; Tanahashi et al., 1997; Brancolini et al., 2000; Stagg et al., 2004) (Fig. F5) complemented by gravity and piston sediment cores (Payne and Conolly, 1972; Hampton et al., 1987; Domack et al., 1980; Domack, 1982; Tsumuraya et al., 1985; Ishihara et al., 1996; Tanahashi et al., 1997; Brancolini et al., 2000; Escutia et al., 2003; Michel et al., 2006), dredging (Mawson 1940, 1942; Domack et al., 1980; Sato et al., 1984; Leventer et al., 2001), and limited deep geological sampling recovery at DSDP Site 269 (Hayes, Frakes, et al., 1975).

Pre–ice sheet stratigraphy

Presumed pre-Oligocene synrift strata are ~3 km thick and are highly variable in seismic character, with discontinuous, faulted, and tilted strata onlapping the flanks of the acoustic basement (Eittreim and Smith, 1987; Eittreim, 1994; De Santis et al., 2003; Stagg et al., 2004; Leitchenkov et al., 2007). Postrift strata across the eastern Wilkes Land margin are as thick as 5 km, well layered on the continental rise, and less stratified and discontinuous landward (Eittreim and Smith, 1987; Wannesson, 1990; Tanahashi et al., 1994; Eittreim, 1994; De Santis et al., 2003). On the continental shelf, a prominent regional unconformity (WL-U3) within the Cenozoic postrift section (Fig. F7) is believed to be due to erosional processes related to the first advance of grounded ice sheets onto the continental shelf (Eittreim and Smith, 1987; Tanahashi et al., 1994; Eittreim et al., 1995; Escutia et al., 1997). Pre–ice sheet strata below Unconformity WL-U3, where resolvable, are flat-lying and less stratified than glacial strata above the unconformity.

The only pre–ice sheet strata sampled from this margin include a series of dredges from the inner continental shelf and slope. Erosion by late Cenozoic glaciers near the Mertz ice tongue exposed Mesozoic sediments at the seafloor, which allowed recovery of lignite (Mawson, 1940, 1942) and lower Cretaceous brecciated carbonaceous siltstone (Domack et al., 1980). Dredges collected in the area by Leventer et al. (2001) also recovered Paleogene lignites with reworked Early Cretaceous flora. Dredging of the upper continental slope off Terre Adélie, sampled Oligocene and Miocene limestones and undated sedimentary, metamorphic, and igneous rocks of mostly ice-rafted origin (Sato et al., 1984).

Continental shelf glacial stratigraphy

Glacial sequences on the shelf form prograding wedges (Fig. **F7**) that are deeply eroded by broad troughs that cross the shelf. The erosional troughs are interpreted to be the paths of rapidly moving ice streams during times of glacial advances into the shelf (Eittreim et al., 1995). Foreset strata are commonly truncated at or near the seafloor beneath the troughs (Fig. **F7**). Topset strata form the banks adjacent to the troughs, where the ice is inferred to have moved slowly.

Two main unconformities of regional character, Unconformities WL-U3 and WL-U8, are identified as truncating the glacial seismic sequences on the shelf (Wannesson et al., 1985; Eittreim and Smith, 1987; Hampton et al., 1987; Escutia et al., 1997; De Santis et al., 2003) (Fig. **F7**). The erosional events represented by these unconformities are interpreted to result from grounded ice sheets moving across the continental shelf (Tanahashi et al., 1994; Eittreim et al., 1995, Escutia et al., 1997). Eittreim et al. (1995) calculated an erosion of 300 to 600 m of strata below Unconformity WL-U3 and of 350 to 700 m of strata below Unconformity WL-U8. Unconformity WL-U3 marks the start of progradation in this sector of the Wilkes Land margin. Across Unconformity WL-U8, a change in the geometry of the outer shelf progradational wedge, from shallower dips below Unconformity WL-U8 to steeper dips above (foreset slopes as much as ~10°), can be seen.

During the interglacial open-marine Holocene, thick laminated diatom mud and oozes were deposited in deep (>1000 m) inner shelf basins, including the Adélie Drift (see IODP Proposal 638 available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) (Costa et al., 2007) (Figs. **F5, F8**). Based on accelerator mass spectrometry radiocarbon dates on a 50 m long sediment core, this drift has unusually high accumulation rates, as much as 20–21 m/k.y. Opal, Ti, and Ba time series show decadal to century variance suggestive of solar forcing and El Niño Southern Oscillation (ENSO) forcing (Dunbar et al., 1985; Crosta et al., 2005; Denis et al. 2005; Leventer et al., 2006; Maddison et al., 2006; Costa et al., 2007).

Continental rise and abyssal plain glacial stratigraphy

Seismic units have been correlated from shelf to rise and abyssal plain based largely on tracing and projecting unconformities and seismic units. Seismic units above Unconformity WL-U8 downlap and pinch out at the base of the continental slope, but deeper units (i.e., between Unconformities WL-U8 and WL-U3) continue across the margin (Hampton et al., 1987; Eittreim et al., 1995; Escutia et al., 1997; De Santis et al., 2003) (Fig. **F7**). The principal marker is Unconformity WL-U3, which in Wilkes Land can be traced from the shelf, where it marks the onset of progradation on the Wilkes Land margin (Eittreim and Smith, 1987), to the rise, where it correlates with an upsection increase in turbidite and contourite deposition (Escutia et al., 1997; 2000; Donda et al., 2003) (Fig. **F9**).

On the eastern Wilkes Land continental rise, strata above Unconformity WL-U3 include six glacial-related seismic units (WL-S4–WL-S9) (De Santis et al., 2003; Donda et al., 2003) (Fig. **F9**). The two deepest units, WL-S4 and WL-S5, consist of stratified and continuous reflectors that onlap at the base of the slope (seismic Units WL1c and WL1b of Escutia et al., 1997; Donda et al., 2003). Acoustic signatures of isolated channel-levee complexes that characterize turbidite deposition are first observed during deposition of Unit WL-S5 (Escutia et al., 1997; Donda et al., 2003). Channel-levee complexes became widespread during deposition of Units WL-S6 and WL-S7, and turbidity flows were the dominant process building the large sedimentary ridges on the rise. Wavy reflectors that are characteristic of bottom contour-current deposition occur on the lower rise in Unit WL-S6 and on the upper rise in Unit WL-S7. Unit WL-S8 mostly fills previous depressions, although there is evidence for bottom contour-current and turbidite flows (Escutia et al., 1997; Donda et al., 2003). Unit WL-S9 is a discontinuous unit on the rise, and, where present, is composed of channel and levee complexes and layered reflectors (Donda et al., 2003).

Previous drilling on the Wilkes Land margin

Operations during Leg 28 drilled Site 269 on the eastern Wilkes Land abyssal plain to determine the geologic and climate history of Antarctica and the Southern Ocean (Hayes, Frakes, et al., 1975). Site 269 was drilled and intermittently cored to a subbottom depth of 958 m in a water depth of 4285 m, with 42% recovery of Eocene–Holocene rocks (Hayes, Frakes, et al., 1975). The cored sections consist predominantly of silts and clays with variable amounts of microfossils. Diatom oozes and diatom mud dominate the upper half of the section, which is dated as Quaternary to late Miocene in age (Hayes, Frakes, et al., 1975). In the lower half, which is late Miocene to early Miocene and Oligocene to ?late Eocene in age, diatoms are absent but calcareous nannofossils are found in trace amounts, with abundant palynomorphs including dinoflagellate cysts and sporomorphs (Kemp et al., 1975). There is a transition in facies from more distal facies in the lower part of the hole to more proximal facies near the surface. Piper and Brisco (1975) interpret this facies change as a result of substantial increased supply of sand, coarse silt, and clay from the Antarctic continent, possibly in response to prograding of the continental margin. The cores document extensive Antarctic glaciation beginning at least by Oligocene to early Miocene time and indicate that water temperatures were cool to temperate in the late Oligocene and early Miocene then cooled during the Neogene, presumably as glaciation intensified.

Inferred long-term record of glaciation

Unconformity WL-U3 is interpreted to mark the first preserved grounding of an ice sheet across the Wilkes Land, eroding the continental shelf (Tanahashi et al., 1994; Eittreim et al., 1995; Escutia et al., 1997; 2005), ~40 m.y. ago (Eittreim et al., 1995) to 33.5 to 30 Ma (Escutia et al., 2005) (Fig. **F10**). Early glacial strata (e.g., likely glacial outwash deposits) above Unconformity WL-U3 were delivered by fluctuating temperate glaciers and deposited as low dip–angle prograding foresets. The increase in stratal dips across Unconformity WL-U8 in the prograding wedge at the shelf edge is interpreted to record a change in the glacier regime inferred to correspond with the transition from intermittent fluctuating glaciers to persistent oscillatory ice sheets during the late Miocene–early Pliocene (Escutia et al., 2005), or ~3 Ma (Rebesco et al., 2006) (Fig. **F10**). The steep foresets above Unconformity WL-U8 likely consist of ice proximal (i.e., waterlain till and debris flows) and open-water sediments deposited as grounded ice sheets extended intermittently onto the outer shelf, similar to sediments recovered from ODP Site 1167 on the Prydz Trough fan (O'Brien, Cooper, Richter, et al., 2001).

On the continental rise, the upsection response to shelf progradation (i.e., seismic facies indicative of distal turbidites to large channel-levee systems modified by bottom contour current deposition) likely resulted from enhanced shelf progradation. Maximum rates of sediment delivery to the rise are reported during the development of seismic Units WL-S6 and WL-S7 during the Miocene (Hayes, Frakes, et al., 1975; Escutia et al., 1997, 2000, 2005; De Santis et al., 2003) (Fig. **F10**). During deposition of seismic Units WL-S8 and WL-S9, sediment supply to the lower continental rise decreased and depocenters shifted landward to the base of the slope and outer shelf (Escutia et al., 2002, 2005; De Santis et al., 2003; Donda et al., 2003). Inferred age for Units WL-S8 and WL-S9 is Pliocene to Holocene (De Santis et al., 2003). Unit WL-S9 is inferred to be deposited under a polar regime with a persistent ice sheet during the Pliocene–Pleistocene. At that time, most sediment delivered to the margin was trapped on the outer shelf and slope, forming steep prograding wedges, with some sediment bypassing the slope in channelized turbidity currents (Escutia et al., 2002, 2005; De Santis, 2003) (Fig. **F10**).

During the Holocene thick open-water interglacial sections of diatom mud and oozes are deposited in deep inner shelf basins (Domack, 1982; Dunbar et al., 1985; Crosta et al., 2005; Denis et al., 2006; Leventer et al., 2006; Maddison et al., 2006; Costa et al., 2007). These sediments hold an ultrahigh resolution record of climate variability and provide a means of tracking interannual- to centennial-scale variability in the response of the ocean to forcing by solar processes, ENSO, and Southern Annular Mode (SAM).

Scientific objectives

The overall aim of drilling the Wilkes Land margin is to obtain a long-term record of Antarctic glaciation and its relationships with global paleoclimatic and paleoceanographic changes along the inshore–offshore transect. Of particular interest are testing the sensitivity of the EAIS toward episodes of global warming and the detailed analysis of climatically critical periods in Earth climatic evolution coupled to the Antarctic cryosphere (i.e., the Eocene–Oligocene and Oligocene–Miocene glaciations, upper Miocene, Pliocene, and the last deglaciation) when the Antarctic cryosphere formed in a step-wise fashion, and while waxing and waning evolved to assume its present day configuration, characterized by a relatively stable EAIS.

To attain these objectives we will drill and analyze sedimentary records along the inshore–offshore gradient to constrain the age, nature, and environments of deposition of the previously only seismically inferred glacial sequences in the Wilkes Land continental shelf rise and abyssal plain (Fig. **F10**). Of particular note are stratigraphic intervals that have the potential of preserving records of the key phases of the evolution of the Antarctic cryosphere in general, and the EAIS in particular, like the Eocene–Oligocene and Oligocene–Miocene transitions, the middle and late Miocene, warm early Pliocene events, and Holocene climate variability (Fig. **F11**). The expected improved chronostratigraphy and integrated multidisciplinary climatic proxy record-based reconstructions are essential to provide accurate constrains for models of the dynamic development of the Antarctic ice sheet and sensitivity to global climate change (Fig. **F2**).

Specific scientific objectives

1. *Timing and nature of the onset of glaciation at the Wilkes Land margin.*

The timing and nature of the first arrival of the ice sheet at the Wilkes Land margin, the so-called "onset" of glaciation, is presently inferred to have occurred during the earliest Oligocene (Fig. **F10**). The late middle Eocene to early Oligocene is universally regarded to represent a long-term episode of global climatic cooling, some time during which the Antarctic ice sheet developed. Ice sheet development is presumed to have been a response to decreasing atmospheric CO_2 values rather than the opening of Southern Ocean conduits like the Drake and Tasman gateways (e.g., Pagani et al., 2005; DeConto and Pollard, 2003a, 2003b; Huber et al., 2004). For example, earlier ODP drilling around Tasmania (ODP Leg 189) indicated that the opening and deepening of the Tasmanian Gateway are much older than the Eocene/Oligocene boundary (Brinkhuis et al., 2003a, 2003b; Sluijs et al., 2003; Huber et al., 2004; Stickley et al., 2004). The pronounced deep-sea benthic foraminifer oxygen earliest Oi-1 (Miller et al., 1985; Zachos et al., 1997; Coxall et al., 2005; Pälike et al., 2006) is widely regarded to mark the strongest step of rapid continental ice growth on Antarctica with concomitant strong sea level response (Fig. **F11**). However, recent studies (e.g., Coxall et al., 2005) indicate that this onset was in fact a two-step phased event, in line with model predictions of DeConto and Pollard (2003a, 2003b) that the EAIS was established somewhat later than the WAIS (Fig. **F2**). Following the initiation of a significant Antarctic cryosphere, indications that it was relatively unstable with cyclic alternations of waxing and waning that show strong orbital forcing components (e.g., O'Brien, Cooper, Richter, et al., 2001; Barrett et al., 2003; Pälike et al., 2006; DeConto et al., 2007) are present. The mid-Oligocene transition (Rupelian/Chattian boundary; ~30 Ma), likely reflected by the Oi-2b isotope event (Van Simaeys et al., 2005; Pälike et al., 2006) represents another strong cooling phase associated with a major eustatic fall that likely represents a large Antarctic ice sheet expansion. Cape Roberts drilling in the Ross Sea and during ODP Leg 188 in Prydz Bay suggests the onset of glaciation at these margins occurred at 34–33 Ma and 35 Ma, respectively (e.g., Macphail and Truswell, 2004; Barrett, 2003; Cooper, O'Brien, and Richter, 2004). Ice sheet development models (Huybrechts, 1993; DeConto and Pollard, 2003a, 2003b; DeConto el al.,

2007) suggest that the arrival of the first ice sheet to the Wilkes Land margin should have taken place at a somewhat later time (Fig. **F2**). Constraints on the age and nature of the onset of glaciation in the Wilkes Land margin expected from continental shelf sites (proposed Site WLSHE-09B or alternates) and abyssal plain proposed Site WLRIS-02A (Fig. **F12**) are therefore essential to providing age constraints for models of Antarctic ice sheet development.

2. *Fluctuations in the glacial regime during the Miocene (?) and transition from wet-based to cold-based glacier regimes (late Miocene–Pliocene?).*

The latest Oligocene to middle Miocene was characterized by a wet-based dynamic ice sheet that fluctuated in size. The Oligocene/Miocene boundary (~23 Ma) is marked by a major excursion in benthic isotopes (Mi-1 glaciation) (e.g., Miller et al., 1985; Zachos et al., 2001) (Figs. **F1, F11**), In the early Miocene, a general trend towards moderately larger ice sheets, tracking global cooling, was interrupted by the middle Miocene "climatic optimum" from ~17 to 14 Ma (Zachos et al., 2001) (Figs. **F1, F11**). At the mid-Miocene transition (~14 Ma) and shortly afterwards, again tracking apparent renewed global cooling, the benthic oxygen isotopic records imply that the EAIS evolved from a wet-based and dynamic setting into a cold-based semipermanent ice sheet. However, even this aspect is highly controversial because some records from the Antarctic continent and margin indicate the presence of a highly dynamic ice sheet from late Miocene into early Pliocene times (e.g., Hambrey and McKelvey, 2000a, 2000b; Webb et al., 1996; Hambrey et al., 2003; Whitehead and Bohaty, 2003; Whitehead et al., 2003, 2004). The glaciomarine continental shelf deposits expected to be recovered from proposed Site WLSHE-08A or alternate should provide the required chronostratigraphic and paleoenvironmental records to help solve this controversy (Fig. **F11**).

3. *Distal record of climate variability during the late Neogene and the Quaternary.*

The record of the middle Miocene climatic optimum and the transition from a dynamic to a persistent ice sheet, inferred to have occurred at the Wilkes Land margin during the late Miocene–Pliocene (Fig. **F10**), is planned to also be sampled at the continental rise proposed Site WLRIS-04A (or alternate) (Fig. **F11**). Additionally, at this site we expect to test the stability of the ice sheet during the late Miocene and the extreme warm early Pliocene events, which has been the subject of almost continuous debate for more than two decades (e.g., Hardwood and Webb, 1998; Stroeven et al., 1998). A key question is whether relatively short warm intervals can cause a loss in ice sheet volume once a stable ice sheet is thought to be in place (i.e., since the middle–late Miocene). The marine oxygen isotope record suggests warming in the earliest Pliocene, culminating at ~3 Ma during the mid-Pliocene climate optimum (e.g., Kennett and Hodell, 1995; Zachos et al., 2001). Marine sediments exposed on land show evidence for a dynamic ice sheet during the late Miocene–early Pliocene as well as for early Pliocene warming. The marine record from drilling in Prydz Bay, the Ross Sea, and the Antarctic Peninsula also shows evidence for repeated advances and retreats of the Antarctic ice sheet during the late Miocene and early Pliocene. For example, the silicoflagellate assemblages at Site 1165 in Prydz Bay pinpoint three intervals within the Pliocene (3.7, 4.3–4.4, and 4.6–4.8 Ma) with sea surface temperatures in the Southern Ocean roughly 5°C warmer than today (Whitehead and Bohaty, 2003). In the Antarctic Peninsula a strong decrease in sea ice coverage starting at 5.3 Ma and maintained during the early Pliocene is indicated by opal deposition (Grützner et al., 2005; Hillenbrand and Ehrmann, 2005). Diatom stratigraphic analyses in these sediments show three warming events between 3.5 and 3.7 Ma, which can be also recognized in cores from the Antarctic Peninsula, implying that these events were of continent-wide significance (Escutia et al., 2007)

Indirect evidence (i.e., sea level changes and ocean floor sediments) also suggests that ice volume during the Pliocene was subject to cyclical variability. Because Northern Hemisphere ice sheets were not fully developed, it is thought that sea level changes were driven by fluctuations of the Antarctic ice sheet. Many scientists believe that the relatively unstable WAIS, grounded below sea level and thus thought to be less stable, was responsible for these changes. The role of the much larger and presumed more stable EAIS remains controversial. The timing of the transition of the EAIS from a polythermal dynamic condition to a predominantly cold stable state is critical to this argument. The eastern Wilkes Land margin receives sediment delivered through the Wilkes subglacial basin, where the EAIS is partly grounded below sea level and thus may have been more sensitive to climate changes in the late Neogene. The record of ice sheet fluctuations during the times that the EAIS is thought to be more stable (after 15 Ma–Holocene) is critical for developing reliable models of ice sheet behavior, which may be the basis for future predictions of Antarctic ice sheet stability as a response to global climate change.

4. *Ultrahigh resolution Holocene record.*

Addressing questions of the circum-Antarctic and global response to climate forcing will advance our understanding of the relative roles of the Pacific, Atlantic, and Indian Oceans in influencing decadal- to millennial-scale climate variation during the

Holocene. In addition, these data will help the assessment of the forcing factors (solar, ocean-atmosphere interaction, and volcanic) responsible for climate change over the past 10,000 y. A continuous Holocene section from the Indian Ocean sector of the East Antarctic margin is desirable as it will provide a comparison to existing Pacific Ocean records, such as those from the Palmer Deep (Antarctic Peninsula-ODP Leg 178) and Ross Sea. In particular we note that modern East Antarctic margin climate is not strongly influenced by ENSO, as is the case for the Arctic Peninsula (Domack et al., 1993, 2001, 2003, 2005; Shevenell et al., 1996; Shevenell and Kennet, 2002; Leventer et al., 1996, 2002; Domack and Mayewski, 1999) and Ross Sea (Leventer and Dunbar, 1988; Leventer et al., 1993; Cunningham et al., 1999; Domack et al., 1999). Rather, this region responds to variability in the SAM, drainage from the East Antarctic ice sheet, and the relative strength of the polar easterlies. Variability in these signals over interannual to millennial timescales needs to be established if we are to understand how forcing factors, such as solar variability, ocean-atmosphere interactions, orbital parameters, and volcanic activity, influence climate and oceanographic processes in the Southern Ocean. Development of high-quality, high-resolution Holocene climate records from the East Antarctic margin is a necessary step toward understanding the circum-Antarctic response to climate forcing and addressing similarities, differences, and possible links to the global record (as in Domack and Mayewski, 1999, for example). These data will help us evaluate the response of the EAIS and margin to global warming. Scientific questions specific to the Adélie Drift proposed drilling are:

1. What was the response of a cold-based glacial system to global and regional Holocene climate fluctuations? Was the response similar to and/or synchronous with marine records obtained from the Antarctic Peninsula and Ross Sea?
2. Was East Antarctica substantially influenced in a substantial way by solar cycle variability? Are the 90, 200, and 400 y cycles of paleoproductivity, as seen in the Palmer Deep, recorded here as well?
3. Are global climatic events such as the Little Ice Age, Holocene climatic optimum, and Younger Dryas preserved in the Eastern Antarctic margin record? More broadly, does the paleoclimatic record from the Eastern Antarctic margin demonstrate synchroneity with Northern Hemisphere records (see Domack and Mayewski, 1999) and, during deglaciation, with other parts of the Antarctic Margin (Siegert et al., 2008)?
4. With annual resolution through at least part of the Holocene, can we observe clear interannual variability in the sea ice extent and/or wind regime (an estab-

lished fact at the Palmer long-term ecological research location in the Antarctic Peninsula, where this is linked to ENSO)?

Additional objectives

Drilling in the Wilkes Land margin will help assess the main controls on sediment transport and deposition on ice-dominated continental shelves and rises in order to test present architectural models of glacial processes and facies for high-latitude margins. Efforts should be made to understand the controlling factors in continental rise deposition in order to make more informed interpretation about their significance in terms of Antarctica's glacial evolution. For example, what is the influence of ice sheet development and evolution that result on the development of the large mounded deposits (i.e., up to 700 m relief) and large upper-fan channel-levee complexes (i.e., 900 m relief) on the continental rise? What caused the shift in depocenters landward causing a decrease in sediment supply to the continental rise deposits? In these mixed turbidite and contourite systems, how we can differentiate the glacial advances and retreats signal of the gravity flow deposits from the paleoceanographic signal represented in the bottom-contour current deposits?

Drilling strategy

To obtain the most complete record of the history of Antarctic glaciation, the drilling strategy is to sample sediments from this margin in a shelf-rise-abyssal plain transect. The continental shelf strata (Fig. **F7**) contain the direct (i.e., presence or no presence of ice), albeit low, resolution record of glaciation. The corresponding continental rise and abyssal plain strata (Figs. **F9, F12**) contain the distal (i.e., cooler versus warmer) but more continuous and easier to date record of glaciation. The Wilkes Land margin has the advantage in that the unconformity presumably reflecting the "onset" of glaciation (Unconformity WL-U3) can be traced from the shelf to the abyssal plain, allowing the links between the proximal and the distal records to be established.

Our plan is to conduct coring and wireline logging operations at five sites: one on inner shelf continental shelf deep basins (proposed Site ADEL-1B or alternates), two on the continental shelf (proposed Sites WLSHE-09B and WLSHE-08A or alternates), one on the continental rise (proposed Site WlRIS-04A-or alternate), and one on the abyssal plain (proposed Site WLRIS-02A or alternate) (Fig. **F5**).

Timing and nature of the onset of glaciation

The timing and nature of the onset of glaciation in this segment of the eastern Wilkes Land margin is targeted in two depositional environments: (1) the continental shelf and (2) the abyssal plain.

