IODP Proposal Cover Sheet

☐ **New** ☐ **Revised** ☐ **Addendum**

Please fill out information in all gray boxes

Title:	Cenozoic Pacific Equatorial Age Transect – Following the Palaeo-equator
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Abstract: (*400 words or less)*

As the largest ocean, the Pacific is intricately linked to major changes in the global climate system that took place during the Cenozoic. Throughout the Cenozoic the Pacific plate 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 ODP Legs 138 and 199 were designed as transects across the paleo-equator in order to study the changing patterns of sediment deposition across equatorial regions, while this proposal aims to recover an orthogonal "age-transect" along the paleo-equator. Both previous legs were 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 ITCZ, and evolutionary patterns for times of climatic change and upheaval. Together with older DSDP drilling in the eastern equatorial Pacific, both Legs also helped to delineate the position of the paleo-equator and variations in sediment thickness from approximately 150°W to 110°W.

As we have gained more information about the past movement of plates, and where in time "critical" climate events are located, we now propose to drill an age-transect ("flow-line") along the position of the paleo-equator in the Pacific, targeting selected time-slices of interest where calcareous sediments have been preserved best. Leg 199 enhanced our understanding of extreme changes of the calcium carbonate compensation depth across major geological boundaries during the last 55 million years. A very shallow CCD during most of the Paleogene makes it difficult to obtain well preserved sediments, but we believe our siting strategy will allow us to drill the most promising sites and to obtain a unique sedimentary biogenic carbonate archive for time periods just after the Paleocene-Eocene boundary event, the Eocene cooling, the Eocene/Oligocene transition, the "one cold pole" Oligocene, the Oligocene-Miocene transition, and the Miocene, contributing to the objectives of the IODP Extreme Climates Initiative, and providing material that the previous legs were not able to recover.

Scientific Objectives: (*250 words or less*)

We propose an ocean drilling cruise with the aim to achieve an age transect along the paleo-equatorial Pacific spanning the early Eocene to Miocene (with earlier intervals being covered by previous ODP Legs). Drill sites target specific time-slices of interest, at locations that provide optimum preservation of calcareous sediments. Recovered cores will contribute towards (1) resolving questions of how and why paleo-productivity of the equatorial Pacific changed over time, (2) provide rare material to validate and extend the astronomical calibration of the geological time scale for the Cenozoic, (3) determine sea-surface and benthic temperature and nutrient profiles and gradients, (4) provide important information about the detailed nature of calcium carbonate dissolution and changes of the CCD, (5) enhance our understanding of bio- and magnetostratigraphic datums at the equator, as well as (6) provide information about rapid biological evolution and turn-over during times of climatic stress. (7) As our strategy also implies a paleo-depth transect, we hope to improve our knowledge about the reorganization of water masses as a function of depth and time. (8) Integrated with additional site-survey proposals, we intend to make use of the high level of correlation between tropical sediment sections and seismic stratigraphy to develop a more complete model of equatorial circulation and sedimentation. (9) Due to the northward component of the Pacific plate motion, our siting strategy also implies a limited N-S transect across the paleo-equator for some of the proposed time slices, providing additional information about N-S hydrographic gradients.

Please describe below any non-standard measurements technology needed to achieve the proposed scientific objectives.

Proposed Sites:

Site Name	Position	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
						Obtain calcareous sediments along an paleo-equatorial age-transect to decipher paleoceanography and paleoclimatology from the:
PEAT-1B	141.8°W 12.3°N	4947	~200m	5m	~205m	earliest Eocene
PEAT-2B	140.8°W 11.5°N	4911	~200m	5m	~205m	middle Eocene
PEAT-3B	138.3°W 10.6°N	4866	~200m	5m	~205m	middle/late Eocene
PEAT-4B	131.7°W 7.5°N	4789	~250m	5m	~255m	E/O boundary
PEAT-5B	128.2°W 7.6°N	4533	~320m	5m	~325m	Oligocene
PEAT-6B	126.1°W 5.1°N	4399	~300m	5m	~305m	O/M boundary
PEAT-7B	123.0°W 4.0°N	4511	~300m	5m	~305m	Miocene
PEAT-8B	118.0°W 1.3°N	3965	~350m	5m	~355m	Miocene

Following the Equator in Time and Space

A proposal for IODP drilling (16th Jan 2003, revised March 2004)

Introduction

The equatorial surface ocean circulation 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 that gives rise to a band of high biologic productivity. The strength of the equatorial circulation and of this divergence is linked to the strength of the trade winds, which are in turn strongly tied to the global climate system. Variation in global climate, inter-hemispheric 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. This proposal is designed to provide an understanding of equatorial Pacific circulation, and the carbonate production, deposition and dissolution, for the last 55 million years at a scale where orbital forcing can be measured. Combined with seismic reflection data following in the vein of Mitchell et al. (2003) and synthesized with earlier drilling (e.g. Moore et al., 2003; Moore et al., submitted) we can reconstruct equatorial Pacific history with high confidence and substantially improve upon work from the early stages of DSDP and recent ODP Legs.

Drilling for the history of the equatorial Pacific has been greatly simplified by a favorable motion for the Pacific Plate. Throughout the Cenozoic, the movement of the Pacific plate has had a northward component of around 0.25°/Myr. 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. 1). This transport prevents the older equatorial sections from being buried deeply beneath the younger sections as the crust moves northward. The diminished overburden resulting from this transport also allows relatively good preservation of the biogenic debris. In addition it allows us to core nearly all sections using the advanced piston coring technique. The northward tectonic displacement, however, is not so large that a traverse of the equatorial zone (within 2°of the equator) was too rapid to record a reasonable period of equatorial ocean history. Typically drill sites remain within the equatorial zone for 10-20 Myr 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 northward. The diminished overburden resulting minimizes burial diagenesis of the biogenic debris. It also allows APC piston coring of much of this section with the right placement strategy for drill sites (Lyle et al., 2002).

In their summary of the Deep Sea Drilling results in the equatorial Pacific, van Andel et al. (1975) gave a general view of the development of the equatorial mound of sediments in the Pacific Ocean, based mostly upon three early drilling legs, 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 varying carbonate preservation. The buildup of the Pacific equatorial mound of sediment has been more recently documented and discussed by Mitchell (1998, 2002; Fig. 1).

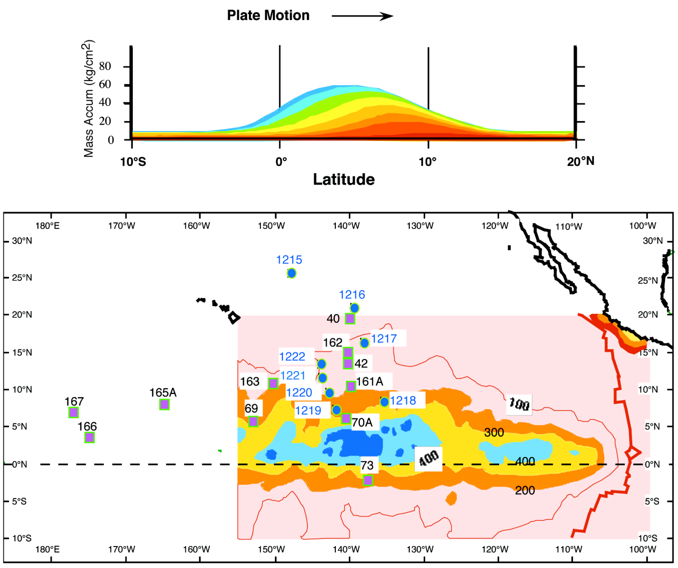

Figure 1: Top: Model cross section of equatorial sediment mound taking into account the northward drift of the Pacific plate. Bottom: Mapped thickness of the Pacific equatorial sediment mound. (Both modified from Mitchell, 1998; Mitchell et al., 2003).

Drilling across the Pacific equatorial mound was addressed again some twenty years after the van Andel et al. (1975) compilation when ODP Leg 138 drilled an equatorial transect along 10 Ma crust, and then again 10 years later when ODP Leg 199 conducted a similar transect along 56 Ma crust. The newer drilling, coupled with major advances in geochronology, has documented the remarkable correlation of paleoceanographic events over thousands of km in the equatorial Pacific, caused by the large scale of Pacific equatorial circulation (Fig. 2). 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.

The early drilling missed most of this detail because of the lack of important drilling technologies. APC coring, MST correlation, and core-log integration now allow the collection of relatively undisturbed sediments, the rebuilding of a continuous sediment column from individual cores, and the correlation to seismic reflection data.

That, and improved knowledge of the plate tectonic regime, will allow us to locate the thick sediment package near the paleo-equator. Combining multiple holes 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 time scale as well as for the paleoceanographic information they contain.

ODP Legs 138 and 199 in the Pacific equatorial area have recovered excellent sections on which the detailed orbital tuning of the geologic time scale is being carried out. These sections give a much clearer picture of variation 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 still parts of the Cenozoic time scale that require further refinement and verification of the proposed orbital tuning. The time scale older than the late Eocene has not been tuned at all, 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).

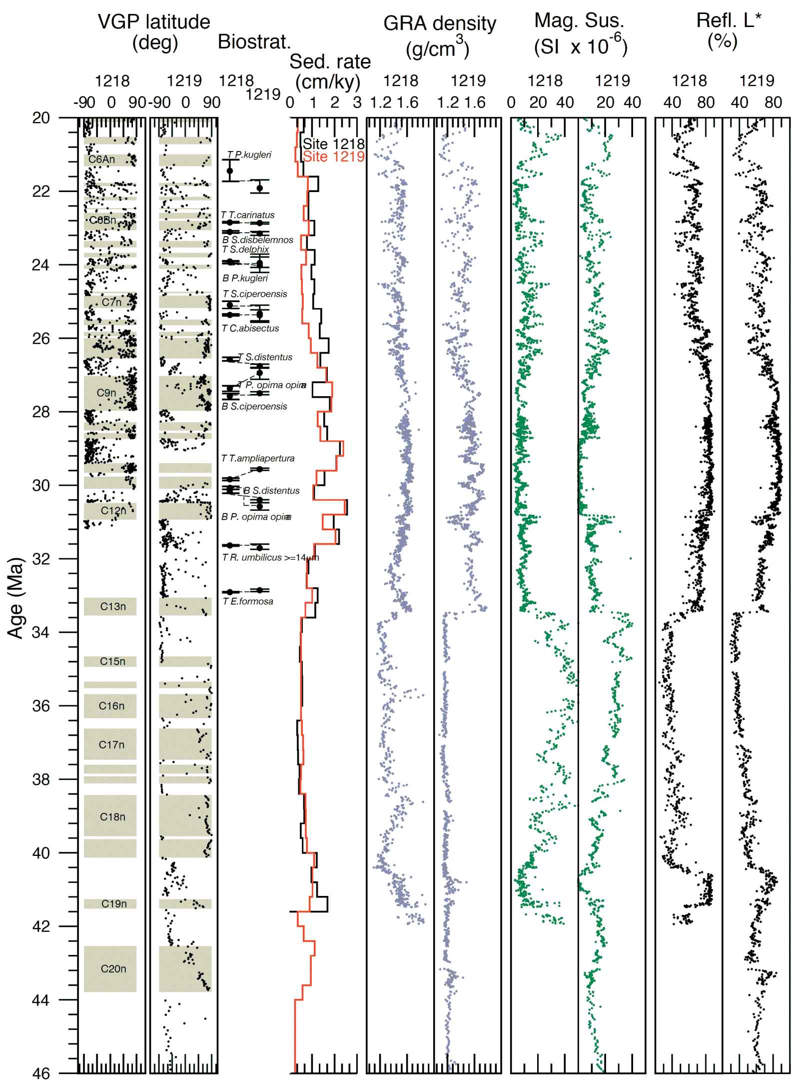

Figure 2 from Shipboard Scientific Party (2002): Coherence of sediment properties between widely separated drill sites in the equatorial Pacific is very high, allowing extrapolation and prediction of sediment properties over hundreds of kilometers. These two sites from ODP Leg 199 are more than 740 km apart.

The Overall Strategy

To develop a detailed history of the Pacific equatorial current system, the strategy pursued in the most recent ODP legs (199 and 138) was to drill along a line of equal age of the ocean crust. This was done in order to obtain a ~N-S transect across the major E-W currents and to overcome the problem of relatively poor carbonate preservation in the Pacific, particularly in times when the CCD was very shallow.

Drilling at a paleo-ridgecrest allows the recovery of the shallowest sections available in the pelagic oceans, and thereby assures the best possible preservation of the carbonate sediments recovered. However, 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 really well preserved part of the sections recovered in such "time-line" transects is restricted by the depth at which carbonate preservation is substantially diminished, 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, which recovered only limited amounts of carbonate prior to the Eocene/Oligocene boundary.

In this drilling effort we propose to overcome this limitation of the "time-line" strategy by pursuing an equatorial age transect, or "flow-line" strategy (Fig. 3), to collect well-preserved equatorial sections through the Cenozoic, while also making use of the Pacific plate motion to add an oblique transect across all time slices.

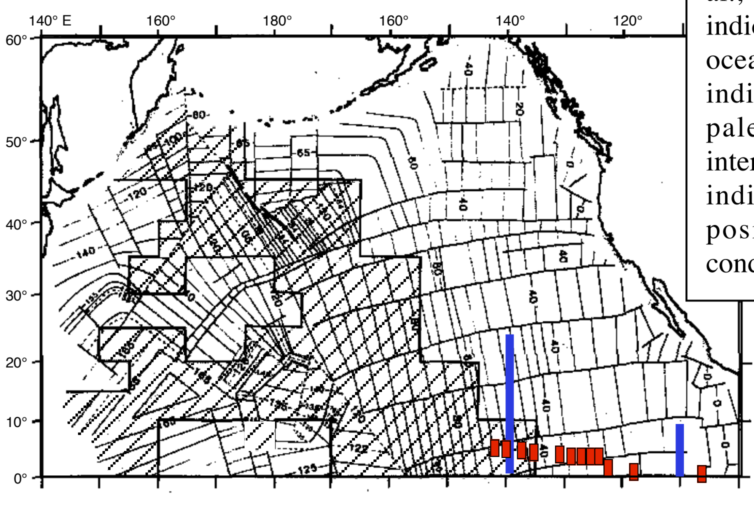

Figure 3: Age of ocean crust in the North Pacific (Renkin and Sclater, 1988) based on magnetic lineations compiled by Cande et al. (1986) and the tectonic histories of Hilde et al. (1977), Larson, (1976), and Rea and Dixon (1983). Contour interval is 5 M.y. (Age model from Berggren et al., 1985). Diagonally shaded area indicates regions where the age of the ocean floor is uncertain. Rectangles indicate estimated location of the paleoequator for the proposed intervals of study. Vertical dotted bars indicate approximate longitudinal positions of seismic transects conducted for ODP Legs 138 and 199.

