Integrated Ocean Drilling Program Expedition 317/319 Scientific Prospectus

Pacific Equatorial Age Transect

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This IODP *Scientific Prospectus* is based on precruise Science Advisory Structure panel discussions and scientific input from the designated Co-Chief Scientists on behalf of the drilling proponents. During the course of the cruise, actual site operations may indicate to the Co-Chief Scientists and the Operations Superintendent that it would be scientifically or operationally advantageous to amend the plan detailed in this prospectus. It should be understood that any proposed changes to the science deliverables outlined in the plan presented here are contingent upon the approval of the IODP-USIO Science Services, TAMU, Deputy Director of Science Services in consultation with IODP-MI.

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Abstract

As the world's largest ocean, the Pacific is intricately linked to major changes in the global climate system. Throughout the Cenozoic, Pacific plate motion has had a northward component. Thus, the Pacific is unique in that the thick sediment bulge of biogenic-rich deposits from the currently narrowly focused zone of equatorial upwelling is slowly moving away from the Equator. Hence, older sections are not deeply buried and can be recovered by drilling. Previous drilling in this area during Ocean Drilling Program (ODP) Legs 138 and 199 was remarkably successful in giving us new insights into the workings of the climate and carbon system, productivity changes across the zone of divergence, time-dependent calcium carbonate dissolution, bio- and magnetostratigraphy, the location of the Intertropical Convergence Zone (ITCZ), and evolutionary patterns for times of climatic change and upheaval. Together with older Deep Sea Drilling Project drilling in the eastern equatorial Pacific, both legs also helped to delineate the position of the paleoequator and variations in sediment thickness from ~150°W to 110°W.

The Pacific equatorial age transect (PEAT) science program is based on Integrated Ocean Drilling Program (IODP) Proposal 626 and consists of Expeditions 317 and 319, grouped into one science program. The goal is to recover a continuous Cenozoic record of the equatorial Pacific by drilling at the paleoposition of the Equator at successive crustal ages on the Pacific plate. Records collected from Expeditions 317 and 319 are to be joined with records of previous drilling during ODP Legs 138 and 199 to make a complete equatorial Pacific record from 0 to 55 Ma. Previously, ODP Legs 138 and 199 were designed as transects across the paleoequator in order to study the changing patterns of sediment deposition across equatorial regions at critical time intervals. As we have gained more information about the past movement of plates and when in Earth's history "critical" climate events took place, it becomes possible to drill an age transect ("flow-line") along the position of the Pacific paleoequator. The goal of this transect is to target important time slices where calcareous sediments have been best preserved and the sedimentary archive will allow us to reconstruct past climatic and tectonic conditions. Leg 199 enhanced our understanding of extreme changes of the calcium carbonate compensation depth (CCD) across major geological boundaries during the last 55 m.y. A very shallow CCD during most of the Paleogene makes it difficult to obtain well-preserved sediments during these stratigraphic intervals, but the strategy of site locations for the current two expeditions is designed to occupy the most promising sites and to obtain a unique sedimentary biogenic sediment archive for time periods just after the Paleocene/Eocene boundary event,

Eocene cooling, the Eocene–Oligocene transition, the "one cold pole" Oligocene, the Oligocene–Miocene transition, and the Miocene. These new cores and data will significantly contribute to the objectives of the IODP Extreme Climates Initiative and will provide material that the previous legs were not able to recover.

For logistical reasons, the PEAT science program is composed of two expeditions but is being implemented as a single science program to best achieve the overall objectives of Proposal 626. Participants on both expeditions (as well as approved shore-based scientists) will comprise a single science party with equal access to data and materials from both cruises. Sampling aboard the ship will be minimal, and the bulk of the sampling will be completed postcruise.

The operational plan is to occupy eight sites along the age transect with the goal of recovering as complete a sedimentary succession as possible. This will probably require three holes to be cored at each site with wireline logging operations in one hole. Basement will be tagged in at least one of the holes. Expedition 317 will be directed primarily to sample the Neogene sites (proposed Sites PEAT-2C, 6C, and 7C, in priority order). The second expedition (319) will primarily sample the Paleogene sites (proposed Sites PEAT-1C, 3C, and possibly 5C, in priority order).

Schedule for Expeditions 317 and 319

Expeditions 317 and 319 (Pacific equatorial age transect [PEAT]) are derived from the original Integrated Ocean Drilling Program (IODP) drilling Proposal 626-Full2 (available for download from the Equatorial Pacific expeditions Web page at **iodp.tamu.edu/scienceops/expeditions/equatorial_pacific.html**). Expeditions 317 and 319 are scheduled for the *JOIDES Resolution,* operating under contract with the U.S. Implementing Organization (USIO).

Expedition 317 is currently scheduled to begin in Honolulu, Hawaii, on 19 May 2008 and to end in Astoria, Oregon, on 18 July 2008. However, this plan includes remedial cementing operations at two of the Juan de Fuca sites (IODP Expedition 301), and the scientists from Expedition 317 will disembark the ship in San Diego, California, on or about 7 July 2008. A total of 27 days will be available for the drilling, coring, and downhole measurements described in this report.

Expedition 319 is currently scheduled to begin in Tomakomai, Japan, on 17 September 2008 and to end in Papeete, Tahiti, on 17 November 2008. However, scientists will board the ship in Honolulu, Hawaii. A total of 32 days will be available for the drilling, coring, and downhole measurements described in this report.

At the time of publication, the ship's schedule could still be modified and readers should refer to the current detailed *JOIDES Resolution*'s schedule available at **iodp.tamu.edu/scienceops.** Further details on the *JOIDES Resolution* can be found at **iodp.tamu.edu/publicinfo/drillship.html.**

Introduction

The circulation of the equatorial surface ocean is inescapably linked to the trade wind system. The equatorial Pacific is the classic "world ocean" example of this linkage. It is dominated by wind-driven circulation and is largely unfettered by ocean boundaries. Here, the Equator itself is characterized by a narrow zone of divergence that results from the change in the sign of the Coriolis effect and gives rise to upwelling of subsurface waters and a band of high biologic productivity. The strength of the equatorial circulation and this divergence is linked to the strength of the trade winds, which are in turn strongly tied to the global climate system. Variations in global climate, interhemispheric differences in temperature gradients, and marked changes in the ocean boundaries are all imprinted on the biogenic-rich sediments that are accumulating in the equatorial zone. The PEAT science program is designed to provide an understanding of equatorial Pacific circulation, carbonate production, deposition, and dissolution for the last 55 m.y. at a scale where orbital forcing can be resolved. Combined with seismic reflection data following in the vein of Mitchell et al. (2003) and synthesized with earlier drilling (e.g., Moore et al., 2002, 2004) we can reconstruct equatorial Pacific history with high confidence and substantially improve upon work from the early stages of Deep Sea Drilling Project (DSDP) and recent Ocean Drilling Program (ODP) legs.

Deciphering the sedimentary history of the equatorial Pacific has been greatly simplified by favorable motion of the Pacific plate. Throughout the Cenozoic, movement of the Pacific plate has had a northward component of ~0.25°/m.y. This northward movement transports the equatorial sediments gradually out from under the zone of highest sediment delivery, resulting in a broad mound of biogenic sediments (Fig. **F1**). This transport prevents the older equatorial sections from being buried deeply beneath the younger sections as the crust moves northward. The northward displacement, however, is not so large that the tectonic traverse of the equatorial zone (within

2° latitude of the Equator) was too rapid to record a reasonable period of equatorial ocean history. Drill sites typically remain within the equatorial zone for 10–20 m.y. before passing beyond the northern edge of high biogenic sedimentation. Older equatorial sections are thus buried beneath a thin veneer of younger sediments as the crust moves northwestward. The resulting diminished overburden minimizes burial diagenesis of the biogenic debris. It also allows advanced piston corer (APC) piston coring of much of this section with the right strategy for locating the drill sites (Lyle et al., 2002).

In their summary of DSDP results in the equatorial Pacific, van Andel et al. (1975) give a general view of the development of the equatorial mound of sediments in the Pacific Ocean, based mostly upon three early DSDP legs (5, 8, and 16). They showed how both temporal and spatial variation in sediment accumulation rates resulted from plate movement, varying biologic productivity at the equatorial divergence, and carbonate preservation. The buildup of the equatorial Pacific mound of sediment has been more recently documented and discussed by Mitchell (1998) and Mitchell et al. (2003) (Fig. **F1**).

Drilling across the equatorial Pacific mound occurred decadally after the van Andel et al. (1975) compilation, first with DSDP Leg 85, then when an equatorial latitudinal transect along 10 Ma crust was drilled during ODP Leg 138, and finally when a similar transect along 56 Ma crust was conducted during ODP Leg 199. The newer drilling, coupled with major advances in geochronology, has documented the remarkable correlation of paleoceanographic events over thousands of kilometers in the equatorial Pacific, caused by the large scale of equatorial Pacific circulation (Fig. **F2**). It is possible, with the addition of a relatively small number of new sites, to build detailed reconstructions of equatorial Pacific circulation through the Cenozoic.

Early drilling missed most of this detail because of the lack of important drilling technologies such as APC coring, multisensor track correlation, and core-log integration that now allow collection of relatively undisturbed sediments, rebuilding of a continuous sediment column from individual cores, and correlation to seismic reflection data. Together with an improved knowledge of the plate tectonic regime, these advances will allow us to locate areas of enhanced depositional rates associated with the paleoequator. Combining multiple sites along the Equator will result in a detailed record from the Pleistocene to the Paleocene. These records will also be invaluable for the continued development of the Cenozoic timescale.

During ODP Legs 138 and 199, excellent sections were recovered that have provided detailed orbital tuning of the geologic timescale. These sections give a much clearer picture of variations in sedimentation rates, isotopic evolution of the oceans, biologic evolution and zoological provenance, variations in carbonate preservation, and variations in geochemical fluxes that result from paleoceanographic and paleoclimate changes. There are, however, still parts of the Cenozoic timescale that require further refinement and verification of the proposed orbital tuning. The timescale older than the late Eocene has not yet been calibrated sufficiently, even though there is evidence of orbital frequencies in parts of the records recovered from this older interval (e.g., Norris and Röhl, 1999; Röhl et al., 2001).

Background

Geologic setting, previous drilling, and site survey

To develop a detailed history of the equatorial Pacific current system, the strategy pursued during the most recent ODP leg (199; also during Leg 138) was to drill along a line of equal oceanic crustal age, thus obtaining an approximate north–south transect across the major east–west currents during time intervals of particular interest.

In the Paleocene and Eocene, the shallow carbonate compensation depth (CCD) prevents deposition of carbonate except at shallow ocean crust. Drilling at the paleoposition of the ridge crest at the critical time interval allows recovery of the shallowest sections available in the pelagic oceans and thereby assures the best possible preservation of the carbonate sediments recovered. As the crust cools and sinks, the seafloor on which the sediments are deposited becomes deeper and deeper—and closer to the lysocline and CCD. Thus, the best preserved part of the sections recovered in such "time-line" transects is restricted by the depth at which carbonate dissolution significantly increases, as well as by the northward movement of sediment sections out of the region of high equatorial productivity. This limitation was exemplified by the results from ODP Leg 199, during which only limited amounts of carbonate prior to the Eocene/Oligocene boundary (e.g., at ODP Site 1218 on 42 Ma crust) were recovered.

For the PEAT science program, we plan to overcome this limitation of the time-line strategy by pursuing an equatorial age transect, or "flow-line" strategy (Figs. **F3, F4**) to collect well-preserved equatorial sections through the Cenozoic. The Pacific plate motion over this time will cause the sites to also form an oblique latitudinal transect across all time slices.

We will drill a series of sites on the paleoequator at key intervals in the evolution of the Cenozoic climate. These intervals span from the very warm early Eocene, through the cooling of the late Eocene and Oligocene and the early Miocene time of relatively warm climates (or low ice volume), and into sections deposited during the development of the major Southern and Northern Hemisphere ice sheets in the middle and late Miocene (Fig. **F5**). There are very few previous drill sites that match our site selection criteria. Each site will be close to the geographic paleoequator and on crust aged slightly older than the age intervals of particular interest.

In this way, we will be able to track paleoceanographic conditions at the paleoequator in the best preserved sediments obtainable. We can also make use of the high level of correlation between tropical sediment sections and seismic stratigraphy to develop a more complete model of equatorial productivity and sedimentation.

Selecting target ages

The time slices to be drilled during this campaign were chosen to cover the overall climatic history of the Cenozoic and to target particular times of marked changes in the climatic regime. The spacing of the sites was determined by what we know of the Cenozoic evolution of the lysocline from previous drilling. Where the CCD is particularly shallow, the spacing in time of age-transect sites needs to be closer than where the CCD is deep (Fig. **F4**). As a guide, Site 1218 was drilled on 42 Ma crust during times when the CCD was near 3.3 km. Nannofossil oozes were deposited at this location up to ~37 Ma before the crust at this site sank below the CCD. An age separation between drill sites of 5 m.y. is a maximum for the shallow CCD of the Eocene; for good preservation of foraminifers, an even closer spacing should be used. The results of our paleoequator reconstruction and proposed drill site locations are shown in Figure **F6.**

Site location strategy

In pursuing the history of the equatorial Pacific Ocean through both time-line and flow-line transects, we have two major advantages over the efforts that took place in the earlier days of scientific ocean drilling. Although previous drill sites have targeted the general area, they mostly do not fulfill all of our criteria in terms of (1) a sufficient number of holes to obtain a continuous record, (2) modern coring technology to obtain undisturbed sediments, (3) a location inside the paleoequatorial zone, or (4) a location on the right crustal age to ensure the presence of calcium carbonate at the targeted time slice.

We have positioned proposed Sites PEAT-1C through 8C somewhat to the south of the estimated paleoequatorial position at their target ages in order to maximize the time that drill sites remain within the equatorial zone (i.e., ±2° of the Equator), to allow for some error in positions (evidence suggests a southward bias of the equatorial sediment mound relative to the hotspot frame of reference; Knappenberger, 2000), and to place the interval of maximum interest above the basal hydrothermally altered sediments. In order to plan site surveys we used the digital age grid of seafloor age from Müller et al. (1997; based on Cande and Kent, 1995), heavily modified and improved with additional magnetic anomaly picks from Petronotis (1991) and Petronotis et al. (1994), and DSDP/ODP basement ages. For this grid, each point is then backrotated in time to zero age, using the fixed-hotspot stage-poles from Koppers et al. (2001) and Engebretson et al. (1985) and the paleopole data from Sager and Pringle (1988). Each latitude–longitude gridpoint was backrotated according to age. After each point was mapped to a new location by this transform, all point ages were regridded by contouring the set of all backrotated points for a given age.

The supporting site survey data for Expeditions 317 and 319 are archived at the IODP Site Survey Databank (**ssdb.iodp.org**).

Eocene (Sites PEAT-1C to 4C)

The Eocene was a time of extremely warm climates that reached a global temperature maximum near 52 Ma (Fig. **F5**). From this maximum there was a gradual climatic cooling through the Eocene to the Eocene/Oligocene boundary. There appears to have been a slight reversal to this trend within the middle Eocene, near 43 Ma, and in the late Eocene at 34–36 Ma, just prior to the pronounced drop in oxygen isotopes that marks the Eocene/Oligocene boundary and one of the most dramatic changes of the CCD (Fig. **F4**). Throughout the Eocene, the CCD lay near 3.2–3.3 km depth, albeit with potentially significant short-term fluctuations (Lyle et al., 2005). Thus, recovering well-preserved carbonate sediments from the equatorial region is a substantial challenge, but it is not impossible if the depth of the East Pacific Rise lay near the global average of 2.7 km. The Eocene equatorial upwelling system appears to differ from the modern equatorial upwelling regime by having strong secondary upwelling lobes ~10° in latitude away from the primary equatorial region (Figs. **F7, F8**). These upwelling lobes produce a much broader region of (relatively) high productivity than is present today.

Early and middle Eocene (Sites PEAT-1C, 2C; ~53 Ma and 50 Ma crust)

During Leg 199 a north–south transect was drilled across the equatorial region on oceanic crust of ~56 Ma age. Sites on this transect had generally drifted below the CCD by 52–53 Ma. Thus we presently lack calcareous sediments from the region of the equatorial circulation system during the time of maximum Cenozoic warmth. Proposed Site PEAT-1C has been located on crust with an estimated age of ~53 Ma in order to intercept the interval between 53 and 50 Ma in basal carbonate sediments above the shallow early Eocene CCD (4200–4300 m). This interval was poorly sampled during Leg 199.

Average (noncarbonate) accumulation rates in the early Eocene were moderate, showing only slight increases in some of the more northern sites on the Leg 199 transect (Sites 1215 and 1220). What is particularly interesting in the records of Leg 199 is that the very shallow CCD of this early Eocene time appears to deepen to the north, perhaps suggesting a northern source for the bottom waters. Sites targeting this time interval would ideally give us sediments with sufficient carbonate material to better constrain the isotopic and biotic characteristics of the near-surface equatorial waters.

During the early Eocene, a very shallow CCD and typical rapid tectonic plate subsidence of young crust near the shallow ridge-crest conspire to make the time window during which carbonate is preserved short (~2–5 Ma). Thus, although good records of pelagic carbonates during and just after the Paleocene/Eocene Thermal Maximum (PETM) were recovered at Leg 199 sites (Lyle, Wilson, Janecek, et al., 2002; Raffi et al., 2005; Nuñes and Norris, 2006), the time period of the early Eocene Climatic Optimum (Zachos et al., 2001a) is not well sampled.

Proposed Sites PEAT-1C (52 Ma crust) and 2C (49–50 Ma crust) aim to provide the sedimentary archive to address causes and responses of the true Cenozoic “Greenhouse” world: the Eocene was a time of extremely warm climates that reached maximum temperatures near 52 Ma (Zachos et al., 2001a). From this maximum there was a gradual climatic cooling to the Eocene/Oligocene boundary. We have positioned the sites to the south of the estimated paleoequatorial position at the target age in order to maximize the time that drill sites remain within the equatorial zone (i.e., ±2° of the Equator), to allow for some southward bias of the equatorial sediment mound relative to the hotspot frame of reference (Knappenberger, 2000) and to place the interval of maximum interest above the basal hydrothermal sediments.

Middle and late Eocene (Site PEAT-3C; 46 Ma crust)

Good paleomagnetic stratigraphy at Leg 199 sites allowed a much improved calibration of nannofossil and radiolarian biostratigraphic datums (Moore et al., 2004; Raffi et al., 2005; Pälike et al., 2005, 2006b; Nigrini et al., 2006). From the combined information, a more detailed picture emerged of temporal variations in sediment accumulation through the middle and upper Eocene of the tropical Pacific. These data show an increase of up to 2–3 times in accumulation rates of siliceous ooze within the middle Eocene (41–45 Ma). There are also several notable periods of highly fluctuating CCD associated with intervals in which carbonate is preserved to 4000 m, or ~700 m deeper than the average Eocene CCD (Lyle, Wilson, Janecek, et al., 2002; Lyle et al., 2005; Rea and Lyle, 2005). Such fluctuations in the CCD are similar in magnitude to those at the Eocene/Oligocene boundary (Coxall et al., 2005).

High siliceous sedimentation occurs near an apparent short reversal in the middle Eocene cooling trend (Fig. **F5**). It is difficult to interpret the cause of such a substantial change in silica flux during a very warm climatic regime. At the very least we need good carbonate recovery during this interval in order to apply the substantial array of carbonate-based proxies to this interval in order to evaluate the temperature and structure of the near-surface ocean.

Eocene/Oligocene boundary (Site PEAT-4C; 38 Ma crust)

Proposed Site PEAT-4C targets the events bracketing the Eocene–Oligocene transition, with the specific aim to recover carbonate-bearing sediments of latest Eocene age (Kennett and Shackleton, 1976; Miller et al., 1991; Zachos et al., 1996; Coxall et al., 2005; Exon, Kennett, Malone, et al., 2001) and testing the hypothesized magnitude of Eocene glaciation events (Lyle et al., 2005; Tripati et al., 2005). Site PEAT-4C is located on upper middle Eocene crust with an estimated age of ~38 Ma. The Eocene–Oligocene transition marks the most dramatic deepening of global CCD in the Cenozoic (van Andel, 1975). Coxall et al. (2005) (Fig. **F9**) demonstrate that the change in CCD coincides with a rapid step-wise increase in benthic oxygen stable isotope ratios, reflecting the growth of the Antarctic ice sheet.

The apparent latest Eocene climate cooling and increased primary productivity at low latitudes seems somewhat at odds with the apparent slight warming indicated by the oxygen isotopes (Fig. **F5**). These oddities, together with the major changes in planktonic assemblages, suggest an important restructuring of the upper mixed layer and thermocline waters in the Pacific that continues into the lower Oligocene. Well-recovered and well-preserved equatorial sections across this relatively short transition between warm and cold global climates will be very valuable in determining the impact of high-latitude ocean boundary changes on climate, circulation, and productivity in the equatorial region.

So far the most complete Eocene/Oligocene boundary section recovered from the equatorial Pacific has been ODP Site 1218 on 42 Ma crust; however, it is far from pristine. Carbonate percentages drop markedly below the boundary and go to zero near 34 Ma (Lyle et al., 2005; Coxall et al., 2005). This prevented the recovery of information about paleoceanographic conditions prior to the Eocene–Oligocene transition and also has implications for the interpretation of paleotemperature proxies such as Mg/Ca ratios in foraminiferal shells that were bathed in waters with very low carbonate ion concentrations (Lear and Rosenthal, 2006; Elderfield et al., 2006). Data from Site 1218 allowed the astronomical time calibration of the entire Oligocene (Coxall et al., 2005; Wade and Pälike, 2004; Pälike et al., 2006b), but the lack of carbonate in the uppermost Eocene at this site made the detailed time control now available for the Oligocene much less certain for the late Eocene. Site PEAT-4C is located on estimated crustal basement age of ~38 Ma and crossed the paleoequator shortly thereafter. It was located to provide the missing information about the crucial chain of events prior and during the Eocene–Oligocene transition.

Oligocene (Site PEAT-5C; ~32 Ma crust)

Proposed Site PEAT-5C targets the Oligocene and is located on lower Oligocene crust. This interval of time is noted for its markedly heavy benthic oxygen isotopes (Fig. **F5**) and its relatively deep CCD (Fig. **F4**). There was probably ice on Antarctica during this interval, but not the large ice sheets found there later in the middle Miocene. There is no compelling evidence for ice sheets in the Northern Hemisphere during the Oligocene and early Miocene. Thus, there was apparently a relatively low global ice volume, relatively cold bottom waters, a relatively cold South Pole, and a relatively warm North Pole. This scenario of a "one cold pole" world has given rise to speculation on the impact of interhemispheric temperature imbalance on pole-to-Equator temperature gradients and on the symmetry of the global wind systems. The extent to which such an imbalance may have affected the trade winds, the position of the Intertropical Convergence Zone, and the seasonal shifts in this zone should be seen in the wind-driven currents of the equatorial region.

The older, low-resolution DSDP data indicate relatively high but variable sediment accumulation rates during this interval and better carbonate preservation south of the

Equator (van Andel et al., 1975). In the Leg 199 equatorial transect, the highest accumulation rates encountered (>15 m/m.y.) occurred in the lower part of the Oligocene, but these were in sites north of the Oligocene Equator or on relatively old (and therefore deep) crust. Thus we expect a better preserved, thicker carbonate section at the Oligocene Equator. Studies of Oligocene sections from Leg 199 and from other ODP sites (e.g., Paul et al., 2000; Zachos et al., 2001b; Billups et al., 2004; Pälike et al., 2006a) indicate the presence of strong eccentricity and obliquity cycles in carbonate preservation and suggest a strong (southern) high-latitude influence on the carbonate record. These cycles are leading to the development of an orbitally tuned timescale that reaches back to the base of the Oligocene (Pälike et al., 2006b). Such a timescale will make it possible to develop a very detailed picture of equatorial geochemical fluxes and of the degree of variability in the equatorial system of the Oligocene.

Latest Oligocene–earliest Miocene (Site PEAT-6C; 27 Ma crust)

Proposed Site PEAT-6C will focus on paleoceanographic events in the late Oligocene and into the early and middle Miocene, including the climatically significant Oligocene–Miocene transition and its recovery. In conjunction with proposed Sites PEAT-5C and 7C, Site PEAT-6C is also designed to provide a latitudinal transect for early Miocene age slices.

At the end of the Oligocene there is a significant multimillion-year-long rise in the oxygen isotope record (Lear et al., 2004), which is closely followed by a relatively short, sharp increase in oxygen isotope values that has been interpreted as a major glacial episode (“Mi-1”) (Fig. **F5**) (Paul et al., 2000; Zachos et al., 1997, 2001a, 2001b; Pälike et al., 2006a) and correlated to a pronounced drop in sea level (Miller et al., 1991). This event is very close to the Oligocene/Miocene boundary and has now been astronomically age calibrated in several ocean basins (Shackleton et al., 2000; Billups et al., 2004). Although there are clear periodic isotopic signals indicating major changes in ice volume, ocean temperatures, and/or ocean structure, this biostratigraphic boundary has always been somewhat of an enigma. Unlike the major changes in the isotopic stratigraphy, the biostratigraphies of the planktonic microfossils show very little change at all across this boundary. In fact it is one of the most difficult epoch boundaries to pick using solely the microfossil biostratigraphies.

At Sites 1218 and 1219 of ODP Leg 199 this interval was well recovered; however, carbonate preservation still presented a problem for classic foraminiferal stratigraphy. Both sites were deep and well within the lysocline, making the application of temperature proxies such as Mg/Ca ratios in foraminiferal tests more difficult (C.H. Lear, pers. comm., 2006). At the time mid-Oligocene sediments were deposited, Site 1218 already resided on 18 m.y. old crust and was ~4100 m deep. Site 1219 was on ~34 m.y. old crust and was ~4500 m deep. There was a relative increase in the large diatoms near this boundary in the siliceous coarse fraction, suggesting increased productivity; however, detailed, high-resolution flux rates across this interval have yet to be determined. A well-recovered section on the latest Miocene–Oligocene Equator, near the late Oligocene ridge-crest as targeted by Site PEAT-6C, should provide both the resolution and the preservation required to better describe the changes in the equatorial ocean taking place at this time.

Miocene (Site PEAT-7C; 24 Ma crust)

Site PEAT-7C is proposed for drilling to focus on the paleoceanographic events in the early and middle Miocene. The latest Oligocene through the middle Miocene appears to have been a time of relative warmth comparable to the latest Eocene. However, the variability in the isotopic record of the early to middle Miocene is larger than that of the Eocene and may indicate more variability in climate and in global ice volume. The climatic "optimum" at ~15 Ma comes just before the major development of ice sheets on Antarctica and the marked increase in ice-rafted debris in circum-Antarctic sediments. The early Miocene also marks a major evolutionary change from the relatively static Oligocene planktonic biota. In the equatorial Pacific, the late Oligocene to early Miocene marks the beginning of abundant diatoms in the stratigraphic record (Barron et al., 2004) and thus may represent a major change in carbon cycling as well.

The only major ocean boundary change proposed for the time near the Oligocene/Miocene boundary was the opening of the Drake Passage to deep flow; however, there is some debate as to the exact timing of this event (Barker, 2001; Pagani et al., 1999; Lawver and Gahagan, 2003; Scher and Martin, 2006), and its direct impact on the tropical ocean is uncertain. It may be that, as in the Eocene/Oligocene boundary section, the link lies in the shallow intermediate waters that provide nutrients to lower latitude upwelling regions. For the equatorial region, an even more pertinent question is what changes were occurring in the Miocene tropical ocean that led to this burst of Miocene evolution?

Middle Miocene (Site PEAT-8C; ~18 Ma crust)

In principle, the age-transect strategy of this proposal would not be complete without data from the Pliocene–Pleistocene. However, in addition to the logistical reasons of cruise length, near-paleoequatorial records have already been targeted by ODP Legs

138 (Pisias, Mayer, Janecek, Palmer-Julson, and Van Andel, 1995) and 202 (Mix, Tiedemann, Blum, et al., 2003), and these provide information about the development of Northern Hemisphere glaciation. Our last proposed site focuses instead on the interesting events following a middle Miocene maximum in deposition (van Andel et al., 1975).

Site PEAT-8C is proposed for drilling to focus on the paleoceanographic events following a middle Miocene maximum in deposition (van Andel et al., 1975). In addition, large changes in the glaciation state and frequency have recently been described in the middle Miocene (Holbourn et al., 2005; Abels et al., 2005), in the interval following ~14 Ma. There is a wide latitude range of $CaCO_3$ deposition during the earliest Neogene, with a relatively sharp transition to a narrower $CaCO_3$ belt after 20 Ma (Lyle, 2003). $CaCO_3$ mass accumulation rates in the central equatorial Pacific recovered from the 18–19 Ma "famine" and in the period between 14 and 16 Ma reached a second maximum in carbonate deposition, which is also evident in the seismic stratigraphy of the equatorial sediment bulge (Knappenberger, 2000; Mitchell et al., 2003). We designed Site PEAT-8C to recover an equatorial record at the early middle Miocene sedimentation maximum.

Understanding the interplay between the CCD, $CaCO_3$ dissolution, and productivity

The Pacific, specifically the equatorial upwelling zone, is the largest oceanic source of CO_2 to the atmosphere and controls atmospheric CO_2 levels (Dore et al., 2003). The release and uptake of CO_2 is the direct consequence of calcium carbonate deposition and the interplay between nutrient delivery, carbonate dissolution, surface water productivity, and export of biogenic carbonate from surface waters to the sediment pile. Distinguishing between the effects of carbonate dissolution and productivity has been a field of intense study in the past. An important objective of this proposal is to address the detailed workings of depth-dependent carbonate dissolution, which is intricately linked to the climate system and paleoceanography. In the standard model for carbonate dissolution, accumulation rates locally decrease linearly from a lysocline to a CCD, reflecting a linearly increasing rate of dissolution. The depth of both of these mapable surfaces varies spatially and temporally, with a result of climatic and physical processes. The equatorial Pacific is one of the classical areas where the lysocline–CCD model was first developed, but there has been little subsequent effort to test it, a necessary step, considering that the functional form of dissolution is now known to depend in a more complex way on organic carbon burial and water mass properties. The age transect will provide the necessary additional data with which to test the carbonate paradigm and to recover previously unavailable carbonate material from important Paleogene time slices in the Pacific.