Continental shelf proposed Sites WLSHE-09A, WLSHE-09B, WLSHE-07A, WLSHE-07B, WLSHE-10A, and WLSHE-11A (Figs. **F7** and **"Appendix figures"**) are designed to obtain a low-resolution but direct record allowing the reconstruction of the timing and nature of first glacial strata preserved at the Wilkes Land margin. Our first priority site is proposed Site WLSHE-09B, where we can sample preglacial and glacial strata separated by a regional unconformity (WL-U3) at relatively shallow depth (165 m). Additionally, we have five alternate sites (proposed Sites WLSHE-09A, WLSHE-07A, WLSHE-07B, WLSHE-10A, and WLSHE-11A) designed as contingency sites for unfavorable ice conditions and/or to account for the possibility that our interpretations are wrong (i.e., strata below and above Unconformity WL-U3 are of glacial origin or they are preglacial, respectively). These alternate sites will allow us to either target older strata by drilling deeper at proposed Site WLSHE-09B or younger strata at alternate sites (proposed Sites WLSHE-09A, WLSHE-07A, WLSHE-07B, WLSHE-10A, and WLSHE-11A) in order to accomplish our main objective, which is to date the onset of glaciation in this segment of the East Antarctic margin.

Abyssal plain proposed Site WLRIS-02A (Fig. **F12** and **"Appendix figures"**) is designed to provide the more continuous but distal (cooler versus warmer) record of the timing and nature of the onset of glaciation. Because the onset of glaciation unconformity (WL-U3) can be traced from the continental shelf to the abyssal plain we expect for the first time to be able to link the response of the margin sedimentation and biota to the first arrival of the ice to the shelf.

Fluctuations and transition of glacier regimes

Drilling at proposed Sites WLSHE-08A or alternate Sites WLSHE-08B, WLSHE-10A, and WLSHE-11A (Fig. **F7** and **"Appendix figures"**) is designed to sample strata below and above the regional erosional Unconformity WL-U8, which marks an important change in the geometry of the progradational wedge. The transition across this unconformity from low-dipping to steeply dipping foreset strata is inferred to correspond with large fluctuations in the glacial regime during the late Miocene and possibly to reflect the transition from a wet-based dynamic to a cold-based persistent ice sheet glacier regime.

Distal record of climate variability

Proposed Site WLRIS-04A (Fig. **F13**) or alternate proposed Site WLRIS-03A (Fig. **F14**) are designed to sample the mixed turbidite-contourite continental rise ridges (Figs. **F9, F13**). These ridges are expected to contain a high-resolution section of inferred late Neogene to Quaternary age and to provide a history of climate and paleoceanographic variability from the middle Miocene to the Quaternary. The record from this site should be similar to that obtained from drilling similar depositional environments during ODP Leg 178 in the Antarctic Peninsula (Barker, Camerlenghi, Acton, et al., 1999) and ODP Leg 188 in Prydz Bay (O'Brien, Cooper, Richter, et al., 2001).

Ultrahigh resolution Holocene record

Proposed Site ADEL-01B and alternate proposed Site ADEL-01C (Figs. **F8, F15, F16, F17**) are designed to sample the 200–230 m of relatively transparent Holocene sedimentary drape (the drift unit) overlying a hard reflector that is interpreted as a glacial diamict.

Operations plan

The overall operations plan and time estimates are summarized in Table **T1**. After departing Wellington (New Zealand), we will transit for ~8 days to the Wilkes Land drilling area and prepare for drilling operations.

Our plan is to conduct operations at the near-shore shelf (proposed Sites WLSHE-09B and WLSHE-08A) and Adélie Drift (proposed Site ADEL-01B) sites followed by the deeper rise sites (proposed Sites WLRIS-02A and WLRIS-04A). However, the sequence of operations will depend on ice, weather, and formation conditions.

The operations plan and time estimates are based on formations and depths inferred from seismic and regional geological interpretations without benefit of prior drilling in this area. We have, however, based our plans on information from previous DSDP and ODP sites located on other portions of the Antarctic margin.

Shelf sites

Proposed Sites WLSHE-09B and WLSHE-08A

Prior to starting drilling operations at proposed Site WLSHE-09B, we will conduct a short seismic reflection survey to provide a cross-line and confirm the regional geometry of the sequences to be penetrated.

The first hole at both shelf sites (proposed Sites WLSHE-09B and WLSHE-08A) will be cored with the advanced piston corer (APC) to refusal. Given the potential for coarse glacial deposits, this may have very limited penetration.

The second hole at these sites will be drilled without coring to depth of the prior hole. Rotary core barrel (RCB) coring will extend from this depth to 200 (proposed Site WLSHE-09B) and 220 (proposed Site WLSHE-08A) meters below seafloor (mbsf).

After coring is completed, the hole will be conditioned and loaded with mud and the bit released in the hole. We will run a series of wireline logs including a check shot vertical seismic profile (VSP) in open hole. Once operations at the two shelf sites re finished, we will transit ~150 nmi to begin operations at proposed Site ADEL-01B.

Proposed Site ADEL-01B

Three holes will be cored with the APC to total depth at proposed Site ADEL-01B. We will attempt to recover a short core of the uppermost diamict with the extended core barrel (XCB) system at one of the three holes.

After coring is completed in the last hole, we will conduct two wireline logging runs. Following operations, we will transit ~145 nmi to begin operations at proposed Site WLRIS-02A.

Rise sites

Proposed Sites WLRIS-02A and WLRIS-04A

The first hole at each of the two rise sites (proposed Sites WLRIS-02A and WLRIS-04A) will be APC/XCB cored to ~500 mbsf. RCB coring will extend from this depth to 1050 (proposed Site WLRIS-02A) and 1000 (proposed Site WLRIS-04A) mbsf.

After coring is completed, the hole will be conditioned and loaded with mud and the bit released in the hole. We will run a series of wireline logs including a check shot

VSP in open hole. After the operations are finished at proposed Site WLRIS-04A, the ship will start the ~8 day transit back to Wellington.

In addition to the logistical hurdles presented by operating in such a remote area, there are environmental threats unique to the region. Floating ice can be a hazard to the vessel and to coring operations. Free-fall funnels can be deployed at designated sites as a means to "bookmark" depth should a hole have to be temporarily abandoned because of the proximity of floating ice.

Although the expedition has been scheduled to take place during the optimum weather window, erratic and katabatic winds can disrupt operations and force landlocked ice over the site. In the Antarctic region, there are prominent cold katabatic winds that blow for most of the year. Our current plan includes participation of an onboard ice/weather specialist to assist in managing weather and ice threats.

Ice-rafted debris can negatively impact core recovery and rate of penetration and can destroy APC shoes and XCB cutting heads. Unconsolidated sediment can create unstable hole conditions and result in lost time because of stuck drill strings and/or core barrels. We anticipate that this may be especially problematic for the shelf sites. We will sail with sufficient bulk material to optimize the management of hole problems.

Downhole measurements

Downhole measurements during Expedition 318 will focus on characterizing in situ formation properties and establishing the link between core, log, and seismic data.

Wireline logging

Wireline logging is planned for the deepest hole at each of the five sites of Expedition 318. Standard IODP tool string configurations will be deployed at each site. Details of the tool strings are available at **iodp.ldeo.columbia.edu/TOOLS_LABS/tools.html.** The first run will be the triple combination (triple combo) tool string, which logs formation resistivity, density, porosity, natural gamma radiation, and borehole diameter. If available, we intend to include the Schlumberger inline check shot tool on this first run. The second run will utilize the Formation MicroScanner (FMS)-sonic tool string, which provides an oriented 360° resistivity image of the borehole wall and logs of formation acoustic velocity, natural gamma radiation, and borehole diameter. At all sites except proposed Site ADEL-01B, an additional logging run will conduct a check shot survey that will require the use of a seismic sound source.

Downhole logging data provide the link between the borehole and the seismic section, and enable lithostratigraphy to be tied to seismic stratigraphy. The check shot surveys give depth to traveltime conversion, and sonic velocity and density data will be used to generate a synthetic seismic profile at each site.

Downhole log data provide the only in situ formation characterization and the only data where core recovery is incomplete, as is likely to be the case at the two Wilkes Land shelf sites (proposed Sites WLSHE-09B and WLSHE-08A). For example, individual clasts in diamict will be apparent in the FMS resistivity images, and silica-cemented layers will be clear in the resistivity and density logs.

The wireline logging plan may be modified in the following cases:

1. To reduce the risk of incomplete logging resulting from bad hole conditions in the deep-penetration sites (proposed Sites WLRIS-02A and WLRIS-04A), we may elect to log in two stages: the upper 500 m of the section in the first APC/XCB hole and the lower part in the second RCB hole. This, however, would only be practical if extra time became available.
2. The seismic sound source used during the check shot survey will be subject to the IODP marine mammal policy and may have to be postponed or cancelled if certain policy conditions are not met.

Formation temperature measurements

The downhole measurement plan includes reconnaissance temperature measurements at one hole per site on the continental rise and the abyssal plain (proposed Sites WLRIS-02A and WLRIS- 04A) principally using the advanced piston corer temperature tool, supplemented by the Davis-Villinger Temperature Probe or new SET tool (if available) if necessary where sediments are more consolidated. The scientific objective of the temperature measurement plan is to provide sufficient data to reconstruct the thermal gradient at each site. This information will help constrain the history of burial diagenesis of the sediments encountered.

Risks and contingency strategy

The planned Wilkes Land and Adélie Basin drill sites are situated in an area of pronounced latitudinal gradients in wind because of the effects of the off-the-continent katabatic winds as well as the location of the frontal zone between polar easterlies and westerlies. Average January–March wind speeds can be from 6.4 to 7.7 m/s, but may reach up to 23 m/s at the shelf sites. The sea ice conditions, based on analysis on satellites, ships, continental stations, and synoptic modeling, may vary strongly from year to year. While the most offshore sites may be presumed to be ice free in the Austral summer, the shelf sites may not. The open-water period at the Adélie site begins about 29 January and extends through 7 March, on average. However, the late summer return of sea ice can begin as early as 20 February or as late as 16 March at this site. The open-water period at proposed shelf sites begins in mid-January and extends through 3 March, on average. However, the late summer return of sea ice can begin as early as 22 February or as late as 16 March at this site. The shelf sites may likely have <10%–0% ice cover between the end of January until the beginning of March.

Based on this information we have developed the following contingency strategies to help us maximize our possibilities of achieving the scientific objectives listed above:

1. If the shelf is covered with ice at the beginning of our drilling operations, we envision two possibilities, both starting with coring and logging the continental rise deposits at proposed Site WLRIS-02A.
   - **Proposed Site WLRIS-02A to WLSHE-09B to WLSHE-08A to ADEL-01A to WLRIS-04A.** This scenario considers that by the time drilling at proposed Site WLRIS-02A is concluded, the shelf is free of ice. In this case we would move to the shelf to core and log shelf proposed Sites WLSHE-09B, WLSHE-08A, and ADEL-01B (or alternates) and conclude our drilling operations at proposed Site WLRIS-04A (or alternate).
   - **Proposed Site WLRIS-02A to WLRIS-04A to WLSHE-09B to WLSHE-08A to ADEL-01B to WLRIS-04A.** This scenario considers that at the end of drilling proposed Site WLRIS-02A the shelf is not free of ice. We would then core and log proposed Site WLRIS-04A until shelf drilling is possible. We would move to drill proposed Sites WLSHE-09B, WLSHE-08A, and ADEL-01B. After completion of drilling the shelf sites we would transit to reoccupy proposed Site WLRIS-04A and core until the end of time allotted for this expedition.

   To account for the possibility that some sectors of the shelf may open while others may remain inaccessible, additional alternate sites with objectives similar to proposed Sites WLSHE-09 and WLRIS-08 on the shelf have been identified (proposed Sites WLSHE-10A, WLSHE-11A, and WLSHE-12A) and submitted for approval.

2. If the shelf is free of ice upon beginning of drilling operations, our strategy would be to start coring and logging the shelf proposed Sites WLSHE-09B, WLSHE-08A, and ADEL-01A then move to the abyssal plain to drill proposed Site WLRIS-02A and finalize with drilling operations at proposed Site WLRIS-04A.
3. If the coast and shelf remains ice covered, we will concentrate our drilling operation on the continental abyssal plain by drilling a third hole at proposed Site WLRIS-02A before proceeding to proposed Site WLRIS-04A. Because the drilling will rely only on these two sites, an alternate site for proposed Site WLRIS-02A will be submitted for approval.

Research plan proposals (sample and data requests)

Shipboard and shore-based researchers should refer to the IODP Sample, Data, and Obligations Policy (**www.iodp.org/program-policies**). This documents the policy for distributing IODP samples and data and defines the obligations that sample and data recipients incur. A primary obligation is that all members of the scientific party must conduct expedition-related scientific research and publish their results by the determined deadline.

Scientists are required to submit their research plans using the Sample/Data Request form available at **smcs.iodp.org** ~3 months prior to the expedition. Access to data and core samples for specific research purposes during the expedition and the subsequent 1 y moratorium must be approved by the Sample Allocation Committee (SAC). The moratorium for Expedition 318 will extend 12 months from the completion of the expedition or from the completion of a significant postcruise sampling party.

The SAC is composed of the Co-Chief Scientists, Staff Scientist, and IODP curator. Based on research requests (sample and data) submitted, the SAC will work with the scientific party to formulate a formal expedition-specific sampling and data-sharing plan for shipboard and postcruise activities. This plan will be subject to modification depending upon the actual material/data recovered and collaborations that may evolve between scientists before and during the expedition. Modifications to the sampling plan (i.e., new plans, research objectives, new collaborations, etc.), during the expedition and postcruise moratorium require the approval of the SAC.

All sample frequencies and sizes must be justified on a scientific basis and will depend on core recovery, the full spectrum of other requests, and the expedition objectives and priorities. Substantial degrees of collaboration will be required. When submitting their research plans (sample and data request), scientists must clearly document the exact role of any proposed co-investigators.

When critical intervals are recovered, there may be considerable demand for samples from a limited amount of cored material. These intervals may require special handling, a higher sampling density, reduced sample size, or continuous core sampling for a set of particular high-priority research objectives. The SAC may require an additional formal sampling plan before critical intervals are sampled.

Sampling to acquire essential ephemeral data types, to describe and characterize the recovered section, and to achieve essential sample preservation will be conducted during the expedition. Although some sampling for individual scientist's postcruise research may be conducted during the expedition, the majority of sampling may be deferred to a postcruise sampling party.

To ensure that the best quality samples are preserved for postcruise research from proposed Site ADEL-1B, our initial plan is to split and describe on the ship only the cores from the first of the three holes acquired at this site. Splitting of the cores from the other two holes and the majority of their description and characterization will likely be accomplished postcruise after the cores arrive at the IODP Gulf Coast Repository (College Station, Texas USA).

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Table T1. Operations, Expedition 318.

Site	Location (latitude, longitude)	Seafloor depth (mbsl)	Operations description	Duration (days)			
				Task	Transit	Drilling/ coring	Logging
	Wellington, NZ		Begin expedition				
			Transit from Wellington, NZ, to WLSHE-09B; ~1907 nmi @ 10.0 kt		8.0		
WLSHE-09B	66°22.03835′S	525	Hole A: Seismic survey, APC to refusal (~50 mbsf)			0.9	
	142°44.70833′E		Hole B: Drilling with RCB center bit to 50 mbsf, RCB to 200 mbsf			1.4	
			- Drop bit with MBR, wiper trip, displace hole with logging mud				
			- Log: triple combo and FMS-sonic (12.3 h)				
			- Log: VSP with WST, plug hole (4.1 h)				1.2
			Subtotal days on site:	3.5			
			Transit to WLSHE-08A; 22 nmi @ 10.0 kt		0.1		
WLSHE-08A	66°5.42394′S	525	Hole A: APC to refusal (~50 mbsf)			0.9	
	143°18.7707′E		Hole B: Drilling with RCB center bit to 50 mbsf, RCB 50–220 mbsf			1.4	
			- Drop bit with MBR, wiper trip, displace hole with logging mud				
			- Log: triple combo and FMS-sonic (12.6 h)				
			- Log: VSP with WST, plug hole (4.4 h)				1.2
			Subtotal days on site:	3.5			
			Transit to ADEL-01B; 150 nmi @ 10.0 kt		0.6		
ADEL-01B	66°24.8′S	1010	Hole A: APC core sediment to refusal ~200 m, XCB diamict ~2 m			1.4	
Adélie Drift	140°25.5′E		Hole B: APC core sediment to refusal ~200 m			0.9	
			Hole C: APC core sediment to refusal ~200 m			0.9	
			- Log: triple combo and FMS-sonic (13.0 h)				1.1
			Subtotal days on site:	4.3			
			Transit to WLRIS-02A; 145 nmi @ 10.0 kt		0.6		
WLRIS-02A	64°1.09973′S	3705	Hole A: APC/XCB to refusal ~500 mbsf, plug with cement			4.5	
	139°48.28302′E		Hole B: Drill with RCB center bit to 500 mbsf, RCB 500–1050 mbsf			8.4	
			- Contingency FFF assumes interruption by iceberg (12 h)			0.5	
			- Drop bit with MBR, displace hole with logging mud				
			- Log: triple combo and FMS-sonic (28.2 h)				
			- Log: VSP with WST, plug hole (12.8 h)				2.8
			Subtotal days on site:	16.2			
			Transit to WLRIS-04A; 121 nmi @ 10.0 kt		0.5		
WLRIS-04A	64°54.23754′S	3075	Hole A: APC/XCB to refusal ~500 mbsf, plug with cement			4.1	
	143°57.68046′E		Hole B: Drill with RCB center bit to 500 mbsf, RCB 500–1000 mbsf				
			- Contingency FFF assumes interruption by iceberg (12 h)			0.5	
			- Drop bit with MBR, displace hole with logging mud			6.5	
			- Log: triple combo and FMS-sonic (27.3 h)				
			- Log: VSP with WST, plug hole (12.0 h)				2.4
			Subtotal days on site:	13.5			
			Transit from WLRIS-04A to Wellington; 1997 nmi @ 10.0 kt		8.2		
	Wellington, NZ		End expedition		18.0	32.3	8.7
			Subtotal time on site:		41.0		
			Total operating days:		59.0		
			Total expedition (including 5 port call days)		64.0		

Note: APC = advanced piston corer, RCB = rotary core barrel, MBR = mechanical bit release, triple combo = triple combination, FMS = Formation MicroScanner, VSP = vertical seismic profile, WST = Well Seismic Tool, XCB = extended core barrel, FFF = free-fall funnel.

Figure F1. Global deep-sea oxygen and carbon isotope records from the last 65 m.y. (Zachos et al., 2001). The $\delta^{18}O$ record exhibits a number of steps and peaks that reflect on episodes of global warming and cooling and ice sheet growth and decay. The general cooling trend from 50 m.y. ago and the abrupt "climatic threshold events" are shown. Note the event 34 m.y. ago when abrupt global cooling led to the first ice sheets developing on Antarctica. Plio. = Pliocene, Pleist. = Pleistocene, Mi-1 = Miocene isotope event 1, Oi-1 = Oligocene isotope event 1.

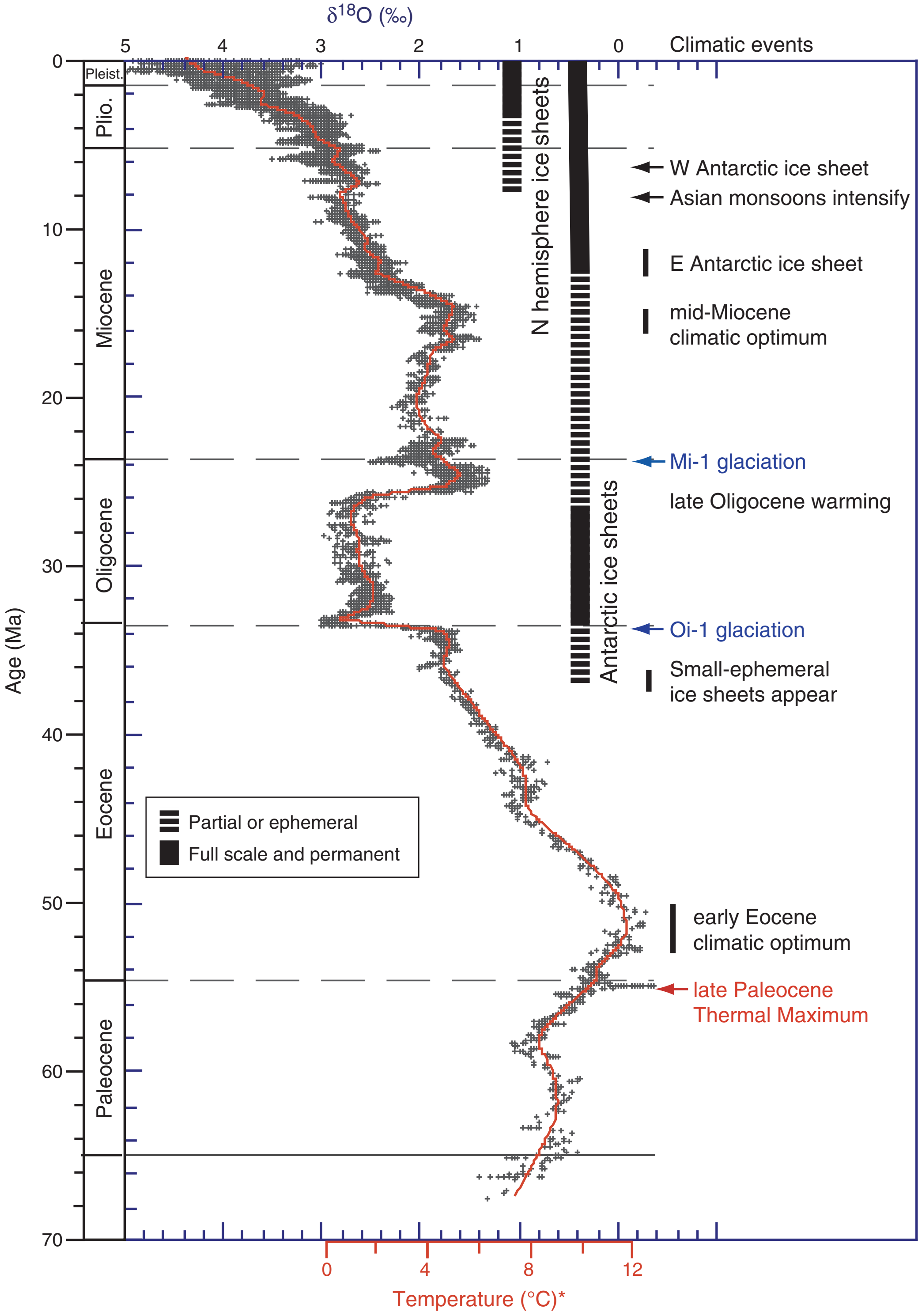


Figure F2. Simulated initiation of East Antarctic glaciation in the earliest Oligocene, using a coupled GCM-ice sheet model (from DeConto and Pollard, 2003a). This model shows the main triggering mechanism for initial inception and development of the East Antarctic Ice Sheet were the decreasing levels of CO_2 concentration in the atmosphere. Note these models show the initiation of glaciation to take place in a "two-step" cooling trend. The first step resulting in glaciation in the Antarctic continental interior, discharging mainly through the Lambert Graben to Prydz Bay, and the second step resulting in the connection an expansion of the ice sheet, reaching sea level in the Wilkes Land at a later stage.