We propose to drill a series of sites on the paleo-equator at key intervals in the evolution of the Cenozoic climate. These intervals span the very warm times of the Eocene, through the cooling of the late Eocene and Oligocene, 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 (Fig. 4). There are only very few previous sites that match our site selection criteria (Table 1). Each site is selected to be close to the geographic paleo-equator and on crust of an age slightly older than the intervals of particular interest.

In this way we track the paleoceanographic conditions at the paleo-equator, in the best preserved sediments obtainable. Integrated with additional site-survey proposals, we will also make use of the high level of correlation between tropical sediment sections and seismic stratigraphy to develop a more complete model of equatorial circulation and sedimentation.

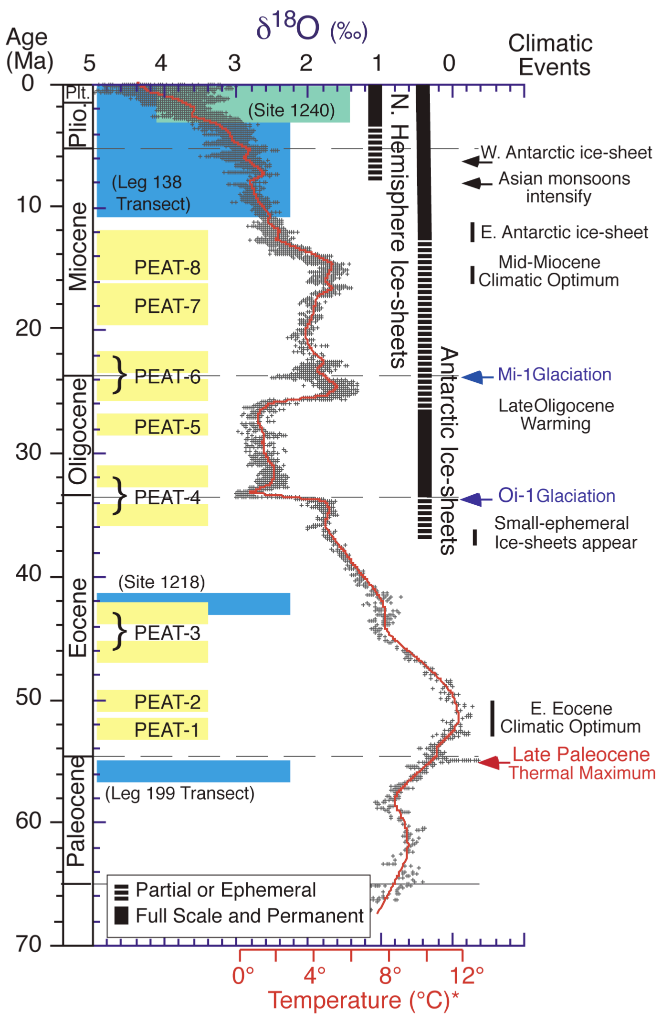

Figure 4: Time slices of specific climatic interest proposed for sampling. Sites with slightly older crustal ages on the Pacific paleo-equator (after Zachos et al., 2001b).

Leg	Site	#Holes (target)	Drilling tech.	PEAT target age (Ma)	Carbonate finds (age in Ma) young	old
DSDP 5	42	2	R	51-49	20	51
DSDP 9	**78**	**1**	**R**	**27-28**	**11**	**34**
DSDP 9	79	2	R	16-20	0	24.5
ODP 199	**1217**	**3**	**A/X**	**49-53**	**32**	**53.5, 34**
ODP 199	**1218**	**3**	**A/X**	**49-53**	**11**	**42.5**
ODP 199	**1219**	**1 of 2**	**A/X**	**49-53**	**19.5**	**34, 55.5**
ODP 199	**1220**	**1 of 3**	**A/X**	**49-53**	**26, 53**	**34, 55.5**
ODP 199	**1221**	**1 of 3**	**A/X**	**49-53**	**31, 54**	**55.5**
ODP 199	**1222**	**1 of 2**	**A/X**	**49-53**	**30, 53**	**34, 55.5**

Table 1: Overview of older DSDP and ODP drill sites close to our proposed target area. Only sites close to target area are listed; only very few sites (bold) cover our time slice intervals, are in the right area, have the right crustal age to preserve calcium carbonate, or have employed modern drilling technology (APC-coring) to ensure recovery of undisturbed and continuous sediment sections.

Selecting target ages

The times selected to be drilled in this proposal were chosen to pay particular attention to the overall climatic history of the Cenozoic, and to target particular times of marked changes in the climatic regime. The spacing of the sites will be determined by what we know of the paleo-lysocline and by results of previous drilling. Where the CCD is particularly shallow, the spacing in time of age-transect sites needs to be closer than when the CCD is deep (Fig. 5). 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 about 37 Ma before the crust at this site sank below the CCD.

This separation of 5 Myr is a minimum for the shallow CCD of the Eocene; for good preservation of foraminifers an even closer spacing is needed.

The results of our paleo-equator reconstruction, and proposed drill site locations are shown in Fig. 6.

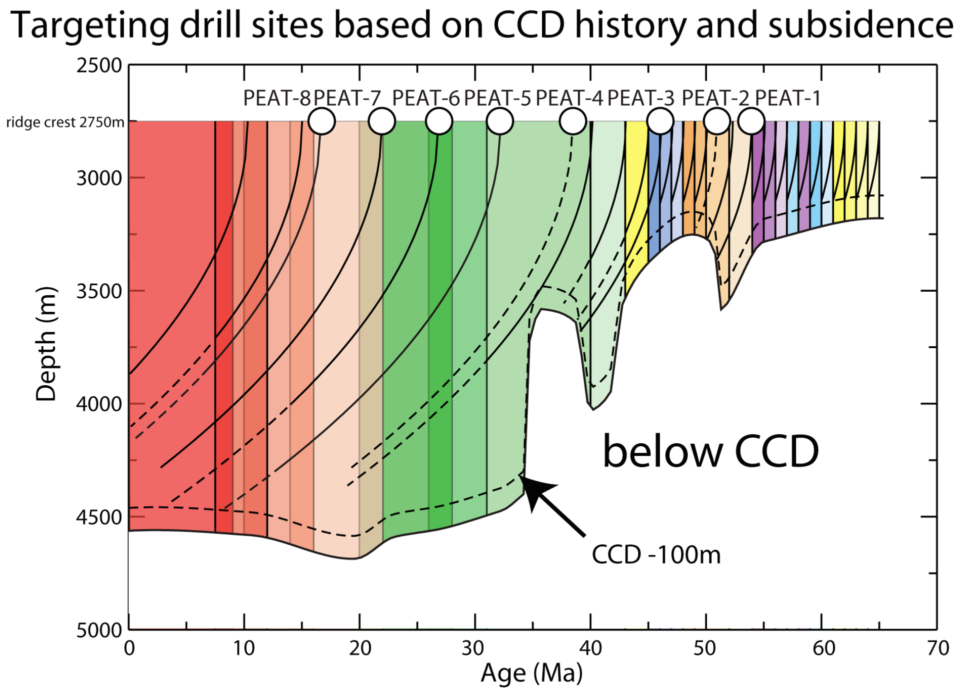

Figure 5: Targeting Pacific equatorial age transect ("PEAT") drill sites for based on the CCD history (van Andel (1975), with new data from ODP Leg 199) to constrain the presence of calcium carbonate. Subsidence curves use a subsidence parameter k=0.35 (a conservative estimate with respect to whether curves trace above the CCD). Additional subsidence due to sediment loading was not modeled.

The Eocene (PEAT-1A to PEAT-4A)

The Eocene was a time of extremely warm climates that reached a maximum in temperatures near 52 Ma (Fig.4). From this maximum there was a gradual climatic cooling through to the Eocene-Oligocene Boundary. There appears to have been a slight reversals in this trend within the middle Eocene, near 43 Ma, and in the late Eocene at 34-36 Ma, just prior to the marked drop in oxygen isotopes that marks the Eocene-Oligocene boundary and one of the most dramatic changes of the CCD (Fig. 5). Throughout

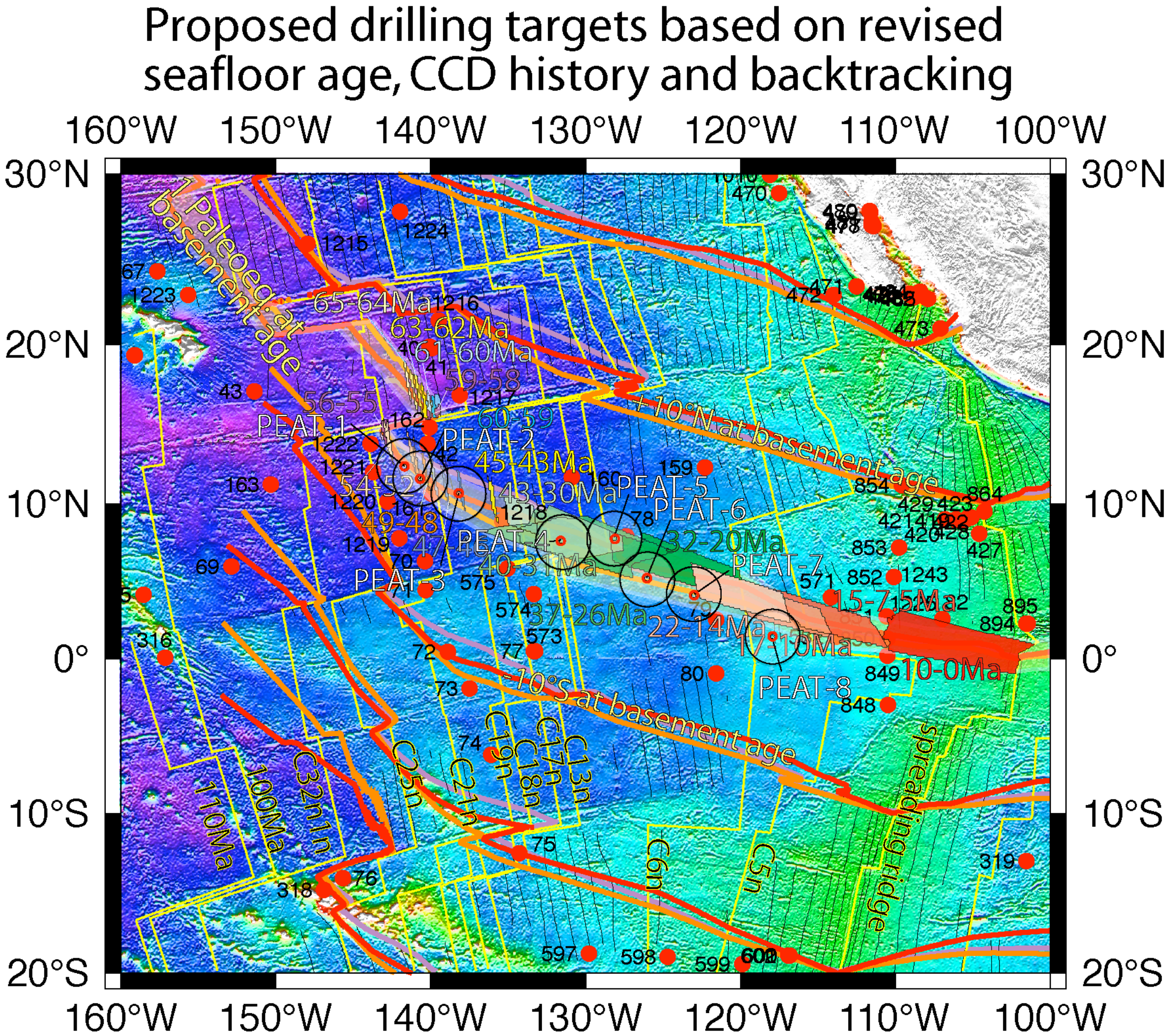

Figure 6: Proposed locations for site-survey work and drilling, corresponding to time slices targeted in this proposal. Shown are present-day bathymetry, revised magnetic anomaly isochrons (thin yellow lines, modified with new points from Petronotis 1991, 1994), and paleo-equator position at the crustal age obtained by backtracking, using fixed-hotspot stage poles from Koppers et al. (2001, red), Engebretson et al. (1985, orange), and palaeomagnetic poles from Sager & Pringle (1988, lilac). The shaded band lies within one degree north and south of the paleo-equator (averaged from fixed-hotspot rotation models). Coloured areas correspond to those in Fig. 3 and represent time intervals of interest. These were obtained by intersecting the white paleo-equator 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 .

the Eocene, the CCD lay near 3.2 – 3.3 km. Thus, recovering well preserved carbonate sediments from the equatorial region is a substantial challenge.

Early and Middle Eocene (PEAT-1B, 2B)

Leg 199 drilled a N-S transect across the equatorial region at about 56 Ma. 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 this time of maximum Cenozoic warmth. Average (non-carbonate) accumulation rates at this time were moderate, showing only slight increases in some of the more northern sites on the Leg 199 transect (1215, 1216, 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 (Fig. 7). 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.