Specifically, the recovery of shallowly buried carbonate sediments from near the paleoequatorial upwelling zone would contribute significantly to separating the various processes that affect carbonate deposition and preservation and would reduce some of the processes that affect climatic proxy records, such as diagenetic recrystallization (Pearson et al., 2001). Neogene productivity has been strongly oriented parallel to the Equator, so differences in carbonate thicknesses at a common latitude but differing depths will permit the effect of dissolution to be isolated following Lyle (2003), Mitchell et al. (2003), and Mitchell and Lyle (2005). In addition, the strategy adopted in this program will provide new data throughout the Cenozoic with which it will be possible to map the spatial evolution of the equatorial CCD with time. This is because the northward component of the Pacific plate movement results in the multiple recovery of the same time slice in different sites but with a slightly different paleolatitude.

Recovering more detailed records from the best possible material will also allow a better understanding of physical processes that might affect or hinder our interpretation of carbonate proxy records, such as the "carbonate ion effect"—an observed and modeled influence of the carbonate ion concentration on stable isotope fractionation in carbonate (Spero et al., 1997; Zeebe and Wolf-Gladrow, 2001).

Preliminary work with *Ewing* seismic data (Mitchell et al., 2003) has revealed a surprising lack of correlation between dissolution and depth in the westerly region of this study area. Our aim is to develop a more extensive three-dimensional model for the stratigraphy of equatorial Pacific deposits that links all existing core data using a grid of high-resolution seismic reflection profiles, including our new data from the PEAT site survey onboard the *Roger Revelle* in 2006 (AMAT03). The numerical stratigraphic model will then be used to assess carbonate dissolution, in particular the spatial pattern of sharp changes in dissolution such as the extremely abrupt change in the CCD at the Oligocene/Eocene boundary, which has been linked to a possible abrupt onset of continental weathering. The sediment archive recovered at the PEAT will allow the application of the substantial array of carbonate-based proxies with which the wider regional seismic study can be ground-truthed.

Reconstructing paleoceanographic properties and sea-surface temperatures

A large number of paleoceanographic interpretations rely on obtaining proxy data (stable isotope measurements, elemental ratios such as Mg/Ca, sea-surface temperature [SST] estimates from faunal distributions and isotope data, alkenone proxies, geochemical productivity, and burial indicators, etc.). In turn, a very large number of these measurements rely on the presence of biogenic calcium carbonate. For the Pacific, the drilling strategy we propose is conceptually the best approach to recover this important material with the best possible preservation and the least amount of diagenetic effects for a long intervals throughout the Cenozoic and will thus contribute to the objectives of the IODP Extreme Climates Initiative.

Spatial range considerations

In order to recover the best preserved and most complete carbonate record from the paleoequatorial Pacific, the age-transect siting strategy necessarily implies a restricted north–south transect, even though the northward movement of the Pacific plate does allow us to recover identical time slices multiple times at different paleolatitudes (separated by several degrees). However, we note that the regional seismic study to be developed as part of our site survey work gives us the opportunity to integrate data from older drill sites with new drilling. The site survey linked the new sites to key drill sites from ODP Legs 9, 85, 138, and 199. The combination will give us more detailed knowledge concerning the age transect so that a more complete model of the evolution of the equatorial Pacific can be developed.

Paleomagnetic objectives

One important aspect of the PEAT science program is the recovery of high-quality paleomagnetic data so that attempts to improve existing geological timescales (Gradstein et al., 2004) can be extended further back in time. Results from ODP Leg 199 demonstrate that these records can be recovered from near-equatorial carbonate (e.g., Lanci et al., 2004, 2005). During Leg 199 we succeeded in recovering almost all magnetic reversals from the Paleogene through to the present. However, biogenic carbonate sediments through most of the Eocene, nor for ages younger than the lower Miocene, were not recovered during Leg 199. Thus, although the paleomagnetic record during these times was of high quality, global stratigraphic correlation is hindered by the lower mass accumulation rate, the absence of a detailed isotope stratigraphy, and sparser biostratigraphic control. In order to facilitate the development of an integrated magneto- and biostratigraphic framework with a stable isotope stratigraphy (necessary to enable global correlation), recovery of magnetic reversals within carbonate sediment is desirable. This prerequisite contributed to the strategy described in this proposal.

In addition, further detailed paleomagnetic, magnetostratigraphic, and magnetic rock fabric data, most importantly from the Eocene, will help to resolve the suggestion that the geographic Equator, as determined from the biogenic sediment bulge, might not coincide with the paleoequator position backtracked with a fixed-hotspot reference frame (Moore et al., 2004; Tarduno, 2003; Acton and Gordon, 1994; Parés and Moore, 2005).

Ancillary benefits (MORB, basement)

Our proposed drilling aims to recover basement samples at all sites. A transect of mid-ocean-ridge basalt (MORB) samples from a fixed location in the absolute mantle reference frame would be a unique sample suite and, although not one of the primary objectives of this proposal, should be of strong potential interest to mantle geochemists. In addition, a transect of basalt samples along a flow line that have been erupted from similar environments should be of interest for low-temperature alteration studies (see, e.g., Elderfield and Schultz, 1996).

Constructing the age transect

The location of drill sites has been accomplished through seismic survey during the site survey Cruise AMAT03 onboard the *Roger Revelle* in 2006. We employed our current knowledge of seafloor age, plate rotation models, and the history of the CCD to initially locate the surveys.

The determination of possible areas for drill sites depends on three types of information: (1) a map of seafloor age, determined from magnetic lineations and previous drilling results; (2) plate rotation models that allow us to hindcast the position of the paleoequator; and (3) a detailed history of the CCD. The reconstruction of the CCD was pioneered by van Andel (1975) and can now be supplemented with additional results from recent drilling. Figure **F4** illustrates the resulting CCD history for the Pacific. Importantly, the early Cenozoic time interval coincides with a very shallow CCD, which makes the location of drill sites more critical. In addition, a shallow CCD implies that one can only obtain calcareous sediments over much shorter time intervals.

The reconstructed history of the CCD was then used as a guide as to how time intervals of particular interest (Fig. **F5**) can be drilled. This approach is shown in Figure **F4**, where we have plotted "ideal" crustal ages needed to drill each of the eight time intervals of interest while remaining above the CCD. In order to implement our age-transect approach, crustal ages shown in Figure **F4** have to be translated to specific locations on today's ocean floor. In particular, for each crustal age shown in Figure **F4**, we attempt to locate those sites that were positioned at the paleoequator during the time interval of interest.

Results are shown in Figure **F6**, together with proposed drill sites, which take into account plate rotation with respect to the paleoequator and which are shifted slightly toward the south to accommodate a potential error in the fixed-hotspot rotation model (Moore et al., 2002, 2004) and to maximize the time in the equatorial zone (±2° of the Equator). The model presented in Figure **F6** is partly corroborated by comparison with previous drilling results. For example, DSDP Site 78, near proposed survey area PEAT-5, has a basement age as predicted.

The equatorial grid of seismic reflection lines needed to extrapolate from our borehole data to the region has been amassed primarily from site surveys for scientific drilling. Digital seismic reflection data have been collected from site surveys for DSDP Leg 85 and ODP Legs 138 and 199, as well as the new survey for the PEAT science program.

Scientific objectives

The PEAT science program is designed to achieve an age transect along the Pacific paleoequatorial region that spans the early Eocene through middle Miocene periods. Time intervals that were covered by previous ODP legs will be integrated with the current transect's results in order to achieve a nearly complete time series. Drill sites target specific time slices of interest (Fig. **F5**) at locations that provide optimum preservation of calcareous sediments (Figs. **F1**, **F4**, **F6**, **F10**). The overall aim is to obtain a continuous well-preserved sediment section that will address the following primary scientific objectives (of equal priority):

- To document the nature of calcium carbonate dissolution and changes of the CCD over the Cenozoic;
- To determine the evolution of paleoproductivity of the equatorial Pacific during the Cenozoic;

- To validate and extend the astronomical calibration of the geological timescale for the Cenozoic using orbitally forced variations in sediment composition known to occur in the equatorial Pacific;
- To determine temperature (sea surface and benthic), nutrient profiles, and upper water column gradients;
- To improve, date, and intercalibrate bio- and magnetostratigraphic datums at the Equator;
- To improve constraints on the motion of the Pacific plate and the Cenozoic equatorial region, primarily using paleomagnetic methods; and
- To make use of the high level of correlation between tropical sediment sections and existing seismic stratigraphy to develop a more complete model of equatorial circulation and sedimentation in the Pacific.

Additional objectives include the following:

- To provide information about rapid biological evolution and turnover rates during times of climatic stress;
- To improve our knowledge of the reorganization of water masses as a function of depth and time, as our strategy also provides a paleodepth transect (Fig. **F4**);
- To develop a limited north–south transect across the paleoequator, caused by the northward offset of the proposed sites by Pacific plate motion and providing additional information about north–south hydrographic and biogeochemical gradients;
- To obtain a transect of MORB samples from a fixed location in the absolute mantle reference frame; and
- To use a transect of basalt samples erupted along a flow line in similar environments to study low-temperature alteration processes.

Drilling strategy

The program consists of six primary sites and four possible alternate sites (Fig. **F3**). The sites have been located to intercept the paleoequatorial position at specific age intervals so that the aggregate records can be formed into a continuous high-resolution profile of the Cenozoic equatorial Pacific. Because critical paleoceanographic information is contained only in the biogenic carbonate fraction and because ocean crust deepens with age until it eventually passes below the CCD, each site has been located on young crust that is only marginally older than the target age interval.

Each site will be cored multiple times until stratigraphic continuity of the targeted age section can be assured; as much of the remaining sediment column as is feasible with the given time constraints will also be sampled. In most cases the uppermost sediments are of secondary importance. Based on prior drilling expeditions (ODP Legs 138 and 199), we plan to core the sedimentary sections using the APC system as much as possible. This will provide the best quality cores, allowing for the determination of paleomagnetic orientations. Additionally, at depths where the APC is no longer deployable, we will use the extended core barrel (XCB) system.

There is a possibility that thin chert layers might occur in the basal sections of the Eocene sites, which could make recovery more challenging (see **"Risks and contingency"**). Logging will be used for correlation of the sediment column to the seismic reflection profiles (see **"Wireline logging"**).

Proposed drill sites

This section contains the essential information about each of the proposed sites (see also **"Site summaries"**). A complete set of site survey data can be found in the Site Summary Report sent to the Environmental Protection and Safety Panel in June 2006 (**eprints.soton.ac.uk/45921**).

Primary Site PEAT-1C (early Eocene Equator)

Proposed Site PEAT-1C (Figs. **F11, F12, F13**) was chosen for survey because it had the right age crust and because the satellite-derived bathymetry map suggested that the crust was slightly elevated above the expected depth for 53 Ma crust. We found a region of abyssal hills bound by a large volcanic rise to the east and several seamounts to the southwest. The abyssal hills are more widely spaced than at previous sites and trend northwest rather than northeast. We noted a change in trend of abyssal hills between proposed Sites PEAT-2C and PEAT-1C, perhaps associated with the Pacific plate reorganization that occurred at ~50 Ma (Rea and Dixon, 1983).

The PEAT-1C survey area has relatively gentle abyssal hills and more uniform sediment cover than some of the other PEAT sites surveyed. The bathymetry ranges between ~4800 to just below 5100 meters below sea level (mbsl). About 150–200 ms two-way traveltime (TWT) of sediment draped all of the topography, with slightly more in the valleys and in the deeper southwest corner of the site. Site PEAT-1C was chosen on a seismic line going down the western valley, in an area where basal reflections were weaker but better imaged than at other sites.

Primary Site PEAT-2C (early Eocene Equator and climatic optimum)

Proposed Site PEAT-2C (Figs. **F14, F15, F16**) is located in abyssal hill topography on 49–50 Ma crust north of the Clipperton Fracture Zone and just south of the "Mahi-Mahi Fracture Zone" that was discovered during site survey Cruise EW9709 in preparation for Leg 199. There is a general slope in topography to the north, with the southern side of the site being more elevated. The topography is dominated by north-south–trending small ridges and troughs (~5 km width). Bathymetric relief across the abyssal hills is 50–200 m, bottom depth is between 4850 and 5150 mbsl, and sediment cover is ~200 ms TWT. The closest previous drilling locations north of the Clipperton and south of the Mahi-Mahi Fracture Zones comprise ODP Sites 1220 and 1221, ~100 nmi to the west (with basement ages just before the Paleocene/Eocene boundary at 56.0 Ma). North of the Mahi-Mahi Fracture Zone and to the east of Site PEAT-2C are DSDP Sites 42 (basement age ~45 Ma; J. Backman pers. comm., 2006) and 162 (basement age estimated at ~49 Ma), and to the west lies ODP Site 1222 (on 56 Ma crust).

The PEAT-2 survey area was located to be on 49 to 50 Ma basement on abyssal hill topography. The 48-channel stacked and migrated data reveal regions at the flanks of tilted ridges where older horizons are exposed nearer the surface (images in cross-strike Lines 1 and 6). Coring suggests that the surface sediments were formed at ~20 Ma. The biostratigrapic analysis of surface sediments indicates an age no older than 19–23 Ma, but because of barren and reworked samples in the sediment core, it is not possible to obtain any further information about the possible sedimentation rates in the basal section, other than that the minimum sedimentation rate across the entire section is of the order of 6 m/m.y.

Primary Site PEAT-3C (middle Eocene Equator)

Proposed Site PEAT-3C (Figs. **F17, F18, F19**) is located in abyssal hill topography north of the Clipperton Fracture Zone on 46 Ma crust. There is a general slope in topography to the north, with the southern side of the site being more elevated. Bathymetric relief across the abyssal hills is 75–150 m, bottom depths range between 4800 and 5100 mbsl, and sediment cover is ~200 ms TWT.

The PEAT-3 survey area was located to be above 46 Ma basement on abyssal hill topography. The 48-channel stacked and migrated data reveal a region where the sediment column that had been deposited is eroding away. Outcropping older horizons are common along Line 1 and at the northern ends of the crosslines. Coring suggests that the surface sediments were formed ~20 Ma and give an average sedimentation rate of 7 m/m.y. for the sediment section.

Primary Site PEAT-4C (late Eocene and Eocene/Oligocene boundary)

Proposed Site PEAT-4C (Figs. **F20, F21, F22**) is located north of the Clipperton Fracture Zone on abyssal hill topography draped with ~270 m sediment. The fabric of the abyssal hills within the sites is oriented either due north or slightly east of due north.

Water depth in the vicinity of Site PEAT-4C ranges between 5 and 5.1 km for the depressions between the abyssal hills. The abyssal hill tops range between 4.7 and 4.85 km water depth and generally show a thicker and more consistent sediment cover than the basins. In fact, a significant amount of the bathymetric difference between hills and depressions is controlled by the amount of sediment cover. The comparison of sediment thickness and clarity of seismic sections led us to choose a location on the middle elevation of one of the abyssal plateaus.

Based upon correlation to the Neogene central equatorial Pacific seismic stratigraphy of Mayer et al. (1985) and the Paleogene equatorial Pacific stratigraphy of Lyle et al. (2002), there is ~200 m (260 ms TWT) of Eocene/Oligocene sediment, for an average Eocene/Oligocene sedimentation rate of about 15 m/m.y. assuming a crustal age of 38 Ma.

Alternate Site PEAT-5C (Oligocene Equator)

Proposed Site PEAT-5C (Figs. **F23, F24, F25, F26**) is located just north of the Clipperton Fracture Zone on abyssal hill topography draped with thick sediment. The location of Site PEAT-5C is ~17 nmi north of the trace of the fracture zone. In order to maintain a position south of the 28 Ma paleoequator, we were constrained to Site PEAT-5C close to the fracture zone. Nevertheless, the survey has shown that Site PEAT-5C is located on abyssal hill topography, with a fabric of the abyssal hills that is oriented slightly west of due north.

Water depth in the vicinity of Site PEAT-5C is relatively shallow for the age of the crust, ranging between 4200 and 4400 m. Surprisingly, there is little or no depth offset between the crust to the south and to the north of the Clipperton Fracture Zone, despite a depth in the middle of the fracture zone trace near 5 km. In fact, the seafloor south of the Clipperton Fracture Zone is perhaps 100 m deeper than that to the north.

Site PEAT-5C is located on abyssal hill topography just north of the Clipperton Fracture Zone. A few oblique ridges and depressed topography occur in the south, showing some interaction between the fracture zone and the Site PEAT-5C region. The site is thickly covered with sediments (300–400 ms TWT). The site has a very thin layer of recent to middle Miocene sediments and most of the sediments are between 13 and 28 m.y. Based upon correlation to the Neogene central equatorial Pacific seismic stratigraphy of Mayer et al. (1985) and the Paleogene equatorial Pacific stratigraphy of Lyle et al. (2002), there is ~120 m of Oligocene sediment, for an average Oligocene sedimentation rate of 13 m/m.y., assuming a crustal age of 32 Ma.

Primary Site PEAT-6C (Oligocene–Miocene transition)

Proposed Site PEAT-6C (Figs. F27, F28, F29) is situated in the central tropical Pacific on a broad deep within north-northwest–trending abyssal hill topography, ~15 and ~30 km west and ~20 km north of three seamounts. Thick sediment deposits cover the abyssal hills, with a thinning sediment cover on the hills. Based on stage-pole reconstructions of Pacific plate motion and observations of basement age from previous drilling sites, along with magnetic anomaly maps (Cande et al., 1989), we determined that Site PEAT-6C is located on 26–27 Ma crust. The best age control is provided by a new aeromagnetic line south of the proposed site (Horner-Johnson and Gordon, 2003) and from the basal age of Site 79, located 4.5° to the east and 3° to the south of Site PEAT-6C, apparently on the same fracture zone segment. The base of Site 79 reaches the Miocene/Oligocene boundary, or 23 Ma on the most recent astronomically calibrated timescales.

Water depth in the vicinity of Site PEAT-6C is between 4300 and 4400 mbsl, apart from the topography around three seamounts that are 15–30 km away from the proposed drill site. Sediment cover is relatively thick but varies around ridges and deeps.

Site PEAT-6C is located along the flank of a wide north-northwest–trending valley, on high ground above the abyss and moat of the seamounts (Fig. F27). Sediment cover is thick in the entire region, ranging from 300 to 500 ms TWT. The seafloor is relatively flat because the sediment has filled in the basement topography (~200 ms TWT).

Primary Site PEAT-7C (early–middle Miocene Equator)

Proposed Site PEAT-7C (Figs. **F30, F31, F32**) is situated in the central tropical Pacific on a broad plateau within north-northeast–trending abyssal hill topography. Thick sediment deposits cover the abyssal hills, but these deposits are being eroded at the edge of the plateau. Based on stage-pole reconstructions of Pacific plate motion and observations of basement age from previous drilling sites, an aeromagnetic line south of the proposed site (Horner-Johnson and Gordon, 2003), and magnetic anomaly maps (Cande et al., 1989), we determined that Site PEAT-7C is located on 24 Ma crust. The best control on age is information from Site 79, located 1.5° to the east of Site PEAT-7C. The base of Site 79 reaches the Miocene/Oligocene boundary, or 23 Ma.

Water depth in the vicinity of Site PEAT-7C is below 4500 mbsl, marking regionally deep basement. Sediment cover is relatively thick, but varies radically around ridges and deeps.

Site PEAT-7C is located on a plateau between high topography to the south of the site, a gentle but pockmarked ridge to the north, and a deep to the east (Fig. **F30**). Sediment cover is thick on the plateau but is highly variable along the edges. Sedimentation was variable sedimentation along the eastern edge, and thick sediment covers the plateau (300–600 ms TWT). Nevertheless, the seafloor is relatively flat because the sediment has filled in the basement topography, of ~200 ms TWT. To the north, along PEAT-7C Line 6, the seafloor is dissected by a series of karstlike holes that cut through the seismic layering (Fig. **F30**). Based upon correlation to the central equatorial Pacific seismic stratigraphy of Mayer et al. (1985), middle Miocene sediment has been exposed.

Alternate Site PEAT-8C (eastern equatorial Pacific)

Proposed Site PEAT-8C (Figs. **F33, F34, F35**) is situated ~1° north of the Galapagos Fracture Zone, on abyssal hill topography. Based on stage pole reconstructions of Pacific plate motion and observations of basement age from previous drilling sites, as well as magnetic maps (Cande et al., 1989), we determined Site PEAT-8C to be located on ~18 Ma basement. During the AMAT-03 site survey we collected magnetic anomaly data that can be correlated to additional collated observations (Barckhausen et al., 2005; Engels et al., submitted) and confirm the anomaly location. Water depth in the general vicinity is ~4.2 km. The closest previous drilling location north of the Galapagos Fracture Zone for which basement age estimates are available comprises DSDP Site 79 (basement age approximately coincident with the Oligocene/Miocene boundary at 23.0 Ma; J. Backman, pers. comm., 2006). No age information was obtainable from DSDP Site 571, and DSDP Site 572 is projected south of the fracture zone.

Site PEAT-8C is in a region of abyssal hills, with highs to 3900 m and basins to 4400 m, close to the center along a 350° trending and deepening valley. A seamount (water depth = 3.7 km) with surrounding moat was found ~10 km north-northwest of the site, facing downslope of the valley. The proposed site in ~4301 m water depth is surrounded by a half-circle of ~4100 m deep elevated hills toward the southeast. The fabric of the hills matches the magnetic anomaly fabric, and trends north-northeast–south-southwest. Sediment thickness at the site ranges from ~400 ms TWT at the top of the abyssal hills to a maximum of a little more than 550 ms TWT. At Site PEAT-8C (shotpoint 36015 on seismic Line PEAT-8C Line 1) it is ~557 ms TWT. Surface sediments consist of a carbonate-rich clay, ranging to nannofossil ooze with cyclical (meter scale) carbonate content at depth. Smaller numbers of siliceous microfossils were found in the sediment as well.

Operations plan

Drilling will be accomplished during two expeditions; for logistical reasons, one is directed primarily to sample the Neogene sites (eastern transect, Exp 317; Table **T1**) and the other the Paleogene sites (western transect, Exp 319; Table **T2**).

For Expedition 317, the primary objectives are to drill two holes at Site PEAT-2C and then core proposed Sites PEAT-6C and 7C. Once these objectives are accomplished, the plan is to core alternate sites if time permits. A decision on which additional site to core at the end of the expedition will have to be made on the ship, when actual time constraints will be known. In principle, all primary sites on one expedition are considered to be secondary priority objectives on the other expedition.

For Expedition 319, the primary sites to be cored are proposed Sites PEAT-1C, 3C, and 4C. If these primary objectives are completed, the preferred option is to core additional holes at Site PEAT-5C.

Because the main objective of both expeditions is to reconstruct a complete sedimentary succession, we plan on drilling several holes per site—tentatively three holes per site or more—until stratigraphic coverage is deemed to be sufficient. Detailed operations and time estimates for PEAT Expeditions 317 and 319 are available in Tables **T1** and **T2,** respectively.

The overall plan for each site follows.

Hole A

Use APC coring until APC refusal and deploy the advanced piston corer temperature (APCT)-3 tool three times during APC coring. Once APC refusal is reached, switch to the XCB system and core until basement is tagged. During XCB drilling we plan on deploying the Davis-Villinger Temperature Probe (DVTP) twice. If hole conditions are adequate, wireline logging operations will take place in Hole A, after which we will pull out of the hole and abandon it. In principle, Hole A will be cored continuously until target depth is reached.

Holes B and C and additional holes

The primary goal of these holes is to fill in sediment sections not recovered in Hole A. Depending on time constraints, operations in these additional holes are envisioned as in Hole A but without downhole temperature measurements. If wireline logging operations were not possible in Hole A, then wireline logging operations will take place in one of the additional holes, depending on operational time constraints (see **"Wireline logging"** for additional information). If time constraints dictate a shorter plan, these holes might be drilled without coring in their upper part, might be only cored through the targeted age interval, and might not reach basement.

The decision to pursue drilling operations in a hole or at a site will have to be taken at time of operations in consultation, whenever possible, with the other Co-Chief Scientists not present on the ship. It is understood that some problems may require rapid decision making and thus must be solved on the ship. The actual section cored and repeated will depend on the typical operational factors: completeness of the sedimentary splice, priorities, and length of time remaining in the expedition. Critical intervals (e.g., Eocene/Oligocene boundary) may be specifically targeted for additional coring.

We plan to core a complete sediment column at each site even if adverse conditions are encountered (e.g., pervasive diagenesis). These intervals may not be recored in later holes. In the unlikely event of pervasive chert deposits, all reasonable efforts will be made to drill forward through the interval, at least in the first hole. However, the primary drilling objective, to obtain well-preserved carbonate sediments, must be kept in mind for time allocation.

Downhole measurements strategy

Temperature measurements

The downhole measurement plan consists of up to five temperature measurements per site in one hole, tentatively Hole A. We plan on deploying the APCT-3 three times in the hole with two DVTP temperature measurements further downhole 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.

Wireline logging

Wireline logging objectives are

- To collect high-resolution downhole physical property data and integrate them with core measurements and
- To integrate seismic reflection with drilling by using sonic velocity data in conjunction with the density results and/or check shot surveys to obtain a velocity profile, a time/depth model, and synthetic seismograms.

Synthetic seismograms results will be compared to the regional seismic sections to interpret the origin and geological significance of the major seismic horizons. It is thus important to choose logging tools that are appropriate for achieving both high-resolution core-log mapping as well as measuring the range of sound velocities anticipated for these expeditions—from 1500 to 1650 m/s for the majority of the unconsolidated sediment but increasing to >1700 m/s in the deeper, more compacted sediments.

The operations plan for Expeditions 317 and 319 lists downhole logging at all proposed sites in Hole A, should it reach target depth. The purpose in logging the first hole is that near–real time core-log integration will provide important information about the sediment column for subsequent drilling operations at that site (Holes B and C) and to help ensure complete recovery of the stratigraphic section. The plan includes using a maximum of two logging tool strings that would require a range of 16 to 20 h per site from the shallowest to deepest sites, respectively, including time for rigging up wireline operations.

The logging strings to be used are

- A modified triple combination (triple combo) tool string (Fig. **F36B**), termed the "paleo-combo," that includes the high-resolution Multisensor Gamma Tool (MGT), the High-Resolution Litho-Density Tool (HLDT), and, potentially, the Magnetic Susceptibility Sonde (MSS) and
- Either the Formation MicroScanner (FMS)-sonic tool string that includes the FMS and the Dipole Sonic Imager (DSI-2) or the Versatile Seismic Imager (VSI) string that includes the VSI if good velocities cannot be achieved by the DSI-2 (Fig. **F36C**). The VSI is a vertical seismic profiling tool that would require use of a separate seismic source deployed from the ship.

Further details on logging tools and their applications can be found at **iodp.ldeo.columbia.edu/TOOLS_LABS/tool.html**.

One advantage of a modified triple combo tool string is that it combines the Lamont-Doherty Earth Observatory Borehole Research Group (LDEO-BRG)'s high-resolution tools such as the MGT and MSS, providing up to 10 cm resolution natural gamma ray (NGR) and magnetic susceptibility (MS) data that are more comparable to planned shipboard measurements. Such resolution will be critical for proper core-log integration. In addition, the HLDT provides the density and caliper data necessary for evaluating important physical properties, hole conditions, and construction of synthetic seismograms.

A second advantage is that this tool string is considerably shorter than the triple combo (Fig. **F36A**) and will be able to provide more hole coverage, especially at sites with thin sediment columns (proposed Sites PEAT-1C through 3C).

At deep-penetrating sites, where tool string length is not as critical, there is an option to include additional tools, such as the Phasor Dual Induction–Spherically Focused Resistivity Tool (DIT). This could provide an additional robust physical property data set. Our preferred approach to achieve good velocities is to use the FMS-sonic tool string, providing high-resolution (centimeter scale) resistivity data from the FMS tool.

Assessment of logging at each site will require consideration of multiple issues. The objectives of these cruises are intimately linked to obtaining complete recovery of the sedimentary section, requiring at least three and possibly four holes at each site. Thus, there is an obvious impact when opting between these two operational activities for these cruises; when logging operations are in progress, core is not being acquired. In addition, because the base of the drill pipe must be securely in the hole during logging operations (typically between 60 and 100 mbsf), the upper part of the sedimentary section is not logged. For this reason, the priority of logging operations can be anticipated to be lower in the shallower (<200 m penetration depth) Sites PEAT-1C, 2C, and 3C. The decision to log these holes will be based on logging data quality and the impact of weather conditions on coring and logging operations, previous logging in the area, depth of coring penetration, and operational time constraints.

Difficulties were encountered during ODP Leg 199 when deploying the DSI-2 to capture quality data in low-velocity unconsolidated sediments. The VSI tool will be available for check shot surveys should the DSI-2 not be capable of recording the desired quality velocity data. The VSI will provide lower vertical resolution, and additional operational and planning time may be necessary to respond to air gun deployment and marine mammal policy issues, respectively.

Risks and contingency

One possible operational problem that could be encountered is the presence of chert layers. Although chert is not generally a problem for Neogene sites in the Pacific, drilling and recovery difficulties related to chert layers are a necessary consideration when drilling Paleogene sediments. Cherts have been found frequently in middle and lower Eocene equatorial Pacific sediments. Although early DSDP coring was generally defeated by chert, technological improvements during ODP have somewhat improved the drilling of chert layers. However, this remains a challenge.

Previous legs have shown the general occurrence of cherts in certain parts of the Eocene Pacific. Prior to ODP Legs 198 and 199, the general belief was that sediment that has never been deeply buried, like that found at the sites proposed here, are likely to contain only oozes. However, Leg 199 drilling results indicate that cherts are present even with shallow burial, particularly at the boundary between the lower and middle Eocene. These sediments were still unlithified, as radiolarian ooze was recovered right up to the upper boundary of chert zones and occasionally below the chertified interval.

Understanding the depth and thickness of chert zones will help to minimize sediment loss. Although it is unlikely that the sites in this proposal will avoid chert altogether, the specific planning of this program aims for calcium carbonate (with higher sedimentation rates than chert-bearing radiolarian ooze), as well as a lower abundance of silica-rich formations. One possibility to address recovery problems around the chert layers would be to shoot the APC barrel after offsetting the drill bit by 4–5 m above the bottom of the hole, thus aiming for a half-stroke core (4–5 m). A potential problem with this technique is penetrating the hole obliquely, thus recovering the same sedimentary sequence multiple times, as well as risking bent core barrels. For this reason, expensive nonmagnetic core barrels will not be used for half-stroked cores. Decisions on how to mitigate poor core recovery due to cherts will have to be made during the expedition by considering all of the actual operational factors and risks involved.