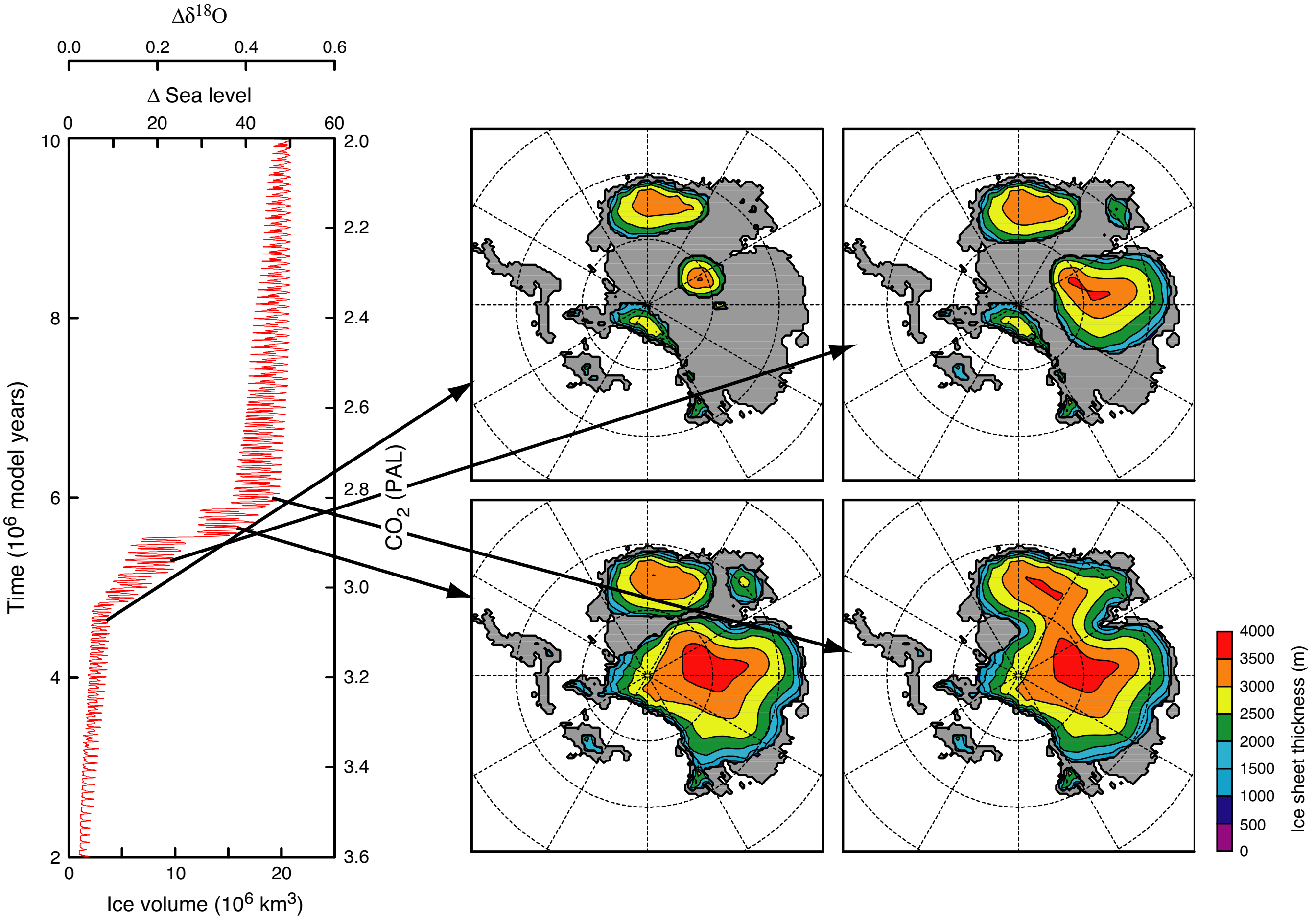


Figure F3. Earth's temperature variability during the last 80 m.y. based on reconstructions from deep-marine oxygen isotope records. Future atmospheric temperature scenarios, based on Intergovernmental Panel on Climate Change 2001 greenhouse trace gas forecasts, are shown at top of diagram.

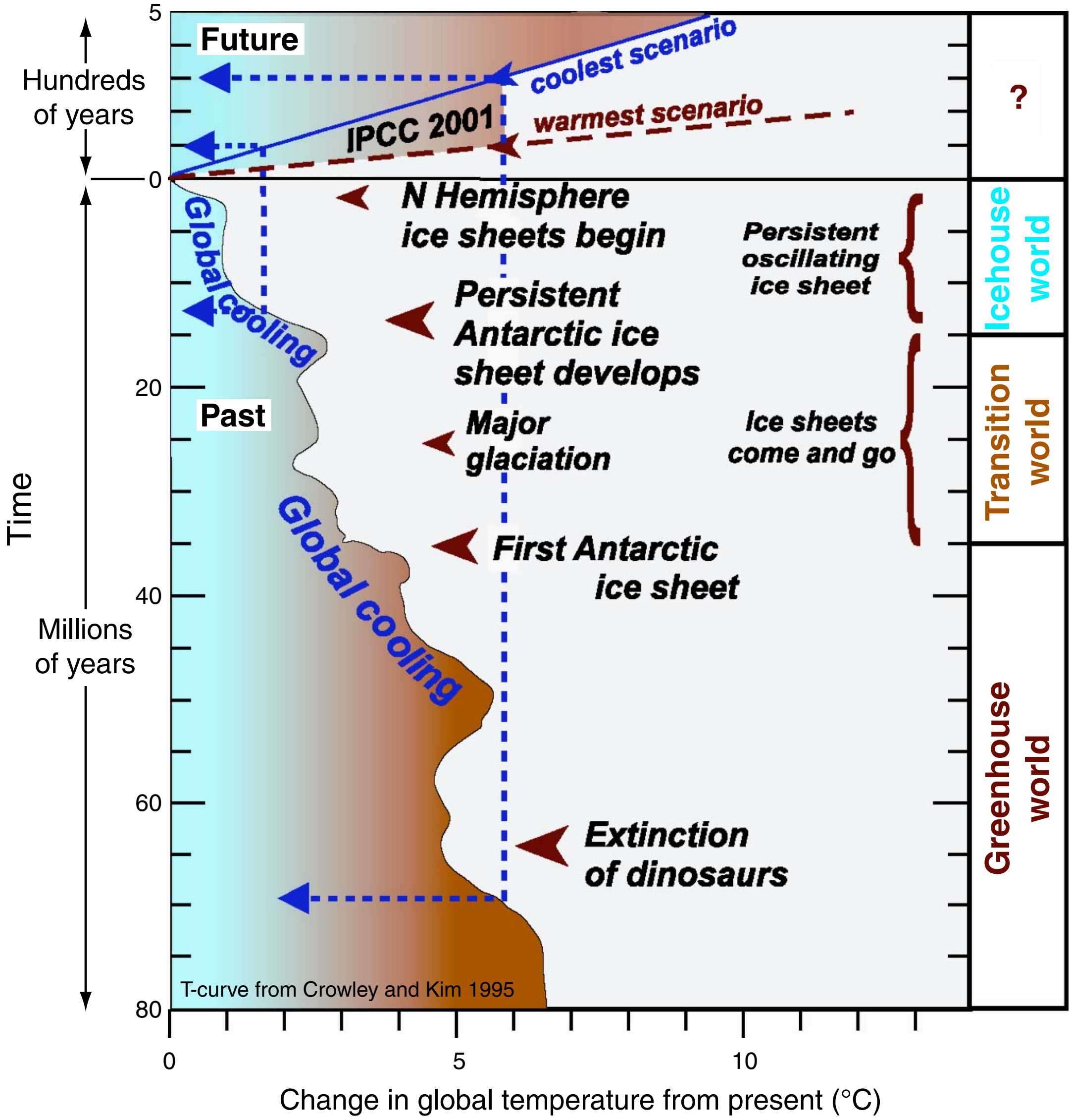


Figure F4. Map of Antarctica showing drainage patterns of the West Antarctic Ice Sheet (WAIS) and the East Antarctic Ice Sheet (EAIS) from the interior to the coast. Red = areas of fast flowing ice streams. Also shown is the drilling area, which partly drains the Wilkes Subglacial Basin, where the EAIS is partly grounded below sea level.

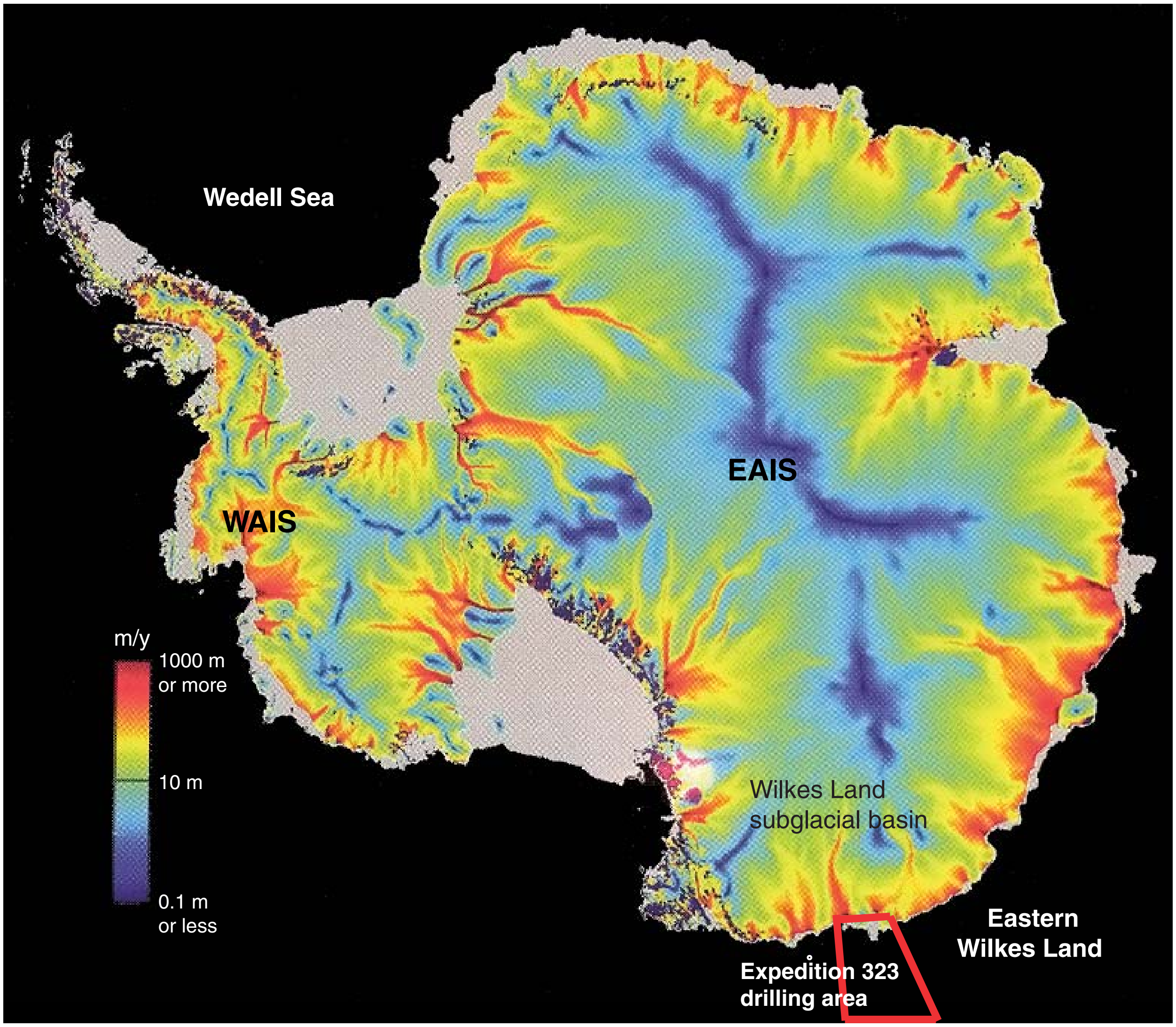


Figure F5. Drilling sites and profile locations (see Figs. F6, F7, F9). Primary sites (red) and all alternate sites (blue) are shown in more detail in Figure F6.

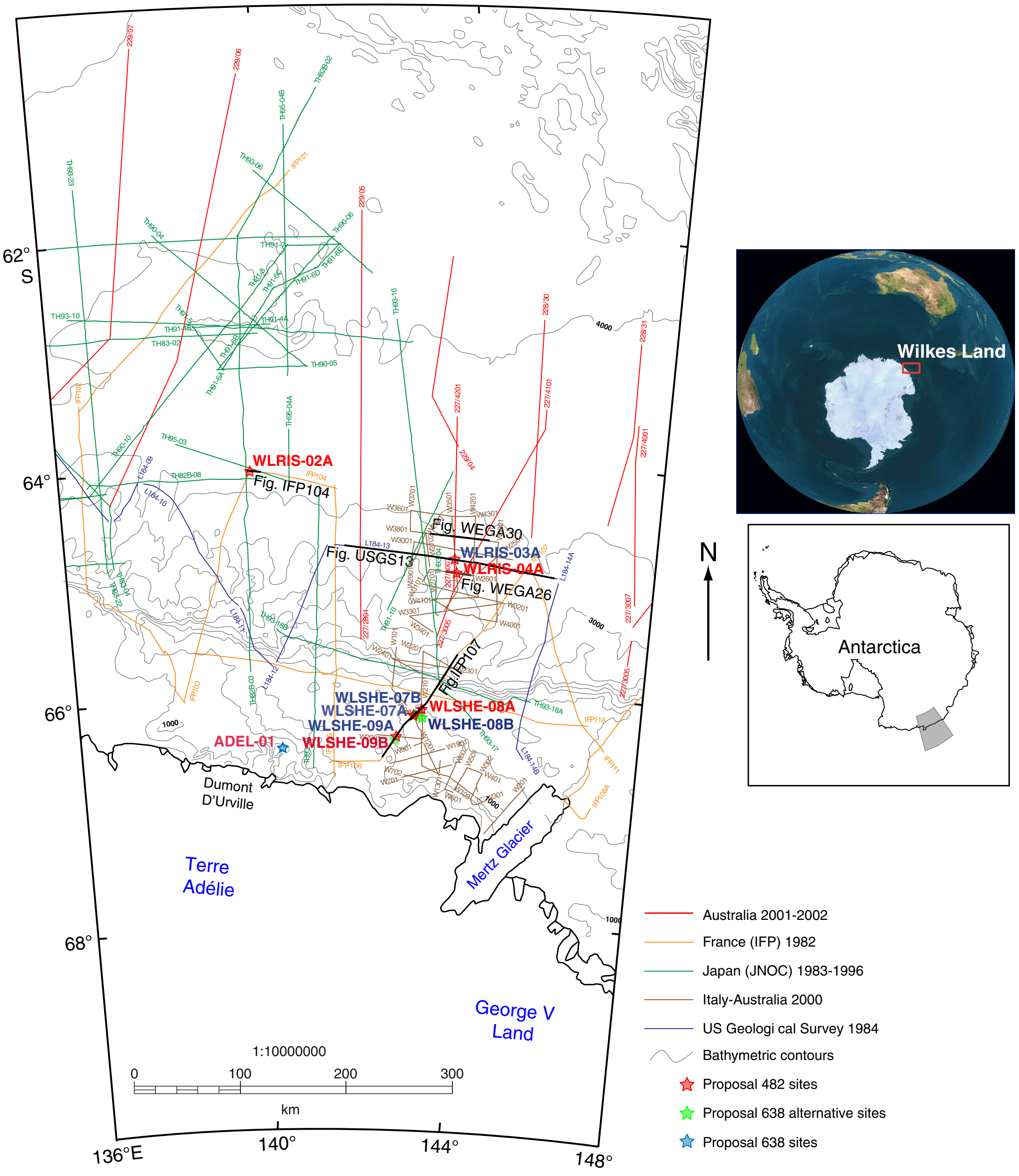


Figure F6. Bathymetry of a sector of the drilling area. Irregular morphology of the continental shelf is characterized by >1000 inner-shelf basins at the mouth of the Mertz Glacier, erosional troughs extending from these basins (proposed Site WLSHE-08) to the shelf edge and shallow banks (proposed Sites WLSH-07 and WLSH-09) adjacent to the trough. The slope is incised by numerous canyons that in the continental rise evolve to channel-levee complexes targeted by proposed Sites WLRIS-03A and WLRIS-04A.

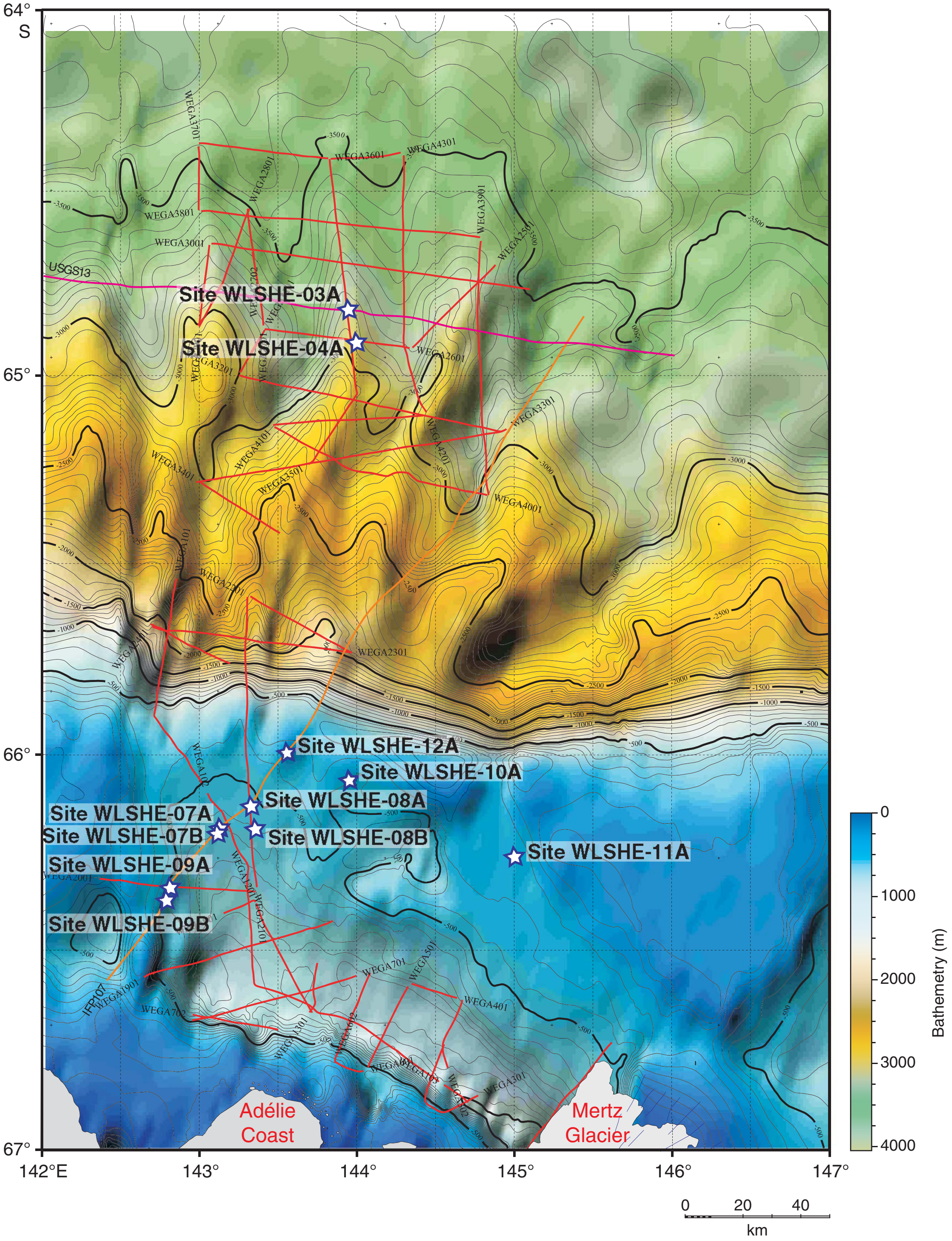


Figure F7. Uninterpreted and interpreted multichannel seismic reflection Profile IFP-107 across the Wilkes Land shelf and continental slope and base of slope. The profile crosses one of the Wilkes Land shelf banks (where Sites WLSHE-09A,-09B, -07A and -07B are located) and an erosional shelf trough (where sites WLSHE-08A and -08B are located). Topset strata form the banks adjacent to the troughs filled with foreset strata. The two main regional erosional unconformities in this margin are shown in the interpreted profile. Unconformity WL-U3 (Unconformity WL2 in IODP proposal) is interpreted to separate preglacial strata below from glacial strata above. Unconformity WL-U8 (Unconformity WL1 in IODP proposal) is interpreted to mark a change in the glacier regime possibly coinciding with the transition from wet-based to a cold-based more persistent ice sheet. Also shown are the locations of proposed priority sites (red) and alternate sites (blue). See Figure F5 for location of profile. SP = shotpoint. (**Figure shown on next page.**)

Figure F7 (continued). (Caption shown on previous page.)

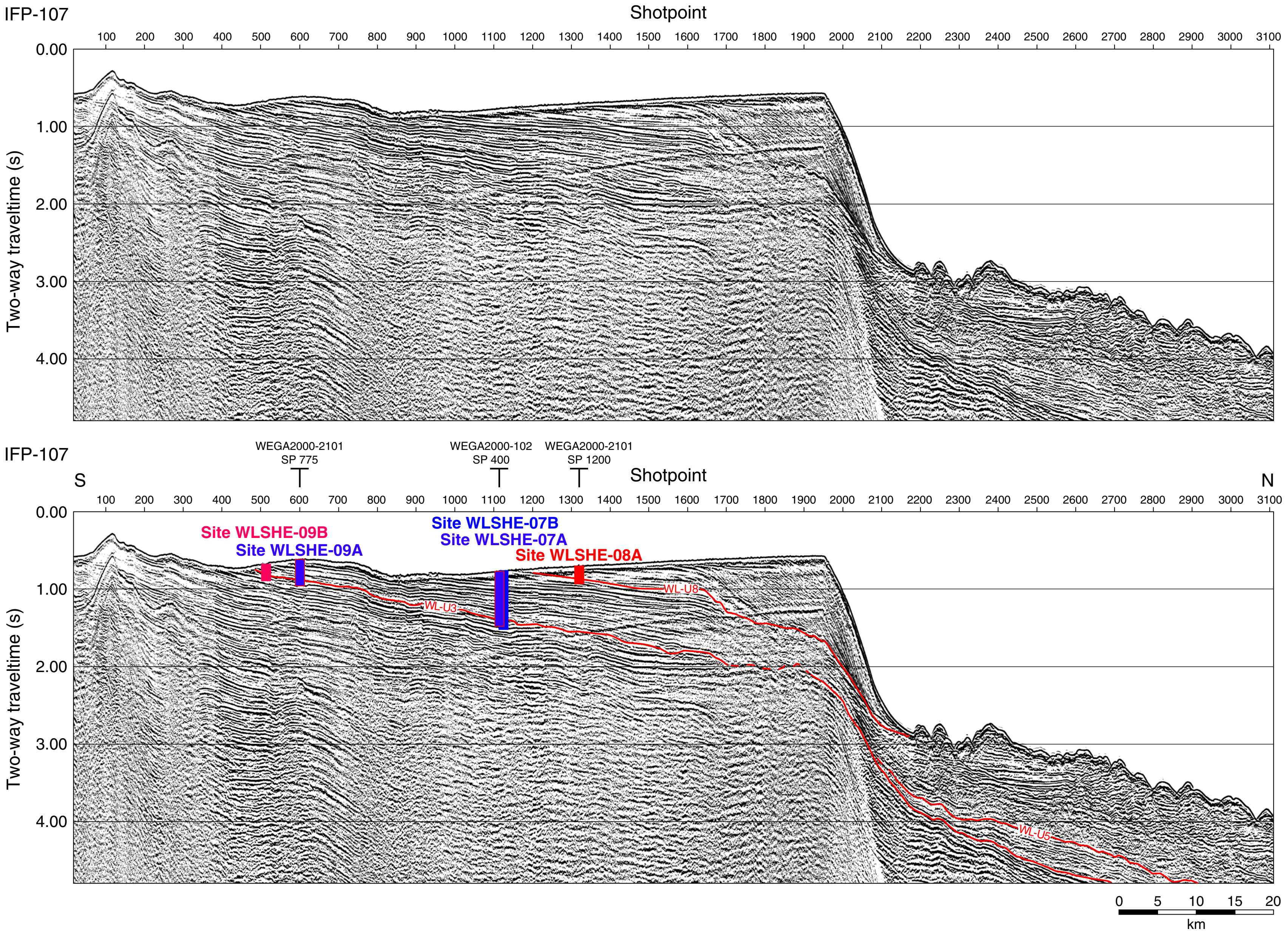


Figure F8. ODEC2000 subbottom profile collected across proposed Site ADEL-01B and the Adélie Drift deposit during February 2003. The profile enters the drift from the northeast and runs southwest going from left to right (Z, X, and Y waypoints in inset). Drift deposits in this cross-section are as thick as 200 m. Four piston cores from the drift, ranging in length from 20 to 60 m, were collected. The inset shows Box A from the swath map in Figure F7 as well as the location of the Bathy2000 profile shown in Figure F16 (blue line). See Figure F15 for location of inset box.

