JOIDES Journal

Volume 30, No. 1
Spring 2004

Joint Oceanographic Institutions
for Deep Earth Sampling

In this issue:

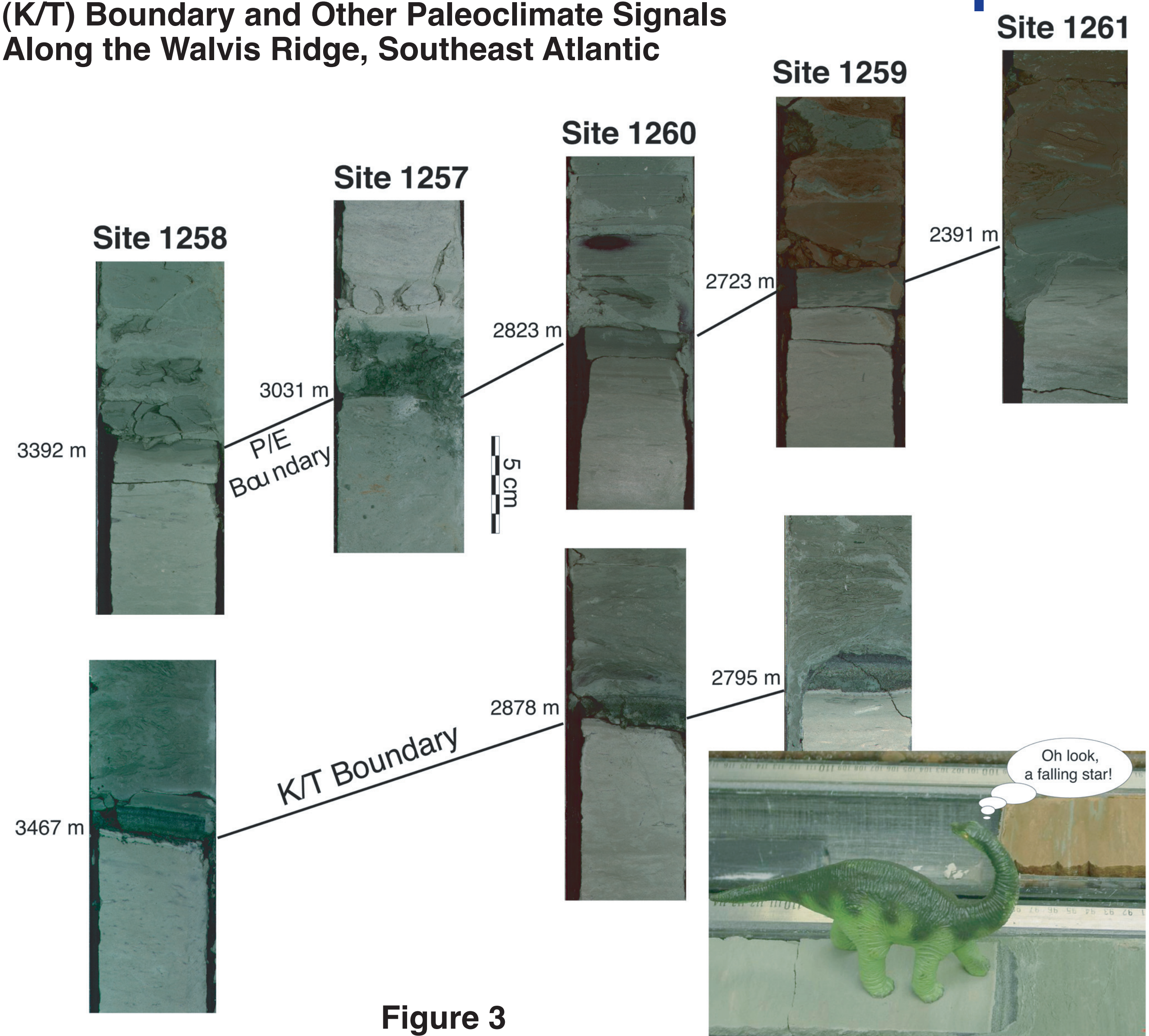

Figure 3
(Caption on Page 1)

In this issue from pages 8-13:

ODP Leg 208: The Early Cenozoic Extreme Climates Transect Along Walvis Ridge

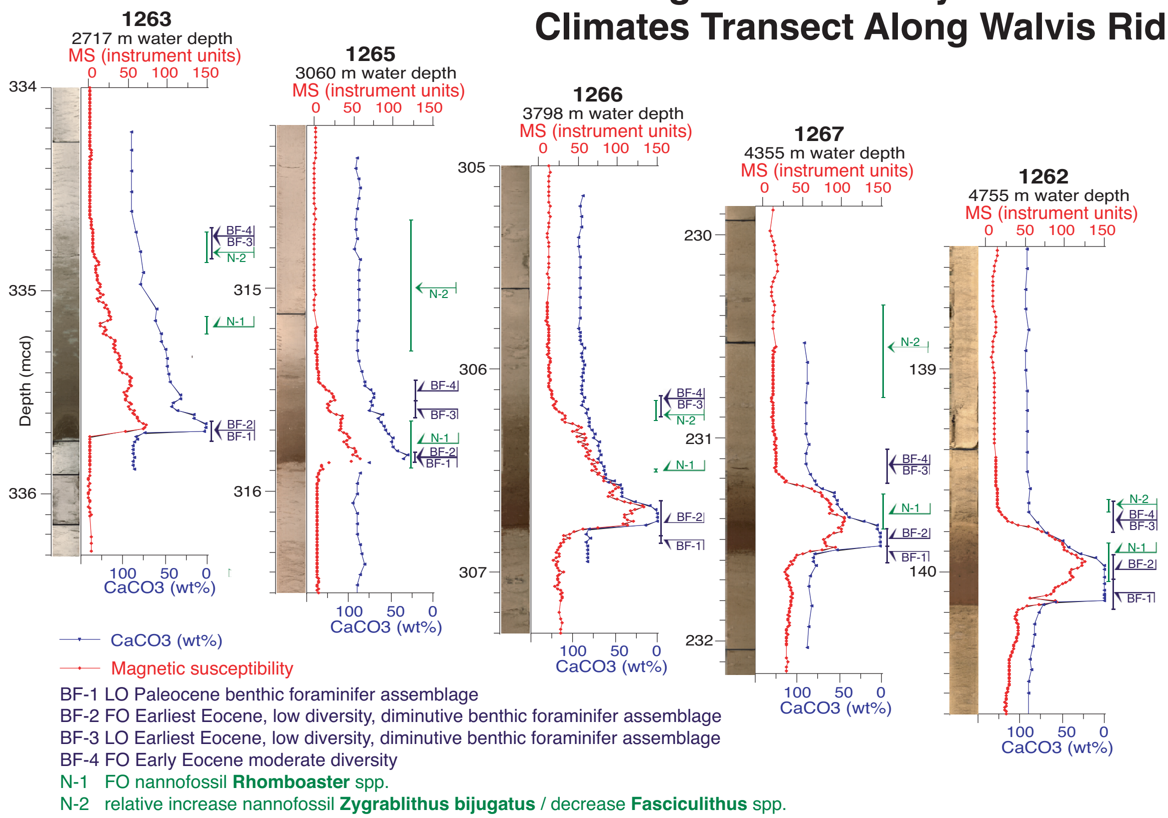

Figure 4. *Magnetic susceptibility (MS) and wt. % $CaCO_3$ through the Paleocene-Eocene transition at the shallow to deep transect. Depths are in m composite depth (mcd). The MS graphs represent both spliced core point magnetic susceptibility (PMS) data measured by the A Multi-Sensor Track (AMST) and whole-core MS data from the Multi-Sensor Track (MST). For correlation 1 cm resolution PMS data were linearly interpolated to 2.5 cm resolution; a linear expansion formula was then calculated and PMS values were normalized to MS values: MS (MST) = 2.0683 x PMS + 7.8257 (R2=0.9885). Site 1263 MS data from Hole C give away to Hole D below 335.88 mcd. Sample depths (mcd) for Hole D were normalized to Hole C mcd using a linear expansion based on PMS correlation through the P/E transition: 1263C mcd=1263D mcd x 1.383 - 128.45. Site 1262 sample depths (mcd) of wt.% $CaCO_3$ data from Hole A-13H were normalized to Hole B mcd using a linear expansion based on PMS correlation through lower part of the P/E transition: 1262B mcd=1262A mcd x 1.1343 - 18.785 (R2=0.996; only for data below 139.95 mcd). Site 1266 wt.% $CaCO_3$ data from Hole B (6H-7) give away to Hole C values at 306.56 mcd.*

In this issue from pages 14-19:

ODP Leg 209 Drills into Mantle Peridotite Along the Mid-Atlantic Ridge from 14°N to 16°N

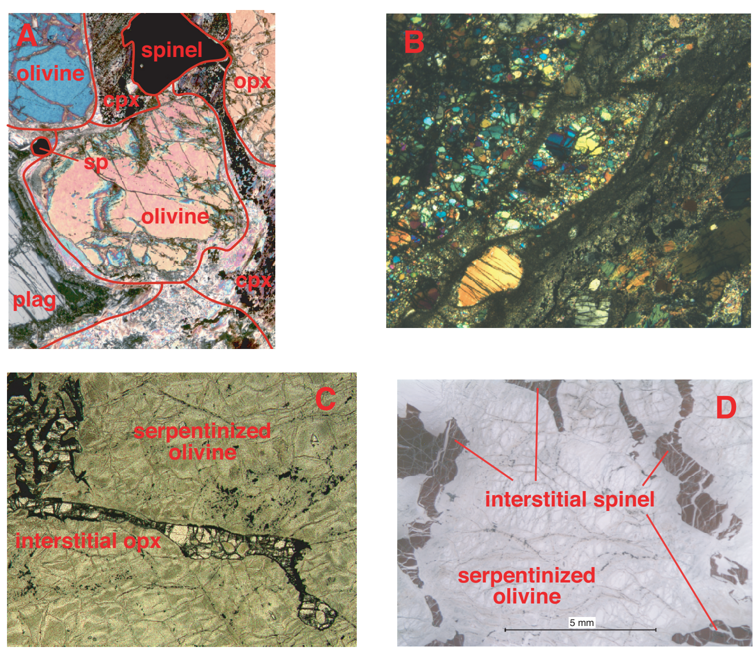

Figure 2. *Photomicrographs of thin sections of samples from ODP Leg 209.* **A.** *Impregnated peridotite with olivine, plagioclase, orthopyroxene, clinopyroxene and spinel showing "equilibrated" textures, overprinted by low temperature alteration along grain boundaries.* **B.** *Mixed gabbro and peridotite mylonite with recrystallized olivine, pyroxene, plagioclase and hornblende.* **C.** *Orthopyroxene crystal (high relief) interstitial to many olivine crystals, now serpentinized.* **D.** *Skeletal spinel crystals (brown) interstitial to many olivine crystals, now serpentinized.*

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IODP Riserless Vessel Schedule: June 2004 - June 2005 (US Implementing Organization)

Cruise[1]		Port (Origin)	Dates[2, 3]	Total Days (Port/Sea)	Co-Chief Scientists	Alliance Contact(s)
Transit		Gamagori, Japan	1 June - 20 June '04	19 (2/17)	N/A	N/A
Mobilization		Astoria	20 June - 27 June '04	7 (7/0)	N/A	N/A
Juan de Fuca Hydrogeology	1	Astoria	27 June - 21 August '04	55 (1/54)	A. Fisher T. Urabe	TAMU: A. Klaus LDEO: G. Iturrino
Costa Rica Hydrogeology/ Transit		Astoria	21 August - 22 September '04	32 (1/31)	To Be Named	TAMU: M. Malone
North Atlantic Climate 1	2	St. John's, Newfoundland	22 September -14 November '04	53 (5/48)	J. Channell T. Sato	TAMU: M. Malone LDEO: S. Robinson
Oceanic Core Complex 1	3	Ponta Delgada	14 November '04 - 5 January '05	52 (5/47)	C. MacLeod B. John	TAMU: J. Miller LDEO: F. Einaudi
Oceanic Core Complex 2	4	Ponta Delgada	5 January - 27 February '05	53 (5/47)	D. Blackman Y. Ohara	TAMU: J. Miller LDEO: H. Delius
North Atlantic Climate 2	5	Ponta Delgada	27 February - 22 April '05	54 (5/49)	R. Stein T. Kanamatsu	TAMU: M. Malone LDEO: B. Rea

Notes:
Acceptance of the vessel will occur on 31 May 2004.
[1] Expedition nomenclature will be adjusted in the future to reflect naming protocols to be established by IODP-MI.
[2] Ship arrival is scheduled for 0600 hr on the first day of port call.
[3] Initial cruise date reflects first day of port call; ship sails when ready.