Middle and Late Eocene (PEAT-3B)

Good paleomagnetic stratigraphy in Leg199 Sites allowed a much improved calibration of nannofossil and radiolarian biostratigraphic datums. Together, these stratigraphies allowed the development of a more detailed picture of temporal variations in sediment accumulation through the mid and upper Eocene of the tropical Pacific. These data show a factor of up to 2-3x increase in accumulation rates of siliceous ooze within the middle Eocene (41 to 45 Ma). At Site 1219 this interval of high biogenic flux is also marked by the preservation of intervals containing calcareous nannofossils. High siliceous sedimentation occurs at a time of an apparent short reversal in the mid Eocene cooling trend (Fig. 4). It is

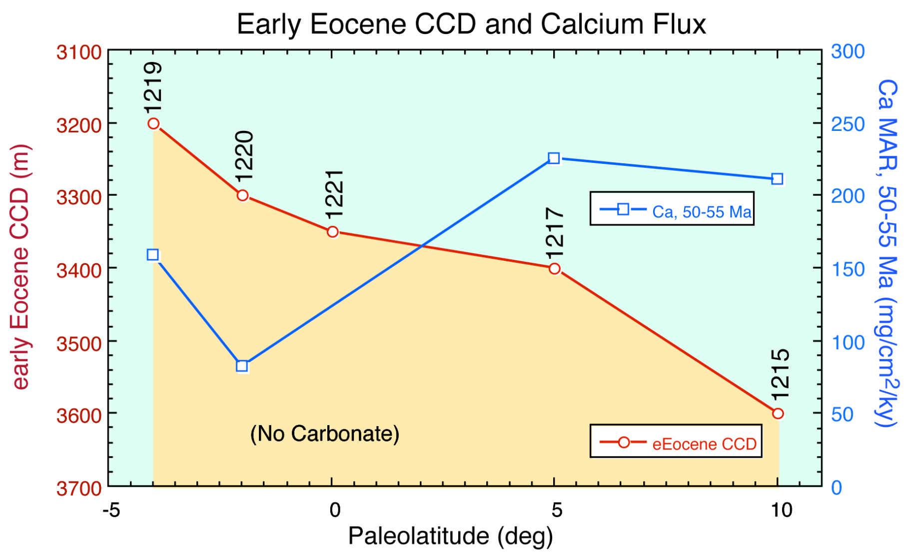

Figure 7: Early Eocene CCD and Ca mass accumulation rates as a function of paleolatitude of ODP Leg 199 Sites.

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 (PEAT-4B)

Results of ODP Leg 189, near the Tasman Rise (Exon, Kennett, Malone et al., 2001) confirmed that the Antarctic-Australian Passage opened to deep-water flow around the time of the Eocene-Oligocene boundary; however, there may have been substantial flow at shallower depths a few million years earlier. An increase in terrigenous flux measured at Site 690 in the Weddel Sea indicates that climatic cooling and the onset of ice rafting from Antarctica occurred at about 35 Ma (Joseph and Rea, 2002) - about a million years earlier than the Eocene Oligocene boundary. These results are borne out by drilling in Prydz Bay (O'Brien, Cooper, Richter et al., 2001) that show evidence of ice streams reaching down to the coast before the end of the Eocene.

Site 1218 contains the most complete Eocene-Oligocene boundary section recovered from the equatorial Pacific; however, it is far from pristine. Carbonate percentages drop markedly below the boundary and go to zero near 34 Ma (Fig. 8). At Site 1218, on the 40 Ma equator, there is a marked increase in the proportion of diatoms in the siliceous fraction of sediments in the uppermost Eocene. This increased diatom abundance continues well into the lower Oligocene and coincides with the biggest turnover in the radiolarian fauna since the Cretaceous-Tertiary boundary. The large diatom abundance in the uppermost

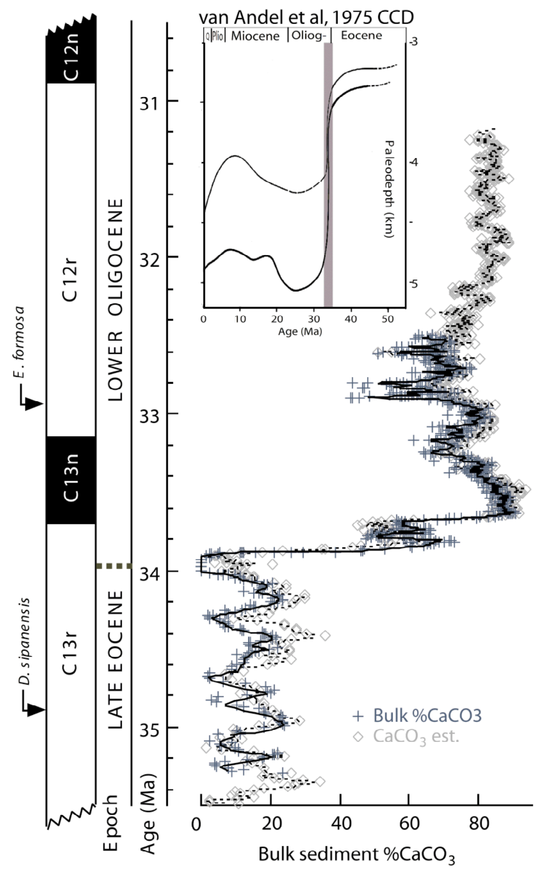

Figure 8: Bulk %$CaCO_3$ in ODP Leg 199 Site 1218 across the Oligocene – Eocene Boundary (P.A. Wilson et al., unpublished data). Note pronounced cyclical nature below and across the boundary, and very low %$CaCO_3$ in the uppermost Eocene and before.

Eocene and lower Oligocene then drops off in the upper Oligocene. There is a comparable drop in measured terrigenous flux at Site 690 (Joseph and Rea, 2002).

This apparent latest Eocene cooling of the climate and increased primary productivity at low latitudes seems somewhat at odds with the apparent slight warming indicated by the oxygen isotopes (Fig. 2). 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.

The Oligocene (PEAT-5B)

This interval of time is noted for its markedly heavy oxygen isotopes (Fig. 4) and its relatively deep CCD (Fig. 5). It is generally thought that there was ice on Antarctica during this interval, but not the large ice sheets to be found there later in the mid Miocene. There is no compelling evidence for ice sheets in the Northern Hemisphere during this time. 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 inter-hemispheric 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 Inter Tropical 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 to the 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 should 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., 2001a) 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 time scale that reaches back to the base of the Oligocene. Such a time scale 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.

The Latest Oligocene – Earliest Miocene (PEAT-6B)

At the end of the Oligocene there is a dramatic rise in the oxygen isotope record (Fig. 2), whether through a decrease in global ice volume or increase in bottom water temperatures (or both) is uncertain. It 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. 2) and correlated to a pronounced drop in sea level (Miller et al., 1991). This event is very close to the Oligocene-Miocene boundary. Although there are clear 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.

In Sites 1218 and 1219 of ODP Leg 199 this interval was well recovered; however, carbonate preservation still presented a problem for the classic foraminiferal stratigraphy. Both sites were deep and well within the lysocline. At the time Mio-Oligocene sediments were deposited, Site 1218 resided on 18 Myr-old crust and was about 4.1 km deep. Site 1219 was on about 34 Myr-old crust and was about 4.5 km deep. There was a relative increase in the large diatoms near this boundary in the siliceous course 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 Oligocene equator, near the late Oligocene ridge crest, should provide both the resolution and the preservation required to better describe the changes in the equatorial ocean taking place at this time.

The Miocene (PEAT-7B)

The latest Oligocene through to the mid Miocene appears to have been a time of relative warmth comparable, at least in the oxygen isotope record, to the latest Eocene. However, the variability in the isotopic record of the early to mid Miocene seems a bit larger than that of the Eocene and may indicate more variability in climate and in global ice volume. The climatic "optimum" that marks the end of this interval, comes just before the major development of ice sheets on Antarctica and the marked increase in ice rafted debris in circum-Antarctic sediments.

Although the spectral character of the carbonate records and the variability of lower to mid Miocene and early Oligocene isotopic records appear comparable (Fig. 4), the mean value of the lower to mid Miocene record is about 1‰ lighter than that of the lower Oligocene. Differences between planktonic biota of these two intervals are also quite striking. In the Oligocene, evolutionary change appears to be minor and biostratigraphic zones span long intervals of time; while in the early to mid Miocene there is a burst of evolutionary vigor. What was it that caused this profound change in the nature of the ocean records? 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), 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? Well recovered sections from these intervals near the ridge crest should give us the best preserved, most strategically located samples to answer questions concerning the changing environment of the near-surface equatorial ocean.

The Mid Miocene (PEAT-8B)

In principle, the age-transect strategy of this proposal would not be complete without data from the Plio-/Pleistocene. However, in addition to logistical reasons in terms of cruise length, near paleo-equatorial records have already been targeted by ODP Legs 138 (Pisias, Mayer, Janecek, et al., 1995) and 202, which provide information about the development of Northern Hemisphere glaciation. Our last proposed site focuses instead on the interesting events following a Mid-Miocene maximum in deposition (van Andel et al., 1975). 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). We designed PEAT-8B to recover a ridge-crest record at the early-mid Miocene sedimentation maximum on 16 Ma old crust. We plan to position the Miocene sites somewhat to the south of the estimated paleo-equatorial position in order to maximize the time these sites remain within the equatorial zone, 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 hydrothermal sediments.

Tuning the Time Scale

The perfect geologic timescale has always been a sought-after goal. Determination of the rates at which earth processes take place and how these rates change are key not only to developing an earth history but also to understanding the nature of the processes themselves. Radiometrically constrained timescales were a great leap forward in this quest for a chronostratigraphy; however, there are a multitude of stratigraphic, geochemical and radiometric difficulties that constrain the accuracy and the applicability of radiometric techniques – not the least of which is the general increase in uncertainty of a radiometric date with increasing age. The paleomagnetic timescale has provided an important set of time markers for the Cenozoic; however, this approach is also far from perfect. Individual reversals are "dated" ultimately by radiometric techniques and by extrapolations that assume constant seafloor spreading rates. In addition, reversals are often widely spaced in time, and thus require some form of time interpolation between the reversals.

The discovery of orbitally driven variations in the earth's climate, and their preservation in the marine sedimentary record, has been the latest advance in our search for the perfect chronostratigraphy. The application of this technique is not without assumptions of its own, including the predictability of the exact beat of the climatic metronome. However, if constrained by a paleomagnetic reversal stratigraphy, and if the same ages are obtained for geologic boundaries in different regions with different sensitivities to each of the different orbital forcings, we can develop a strong confidence in the time scale. A complete orbitally tuned Cenozoic timescale can provide estimates of process rates that have comparable precision throughout the Cenozoic.

We are working towards an astronomically tuned Cenozoic time scale. As of now, there is an anchored astronomical time scale back to 30 Ma (mostly from ODP Leg 154), apart from an interval from 16-20 Ma that requires additional confirmation. Recent results from Leg 199 have resulted in an extension of the tuning across the Eocene/Oligocene boundary. Several other ODP Legs provide suitable data for the time interval 35-42 Ma (ODP Legs 171B and 177), 55-57 (ODP Leg 171B), 62 to 65 Ma (ODP Legs 165 and 171B). From this perspective, the current proposal would be useful to narrow existing gaps in our tuning efforts, particularly in the Eocene slice targeted by PEAT-3B. Additional drilling will be required for the time interval from 52 to 62 Ma, which is difficult to achieve in the Pacific due to the very shallow CCD, and will most likely have to be provided by data from the Atlantic.

Siting 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. Table 1 demonstrates that, 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) being located inside the paleo-equatorial zone, or (4) on the right crustal age, to ensure the presence of calcium carbonate at the targeted time slice.

We have developed the technical capability of recovering complete, relatively undisturbed sections, and we have established a seismic stratigraphy for the equatorial Pacific that allows us to map discrete intervals of time throughout the equatorial mound of biogenic sediments (Mayer et al, 1985; Knappenberger 2000; Moore et al, 2002, Mitchell et al., 2002). This later capability is key to two aspects of the present proposal. First, it facilitates the location of the thickest part of the mound for each of the time intervals. This temporal mound "crest" we take to be the "geographic" equator for each time interval traced in the seismic records (Fig. 9).

Depth-dependent dissolution potentially complicates the interpretation of mound thickness as the "geographic" equator, and needs to be resolved through modeling as well as new data obtained through this proposal.

We commonly use locations of plate rotation poles, determined with paleomagnetic measurements, to reconstruct site positions through most of the Cenozoic; however, there is always some error involved in this procedure. With the equatorial divergence zone being only a few degrees of latitude wide, the unquestioning acceptance of an equator determined by plate model rotations could lead to the placement of a site substantially off the geographic equator (Fig. 9). The divergence of surface waters at the equator and the resulting narrow zone of high productivity (at least since the beginning of the Oligocene) give an unambiguous locus of maximum sediment flux and characteristic sediment facies.

Van Andel et al. (1975) used this approach to establish a rotation pole for the Pacific plate that has compared well to subsequent refinements using other techniques. However, van Andel et al. (1975) depended solely on drilled sections to establish the center of the sediment mound for different times in the past. We can use seismic records, tied to recovered sedimentary sections, to map out sediment thickness variation in both time and space, and to pinpoint the most desirable site location for each of the intervals we wish to sample.