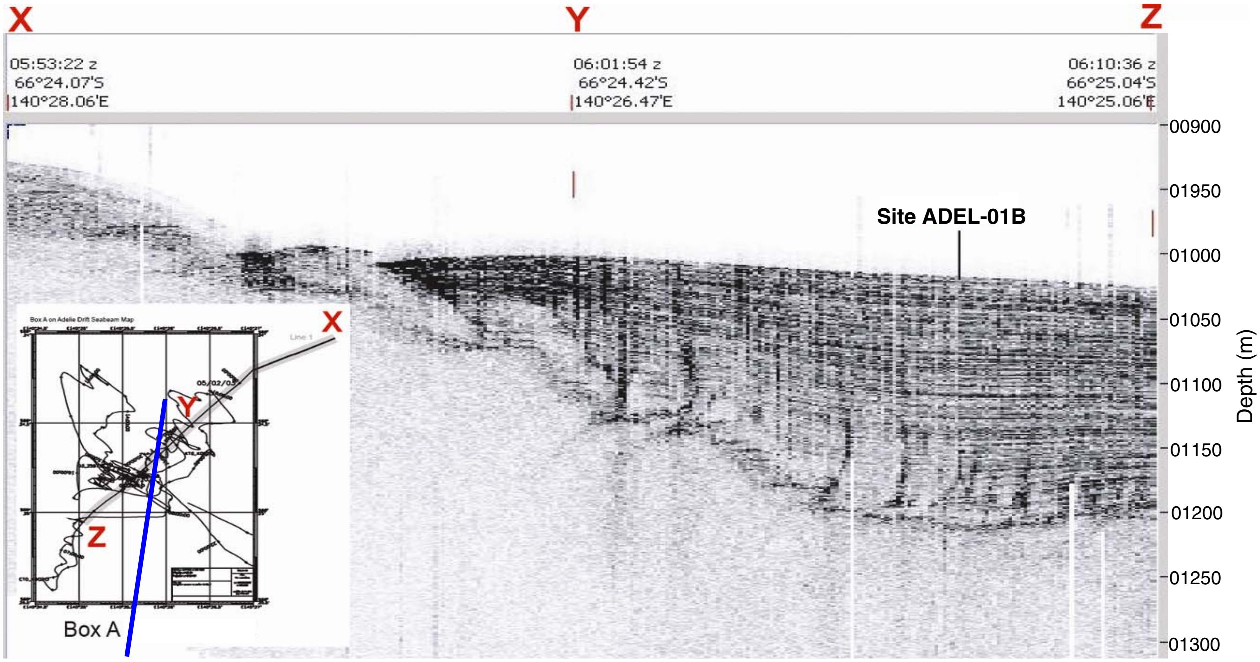


Figure F9. Uninterpreted and interpreted high-resolution multichannel seismic Profile WEGA W30 across the continental rise. Interpretation after Donda et al. (2003). This profiles shows the upsection increase in the energy of the depositional environment above Unconformity WL-U3 as a response to margin progradation. Note that the high-volume of sediment supply to the continental rise takes place between Unconformities WL-U5 and WL-U7. Above Unconformity WL-U7, a decrease in the sediment supply to the continental rise corresponding with a shift in depocenters to the base of the slope is apparent. See Figure F5 for location of profile.

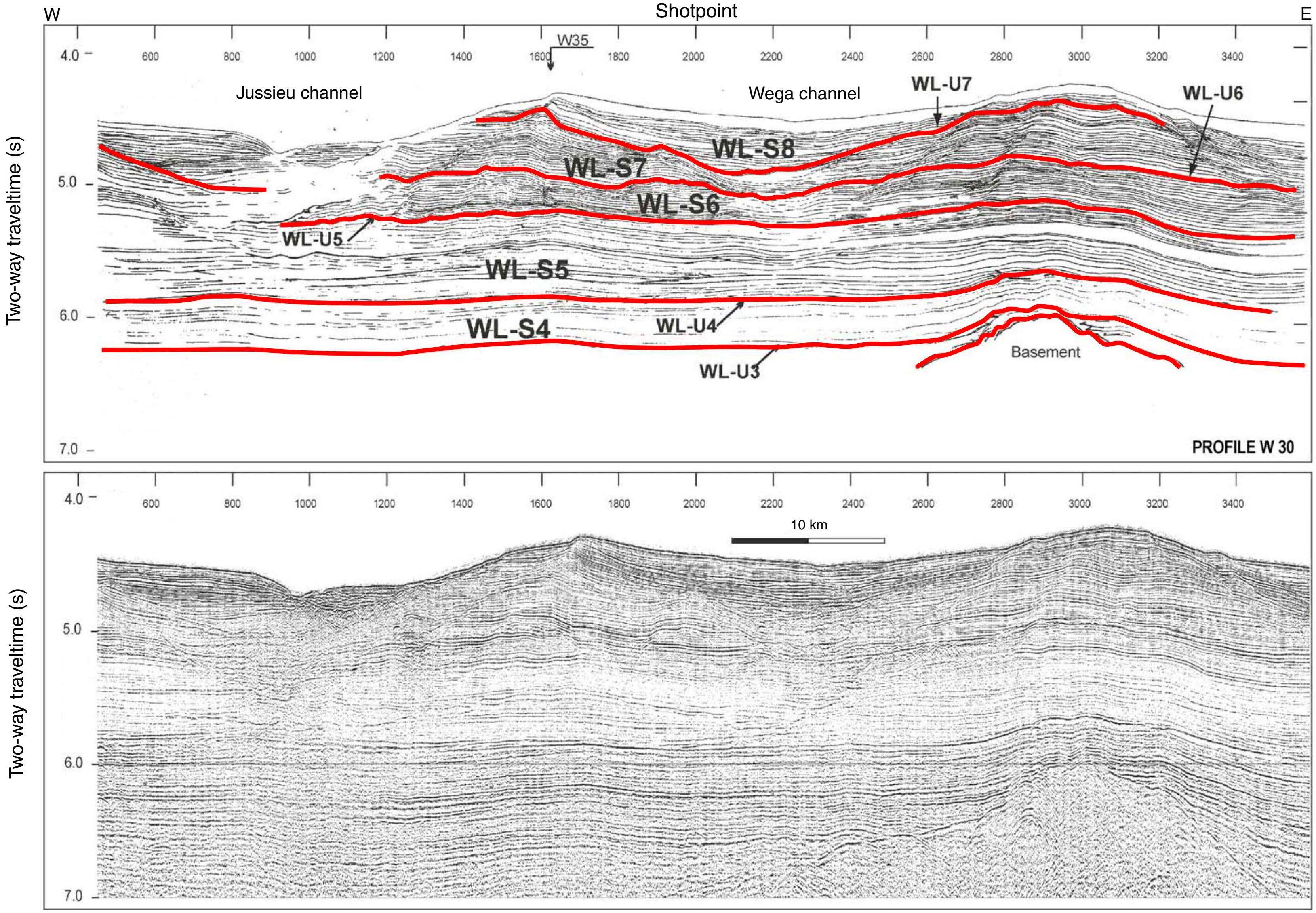
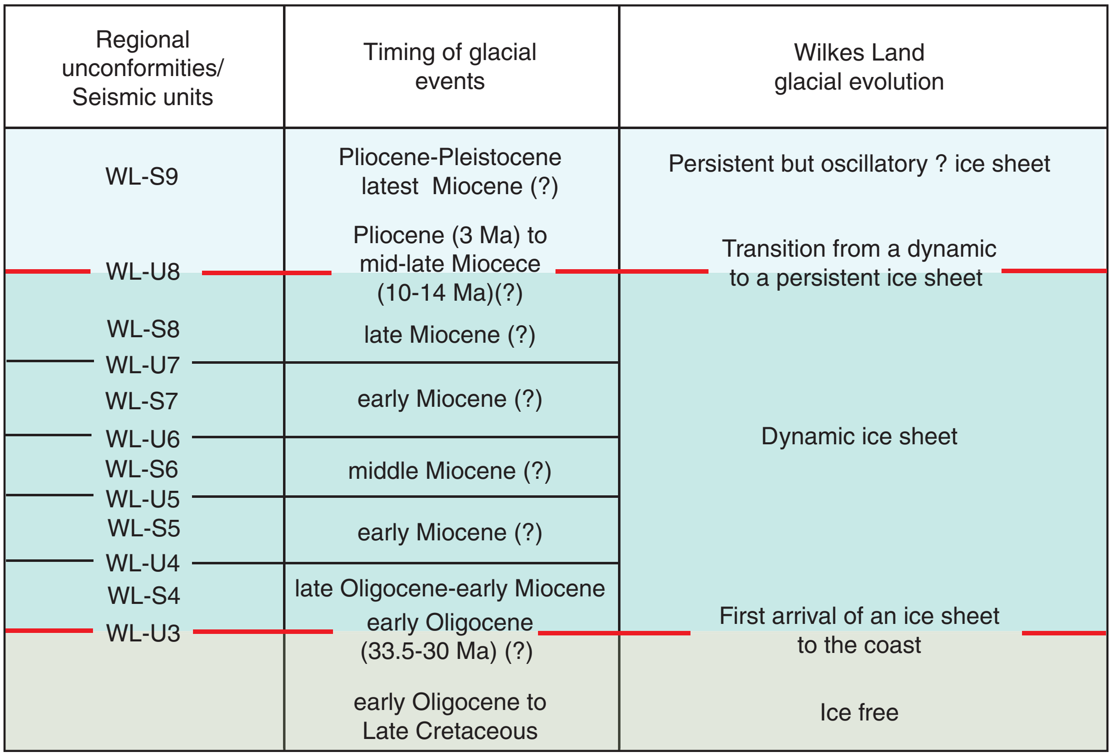


Figure F10. East Antarctic Ice Sheet evolution in the Wilkes Land margin and timing of events (modified from Escutia et al., 2005) inferred from continental shelf and rise stratigraphy (i.e., seismic regional unconformities and units).



Regional unconformities/ Seismic units	Timing of glacial events	Wilkes Land glacial evolution
WL-S9	Pliocene-Pleistocene latest Miocene (?)	Persistent but oscillatory ? ice sheet
WL-U8	Pliocene (3 Ma) to mid-late Miocece (10-14 Ma)(?)	Transition from a dynamic to a persistent ice sheet
WL-S8	late Miocene (?)	Dynamic ice sheet
WL-U7		
WL-S7	early Miocene (?)	
WL-U6		
WL-S6	middle Miocene (?)	
WL-U5		
WL-S5	early Miocene (?)	
WL-U4		
WL-S4	late Oligocene-early Miocene	
WL-U3	early Oligocene (33.5-30 Ma) (?)	First arrival of an ice sheet to the coast
	early Oligocene to Late Cretaceous	Ice free

Figure F11. Stratigraphic intervals targeted by drilling a shelf to abyssal plain transect in the eastern Wilkes Land margin. The targeted intervals are designed to provide direct constrains on Antarctic ice sheet behavior and related changes in sea level, which are now mostly interpreted from the oxygen isotope record from remote oceans and from passive continental margins (modified from ANDRIL International Science Proposal, 2003). Quat. = Quaternary, Disc. = Discovery, res. = resolution, IODP = Integrated Ocean Drilling Program.

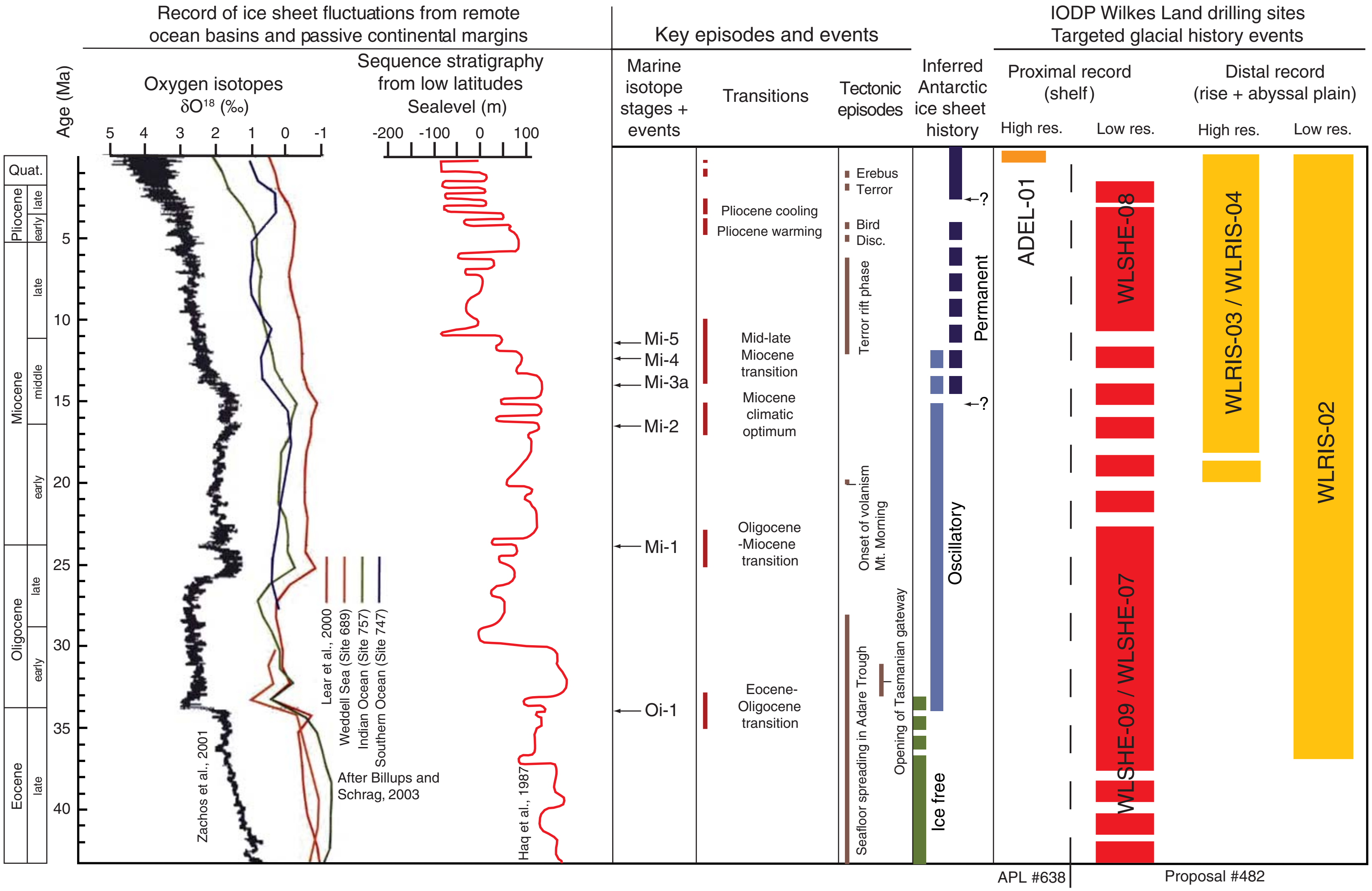


Figure F12. Multichannel seismic reflection Profile IFP-104 across proposed Site WLRIS-02A on the abyssal plain. Unconformity WL-U3, the “onset” of glaciation, has been traced through the grid of seismic profiles to this location, where it can be sampled at relatively shallow depths. See Figure **F5** for location of profile. SP = shotpoint.

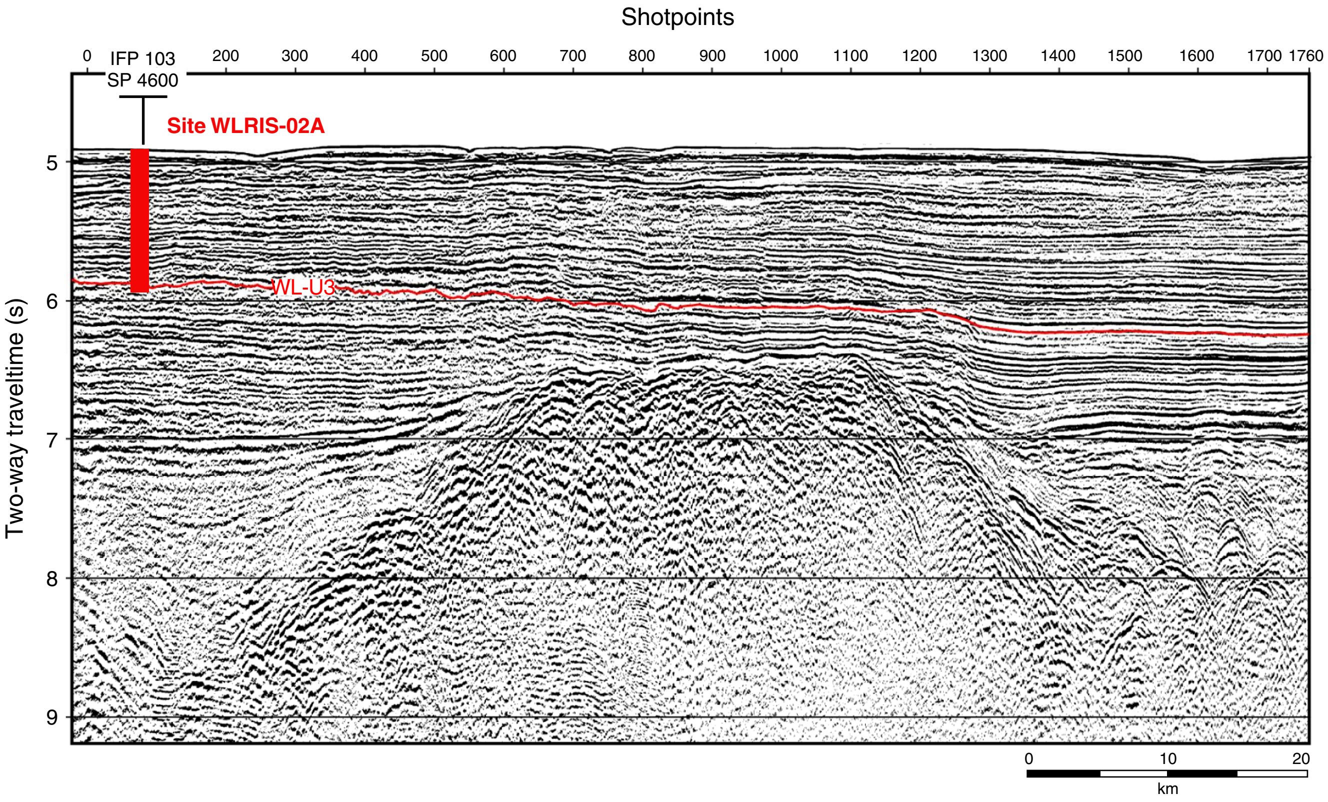


Figure F13. Uninterpreted and interpreted high-resolution multichannel seismic Profile WEGA 26 across the continental rise (proposed Site WLRIS-04A). Profile shows the drilling target to obtain a high-resolution Neogene record that should provide insights to the age and the nature of the onset of the large sediment supply to the continental rise (i.e., strata below and above Unconformity WL-U5) and the response of continental rise sedimentation to the transition from a wet-based to a cold-based and more persistent ice sheet. See Figure F5 for location of profile. SP = shotpoint.

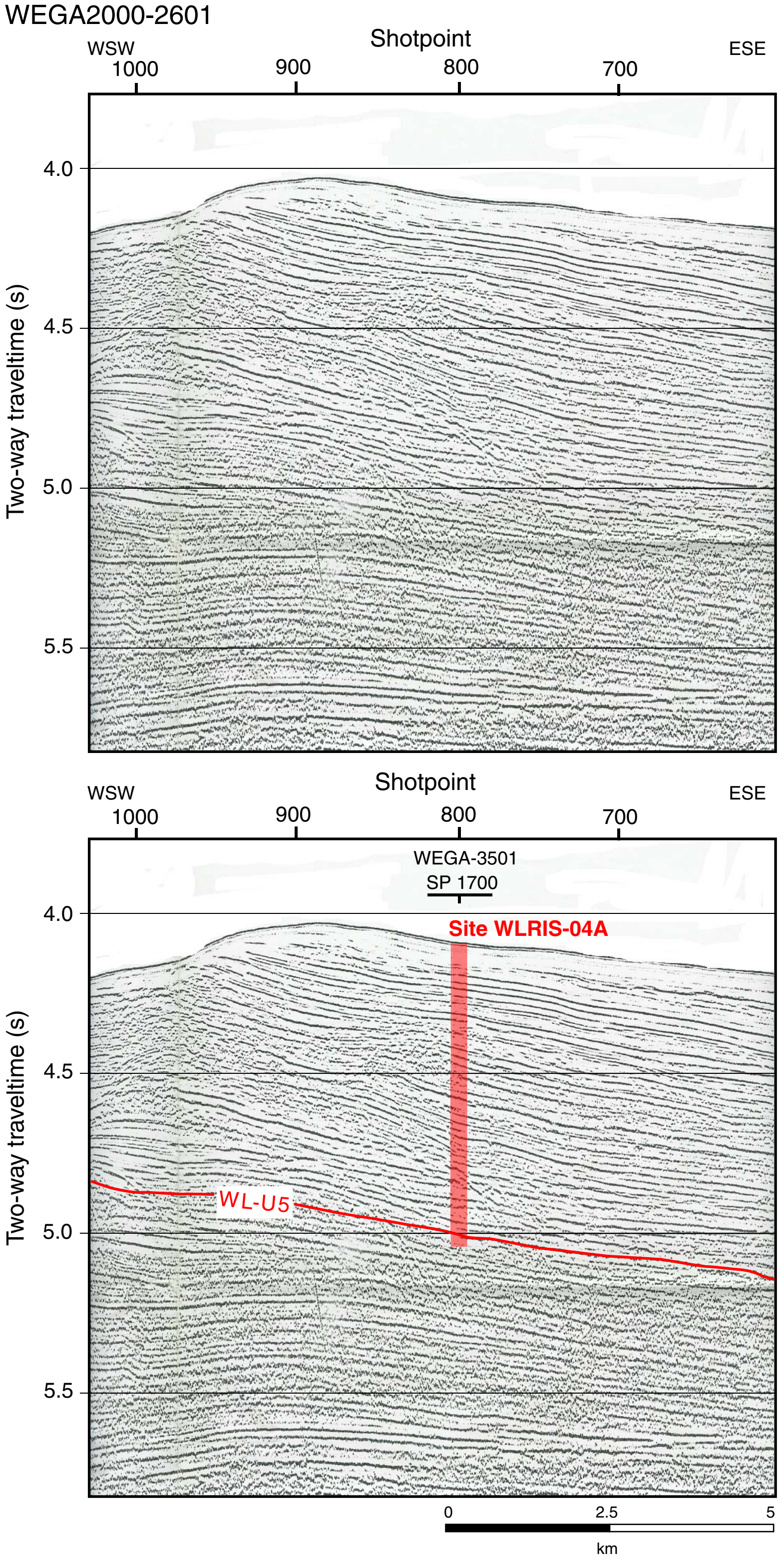


Figure F14. Interpreted multichannel seismic Profile USGS-13 across the continental rise (proposed Site WLRIS-03A). Although the profile is of low resolution, it shows the same upsection increase in the energy of the depositional environment described in Figure **F9**. Unconformities WL-U3 and WL-U5 are, nevertheless, clearly shown. Proposed Site WLRIS-03A is an alternate to proposed Site WLRIS-04A (see Fig. **F14**), targeted to obtain a high-resolution Neogene record that should provide insights to the age and nature of the onset of the large sediment supply to the continental rise (i.e., strata below and above Unconformity WL-U5), as well as the response of continental rise sedimentation to the transition from a wet-based to a cold-based and more persistent ice sheet. See Figure **F5** for location of profile. SP = shotpoint.

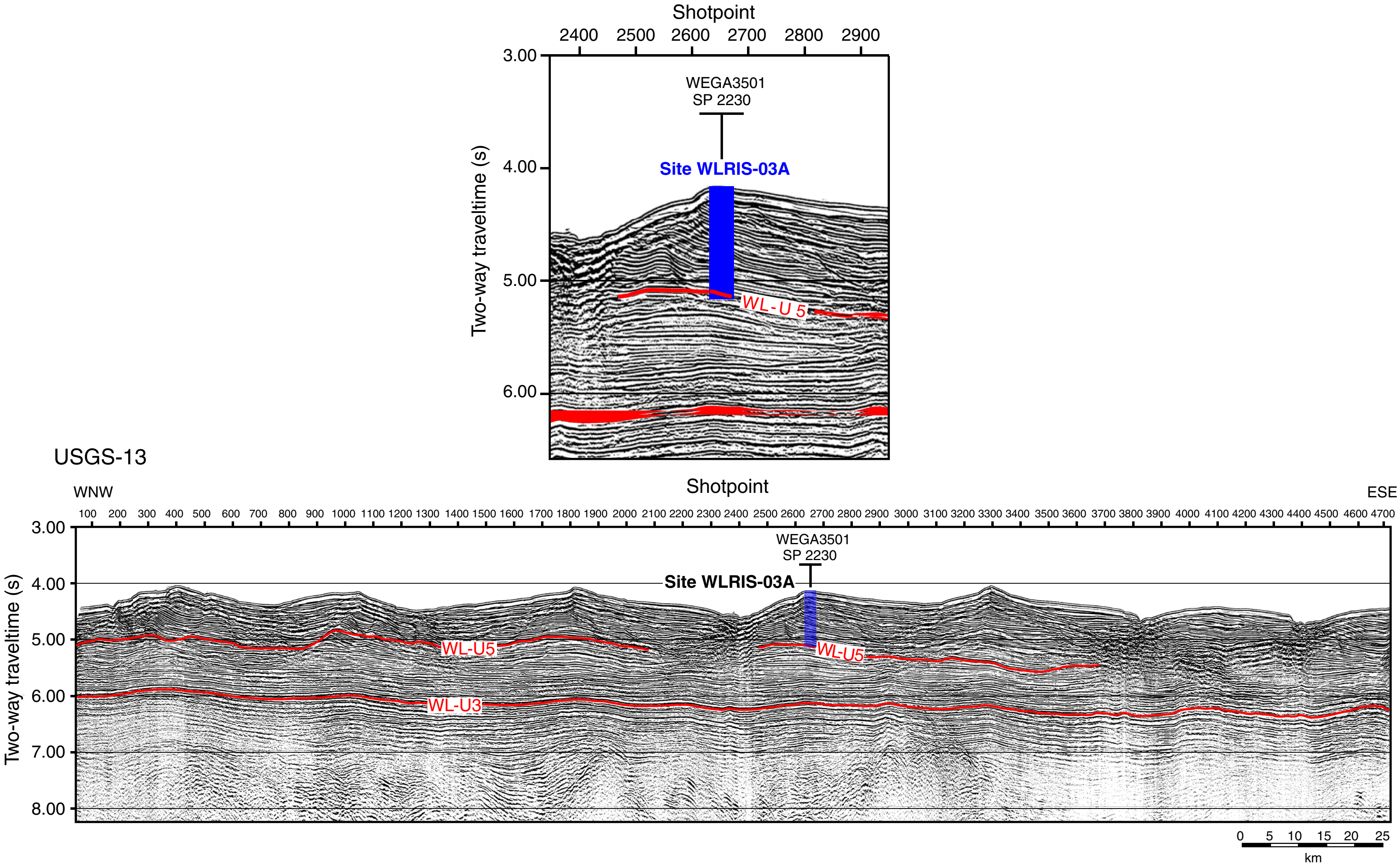


Figure F15. Swath bathymetry of the Adélie Basin showing the region of the Adélie Drift (Box A) as well as three crossing chirp lines. Blue = Bathy 2000 line collected from the *NB Palmer* in 2001 (Fig. **F16**), gray = ODEC chirp line collected on the CADO cruise of the *Marion DuFresne* in 2003 (Fig. **F8**), black = ODEC chirp line collected on the CADO cruise of the *Marion DuFresne* in 2003 (Figure **F17**). Black circle = location of proposed Site ADEL-01B, blue circle = alternate proposed Site ADEL-01C.