7 May 2004

Figure Caption for the Front Cover Illustration:

Figure 3. *Lithology of the PETM and K/T cores across the Demerara Rise paleoceanographic depth transect. Note the abrupt change from light, carbonate rich chalk to dark green and red claystones that mark the PETM. A graded bed of clayey spherules that represents the altered fallout layer marks the K/T-boundary. Note also the thin white layer of calcareous nannofossil chalk at the base of the spherule bed that is interpreted as deposited after resuspension caused by the seismic shock of the impact event. Depths indicated represent present depths from sea level datum.*

GOODBYE from JOIDES

Vol. 30, No. 1
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Farewell to the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) and the JOIDES Journal

Keir Becker and Henny Gröschel, JOIDES Office

With the new Integrated Ocean Drilling Program (IODP) fully underway this summer, the phase-out of JOIDES, and its activities as known during the Deep Sea Drilling Project and Ocean Drilling Program, are almost complete. All of the JOIDES functions in ODP will be assumed by other bodies in IODP. Many will be taken over by the IODP-Management International, Inc. (IODP-MI) Sapporo Office. The term JOIDES will no longer be used in IODP.

Thus, the Spring 2004 issue of the JOIDES *Journal* is the last issue of a publication that has been produced continuously for 30 years since the incarnation of the first JOIDES Office in 1975 at the Lamont Geological Observatory. This final JOIDES *Journal*, in addition to presenting the scientific achievements of the final four ODP Legs 207, 208, 209 and 210 (pages 3 to 24), is intended partly to commemorate the accomplishments of JOIDES and all the participants in its history, and to provide an overview of the IODP.

The original JOIDES agreement of 1964, recreated on pages 34 to 36, was crafted to define JOIDES as the overarching organization that handled all aspects of the program envisioned at the time for scientific ocean drilling. In the first decade, membership in the program was signified by formal membership in JOIDES itself. This began to change when JOI was formed in 1975 to act as prime contractor for the Deep Sea Drilling Project, and the role of JOIDES evolved to represent primarily the scientific advisory structure and its activities. These advisory activities were coordinated by a JOIDES Office whose leadership and location rotated every two years, first among JOI institutions and later among ODP member countries. Motions were passed at the final meetings of the JOIDES Science and Executive Committees commemorating all the participants in the JOIDES advisory structure through the years. We add our final thanks as well. It has been a great honor to host the final rotation of the JOIDES Office at one of the original four JOIDES member institutions.

It is also gratifying to see the seamless adoption of most of the JOIDES Office functions by, at first, the iSAS Office during the ODP/IODP transition, and now the IODP Science Advisory Structure (SAS) and IODP-MI Sapporo Office. We thank IODP-MI Vice President Tom Janecek for contributing a summary article on how IODP and its SAS activities will work (see pages 25 to 30). We also thank Andy Kingdon and Colin Brett for providing a preview of the late summer 2004 Arctic Coring Expedition, IODP's first Mission Specific Platform effort (see pages 31 to 33). IODP-MI indicates that the publication of an IODP journal or newsletter reporting shipboard science results will continue on a schedule similar to the regular biannual schedule of the JOIDES *Journal*. The name and format of this IODP publication remains to be finalized.

Products of the JOIDES Office will be included in the ODP legacy project being assembled by JOI. Many aspects of the JOIDES legacy in digital form will be preserved on the ODP legacy website (e.g., PDF versions of recent JOIDES *Journal* issues, electronic versions of recent panel minutes). The JOIDES web site based at the University of Miami-RSMAS soon will be taken off line because the JOIDES Office formally ends on June 30, 2004. A filtered subset of older paper files other than drilling proposal files, which were forwarded to the iSAS Office in 2001, will be maintained for an unspecified period at RSMAS as space permits.

SCIENCE Leg Reports

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ODP Leg 207: Causes and Consequences of Carbon Cycle Perturbations During the Cretaceous to Paleogene Greenhouse; Demerara Rise, Western Equatorial Atlantic

David C. Mosher [1], Jochen Erbacher [2], Mitchell J. Malone [3] and the Leg 207 Scientific Party

INTRODUCTION

Rapid (1 k.y. to 1 m.y.) and massive perturbations of the global carbon cycle and extreme changes in Earth's climate occurred during the Cretaceous and Paleogene Periods (e.g., Cretaceous oceanic anoxic events (OAEs) and the Paleocene/Eocene Thermal Maximum (PETM)). In many cases, these events were accompanied by wholesale extinctions of marine and terrestrial biota. Little is known, however, about the underlying causes and effects of these critical events in Earth history. High-resolution paleoceanographic records from ocean drill sites, particularly in the tropics that are important in driving global ocean-atmospheric circulation, can address these knowledge gaps.

Demerara Rise, a submarine plateau north of Suriname and French Guyana, stretches ~380 km along the South American coast and is ~220 km wide from the shelf break to the northeastern escarpment, where water depths increase from 1000 m to more than 4500 m (Fig. 1). Ocean Drilling Program Leg 207 focused on the northwestern extent of this plateau (~9°N, in 1800 to 3400 m water depth) where expanded sections of shallowly buried Cretaceous and Paleogene deep-sea sediments exist (Fig. 1). The paleogeographic position of Demerara Rise is within the core of the

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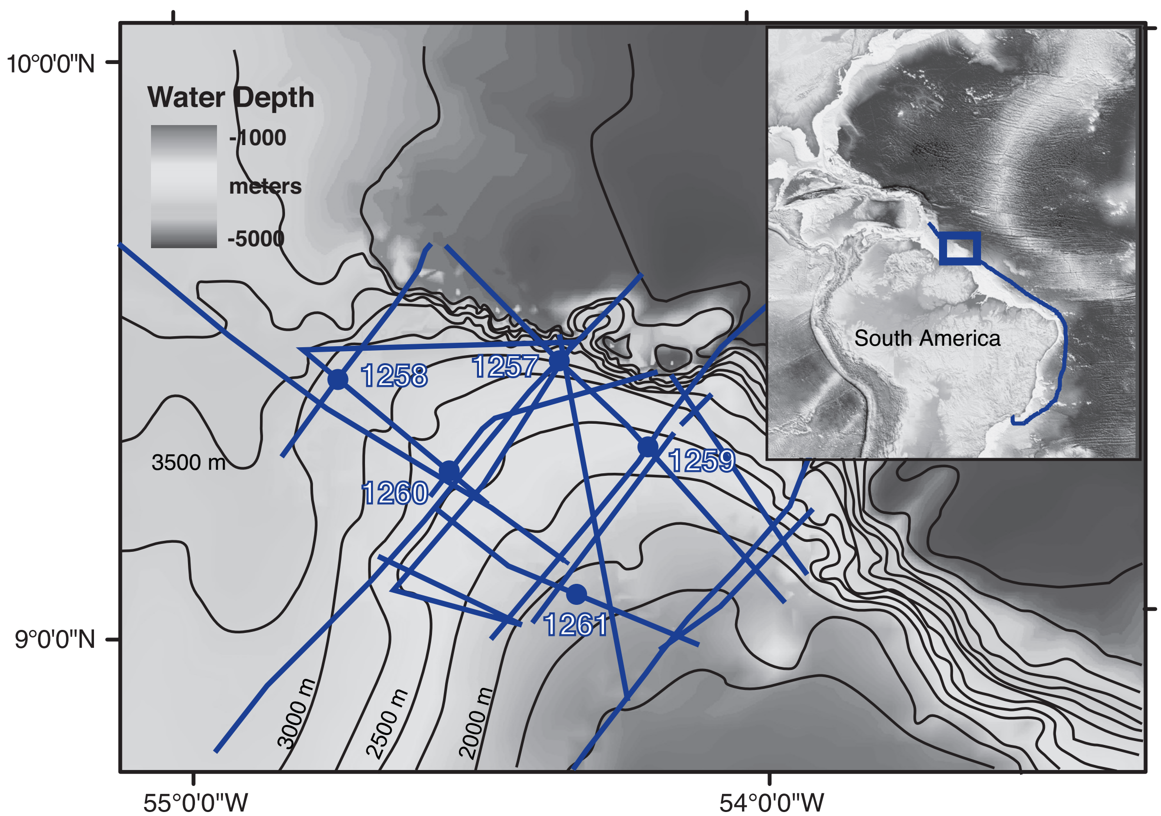

Figure 1. *Map of Ocean Drilling Program Leg 207 sites on Demerara Rise and geophysical survey lines (blue). Inset shows the location of the Demerara Rise, and Leg 207 drill sites (box), on the northeastern margin of South America.*

tropics in a proximal location to the Equatorial Atlantic Gateway between South America and Africa that is believed to have played an important role in controlling changes in global climate during the Cretaceous. Continuous records of the PETM, the Cretaceous/Tertiary boundary (K/T), and the OAEs were observed in sediment cores recovered during the cruise.

STRATIGRAPHY

Seismic and lithologic data from ODP Site 1260 are presented in Figure 2 as an example of generalized stratigraphy for Demerara Rise. A striking angular unconformity present across Demerara Rise, identified as the "C" horizon on the site survey reflection profiles of Figure 2, separates pre-Cenomanian synrift sequences from Cenomanian to present-age sediments (see Erbacher, Mosher, Malone et al., 2004). Synrift sediments consist of mixed lithologies of an apparent shallow marine setting, including claystone, siltstone and sandstone. Sedimentary structures in siltstone from Site 1259 suggest a tidal depositional environment. Between the C and the B' reflection horizons is a relatively flat-lying sequence of reflections representing Cenomanian to Santonian laminated black shales (Fig. 2), which sometimes contain spectacularly well-preserved calcareous microfossils and stringers of limestone and rare chert.