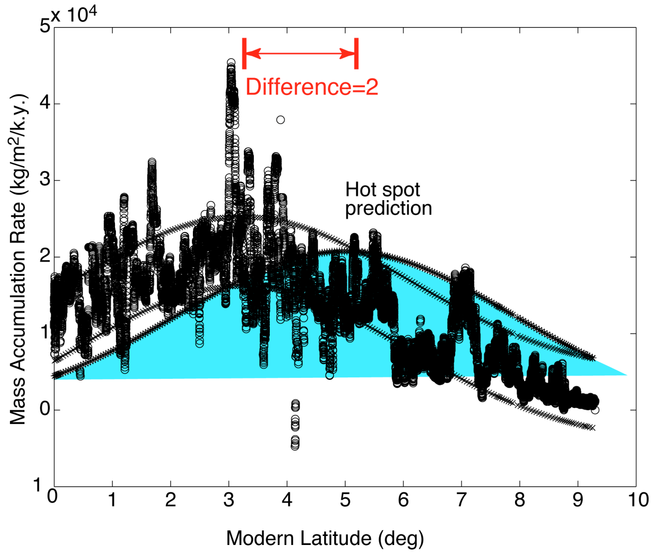

Figure 9: Estimated bulk sediment accumulation rates for the time interval 16.3 –20 Ma based on a seismic stratigraphic interpretation of seismic line recorded in an Pacific equatorial transect along 40 Ma crust, combined with estimates of sediment bulk density from drilling results (Knappenberger, 2000). Note the difference in latitudinal position of the maximum in flux rates and the estimated position of the equator based on a fixed hotspot plate rotation model.

Such an approach for locating our sites has the added advantage that it allows us to develop a map view of sediment thickness for each broad time interval selected, overcoming the problems associated with spatially varied deposition caused by bottom boundary layer processes. It also allows us to tie in previously recovered sections in the region and to study sediment fluxes in the tropical Pacific in three dimensions. The mapping approach will require additional survey data, as older data are mostly of poor quality, or not well located for this problem. However, this will be a prime objective of site survey cruises – existing Ventura, Ewing and other seismic data demonstrate that this mapping will be straightforward.

With the ability to map the time evolution of the sediment mound, all that is remaining in order to develop a age-transect is to cross check the seismic mapping results with independent estimates of the age of the ocean crust. We can establish the age of the crust both through mapped crustal magnetic lineations (Petronotis, 1991; Petronotis et al., 1994; Müller et al., 1997) and through interpolation of basement ages between previously drilled sites (see figs. 1 and 3 in Mitchell, 1998).

The mapping approach should work well back to about 40 Ma. In the older Eocene sections, fixed hotspot plate rotation models are questionable, and need to be supplemented with coarser polar wander paths (Sager and Pringle, 1988). Furthermore, general circulation models of the near-surface tropical Eocene ocean (e.g., Huber, 2002: Fig. 10) leave us with a much more complicated view of the possible spatial pattern of tropical divergence and sedimentation than that seen in the younger Cenozoic. However, recent results from ODP Leg 199, when combined with results from older DSDP sites, give a comparatively simple mid Eocene patterns of siliceous sediment accumulation, even if the reconstructed latitudinal positions of the sites are open to question (Fig. 11). The Eocene sedimentation pattern does not look like one derived from the Neogene, however, and carbonate deposition appears to be displaced away from the equatorial

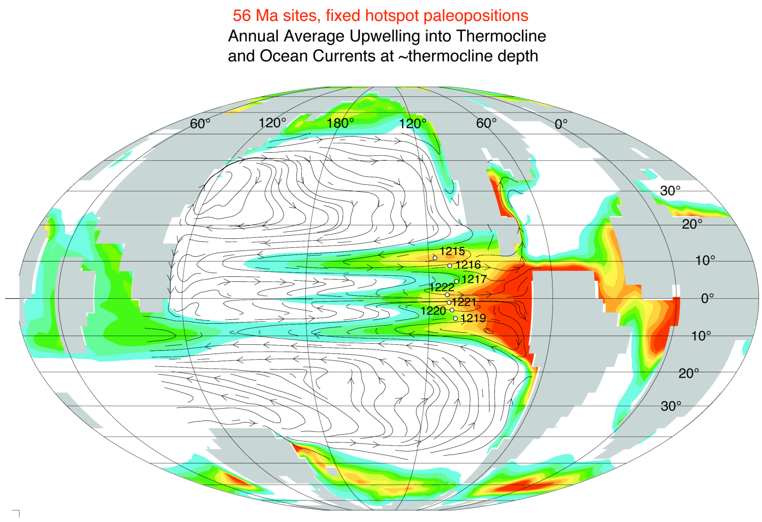

Figure 10: Modeled patterns of divergence in the 56 Ma oceans (Huber, 2002). Paleo-positions of Leg 199 sites shown for reference.

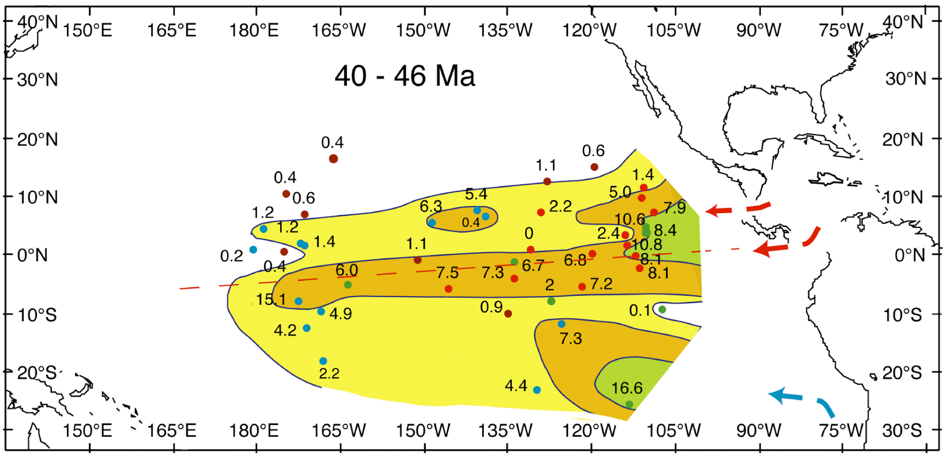

Figure 11: from Moore et al. (2003, 2004 submitted). Average sediment accumulation for the interval 40–46 Ma, given in m/My. Site positions are backtracked to their estimated position at 43 Ma. Site location filled circles are coloured according to sediment type for the time interval: blue = carbonate, green = siliceous carbonate, red = siliceous; brown = clay. A red dashed line marks the approximate center of the equatorial divergence (geographic equator). Contours are at 1, 5, and 10 m/My. The red dashed line indicates the approximate geographic paleo-equator based on the sediment archive – with a notable difference compared to the fixed hotspot based rotation.

region. Additional seismic coverage is needed to the west and east of the Leg 199 transect to better define the older Eocene sections and to more confidently locate regions of maximum thickness.

A strategy for 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 carbonate dissolution, surface water productivity, and export of biogenic carbonate from the 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 classical model for carbonate dissolution, accumulation rates locally decrease linearly from a lysocline down to a carbonate compensation depth (CCD), reflecting linearly increasing rate of dissolution. The depth of both of these mapable surfaces is variable spatially and in time, and interacts with 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 paleo-equatorial upwelling zone would contribute significantly towards separating the various processes that affect carbonate deposition and preservation, and reduce some of the processes that affect climatic proxy records, such as diagenetic recrystallisation (Pearson et al., 2001). The Neogene productivity has been strongly oriented parallel to the equator, so differences in carbonate thicknesses at a common latitude but differing depth will permit the effect of dissolution to be isolated, following Lyle, 2003 and Mitchell, 2003. In addition, the strategy adopted in this proposal 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 so 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 (Spiro et al., 1997; Zeebe and Wolf-Gladrow, 2001).

Preliminary work with Ewing seismic data (Mitchell et al., 2002) has revealed a surprising lack of dissolution with depth in the westerly region of this study area. Our aim is to develop a more extensive 3D model for the stratigraphy of the equatorial Pacific deposits that links all existing core data using a grid of high-resolution seismic reflection profiles. The numerical stratigraphic model will then be used to assess carbonate dissolution, and 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 in this proposal will allow the application the substantial array of carbonate-based proxies with which the wider regional seismic study can be ground-truthed.

Reconstructing paleoceanographic properties and SST

A large number of paleoceanographic interpretations rely on obtaining proxy data (stable isotope measurements, elemental ratios such as Mg/Ca, sea-surface temperature 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 here 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 paleo-equatorial Pacific, the "age-transect" siting strategy necessarily implies a more restricted N-S transect, even though the northward movement of the Pacific Plate does allow us to recover identical time slices multiple times at different paleo-latitudes (separated by several degrees). However, we note that the regional seismic study to be developed as part of our site-survey work would give us the opportunity to begin integrating data from older drill sites with the new drilling, both the IODP-626 proposed drilling and that from ODP Legs 199 and 138. Addition of new data from existing drill sites will flesh out the age transect so that a more complete model of the evolution of the equatorial Pacific can be developed.

We are proposing to measure changes in biogenic sedimentation over a critical interval, to understand an impressive but poorly documented change in C-org deposition and a turnover in the biogenic silica dynamics in the Pacific. These changes coincide with a minimum in the deposition of carbonate that needs better documentation (Lyle, 2003).

Paleomagnetic objectives

One important aspect of this proposal is the recovery of high-quality paleomagnetic data. Results from ODP Leg 199 demonstrate that high-quality data can be recovered from near-equatorial carbonate. Leg 199 succeeded in recovering almost all magnetic reversals from the Paleogene through to the present. However, Leg 199 did not recover biogenic carbonate sediments through most of the Eocene, nor for ages younger than the lower Miocene. Thus, while the paleomagnetic record during these times was of high quality, global 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), a recovery of magnetic reversals within carbonate sediment is desirable. This pre-requisite contributed to the strategy described in this proposal.

In addition, further detailed magnetostratigrapic data, particularly 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 paleo-equator position backtracked with a fixed-hotspot reference frame (Moore et al., 2003, 2004 (submitted); Tarduno, 2003).

Ancillary benefits (MORB, basement)

Our proposed drilling aims to recover basement samples at all sites. A transect of MORB samples from a fixed location in the absolute mantle reference frame would be a unique sample suite and, while 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 the flow-line that have been erupted in similar formation-water environments should be of interest for low-temperature alteration studies (see, e.g., Elderfield & Schultz, 1996).

Possible problems that could be encountered: cherts, dolomite

While 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. While early DSDP coring was generally defeated by chert, better cutting shoes and active heave compensation have helped in the management of chert layers during drilling.

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 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, with radiolarian ooze and carbonates below.

Understanding where chert zones lie will help to minimize sediment loss. Data from Leg 199 suggest that chertified intervals were deposited slowly. While it is unlikely that the sites in this proposal will avoid chert altogether, the specific planning of this proposal aims for calcium carbonate (with higher sedimentation rates than chert-bearing radiolarian ooze), as well as a lower abundance of silica rich formations. Thus, we believe that the chert problem can be overcome.

For this proposal, we suggest the technical preparation of half-length APC facilities, as this would overcome some of the sediment loss problems encountered during Leg 199 and other equatorial Pacific cruises, in case chert is encountered. The sites proposed here that could be affected by chert horizons include PEAT-1B through 4B.

Another possible problem worthy of consideration is that several of the Leg 199 sites showed abundance of dolomitization near the basement of recovered holes (early Paleogene age). To avoid such sediment in our time slices, we have chosen basement ages that are slightly older than the target age. This procedure necessarily involves a trade-off between maximum recovery of target carbonate, and avoiding dolomitized sediments and compensating for potential age uncertainties (Fig. 5).

Planning the Site Survey

The exact determination of drill site locations should be accomplished through seismic survey during a site survey cruise. We can employ our current knowledge of sea-floor age, plate rotation models, and the history of the CCD to plan this survey. We note that proposals have now been submitted to accomplish site-survey work: a proposal led by Lyle to the US NSF, and a proposal led by Mitchell to the UK IODP. The proposed track for the site survey is shown in Fig. 12.

The determination of possible areas for cruise surveys depends on three types of information: 1) a map of sea-floor age as determined from magnetic lineations and previous drilling results, 2) plate rotation models that allow us to predict which locations once were underneath the paleo-equator, 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.

Fig. 5 illustrates the resulting CCD history for the Pacific. Importantly, the early Cenozoic time interval coincides with a very shallow CCD, which will make the detailed planning of future drill-sites a more crucial and important task. In addition, a shallow CCD implies that one can obtain calcareous rich sediments over much shorter time intervals.

The reconstructed history of the CCD can then be used as a guide as to how time intervals of particular interest (Fig. 4) can be targeted. This approach is shown in figure 5, where we have plotted “ideal” crustal ages to drill each of the 12 time intervals of interest while remaining above the CCD. Colored intervals correspond to those in figure 6.

In order to implement our age transect approach, the crustal ages shown in Fig. 5 have to be translated to specific locations on today’s ocean floor. In particular, for each crustal age shown in figure 5, we attempt to locate those sites that were positioned at the paleo-equator during the time interval of interest.

Our methodology is to use the digital age-grid of sea-floor age from Müller et al., 1997, modified and improved with additional magnetic anomaly picks from Petronotis (1991, 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 paleo-pole data from Sager and Pringle (1988). From the backtracked latitudes for each grid point we then obtained the paleo-equator at the crustal age by contouring.

The results are shown in Fig. 6, together with proposed locations for site-survey work for this proposal, which take into account the plate-rotation with respect to the paleo-equator, moved slightly towards the south to accommodate a potential error in the fixed hotspot rotation model (Moore et al., 2003; 2004 submitted). The model presented in Fig. 6 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.