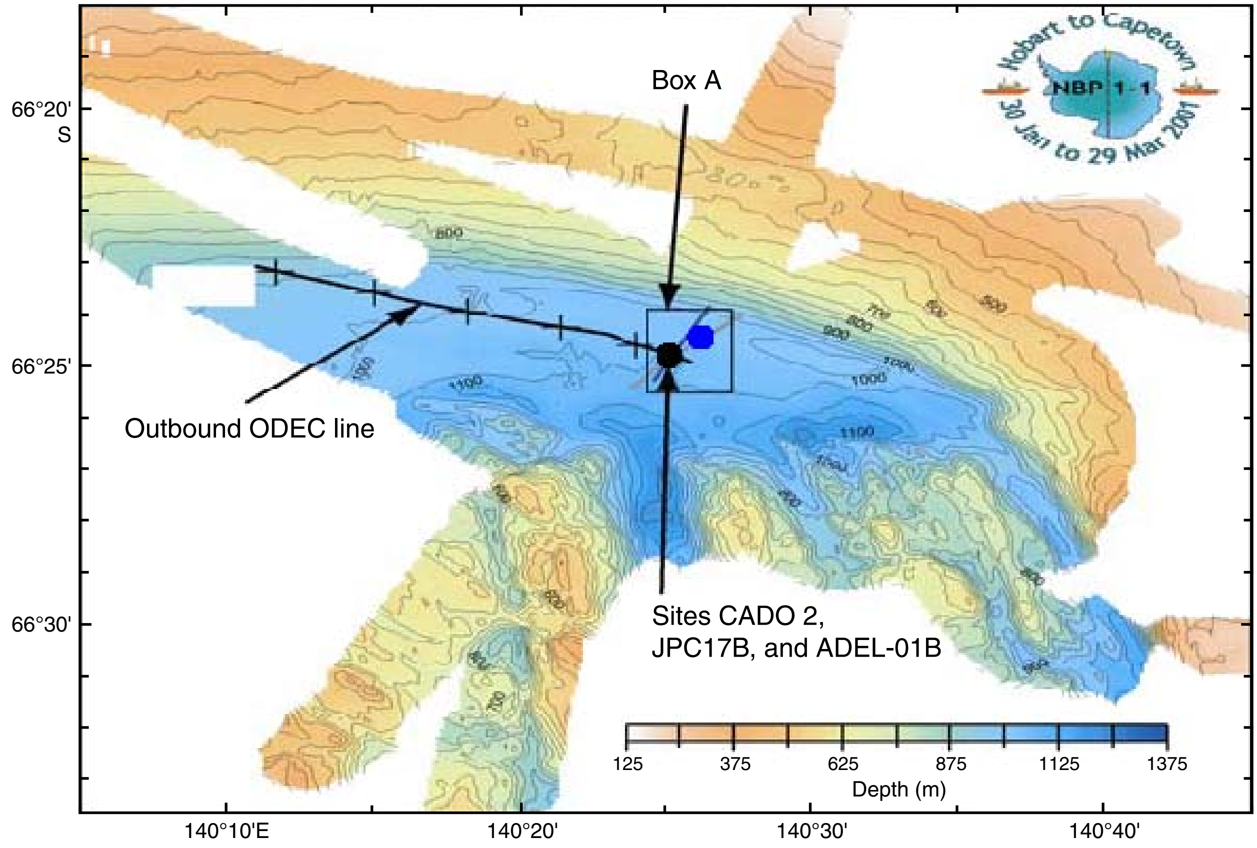


Figure F16. Chirp line across proposed Sites ADEL-01B and ADEL-01C collected with a Bathy2000 system. See Figure F15 for location of profile. Previous coring sites are also shown. Distance between dashed depth scale lines = 125 m. Estimated sediment thickness at proposed Site ADEL-01B is 200 m; at proposed Site ADEL-01C it is 230 m.

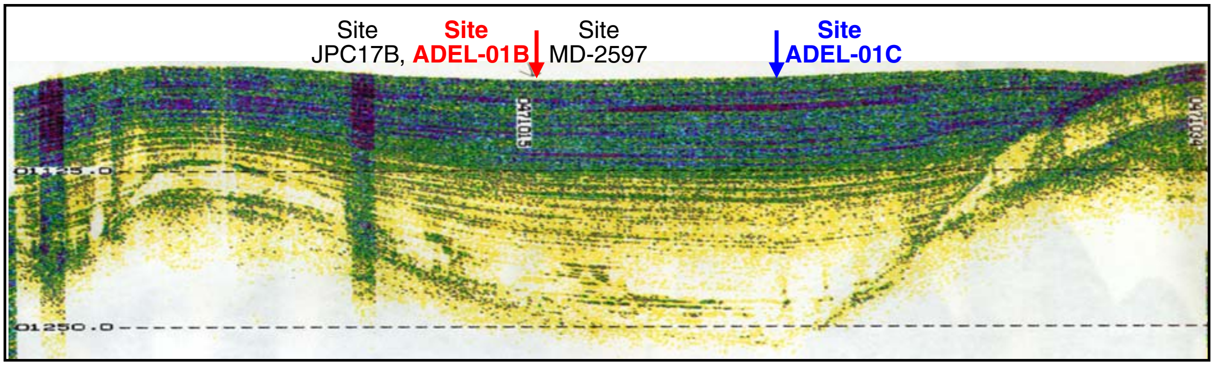
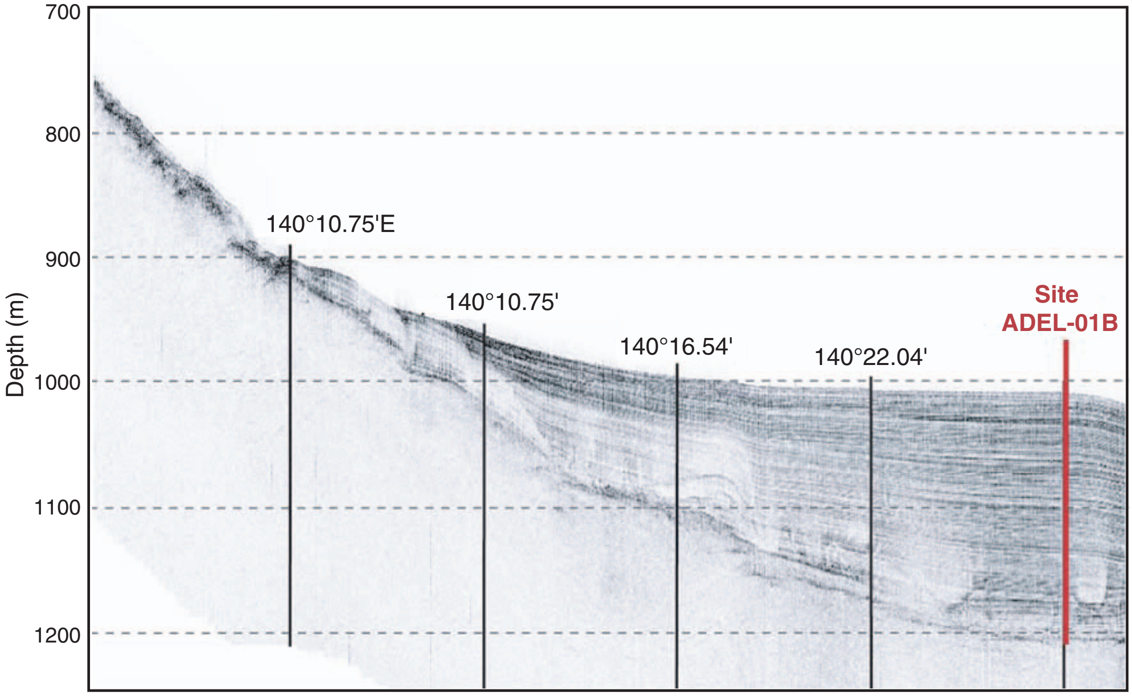


Figure F17. ODEC2000 chirp line across proposed Site ADEL-01B extending from the CADO2 core site to the western edge of the Adélie Basin. The location of this profile is the black line in Figure **F15.** Labeled positions are plus symbols in Box A in Figure **F15.**



Site summaries

Proposed Site ADEL-01A

Priority:	Alternate
Position:	66°24.8′S, 140°25.7′E
Water depth (m):	1010
Target drilling depth (mbsf):	190
Approved maximum penetration (mbsf):	• 250 (approved by TAMU safety panels based on EPSP Dec 2005 recommendation) • Limit penetration to Holocene drift • Terminate when drilling encounters glacial diamict but no more than 250 mbsf
Survey coverage:	• Site survey data outlined in Proposal 638-APL2 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) • Track map (Fig. **AF1**) • Seismic profile (Fig. **AF2**)
Objective (see text for full details):	Ultrahigh resolution of Holocene climate
Drilling, coring, and downhole measurement program:	See **"Proposed Site ADEL-01B"**
Anticipated lithology:	• 0–200 mbsf: very soft Holocene diatom ooze • >200 mbsf: glacial diamict

Site summaries (continued)

Proposed Site ADEL-01B

Priority:	Primary
Position:	66°24.8′S, 140°25.5′E
Water depth (m):	1010
Target drilling depth (mbsf):	190
Approved maximum penetration (mbsf):	• 250 (approved by TAMU safety panels based on EPSP Dec 2005 recommendation) • Limit penetration to Holocene drift • Terminate when drilling encounters glacial diamict but no more than 250 mbsf
Survey coverage:	• Site survey data outlined in Proposal 638-APL2 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) • Track map (Fig. **F15**) • Seismic profile (Figs. **F8**, **F16, F17**)
Objective (see text for full details):	Ultrahigh resolution of Holocene climate
Drilling, coring, and downhole measurement program:	• Hole A: APC to total depth; XCB one core of diamict; APC core orientation and formation temperature measurements • Hole B: APC to total depth; APC core orientation • Hole C: APC to total depth; APC core orientation; possibly wireline log (triple combo, FMS-sonic)
Anticipated lithology:	• 0–200 mbsf: very soft Holocene diatom ooze • >200 mbsf: glacial diamict

Site summaries (continued)

Proposed Site ADEL-01C

Priority:	Alternate
Position:	66°24.2′S, 140°26.0′E
Water depth (m):	1010
Target drilling depth (mbsf):	200
Approved maximum penetration (mbsf):	• 275 (approved by TAMU safety panels based on EPSP Dec 2005 recommendation) • Limit penetration to Holocene drift • Terminate when drilling encounters glacial diamict but no more than 250 mbsf
Survey coverage:	• Site survey data outlined in Proposal 638-APL2 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) • Track map (Fig. **F15**) • Seismic profile (Fig. **F16**)
Objective (see text for full details):	Ultrahigh resolution of Holocene climate
Drilling, coring, and downhole measurement program:	See **"Proposed Site ADEL-01B"**
Anticipated lithology:	• 0–200 mbsf: very soft Holocene diatom ooze • >200 mbsf: glacial diamict

Site summaries (continued)

Proposed Site WLRIS-02A

Priority:	Primary
Position:	64°1.09973′S, 139°48.28302′E
Water depth (m):	3705
Target drilling depth (mbsf):	1050
Approved maximum penetration (mbsf):	1050 (approved by TAMU safety panel based on EPSP Dec 2005 recommendation)
Survey coverage:	• Site survey data outlined in Proposal 482-Full3 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) • Track map (Fig. **AF3**) • Seismic profile (Fig. **AF4**), crossing seismic profile (Fig. **AF5**).
Objective (see text for full details):	Timing and nature of onset of glaciation
Drilling, coring, and downhole measurement program:	• Hole A: APC/XCB to refusal (~500 mbsf); APC core orientation and formation temperature measurements • Hole B: RCB to total depth; formation temperature measurements, wireline log (triple combo, FMS-sonic), and check shot
Anticipated lithology:	Fine-grained hemipelagites, turbidites, and contourites

Site summaries (continued)

Proposed Site WLRIS-03A

Priority:	Alternate
Position:	64°47.47817′S, 143°55.83114′E
Water depth (m):	3140
Target drilling depth (mbsf):	950
Approved maximum penetration (mbsf):	1000 (approved by TAMU safety panels based on EPSP Dec 2005 recommendation)
Survey coverage:	• Site survey data outlined in Proposal 482-Full3 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) • Track map (Fig. **AF6**) • Seismic profile (Fig. **F13**), crossing seismic profile (Fig. **AF7**)
Objective (see text for full details):	Climate variability during late Neogene–Quaternary
Drilling, coring, and downhole measurement program:	See **"Proposed Site WLRIS-04A"**
Anticipated lithology:	Fine-grained hemipelagites, turbidites, and contourites

Site summaries (continued)

Proposed Site WLRIS-04A

Priority:	Primary
Position:	64°54.23754′S, 143°57.68046′E
Water depth (m):	3075
Target drilling depth (mbsf):	1000
Approved maximum penetration (mbsf):	1050 (approved by TAMU safety panels based on EPSP Dec 2005 recommendation)
Survey coverage:	• Site survey data outlined in Proposal 482-Full3 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) • Track map (Fig. **AF6**) • Seismic profile (Fig. **F14**), crossing seismic profile (Fig. **AF8**)
Objective (see text for full details):	Climate variability during late Neogene–Quaternary
Drilling, coring, and downhole measurement program:	• Hole A: APC/XCB to refusal; APC core orientation and formation temperature measurements • Hole B: RCB to total depth; formation temperature measurements, wireline log (triple combo, FMS-sonic), and check shot
Anticipated lithology:	Fine-grained hemipelagites, turbidites, and contourites

Site summaries (continued)

Proposed Site WLSHE-07A

Priority:	Alternate
Position:	66°08.82761′S, 143°08.76300′E
Water depth (m):	563
Target drilling depth (mbsf):	770
Approved maximum penetration (mbsf):	875 (approved by TAMU safety panels based on EPSP Dec 2005 recommendation)
Survey coverage:	• Site survey data outlined in Proposal 482-Full3 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) • Track map (Fig. **AF9**) • Seismic profile (Fig. **AF10**), crossing seismic profile (Fig. **AF11**)
Objective (see text for full details):	Timing and nature of onset of glaciation
Drilling, coring, and downhole measurement program:	See **"Proposed Site WLSHE-08A"**
Anticipated lithology:	Diamicton and thin diatomaceous mud

Site summaries (continued)

Proposed Site WLSHE-07B

Priority:	Alternate
Position:	66°8.74002′S, 143°8.99334′E
Water depth (m):	570
Target drilling depth (mbsf):	715
Approved maximum penetration (mbsf):	1595 (approved by TAMU safety panels based on EPSP Dec 2005 recommendation)
Survey coverage:	• Site survey data outlined in Proposal 482-Full3 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) • Track map (Fig. **AF9**) • Seismic profile (Fig. **AF10**), crossing seismic profile (Fig. **AF11**)
Objective (see text for full details):	Timing and nature of onset of glaciation
Drilling, coring, and downhole measurement program:	See **“Proposed Site WLSHE-08A”**
Anticipated lithology:	Diamicton and thin diatomaceous mud

Site summaries (continued)

Proposed Site WLSHE-08A

Priority:	Primary
Position:	66°5.42394′S, 143°18.7707′E
Water depth (m):	525
Target drilling depth (mbsf):	220
Approved maximum penetration (mbsf):	270 (approved by TAMU safety panels based on EPSP Dec 2005 recommendation)
Survey coverage:	• Site survey data outlined in Proposal 482-Full3 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) • Track map (Fig. **AF9**) • Seismic profile (Fig. **AF10**), crossing seismic profile (Fig. **AF12**)
Objective (see text for full details):	Timing and nature of large changes in the glacial regime during the late Miocene–Pliocene
Drilling, coring, and downhole measurement program:	• Hole A: APC to refusal; APC core orientation and formation temperature measurements (see Table **T1**) • Hole B: RCB to total depth; formation temperature measurements, wireline log (triple combo, FMS-sonic), and check shot
Anticipated lithology:	Diamicton and thin diatomaceous mud

Site summaries (continued)

Proposed Site WLSHE-08B

Priority:	Alternate
Position:	66°06.8334′S, 143°19.12013′E
Water depth (m):	525
Target drilling depth (mbsf):	170
Approved maximum penetration (mbsf):	220 (approved by TAMU safety panels based on EPSP Dec 2005 recommendation)
Survey coverage:	• Site survey data outlined in Proposal 482-Full3 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) • Track map (Fig. **AF9**) • Seismic profile (Fig. **AF10**, crossing seismic profile (Fig. **AF12**)
Objective (see text for full details):	Timing and nature of large changes in the glacial regime during the late Miocene–Pliocene
Drilling, coring, and downhole measurement program:	See **"Proposed Site WLSHE-08A"**
Anticipated lithology:	Diamicton and thin diatomaceous mud

Site summaries (continued)

Proposed Site WLSHE-09A

Priority:	Alternate
Position:	66°20.22546′S, 142°46.27926′E
Water depth (m):	469
Target drilling depth (mbsf):	380
Approved maximum penetration (mbsf):	380 (approved by TAMU safety panels based on EPSP Dec 2005 recommendation
Survey coverage:	• Site survey data outlined in Proposal 482-Full3 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) • Track map (Fig. **AF9**) • Seismic profile (Fig. **AF10**), crossing seismic profile (Fig. **AF13**)
Objective (see text for full details):	Timing and nature of onset of glaciation
Drilling, coring, and downhole measurement program:	See **"Proposed Site WLSHE-09B"**
Anticipated lithology:	Diamicton and thin diatomaceous mud

Site summaries (continued)

Proposed Site WLSHE-09B

Priority:	Primary
Position:	66°22.03835′S, 142°44.70833′E
Water depth (m):	525
Target drilling depth (mbsf):	200
Approved maximum penetration (mbsf):	770 (approved by TAMU safety panels based on EPSP Dec 2005 recommendation)
Survey coverage:	• Site survey data outlined in Proposal 482-Full3 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**) • Track map (Fig. **AF9**) • Seismic profile (Fig. **AF10**)
Objective (see text for full details):	Timing and nature of onset of glaciation
Drilling, coring, and downhole measurement program:	• Hole A: seismic survey on approach; APC to refusal; APC core orientation and formation temperature measurements • Hole B: RCB to total depth; formation temperature measurements, wireline log (triple combo, FMS-sonic), and check shot
Anticipated lithology:	Diamicton and thin diatomaceous mud

Site summaries (continued)

Proposed Site WLSHE-10A

Priority:	Alternate
Position:	66°6.8223′S, 143°54.3437′E
Water depth (m):	450
Target drilling depth (mbsf):	1150
Approved maximum penetration (mbsf):	1150; pending review and approval by EPSP and TAMU Safety Panel
Survey coverage:	• Site survey data outlined in Proposal 482-Full3 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**): • Track map (Fig. **AF14**) • Seismic profiles (Figs. **AF15, AF16**)
Objective (see text for full details):	Timing and nature of onset of glaciation
Drilling, coring, and downhole measurement program:	See **“Proposed Site WLSHE-09B”**
Anticpated lithology:	Diamicton and thin diatomaceous mud

Site summaries (continued)

Proposed Site WLSHE-11A

Priority:	Alternate
Position:	66°15.0745′S, 145°0.0252′E
Water depth (m)	435
Target drilling depth (mbsf):	1125
Approved maximum penetration (mbsf):	1125; pending review and approval by EPSP and TAMU Safety Panel
Survey coverage:	• Site survey data outlined in Proposal 482-Full3 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**): • Track map (Fig. **AF14**) • Seismic profiles (Figs. **AF17, AF18**)
Objective (see text for full details)	Timing and nature of onset of glaciation
Drilling, coring, and downhole measurement program:	See **“Proposed Site WLSHE-09B”**
Anticpated lithology:	Diamicton and thin diatomaceous mud

Site summaries (continued)

Proposed Site WLSHE-12A

Priority:	Alternate
Position:	65°58.0413′S, 143°31.0848′E
Water depth (m):	424
Target drilling depth (mbsf):	860
Approved maximum penetration (mbsf):	990; pending review and approval by EPSP and TAMU Safety Panel
Survey coverage:	• Site survey data outlined in Proposal 482-Full3 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**): • Track map (Fig. **AF14**) • Seismic profiles (Fig. **AF19**)
Objective (see text for full details):	Timing and nature of onset of glaciation
Drilling, coring, and downhole measurement program:	See **"Proposed Site WLSHE-08A"**
Anticpated lithology:	Diamicton and thin diatomaceous mud

Site summaries (continued)

Proposed Site WLSHE-13A

Priority:	Alternate for WLRIS-02A
Position:	64°0.04083′S, 139°49.14′E
Water depth (m):	3675
Target drilling depth (mbsf):	1000
Approved maximum penetration (mbsf):	1000; pending review and approval by EPSP and TAMU Safety Panel
Survey coverage:	• Site survey data outlined in Proposal 482-Full3 (available at **iodp.tamu.edu/scienceops/expeditions/wilkes_land.html**): • Track map (Fig. **AF20**) • Seismic profiles (Figs. **AF21, AF22**)
Objective (see text for full details):	Distal record of the timing and nature of onset of glaciation and East Antarctic ice sheet evolution
Drilling, coring, and downhole measurement program:	See **"Proposed Site WLRIS-02A"**
Anticpated lithology:	Fine-grained hemipelagites, turbidites, and contourites

Figure AF1. Track map for proposed Site ADEL-01A.