Campanian to Paleogene sediments are open marine calcareous chalks (Fig. 2) that include long intervals of relatively constant sedimenta-

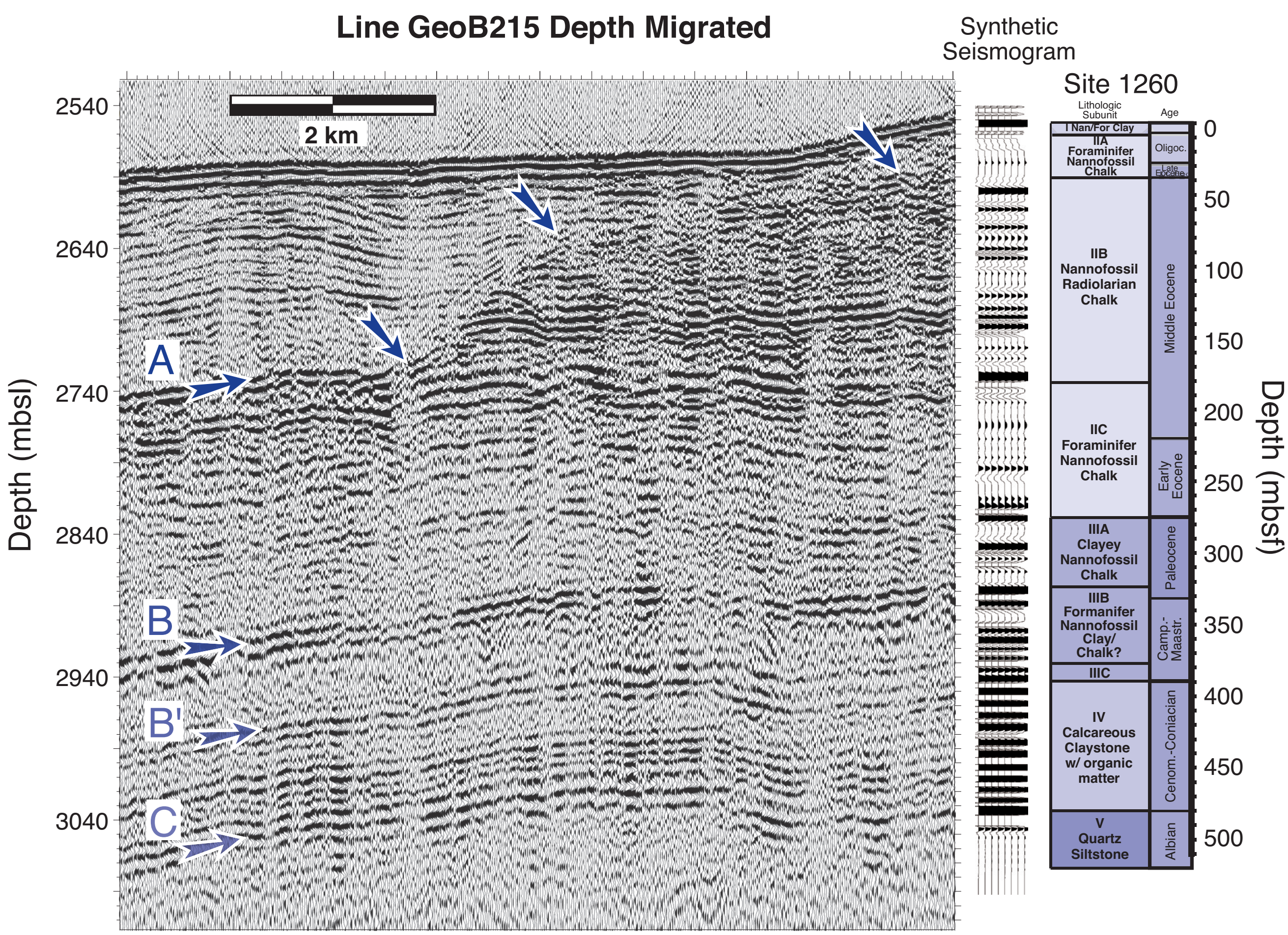

Figure 2. *Site 1260 stratigraphy, an example of the general seismic-, litho-, and chronostratigraphy of the Demerara Rise. The seismic line is part of R/V* Meteor *49-4 site survey line GeoB215. Logging and laboratory velocity and density data, as well as check shot velocity data, were used to generate the synthetic seismogram. After confirmation of the correlation between the synthetic and geophysical data, the velocity data were used to depth migrate the seismic line and accurately match seismic and core information. Strong ties between the seismic and core stratigraphies result from strong physical property contrasts between lithologies and critical intervals.*

tion and contain generally good microfossil preservation. Hiatuses and mass-flow deposits are present at various intervals, especially on the extreme flanks of the plateau. Reflection "B" correlates throughout the northern tip of the Demerara Rise with the K/T boundary (Fig. 2) that is demarcated by a significant change in sediment physical properties. An increase in clay content marks the PETM; overlying sediments return to calcareous ooze and chalk. A prominent submarine channel system and erosional surface, developed on the Demerara Rise in the late Oligocene to early Miocene, was correlated as reflection "A" on seismic profiles across the entire northwestern portion of the plateau (Fig. 2). The channels presumably carried sediment east-to-west over the flank of the plateau; as a result most of the Neogene sedimentary sequence (calcareous ooze) is thin or absent from the distal portions of the plateau.

CRITICAL INTERVALS

Paleocene-Eocene Thermal Maximum

Global warming at the end of the Paleocene is believed to be the precursor of the dramatic events at the Paleocene/Eocene boundary that produced the PETM. Models suggest that this warming led to dissociation of methane gas hydrates of the ocean margins, with a consequent abrupt release of methane to the atmosphere where it was oxidized to carbon dioxide (Dickens, 2000). This increase of atmospheric carbon dioxide led to even higher global temperatures that served as an amplifier for the methane release. Recent investigations have shown that the injection of fossil carbon to the atmosphere probably occurred in a series of short, few thousand year long, steps (Norris and Röhl, 1999).

The PETM record on Demerara Rise shows a pronounced, sharp lithologic change from calcareous chalks to green clay-rich beds (Fig. 3, front cover). This change, documented in ten cores at five sites across a depth transect of 1300 m present water depth, records the hypothesized calcite dissolution associated with the sudden methane released during the PETM. The oxidation of methane to carbon dioxide decreased the pH of seawater, dissolved calcite, and hindered the precipitation of calcareous shells of benthic organisms (Zachos et al., 1993; Thomas, 1998; Dickens, 2000). Accordingly, no calcareous microfossils are present in the clay beds. These clay layers are massive at the shallow and deep sites and laminated at intermediate water depth sites. The re-occurrence of bioturbation is paralleled by the return of tiny, poorly preserved benthic foraminifers. However, as preservation of foraminifers improves, a distinct planktonic foraminiferal fauna typical for the PETM appears. At the Demerara Rise, the thickness of clay and clay-rich lithologies associated with the PETM is approximately 1.5 m. Given a sedimentation rate of about 1.5 cm/k.y., the duration of the event, including recovery of the system, was at least as long as 100,000 k.y.

Cretaceous-Tertiary Boundary Sediments

Greenish chalks of latest Maastrichtian age are overlain by a thin (1 to 2 mm), fine-grained, white layer composed of Cretaceous calcareous nannofossils at three drill sites on Demerara Rise. Above the white layer is a ~1.5 cm interval composed of clay spherules that are up to 3 mm in diameter. The spherule layer thickness is the same across the plateau depth transect (Fig. 3, front cover). Above the spherule layer lies a dark gray clay layer that is low in carbonate. The thin white laminum is believed to represent sediment deposited after resuspension caused by the seismic shock of the K/T impact event, and the spherule layer is the result of primary ejecta fallout.

The consistent thickness of this layer across the plateau suggests it was deposited via settling through the water column rather than as a redepositional event. The overlying clay layer is present because of a lack of productivity of calcareous and siliceous biota following the impact. Demerara Rise is located approximately 3500 km southeast of the Chixculub impact crater on the Yucatan Peninsula.
The Leg 207 discovery and traces of impact ejecta found in a K/T boundary section from Northeast Brazil (Albertao et al., 1994) are the only evidence of the K/T impact event found on the South American continent.

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Cretaceous Black Shales and Oceanic Anoxic Events

Oceanic anoxic events, defined by massive and synchronous deposition of organic carbon, represent major perturbances of the ocean system, and played fundamental roles in the evolution of Earth's climatic and biotic history. Arguably, between two and six OAEs occurred during the mid- and Late Cretaceous (OAE 1a-d, OAE 2 and OAE 3; Schlanger and Jenkyns, 1976; Arthur et al., 1990; Erbacher et al., 1996). These are particularly important because they have left records from shallow basins to the deep sea. A thick sequence of laminated organic-rich claystones, referred to here as black shales, was recovered during Leg 207. Based on biostratigraphic observations, the black shales are assigned a middle Albian to earliest Campanian age, and cover two of the major OAEs: (1) OAE 2, which marks the Cenomanian/Turonian boundary, and (2) the Coniacian to Santonian OAE 3.

The black shales represent the local equivalent of widespread organic-rich sedimentation in the southern part of the mid-Cretaceous North Atlantic (e.g., Erlich et al., 2000). During Coniacian and, especially, Santonian times, oceanographic conditions in the region were apparently unstable, as indicated by intercalated glauconitic and bioturbated intervals. A probable tectonic instability related to the opening of the Equatorial Atlantic Gateway led to widespread mass wasting, resulting in numerous debris flows affecting this part of the black shale sequence. Sediment clasts of Campanian age in one debris flow indicate mass wasting extended at least into the Campanian. The lithologic transition from the black shales into the overlying Campanian pelagic deposits at some sites occurs over several m of glauconite-rich bioturbated claystone. At other sites, the contact is sharp and sometimes faulted at the top of the black shales.

The thickness of the succession varies between 93 m at Site 1260 and 56 m at Site 1259. The black shales are characterized by two distinct facies. Laminated organic-rich claystones, with variable carbonate content (5 to 50 wt.%) and up to 30 wt. % total organic carbon (TOC) of marine origin, are particularly well developed in the Cenomanian/Turonian (including OAE 2) part of the black shale interval. Lighter laminated to finely bedded foraminifer wackestones to packstones form either light-dark cycles with the organic-rich claystones or show a sharp base and a gradual transition (storm deposits?) into overlying sediments. The organic-rich claystones are characterized by distinct and sometimes very high content of well-preserved fish debris and phosphatic nodules (~2 cm). These occurrences form either discrete layers or are scattered in the background sediment.

Black shale sediments show a clear deepening upward trend and seem to have been deposited in a shallow to moderately deep water environment. Existing seismic lines do not support a silled basin model but rather an intensified oxygen-minimum layer impinging on Demerara Rise.

Black Shales Are an Active Bioreactor

Nearly 90 m.y. after deposition, the black shale sequence continues to act as a bioreactor that dominates the interstitial water chemistry. The linear downhole profiles shown in Figure 4 (next page) suggest the existence of one major stratigraphic sulfate sink and ammonium and methane source (i.e., the black shales). The linearity of these profiles reflects the low accumulation rates of sediments younger than the middle Eocene and low TOC values of sediments above the black shales. Methane concentrations of up to 110,000 ppmv were determined in headspace gas samples from the black shales. In addition, methane diffusing upward from the black shales may furnish metabolic activity above the black shale succession via anaerobic methane oxidation. These elevated methane values, together with the aforementioned chemistry profiles, suggest ongoing and high levels of microbial activities in the shales.