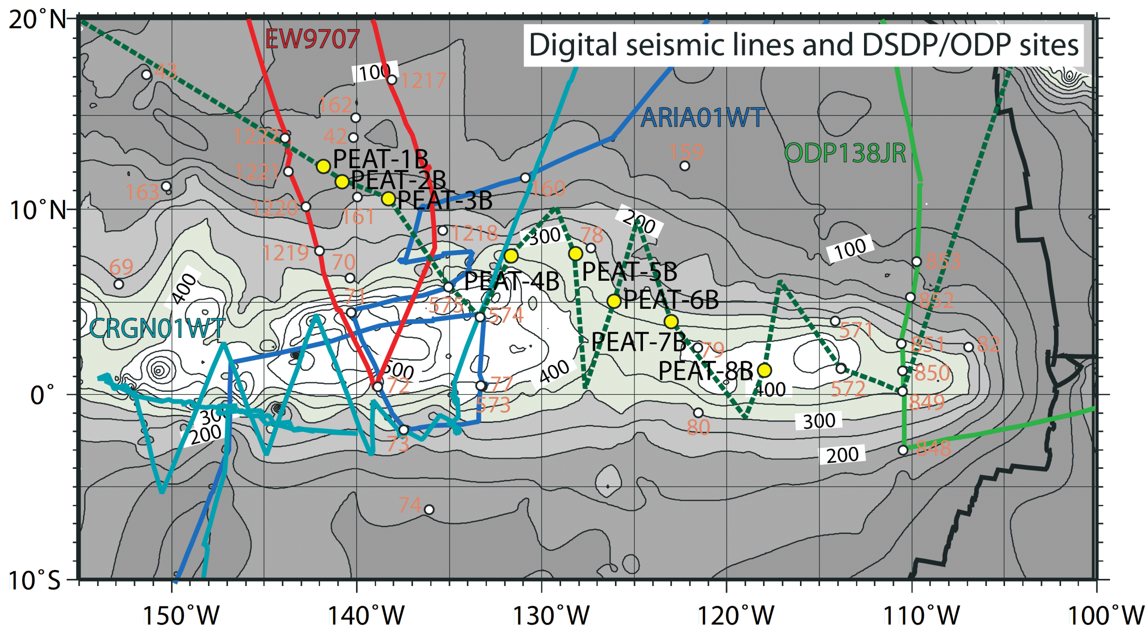

Figure 12: Proposed site survey trackline (dashed), with drillsite locations and available digital seismic reflection data from previous cruises. The new trackline is designed to locate drillsites, and to fill in gaps in the coverage of the older surveys. Light green: Venture-1; blue: Ariadne-1; blue-green: Crossgrain-1; red: Ewing EW9707. Only proposed Site PEAT-4B is in the vicinity of an existing trackline (CROSSGRAIN), but due to technical problems no records were collected for ~10 hours as the Site location was approached.

Presently we have two excellent seismic transects across the Pacific equatorial mound, plus a few other older seismic lines that provide useful ties (Fig. 12). To accurately locate the sites that sample all the intervals proposed here, further seismic survey is needed. However, based on the simple plate rotation models and on the patterns of sedimentation derived from seismic transects (Fig. 6) and from drilling results (Fig. 8) we can focus on the survey areas for the Oligocene and Miocene intervals by interpolation between Venture and EW9709 track lines (Fig. 12). For the early Pliocene interval existing seismic lines may give us information to tentatively identify a site location for further detailed survey. For the Eocene intervals a comprehensive interpretation of existing seismic lines and drilling data will guide us in a more complete survey of the 34 –54 Ma crust. One of the proposed sites (PEAT-5B) is close to previous drilling sites (DSDP-78).

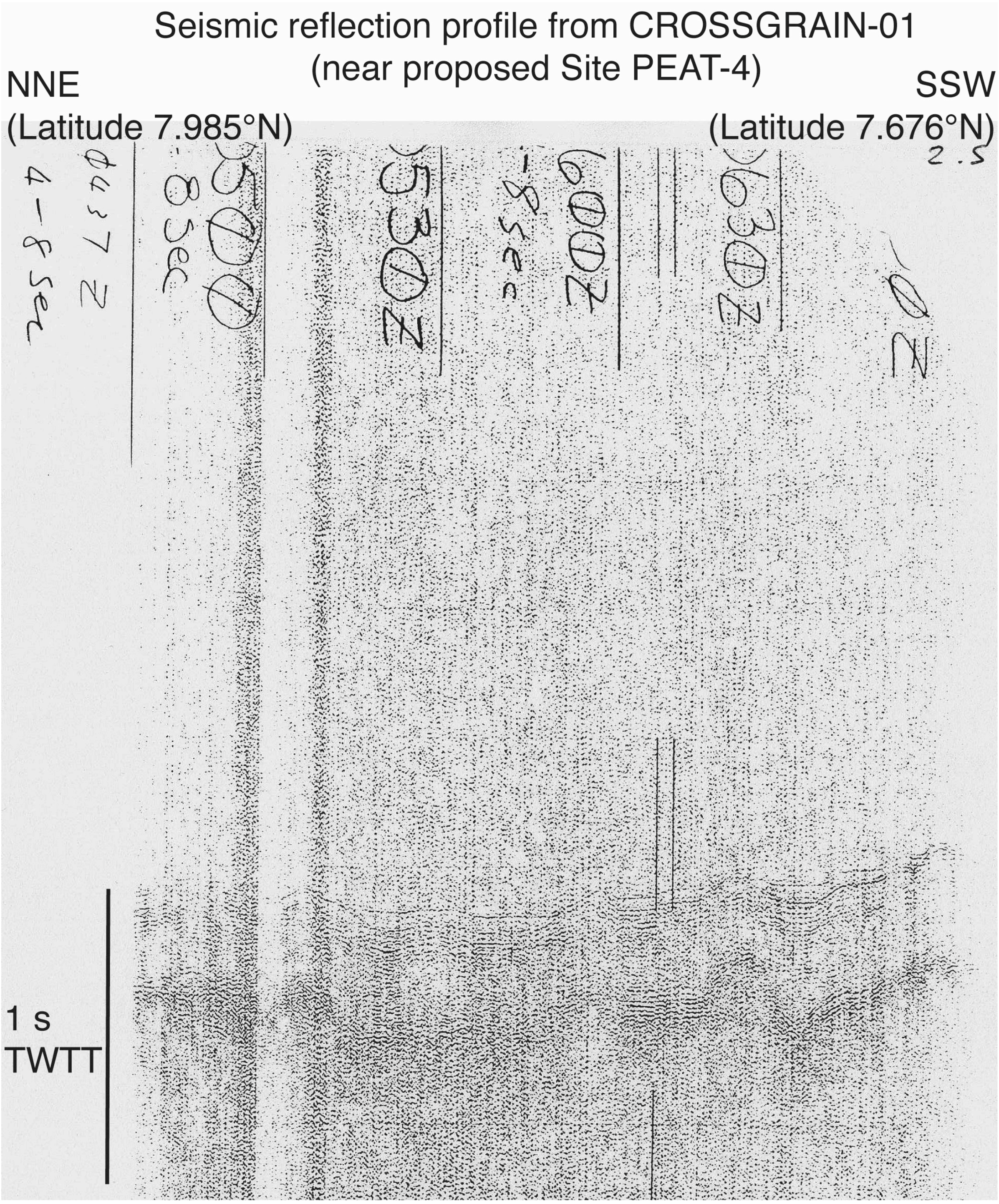

Figure 13: Example of seismic reflection profile from CROSSGRAIN-1 survey (NGDC #15040172, T. Washington, Scripps, 1987) very close to PEAT-4 (Figure 12). Unfortunately the seismic data were collected at transit speed, resulting in a low-quality survey. However, this section establishes that the sediment cover's thickness is near our prediction (~0.3-0.4 s TWT, ~200-300m). We cannot yet distinguish any features about the sediment section, nor can we optimize the location based upon existing data. Exact positions of proposed sites will have to await additional proposed site

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Site Description Forms:

Site description forms for the 8 proposed drillsites are attached here. Because of the poor quality of most of the existing seismic records, we have a good indication of sediment thickness at only five of the sites, based on previous DSDP and ODP drilling. The nature of the existing records is demonstrated by a seismic line near Site PEAT-4B (Figure 13).

In the absence of data, we have estimated the sediment thickness on the basis of our understanding of the regional depositional patterns. Water depths for the sites are range from ~4 to 5 km. At each site we would like to plan on 3 APC/XCB cores through the entire section, and logging as appropriate, with particular emphasis on obtaining FMS logs for stratigraphic correlation.

Because there is no modern site survey data, we have not submitted forms 2, 3, 4, or 5 for each site. Form 2 would be blank in the absence of useful data; we anticipate a standard logging program which will be outlined in detail with the logging contractor after site surveys are completed. There has never been a safety problem at open-ocean pelagic sites, and the lithologic summary information must also await a site survey and analysis of the accompanying piston cores.

Clearly a site-survey cruise will be required before this can become a fully mature drilling proposal, and in that eventuality we will provide a complete and accurate description of each proposed drill site. We note that proposals have now been submitted to accomplish site-survey work: a proposal led by Lyle to the US NSF, and a proposal led by Mitchell to the UK IODP.

iSAS/IODP Site Summary Forms:

Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New

Section A: Proposal Information

Title of Proposal:	Cenozoic Pacific Equatorial Age Transect
Date Form Submitted:	24th Mar. 2004
Site Specific Objectives with Priority (Must include general objectives in proposal)	Obtain calcareous sediments from the region of the equatorial circulation system during maximum Cenozoic warmth (52-54 Ma). Constrain the isotopic and biotic characteristics of the near surface equatorial waters. Gain information about the nature of very shallow CCD at this time.
List Previous Drilling in Area:	ODP 1221, 1222; DSDP 42, 162

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	PEAT-1B	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Eastern equatorial Pacific
Latitude:	Deg: 12°N	Min: 18	Jurisdiction:	International
Longitude:	Deg: 141°W	Min: 48	Distance to Land:	1621 km (Hawaii)
Coordinates System:	WGS 84			
Priority of Site:	Primary: X	Alt:	Water Depth:	4800-5000 m

Section C: Operational Information

	Sediments		Basement
Proposed Penetration: (m)	200m		5m
	What is the total sed. thickness?	~200m m	
		Total Penetration:	205 m
General Lithologies:	Pelagic clay, siliceous ooze, calcareous ooze, chalk and chert.		basalt
Coring Plan: *(Specify or check)*	1-2-3-APC, XCB as needed		

Wireline Logging Plan:

Standard Tools		Special Tools				LWD	
Neutron-Porosity	☐	Borehole Televiewer	☐	Formation Fluid Sampling	☐	Density-Neutron	☐
Litho-Density	☐	Nuclear Magnetic Resonance	☐	Borehole Temperature & Pressure	☐	Resistivity-Gamma Ray	☐
Gamma Ray	☐	Geochemical	☐	Borehole Seismic	☐	Acoustic	☐
Resistivity	☐	Side-Wall Core Sampling	☐				
Acoustic	☐						
Formation Image	☐			Others ( )		Others ( )	

Max.Borehole Temp. : **Expected value (For Riser Drilling)** ________ °C

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals					
from	m	to	m,		m intervals
from	m	to	m,		m intervals

Basic Sampling Intervals: 5m

Estimated days:	Drilling/Coring:4	Logging:1	Total On-Site:5

Future Plan: **Longterm Borehole Observation Plan/Re-entry Plan**

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Methane Hydrate	☐
Abnormal Pressure	☐	Fractured Zone	☐	Diapir and Mud Volcano	☐
Man-made Objects	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐
CO_2	☐				

What is your Weather window? (Preferable period with the reasons)

iSAS/IODP Site Summary Forms:
Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New

Section A: Proposal Information

Title of Proposal:	Cenozoic Pacific Equatorial Age Transect
Date Form Submitted:	24th Mar. 2004
Site Specific Objectives with Priority (Must include general objectives in proposal)	Obtain calcareous sediments from the region of the equatorial circulation system during maximum Cenozoic warmth (50-52 Ma). Constrain the isotopic and biotic characteristics of the near surface equatorial waters. Gain information about the nature of very shallow CCD at this time.
List Previous Drilling in Area:	DSDP 42, DSDP 162, ODP 1221

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	PEAT-2B	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Eastern equatorial Pacific
Latitude:	Deg: 11°N	Min: 30	Jurisdiction:	International
Longitude:	Deg: 140°W	Min: 48	Distance to Land:	1761 km (Hawaii)
Coordinates System:	WGS 84			
Priority of Site:	Primary: X	Alt:	Water Depth:	4800-5000 m

Section C: Operational Information

	Sediments		Basement
Proposed Penetration: (m)	200m		5m
	What is the total sed. thickness? ~200m m		
		Total Penetration: 205 m	
General Lithologies:	Pelagic clay, siliceous ooze, calcareous ooze, chalk and chert.		basalt
Coring Plan: *(Specify or check)*	1-2-3-APC, XCB as needed		

Wireline Logging Plan:

Standard Tools		Special Tools				LWD	
Neutron-Porosity	☐	Borehole Televiewer	☐	Formation Fluid Sampling	☐	Density-Neutron	☐
Litho-Density	☐	Nuclear Magnetic Resonance	☐	Borehole Temperature & Pressure	☐	Resistivity-Gamma Ray	☐
Gamma Ray	☐	Geochemical	☐	Borehole Seismic	☐	Acoustic	☐
Resistivity	☐	Side-Wall Core Sampling	☐				
Acoustic	☐						
Formation Image	☐			Others ( )		Others ( )	

Max.Borehole Temp. : **Expected value (For Riser Drilling)** ______ °C

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals

from	m	to	m,		m intervals
from	m	to	m,		m intervals

Basic Sampling Intervals: 5m

Estimated days:

Drilling/Coring:4	Logging:1	Total On-Site:5

Future Plan: **Longterm Borehole Observation Plan/Re-entry Plan**

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Methane Hydrate	☐
Abnormal Pressure	☐	Fractured Zone	☐	Diapir and Mud Volcano	☐
Man-made Objects	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐
CO_2	☐				

What is your Weather window? (Preferable period with the reasons)

iSAS/IODP Site Summary Forms:
Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New

Section A: Proposal Information

Title of Proposal:	Cenozoic Pacific Equatorial Age Transect
Date Form Submitted:	24th Mar. 2004
Site Specific Objectives with Priority (Must include general objectives in proposal)	Obtain calcareous sediments from the middle and late Eocene as part of the equatorial age transect to investigate reason for 2-3x increase in accumulation rates of siliceous ooze within the middle Eocene (41 to 45 Ma). Evaluate the temperature and structure of the near-surface ocean. Investigate the nature of a strong and rapid change of CCD, identified during ODP Leg 199.
List Previous Drilling in Area:	DSDP 161, DSDP 42, ODP 1221, ODP 1220