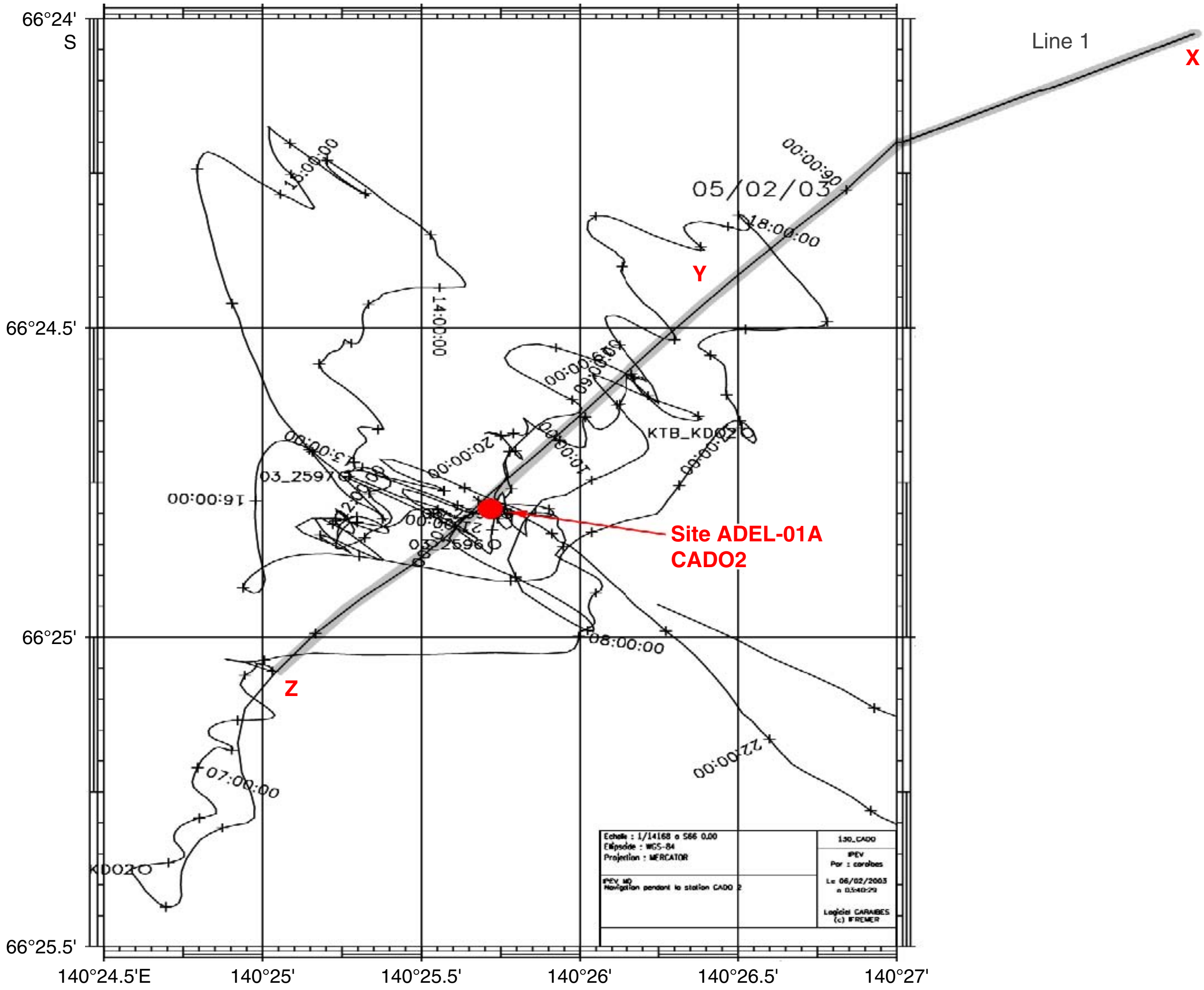


Figure AF2. Seismic profile at proposed Site ADEL-01B.

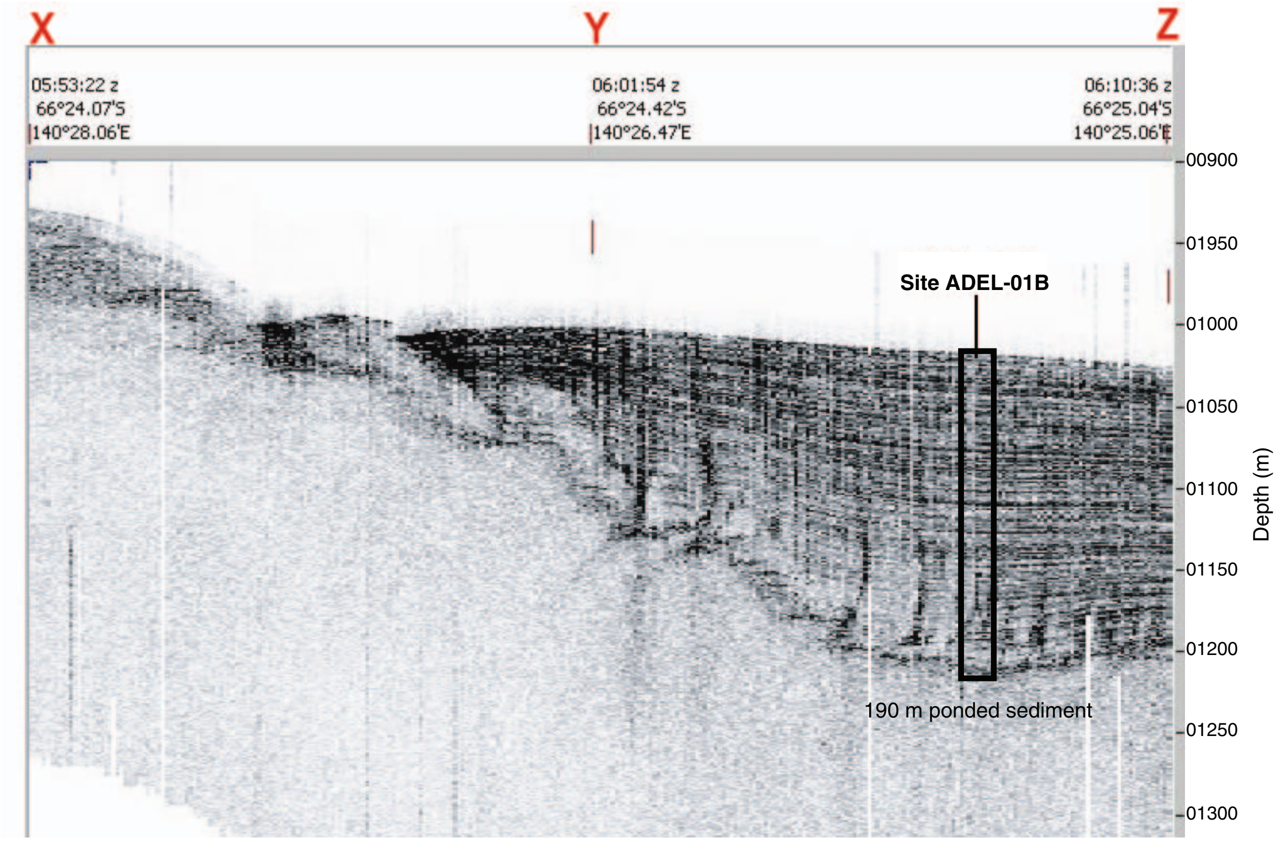


Figure AF3. Track map for proposed Site WLRIS-02A.

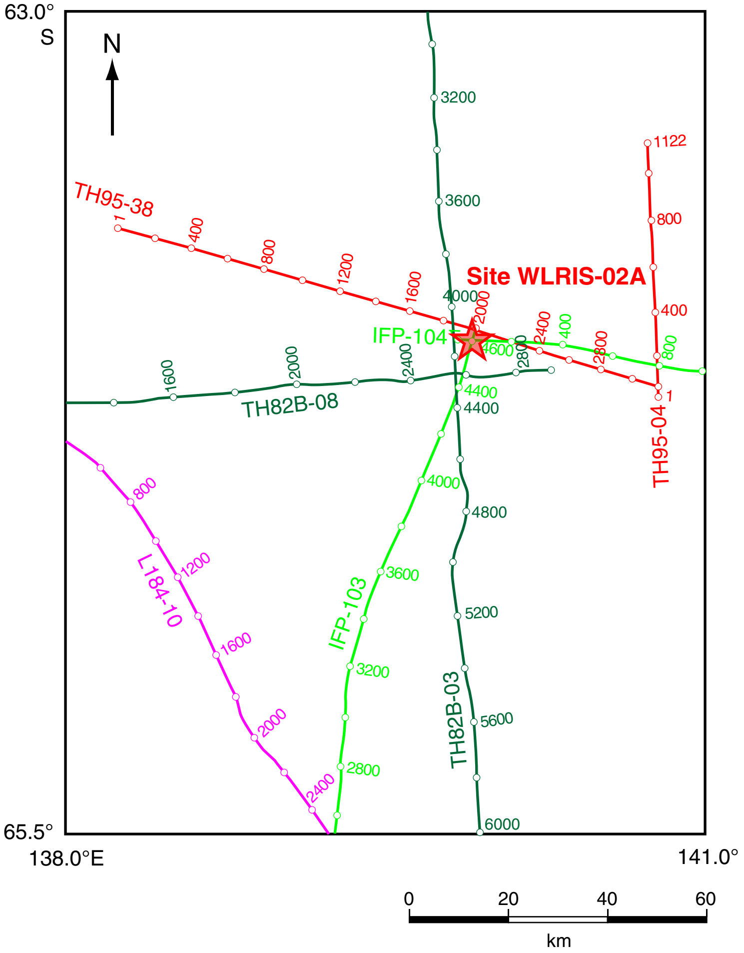


Figure AF4. Seismic profile at proposed Site WLRIS-02A. SP = shotpoint.

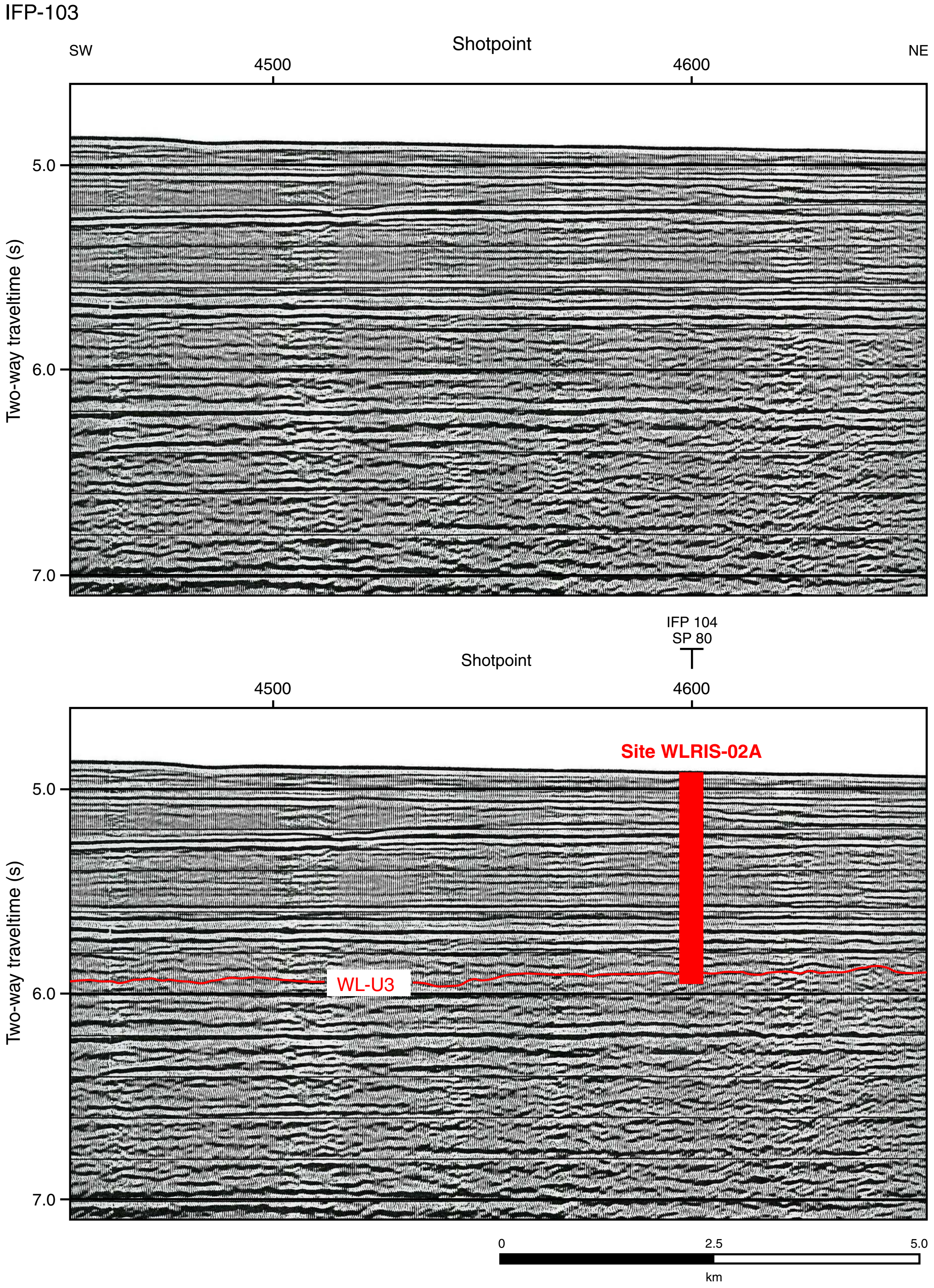


Figure AF5. Crossing seismic profile at proposed Site WLRIS-02A. SP = shotpoint.

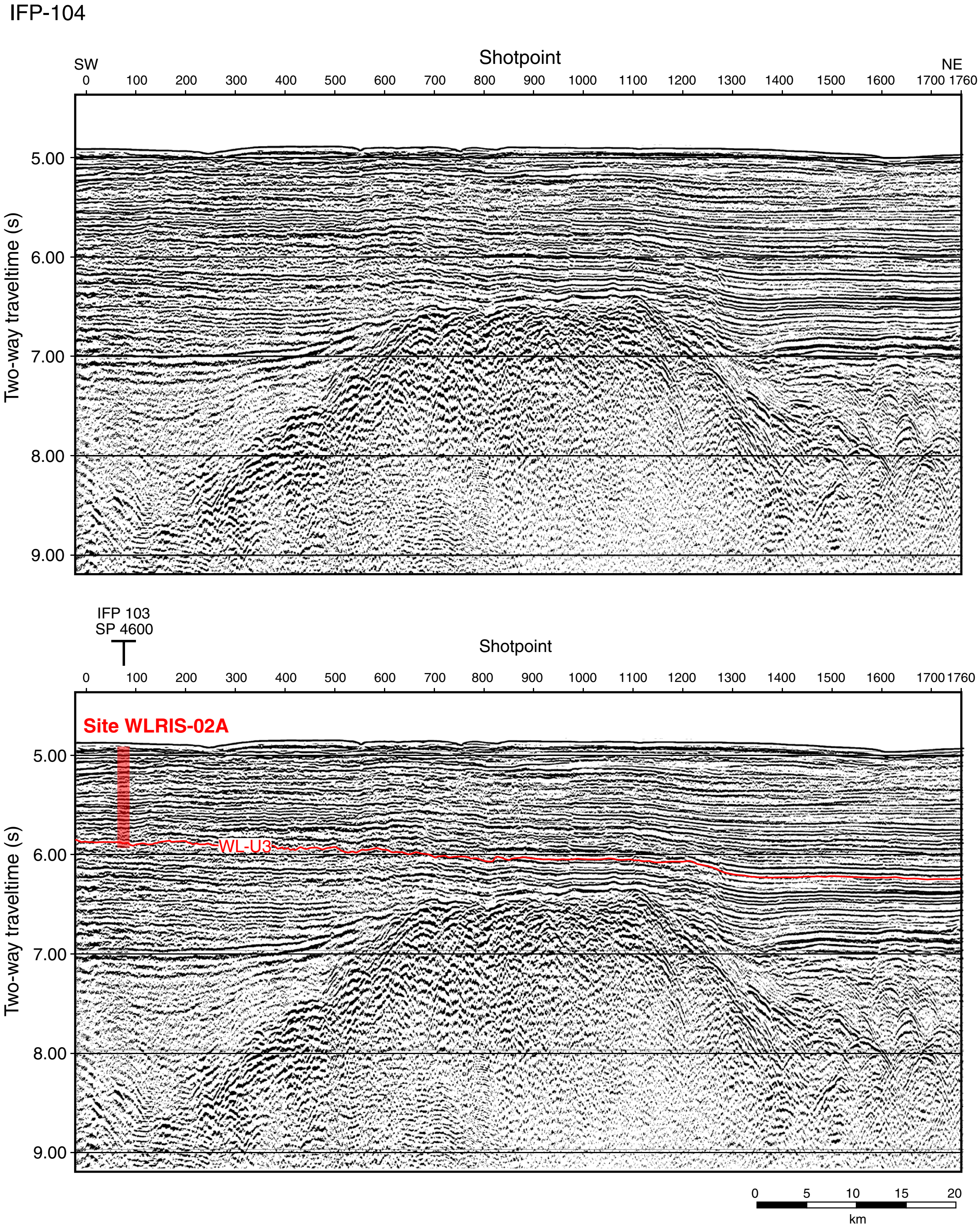


Figure AF6. Track map for proposed Site WLRIS-04A (red) and alternate proposed Site WLRIS-03A (blue).

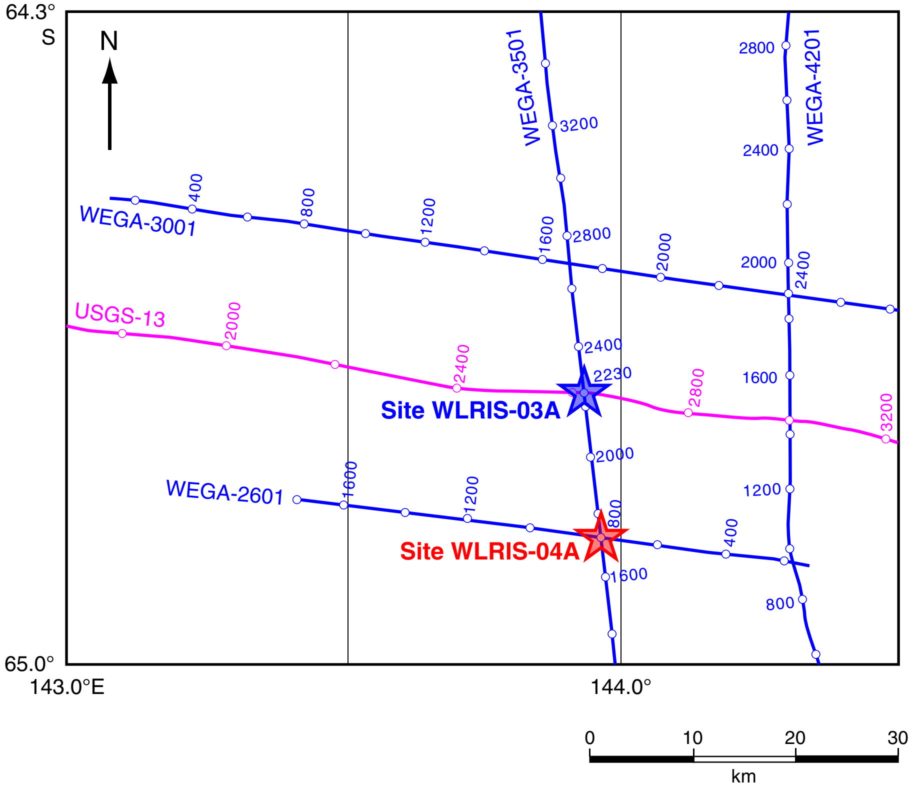


Figure AF7. Crossing seismic profile at proposed Site WLRIS-03A. SP = shotpoint.

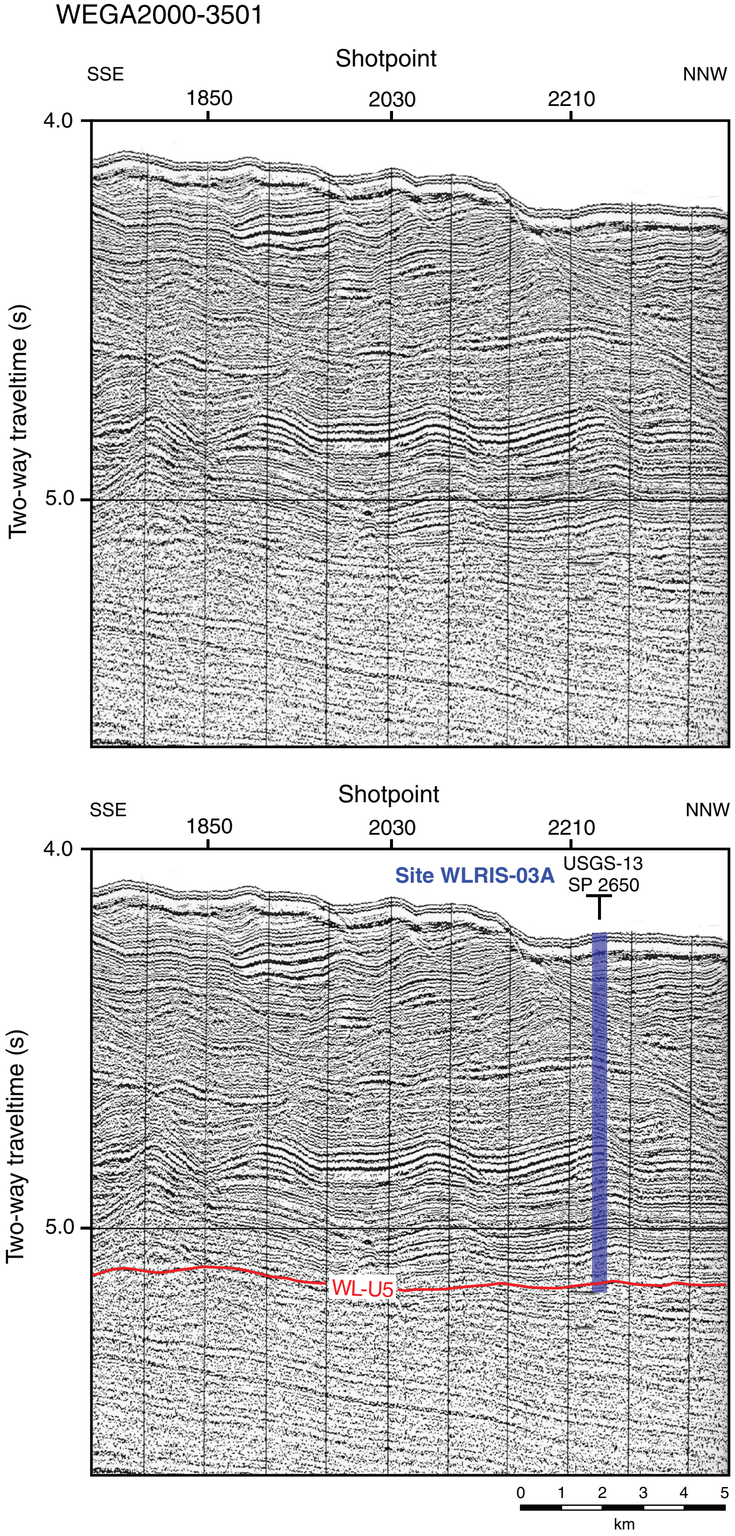


Figure AF8. Crossing seismic profile at proposed Site WLRIS-04A. SP = shotpoint.

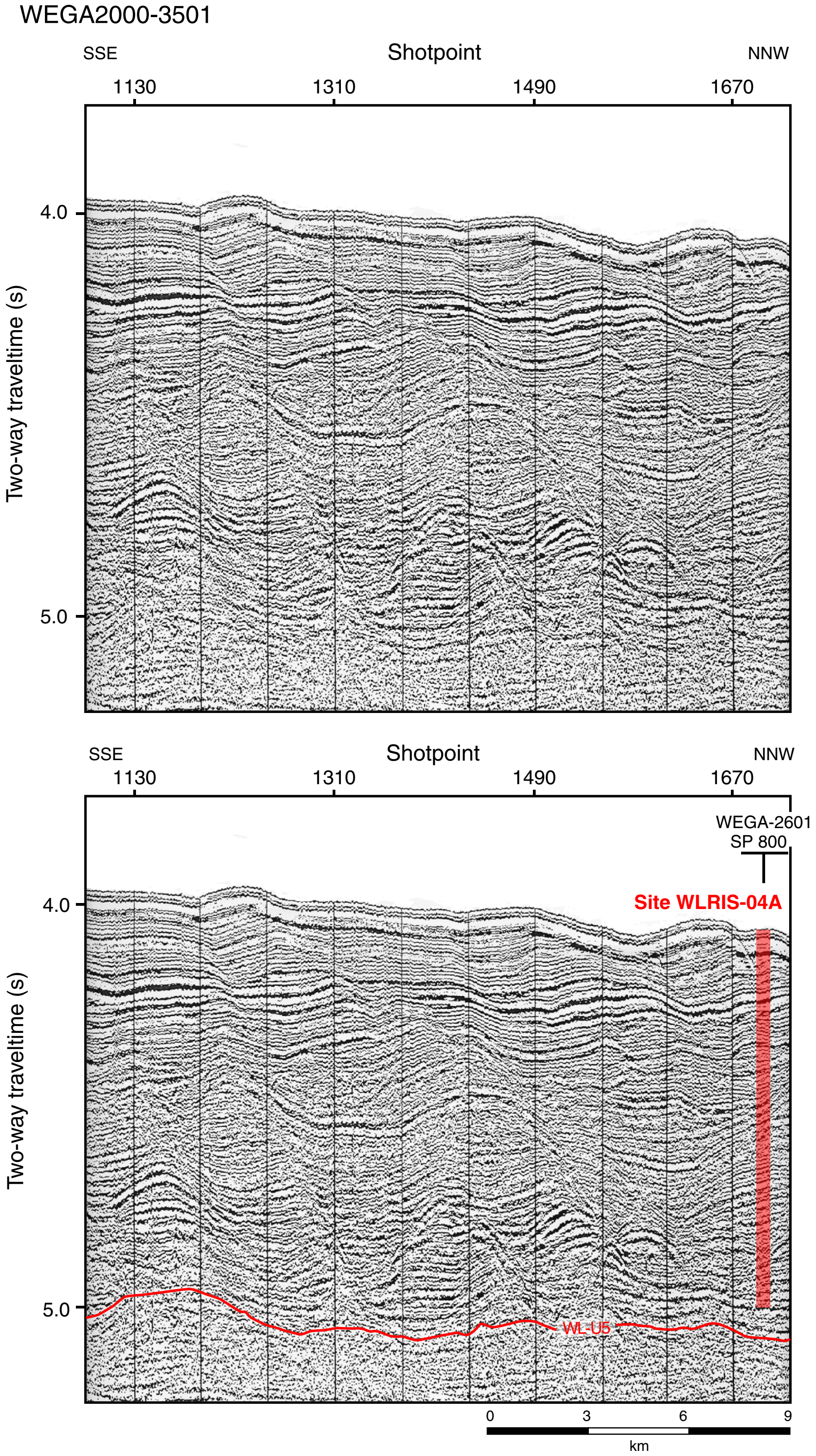


Figure AF9. Track map for proposed Sites WLSHE-07A, WLSHE-07B, WLSHE-08A, WLSHE-08B, WLSHE-09A, and WLSHE-09B. Red stars = primary sites, blue stars = alternate sites.