ACKNOWLEDGEMENTS

We thank the ODP Leg 207 technicians, drilling operations team, and ship's crew for their exemplary support. Site survey geophysi-

cal data were acquired, processed and supplied by the geophysical group of the University of Bremen (L. Zühlsdorff and V. Spieß) as partof the R/V *Meteor* 49-4 expedition in May 2001. Older vintage industrygeophysical data were reprocessed by Dr. H. Meyer (BGR, Hannover). This article is Geological Survey of Canada contribution no. 2004007.

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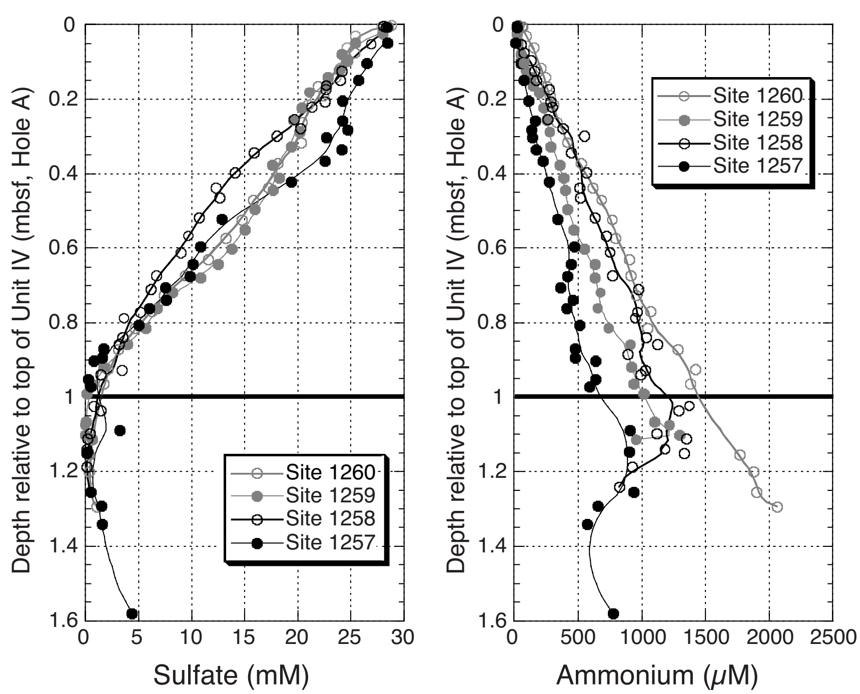

Figure 4. *Pore water chemistry profiles showing sulfate and ammonium at each drill site. The profiles are reduced to depth-match between the seafloor and the top of the black shale sequence. The strongly linear nature of the profiles indicates the black shales dominate chemical reactions within the sediment column, even after 95 million years of deposition.*

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ODP Leg 208: The Early Cenozoic Extreme Climates Transect Along Walvis Ridge

James C. Zachos [1], Dick Kroon [2], Peter Blum [3], and the Leg 208 Scientific Party

INTRODUCTION

The early Cenozoic is characterized by several episodes of rapid but extreme climate change. The best example is the Paleocene-Eocene Thermal Maximum (PETM), a short-lived time of global warming of more than 5°C (Kennett and Stott, 1991; Thomas and Shackleton, 1996). Other early Cenozoic climate anomalies or transients include the mid-Eocene Climatic Optimum (MECO; Bohaty and Zachos, 2003) and the early Oligocene glacial maximum (Oi-1; Zachos et al., 2001). Each of these aberrations from background variability was relatively short-lived, and accompanied by significant changes in ocean carbon chemistry inferred from anomalies in carbon isotope ratios and/or sudden shifts in lysocline depth or Carbonate Compensation Depth (CCD), implying a cause and effect relationship.

The exact nature of these carbon cycle perturbations is not well understood due, in part, to the lack of high-resolution, full recovery core sections needed to constrain the rate, magnitude, and extent of these anomalies. Such cores have been recovered in widely scattered locations, and provide only a one-dimensional perspective of regional paleoceanographic change.

Ocean Drilling Program Leg 208 was conceived to address these deficiencies, and to recover early Cenozoic pelagic sediments from 2.4 to 4.8 km water depth in the Southeast Atlantic Ocean (Fig. 1) with sufficient strati-

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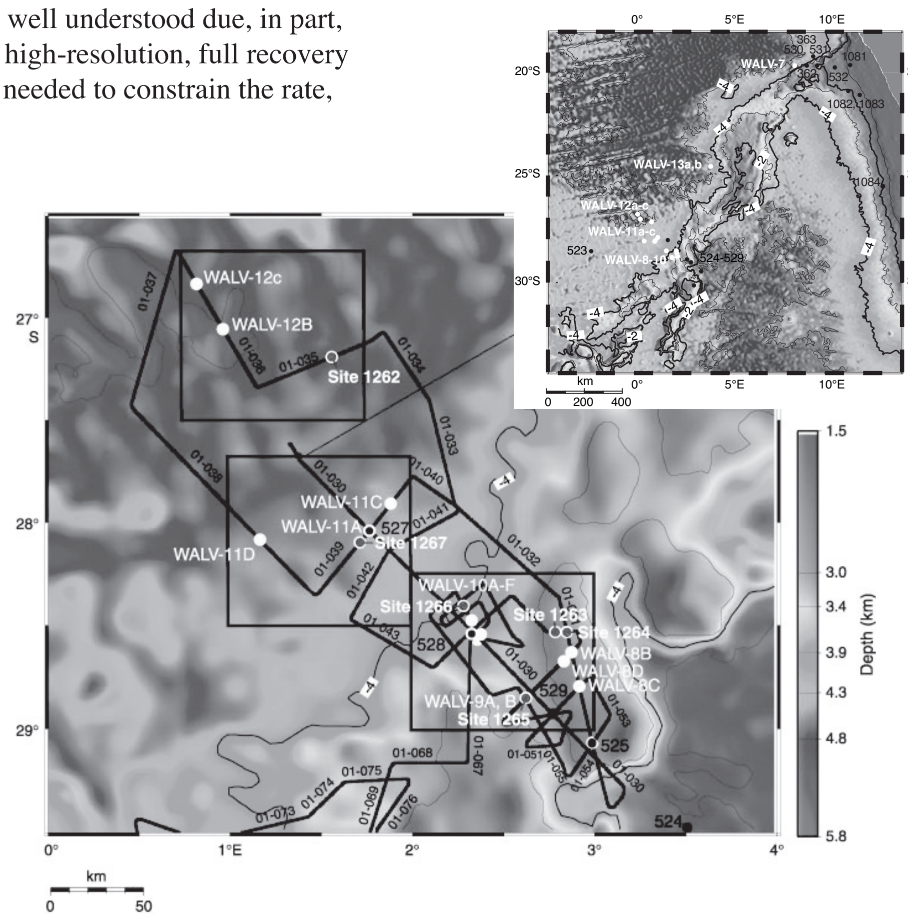

Figure 1. *Map of six ODP Leg 208 drill sites and primary site survey seismic lines along the northern flank of the Walvis Ridge. The inset shows the location of Walvis Ridge off the African margin in the southeast Atlantic Ocean. Deep Sea Drilling Project Leg 74 sites are shown by black circles.*

graphic resolution to constrain changes in deep-sea carbon chemistry during the transient events. Drilling occurred along a transect from Sites 1262 to 1267 on the northern flank of Walvis Ridge (Fig. 1), near Deep Sea Drilling Program Leg 74 sites that penetrated Cenozoic pelagic oozes and chalk but had poor recovery (Moore et al.,1984).

RESULTS

The upper Paleocene through lower Eocene sections are relatively expanded at all sites, with sedimentation rates of 12 to 20 m/m.y (Fig. 2). Because of exceptional core recovery in multiple holes and the quality of high-resolution core logs, we were able to resolve a wide spectrum of lithologic variability including that associated with orbital forcing. Marked cyclic variations in magnetic susceptibility and color reflectance occur throughout the Cenozoic at all sites. These variations, expressed as subtle lithologic cycles with wavelengths at the dm to m scale, were used to correlate between the parallel holes drilled at each site and to build composite sections. About 300 major cycles (peaks) in magnetic susceptibility were used to correlate all Leg 208 boreholes, and to construct a detailed but as yet tentative cycle-tuned age model for the complete ~68 m.y. long record.

Initial shipboard analyses of time series from selected intervals (late Maastrichtian, early Eocene, early to early late Miocene) reveal persistent precessional (~20 k.y.) scale oscillations through most of the recovered intervals. Modulation by the shorter (~100 k.y.) eccentricity cycle is nicely documented, particularly in the Maastrichtian through Eocene sections

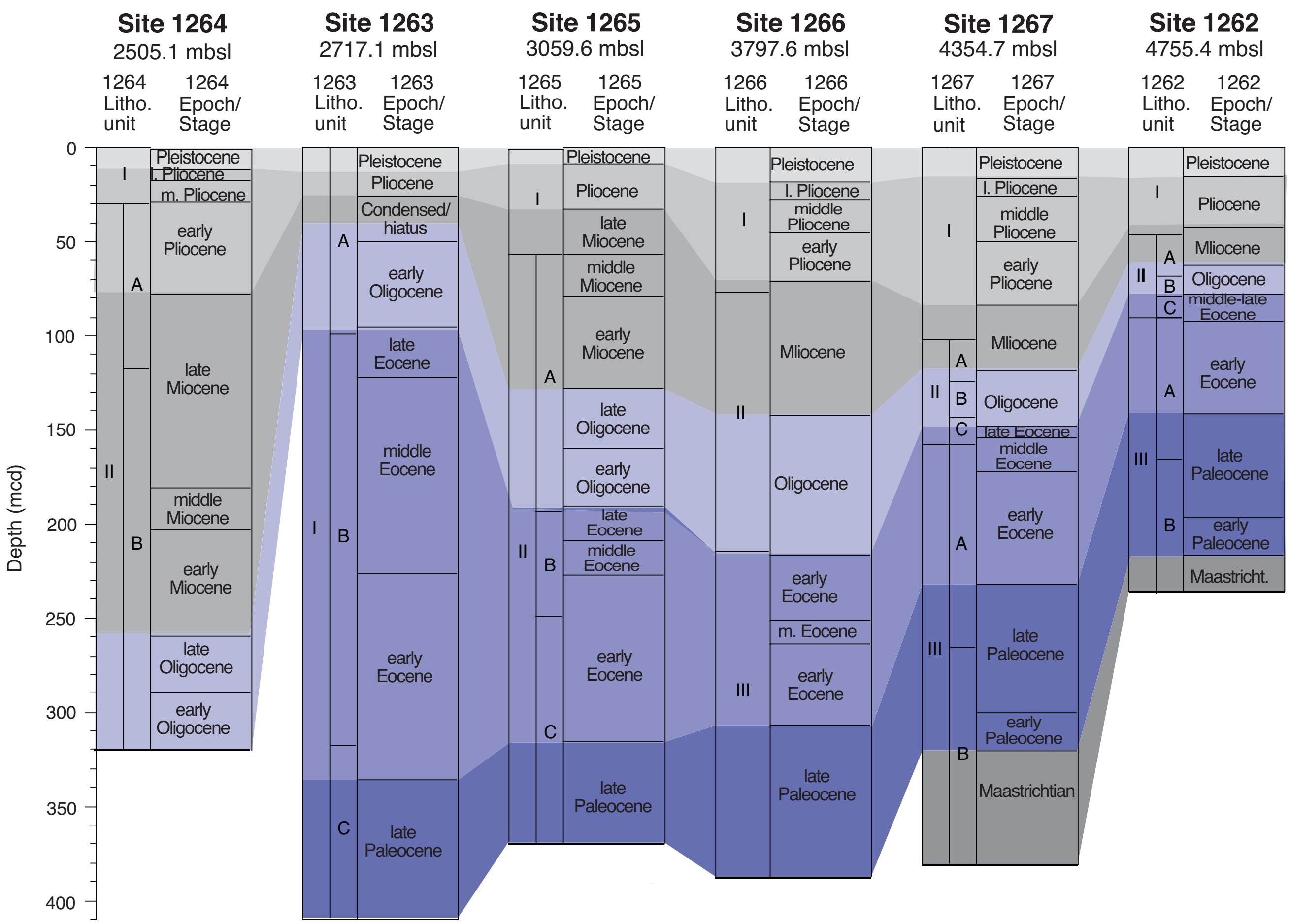

Figure 2. *Sediment age distribution plotted versus meters composite depth (mcd) for boreholes at each Leg 208 site.*

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(Fig. 3). The distinct record of cyclic alternations in sediment physical properties offers potential for the development of an astronomically tuned timescale of the upper Maastrichtian, Paleocene and Eocene.