During Leg 199, euhedral dolomite often occurred within the chalks just above basement, which we think is linked to Mg-rich fluids from the basement. Because dolomitization resets many of the important geochemical systems used by paleoceanographers, we have chosen sites with basement ages slightly older than the target age. Thus, the target carbonate intervals are not in direct contact with basement rocks. We thus trade off between maximum recovery of target carbonates and avoiding a diagenesis problem.

Sampling and data sharing strategy

To maximize the science return, the two PEAT expeditions will be implemented as a single science program with samples and data shared across both expeditions. This presents unique opportunities and challenges to ensure that overall project, individual expedition, and individual science participant objectives are fully realized.

Research plan proposals (sample and data requests)

Every member of the science party is obligated to carry out scientific research for the program and publish it. For this purpose each scientist must submit a sample and/or data request prior to the expedition detailing their science plan. A sample request is also required for individuals not requesting samples but working on cruise data only. This is both to indicate their interest in a particular aspect of postcruise research and to provide the Sample Allocation Committee (SAC) with a documented postcruise science plan. The sampling plan should be limited to samples needed for the research to fulfill the expedition science obligation, not for research that may occur significantly in the future.

For the PEAT science program, there will be a single SAC covering both expeditions. The SAC is composed of the four Co-Chief Scientists, the two Staff Scientists, the IODP Curator on shore, or the curatorial representative in place of the curator on board ship. Shipboard and shore-based researchers should refer to the IODP Sample, Data, and Obligations policy (**www.iodp.org/program-policies**), which outlines how IODP samples and data are distributed and defines the obligations that sample and data recipients incur.

We will develop an integrated sampling plan before the first expedition commences. For both Expeditions 317 and 319, each participating scientist must submit a coordinated research plan covering all samples and data requests by 1 November 2007. This date has been set well in advance of the first expedition, scheduled to start in May 2008. The early deadline is required to be able to ensure coordination between both expeditions to achieve the overall project science objectives. Scientists need to submit their research plans using the Sample/Data Request form (**smcs.iodp.org**). The sampling plan can be modified, with SAC approval, during and after the expedition to accommodate unexpected discoveries or poor recovery of intervals important to the scientist.

Individual expedition scientific participants are expected to help achieve expedition-specific as well as cross-expedition scientific objectives. Substantial collaboration and cooperation are highly encouraged. Access to data and core samples for specific research purposes, during both expeditions (317 and 319) and the subsequent 1 y moratorium, must be approved by the SAC. Sampling is restricted to the science party (shipboard and shore based) until 1 y after the completion of the sampling party of the second PEAT expedition (moratorium period).

All sampling to acquire ephemeral data types or to achieve essential sample preservation will be conducted during the expedition. Following these expeditions, cores will be delivered to the IODP Gulf Coast Core Repository at Texas A&M University, College Station.

Cruise-specific sampling, postcruise sampling parties, and critical intervals

Based on individual research plans (sample and data requests submitted), the SAC will work with the scientific party to formulate an 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 two expeditions. Modifications to the sampling plan during the expeditions and moratorium period 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, the expedition objectives, and overall objectives of the PEAT science program.

Shipboard sampling during both expeditions will generally be restricted to low-resolution sampling (e.g., biostratigraphic sampling, and toothpick-sized samples for bulk carbonate isotopes), mainly so that we can rapidly produce age-model data critical for the overall objectives of the expeditions and for planning the higher resolution sampling. Small intervals (e.g., one core) of high-resolution sampling may be sampled at sea with SAC approval to provide initial material for study prior to the postcruise sampling. Thus, the bulk of the sampling for both expeditions is planned to occur during postcruise sampling parties at the Gulf Coast Repository, not at sea. For postcruise samples to be taken at the sampling parties, science party members must submit revisions to their precruise sample request at least 2 months before the sampling party for each expedition; SAC approval of these modifications will be required.

There may be considerable demand for samples from a limited amount of cored material for some critical intervals. These intervals could include but are not limited to the early Eocene interval of maximum Cenozoic warmth, the Eocene/Oligocene and Oligocene/Miocene boundaries, the middle Miocene climate transition, and the middle–late Miocene “carbonate crash.” A special sampling plan will be developed for critical intervals to maximize scientific return and scientific participation and to preserve some material for future studies. The SAC can decide at any stage during the expeditions or during the 1 y moratorium period which recovered intervals should be considered as critical.

Critical 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. The sampling of critical intervals will most likely not be carried out during expeditions, except for limited toothpick sampling for preliminary biostratigraphic and bulk isotope analyses.

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Table T1. Summary of operations for Pacific equatorial Expedition 317.

Site	Location (latitude, longitude)	Seafloor depth (mbrf)	Operations description	Duration (days) Task	Transit	Drilling/ Coring	Logging
Honolulu, Hawaii			Begin expedition	5.00			
			Transit ~1128 nmi to Site PEAT-2C at 10.5 kt		4.5		
PEAT-2C EPSP approved to 250 mbsf	11°54.711′N, 141°02.744′W	4952	Hole A: APC ~70 m/XCB to ~163 mbsf (~1 m into basement) - 3 APCT-3 and 2 DVTP temperature measurements - Wireline logging with triple combo and FMS-sonic			2.2	1.3
			Hole B: APC ~70 m/XCB to ~162 mbsf			1.8	
			Subtotal days on site:	3.5			
			Transit ~961 nmi to Site PEAT-6C at 10.5 kt		3.8		
PEAT-6C EPSP approved to 400 mbsf	05°18.736′N, 126°16.997′W	4362	Hole A: APC ~70 m/XCB to ~363 mbsf (~1 m into basement) - 3 APCT-3 and 2 DVTP temperature measurements - Wireline logging with triple combo and FMS-sonic			3.5	1.0
			Hole B: APC ~70 m/XCB to ~362 mbsf			2.9	
			Hole C: APC ~70 m/XCB to ~362 mbsf			3.3	
			Subtotal days on site:	10.7			
			Transit ~204 nmi to Site PEAT-7C at 10.5 kt		0.8		
PEAT-7C EPSP approved to 480 mbsf	03°50.009′N, 123°12.352′W	4502	Hole A: APC ~70 m/XCB to ~453 mbsf (~1 m into basement) - 3 APCT-3 and 2 DVTP temperature measurements - Wireline logging with triple combo and FMS-sonic			4.2	1.1
			Hole B: APC ~70 m/XCB to ~452 mbsf			3.6	
			Hole C: APC ~70 m/XCB to ~452 mbsf			3.9	
			Subtotal days on site:	12.8			
			Transit ~1726 nmi to San Diego at 10.5 kt		6.9		
San Diego, California			Discharge science party	2.0			
			Juan de Fuca remedial cementing				
			Transit ~1134 nmi to Hole U1301B at 10.5 kt		4.5		
Hole U1301B	47.7538°N, 127.7638°W	2667	Install DP stabilizing collar for cementing operations; reenter hole (1.1 days) Pump additional cement into reentry hole/POOH (0.4 days)			1.5	
			Subtotal days on site:	1.5			
			DP offset ~36 nmi to Hole U1301A at 0.5 kt		0.0		
Hole U1301A	47.7535°N, 127.7639°W	2671	Reenter Hole U1301A after offsetting from Hole U1301B (0.6 days) Pump additional cement into reentry hole/POOH (0.5 days) Recover drill string/continue to insure all holes plugged with cement (1.4 days)			2.5	
			Subtotal days on site:	2.5			
			Transit ~187 nmi to Astoria, Oregon at 10.5 kt		0.7		
Astoria, Oregon			End expedition		21.2	29.4	3.4
			Subtotal time on site:	32.8			
			Total operating days:	54.0			
			Total expedition (including 7 Port Call days):	61.0			

Notes: Seafloor depth = prospectus water depth plus 11.0 m adjustment from water line to rig floor (i.e., drillers depth). All costs associated with the Juan de Fuca “remedial cementing” program will be calculated in a separate IPE and are not included in this Pacific equatorial 2 IPE. The Juan de Fuca program is included in the operating plan only because it impacts operations. APC = advanced piston corer, XCB = extended core barrel, APCT-3 = advanced piston corer temperature-3 tool, DVTP = Davis-Villinger Temperature Probe, triple combo = triple combination, FMS-sonic = Formation MicroScanner-sonic tool string, DP = Dynamic Positioning, POOH = pull out of hole.

Table T2. Summary of operations for Pacific equatorial Expedition 319.

Site	Location (latitude, longitude)	Seafloor depth (mbrf)	Operations description	Duration (days) Task	Transit	Drilling/ Coring	Logging
Tomakomai, Japan			Begin expedition	5.00			
			Transit ~3300 nmi to Honolulu at 10.5 kt		1.3		
Honolulu, Hawaii				1.00			
			Transit ~1068 nmi to Site PEAT-1C at 10.5 kt		4.2		
PEAT-1C EPSP approved to 250 mbsf	12°04.089′N, 142°09.698′W	5143	Hole A: APC ~70 m/XCB to ~188 mbsf (~1 m into basement) - 1st site includes PU drill collars/BHA and "strapping" tubulars - 3 APCT-3 and 2 DVTP temperature measurements - Wireline logging with triple combo and FMS-sonic			3.0	0.9
			Hole B: APC ~70 m/XCB to ~187 mbsf			1.7	
			Hole C: APC ~70 m/XCB to ~187 mbsf			2.2	
			Subtotal days on site:	7.9			
			Transit ~239 nmi to Site PEAT-3C at 10.5 kt		1.0		
PEAT-3C EPSP approved to 250 mbsf	10°30.997′N, 138°25.175′W	4885	Hole A: APC ~70 m/XCB to ~175 mbsf (~1 m into basement) - 3 APCT-3 and 2 DVTP temperature measurements - Wireline logging with triple combo and FMS-sonic			2.2	1.0
			Hole B: APC ~70 m/XCB to ~174 mbsf			1.6	
			Hole C: APC ~70 m/XCB to ~174 mbsf			2.1	
			Subtotal days on site:	6.8			
			Transit ~411 nmi to Site PEAT-4C at 10.5 kt		1.6		
PEAT-4C EPSP approved to 300 mbsf	07°59.999′N, 131°58.396′W	4820	Hole A: APC ~70 m/XCB to ~269 mbsf (~1 m into basement) - 3 APCT-3 and 2 DVTP temperature measurements - Wireline logging with triple combo and FMS-sonic			3.1	1.0
			Hole B: APC ~70 m/XCB to ~268 mbsf			2.4	
			Hole C: APC ~70 m/XCB to ~268 mbsf			2.8	
			Subtotal days on site:	9.2			
			Transit ~222 nmi to Site PEAT-5C at 10.5 kt		0.9		
PEAT-5C EPSP approved to 300 mbsf	07°42.075′N, 128°15.254′W	4322	Hole A: APC ~70 m/XCB to ~130 mbsf - 3 APCT-3 temperature measurements - LO drill collars/BHA and securing for transit to port			2.5	
			Subtotal days on site:	2.5			
			Transit ~1972 nmi to Papeete at 10.5 kt		7.8		
Papeete, Tahiti			End expedition		28.6	23.5	2.9
			Subtotal time on site:	26.4			
			Total operating days:	55.0			
			Total expedition (including 6 Port Call days):	61.0			

Notes: Seafloor depth = prospectus water depth plus 11.0 m adjustment from water line to rig floor (i.e., drillers depth). APC = advanced piston corer, XCB = extended core barrel, PU = picking up, BHA = bottom-hole assembly, APCT-3 = advanced piston corer temperature-3 tool, DVTP = Davis-Villinger Temperature Probe, triple combo = triple combination, FMS-sonic = Formation MicroScanner-sonic tool string, LO = laying out.

Figure F1. A. Model cross section of equatorial sediment mound taking into account the northward drift of the Pacific plate. MAR = mass accumulation rate. **B.** Mapped thickness of the equatorial Pacific sediment mound. Notice the position of the Equator, Hawaii, and Central America. Previously drilled sites are also indicated. Both parts modified from Mitchell (1998) and Mitchell et al. (2003).

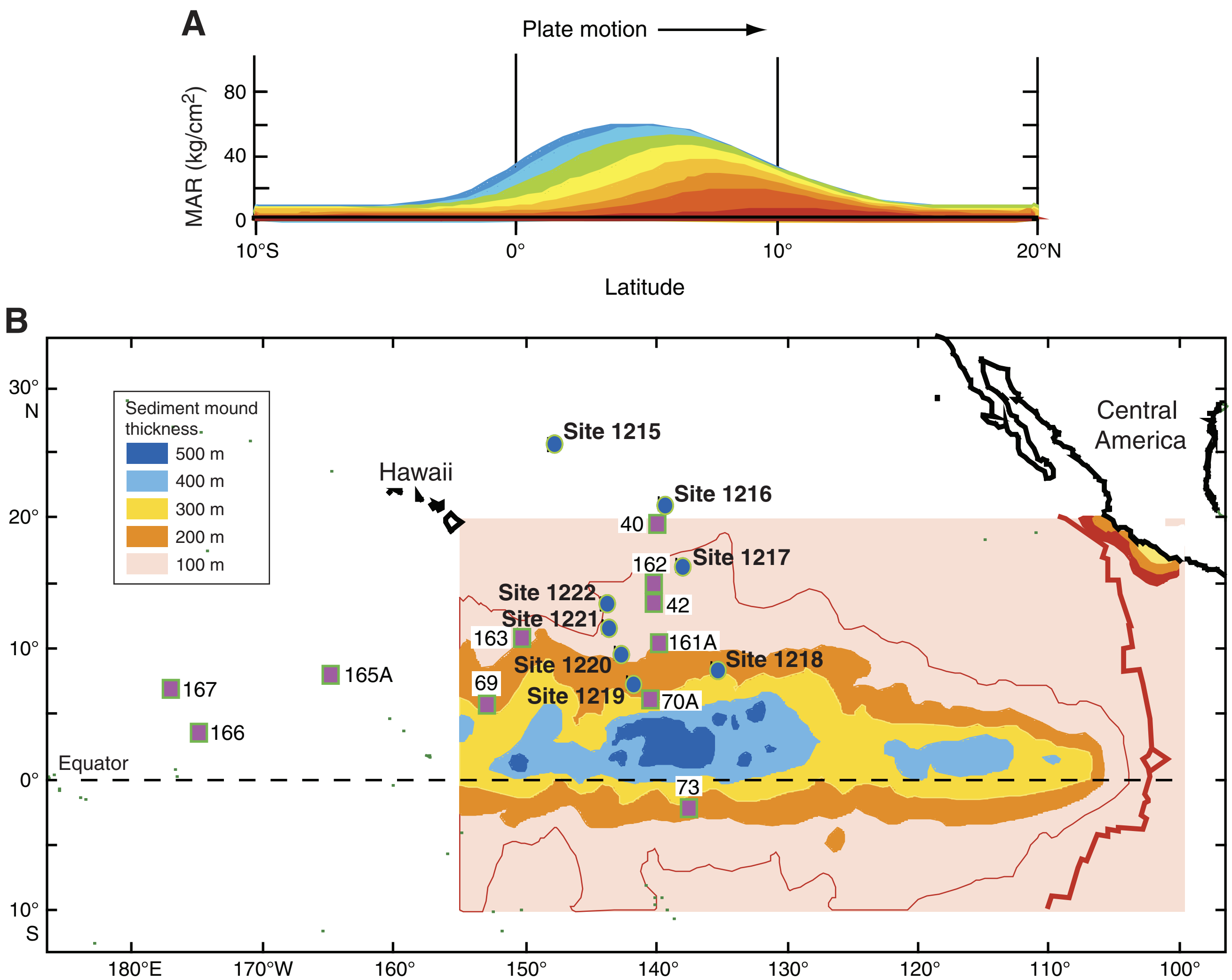


Figure F2. The coherence of sediment properties between widely separated drill sites in the equatorial Pacific is very high, allowing correlation of sediment properties over hundreds of kilometers. The example in this figure is from ODP Sites 1218 and 1219 (ODP Leg 199; modified from Shipboard Scientific Party, 2002), two sites that are >740 km apart. VGP = virtual geomagnetic pole. GRA density = density estimated shipboard using gamma ray attenuation, Reflectance L* = lightness value of sediment as defined in the L*a*b* color model. T = top, B = bottom.

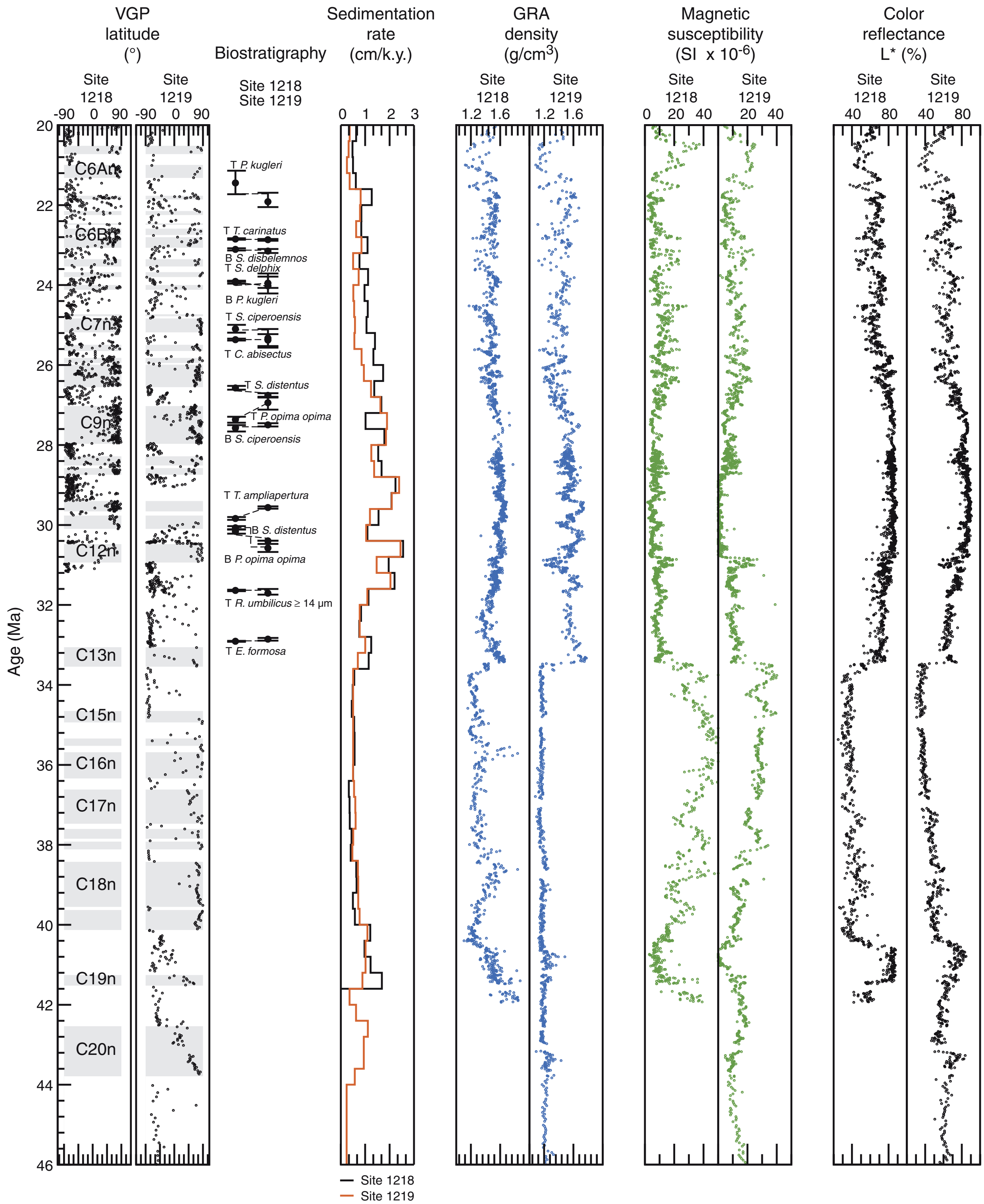


Figure F3. Proposed drill sites and survey coverage. Sites in yellow will be drilled during Expedition 317, sites in orange will be drilled during Expedition 319, and sites in light gray are alternate sites. F.Z. = fracture zone. Hawaii, Tahiti, and Baja California, are indicated for orientation.

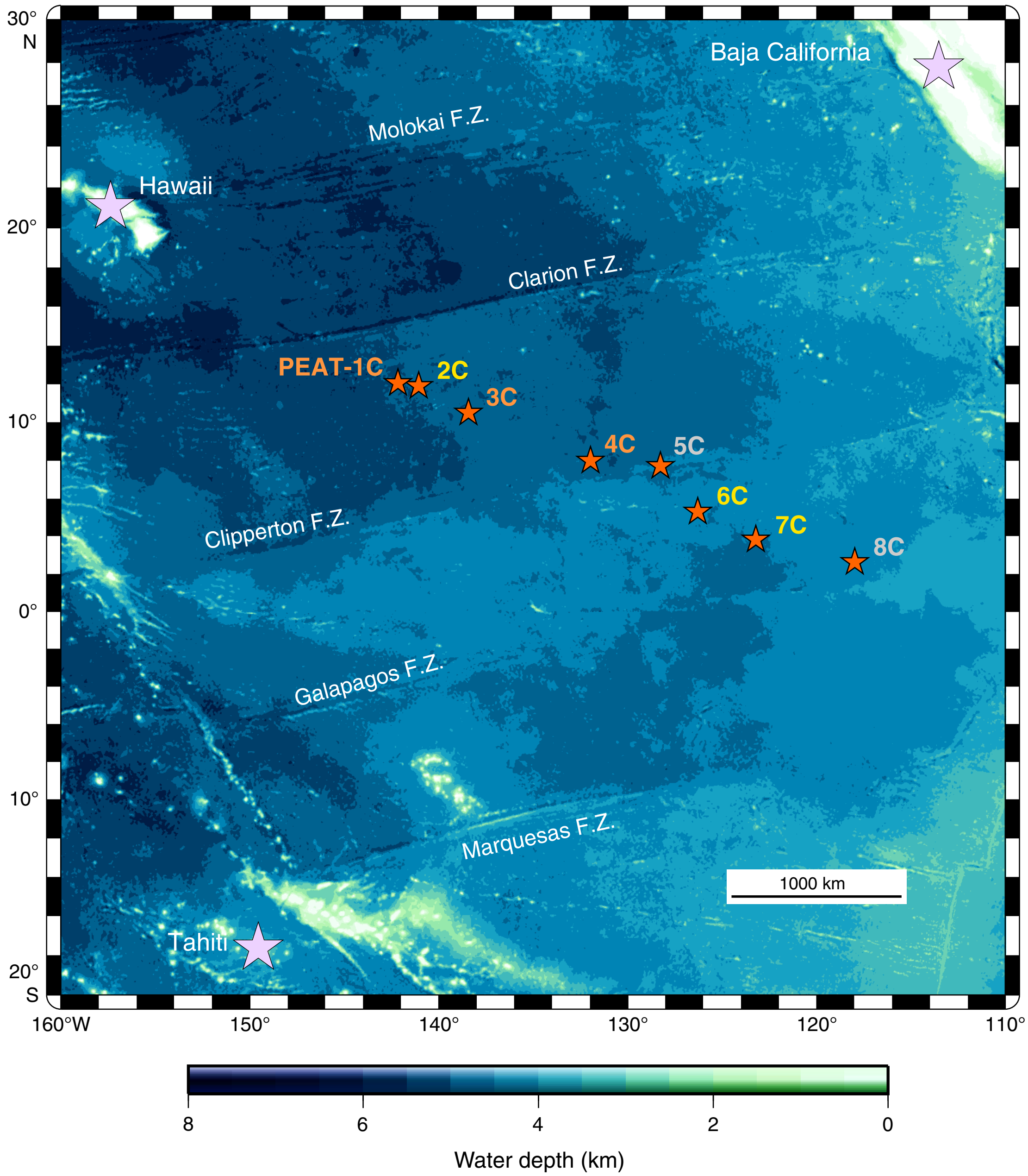


Figure F4. Targeting Pacific equatorial age transect (PEAT) drill sites based on the calcium compensation depth (CCD) history (van Andel, 1975), with new data from ODP Leg 199. Colored boxes represent the critical time interval targeted for each site. Subsidence curves use a subsidence parameter calculated from the estimated basement age of PEAT sites and their present-day depth (k = 0.35). Additional subsidence due to sediment loading was not modeled. Colored subsidence lines show the time interval when we expect carbonate to be deposited (i.e., when the site is above the CCD).

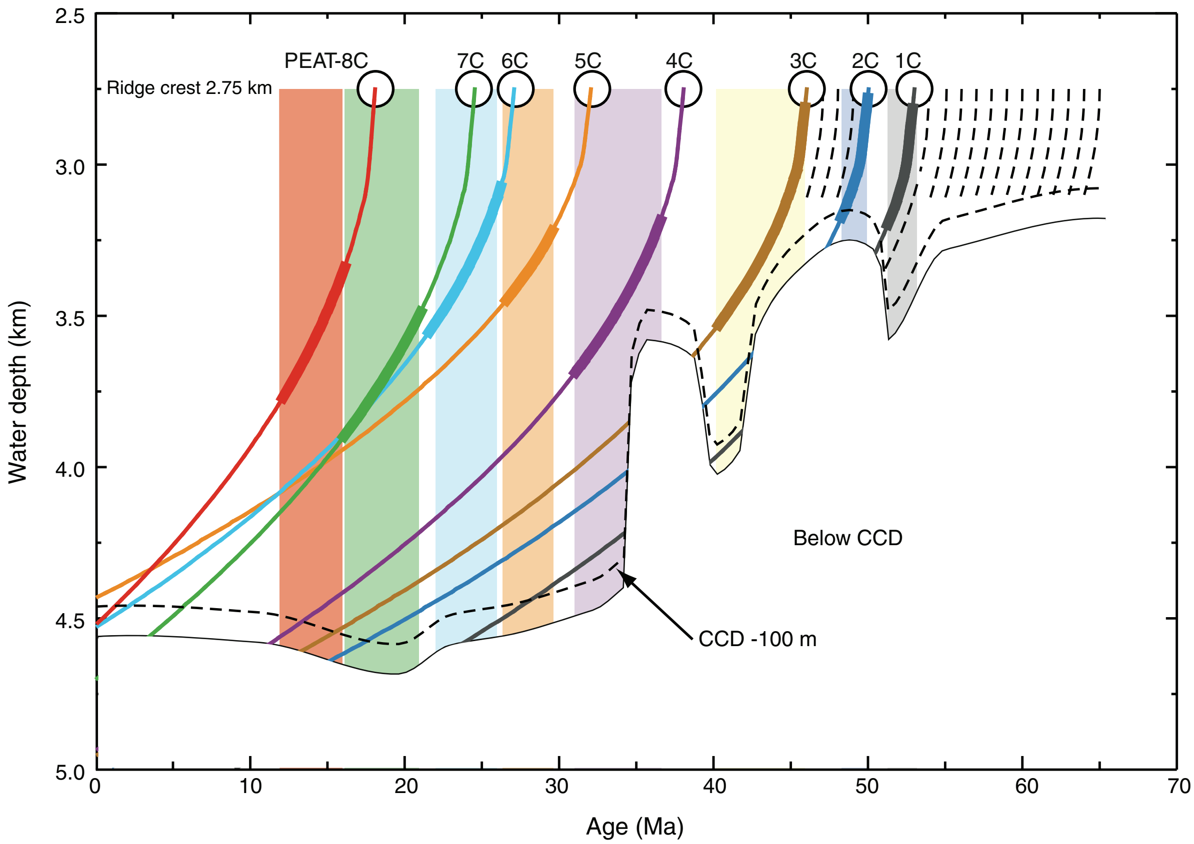


Figure F5. Evolution of oxygen stable isotope ($\delta^{18}O$) through the Cenozoic and related major phases of climate change (modified from Zachos et al., 2001b). Time slices of interest for the Pacific equatorial age transect (PEAT) cruises are marked as yellow boxes labeled with the proposed site name. Green and blue boxes refer to ODP legs and sites previously drilled in the equatorial Pacific region; these additional sites will be used with the proposed PEAT sites to obtain a nearly continuous Cenozoic record of the equatorial Pacific region. Oi-1 = Oligocene isotopic event 1, Mi-1 = Miocene isotopic event 1 (both as described in Miller et al., 1991). VPDB = Vienna Peedee Belemnite.