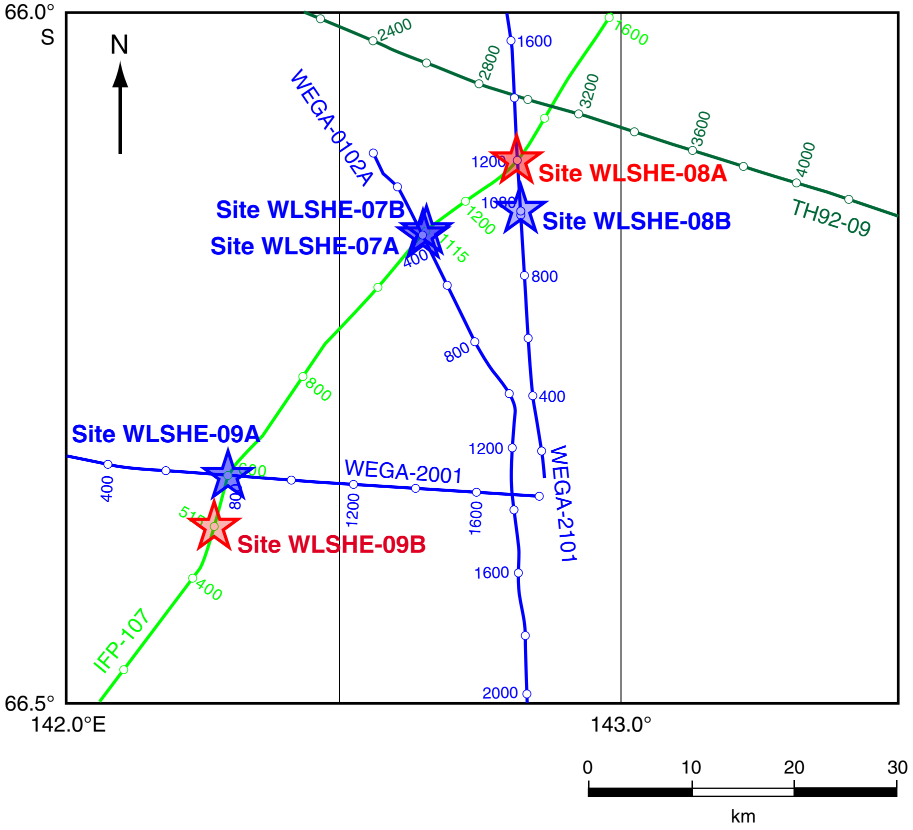
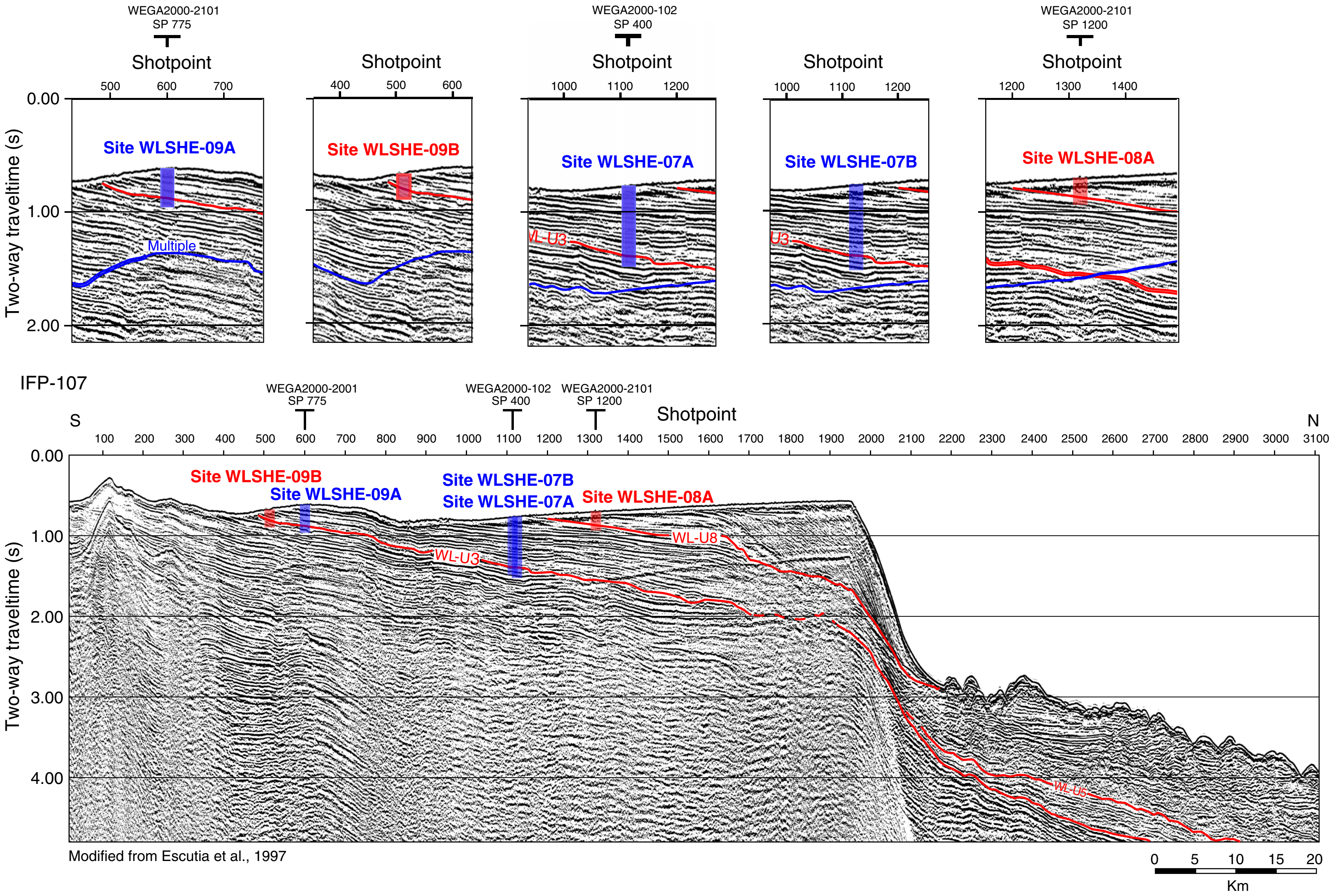


Figure AF10. Seismic profile at proposed Sites WLSHE-07A, WLSHE-07B, WLSHE-08A, WLSHE-09A, and WLSHE-09B. Red = primary sites, blue = alternate sites. SP = shotpoint.



Modified from Escutia et al., 1997

Figure AF11. Crossing seismic profile at alternate proposed Site WLSHE-07A. SP = shotpoint.

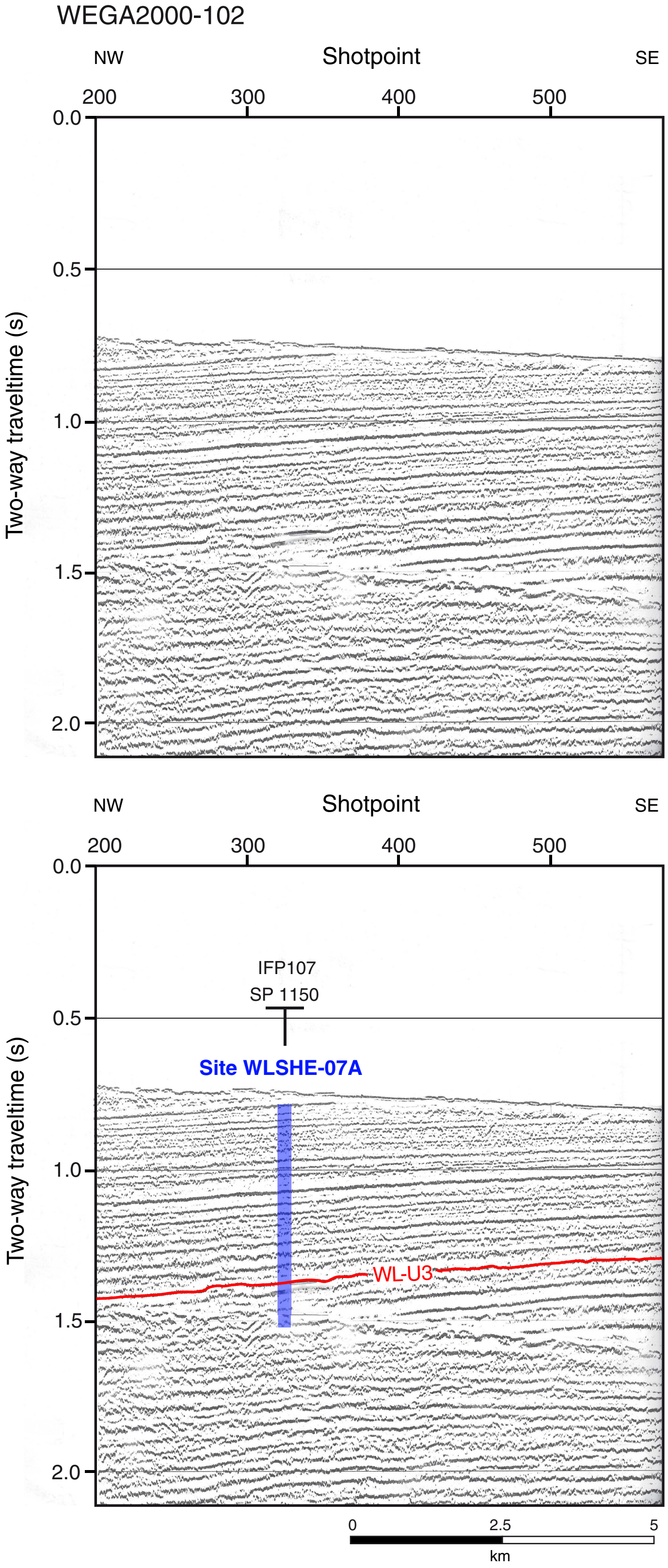


Figure AF12. Crossing seismic profile at proposed Site WLSHE-08A. SP = shotpoint.

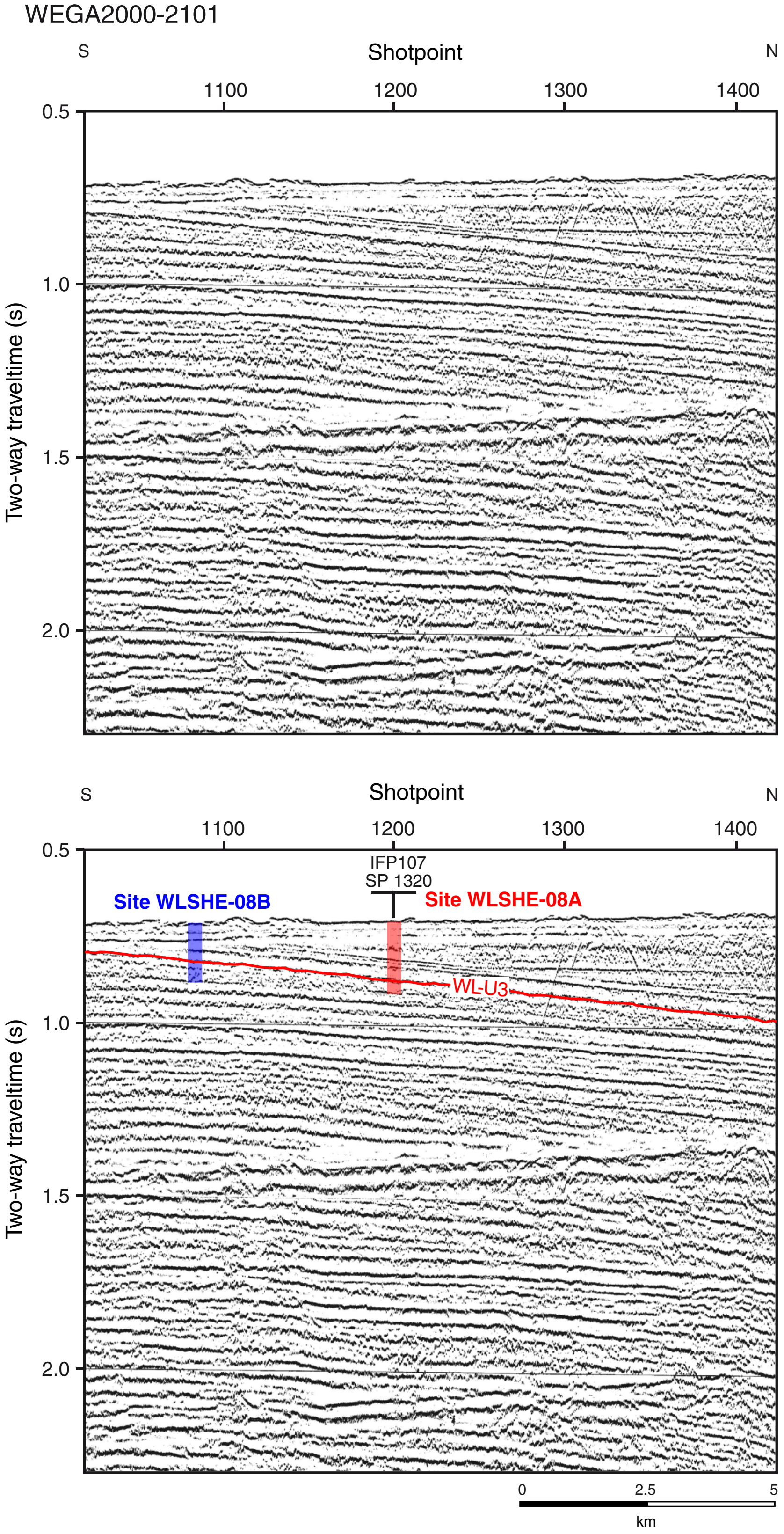


Figure AF13. Crossing seismic profile at alternate proposed Site WLSHE-09A. SP = shotpoint.

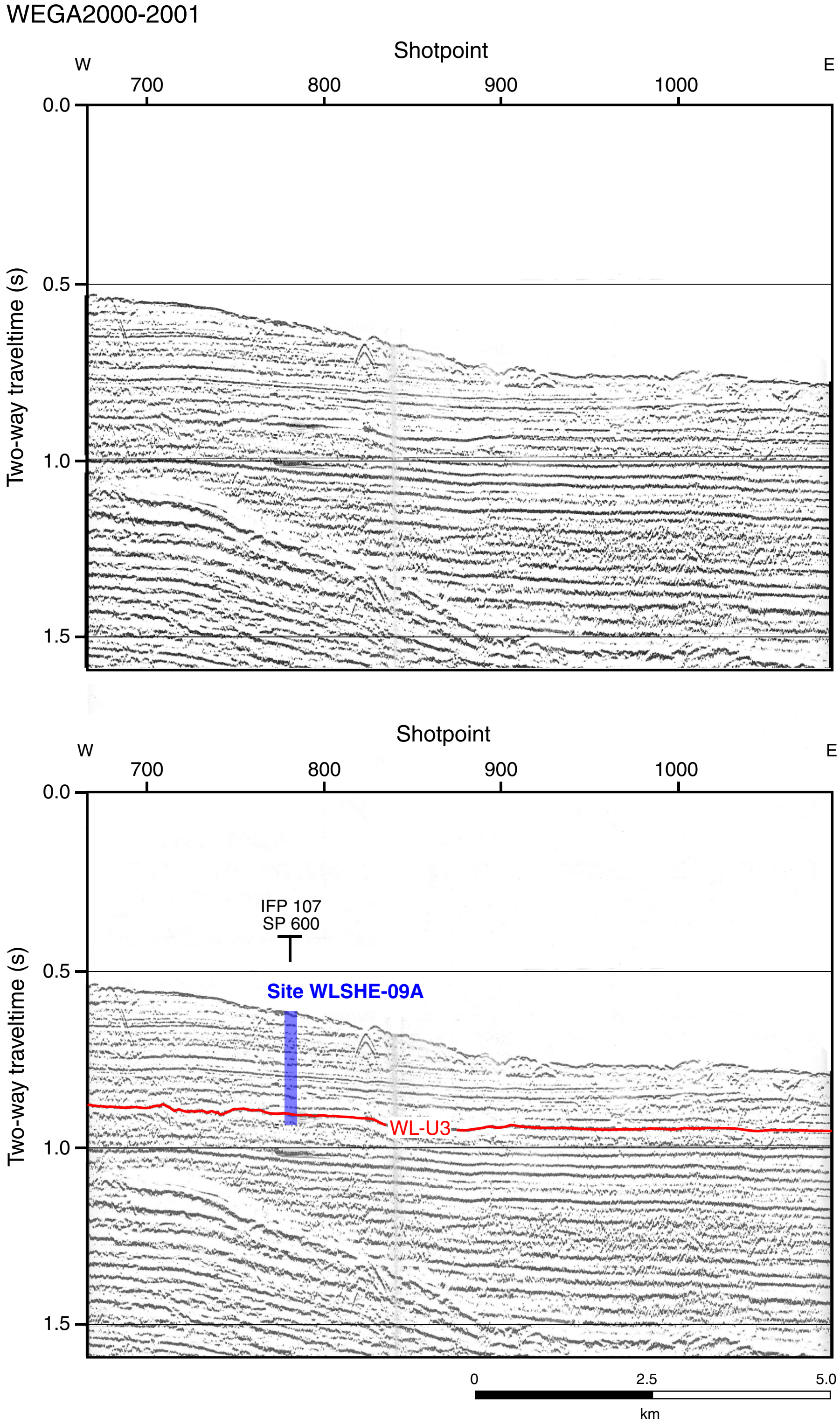


Figure AF14. Track maps of alternate proposed Sites WLSHE-10A, WLSHE-11A, and WLSHE-12A.

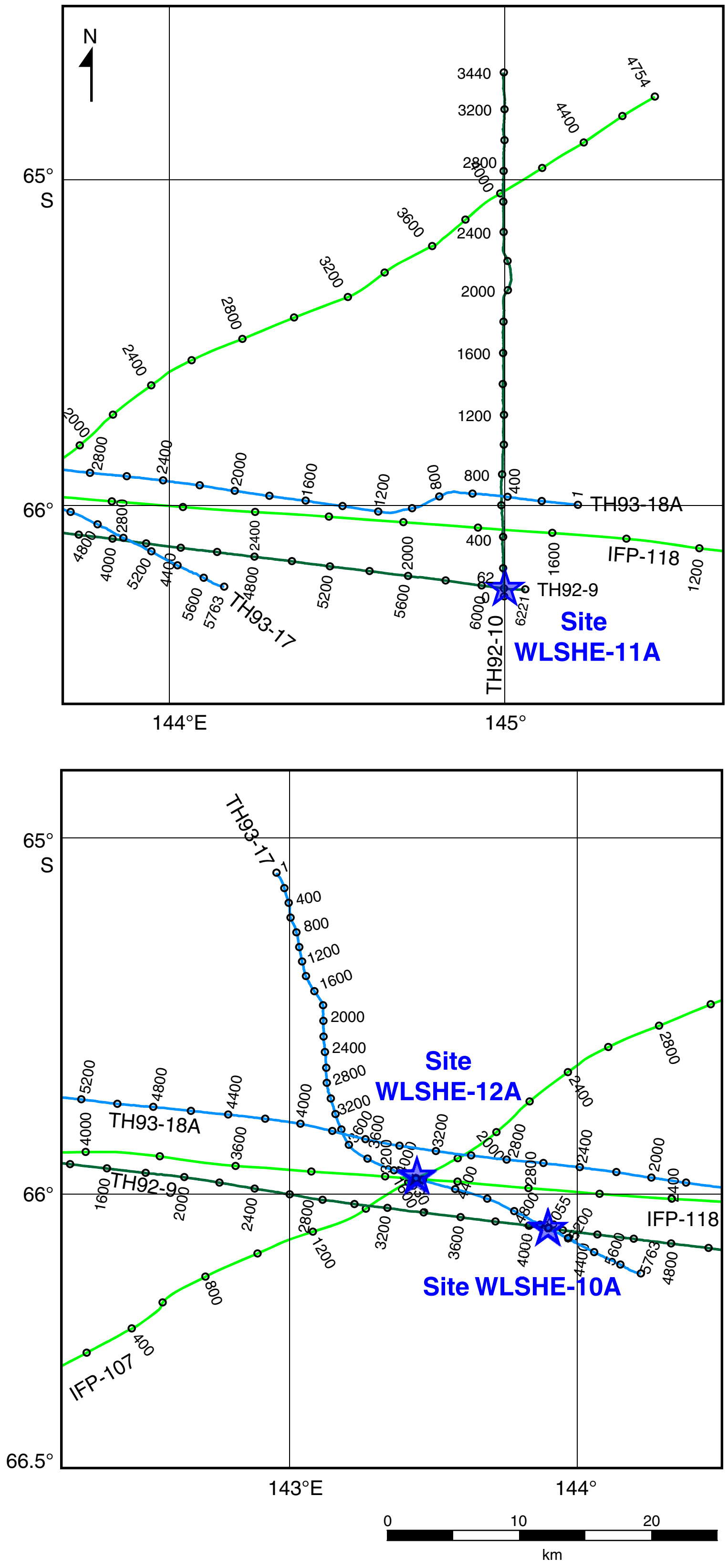


Figure AF15. Profile of seismic Line TH92-09 at alternate proposed Site WLSHE-10A. SP = shotpoint.

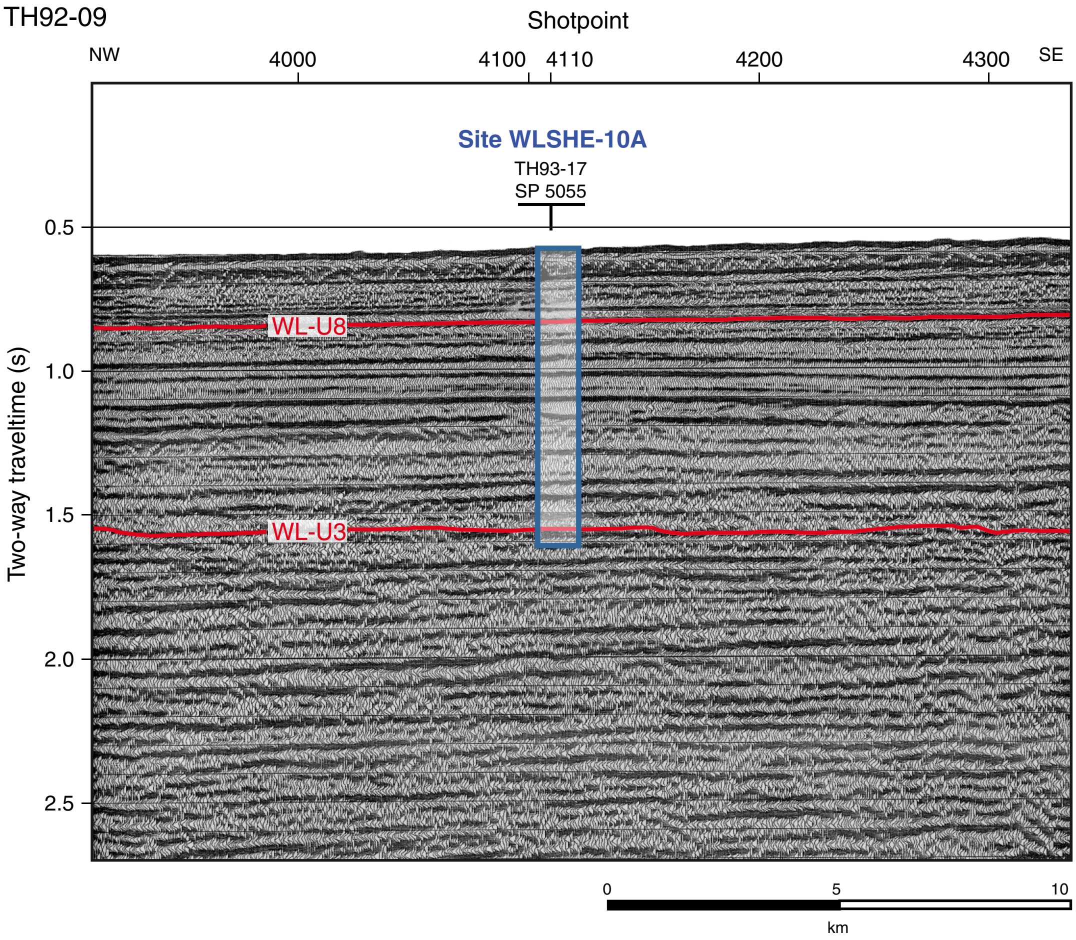


Figure AF16. Profile of seismic Line TH93-17 at alternate proposed Site WLSHE-10A. SP = shotpoint.