In addition, the high-resolution time series resolve several relatively abrupt or short-lived paleoceanographic events, all of which were identified in at least 2 or more sites. This includes the primary drilling targets of the P/E and K/P boundaries as well as several previously unrecognized "events" in the early Eocene and Paleocene. A brief synopsis of several of the critical intervals recovered during Leg 208 is provided here.

The Cretaceous-Paleogene (K/P) Boundary

The K/P boundary interval, marked by a sharp lithologic transition, was recovered at the deepest Sites 1262 and 1267. The uppermost Maastrichtian (nannofossil zone CC26) is represented by a light reddish brown and brown clay-bearing nannofossil ooze with foraminifers, with marked color cycles. The lowermost Danian is represented by a 2- to 3-cm thick, dark red to reddish brown clay and Fe-oxide bearing, non-bioturbated foraminifer nannofossil ooze/chalk, with microtectites at Site 1262. The sediment grades upward into a brown nannofossil-and foraminifer-bearing clay (foraminiferal zone Pa and P1a). The K/P boundary is represented by intervals of decreased carbonate deposition/preservation and increased clay, iron oxide and volcanic ash accumulation expressed as sharp increases in magnetic susceptibility.

Preliminary biostratigraphy of the K/P boundary shows the well-established, abrupt change in plankton assemblages across the boundary. The light colored nannofossil ooze yields diverse assemblages of the uppermost Maastrichtian *Abathomphalus mayaroensis* planktonic foraminifer Zone and the *Micula prinsii* nannofossil Zone (CC26). The brown nannofossil- and foraminifer-bearing clay

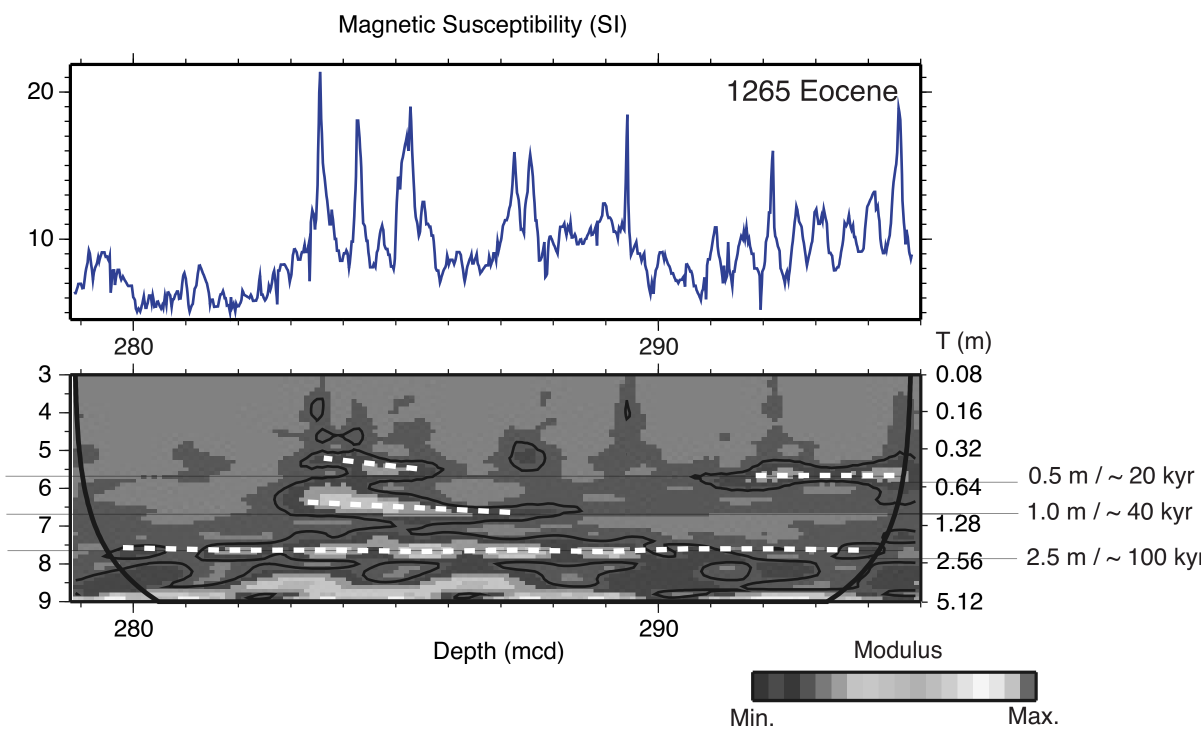

Figure 3. *Top panel: Magnetic susceptibility record of Eocene-age sediments recovered from Site 1265 boreholes. Bottom panel: Depth-scale representation of the magnetic susceptibility record at Site 1265 between 278.9 and 294.8 mcd (m composite depth) in early Eocene (53.3 to 53.9 Ma, ~600 k.y.). Assuming an average sedimentation rate of ~2.1 cm/kyr, the energy bands centered on the 0.5 and 2.5 m depth-scale may be linked to precession and eccentricity forcing, respectively. The 1 m energy band may be linked to obliquity. Modulations in the energy bands are probably related to slight changes in sedimentation rates.*

contains high abundance of *Woodrinia hornerstownensis, Chiloguembelina midwayensis,* and *Chiloguembelina morsei* as well as increasing abundance of *Parvulorugoglobigerina eugubina* through the basal Paleocene (Pa). Based on this preliminary analysis, P0 is not present at Walvis Ridge, but Zone Pa is represented by remarkably well-preserved planktonic foraminifers over the lowermost 20 cm of the Paleocene at Site 1262. The substantial thickness of the uppermost Maastrichtian *M. prinsii* Zone and the lowermost Danian *P. eugubina* Zone indicate the K/P boundary is paleontologically complete. The cycle stratigraphy is very robust, with distinct spectral peaks in the precession and eccentricity bands. The Walvis Ridge sections provide an excellently preserved and little disrupted deep-sea record of this major extinction event and the subsequent biotic recovery, and provide a unique opportunity to constrain precisely the pace of biotic/ecologic recovery following the extinction.

Mid-Paleocene Biotic Event (PBE)

A prominent 10- to 30-cm thick, dark-brown clay-rich calcareous nannofossil ooze occurs in the middle Paleocene at Sites 1262 and 1267, and a 10-cm thick brown nannofossil chalk was found at Site 1266. These layers show a pronounced peak in magnetic susceptibility and an increase in natural gamma values reflecting an increase in clay content. Preliminary micropaleontological investigations suggest that this interval represents a short-lived event of considerable evolutionary and paleoceanographic significance. This interval corresponds to the P4 *Globanomalina pseudomenardii* planktonic foraminiferal zone, and coincides with the evolutionary first occurrence of the nannofossil *Heliolithus kleinpellii*, an important component of late Paleocene assemblages and a marker for the base of Zone CP5 (NP6), early late Paleocene at ~58.2 Ma. A coeval event has been identified in cores recovered from ODP Leg 198 Sites 1209 through 1212 (Bralower et al., 2002).

Fundamental changes in foraminiferal populations occur before, during and after the deposition of the clay-rich ooze. Planktonic foraminifers in the clay-rich layer are characterized by a low-diversity, largely dissolved assemblage dominated by representatives of the genus *Igorina* (mainly *I. tadjikistanensis*). The occurrence of such a low diversity assemblage suggests an environmental perturbation of unknown origin. Together with the documented severe dissolution in this interval, the observed lithologic changes are likely to represent a response to increased seafloor carbonate dissolution owing to a transient shoaling of the lysocline and CCD. Regardless of origin, it is now clear from the high-resolution stratigraphy of the Leg 208 sites that this was a global event.

Paleocene-Eocene Boundary

The P/E boundary interval was recovered at all sites between 2.6 and 4.8 km water depth except Site 1264. The sediment sequence is marked by a deep red clay layer, which varies in thickness from 20 to 50 cm from site to site, within a thick and uniform sequence of upper Paleocene and lower Eocene foraminifer-bearing nannofossil ooze (Fig. 4, inside front cover). The basal color contact is relatively sharp, though magnetic susceptibility data show a more gradual, step-like increase in the deeper Sites 1262 and 1267. The carbonate content drops to 0% at all sites except for Site 1265. The upper contact is gradational in the shallow sites but relatively sharp in the deeper sites. Overlying the clay layer is a sequence of nannofossil ooze that is slightly richer in carbonate than the unit immediately underlying the clay layer.

This depth dependent pattern represents some combination of time-transgressive shoaling of the CCD, differential burn down of previously deposited carbonate, and increased terrigenous input from enhanced chemical weathering and erosion. Most importantly, these new data clearly demonstrate that the South Atlantic CCD shoaled much more (>2 km) than predicted by current models (~400 m; Dickens et al., 1995), suggesting the release of a much larger volume of isotopically ($\partial^{13}C$) depleted methane. This suite of cores will permit testing of the methane hydrate dissociation hypothesis by constraining the magnitude and rate of change in the position of the lysocline/CCD. The cores also will be instrumental in documenting biotic responses to the environmental changes as a response to the methane release and CCD shoaling. The severe dissolution over such a large depth range may well have been an important factor in the benthic foraminiferal extinction event coincident with the base of the clay layer at every site.

C24N "ELMO" Event

At ~20 to 35 m above the P/E boundary, a red, 5- to 15-cm thick carbonate-depleted layer was found covering the lower Eocene at all sites. This layer, called the Eocene Layer of Mysterious Origin ("ELMO"), was a faithful reference point for estimating the depth to the P/E boundary in the parallel holes of each site. The ELMO event has similar color, magnetic susceptibility, natural gamma ray, and carbonate signatures as the P/E boundary layer, but the transitions are more gradual and the signals less pronounced. The ELMO is characterized by a double dip in the 1-cm point magnetic susceptibility records of all sites. At the mid-depth site 1266, a thin white layer is found immediately above the red layer.

This layer is associated with benthic foraminifer assemblages similar in character to those of the PETM, but with a less severe drop in diversity. This implies a transient shift of paleoenvironmental conditions similar to those documented for the PETM. Shorebased isotope and other studies should provide insight into the origin of this anomaly.