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	PEAT-3B	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Eastern equatorial Pacific
Latitude:	Deg: 10°N	Min: 36	Jurisdiction:	International
Longitude:	Deg: 138°W	Min: 18.0	Distance to Land:	2046 km (Hawaii)
Coordinates System:	WGS 84			
Priority of Site:	Primary: X	Alt:	Water Depth:	4800-5000 m

Section C: Operational Information

	Sediments	Basement
Proposed Penetration: (m)	200m What is the total sed. thickness? ~200m m	5m
		Total Penetration: 205 m
General Lithologies:	Pelagic clay, siliceous ooze, calcareous ooze, chalk and chert.	basalt
Coring Plan: *(Specify or check)*	1-2-3-APC, XCB as needed	

Wireline Logging Plan:

Standard Tools		Special Tools				LWD	
Neutron-Porosity	☐	Borehole Televiewer	☐	Formation Fluid Sampling	☐	Density-Neutron	☐
Litho-Density	☐	Nuclear Magnetic Resonance	☐	Borehole Temperature & Pressure	☐	Resistivity-Gamma Ray	☐
Gamma Ray	☐	Geochemical	☐	Borehole Seismic	☐	Acoustic	☐
Resistivity	☐	Side-Wall Core Sampling	☐				
Acoustic	☐						
Formation Image	☐			Others ( )		Others ( )	

Max.Borehole Temp. : **Expected value (For Riser Drilling)** ______ °C

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals

from m to m, m intervals

from m to m, m intervals

Basic Sampling Intervals: 5m

Estimated days:	Drilling/Coring:5	Logging:1	Total On-Site:6

Future Plan: **Longterm Borehole Observation Plan/Re-entry Plan**

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Methane Hydrate	☐
Abnormal Pressure	☐	Fractured Zone	☐	Diapir and Mud Volcano	☐
Man-made Objects	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐
CO_2	☐				

What is your Weather window? (Preferable period with the reasons)

iSAS/IODP Site Summary Forms:
Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New

Section A: Proposal Information

Title of Proposal:	Cenozoic Pacific Equatorial Age Transect
Date Form Submitted:	24th Mar. 2004
Site Specific Objectives with Priority (Must include general objectives in proposal)	Eocene/Oligocene Boundary: obtain well recovered and well preserved equatorial sections across this relatively short transition between warm and cold global climates to determine the impact of high latitude ocean boundary changes on climate, circulation, and productivity in the equatorial region.
List Previous Drilling in Area:	DSDP 160, DSDP 575, ODP 1218

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	PEAT-4B	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Eastern equatorial Pacific
Latitude:	Deg: 7°N	Min: 31.4	Jurisdiction:	International
Longitude:	Deg: 131°W	Min: 39.9	Distance to Land:	2616 km (Clipperton Island)
Coordinates System:	WGS 84			
Priority of Site:	Primary: X	Alt:	Water Depth:	4800-5000 m

Section C: Operational Information

	Sediments		Basement
Proposed Penetration: (m)	300m		5m
	What is the total sed. thickness? ~300m m		
		Total Penetration: 305 m	
General Lithologies:	Pelagic clay, siliceous ooze, calcareous ooze, chalk and chert.		basalt
Coring Plan: *(Specify or check)*	1-2-3-APC, XCB as needed		

Wireline Logging Plan:	Standard Tools		Special Tools					
	Neutron-Porosity	☐	Borehole Televiewer	☐	Formation Fluid Sampling	☐	Density-Neutron	☐
	Litho-Density	☐	Nuclear Magnetic Resonance	☐	Borehole Temperature & Pressure	☐	Resistivity-Gamma Ray	☐
	Gamma Ray	☐	Geochemical	☐	Borehole Seismic	☐	Acoustic	☐
	Resistivity	☐	Side-Wall Core Sampling	☐				
	Acoustic	☐						
	Formation Image	☐			Others ( )		Others ( )	

Max.Borehole Temp. :	**Expected value (For Riser Drilling)** ________ °C		
Mud Logging: *(Riser Holes Only)*	Cuttings Sampling Intervals		
	from m to m,		m intervals
	from m to m,		m intervals
	Basic Sampling Intervals: 5m		
Estimated days:	Drilling/Coring:5	Logging:1	Total On-Site:6
Future Plan:	**Longterm Borehole Observation Plan/Re-entry Plan**		

Hazards/ Weather:	**Please check following List of Potential Hazards**						*What is your Weather window? (Preferable period with the reasons)*
	Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	
	Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
	Shallow Water Flow	☐	Currents	☐	Methane Hydrate	☐	
	Abnormal Pressure	☐	Fractured Zone	☐	Diapir and Mud Volcano	☐	
	Man-made Objects	☐	Fault	☐	High Temperature	☐	
	H_2S	☐	High Dip Angle	☐	Ice Conditions	☐	
	CO_2	☐					

iSAS/IODP Site Summary Forms:
Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New

Section A: Proposal Information

Title of Proposal:	Cenozoic Pacific Equatorial Age Transect
Date Form Submitted:	24th Mar. 2004
Site Specific Objectives with Priority (Must include general objectives in proposal)	Oligocene: 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 Inter Tropical Convergence Zone, and the seasonal shifts in this zone, as reflected by the wind-driven currents of the equatorial region.
List Previous Drilling in Area:	DSDP 78, DSDP 159, DSDP 160, DSDP574

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	PEAT-5B	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Eastern equatorial Pacific
Latitude:	Deg: 7°N	Min: 38.4	Jurisdiction:	International
Longitude:	Deg: 128°W	Min: 11.1	Distance to Land:	2235 km (Clipperton Island)
Coordinates System:	WGS 84			
Priority of Site:	Primary: X	Alt:	Water Depth:	4500-4600 m

Section C: Operational Information

	Sediments		Basement
Proposed Penetration: (m)	320m		5m
	What is the total sed. thickness? ~320m m		
		Total Penetration: 325 m	
General Lithologies:	Pelagic clay, siliceous ooze, calcareous ooze, chalk and chert.		basalt
Coring Plan: *(Specify or check)*	1-2-3-APC, XCB as needed		

Wireline Logging Plan:

Standard Tools		Special Tools					
Neutron-Porosity	☐	Borehole Televiewer	☐	Formation Fluid Sampling	☐	Density-Neutron	☐
Litho-Density	☐	Nuclear Magnetic Resonance	☐	Borehole Temperature & Pressure	☐	Resistivity-Gamma Ray	☐
Gamma Ray	☐	Geochemical	☐	Borehole Seismic	☐	Acoustic	☐
Resistivity	☐	Side-Wall Core Sampling	☐				
Acoustic	☐						
Formation Image	☐			Others ( )		Others ( )	

Max.Borehole Temp. : **Expected value (For Riser Drilling)** ______ °C

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals

from	m to	m,	m intervals
from	m to	m,	m intervals

Basic Sampling Intervals: 5m

Estimated days:

Drilling/Coring:5.5	Logging:0.5	Total On-Site:6.0

Future Plan: **Longterm Borehole Observation Plan/Re-entry Plan**

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Methane Hydrate	☐
Abnormal Pressure	☐	Fractured Zone	☐	Diapir and Mud Volcano	☐
Man-made Objects	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐
CO_2	☐				

What is your Weather window? (Preferable period with the reasons)

iSAS/IODP Site Summary Forms:
Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New

Section A: Proposal Information

Title of Proposal:	Cenozoic Pacific Equatorial Age Transect
Date Form Submitted:	24th Mar. 2004
Site Specific Objectives with Priority (Must include general objectives in proposal)	Latest Oligocene: recover sections on the latest Oligocene equator to investigate the major changes in the equatorial ocean taking place around the Oligocene/Miocene boundary, including a possible major glaciation and/or major changes in ice volume. Provide the least possible dissolved material to improve bio- and magnetostratigraphy of this critical time interval.
List Previous Drilling in Area:	DSDP 78, DSDP 574, DSDP 79

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	PEAT-6B	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Eastern equatorial Pacific
Latitude:	Deg: 5°N	Min: 5.2	Jurisdiction:	International
Longitude:	Deg: 126°W	Min: 5.8	Distance to Land:	2068 km (Clipperton Island)
Coordinates System:	WGS 84			
Priority of Site:	Primary: X	Alt:	Water Depth:	4300-4500 m

Section C: Operational Information

Proposed Penetration: (m)

Sediments	Basement
300m	5m
What is the total sed. thickness? ~300m m	
	Total Penetration: 305 m

General Lithologies:

Sediments	Basement
Pelagic clay, siliceous ooze, calcareous ooze, chalk and chert.	basalt

Coring Plan: *(Specify or check)*

1-2-3-APC, XCB as needed

Wireline Logging Plan:

Standard Tools		Special Tools					
Neutron-Porosity	☐	Borehole Televiewer	☐	Formation Fluid Sampling	☐	Density-Neutron	☐
Litho-Density	☐	Nuclear Magnetic Resonance	☐	Borehole Temperature & Pressure	☐	Resistivity-Gamma Ray	☐
Gamma Ray	☐	Geochemical	☐	Borehole Seismic	☐	Acoustic	☐
Resistivity	☐	Side-Wall Core Sampling	☐				
Acoustic	☐						
Formation Image	☐			Others ( )		Others ( )	

Max.Borehole Temp. :

Expected value (For Riser Drilling)
°C

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals

from m to m, m intervals
from m to m, m intervals

Basic Sampling Intervals: 5m

Estimated days:

Drilling/Coring:5.5	Logging:1	Total On-Site:6.5

Future Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Methane Hydrate	☐
Abnormal Pressure	☐	Fractured Zone	☐	Diapir and Mud Volcano	☐
Man-made Objects	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐
CO_2	☐				

What is your Weather window? (Preferable period with the reasons)

iSAS/IODP Site Summary Forms:
Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New

Section A: Proposal Information

Title of Proposal:	Cenozoic Pacific Equatorial Age Transect
Date Form Submitted:	24th Mar. 2004
Site Specific Objectives with Priority (Must include general objectives in proposal)	Miocene: obtain well preserved sections to investigate what led to the large burst of evolutionary change during this time in equatorial regions. Obtain material to further study the larger climatic variability compared to Eocene.
List Previous Drilling in Area:	DSDP 78, DSDP 79

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	PEAT-7B	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Eastern equatorial Pacific
Latitude:	Deg: 3°N	Min: 59.1	Jurisdiction:	International
Longitude:	Deg: 123°W	Min: 1.3	Distance to Land:	1787 km (Clipperton Island)
Coordinates System:	WGS 84			
Priority of Site:	Primary: X	Alt:	Water Depth:	4400-4600 m

Section C: Operational Information

	Sediments		Basement
Proposed Penetration: (m)	300m		5m
	What is the total sed. thickness? ~300m m		
		Total Penetration:	305 m

General Lithologies:	Pelagic clay, siliceous ooze, calcareous ooze, chalk.	basalt
Coring Plan: *(Specify or check)*	1-2-3-APC, XCB as needed	

Wireline Logging Plan:

Standard Tools		Special Tools					
Neutron-Porosity	☐	Borehole Televiewer	☐	Formation Fluid Sampling	☐	Density-Neutron	☐
Litho-Density	☐	Nuclear Magnetic Resonance	☐	Borehole Temperature & Pressure	☐	Resistivity-Gamma Ray	☐
Gamma Ray	☐	Geochemical	☐	Borehole Seismic	☐	Acoustic	☐
Resistivity	☐	Side-Wall Core Sampling	☐				
Acoustic	☐						
Formation Image	☐			Others ( )		Others ( )	

Max.Borehole Temp. : **Expected value (For Riser Drilling)** ______ °C

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals

from m to m, m intervals

from m to m, m intervals

Basic Sampling Intervals: 5m

Estimated days:	Drilling/Coring:5.5	Logging:1	Total On-Site:6.5

Future Plan: **Longterm Borehole Observation Plan/Re-entry Plan**

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Methane Hydrate	☐
Abnormal Pressure	☐	Fractured Zone	☐	Diapir and Mud Volcano	☐
Man-made Objects	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐
CO_2	☐				

What is your Weather window? (Preferable period with the reasons)

iSAS/IODP Site Summary Forms:
Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New

Section A: Proposal Information

Title of Proposal:	Cenozoic Pacific Equatorial Age Transect
Date Form Submitted:	24th Mar. 2004
Site Specific Objectives with Priority (Must include general objectives in proposal)	Middle Miocene: To recover a ridgecrest calcium carbonate record of the early-mid Miocene sedimentation maximum on 16 Ma old crust, spanning 16 to 12 Ma.
List Previous Drilling in Area:	DSDP 79, 571

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	PEAT-8B	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Eastern equatorial Pacific
Latitude:	Deg: 1°N	Min: 19	Jurisdiction:	International
Longitude:	Deg: 117°W	Min: 58.5	Distance to Land:	1462 km (Clipperton Island)
Coordinates System:	WGS 84			
Priority of Site:	Primary: X	Alt:	Water Depth:	3900-4100 m

Section C: Operational Information

	Sediments	Basement
Proposed Penetration: (m)	350m	5m
	What is the total sed. thickness? ~350m m	
		Total Penetration: 355 m
General Lithologies:	Pelagic clay, siliceous ooze, calcareous ooze, chalk.	basalt
Coring Plan: *(Specify or check)*	1-2-3-APC, XCB as needed	

Wireline Logging Plan:

Standard Tools		Special Tools					
Neutron-Porosity	☐	Borehole Televiewer	☐	Formation Fluid Sampling	☐	Density-Neutron	☐
Litho-Density	☐	Nuclear Magnetic Resonance	☐	Borehole Temperature & Pressure	☐	Resistivity-Gamma Ray	☐
Gamma Ray	☐	Geochemical	☐	Borehole Seismic	☐	Acoustic	☐
Resistivity	☐	Side-Wall Core Sampling	☐				
Acoustic	☐						
Formation Image	☐			Others ( )		Others ( )	