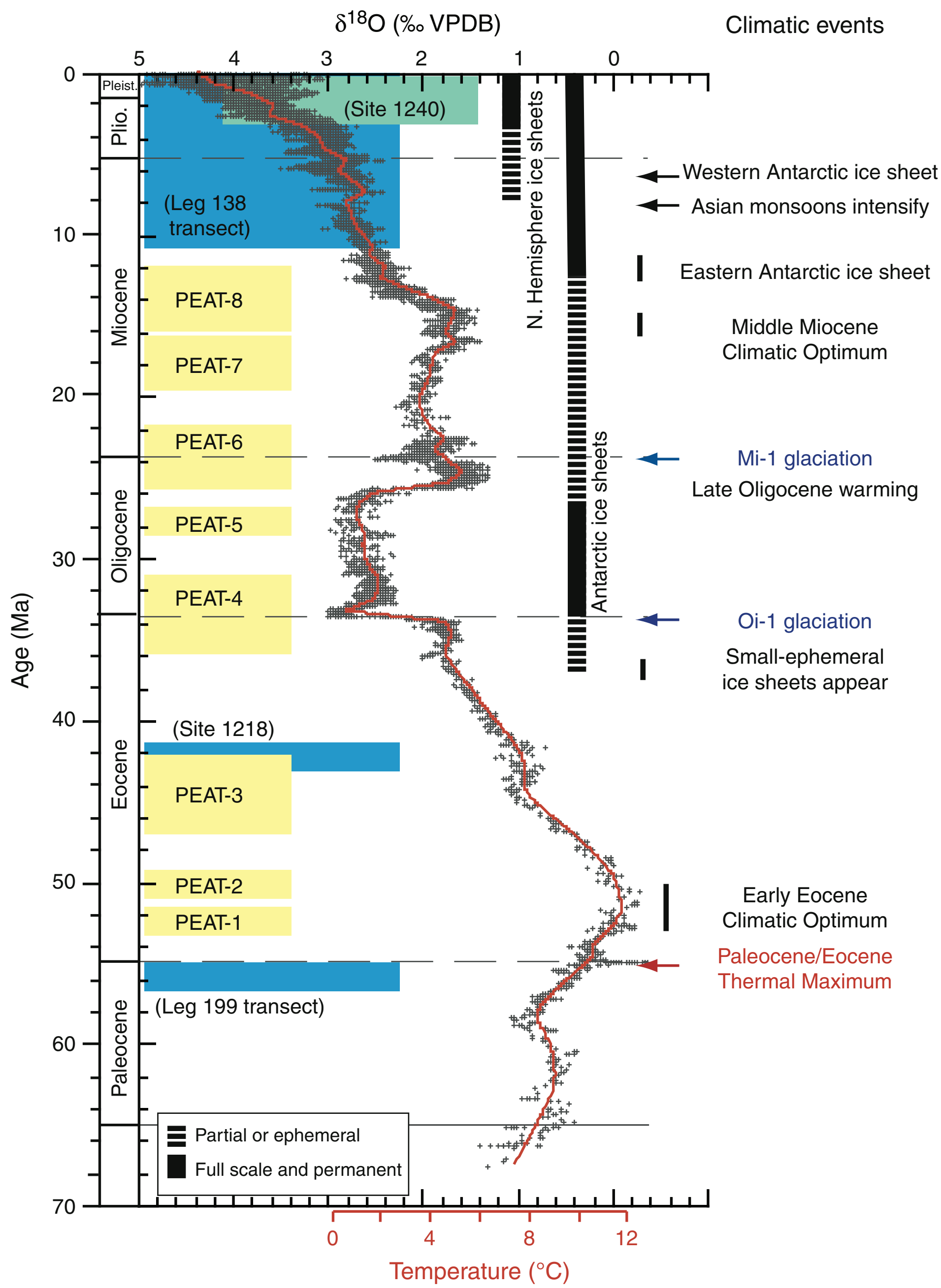


Figure F6. Proposed locations of drill sites with backtracked position of paleoequator, corresponding to time slices targeted. Shown are present-day bathymetry in grayscale (darker = deeper); revised magnetic anomaly isochrons (thin yellow lines, modified with new points from Petronotis 1991; Petronotis et al., 1994); and paleoequator position at the crustal age obtained by backtracking, using fixed-hotspot stage-poles from Koppers et al. (2001; pink) and Engebretson et al. (1985; orange), as well as palaeomagnetic poles from Sager and Pringle (1988; purple). The shaded band lies within 1° north and south of the paleoequator (averaged from fixed-hotspot rotation models). Colored areas correspond to time intervals of interest; the age range is indicated on the figure. These were obtained by intersecting the white paleoequator area with the younger end of the time interval of interest, which was then backrotated to the older boundary of the time slice. This method requires correction if backtracking occurs across fracture zones. Red numbers 1–8 indicate PEAT Sites 1–8. Note that PEAT sites as plotted are slightly different from final positions. Gray dots and numbers refer to the locations of existing DSDP and ODP sites.

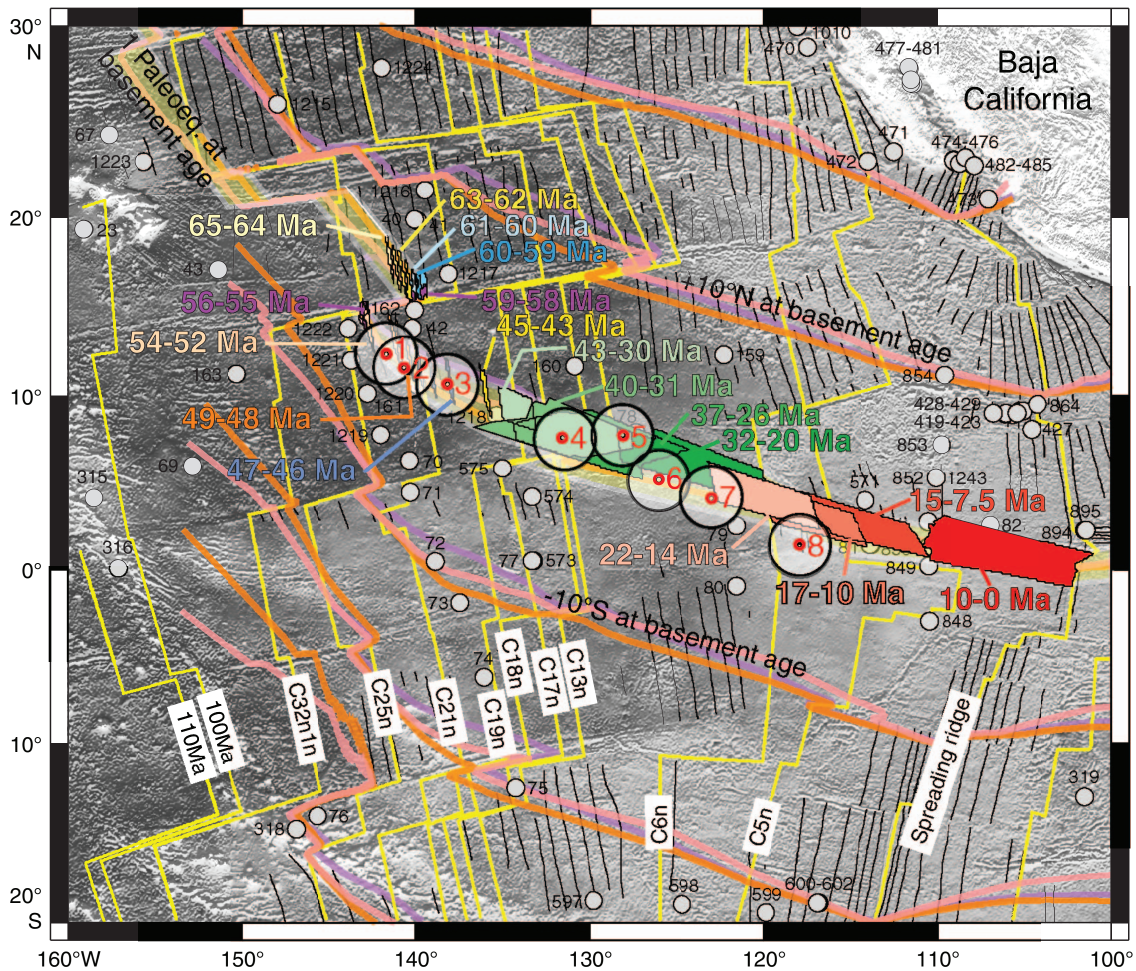


Figure F7. Average sediment accumulation for the interval 40–46 Ma (after Moore et al., 2004). Site positions are backtracked to their estimated position at 43 Ma. Site location solid circles are colored according to sediment type for the time interval: blue = carbonate, green = siliceous carbonate, red = siliceous, brown = clay. Contours are at 1, 5, and 10 m/m.y. Red dashed line indicates the approximate geographic paleoequator based on the sediment archive—with a notable difference compared to the fixed-hotspot rotation. Two regions of relatively high accumulation occur on both sides of the paleoequator in addition to the primary upwelling center.

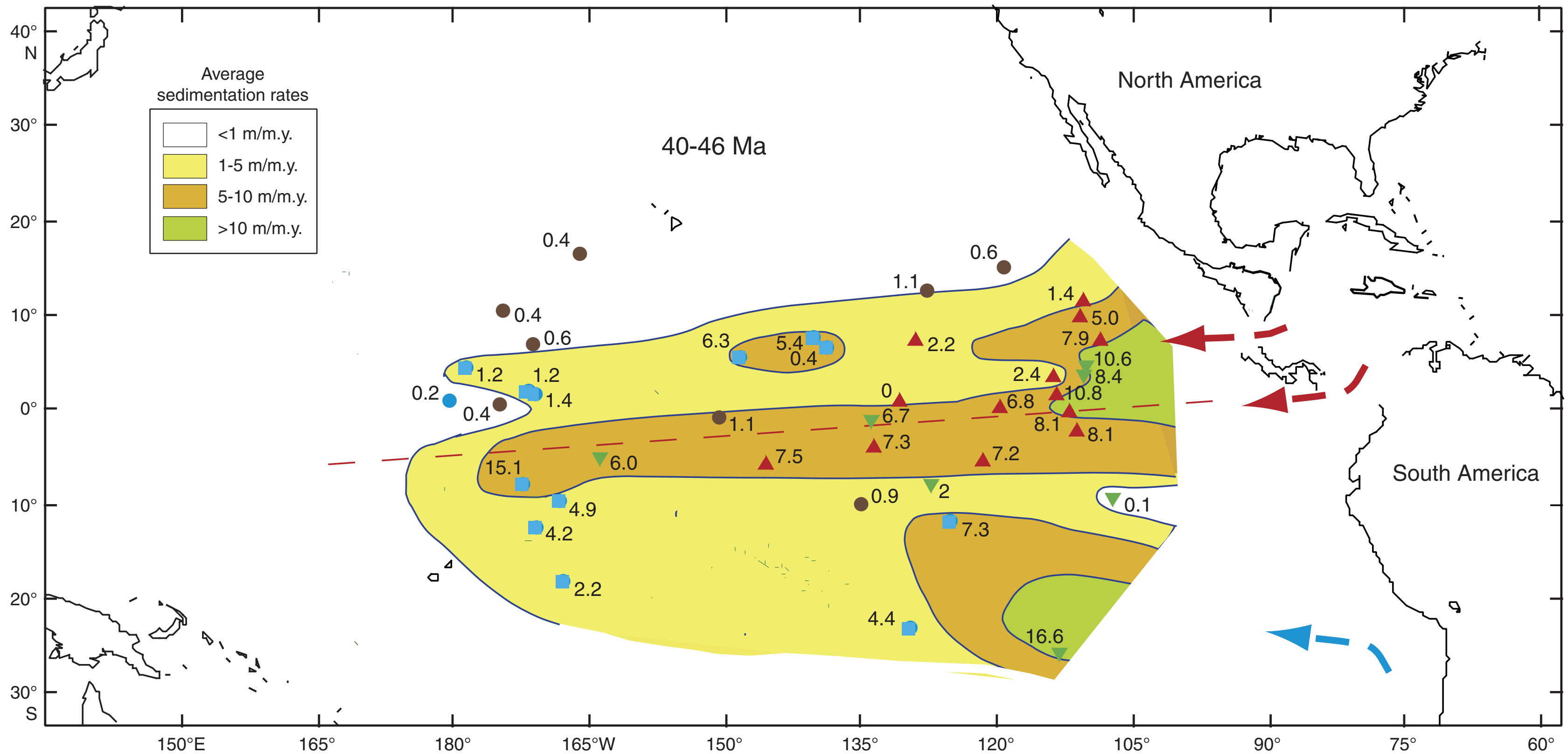


Figure F8. Model of early Eocene equatorial upwelling from Huber (2002), showing global land-sea distribution and annual average upwelling into the thermocline. Red = regions of vigorous upwelling, green to blue = regions of weak upwelling, white = areas of average downwelling. Current streamlines at ~100 m ocean depth are shown for the Pacific. All map views are projected on a Mollweide projection. The upwelling region in the eastern Pacific was broader than that of the modern region, primarily because of secondary upwelling centers on the edges of the region.

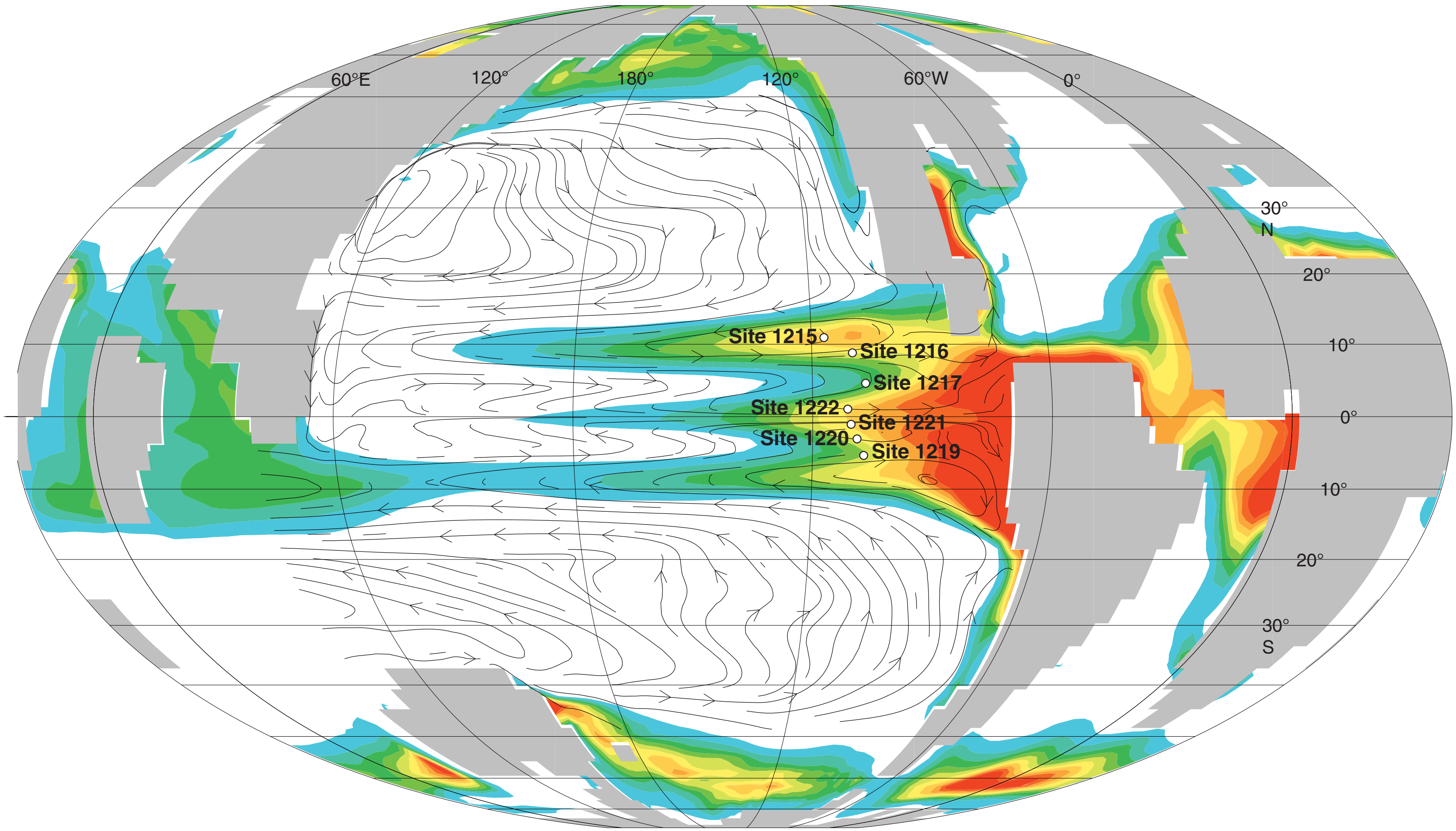


Figure F9. Oxygen isotope and carbonate time series across the Eocene/Oligocene boundary at Site 1218, ODP Leg 199 (Coxall et al., 2005). Oxygen isotope changes are in step with carbonate changes. The transition was accomplished in two steps of ~40 k.y. length, separated by a pause of ~100 k.y. MAR = mass accumulation rates. VPDB = Vienna Peedee Belemnite.

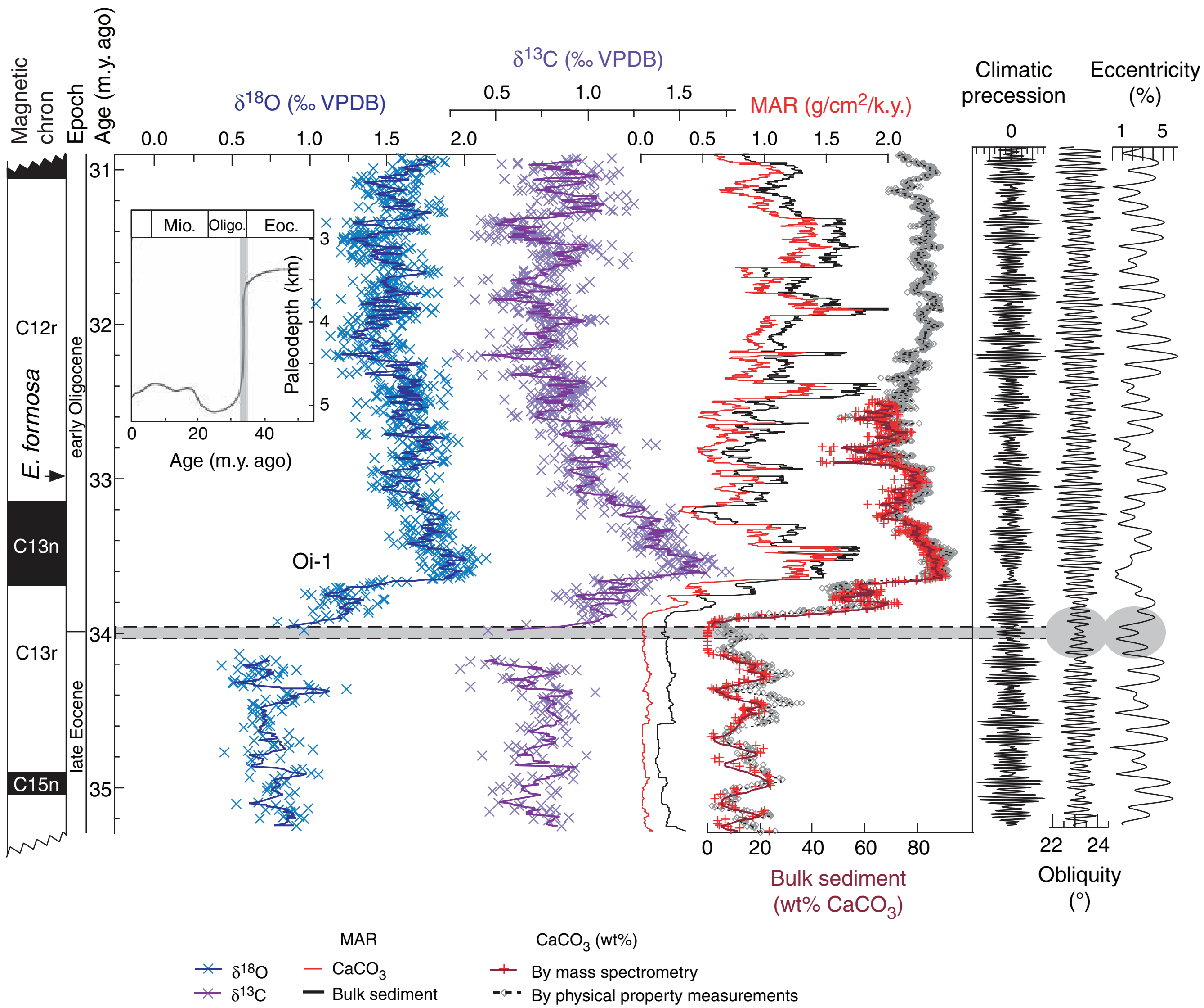


Figure F10. Times when proposed and existing sites were positioned within the paleoequatorial band. The equatorial band is defined as being within 2° latitude of the Equator. Paleopositions were calculated with a fixed-hotspot model. Shaded areas represent times when a site lies below the calcium compensation depth (< CCD).

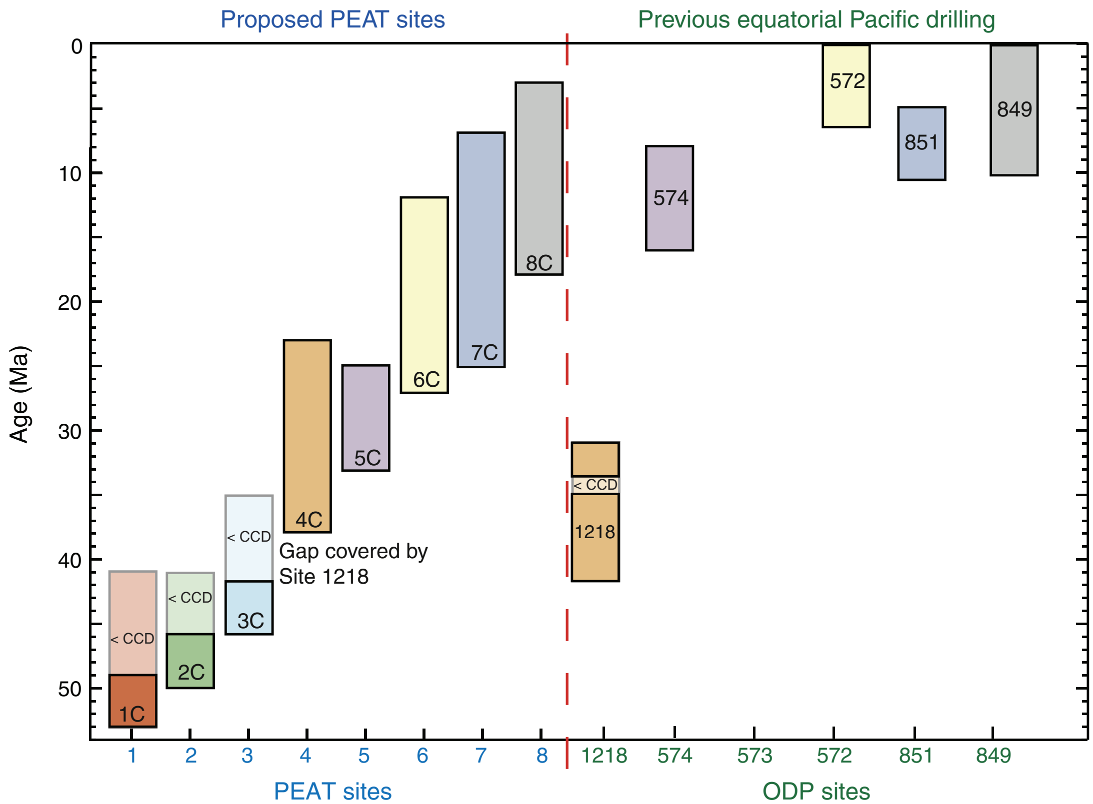


Figure F11. Swath map bathymetry for the proposed Site PEAT-1C region from the AMAT-03 site survey. Proposed drill site and location of piston Core RR0603-11JC are marked.

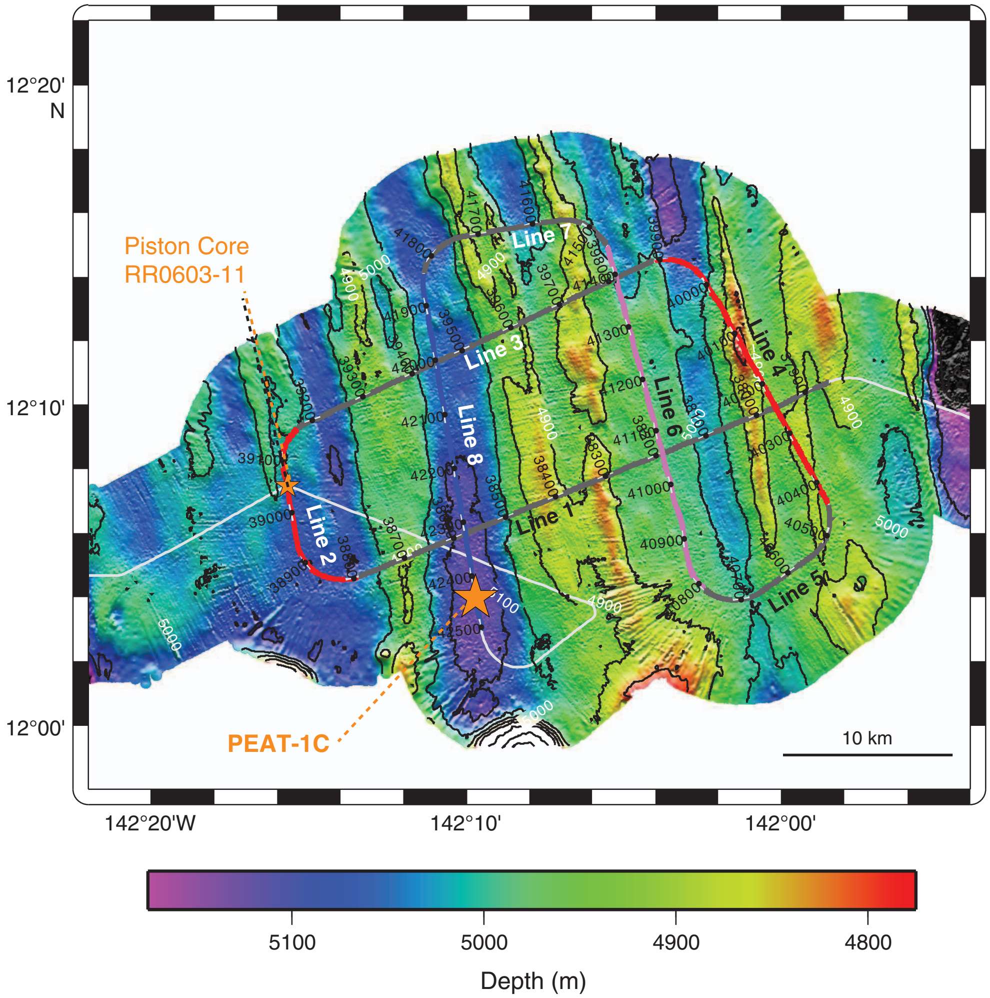


Figure F12. Seismic reflection profile PEAT-1 Line 8 from the 48-channel seismic reflection survey, annotated in shotpoints. Data are filtered, stacked, and migrated. PEAT-1C Line 8 goes down the western abyssal valley at the site. The site was chosen where basal reflections appeared less strong to avoid possible cherts. Colors correspond to the relative amplitude of the seismic signal (black = negative amplitude, red = positive amplitude). TD = total depth.

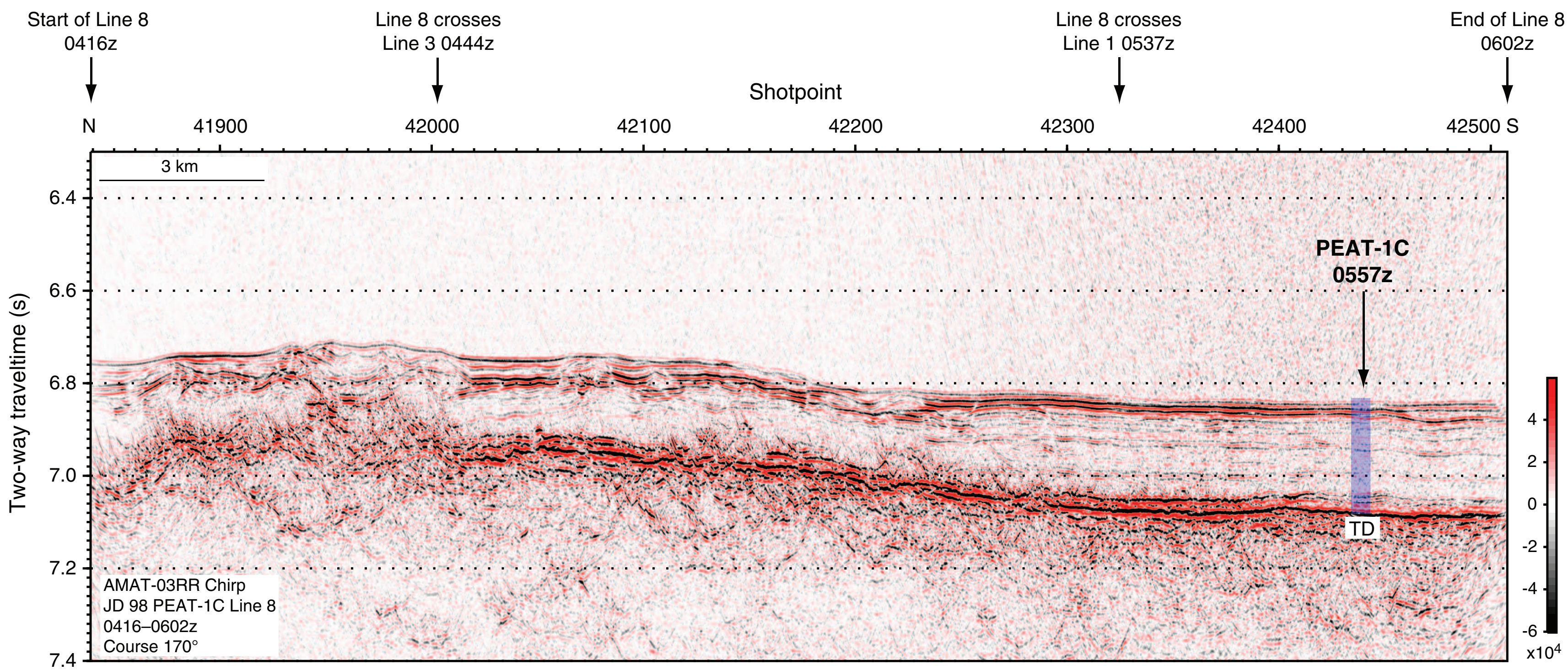


Figure F13. Crossline seismic profile PEAT-1C Line 1 from the AMAT-03 site survey, annotated in shotpoints. Site PEAT-1C was located south of the crossline in an area with better defined older seismic horizons. Colors correspond to the relative amplitude of the seismic signal (black = negative amplitude, red = positive amplitude).