E-O Boundary and Early Oligocene Glacial Maximum

The Eocene/Oligocene (E/O) transition was recovered at Sites 1262, 1263, 1265, 1266, and 1267. This interval showed signs of extensive reworking, down slope transport, and dissolution of microfossils at all sites. The lithologic changes are most pronounced at deepest Sites 1262 and 1267, where, over a ~0.5 m interval in the uppermost Eocene and lowermost Oligocene, sediments change from brown clay below to light brown to gray nannofossil ooze or foraminifer-bearing nannofossil ooze above. This transition is associated with a distinct shift in carbonate content where values increase from <20% to >80% at the deeper sites. In comparison to the condensed deep sites, the E/O interval is relatively expanded in the two shallowest sites. Increases in carbonate content are more gradual.

The increased carbonate content and improved microfossil preservation across the boundary interval indicate that the lysocline and CCD deepened substantially and rapidly along this transect during the transition into the earliest Oligocene. The exact timing could not be determined on board ship because of the poor preservation of calcareous microfossils. In the latest Eocene, the CCD on Walvis Ridge was between the paleodepths of Sites 1266 and 1267, and then deepened to well below Site 1262, possibly at the at the onset of "Oi-1", as has been observed at other localities (e.g., ODP Leg 199). At all sites, the carbonate values peak for a short-interval, possibly in Chron C13N. These events suggest that this CCD migration may be related to the first widely accepted sustained glaciation of Antarctica. By tightly constraining the timing and magnitude on a global scale, it should be possible to determine what role, if any, climate change played in driving this unique transition in ocean chemistry.

Other Events

Other critical intervals recovered at multiple sites include a series of Oligocene monospecific oozes/chalks, thin layers containing nannofloras highly enriched in calcareous debris derived from *Braarudosphaera* dinocysts, and an early Miocene layer with high abundances of benthic foraminifera *Bolivina* (HAB). The *Braarudosphaera* layers found throughout the south Atlantic are thought to be related to short-lived changes in regional climate and circulation patterns (Moore et al., 1984; Kelly et al., 2003), whereas the HAB layer is thought to reflect on a sudden switch in deep circulation patterns (Thomas, 1986; Smart and Ramsay, 1995). The Leg 208 cores will allow for these unique layers as well as the other events to be placed into an orbital cycle stratigraphic context, thereby improving our understanding of their frequency and relation to long- and short-term variations global climate and orbital parameters.

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ODP Leg 209 Drills into Mantle Peridotite Along the Mid-Atlantic Ridge from 14°N to 16°N

Peter Kelemen [1], Eiichi Kikawa [2], D. Jay Miller [3], and the Leg 210 Scientific Party

INTRODUCTION

Nineteen holes at eight sites along the Mid-Atlantic Ridge from 14°43'N to 15°44'N were drilled during Ocean Drilling Program Leg 209 (Fig. 1). Site locations, previously surveyed by submersible, were less than 200 m from peridotite or dunite exposed on the seafloor, and outcrops of gabbroic rock were also near some sites. The primary goals of Leg 209 were to constrain deformation associated with mantle upwelling and corner flow, mechanisms of melt migration, and igneous petrogenesis in this region where residual peridotites are exposed on both sides of the ridge axis. Residual peridotites along mid-ocean ridges are mantle peridotites which have undergone decompression partial melting, and melt extraction, due to plate spreading. A mixture of residual peridotite and gabbroic rocks intrusive into peridotite were recovered in 354 m of core from thirteen holes at six sites that penetrated a total of 1075 m.

The major shipboard scientific results are described here. Additional results are available in the Leg 209 Preliminary Report (Shipboard Scientific Party, 2003).

RESULTS

Proportion of residual peridotites and gabbroic rocks

Drilling at Sites 1268, 1270, 1271 and 1272 recovered ~25% gabbroic rocks and ~75% residual mantle peridotite. Core from Site

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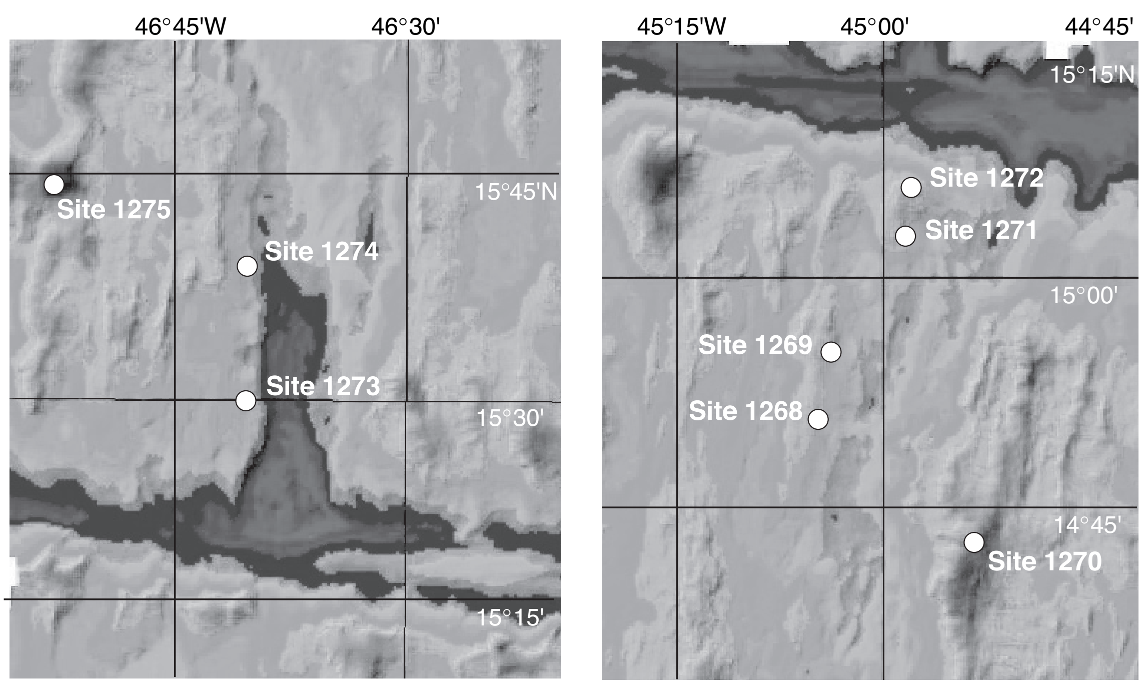

***Figure 1.** Location map of ODP Leg 209 drill sites along the Mid-Atlantic Ridge from 14°43'N to 15°44'N.*

1274 is mainly residual peridotite, with a few m-scale gabbroic intrusions. Core from Site 1275 is mainly gabbroic, but contains 24% poikilitic lherzolite interpreted as residual peridotite "impregnated" by plagioclase and pyroxene crystallized from melt migrating along olivine grain boundaries; these impregnated peridotites were later intruded by evolved gabbros. Impregnated peridotites also are common at Site 1271, and are present at Sites 1268 and 1270. Thus, the entire area may be underlain by mantle peridotite with 20 to 40% gabbroic intrusions and impregnations. The overall proportion of gabbroic rocks versus residual peridotites from these six sites is consistent with results of previous dredging and submersible sampling in the area.

Estimated Igneous and Metamorphic Conditions for Impregnated Peridotites

Impregnated peridotites from Site 1275 have "equilibrated" textures and contain the minerals olivine, orthopyroxene, clinopyroxene, plagioclase and Cr-rich spinel (Fig. 2A, inside front cover). Their whole rock and mineral compositions extend to residual peridotite values. However, plagioclase ranges from 54 to 75 mole% anorthite, and is much richer in sodium than plagioclase in truly residual peridotites. The wide range of plagioclase composition, and nearly constant composition in all other minerals, is best understood as the result of crystallization during reaction between residual mantle peridotite and cooling, fractionating melt migrating along olivine grain boundaries.

Rare earth element contents in clinopyroxenes in Site 1275 impregnated peridotites are consistent with crystallization from "normal" mid-ocean ridge basalt. Thus, the pressure and temperature of equilibration between melt and a mineral assemblage including olivine, two pyroxenes and plagioclase can be estimated from the local mid-ocean ridge basalt compositions via the method of Kinzler and Grove (1992). Primitive mid-ocean ridge basalt glass compositions from 14° to 16°N could be plagioclase lherzolite saturated at 0.54 GPa (± 0.14 GPa, 2σ) and 1220°C (± 16°C, 2σ) (Fig. 3). Impregnated peridotites and olivine gabbronorites at Sites 1268, 1270 and 1271 contain olivine, two pyroxenes and plagioclase, ± spinel. They probably record crystallization conditions similar to Site 1275 impregnated peridotites.

The mineral assemblage olivine, plagioclase, two pyroxenes and spinel is stable only within a limited range of metamorphic pressures and temperatures. Based on their mineral compositions, Site 1275 impregnated peridotites last equilibrated at about 0.625 ± 0.2 GPa and 1100° ± 75°C. This is consistent, within uncertainty, with isobaric cooling from the estimated igneous crystallization conditions for these samples described in the previous section. Thus, these results support the inference that igneous rocks crystallized and began to conductively cool at depths of 15 to 20 km below the seafloor.

Deformation of Peridotite and Gabbroic Rocks

Spinel and pyroxene in most peridotite samples formed equant grains, or irregular grains with projections that were interstitial to olivine crystals (Fig. 2C, D; inside front cover). Thus, preferred alignment of minerals was impossible to measure in many peridotite samples. These rocks have not undergone measurable deformation since the interstitial spinels and pyroxenes formed. The interstitial textures probably formed during melting, melt migration, igneous dissolution and/or precipitation from melt migrating by porous flow along crystal grain boundaries at temperatures greater than 1200°C. Thus, we infer that most peridotites recovered by drilling during Leg 209 have not undergone measurable shear strains below 1200°C.

Smaller proportions of "mylonites", highly deformed rocks with recrystallized olivine and pyroxene grain sizes of 20 to 100 microns at Sites 1268, 1270, 1271, and 1274, were recovered after cutting these nearly undeformed peridotites. The mylonites formed via localized, high strain, ductile deformation in narrow shear zones at temperatures greater than 900°C. Fault gouge was recovered in addition to ductile shear zones in boreholes at Sites 1268, 1270, 1271, 1272, and 1274.

Several gouge intervals that formed in large, brittle fault zones were present in each hole. The recovery of samples from more than one ductile shear zone at Sites 1268, 1270 and 1271, and more than one brittle fault zone at Sites 1268, 1270, 1271, 1272 and 1274, is striking. These results are more remarkable since bathymetry and dive observations at Sites 1270, 1274 and 1275 led to interpretations that the seafloor is a fault surface at each site. This indicates that the "typical" spacing between adjacent shear zones and faults in the 14° to 16°N region, at least close to the seafloor, is less than ~100 m.

Tectonic Rotation of Peridotite and Gabbroic Rocks

Paleomagnetic data for residual mantle peridotites and gabbroic rocks from Sites 1268, 1270, 1272, 1274 and 1275 yield remanent magnetization directions that require tectonic rotation after the samples acquired their remanent magnetization. Only Site 1271 samples yielded remanent magnetization vectors that were statistically indistinguishable from the expected inclination of 28° at this latitude.