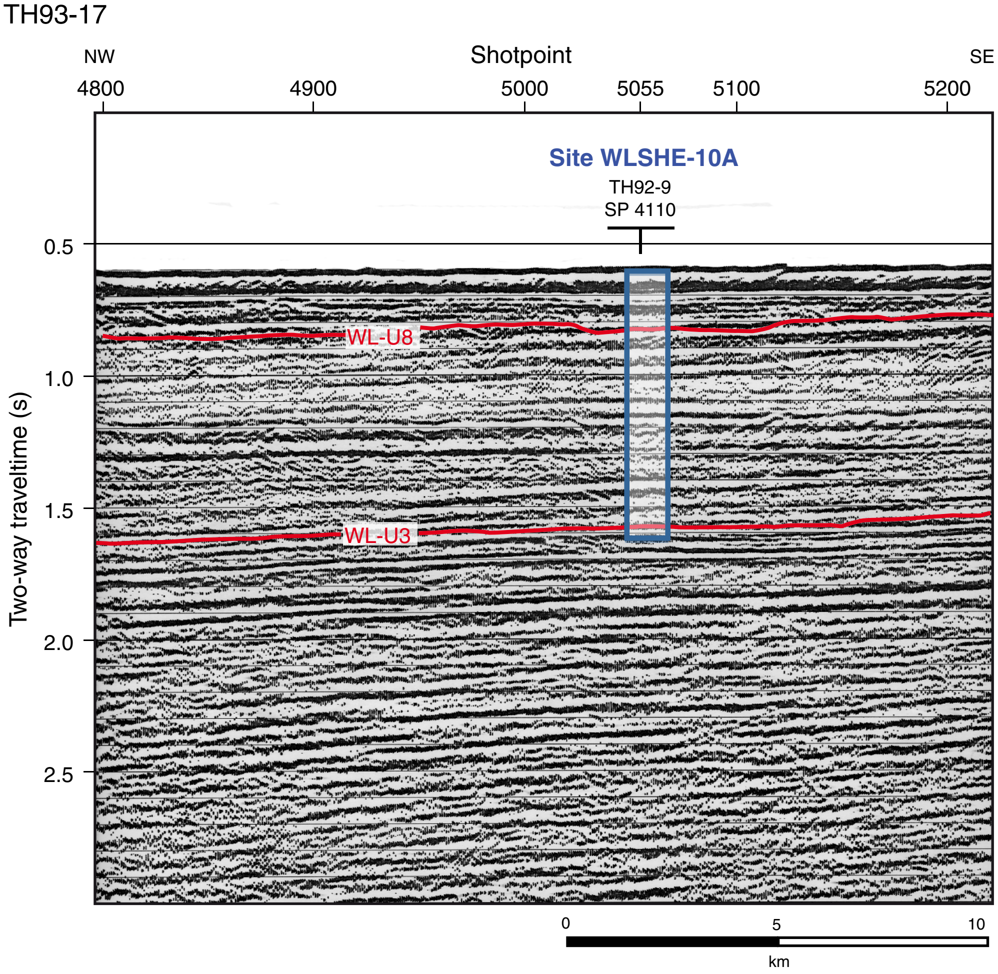


Figure AF17. Profile of seismic Line TH92-09 at alternate proposed Site WLSHE-11A. SP = shotpoint.

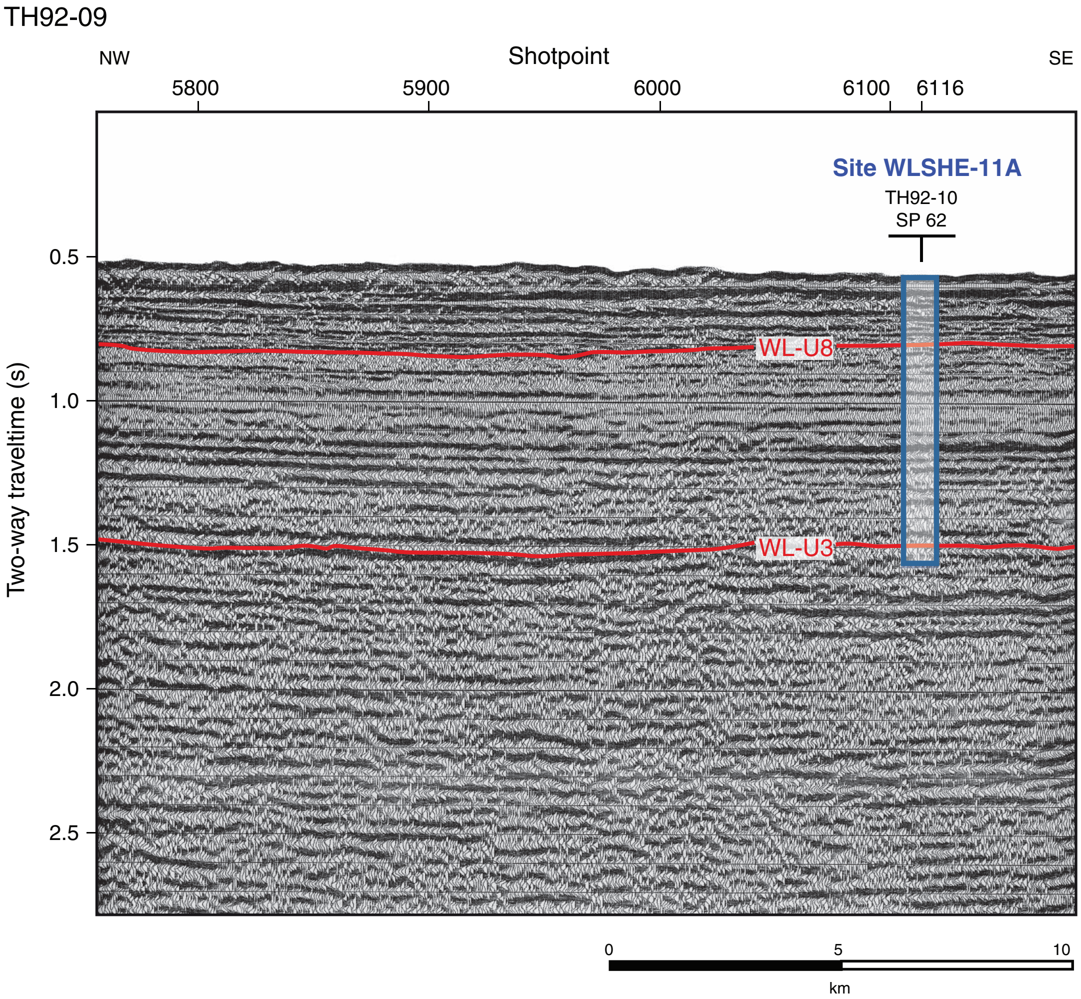


Figure AF18. Profile of seismic Line TH92-10 at alternate proposed Site WLSHE-11A. SP = shotpoint.

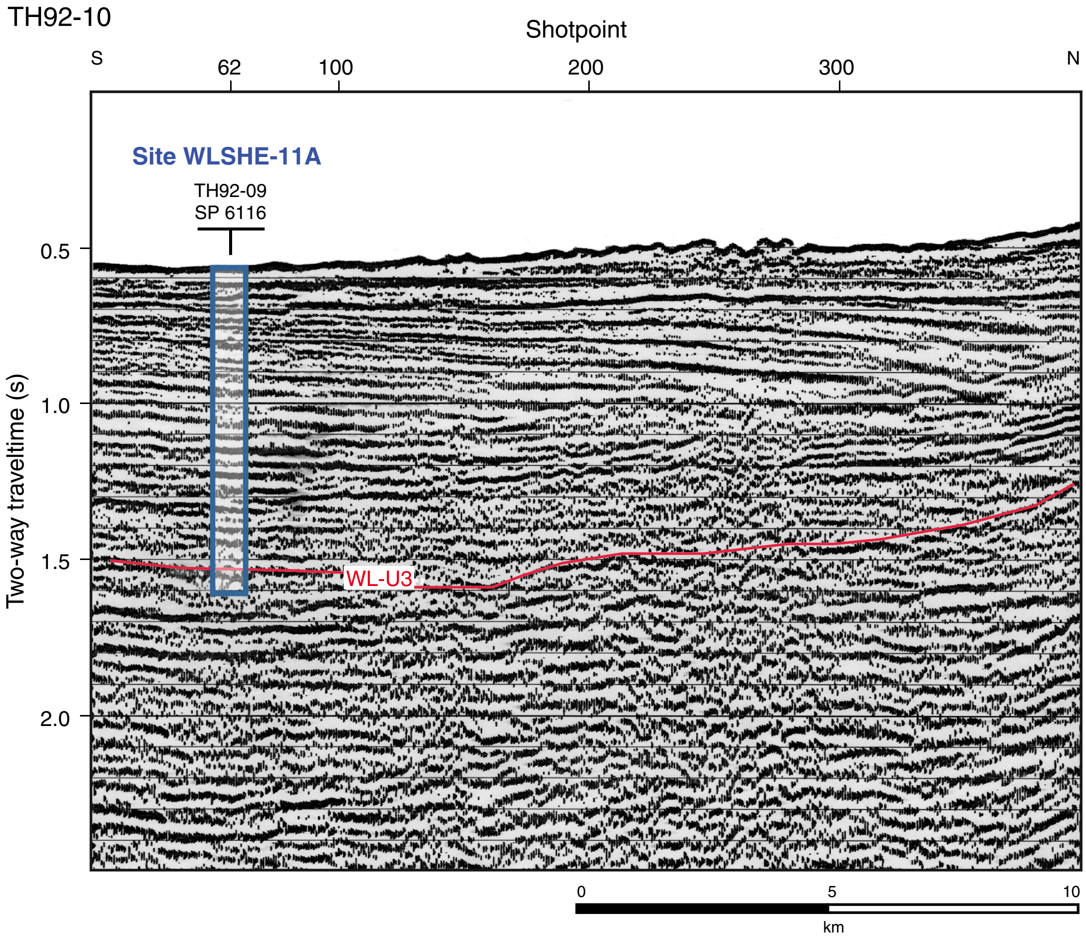


Figure AF19. Crossing seismic line at alternate proposed Site WLSHE-12A. SP = shotpoint.

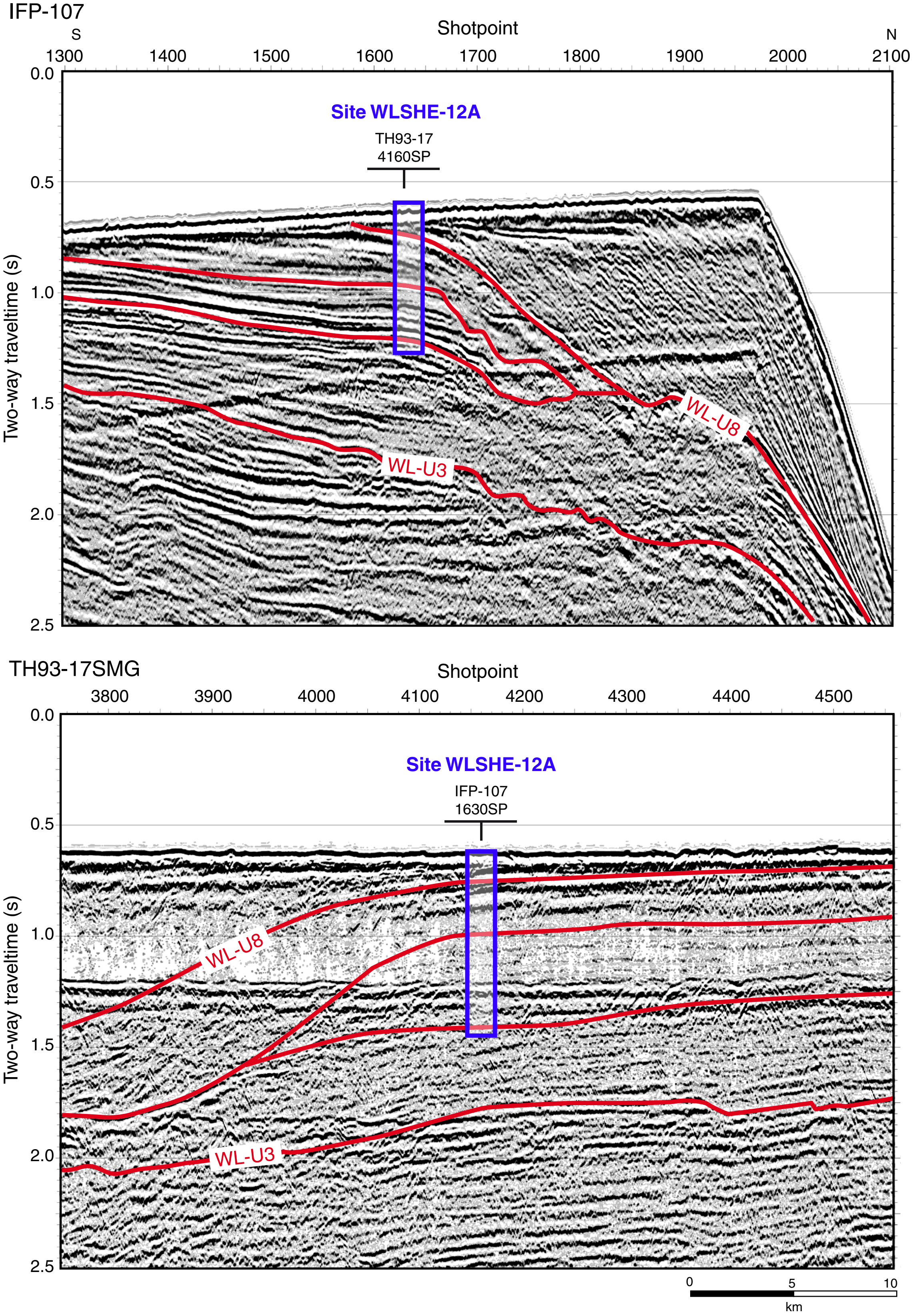


Figure AF20. Track map of alternate proposed Site WLSHE-13A.

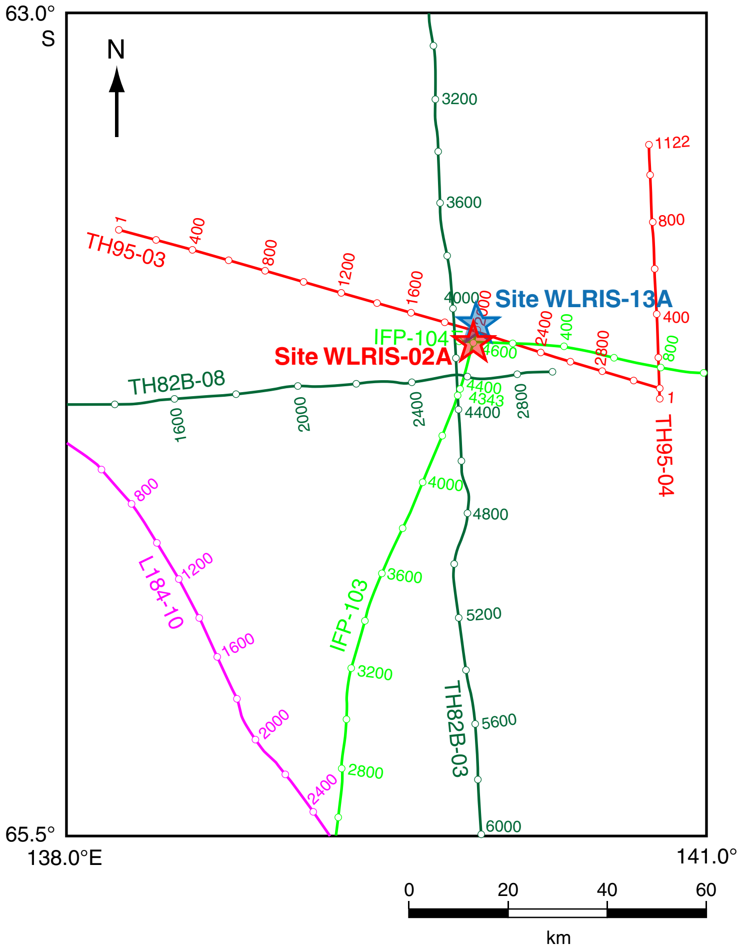


Figure AF21. Crossing seismic profile line at alternate proposed Site WLSHE-13A. SP = shotpoint.

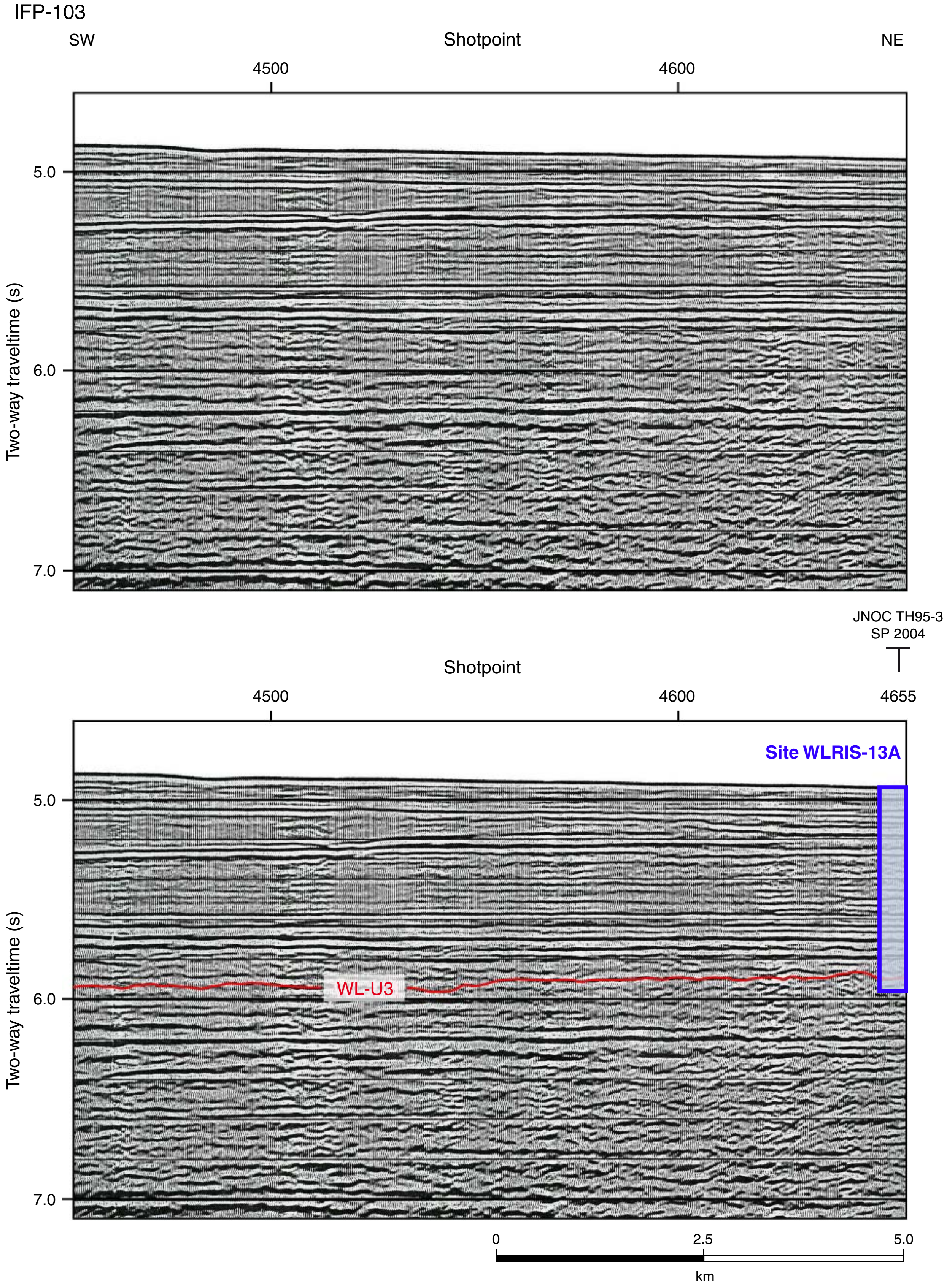
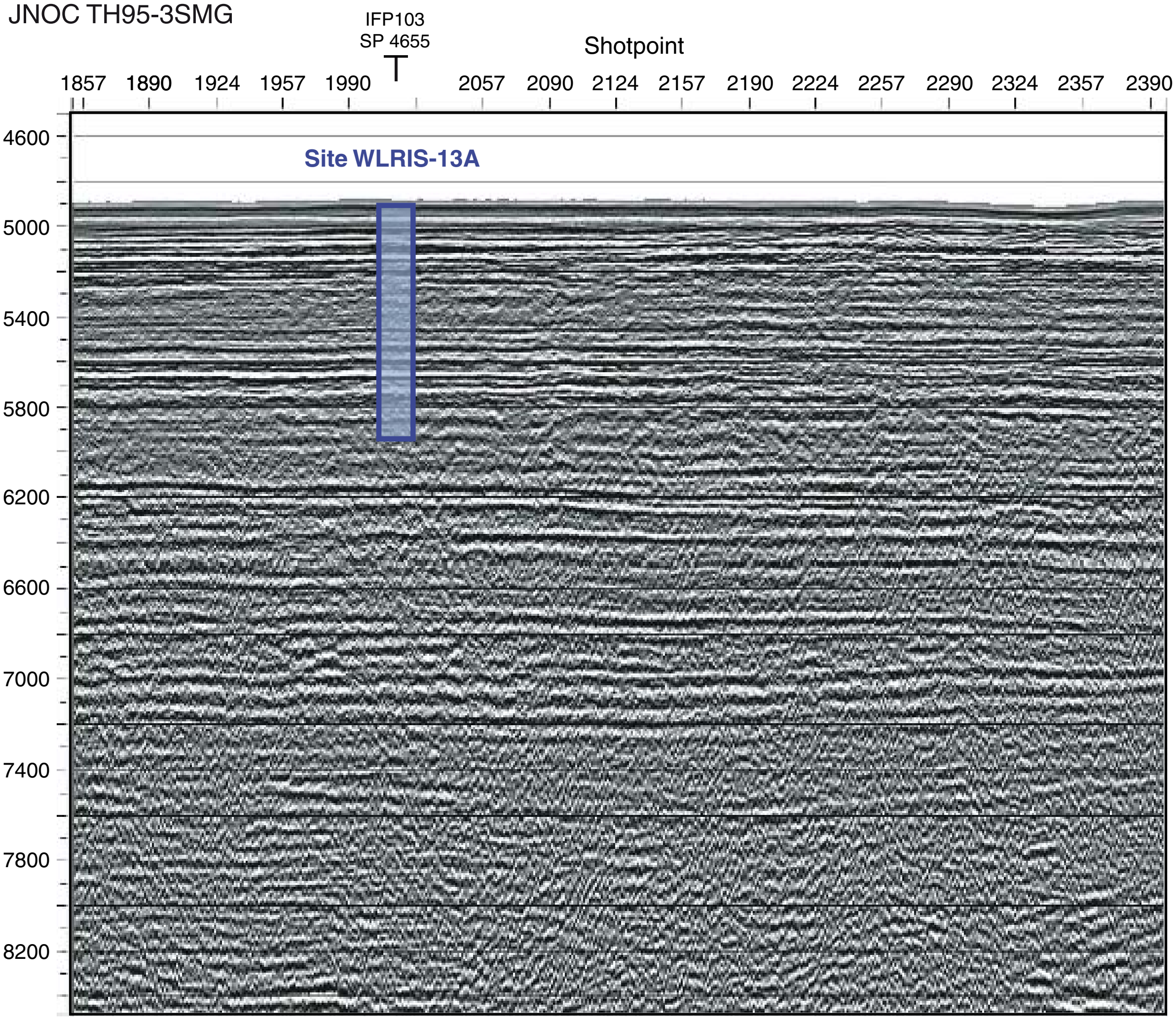


Figure AF22. Profile of seismic Line TH95-3SMG at alternate proposed Site WLSHE-13A. SP = shotpoint.



Scientific participants

The current list of participants for Expedition 318 can be found at **iodp.tamu.edu/scienceops/precruise/wilkesland/participants.html.**