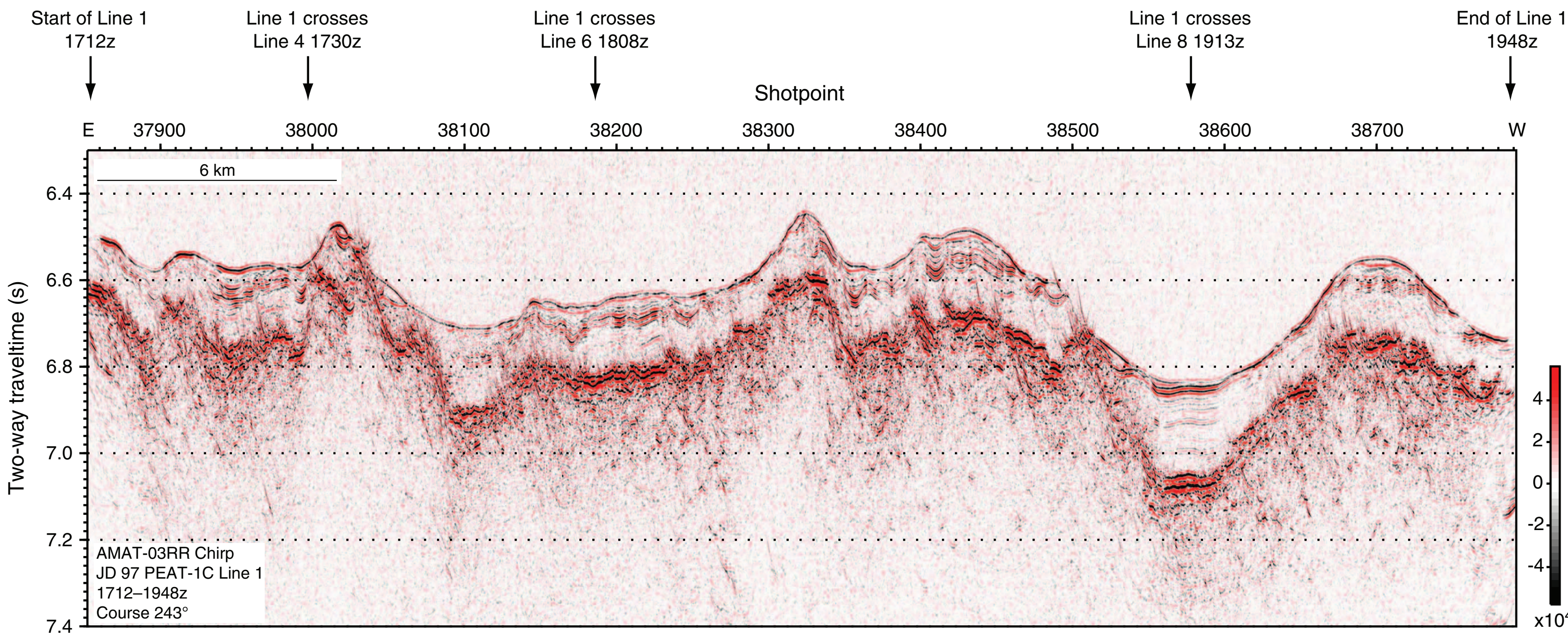


Figure F14. Swath map bathymetry for the proposed Site PEAT-2C region from the AMAT-03 site survey. Proposed drill site and location of piston Core RR0603-10JC are marked.

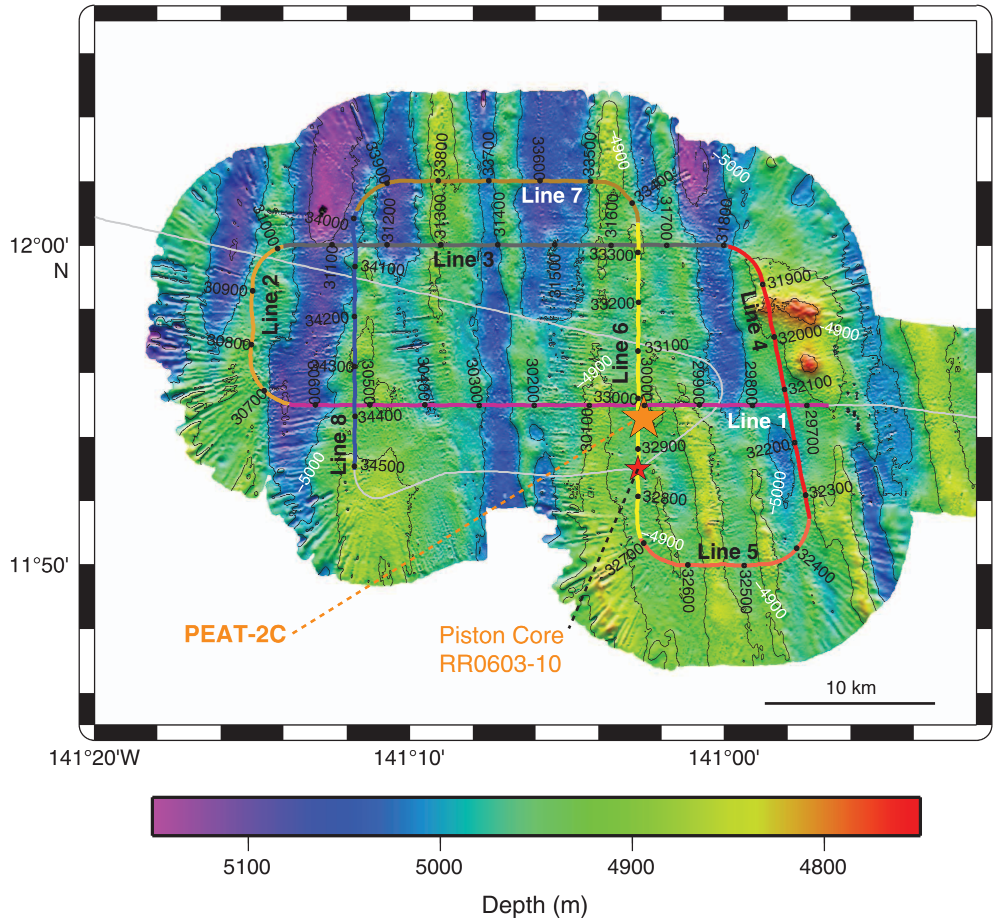


Figure F15. Seismic profile PEAT-2C Line 6 annotated in shotpoints, with position and penetration depth of Site PEAT-2C marked. Data are filtered, stacked, and migrated. Colors correspond to the relative amplitude of the seismic signal (black = lower amplitude, red = higher amplitude).

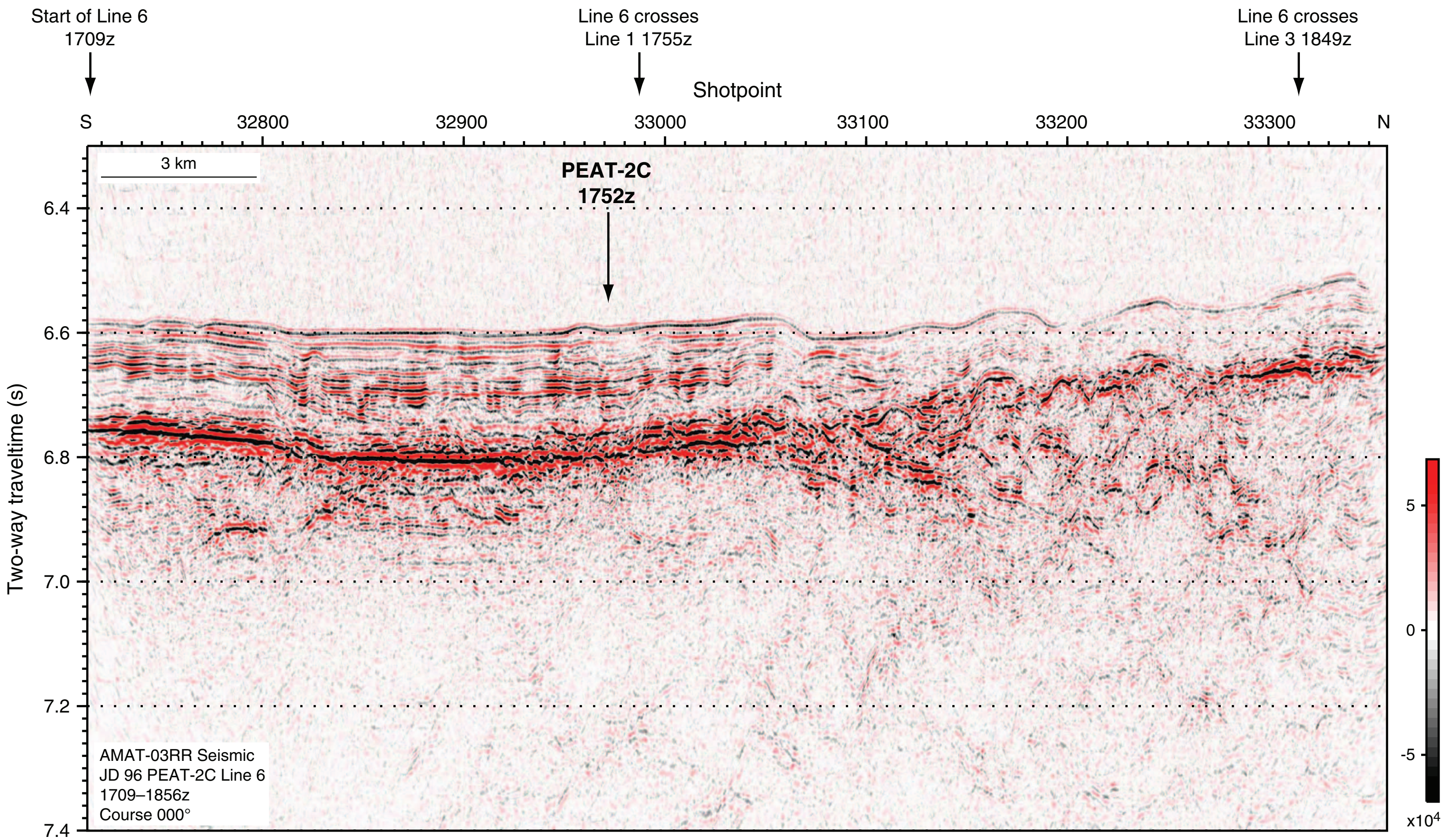


Figure F16. Crossline seismic profile PEAT-2C Line 1 from AMAT-03 site survey, annotated in shotpoints. Colors correspond to the relative amplitude of the seismic signal (black = negative amplitude, red = positive amplitude).

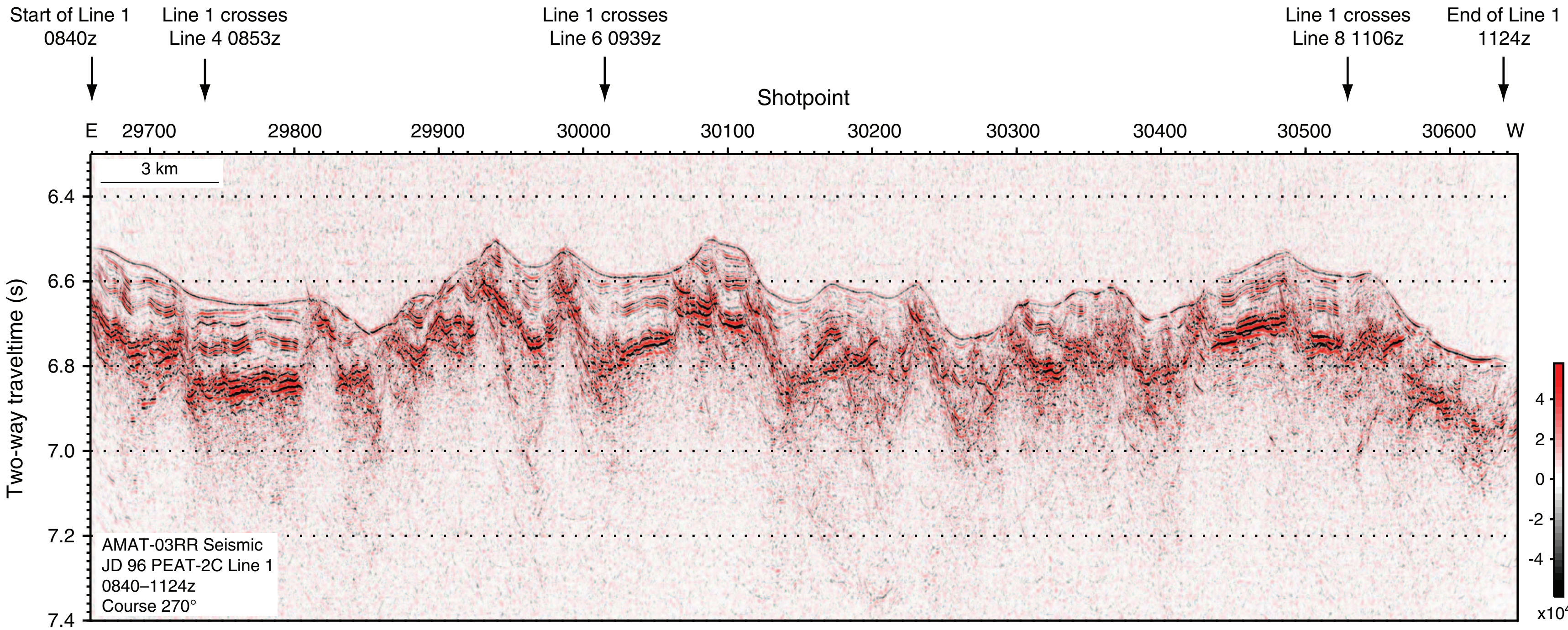


Figure F17. Swath map bathymetry for the proposed Site PEAT-3C region from the AMAT-03 site survey. Proposed drill site and location of piston Core RR0603-09JC are marked.

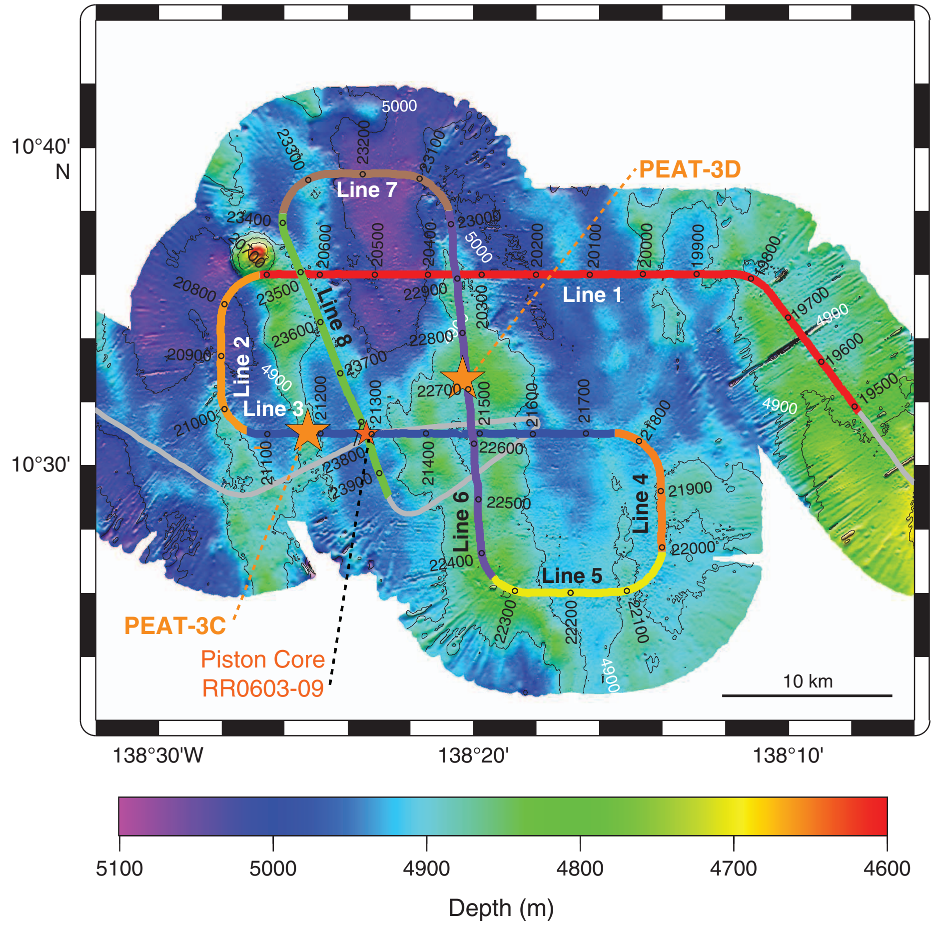


Figure F18. PEAT-3C Line 3, annotated in shotpoints. Profiles are filtered, stacked, and migrated. Colors correspond to the relative amplitude of the seismic signal (black = negative amplitude, red = positive amplitude). TD = total depth.

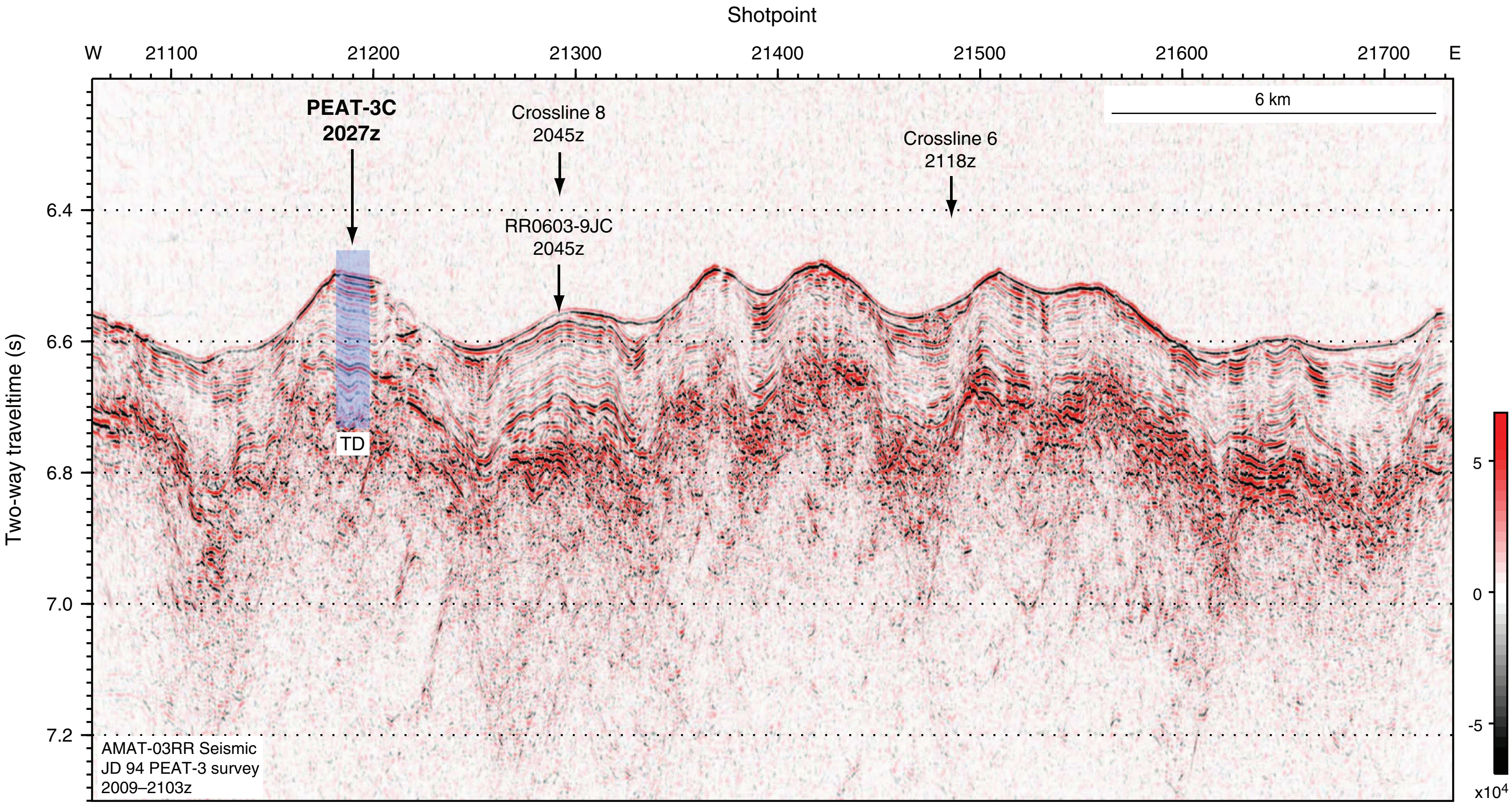


Figure F19. Alternate Site PEAT-3D shown on PEAT-3C Line 6, annotated in shotpoints. The site was moved north of the cross with Line 3 to an area with a better defined sediment column. Color corresponds to the relative amplitude of the seismic signal (black = negative amplitude, red = positive amplitude). TD = total depth.

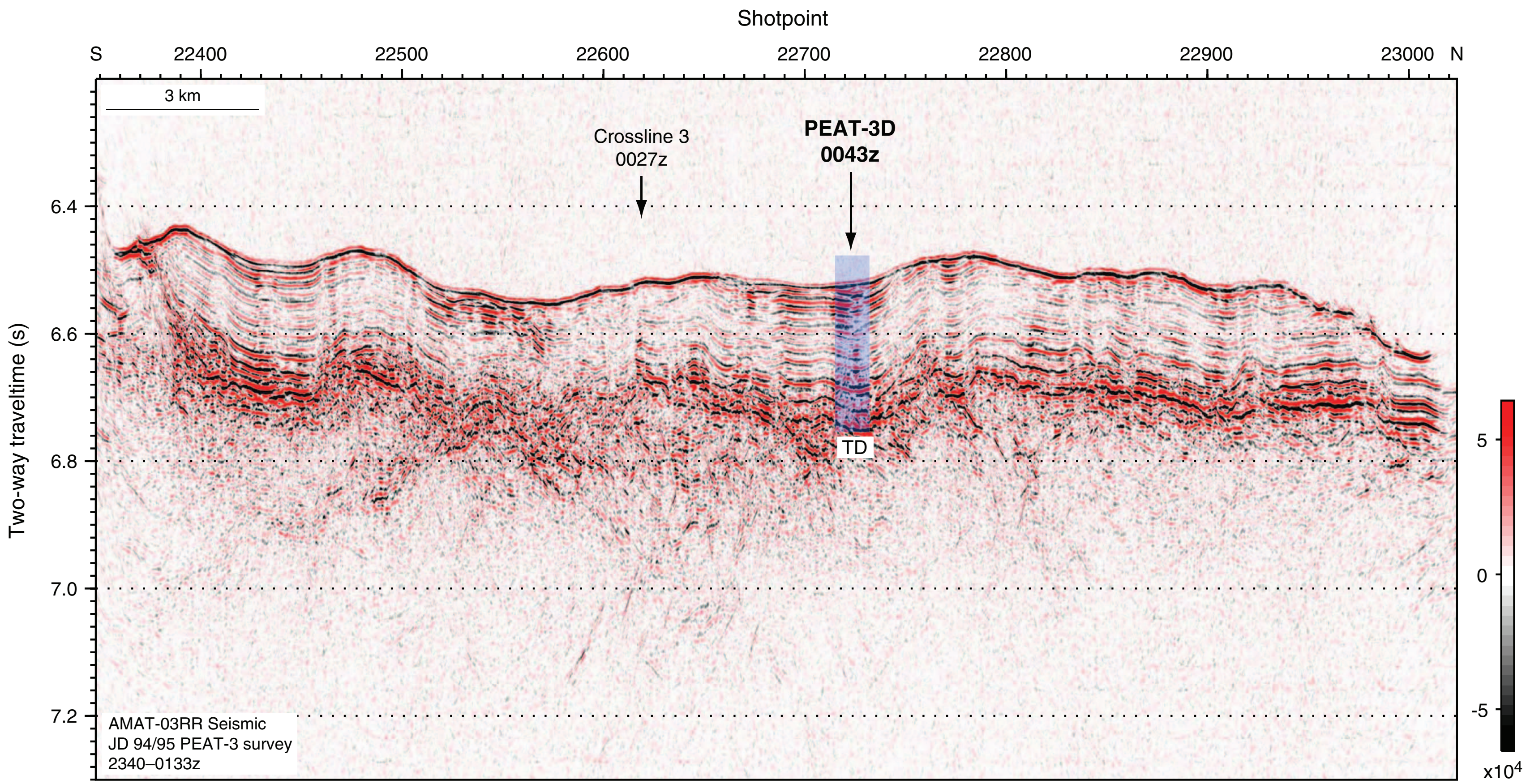


Figure F20. Swath map bathymetry for the proposed Site PEAT-4C region from the AMAT-03 site survey. Proposed drill site and location of piston Core RR0603-08JC are marked.

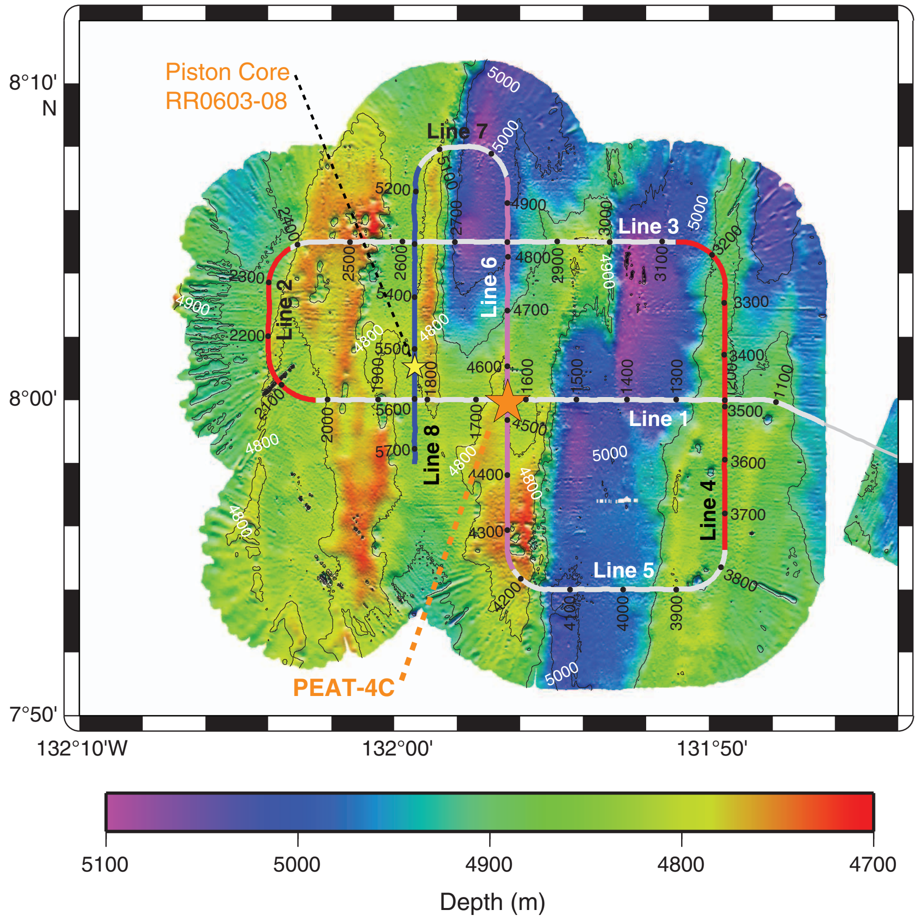


Figure F21. Seismic profile PEAT-4C Line 1 across PEAT-4C from AMAT-03 site survey, annotated in shotpoints. Data are stacked, filtered and migrated. The location of PEAT-4C is at the cross of Lines 1 and 6. Colors correspond to the relative amplitude of the seismic signal (black = negative amplitude, red = positive amplitude). TD = total depth.

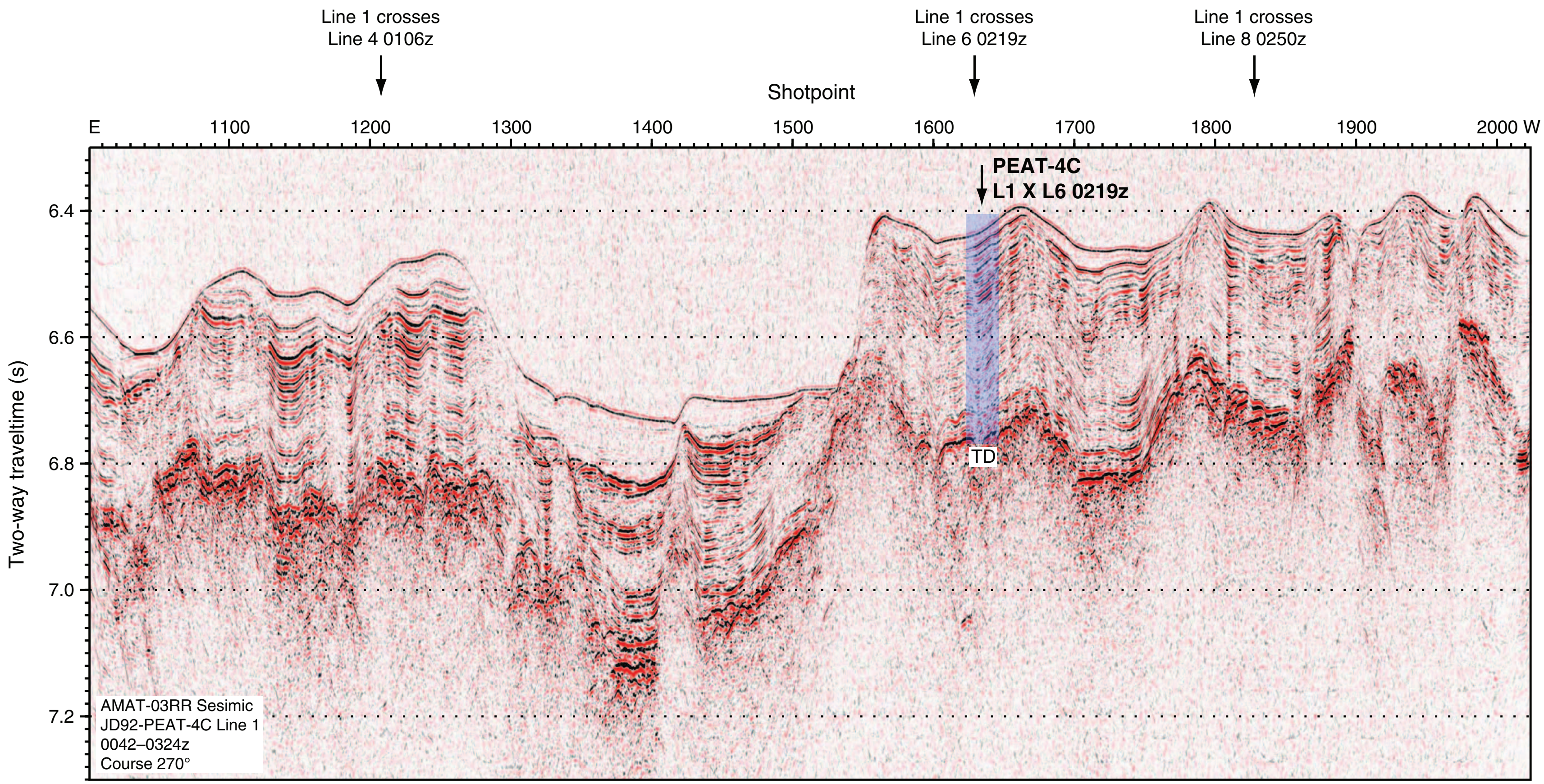


Figure F22. Cross seismic profile PEAT-4C Line 6 from AMAT-03 site survey, annotated in shotpoints. Data are stacked, filtered and migrated. The location of PEAT-4C is at the cross of Lines 1 and 6. Colors correspond to the relative amplitude of the seismic signal (black = negative amplitude, red = positive amplitude).