Sites 1268 and 1270 lie well south of the 15°20' Fracture Zone, in areas with relatively well-developed, ridge-parallel bathymetric fabrics. This pattern is generally interpreted as the bathymetric expression of normal fault blocks, with steep fault surfaces dipping toward the rift valley, and shallower block tops dipping away from the rift. Expected rotations in such a setting are top away from the ridge around nearly horizontal, rift parallel axes. With these assumptions, we developed a quantitative model for the rotations at Site 1268 that explains the magnetic data. The gabbroic rocks underwent a large amount of counterclockwise rotation (~60° to 120°) around a nearly horizontal, rift-parallel axis after acquisition of the magnetic remanence, probably after they cooled below ~500°C. The peridotites acquired magnetic remanence

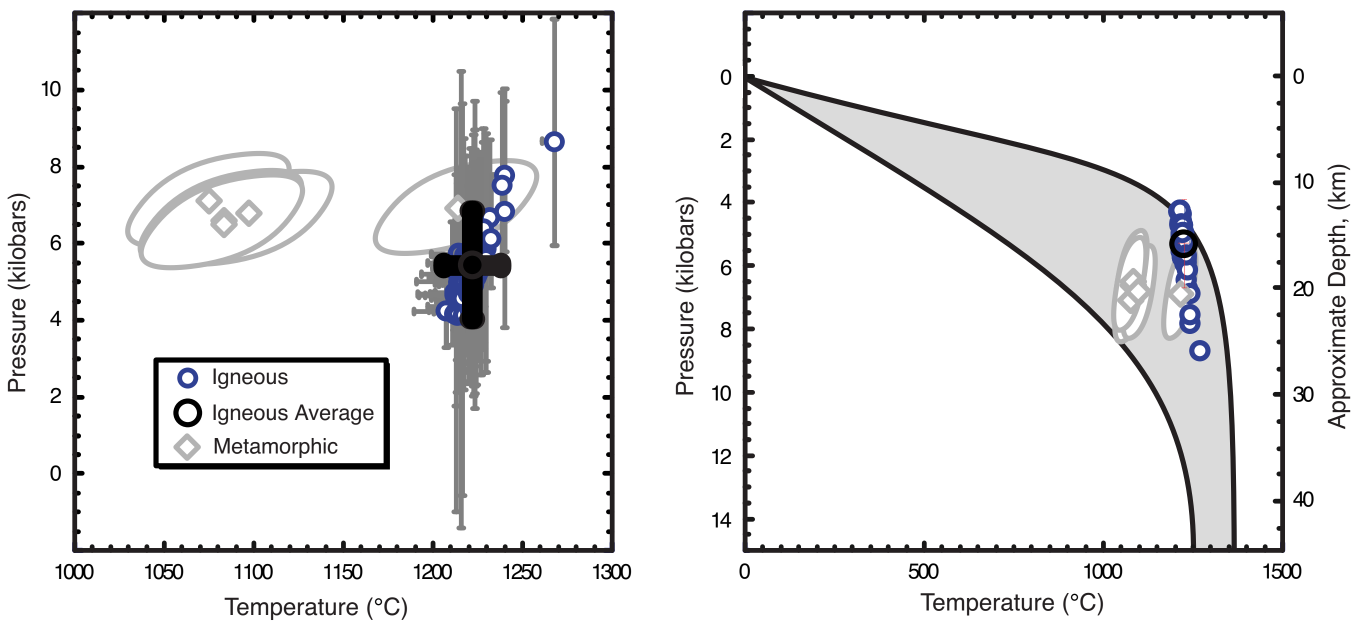

Figure 3. *Igneous and metamorphic estimates of pressure and temperature of equilibration of impregnated peridotites from Site 1275. Left panel shows detail, whereas the right panel illustrates possible geotherms (grey field) consistent with Leg 209 data. Igneous rocks began to cool and crystallize where they entered the conductive boundary layer in the shallow mantle, at depths greater than 17 to 20 km in this region. Igneous conditions are estimated for olivine + plagioclase + orthopyroxene + clinopyroxene + spinel saturation in primitive MORB glasses (Mg# >0.6) from 14° to 16°N along the Mid-Atlantic Ridge. Estimated pressures and temperatures for each glass composition are in grey; the average and standard error of the mean (2 sigma) are shown in dark gray. Metamorphic conditions, in light gray, are for two pyroxene thermometry, combined with thermodynamic calculations for the equilibrium forsterite + anorthite = enstatite + diopside + spinel, with approximate uncertainties based on both analytical error and uncertainties in mineral solid solution models.*

during serpentinization at temperatures less than ~300°C, and record only ~30° of this rotation. Magnetic data and/or tectonic interpretation of bathymetry are less clear for other sites, but similar rotations, exceeding 60°, could have occurred at several of them.

High-Angle Intersections Between Mylonitic Shear Zones

Submersible observations at Site 1270 indicated the presence of striated fault surfaces with a consistent dip of about 20° to the WNW exposed on the seafloor, and submersible samples included fine-grained, low-temperature peridotite ultramylonite. Coarser, higher temperature mylonitic shear zones, dipping about 40°, were recovered tens of m below the seafloor in all four holes at Site 1270. Some of these mylonites record a reverse sense of shear. Magnetic and structural data require that the low-temperature mylonitic fault surface on the seafloor must cut some of the high-temperature shear zones at an angle of 65° or more.

Crystallization and Deformation in a Thick Thermal Boundary Layer

Ascending melts entered the conductively cooled, "thermal boundary layer" beneath the Mid-Atlantic Ridge at more than 15 km depth. As they cooled, the ascending melts began to crystallize along olivine grain boundaries to form impregnated peridotites, and within magma lenses to form discrete plutons. This is consistent with thermal models (e.g., Sleep, 1975), geological inferences from dredgesand dives in the 14°-16°N region (e.g., Cannat and Casey, 1995), and interpretation of chemical variations in Mid-Atlantic Ridge basalts, which indicate cotectic crystallization at pressures of 0.4 to 0.6 GPa in some regions (e.g., Michael and Chase, 1987; Grove et al., 1992).

The geometry of plate spreading, and the presence of exhumed, residual mantle peridotites and high pressure igneous cumulates on the sea floor, demands that some rocks underwent tectonic uplift and rotation during corner flow within the upper 15 to 20 km below the seafloor. The paucity of ductile deformation fabrics in most peridotites, coupled with the abundance of mylonites and fault gouge, suggests that blocks of undeformed peridotite were passively uplifted and rotated along localized shear zones and faults. While some faults in the region, particularly at Site 1275, could have formed at shallow depth - for example, at the dike-gabbro transition as inferred by Escartin et al. (2003) - the exhumation of nearly undeformed residual peridotites and high pressure cumulates requires uplift along some localized shear zones and faults that extend to depths of more than 15 km.

Tilting of blocks along ductile shear zones and brittle faults probably exceeded rotations of 60° at some sites, andis best documented at Site 1268. These large rotations were probably accommodated along a series of progressively younger shear zones and faults, as proposed for progressive rotation of normal fault blocks documented in the U.S. Basin and Range province (Proffett, 1977). This hypothesis is consistent with the observation of high-angle intersections between different ductile shear zones, and with the apparent presence of reverse shear sense along some shear zones, especially at Site 1270. More generally, such a process could explain the presence of nearly horizontal fault surfaces on the seafloor in some oceanic core complexes, without requiring slip on such low-angle surfaces, or plastic "bending" of fault surfaces after they are exposed on the seafloor.

Rift Valley May Not Be Magma Starved

Numerous studies have documented the presence of extensive outcrops of mantle peridotite on both sides of the rift valley, extending for at least 50 km from the 15°20' Fracture Zone. As a result, the 14° to 16°N region was postulated to be "magma starved". Leg 209 observations suggest that much of the area may be underlain by mantle peridotite hosting 20 to 40% gabbroic intrusions and impregnations. If so, the region may not be magma starved at all.

Recently, Lizarralde et al. (submitted) performed a refraction experiment along a flow line in the Atlantic. They found that crust is ~5 km thick and shallow mantle V_p is slower beneath crust formed during episodes of relatively slow spreading, whereas areas formed during faster spreading have 7 km

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thick crust and faster mantle V_p. The slower mantle velocities beneath thin crust, and their gravity data, are consistent with the presence of about ~5% gabbroic material within the uppermost 30 km of mantle peridotite. Generalizing from this result and our observations, we hypothesize that some of the observed along strike variations of Bouger gravity along the Mid-Atlantic Ridge may be due to variable depth of gabbroic emplacement, rather than to variable amounts of gabbroic rocks.

"Tectonic Corner Flow" May Be Very Common

The strength of seismic anisotropy in the shallow mantle, formed by alignment of olivine a-axes during penetrative, viscous deformation, must be smaller where ridge deformation in the uppermost 15 to 20 km is accomodated by "tectonic corner flow", i.e., block rotation along localized shear zones, rather than by penetrative, ductile deformation. Below fast spreading ridges, where conductive cooling of the mantle is minor or absent, corner flow in the shallow mantle is probably accommodated entirely by high temperature, ductile deformation of all peridotites. In the uppermost mantle beneath some slow spreading ridges, where conductive cooling extends more than 15 km downward from the seafloor, localized deformation and passive rotation of undeformed rocks is likely (Fig. 4). Thus, during Leg 209 we hypothesized that seismic anisotropy in the upper 15 to 30 km of the mantle would be greater beneath crust formed at fast-spreading ridges compared