Max.Borehole Temp. :

Expected value (For Riser Drilling)
____ °C

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals

from m to m, m intervals

from m to m, m intervals

Basic Sampling Intervals: 5m

Estimated days:

Drilling/Coring:6	Logging:1	Total On-Site:7

Future Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Methane Hydrate	☐
Abnormal Pressure	☐	Fractured Zone	☐	Diapir and Mud Volcano	☐
Man-made Objects	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐
CO_2	☐				

What is your Weather window? (Preferable period with the reasons)

POTENTIAL EXTERNAL REVIEWERS (Jan. 2003)

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EDUCATION

1997 B.A. (Hons)/M.A. Cantab Natural Sciences, Clare College, University of Cambridge
1998 M.Sc. (Distinction) Hydrogeology, University College London
2002 Ph.D. Earth Sciences, University of Cambridge

PROFESSIONAL EXPERIENCE

2002 – Present
Research Scientist, University of Stockholm
2002 NERC ODP Postdoc, Godwin Laboratory, University of Cambridge
2001 Ocean Drilling Program (ODP), College Station, Texas
ODP 199 Stratigraphic Correlator: "The Paleogene Equatorial Transect"
1997 Mobil North Sea Limited, Aberdeen
Summer Student Researcher

SELECTED PUBLICATIONS

2000 Pälike, H., Shackleton, N.J., Constraints on astronomical parameters from the geological record for the last 25My, Earth and Planetary Science Letters **182**, 1-14.
2001 Pälike, H., Shackleton, N.J., Röhl, U., Astronomical forcing in late Eocene marine sediments, Earth and Planetary Science Letters **193**, 589-602.
2001 Zachos, J.C., Shackleton, N.J., Revenaugh, J.S., Pälike, H., Flower, B.P., Climate response to orbital forcing across the Oligocene-Miocene boundary, Science **292**, 5515, 274-278.
2002 Horng, C.-S., Lee, M.-Y., Pälike, H., Wei, K.-Y., Liang, W.-T., Iizuka, Y., Tori, M., Astronomically calibrated ages for geomagnetic reversals within the Matuyama chron, Earth Planets Space **54**, 679-69.
2002 Wilson, P.A., Pälike, H., Coxall, H.K., Backman, J., New palaeoceanographic contraints on the Eocene-Oligocene Transition in the Pacific, Eos Trans. AGU **83** (47), Fall Meet. Suppl., Abstract PP22A-0354.
2002 Pälike, H., Moore, T.C. Jnr., Janecek, T.R., Correlation and Astronomical Calibration of Pacific Sediments From ODP Leg 199, Eos Trans. AGU **83** (47), Fall Meet. Suppl., Abstract PP21D-11.

Mitchell W. Lyle

EDUCATION

B.S (Geology,with honors)	The University of Michigan	1973
Ph.D. (Oceanography)	Oregon State University	1978

POSITIONS since 1998

Research Professor, Boise State University 1992-present

PROFESSIONAL EXPERIENCE SINCE 1998

(27 oceanographic cruises from 1973-1997 including 6 DSDP/ODP Drilling Legs)

MEMBER Ocean Drilling Program
1998-2001
Site Survey Panel

STEERING COMMITTEE MEMBER 1999
NSF workshop: "Workshop on U.S. marine seismic reflection acquisition for the next decade"

INVITED PARTICIPANT 1999
Ocean Drilling Program Conference: "COMPLEX: Conference on Multiple Platform Exploration"

NEMO Expedition, Leg 3 2000
R/V Melville, Site survey for ODP Leg 202 drillsites and for high resolution studies of Pleistocene intermediate water circulation in the eastern tropical Pacific

OCEAN DRILLING PROJECT, leg 199 co-Chief Scientist 2001
Paleoceanographic study of equatorial circulation during thewarmest climate of the Cenozoic

INVITED PARTICIPANT 2002
Ocean Drilling Program Conference: "CUSP: Conference on US Participation in IODP"

INVITED PARTICIPANT 2002
NSF Earth Systems History planning workshop on the tropical oceans

SELECTED PUBLICATIONS

1985 Flux comparisons between sediments and sediment traps in the eastern tropical Pacific: implications for atmospheric CO_2 variations during the Pleistocene (Dymond and Lyle) *Limnol. Oceanogr., 30*, 699-712.

1987 Late Tertiary history of hydrothermal deposition at the East Pacific Rise, 19°S: correlation to volcano-tectonic events. (Lyle, Leinen, Owen, Rea) *Geophys. Res. Lett., 14*, 595-598.

1988 The record of Late Pleistocene biogenic sedimentation in the eastern tropical Pacific Ocean (Lyle, Murray, Finney, Dymond, Robbins, and Brooksforce) *Paleoceanography, 3*, 39-59.

1988 Climatically forced organic carbon burial in the equatorial Atlantic and Pacific oceans (Lyle). *Nature, 355*, 529-532.

1992 Upwelling and productivity changes inferred from a temperature record in the equatorial Pacific (Lyle, Prahl, and Sparrow) *Nature, 355*, 812-815.

1992 Paleoproductivity and carbon burial across the California Current: the MULTITRACERS transect, 42°N (Lyle, Zahn, Prahl, Dymond, Collier, Pisias, Suess) *Paleoceanography, 7*, 251-272.

1992 Late Glacial to Holocene changes in upwelling and seasonal production of the northern California Current system (Sancetta, Lyle, Heusser, and Zahn).*Quaternary Research*, 38, 359- 370.

1995 The Late Miocene (11-8 Ma) Eastern Pacific Carbonate Crash: Reorganization of deep water circulation by closing the Panama Gateway. (Lyle, Dadey, and Farrell) *In* Pisias, N., Mayer, L.A., Janecek, T.R., and the Shipboard Scientific Party. *Proceedings of the Ocean Drilling Program, Scientific Results, Leg 138*. (College Station, TX, Ocean Drilling Program), 821-839.

1997 Could early Cenozoic thermohaline circulation have warmed the poles? (Lyle) *Paleoceanography*, *12(2)*, 161-167.

2000 The sedimentary record of the California Current system, middle Miocene to Holocene: a synthesis of Leg 167 results (Lyle, Koizumi, Delaney, and Barron) *Proceedings of the Ocean Drilling Program, Scientific Results, Leg 167*, 341-376.

2001 Collapse of the California Current during glacial maxima linked to climate change on land (Herbert, Schuffert, Andreasen, Heusser, Lyle, Mix, Ravelo, Stott, Herguera), *Science*, 293, 71-76.

2001 Interglacial theme and variations: 500 k.y. of orbital forcing and associated responses from the terrestrial and marine biosphere, U.S. Pacific Northwest. (Lyle, Heusser, Herbert, Mix, and Barron) *Geology 29(12)*, 1115-1118.

2002 Equatorial Ocean circulation in an extreme warm climate (Moore, Rea, Lyle, Liberty) *Paleoceanography 17(1)*, 5-1–5-6.

2002 Patterns of $CaCO_3$ deposition in the eastern tropical Pacific Ocean for the last 150 kyr: evidence for a southeast Pacific depositional spike at 18 ka (Lyle, Mix, and Pisias). *Paleoceanography*, 17(2), DOI 10.1029/2000PA000538.

2002 Development of a seismic stratigraphy for the Paleogene sedimentary section, central equatorial Pacific Ocean (Lyle, Liberty, Moore, and Rea), in Proceedings of the Ocean Drilling Program, Initial Reports, edited by M. Lyle, P. Wilson, and T.R. Janecek, and the Leg 199 shipboard scientific party, http://www-odp.tamu.edu/publications/199_IR/199ir.htm, Ocean Drilling Program, College Station TX, Chapter 4.

2002 Determination of biogenic opal in pelagic marine sediments: a simple method revisited, in Proceedings of the Ocean Drilling Program, Initial Reports Volume 199, edited by M. Lyle, Wilson, P.A., Janecek, T.R., and the Leg 199 shipboard scientific party, http://www- odp.tamu.edu/publications/199_IR/199ir.htm, Ocean Drilling Program, College Station TX, 2002.

2002 Silicate, diatoms and atmospheric CO2 during the last glacial cycle: a comparison of core data and model results. (Dugdale, Wischmeyer, Wilkerson, Chai, Barber, Peng, and Lyle) *EOS, 83(47)*, F387.

2002 Holocene evolution of two upwelling systems - offshore northern California and the central Gulf of California (Barron, Bukry, Heusser, Herbert, and Lyle), *EOS, 83(47)*, F943.

2002 The Eocene and Oligocene Pacific equatorial region from ODP Leg 199 Drilling (Lyle, Wilson, and the Leg 199 shipboard scientific party), *EOS, 83(47)*, F946.

2002 The CCD of the Paleogene tropical Pacific - results of ODP Leg 199 (Rea, Wilson, Lyle, Janecek, and the Leg 199 shipboard scientific party), *EOS, 83(47),* F946

2002 Initial seismic characterization of a fault-controlled hydrothermal area (Bradford, Lyle, Clement, Liberty, Myers, and Paul), *EOS, 83(47)*, F1370.

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September 2002

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Professional Preparation

B.S.,	University of North Carolina, 1960 Major: Geology
Ph.D.,	Scripps Institution of Oceanography, U.C.S.D., 1968 Major: Oceanography

Appointments

1989-present:	Professor of Marine Geology, The University of Michigan
1989-1998	Director, Center for Great Lakes and Aquatic Sciences, The University of Michigan
1981-1989	Research Associate, Exxon Production Research Co.
1975-1981	Professor, Graduate School of Oceanography, University of Rhode Island
1969-1975	Associate Professor, School of Oceanography, Oregon State University
1968-1969	Research Associate, School of Oceanography, Oregon State University
1963-1968	Research and Teaching Assistant, Scripps Institution of Oceanography
1960-1963	Naval Officer, U.S.S. Eaton DD 510, Engineering Dept., Navigator

Selected References

T.C. Moore, D.K. Rea. M. Lyle, and L.M. Liberty, (2001) Equatorial Ocean Circulation in an Extremely Warm Climate. Paleoceanography. , 17 (1), 5.1-5.6 (10.1029/2000PA000566).

T. C. Moore, M. Lyle, D. K. Rea, L. Liberty, M. Knappenberger, D. Mitchell, and R. Fonda, 1998. What happened to the early Paleogene circulation? Reconstructing Ocean History, a window into the Future, 6th International Conference on Paleoceanography, Lisbon. Program & Abstracts, p.167-168.

L. C. Sloan, J. C. G. Walker, and T. C. Moore, Jr., 1995. The possible role of Oceanic heat transport in early Eocene climate. Paleoceanography, 10(2): 347-356.

T. C. Moore, Jr., N. G. Pisias, and N. J. Shackleton, 1993. Paleoceanography and the diachrony of radiolarian events in the eastern equatorial Pacific. Paleoceanography. 8(5): 567-586.

L. Cirbus Sloan, J.C.G. Walker, T. C. Moore, Jr., D. K. Rea, and J. C. Zachos, 1992. Methane in the Eocene Atmosphere. Nature, 357:320-322.

T.C. Moore, Jr., J.C.G. Walker, and D.K. Rea, C.F.M. Lewis, L.C.K. Shane, and A.J. Smith, 2000. The Younger Dryas interval and outflow from the Laurentide ice sheet. Paleoceanography, 15: 1-18.

Safarudin and T. C. Moore, 1999. The history and architecture of depositional systems in northern Lake Michigan. Journal of Paleolimnology, 22: 475-496..

H. Godsey, T. C. Moore, Jr., D. K. Rea, and L. C. K. Shane, 1999. Younger Dryas seasonality in the North American mid-continent region as recorded in Lake Huron varved sediments. Canadian Journal of Earth Sciences, 36:533-547.

T.C. Moore, Jr., K. D. Klitgord, A.J. Golmshtok, and E. Weber, 1997, Sedimentation and subsidence patterns in the Central and North Basins of Lake Baikal from seismic stratigraphy. Geol. Soc. Amer. Bull.109(6): 746-766.

N. G. Pisias, and T. C. Moore, Jr., 1995. Radiolarian response to oceanographic changes in the eastern equatorial Pacific at 2.3 and 4.8 Ma: relationship between changing carbonate deposition and surface oceanography, in Mayer, L., Pisias, N., Janecek, T. et al. 1995, *Proc. ODP, Scientific Results 138:* College Station (Ocean Drilling Program), p. 461-478.

Recent Research Cruise Participation

JOIDES Resolution, Leg 199, Equatorial Pacific, October-December, 2001, stratigraphic correlator

Laurentian, Lake Huron, Georgian Bay, August-September 1991, co-chief scientist

JOIDES Resolution, Leg 138, Equatorial Pacific, July-September, 1992, biostratigrapher

Laurentian, Lakes Michigan, Huron, and Georgian Bay, July 1995, co-chief scientist

El Gustavo Orozco , Lake Nicaragua, June, 1997, co-chief scientist

Maurice Ewing, Tropical Pacific, December 1997-January 1998, co-chief scientist

Selected National and International Committee Participation

Advisory Committee on Ocean Sciences, NSF, (1991 - 1993)
Steering Committee, Council on Ocean Affairs (1991 - 1994)
Advisory Committee on Geosciences, NSF, (1993 - 1996)
JOIDES Ocean History Panel (1994 - 1996)
Committee of Visitors for NSF/OCE (1995)
Steering Committee, Marine Earth Systems History (MESH) Program (1992 - 1996)
Working Group on Paleoceanography, (co-chair) FUMAGES Workshop
JOIDES Science Steering and Eval. Panel for the Dynamics of the Earth's Environ. (chair) (1997 - 1999)
Decadal Synthesis Committee, NSF/OCE (co-chair) (1998-2001)
IODP Planning Sub-Committee (chair) (1999-2001)
Interim Planning Committee for IODP (co-chair) (2001--)

Professional Affiliations

American Geophysical Union
Geological Society of America

Curriculum Vita: Neil C. Mitchell

Royal Society University Research Fellow

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Qualifications and employment history

1986 BA (Hons), Geological Sciences, University of Cambridge.
1989 DPhil in Marine Geophysics, University of Oxford.

Sep 1997 onwards: Royal Society University Research Fellow
Departments of Earth Sciences, Universities of Oxford and Cardiff
and Research Fellow, Wolfson College, Oxford from 1 April 1998.
Dec 1992 to Aug 1997: Research Fellow of the NERC
Department of Geological Sciences, University of Durham.
Research concerned with mid-ocean ridge tectonics and sedimentation.
Jan to Aug 1993: International Fellow of the NSERC
Department of Surveying Engineering, University of New Brunswick (Canada).
Research into seafloor classification methods based on multibeam echosounder data.
Feb to Nov 1992: Senior Geophysicist with Wimpol Ltd
Commercial surveys and software development.
Jan 1990 to Jan 1992: Research Fellow of the Royal Commission for the Exhibition of 1851
Lamont-Doherty Geological Observatory of Columbia University, New York.