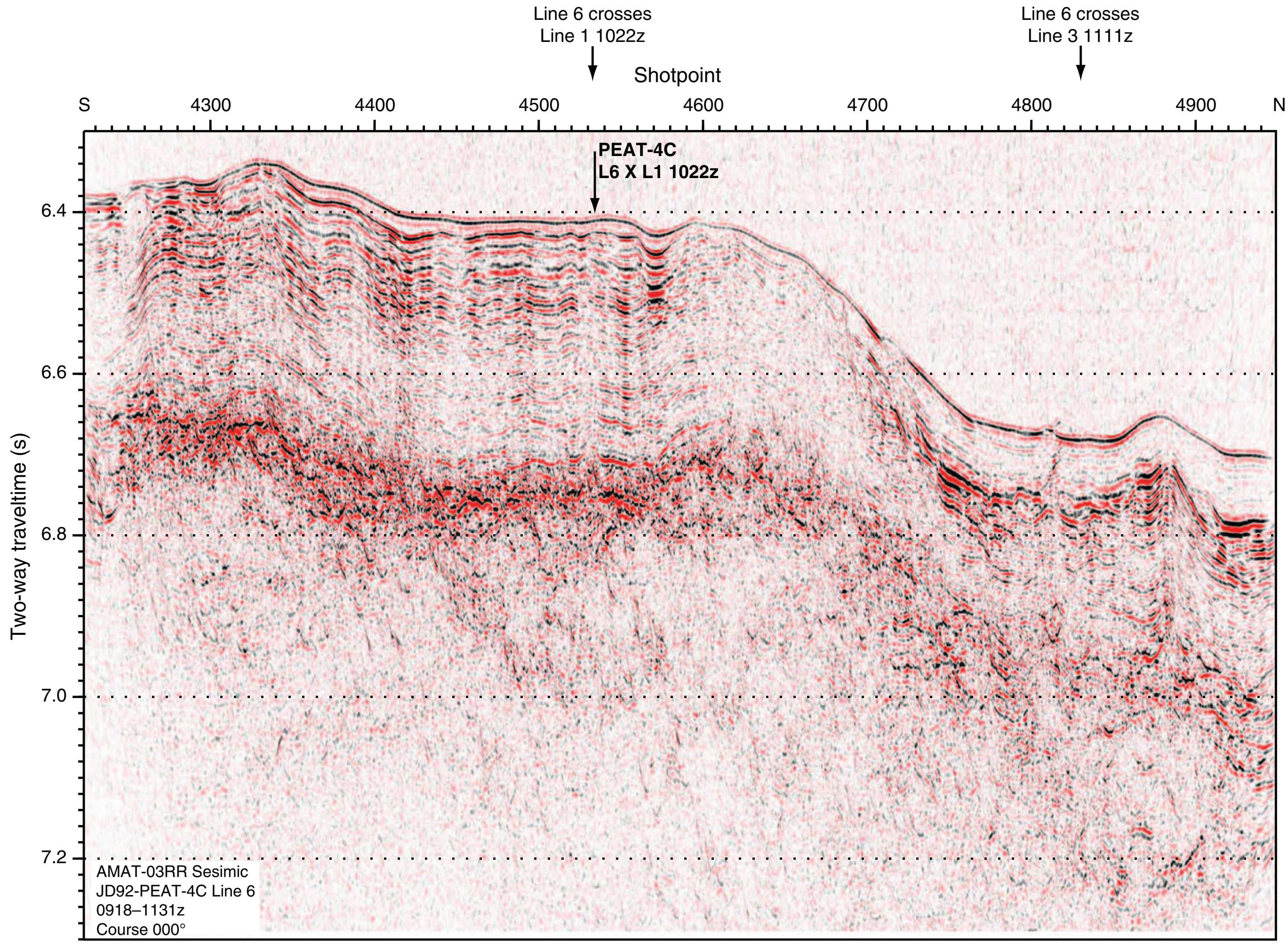


Figure F23. Swath map bathymetry showing proposed Site PEAT-5C in relation to Clipperton Fracture Zone. Site positions are marked.

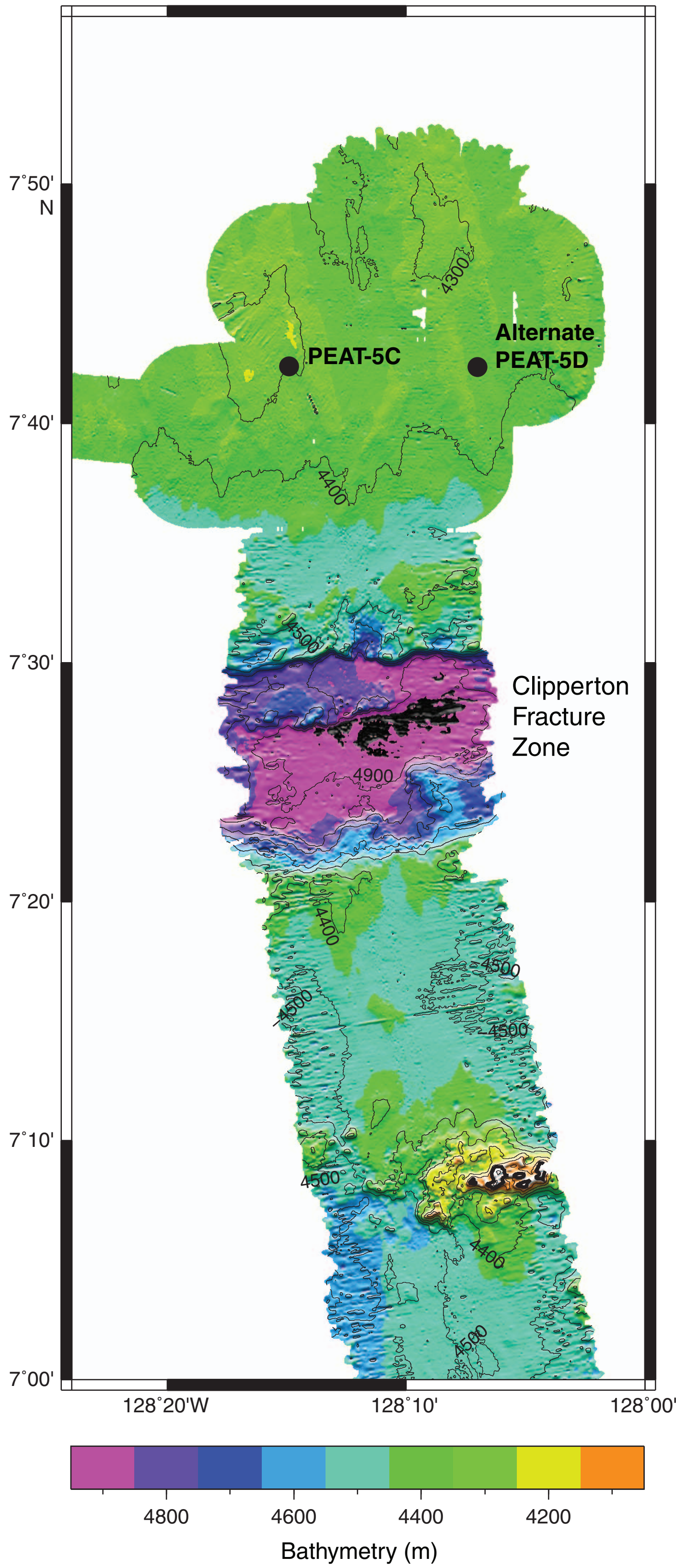


Figure F24. Swath map bathymetry for the PEAT-5C region from the AMAT-03 site survey. Proposed drill site and location of piston Core RR0603-07JC are marked.

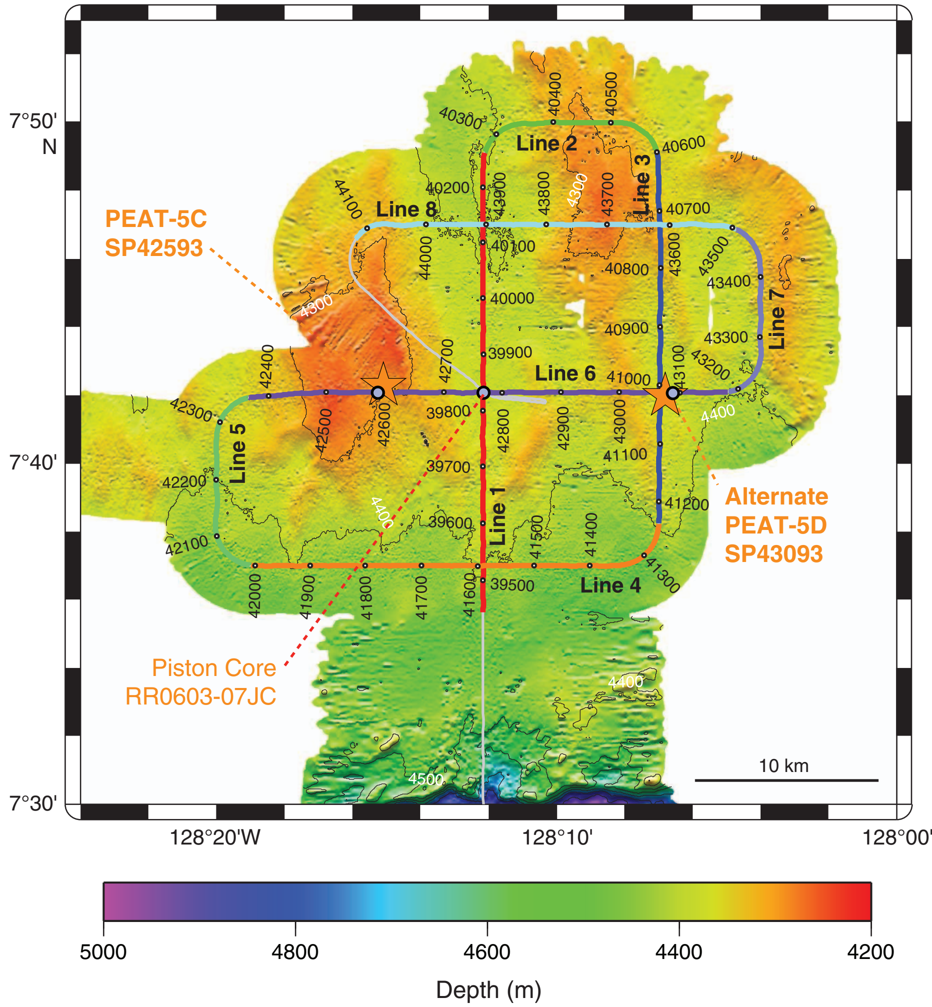


Figure F25. Seismic profile PEAT-5C Line 6 across PEAT-5C and the alternate PEAT-5D from AMAT-03, annotated in shotpoints. Colors correspond to the relative amplitude of the seismic signal (red = negative amplitude, black = positive amplitude).

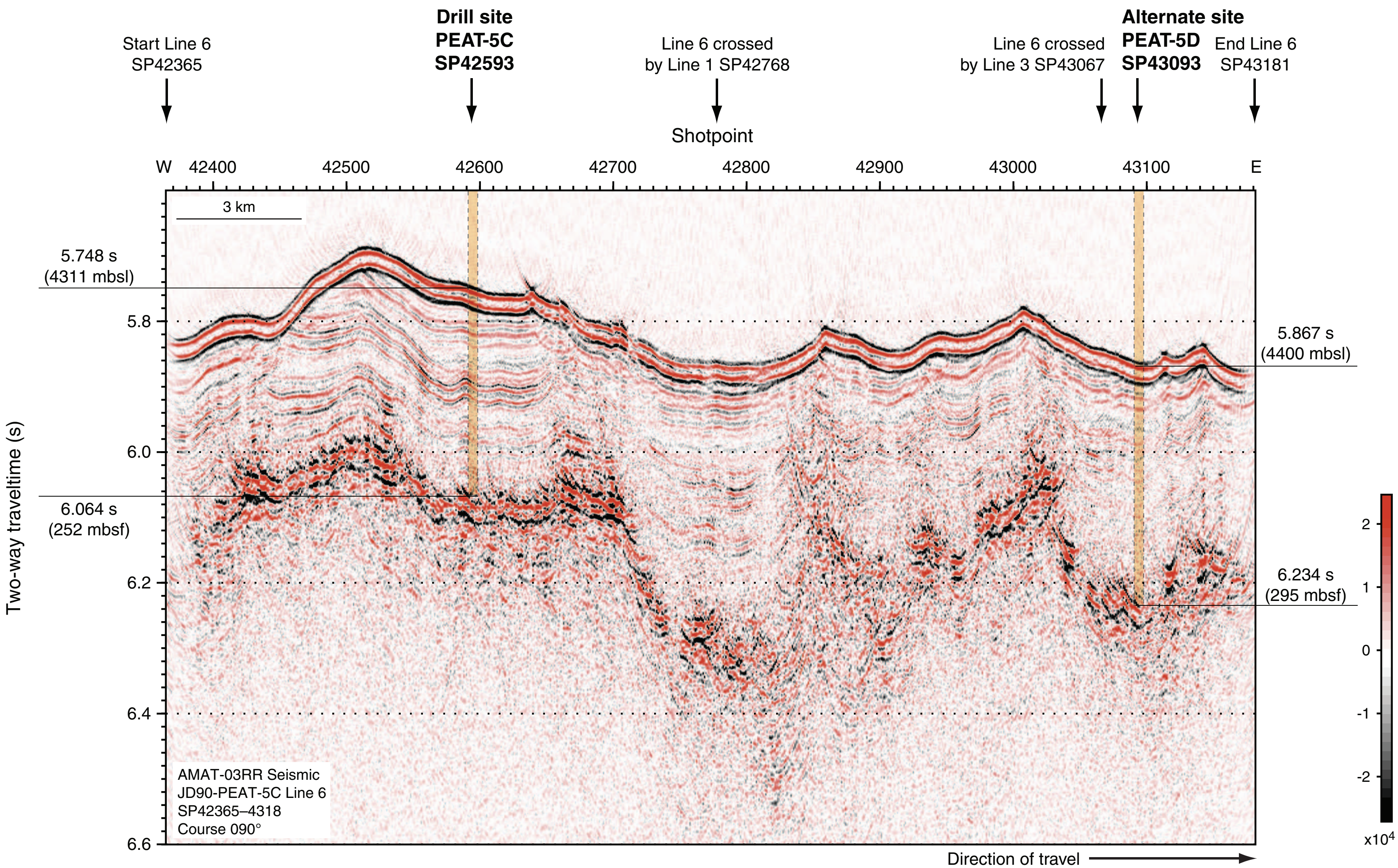


Figure F26. Crossline seismic profile PEAT-5C Line 1 from AMAT-03 site survey versus shotpoints. Site was moved west of the crossline to an area with better defined older seismic horizons. Colors correspond to the relative amplitude of the seismic signal (red = negative amplitude, black = positive amplitude).

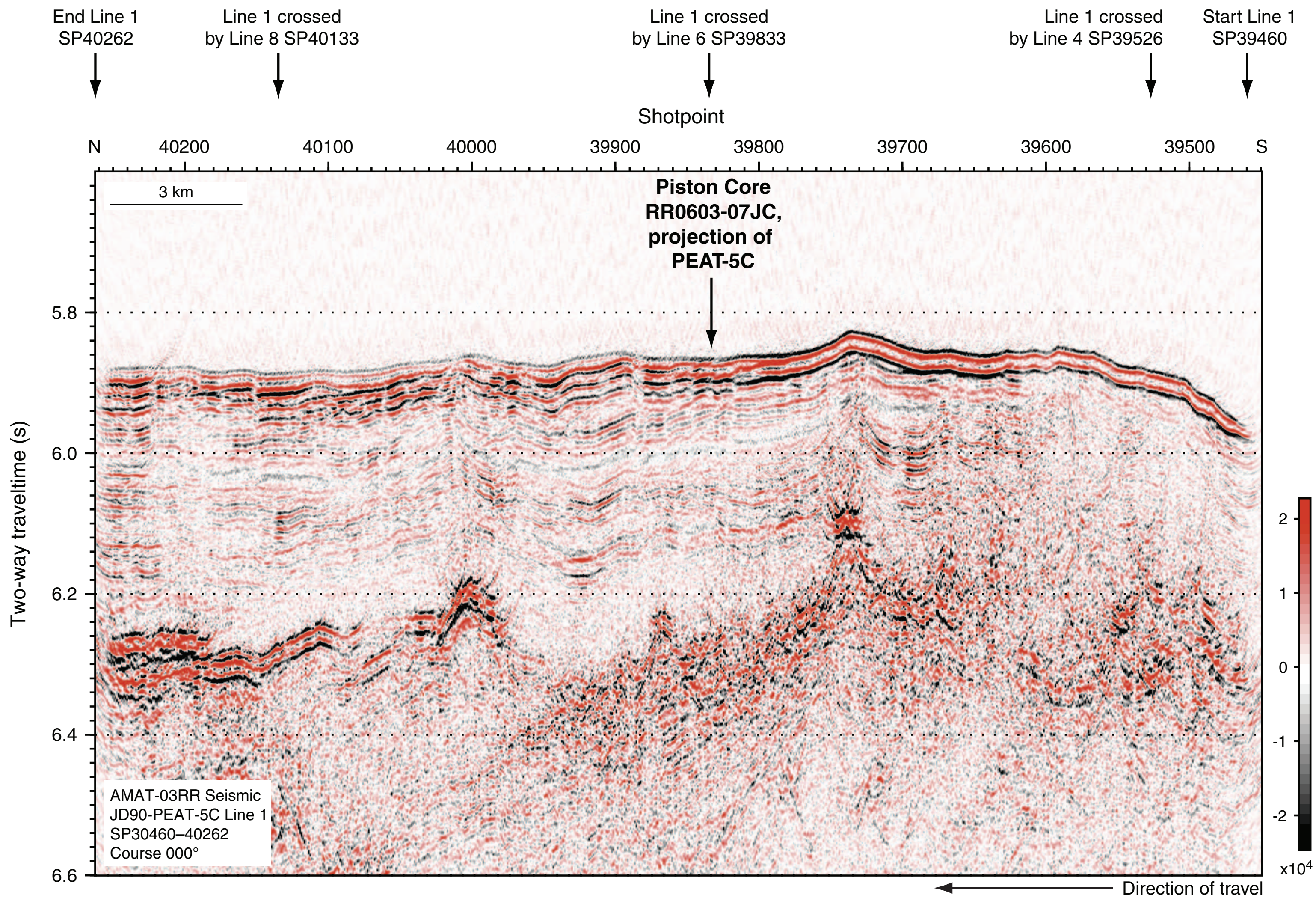


Figure F27. Swath map bathymetry for the PEAT-6C region from the AMAT-03 site survey. Proposed drill site and location of piston Core RR0603-06JC are marked.

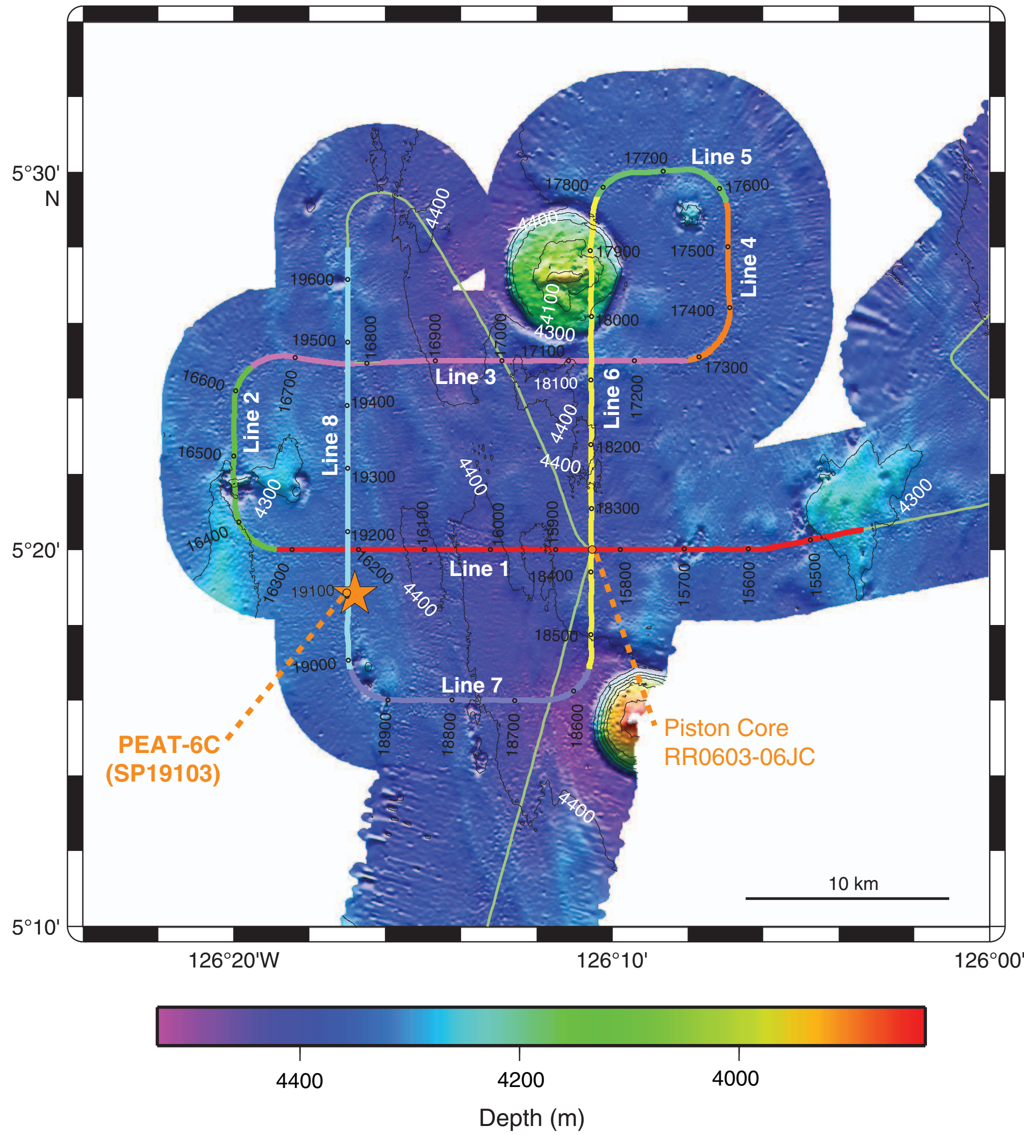


Figure F28. Seismic profile PEAT-6C Line 8 across PEAT-6C from AMAT-03 site survey, annotated in shotpoints. Proposed drill site is marked. Colors correspond to the relative amplitude of the seismic signal (black = negative amplitude, red = positive amplitude).

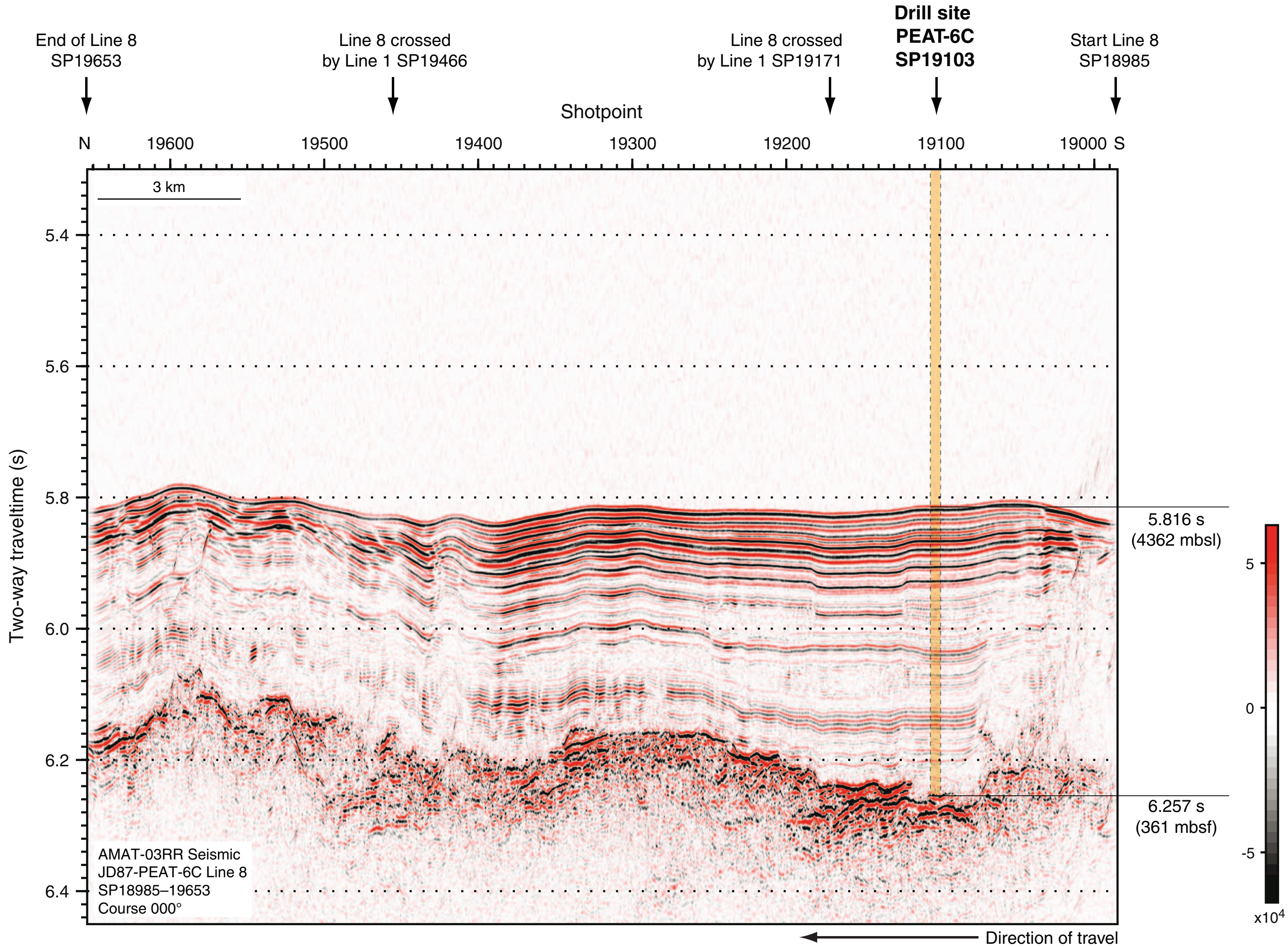


Figure F29. Crossline seismic profile PEAT-6C Line 1 from AMAT-03 site survey, annotated in shotpoints. Site was moved west of the crossline to avoid the basement deep. Colors correspond to the relative amplitude of the seismic signal (black = negative amplitude, red = positive amplitude).

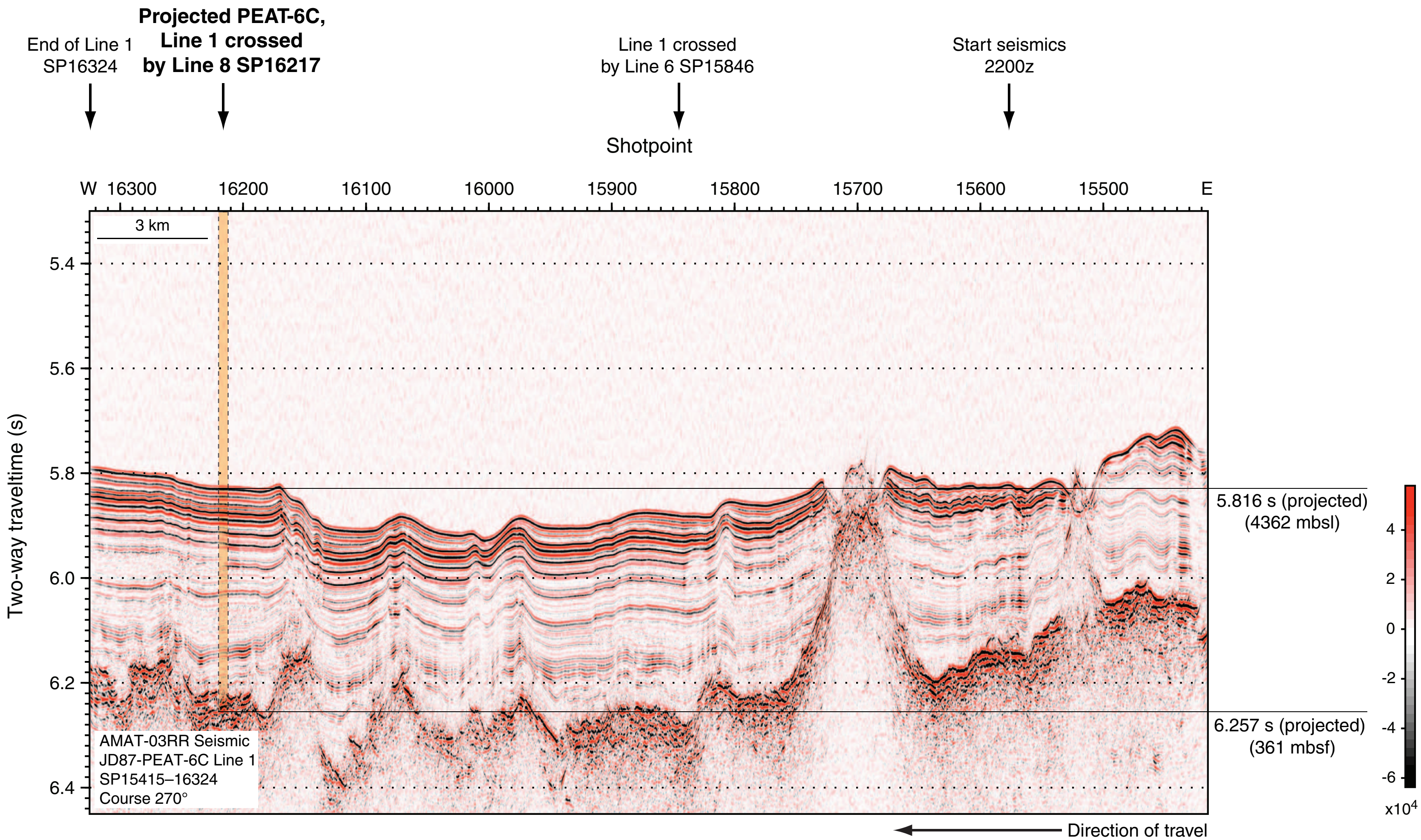


Figure F30. Swath map bathymetry for the PEAT-7C region from AMAT-03 site survey. Proposed drill site and location of piston Core RR0603-05JC are marked.

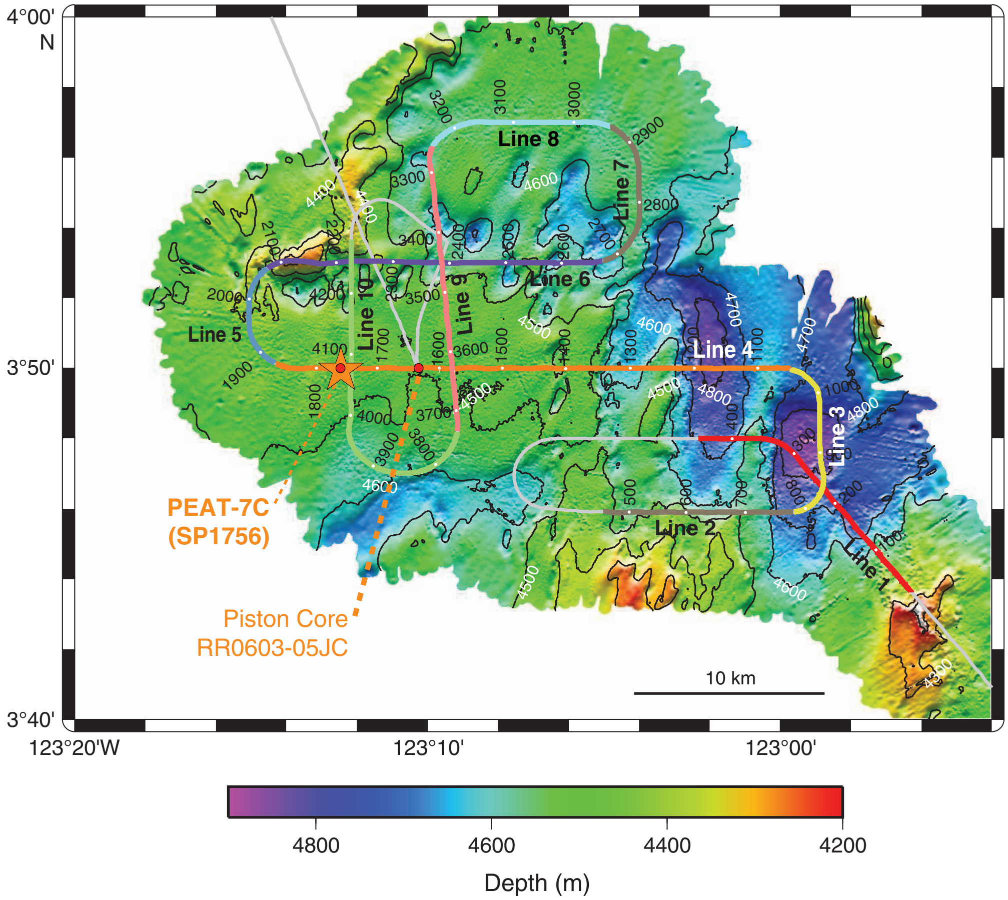


Figure F31. Seismic profile PEAT-7C Line 4 across PEAT-7C from AMAT-03 site survey, annotated in shotpoints. Proposed drill site is marked. Colors correspond to the relative amplitude of the seismic signal (black = negative amplitude, red = positive amplitude).

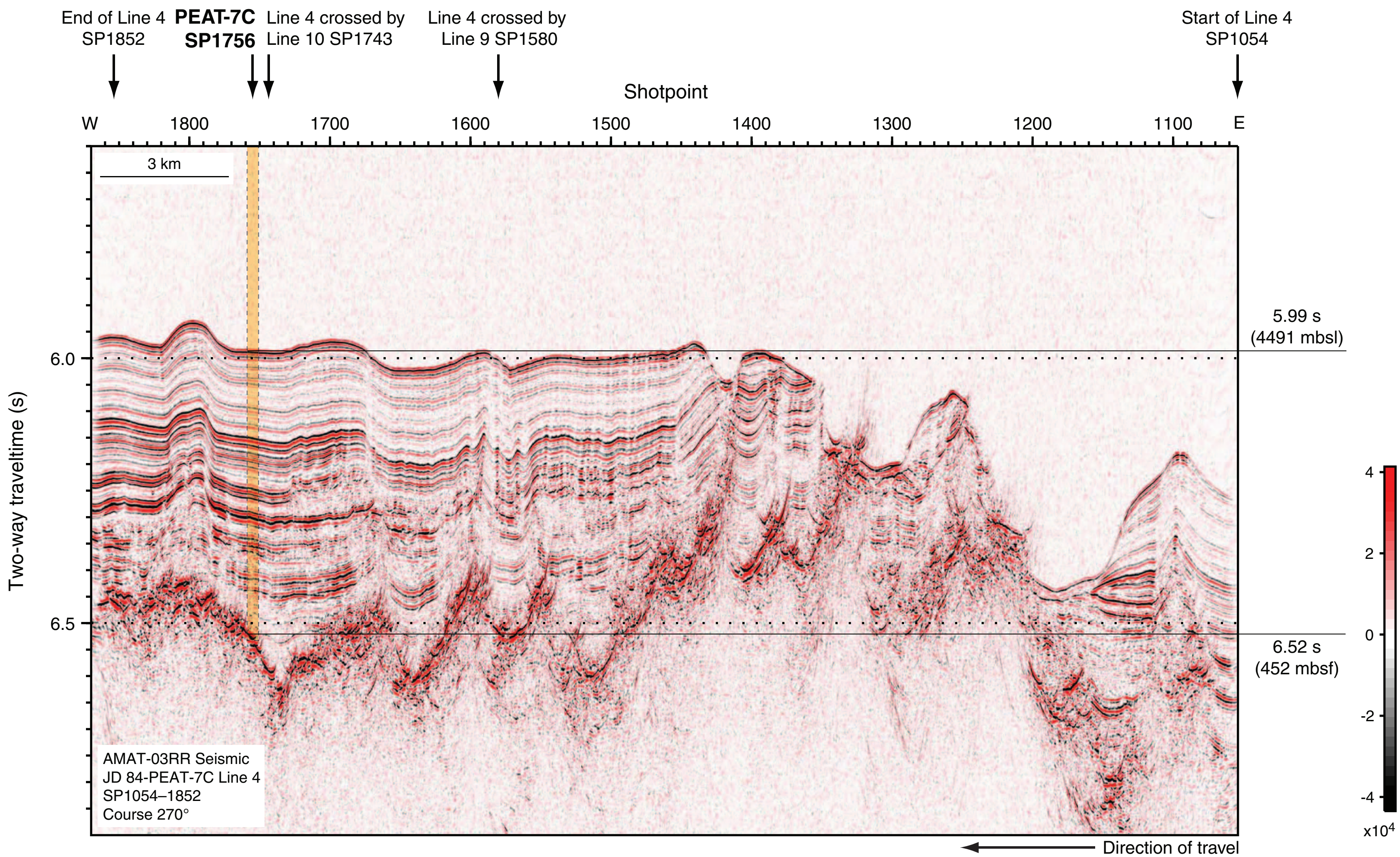


Figure F32. Crossline seismic profile PEAT-7C Line 10 from AMAT-03 site survey, annotated in shotpoints. Site was moved west of the crossline to avoid the basement deep. Colors correspond to the relative amplitude of the seismic signal (black = negative amplitude, red = positive amplitude).

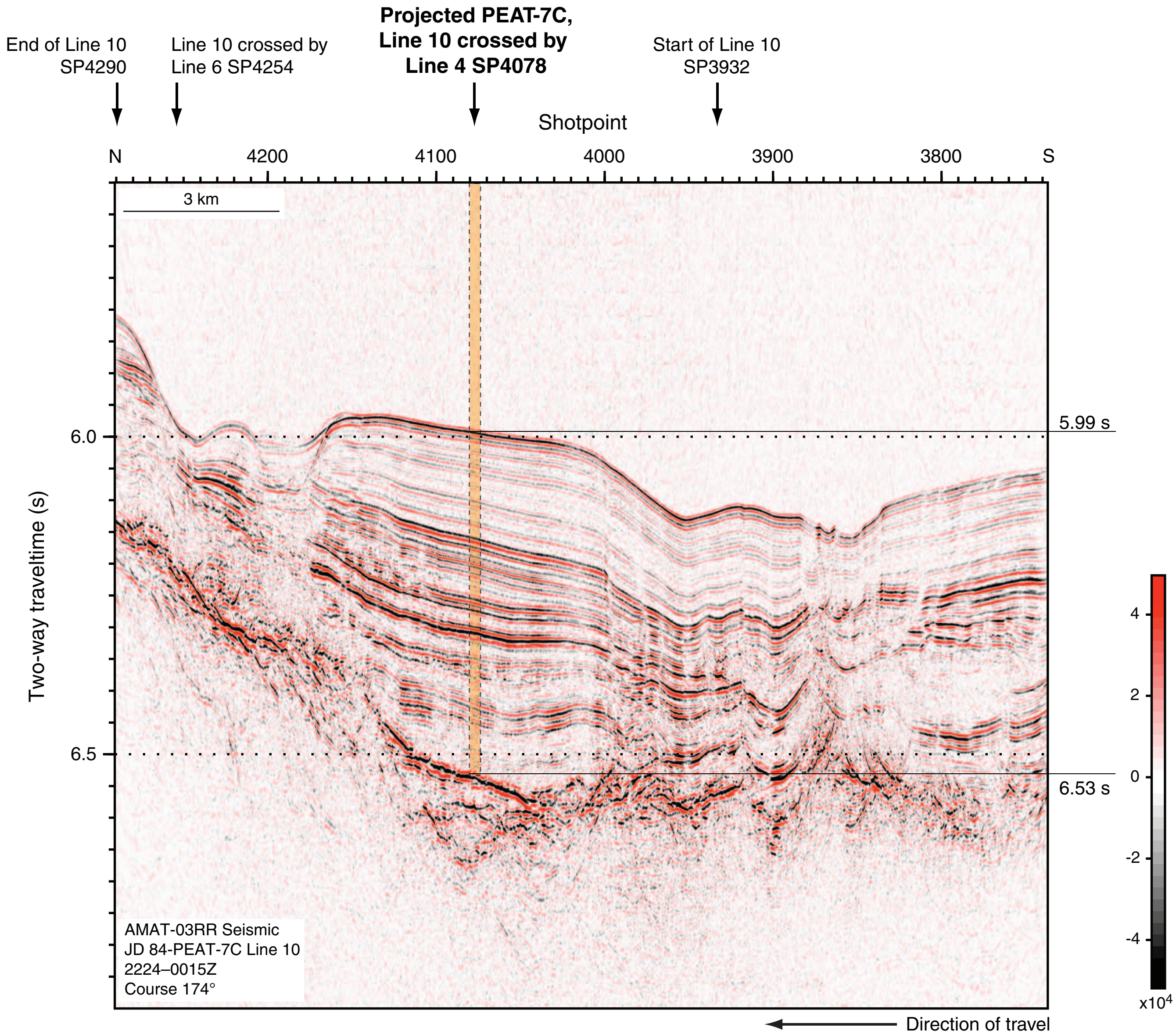


Figure F33. Swath map bathymetry for the PEAT-8C region from AMAT-03 site survey. Proposed drill site and location of piston Core RR0603-03JC are marked.

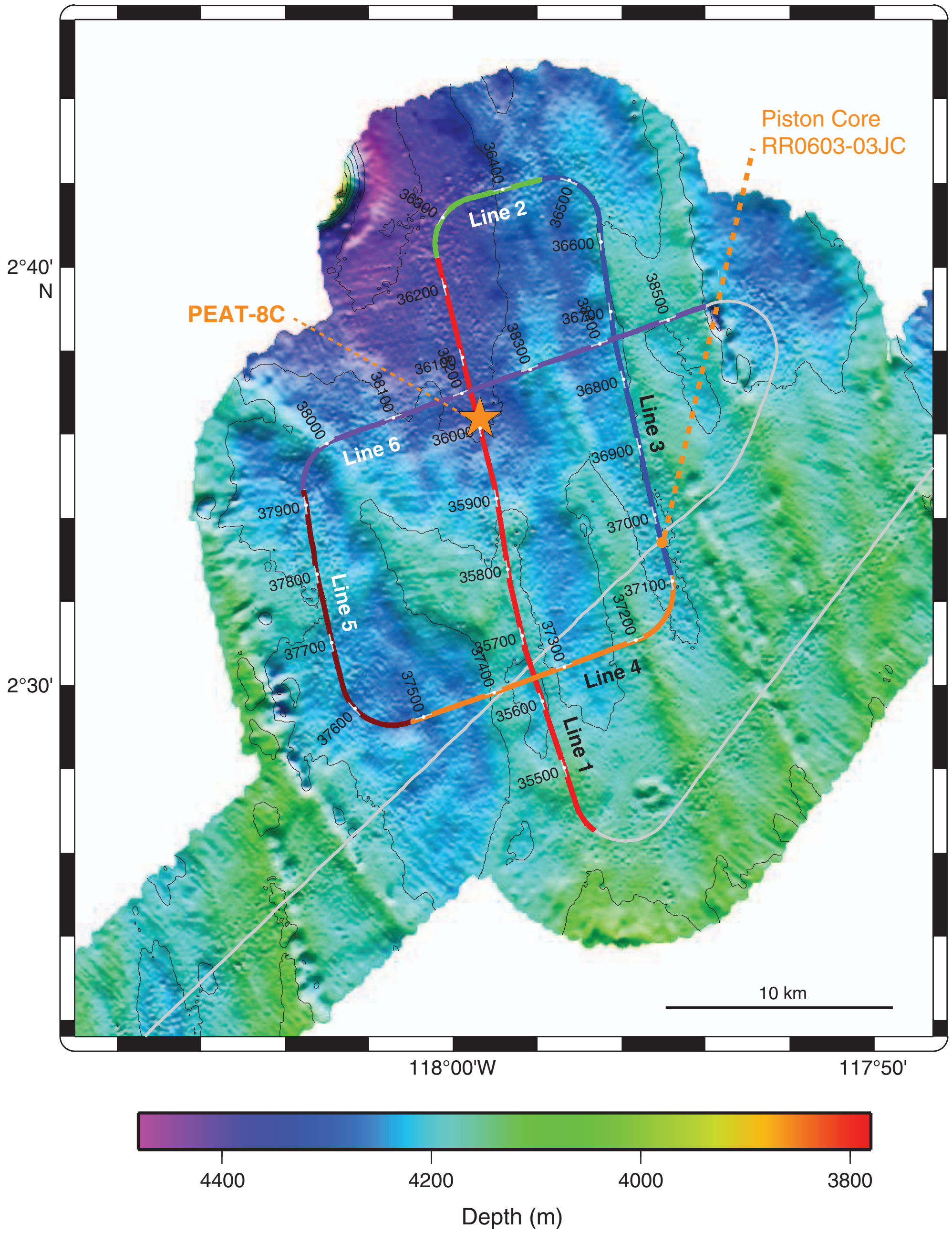


Figure F34. Seismic profile PEAT-8C Line 1 across PEAT-8C from AMAT-03 site survey, annotated in shotpoints. Proposed drill site is marked. Colors correspond to the relative amplitude of the seismic signal (black = negative amplitude, red = positive amplitude).

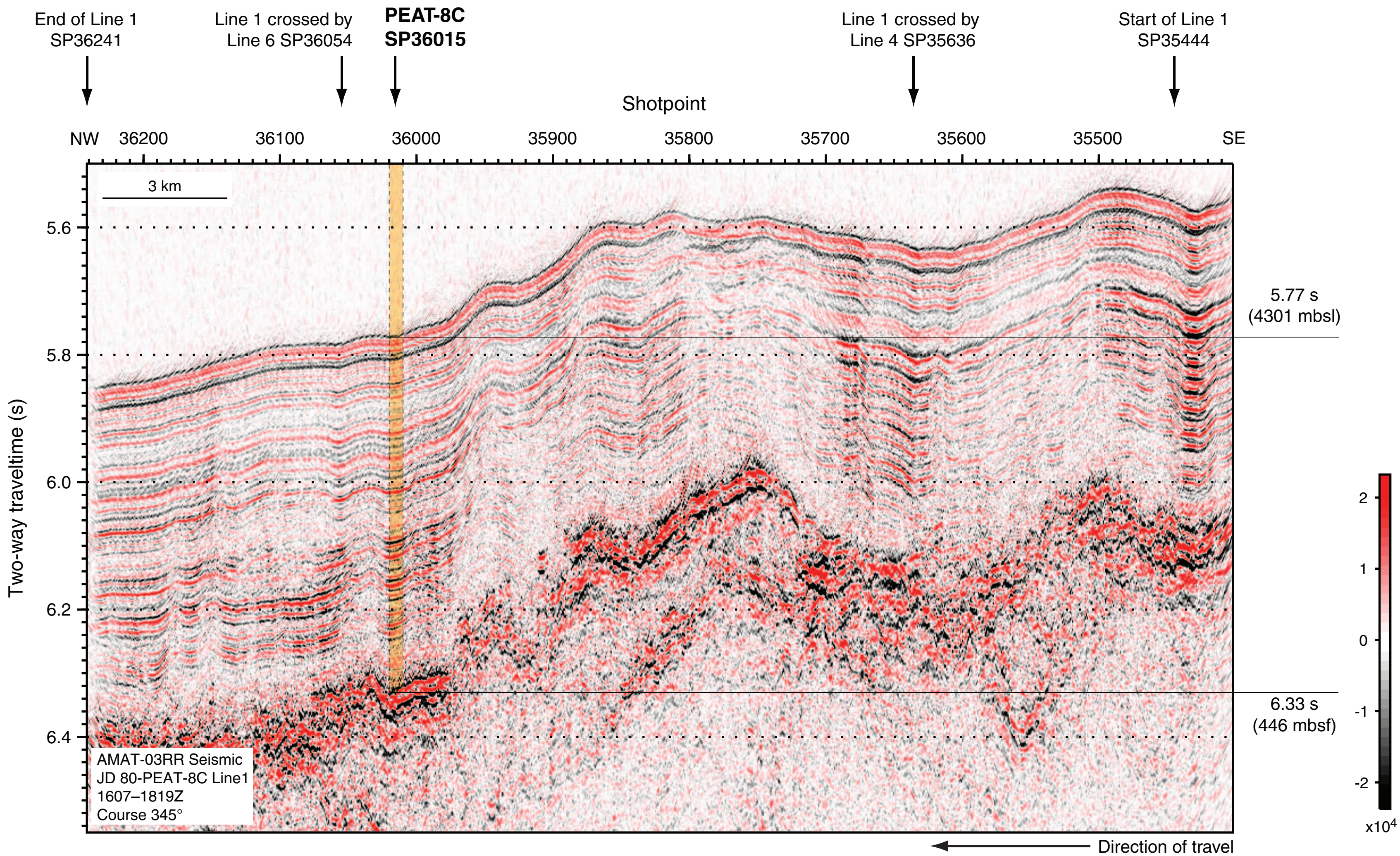


Figure F35. Crossline seismic profile PEAT-8C Line 6 from AMAT-03 site survey, annotated in shotpoints. Site was moved away from the cross with Line 1 because of the small fault nearby. Colors correspond to the relative amplitude of the seismic signal (black = negative amplitude, red = positive amplitude).

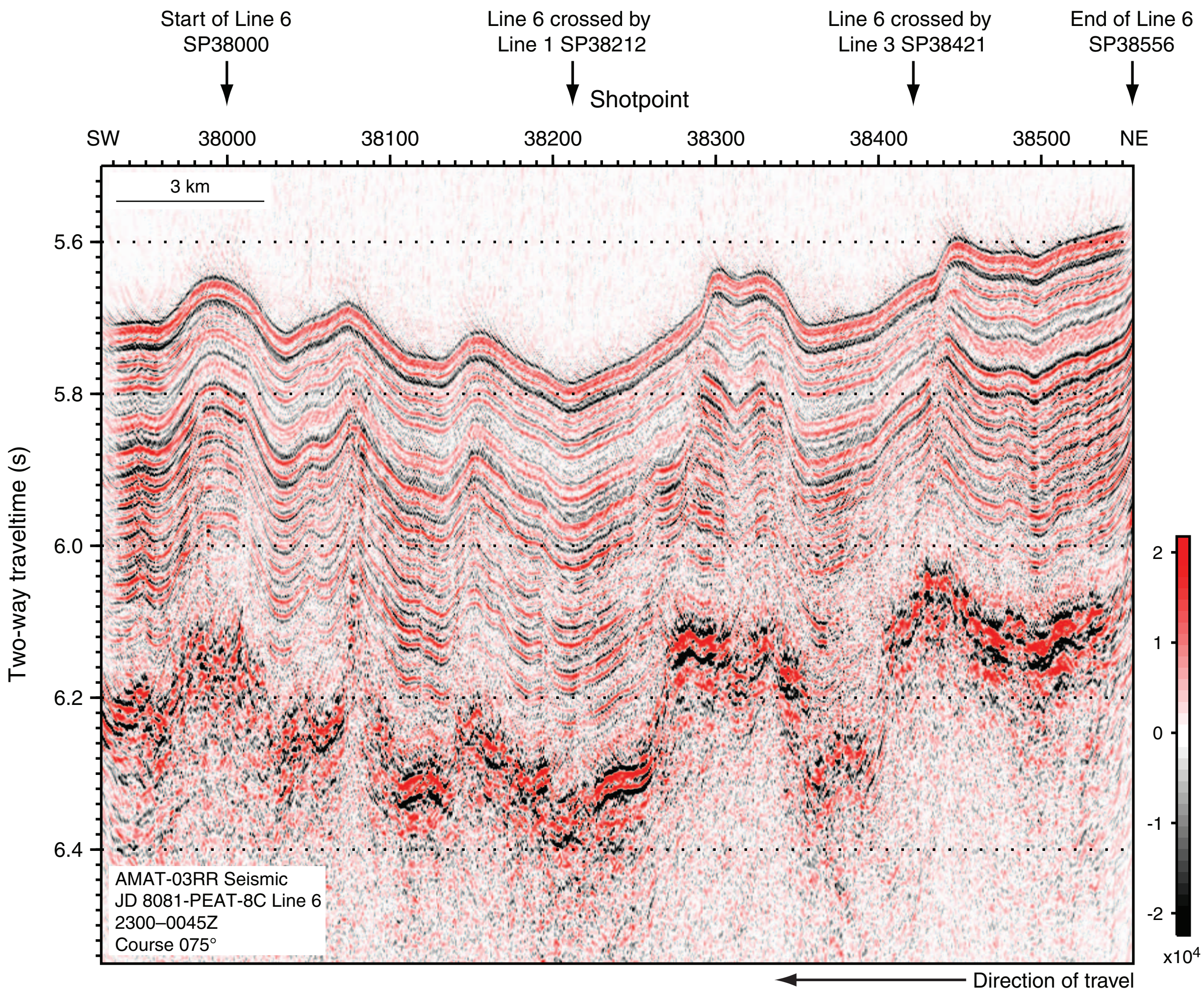
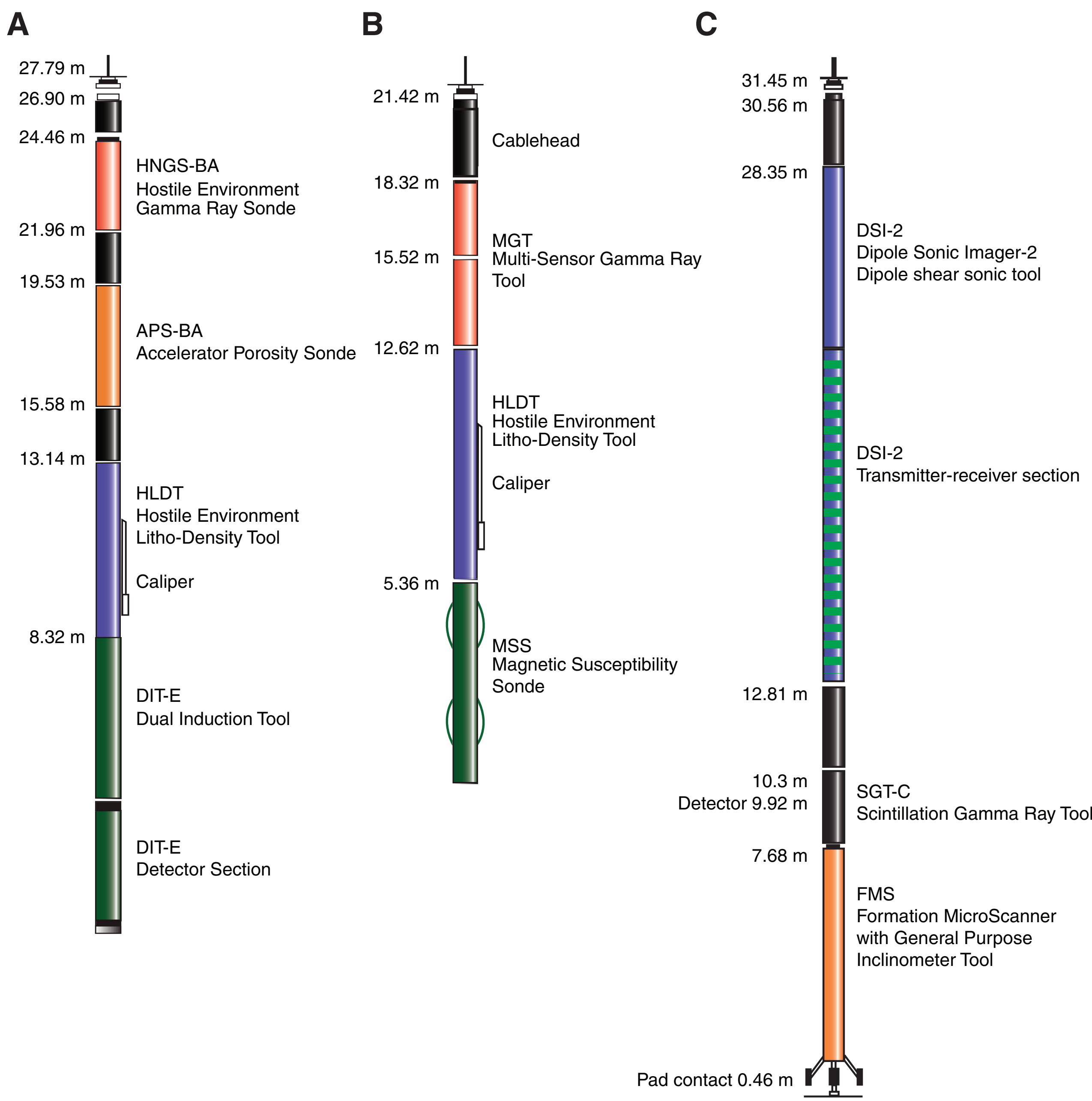


Figure F36. A. LDEO-BRG triple combo wireline tool string. **B.** LDEO-BRG wireline tool string and "paleo-combo," the preferred option for these expeditions. The paleo-combo is a combination of high-resolution tools that could be used enhance the potential for decimeter-scale core-log integration using natural gamma, density, and magnetic susceptibility. **C.** FMS-sonic tool string consisting of the Formation MicroScanner and Dipole Sonic Imager-2 for conductivity/resistivity and velocity data, respectively.



Site summaries

Site PEAT-1C (early Eocene Equator)

Priority:	Primary for Expedition 319, alternate for Expedition 317
Position:	12°04.089′N, 142°09.698′W (WGS-84)
Water depth (m):	5132 (6.842 s TWT)
Target drilling depth (mbsf):	187 then tag basement
Approved maximum penetration (mbsf):	250 (approved by TAMU safety panel based on EPSP June 2006 recommendation)
Survey coverage (track map; seismic profile):	*Roger Revelle* (7 April 2006; ~6 kt): • Simrad EM-120 multibeam system • Knudsen 320B subbottom profiler • Dual 150 c.i. GI seismic sources • Scripps 48-channel Geometrics GeoEel Piston core: 11.3 m (RR0603-11JC) Primary seismic line: PEAT-1 Line 8 (Figs. **F11, F12, F13**) (see also report to the EPSP panel, available at **eprints.soton.ac.uk/45921**)
Objectives:	Located on ~53 Ma crust to Intercept the 53–50 Ma interval in basal carbonate sediments above the shallow early Eocene CCD (4200–4300 m) and to obtain and characterize continuous sediment archive to basement.
Drilling program:	Preferred: • Holes A, B, C: APC with core orientation to refusal; XCB to basement; logging in Hole A Minimum: • Hole A: APC/XCB to basement • Holes B and C: wash to 100 m; APC/XCB to basement.
Downhole measurement program (low priority at this site):	• Wireline logging: triple combo, FMS-sonic, possibly check shot • Temperature measurements: 3 APCT-3, 2 DVTP
Nature of rock anticipated:	Clay, radiolarian ooze, nannofossil ooze/chalk, possibility of chert strings, hydrothermically altered ridge basalt

Site summaries (continued)

Proposed Site PEAT-1C: additional site survey data

PEAT-1 Line 8:	2006 JD 098 05:57:59 UTC SP 42439		
Nearest crossing:	Line 1 crosses Line 8 at 2006 JD 097 19:13:47 UTC, SP 38579		
Estimated crustal age (Ma):	53		
Ship location:	SP 42439: 12°04.039′N, 142°09.692′W		
Basement depth (m):	5319 (7.078 s TWT)		
Sediment thickness (m):	187 Estimated from Leg 199 composite (0.236 s TWT)		
Velocity (Busch et al., 2006):	**Depth (mbsf)**	**TWT (ms)**	**Velocity (m/s)**
	0–50	0–65	1540
	50–250	65–315	1600
	250–TD	>315	1660
Site PEAT-1C was sited south of the intersection between Lines 1 and 8 because the basal seismic horizons look weaker but are well imaged. The lack of nearby hills implies that this change is not the result of out-of-plane geometry. We looked for less strong basal seismic horizons to avoid cherts as much as possible. The sediment section is slightly thicker than average for the PEAT-1C survey region.			