Research

Extensive experience of marine geophysical methods, including processing and analysis of multibeam, sidescan and sediment profiling sonar data. Research has included quantifying aspects of deep-water pelagic sedimentation, in particular modelling the equatorial Pacific sediment bulge, studies of mid-ocean ridges, the growth and modification of volcanic ocean islands and seamounts, submarine erosion of continental slopes. Participated in 16 research cruises. 36 peer-reviewed publications since 1989. Holder of grants from a variety of sources (NERC, Royal Society, British Council, HEFCW and commercial enterprises). These include (lead-PI) non-thematic NERC funded project concerning the Bouvet Triple Junction and (co-PI) BRIDGE project on quantifying tectonic strain on the Mid-Atlantic Ridge and on a Royal Society-funded project on tectonics on Iceland.

Professional service

Currently serving on the NERC peer-review committee for Earth Sciences. Supervisor of two PhD students. Referee for a variety of funding organisations, research journals and tenure committees. Member of the Geological Society, London (Marine Studies Group committee member), American Geophysical Union, European Geophysical Society.

Major equipment procurement

Involved in or led major equipment procurement including a high-resolution portable multibeam echo-sounder based in Cardiff (£324k), a swath system and sediment profiler for Autosub, the NERC Autonomous Underwater Vehicle (£200k) and a deep-water multibeam echo-sounder and sediment profiler on RRS James Clark Ross (£2M).

Wider engagement of science with society

Selected by the Royal Society as one of the first 6 Research Fellows to take part in a scheme linking scientists with Members of Parliament (2001). Participated in various other schemes at the Royal Society and given external lectures.

PUBLICATIONS

Mitchell, NC, MW Lyle, MB Knappenberger and LM Liberty, The Lower Miocene to Present stratigraphy of the equatorial Pacific sediment bulge and carbonate dissolution anomalies, Paleoceanography, in review, 2003.

Mitchell, NC, Susceptibility of Mid-Ocean Ridge Volcanic Islands and Seamounts to Large-Scale Landsliding, J. Geophys. Res., in press, 2003.

Coogan, LA, **NC Mitchell** and MJ O'Hara, Roof assimilation at fast-spreading ridges: an investigation combining geophysical, geochemical and field evidence, *J. Geophys. Res.*, 108, 2003 (DOI: 10.1029/2001JB001171).

Reston, TJ, W Weinrebe, I Grevemeyer, ER Flueh, **N C Mitchell,** L Kirstein, C Kopp, H Kopp and participants of Meteor 47/2, A rifted inside corner massif on the MAR at 5°S, *Earth Planet. Sci. Lett.*, 200, 255-269, 2002.

Mitchell, NC, DG Masson, AB Watts, MJR Gee and R Urgeles, The morphology of the flanks of volcanic ocean islands: A comparative study of the Canary and Hawaiian hotspot islands, *J. Volcanol. Geotherm. Res*., 115, 83-107, 2002.

DG Masson, AB Watts, MJR Gee, R Urgeles, **NC Mitchell**, TP Le Bas, M Canals, Slope failures on the flanks of the western Canary Islands, *Earth Sci. Rev*., 57, 1-35, 2002.

Gee, M.J.R., D.G. Masson, A.B. Watts, and **N.C. Mitchell**, Passage of debris flows and turbidity currents through a topographic constriction: Seafloor erosion and deflection of flow pathways, *Sedimentology*, 48, 1389-1409, 2001.

Gee, M.J.R., D.G. Masson, A.B. Watts, and **N.C. Mitchell**, Landslides and the evolution of El Hierro in the Canary Islands, *Mar. Geol.*, 177, 271-293, 2001.

Mitchell, NC, Random sequences of lithologies exposed on the Mid-Atlantic Ridge, *J. Geophys. Res*., 106, 26,365-26,378, 2001.

Gee, M.J.R., D.G. Masson, A.B. Watts, and **N.C. Mitchell**, Offshore continuation of volcanic rift zones, El Hierro, Canary Islands, *J. Volcanol. Geotherm. Res.*,105, 107-119, 2001.

Mitchell, NC, The transition from circular to stellate forms of submarine volcanoes, *J. Geophys. Res*, 106, 1987-2003, 2001.

Mitchell, NC, MA Tivey and P Gente, Seafloor slopes at mid-ocean ridges from submersible observations and implications for interpreting geology from seafloor topography, *Earth Planet. Sci. Lett*., 183, 543-555, 2000.

Mitchell, NC, RA Livermore, P Fabretti and G Carrara, The Bouvet triple junction, 20 to 10 Ma, and extensive transtensional deformation adjacent to the Bouvet and Conrad transforms, *J. Geophys. Res., 105,* 8279-8296, 2000.

Escartin, J, PA Cowie, RC Searle, S Allerton, **NC Mitchell**, CJ MacLeod, and AP Slootweg, Quantifying tectonic and magmatic strain at a slow-spreading ridge segment (Mid-Atlantic Ridge, 29°N), *J. Geophys. Res.*, *104*, 10421-10437, 1999.

Mitchell, NC, and RC Searle, Fault scarp statistics at the Galapagos Spreading Centre from Deep Tow data, *Mar. Geophys. Res.*, *20,* 183-193, 1998.

Mitchell, NC, Modeling Cenozoic sedimentation in the central equatorial Pacific and implications for true polar wander, *J. Geophys. Res.*. 103, 17749-17766, 1998.

Mitchell, NC and RA Livermore, Spiess Ridge: An axial high on the slow-spreading Southwest Indian Ridge, *J. Geophys. Res.*, 103, 15457-15471, 1998.

Mitchell, NC and RA Livermore, The present configuration of the Bouvet triple junction, *Geology*, *26*, 267-270, 1998.

Mitchell, NC, Sediment accumulation rates from Deep Tow profiler records and DSDP Leg 70 cores over the Galapagos Spreading Centre, in: A Cramp, CJ MacLeod, SV Lee and EJW Jones (eds) The Geological Evolution of Ocean Basins: Results From the Ocean Drilling Program, Spec. Publ. Geol. Soc. Lond., 131, 199-209, 1998.

Mitchell, NC, Characterising the irregular coastlines of volcanic ocean islands, *Geomorph.*, 23, 1-14, 1998.

Searle, RC, PA Cowie, **NC Mitchell,** S Allerton, CJ MacLeod, J Escartin, SM Russell, PA Slootweg, and T Tanaka, Fault structure and detailed evolution of a slow spreading ridge segment: the Mid-Atlantic Ridge at 29°N, *Earth Planet. Sci. Lett.,* 154, 167-183, 1998.

Mitchell, NC, S Allerton and J Escartin, Sedimentation on young ocean floor at the Mid-Atlantic Ridge, 29° N, *Mar. Geol.*, 148, 1-8, 1998.

Mitchell, NC, Processing and analysis of Simrad multibeam sonar data, *Mar. Geophys. Res.*, 18, 729-739, 1996.

Mitchell, NC, Creep in pelagic sediments and potential for morphologic dating of marine fault scarps, *Geophys. Res. Lett.*, 23, 483-486, 1996.

Mitchell, NC, Diffusion transport model of pelagic sediments on the Mid-Atlantic Ridge, *J. Geophys. Res.*, 100, 19,991-20,009, 1995.

Mitchell, NC, Characterising the extent of volcanism at the Galapagos spreading centre using Deep Tow sediment profiler records, *Earth Planet. Sci. Lett.*, 134, 459-472, 1995.

Mitchell, NC, and JA Spencer, An algorithm for finding routes for submarine cables or pipelines over complex bathymetry using Graph Theory, *The Hydrographic J.*, 78, 29-32, 1995.

Mitchell, NC, Representing backscatter fluctuations with a PDF convolution equation, and its application to study backscatter variability in side-scan sonar images, *IEEE Trans. Geosci. Remote Sens.*, 33, 1328-1331, 1995.

Mitchell, NC, and JE Hughes Clarke, Classification of seafloor geology using multibeam sonar data from the Scotian Shelf, *Mar. Geol.*, 121, 143-160, 1994.

Mitchell, NC, A model for attenuation of backscatter due to sediment accumulations and its application to determine sediment thickness with GLORIA sidescan sonar, *J. Geophys. Res.*, 98, 22477-22493, 1993.

Mitchell, NC and LM Parson, The tectonic evolution of the Indian Ocean Triple Junction, anomaly 6 to present, *J. Geophys. Res.*, 98, 1793-1812, 1993.

Mitchell, NC, Comment on the mapping of iron-manganese nodule fields using reconnaissance sonars such as GLORIA, *Geo-Mar. Lett.* 13, 244-247, 1993.

Mitchell, NC, Improving GLORIA images using Sea Beam data, *J. Geophys. Res.* 96, 337-351, 1991.

Mitchell, NC, Distributed extension at the Indian Ocean Triple Junction, *J. Geophys. Res*., 96, 8019-8043, 1991.

Mitchell, NC, An evolving ridge system around the Indian Ocean Triple Junction, *Mar. Geophys. Res.*, 13, 173-201, 1991.

Searle, RC, TP LeBas, **NC Mitchell**, ML Somers, LM Parson and P Patriat, GLORIA image processing: the state of the art, *Mar. Geophys. Res.*, 12, 21-39, 1990.

Mitchell, NC, and ML Somers, Quantitative backscatter measurements with a long-range side-scan sonar, *IEEE J. Oceanic Engineering*, 14, 368-374, 1989.

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Education
- A.B., Princeton University, 1964.
  - Major: Geology
- M.S., University of Arizona, 1967.
  - Major: Sedimentation/Stratigraphy
- Ph.D., Oregon State University, 1974.
  - Major: Geological Oceanography; Minor: Geophysics

Professional Experience
1975-present: Assistant Professor (1975-1980), Associate Professor (1980-1986), Professor (1986-), University of Michigan, Ann Arbor, Michigan
2002: Visiting Scientist, Department of Earth Sciences, University of California, Santa Cruz, Santa Cruz, California
1995-2000: Chair, Department of Geological Sciences, University of Michigan
1988-1989: Interim Director, Center for Great Lakes and Aquatic Sciences, University of Michigan, Ann Arbor, Michigan
1988-present: Research Scientist, Center for Great Lakes and Aquatic Sciences, University of Michigan, Ann Arbor, Michigan
1986-1987: Associate Director, Climate Dynamics Program, Atmospheric Sciences Division, National Science Foundation, Washington, D.C.
1982-1983: Visiting Associate Professor, College of Oceanography, Oregon State University, Corvallis, Oregon
1974-1975: Assistant Professor, School of Oceanography, Oregon State University, Corvallis, Oregon

Selected Research Cruise Participation
Glomar Challenger, Legs 61 and 62, North Pacific, July-Sept., 1978, sedimentologist
Lee, central North Pacific, June-July, 1982
Wecoma, northeast Pacific, September-October, 1982, chief scientist
Glomar Challenger, Leg 92, southeast Pacific, February-April, 1983, co-chief scientist
JOIDES Resolution, Leg 121, eastern Indian Ocean, May-June, 1988, sedimentologist
Thomas Washington, eastern Equatorial Pacific, August-October, 1989
Laurentian, Lake Huron and Georgian Bay, August-September, 1991, co-chief scientist
JOIDES Resolution, Leg 145, North Pacific, July-September, 1992, co-chief scientist
Laurentian, Lakes Michigan and Huron, July-August, 1995, co-chief scientist
JOIDES Resolution, Leg 199, northeast Pacific, October-December, 2001, sedimentologist

Selected National and International Committee Participation

Ocean Drilling Program, Central and Eastern Pacific Regional Panel, 1984-1986, 1987-1990; Chair, Fall 1985 to Summer 1986, and Fall 1987 to Spring 1990. Atolls and Guyots Detailed Planning Group, Chair, Winter/Spring, 1991; Climate and Tectonics Program Planning Group, 1998-1999; IODP Scientific Planning Working Group, 1999-2001; JOIDES Science Committee, 2000-2003

University of Arizona, Geosciences Advisory Board, 1997-present.

University of Minnesota, External Advisory Group for the National Lacustrine Core Facility, 2001-present

National Science Foundation, Steering Committee for the MESH (Marine aspects of Earth System History) Initiative, 1993-2001.

American Association for the Advancement of Science, Electorate Nominating Committee, Geology and Geography Section, 1992-1995; Chair, 1994-1995

American Geophysical Union, Committee on Paleoceanography, 1988-1990, 1992-1994. All-Union Committee on Global Environmental Change, Chair, 1993-1996. Geological Society of America, Technical Program Committee; responsibility for paleoceanography and paleoclimatology,
1990-1992.

National Academy of Sciences, Geophysics Study Committee on Geomaterial Fluxes: Glacial to Recent, 1988 to 1991.

Professional Affiliations

American Geophysical Union, Fellow
Geological Society of America, Fellow
American Association for the Advancement of Science
The Oceanography Society

Editorial Boards

Paleoceanography, 1985-present.
Geology, 2000-2002

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