Site summaries (continued)

Proposed Site PEAT-2C (early Eocene Equator and climatic optimum)

Priority:	Primary for Expedition 317, alternate for Expedition 319
Position:	11°54.711′N, 141°02.744′W (WGS-84)
Water depth (m):	4941 (6.588 s TWT)
Target drilling depth (mbsf):	162 then tag basement
Approved maximum penetration (mbsf):	250 (approved by TAMU safety panel based on EPSP June 2006 recommendation)
Survey coverage (track map; seismic profile):	*Roger Revelle* (6 April 2006; 6 kt): • Simrad EM-120 multibeam system • Knudsen 320B subbottom profiler • Dual 150 c.i. GI seismic sources • Scripps 48-channel Geometrics GeoEel Piston core: 11.31 m (RR0603-10JC) Primary seismic line: PEAT-2 Line 6 Crossline: PEAT-2 Line 1 (Figs. **F14, F15, F16**) (see also report to the EPSP panel, available at **eprints.soton.ac.uk/45921**)
Objective:	Sites PEAT-1C and 2C are located above 49–50 Ma basement to provide material from previously poorly recovered early and middle Eocene material at times of a very shallow CCD, during and after the early Eocene Climatic Optimum. This time period represents true Cenozoic “greenhouse” conditions followed by gradual climatic cooling.
Drilling program:	Preferred: • Holes A, B, and C: APC with core orientation to refusal; XCB to basement. Logging in Hole A. Minimum: • Hole A: APC/XCB to basement • Holes B and C: wash to 100 m; APC/XCB to basement
Downhole measurement program (low priority at this site):	• Wireline logging: triple combo, FMS-sonic, possibly check shot • Temperature measurements: 3 APCT-3, 2 DVTP
Nature of rock anticipated:	Clay, radiolarian ooze, nannofossil ooze/chalk, possibility of chert strings, hydrothermally altered ridge basalt

Site summaries (continued)

Proposed Site PEAT-2C: additional site survey data

<table>
<tr><td>PEAT-2 Line 6:</td><td colspan="3">2006 JD 096 17:52:29 UTC, SP 32971</td></tr>
<tr><td>Nearest crossing:</td><td colspan="3">Line 1 and Line 6 cross at 2006 JD 096 17:55:22 UTC, SP 32987 (L6) and 2006 JD 096 09:39:41 UTC, SP 30013 (L1)</td></tr>
<tr><td>Estimated crustal age (Ma):</td><td colspan="3">49–50</td></tr>
<tr><td>Ship location:</td><td colspan="3">SP 32971: 11°54.760′N, 141°02.748′W</td></tr>
<tr><td>Basement depth (m):</td><td colspan="3">5103 (6.793 s TWT)</td></tr>
<tr><td>Sediment thickness (m):</td><td colspan="3">162 from Leg 199 composite (0.205 s TWT)</td></tr>
<tr><td rowspan="4">Velocity (Busch et al., 2006):</td><td>Depth (mbsf)</td><td>TWT (ms)</td><td>Velocity (m/s)</td></tr>
<tr><td>0–50</td><td>0–65</td><td>1540</td></tr>
<tr><td>50–250</td><td>65–315</td><td>1600</td></tr>
<tr><td>250–TD</td><td>>315</td><td>1660</td></tr>
<tr><td colspan="4">Site PEAT-2C was sited close to the intersection between Lines 1 and 6 to maximize the thickness of the deeper section and minimize a set of high-amplitude, flat reflectors south of the crossing lines (possible chert, “peg-leg” type reflector between SPs 32713 and 32932). The cross and proposed drill sites are within the deep sediment fill between to north-south–running minor basement hills.</td></tr>
</table>

Site summaries (continued)

Proposed Site PEAT-3C (middle Eocene Equator)

Priority:	Primary for Expedition 319, alternate for Expedition 317
Position:	10°30.997′N, 138°25.175′W (WGS-84)
Water depth (m):	4874 (6.498 s TWT)
Target drilling depth (mbsf):	174 then tag basement
Approved maximum penetration (mbsf):	250 (approved by TAMU safety panel based on EPSP June 2006 recommendation)
Survey coverage (track map; seismic profile):	*Roger Revelle* (4–5 April 2006; 6 kt): • Simrad EM-120 multibeam system • Knudsen 320B subbottom profiler • Dual 150 c.i. GI seismic sources • Scripps 48-channel Geometrics GeoEel Piston core: 11.3 m (RR0603-09JC) Primary seismic line: PEAT-3 Line 3 Crossline: PEAT-3 Line 8 (Figs. F17, F18, F19) (see also report to the EPSP panel, available at eprints.soton.ac.uk/45921)
Objective:	Site PEAT-3C was sited on ~46 Ma crust to target the middle Eocene. Recent results from Leg 199 show a factor of up to 2–3 times increase in accumulation rates of siliceous ooze in the middle Eocene (41–45 Ma) and several notable periods of highly fluctuating CCD, associated with intervals in which carbonate is preserved to 4000 m, or ~700 m deeper than the average Eocene CCD. Such fluctuations in the CCD are similar in magnitude to those at the Eocene/Oligocene boundary. Site PEAT-3C aims to provide good carbonate recovery from this interval in order to apply the substantial array of carbonate-based proxies to this interval to evaluate the temperature and structure of the near-surface ocean.
Drilling program:	Preferred: • Holes A, B, and C: APC with core orientation to refusal; XCB to basement; logging in Hole A Minimum: • Hole A: APC/XCB to basement • Holes B and C: wash to 100 m; APC/XCB to basement
Downhole measurement program (low priority at this site):	• Wireline logging: triple combo, FMS-sonic, possibly check shot • Temperature measurements: 3 APCT-3, 2 DVTP
Nature of rock anticipated:	Clay, radiolarian ooze, nannofossil ooze/chalk, possibility of chert strings, hydrothermally altered ridge basalt

Site summaries (continued)

Proposed Site PEAT-3C: additional site survey data

PEAT-3 Line 3:	2006 JD 095 20:27:35 UTC, SP 21183		
Nearest crossing:	PEAT-5 Line 8 at 2006 JD 095 03:47:46 UTC, SP 12824		
Estimated crustal age (Ma):	46		
Ship location:	SP 21183: 10°30.999′N, 138°25.123′W		
Basement depth (m):	5048 (6.719 s TWT)		
Sediment thickness (m):	174 from Site 574 velocity profile (0.221 s TWT)		
Velocity (Mayer et al., 1985):	**Depth (mbsf)**	**TWT (ms)**	**Velocity (m/s)**
	0–76	0–100	1520
	76–151	100–193	1613
	151–330	193–410	1650
	>330–TD	>410	1970

Site PEAT-3C was chosen slightly west of the intersection between Lines 3 and 8 to maximize the thickness of the deeper section. The cross with Line 8, unfortunately, was just south of a minor basement hill. The low amplitudes of the seismic horizons suggest that the sediment is not lithified, fitting in with the shallow depth to basement. The drill site is a relatively small target, ~720 m across.

A second site, PEAT-3D, was chosen as an alternate (see **"Proposed Site PEAT-3D [alternate to Site PEAT-3C]"**). It is located ~2 km north of the cross between Lines 6 and 3 along Line 6. This alternate site has a slightly thinner basal section, although the total sediment column is slightly thicker. Subbottom profiling occasionally reveals indistinct horizons to ~60 m subsurface. However, over most of the area few or no subsurface horizons can be distinguished.

Site summaries (continued)

Proposed Site PEAT-4C (late Eocene and Eocene/Oligocene boundary)

Priority:	Primary for Expedition 319, alternate for Expedition 317
Position:	07°59.999′N, 131°58.396′W (WGS-84)
Water depth (m):	4809 (6.412 s TWT)
Target drilling depth (mbsf):	268 then tag basement
Approved maximum penetration (mbsf):	300 (approved by TAMU safety panel based on EPSP June 2006 recommendation)
Survey coverage (track map; seismic profile):	*Roger Revelle* (2 April 2006; 6 kt): • Simrad EM-120 multibeam system • Knudsen 320B subbottom profiler • Dual 150 c.i. GI seismic sources • Scripps 48-channel Geometrics GeoEel Piston core: 11.25 m (RR0603-08JC) Primary seismic line: PEAT-4 Line 1 Crossline: PEAT-4 Line 6 (Figs. **F20, F21, F22**) (see also report to the EPSP panel, available at **eprints.soton.ac.uk/45921**)
Objective:	Site PEAT-4C targets events bracketing the Eocene–Oligocene transition, specifically to recover latest Eocene carbonate-bearing sediments prior to deepening of the CCD that occurred during this greenhouse-to-icehouse transition. The site is located on late middle Eocene crust (~38 Ma). The Eocene–Oligocene transition experienced the most dramatic deepening of the Pacific CCD during the Paleogene, which has now been shown to coincide with a rapid stepwise increase in benthic oxygen stable isotope ratios, interpreted to reflect growth of the Antarctic ice sheet. Site PEAT-4C will be instrumental in obtaining a carbonate-bearing record in the late Eocene through the Eocene–Oligocene transition.
Drilling program:	Preferred: • Holes A, B, and C: APC with core orientation to refusal; then XCB to basement; logging in Hole A Minimum: • Hole A: APC/XCB to basement • Holes B and C: wash to 100 m; APC/XCB to basement
Downhole measurement program:	• Wireline logging: triple-combo, FMS-sonic, possibly check shot • Temperature measurements: 3 APCT-3, 2 DVTP
Nature of rock anticipated:	Clay, radiolarian ooze, nannofossil ooze/chalk, possibility of chert strings and thin diatom layers, hydrothermically altered ridge basalt

Site summaries (continued)

Proposed Site PEAT-4C: additional site survey data

PEAT-4 Line 3:	2006 JD 092 02:19:49 UTC, SP 01639		
Nearest crossing:	PEAT-4 Line 1 at 2006 JD 092 02:19:49 UTC, SP 01639 and Line 6 at JD 092 10:23:29 UTC, SP 04541		
Estimated crustal age (Ma):	37–39		
Ship location:	SP 01639: 7°59.9968′N, 131°58.443′W		
Basement depth (m):	5077 (6.757 s TWT)		
Sediment thickness (m):	268 from Site 574 velocity profile (0.345 s TWT)		
Velocity (Mayer et al., 1985):	**Depth (mbsf)**	**TWT (ms)**	**Velocity (m/s)**
	0–76	0–100	1520
	76–151	100–193	1613
	151–330	193–410	1650
	>330–TD	>410	1970
Site PEAT-4C was sited at the intersection of Lines 1 and 6 because the sediment and basement are well imaged. Additional thickness away from the cross of Lines 1 and 6 is primarily Miocene sediment on top, not the section of primary interest below. The subbottom profiler sections image ~20 m of transparent surface sediment and ~100 m of layered sediments in the upper sediment column.			

Site summaries (continued)

Proposed Site PEAT-5C (Oligocene Equator)

Priority:	Primary alternate for Expedition 319, alternate for Expedition 317
Position:	07°42.075′N, 128°15.254′W (WGS-84)
Water depth (m):	4311 (5.748 s TWT)
Target drilling depth (mbsf):	253 then tag basement
Approved maximum penetration (mbsf):	300 (approved by TAMU safety panel based on EPSP June 2006 recommendation)
Survey coverage (track map; seismic profile):	*Roger Revelle* (31 March 2006): • Simrad EM-120 multibeam system • Knudsen 320B subbottom profiler • Dual 150 c.i. GI seismic sources • 4-channel streamer Piston core: 11.1 m (RR0603-07JC) Primary seismic line: PEAT-5 Line 6 Crossline: PEAT-5 Line 1 (Figs. **F23, F24, F25, F26**) (see also report to the EPSP panel, available at **eprints.soton.ac.uk/45921**)
Objective:	Site PEAT-5C targets lower Oligocene crust to • Obtain well-recovered and well-preserved equatorial sections during a time of relatively deep CCD to extend and supplement existing astronomical time calibrations • Investigate how a "one cold pole" world might impact the inter-hemispheric temperature imbalance on pole-to-Equator temperature gradients and on the symmetry of the global wind systems • Gain new information on the position of trade winds, the position of the ITCZ, and the seasonal shifts in this zone, as reflected by the wind-driven currents of the equatorial region • Form a limited depth transect with Sites PEAT-4C and 6C
Drilling program:	Preferred: • Holes A, B, and C: APC with core orientation to refusal; XCB to basement; logging in Hole A Minimum: • Hole A: APC/XCB to basement • Holes B and C: wash to 100 m; APC/XCB to basement
Downhole measurement program:	• Wireline logging: triple combo, FMS-sonic, possibly check shot • Temperature measurements: 3 APCT-3, 2 DVTP
Nature of rock anticipated:	Clay, radiolarian/nannofossil ooze, nannofossil ooze/chalk, possibility of thin diatom layers, hydrothermically altered ridge basalt. Low possibility of chert strings

Site summaries (continued)

Proposed Site PEAT-5C: additional site survey data

PEAT-5 Line 6:	2006 JD 090 11:07:48 UTC, SP 42593	
Nearest crossing:	PEAT-5C Line 1 at 2006 JD 090 03:27:49 UTC, SP 39833 and Line 6 at JD 090 11:36:58 UTC, SP 42768	
Estimated crustal age (Ma):	31–32	
Ship location:	SP 42593: 7°42.062′N, 128°15.188′W	
Basement depth (m):	4564 (6.064 s TWT)	
Sediment thickness (m):	252 (estimated) (0.316 s TWT)	
Velocity (Mayer et al., 1985):	**Depth (mbsf)**	**Velocity (m/s)**
	0–100	1520
	100–193	1613
	193–410	1650
	>410	1970
Site PEAT-5C was chosen on a hill west of the intersection of Lines 6 and 1 because the lower section was better imaged and the basement was distinct and because the additional thickness at the cross of Lines 1 and 6 was primarily caused by Miocene sediment on top and not by the section of primary interest below. Subbottom profiler sections image ~60 m of layered sediments in the upper sediment column.		

Site summaries (continued)

Proposed Site PEAT-6C (Oligocene–Miocene transition)

Priority:	Primary for Expedition 317, alternate for Expedition 319
Position:	05°18.736′N, 126°16.997′W (WGS-84)
Water depth (m):	4362 (5.816 s TWT)
Target drilling depth (mbsf):	362 then tag basement
Approved maximum penetration (mbsf):	400 (approved by TAMU safety panel based on EPSP June 2006 recommendation)
Survey coverage (track map; seismic profile):	*Roger Revelle* (27–28 March 2006): • Simrad EM-120 multibeam system • Knudsen 320B subbottom profiler • Dual 150 c.i. GI seismic sources • Scripps 48-channel Geometrics GeoEel Piston core: 12.67 m (RR0603-06JC) Primary seismic line: PEAT-6 Line 8 Crossline: PEAT-6 Line 1 (Figs. F27, F28, F29) (see also report to the EPSP panel, available at eprints.soton.ac.uk/45921)
Objective:	Site PEAT-6C, on 26 Ma crust, focuses on the paleoceanographic events in the late Oligocene and into the early and middle Miocene, including the climatically significant Oligocene–Miocene transition and its recovery. In conjunction with Sites PEAT-5C and 7C it is also designed to provide a latitudinal transect for early Miocene age slices, as well as a limited depth transect.
Drilling program:	Preferred: • Holes A, B, and C: APC with core orientation to refusal; XCB to basement; logging in Hole A Minimum: • Hole A: APC/XCB to basement • Holes B and C: wash to 100 m; APC/XCB to basement
Downhole measurement program:	• Wireline logging: triple combo, FMS-sonic, possibly check shot • Temperature measurements: 3 APCT-3, 2 DVTP
Nature of rock anticipated:	Clay, radiolarian/nannofossil ooze, nannofossil ooze/chalk, possibility of thin diatom layers, hydrothermically altered ridge basalt; low possibility of chert strings

Site summaries (continued)

Proposed Site PEAT-6C: additional site survey data

PEAT-6 Line 8:	2006 JD 087 08:14:59 UTC, SP 19103	
Nearest crossing:	PEAT-6 Line 1 at 2006 JD 087 08:26:19 UTC, SP 16216 (SP 19171 on Line 8 using ship's position)	
Estimated crustal age (Ma):	26–27	
Ship location:	SP 19103: 5°18.807′N, 126°16.998′W	
Basement depth (m):	4723 (6.257 s TWT)	
Sediment thickness (m):	361 (estimated) (0.441 s TWT)	
Velocity (Mayer et al., 1985):	**Depth (mbsf)**	**Velocity (m/s)**
	0–100	1520
	100–193	1613
	193–410	1650
	>410	1970
Site PEAT-6C was initially chosen near the intersection of Lines 1 and 8. The thickness of the deposits in basins along the seismic lines are typical. The site was then moved south along seismic Line 8 where it was originally located in order to obtain a better imaged basement reflector and to capture the slightly expanded lower target section. Subbottom profiler sections image ~100 m of layered sediments in the upper sediment column.		

Site summaries (continued)

Proposed Site PEAT-7C (early to middle Miocene Equator)

Priority:	Primary for Expedition 317, alternate for Expedition 319
Position:	03°50.009′N, 123°12.352′W (WGS-84)
Water depth (m):	4491 (5.988 s TWT)
Target drilling depth (mbsf):	452 then tag basement
Approved maximum penetration (mbsf):	480 (approved by TAMU safety panel based on EPSP June 2006 recommendation)
Survey coverage (track map; seismic profile):	*Roger Revelle* (25 March 2006): • Simrad EM-120 multibeam system • Knudsen 320B subbottom profiler • Dual 150 c.i. GI seismic sources • Scripps 48-channel Geometrics GeoEel Piston core: 14.09 m (RR0603-05JC) Primary seismic line: PEAT-7 Line 4 Crossline: PEAT-7 Line 10 (Figs. **F30, F31, F32**) (see also report to the EPSP panel, available at **eprints.soton.ac.uk/45921**)
Objective:	Site PEAT-7C, on 24 Ma crust, focuses on early and middle Miocene paleoceanographic events. The latest Oligocene–middle Miocene appears to have been relatively warm, comparable to the latest Eocene. However, variability in the isotopic record of the early–middle Miocene compared to that of the Eocene may indicate more variability in climate and global ice volume. The climatic “optimum” at ~15 Ma is just before development of major ice sheets on Antarctica and a marked increase in ice-rafted debris in circum-Antarctic sediments. The early Miocene also marks a major evolutionary change from relatively static Oligocene planktonic biota; in the equatorial Pacific abundant diatoms imply a major change in carbon cycling as well. In conjunction with Sites PEAT-5C, 6C, and 8C, it is designed to provide a latitudinal transect for early Miocene age slices, as well as a limited depth transect.
Drilling program:	Preferred: • Holes A, B, and C: APC with core orientation to refusal; XCB to basement.; logging in Hole A Minimum: • Hole A: APC/XCB to basement • Holes B and C: wash to 200 m; APC/XCB to basement
Downhole measurement program:	• Wireline logging: triple combo, FMS-sonic, possibly check shot • Temperature measurements: 3 APCT-3, 2 DVTP
Nature of rock anticipated:	Clay, radiolarian/nannofossil ooze, nannofossil ooze/chalk, possibility of thin diatom layers, hydrothermically altered ridge basalt; low possibility of chert strings

Site summaries (continued)

Proposed Site PEAT-7C: additional site survey data

PEAT-7 Line 4:	2006 JD 084 16:53:48 UTC, SP 1756	
Nearest crossing:	PEAT-7C Line 10 at 2006 JD 084 23:20:59 UTC, SP 4071	
Estimated crustal age (Ma):	24	
Ship location:	SP 1756: 3°50.006′N, 123°12.352′W	
Basement depth (m):	4966 (6.522 s TWT)	
Sediment thickness (m):	452 (estimated) (0.534 s TWT)	
Velocity (Mayer et al., 1985):	**Depth (mbsf)**	**Velocity (m/s)**
	0–100	1520
	100–193	1613
	193–410	1650
	>410	1970
Site PEAT-7C was chosen near the intersection of Lines 4 and 10. The section is typical in the thickness of the deposits within the small basins imaged along Line 4. The site was moved to the west side of the basin so that it would be over well-imaged basement. Subbottom profiler sections image ~80 m of layered sediments in the upper sediment column.		

Site summaries (continued)

Proposed Site PEAT-8C (eastern equatorial Pacific)

Priority:	Alternate for both expeditions
Position:	02°36.327′N, 117°59.412′W (WGS-84)
Water depth (m):	4330 (5.773 s TWT)
Target drilling depth (mbsf):	455 then tag basement
Approved maximum penetration (mbsf):	480 (approved by TAMU safety panel based on EPSP June 2006 recommendation)
Survey coverage (track map; seismic profile):	*Roger Revelle* (21 March 2006): • Simrad EM-120 multibeam system • Knudsen 320B subbottom profiler • Dual 150 c.i. GI seismic sources • Scripps 48-channel Geometrics GeoEel Piston core: 10.87 m (RR0603-03JC) Primary seismic line: PEAT-8 Line 1 Crossline: PEAT-8 Line 6 (Figs. **F33, F34, F35**) (see also report to the EPSP panel, available at **eprints.soton.ac.uk/45921**)
Objective:	Site PEAT-8C focuses on paleoceanographic events following a middle Miocene maximum in deposition along with large changes in the glaciation state and frequency in the interval following ~14 Ma. There is a wide latitude range of $CaCO_3$ deposition during the earliest Neogene, with a relatively sharp transition to a narrower $CaCO_3$ belt after 20 Ma. $CaCO_3$ MARs in the central equatorial Pacific recovered from the 18–19 Ma "famine" and at 14–16 Ma reached a second maximum in carbonate deposition, which is also evident in the seismic stratigraphy of the equatorial sediment bulge. We designed Site PEAT-8C to recover an equatorial record at the early middle Miocene sedimentation maximum on 18 Ma crust.
Drilling program:	Preferred: • Holes A, B, and C: APC with core orientation to refusal; XCB to basement; logging in Hole A Minimum: • Hole A: APC/XCB to basement • Holes B and C: wash to 200 m; APC/XCB to basement
Downhole measurement program:	• Wireline logging: triple combo, FMS-sonic, possibly check shot • Temperature measurements: 3 APCT-3, 2 DVTP
Nature of rock anticipated:	Clay, nannofossil ooze, nannofossil ooze/chalk, possibility of thin diatom layers, hydrothermically altered ridge basalt; low possibility of chert strings

Site summaries (continued)

Proposed Site PEAT-8C: additional site survey data

PEAT-8 Line 1:	2006 JD 080 17:41:53 UTC, SP 36015	
Nearest crossing (1.24 km):	PEAT-8C Line 6 at 2006 JD 080 23:48:13 UTC, SP 38212	
Estimated crustal age (Ma):	18	
Ship location:	SP 36015: 2°36.395′N, 117°59.429′W	
Basement depth (m):	4746 (6.330 s TWT)	
Sediment thickness (m):	446 (estimated) (0.557 s TWT)	
Velocity (from ODP Site 849):	**TWT (ms)**	**Velocity (m/s)**
	0–100	1504.4
	100–200	1542.3
	200–300	1633.7
	300–544	1700.8
Site PEAT-8C was chosen near the intersection of Lines 1 and 6. The sediment here is of typical thickness but was moved away from the line crossing primarily because of a small fault right at the cross-imaged in Line 6 and also because the basement reflector was well developed at the new location. The site location has a relatively flat basement structure that was well imaged by seismic reflection. Sediment thickness was estimated from ODP Site 849, which has lithologies similar to Site PEAT-8C. Subbottom profiler sections image ~50 m of layered sediments in the upper sediment column.		

Site summaries (continued)

Proposed Site PEAT-3D (alternate to Site PEAT-3C)

Priority:	Alternate to Site PEAT-3C
Position:	10°32.720′N, 138°20.183′W (WGS-84)
Water depth (m):	4889 (6.519 s TWT)
Target drilling depth (mbsf):	181 then tag basement
Approved maximum penetration (mbsf):	250 (approved by TAMU safety panel based on EPSP May–June 2007 recommendation)
Survey coverage (track map; seismic profile):	*Roger Revelle* (4–5 April 2006): • Simrad EM-120 multibeam system • Knudsen 320B subbottom profiler • Dual 150 c.i. GI seismic sources • Scripps 48-channel Geometrics GeoEel Piston core: 11.3 m (RR0603-09JC) Primary seismic line: PEAT-3 Line 6 Crossline: PEAT-3 Line 3 (Figs. **F17, F18, F19**) (see also report to the EPSP panel, available at **eprints.soton.ac.uk/45921**)
Objective:	Site PEAT-3D was sited on ~46 Ma crust to target the middle Eocene. Recent results from Leg 199 show a factor of up to 2–3 times increase in accumulation rates of siliceous ooze within the middle Eocene (41–45 Ma). Several notable periods of highly fluctuating CCD are associated with intervals in which carbonate is preserved to 4000 m, or ~700 m deeper than the average Eocene CCD. Such fluctuations in the CCD are similar in magnitude to the Eocene/Oligocene boundary. Site PEAT-3C aims to provide good carbonate recovery during this interval in order to apply the substantial array of carbonate-based proxies to this interval in order to evaluate the temperature and structure of the near-surface ocean.
Drilling program:	Preferred: • Holes A, B, and C: APC with core orientation to refusal; XCB to basement; logging in Hole A Minimum: • Hole A: APC/XCB to basement • Holes B and C: wash to 100 m; APC/XCB to basement.
Downhole measurement program (low priority at this site):	• Wireline logging: triple combo, FMS-sonic, possibly check shot • Temperature measurements: 3 APCT-3, 2 DVTP
Nature of rock anticipated:	Clay, radiolarian ooze, nannofossil ooze/chalk, possibility of chert strings, hydrothermically altered ridge basalt

Site summaries (continued)

Proposed Site PEAT-3D: additional site survey data

<table>
<tr><td>PEAT-3 Line 6:</td><td colspan="3">2006 JD 095 00:43:29 UTC, SP 22721</td></tr>
<tr><td>Nearest crossing:</td><td colspan="3">PEAT-3 Line 3 at 2006 JD 094 21:18:15 UTC, SP 21487</td></tr>
<tr><td>Estimated crustal age (Ma):</td><td colspan="3">46</td></tr>
<tr><td>Ship location:</td><td colspan="3">SP 22721: 10°32.772′N, 138°20.183′W</td></tr>
<tr><td>Basement depth (m):</td><td colspan="3">4889 (6.519 s TWT)</td></tr>
<tr><td>Sediment thickness (m):</td><td colspan="3">181 from Site 574 velocity profile (0.229 s TWT)</td></tr>
<tr><td rowspan="5">Velocity (Mayer et al., 1985):</td><td>Depth (mbsf)</td><td>TWT (ms)</td><td>Velocity (m/s)</td></tr>
<tr><td>0–76</td><td>0–100</td><td>1520</td></tr>
<tr><td>76–151</td><td>100–193</td><td>1613</td></tr>
<tr><td>151–330</td><td>193–410</td><td>1650</td></tr>
<tr><td>>330–TD</td><td>>410</td><td>1970</td></tr>
<tr><td colspan="4">Site PEAT-3D was chosen as an alternate site, ~2 km north of the cross between Lines 6 and 3 along Line 6. This site has a slightly thinner basal section, although the total sediment column is slightly thicker. Subbottom profiling occasionally reveals indistinct horizons to ~60 m subsurface. However, over most of the area few or no subsurface horizons can be distinguished.</td></tr>
</table>

Site summaries (continued)

Proposed Site PEAT-5D (alternate to Site PEAT-5C)

Priority:	Alternate to Site PEAT-5C
Position:	07°42.069′N, 128°06.568′W (WGS-84)
Water depth (m):	4400 (5.867 s TWT)
Target drilling depth (mbsf):	296 then tag basement
Approved maximum penetration (mbsf):	330 (approved by TAMU safety panel based on EPSP May–June 2007 recommendation)
Survey coverage (track map; seismic profile):	*Roger Revelle* (31 March 2006): • Simrad EM-120 multibeam system • Knudsen 320B subbottom profiler • Dual 150 c.i. GI seismic sources • 4-channel streamer Piston core: 11.1 m (RR0603-07JC) Primary seismic line: PEAT-5 Line 6 Crossline: PEAT-5 Line 3 (Figs. **F24, F25, F26**) (see also report to the EPSP panel, available at **eprints.soton.ac.uk/45921**)
Objective:	Site PEAT-5D (alternate to Site PEAT-5C) targets the Oligocene and is located on lower Oligocene crust. Our aims are to • Obtain continuous and well-preserved equatorial sections during a time of relatively deep CCD to extend and supplement existing astronomical time calibrations • Investigate how a "one cold pole" world might impact the inter-hemispheric temperature imbalance on pole-to-Equator temperature gradients and on the symmetry of the global wind systems • Gain new information on the position of trade winds, the position of the ITCZ, and the seasonal shifts in this zone, as reflected by the wind-driven currents of the equatorial region • Form a limited depth transect with Sites PEAT-4C and 6C
Drilling program:	Preferred: • Holes A, B, and C: APC with core orientation to refusal; XCB to basement; logging in Hole A Minimum: • Hole A: APC/XCB to basement • Holes B and C: wash to 100 m; APC/XCB to basement
Downhole measurement program (low priority at this site):	• Wireline logging: triple combo, FMS-sonic, possibly check shot • Temperature measurements: 3 APCT-3, 2 DVTP
Nature of rock anticipated:	Clay, radiolarian/nannofossil ooze, nannofossil ooze/chalk, possibility of thin diatom layers, hydrothermically altered ridge basalt; low possibility of chert strings

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