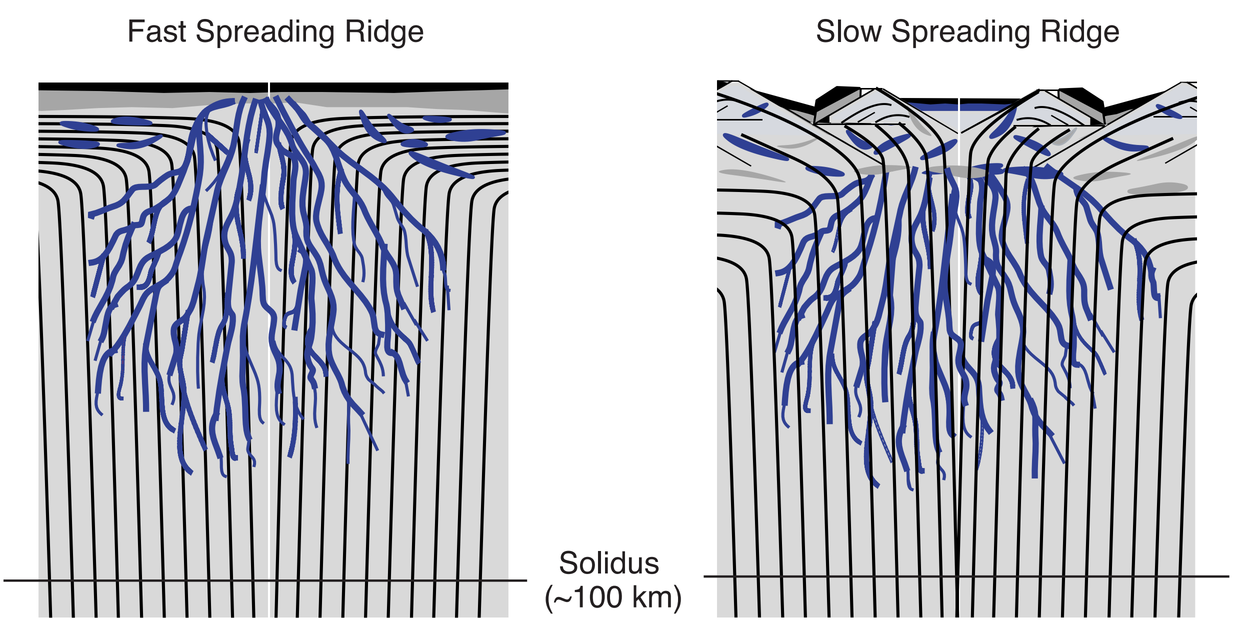

Figure 4. *Synoptic diagram of inferred difference between igneous accretion and seafloor spreading at fast-spreading versus slow-spreading ridges. Residual peridotites shown by light gray shading. Blue areas represent dunites formed as conduits for melt transport in the shallow mantle. Gray areas represent gabbroic plutonic rocks and black areas represent volcanic rocks. The left panel is based in part on observations in the Oman ophiolite, where impregnated peridotites and gabbroic plutons are rare in the mantle section more than ~500 km below the crust-mantle transition zone, and where plate spreading in the shallow mantle is accommodated by penetrative, ductile deformation of residual peridotites. We infer that this represents a medium- to fast-spreading ridge, where the conductive boundary layer beneath the ridge axis does not extend far below the base of igneous crust. The right panel illustrates a hypothetical end-member scenario for igneous accretion and seafloor spreading at a slow-spreading ridge, based on a synthesis of results from Leg 209 with previous and ongoing research results. Impregnated peridotites and gabbroic plutons begin to form at the base of the conductive boundary layer, more than 17 km below the seafloor. Throughout much of this conductive boundary layer, at less than ~1100° or 1000°C, plate spreading is accommodated by localized deformation along mylonitic shear zones and, at lower temperatures along brittle faults. These shear zones and faults rotate and uplift passive blocks of residual peridotite that host gabbroic intrusions, some of which are exposed on the seafloor. In such a scenario, the thickness of igneous crust above the seismic Moho will be less than at fast spreading ridges, and, because of the lack of penetrative deformation and the variable extent of tectonic rotation, seismic anisotropy in the uppermost mantle will be less than in plates formed at fast-spreading ridges.*

to slow-spreading ridges. We were delighted to discover that our hypothesis is consistent with recent measurements of anisotropy in the uppermost 20 to 30 km of the Atlantic mantle (Gaherty et al., submitted) that is small compared to previously measured anisotropy in the Pacific.

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SCIENCE Leg Reports

ODP

Margins of the Newfoundland-Iberia Rift: ODP Leg 210 Explores the Newfoundland Basin

Brian E. Tucholke [1], Jean-Claude Sibuet [2], Adam Klaus [3] and the Leg 210 Scientific Party

INTRODUCTION

Ocean Drilling Program Leg 210 represented the first time in the history of ocean drilling that drilling was accomplished on conjugate margins of a non-volcanic rift. The first of two primary objectives of Leg 210 was to sample the deep and basement sections in the Newfoundland Basin (Fig. 1) to determine basement origin and investigate tectonic development of the Newfoundland-Iberia rift from the rifting stage through the early seafloor-spreading stage. The main focus was on the transition zone between known continental crust and apparent ocean crust; a related focus was on the ocean crust immediately seaward of the transition zone. The second primary objective was to study the paleoceanographic evolution of the opening seaway through the Newfoundland-Iberia rift. This ocean basin was the gateway to higher-latitude oceans

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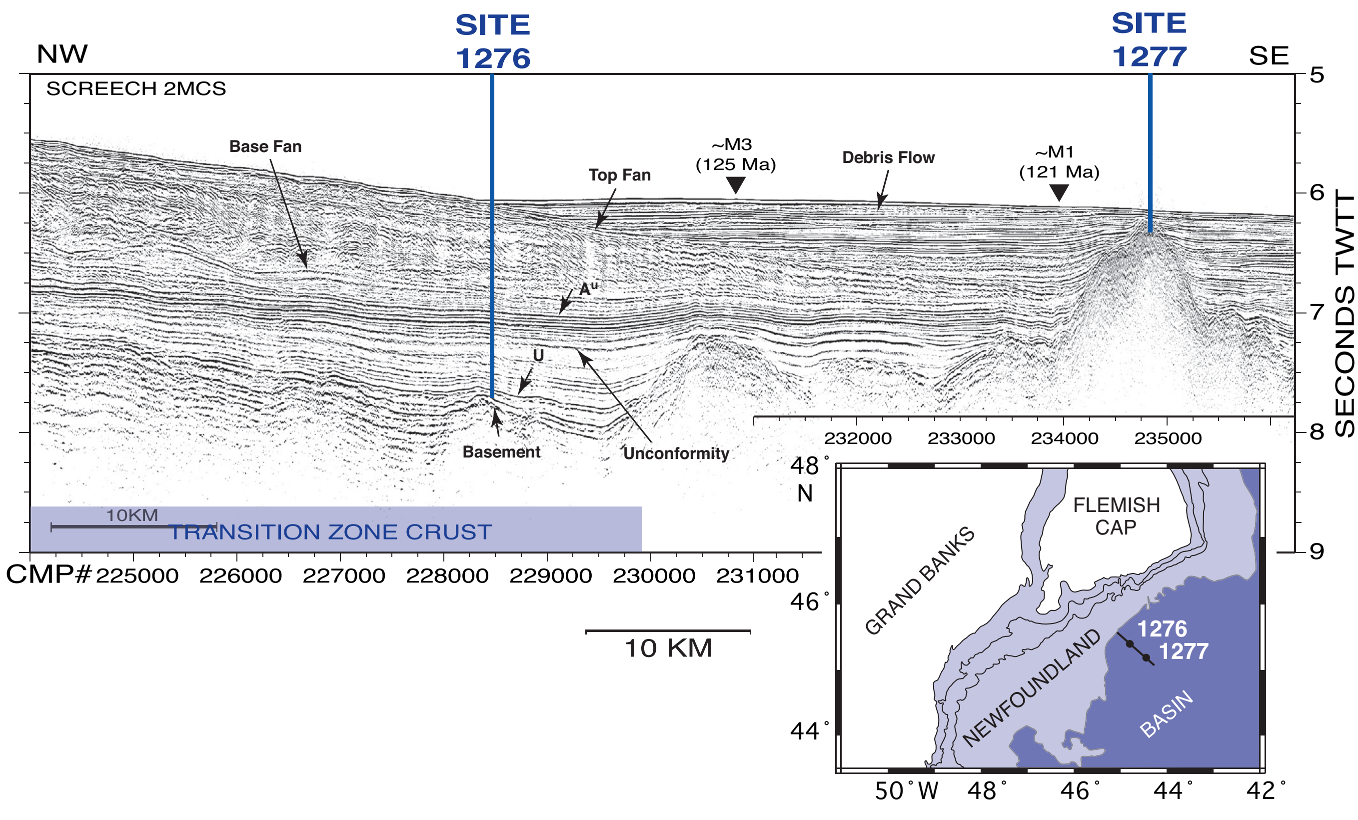

Figure 1. *Segment of multichannel seismic reflection line SCREECH 2MCS through ODP Leg 210 Sites 1276 and 1277. The eastern edge of the continent-ocean transition zone in the Newfoundland Basin is near CMP 230,000. Triangles indicate magnetic anomaly identifications and ages of interpreted oceanic crust. Principal reflections that define seismic tratigraphic intervals of basin-wide significance are indicated. The inset shows site locations in the Newfoundland Basin and the location of the illustrated seismic reflection profile; bathymetric contour interval is 1000 m.*

as they opened progressively northward and eventually connected to the Arctic Ocean, and it contains a valuable paleoceanographic record of this developing connection.

DEEP AND BASEMENT OBJECTIVES

Extensive geophysical surveys and drilling results indicate that the transition zone off Iberia consists of exhumed, serpentinized mantle (e.g., Pickup et al., 1996; Discovery 215 Working Group, 1998; Whitmarsh et al., 1998). The transitional basement off Newfoundland is shallower and smoother. Seismic refraction data indicate the crust is only 4 to 5 km thick with a Poisson's ratio of 0.27 to 0.29 that suggests that it is oceanic crust (Nunes, 2002). Three main hypotheses have been presented to explain this crustal asymmetry across the rift (Tucholke et al., 1999; Whitmarsh et al., 2001).

1) The Newfoundland transitional crust is continental crust that was strongly thinned during simple-shear extension, with the exhumed mantle off Iberia comprising a lower plate.

2) The Newfoundland crust is serpentinized mantle, possibly exhumed by pure-shear extension. If the system then evolved to simple shear, the upper, Newfoundland plate might have been permeated by melt derived from the underlying Iberia plate as it was exhumed.

3) The Newfoundland crust is oceanic, and this ocean crust became isolated on the Newfoundland side by an eastward spreading-ridge jump during an early stage of seafloor spreading.

In addition to being shallower and smoother than Iberia transitional crust, the Newfoundland transitional basement is covered by a strongly reflective, basin-wide seismic sequence capped by a reflection termed 'U' (Fig. 1; Tucholke et al., 1989). A stratigraphically similar deep reflection sequence off Iberia is much less reflective and less widespread.

A deep borehole was drilled at ODP Leg 210 Site 1276 to test the hypotheses for the origin of Newfoundland transitional basement and to understand the significance of the U reflection (Fig. 1). The site is in a position exactly conjugate to the ODP Leg 149/173 drilling transect on the Iberia margin, within the limitations of plate reconstructions, and projected depth to basement was ~2080 m below seafloor (mbsf). To improve the chances of accomplishing this deep objective, the uppermost 800 m of sediment at Site 1276 were drilled and cased without coring.

The first sediment core was recovered one month after departing from Bermuda, and rotary coring from 800 to 1737 mbsf (Fig. 2, inside back cover) resulted in remarkable core recovery, averaging ~85%, and an excellent suite of shipboard physical properties data. Closure of the open hole below 800 mbsf prevented logging, and the site was abandoned without reaching basement. The hole penetrated a 10 m-thick diabase sill at 1613 mbsf and bottomed within a second sill encountered at 1719 mbsf. Based on shipboard velocity data and seismic-borehole correlation, the bottom of the hole is estimated to be 100 to 200 m above basement (Fig. 1).

Both sills were intruded into lower Albian sediments and they probably are of early Albian age, dating to at least 10 to 15 m.y. after the transitional basement was formed. Compaction features in the surrounding hydrothermally altered sediments suggest that the sills were emplaced in unconsolidated sediments at very shallow levels beneath the contemporary seafloor. A unique zone of underconsolidated sediments, with velocities of < 2 km/s and porosities of 30% to 45%, was encountered at 1690 to 1710 mbsf above the hydrothermally altered sediments overlying the deeper sill; it was associated with methane concentrations up to ~18,000 ppm. The presence of the sills may have prevented normal consolidation of the sediments.

Shipboard velocity measurements and seismic-borehole correlations indicate that the upper diabase sill appears to correlate with the U reflection (Fig. 1). It does not seem likely, however, that sills explain the widespread distribution of the U reflection across the full ~150 x 600 km area of the Newfoundland Basin. Instead, the reflection may correlate with the top of coarse gravity flows that flooded the basin in the early Albian. Shore-based seismic analysis together with physical properties and geochemical studies are planned to investigate the distribution, source, and age of the intrusives.

With only four days remaining during Leg 210, basement was drilled in a shallow hole at Site 1277, about 40 km southeast of Site 1276 (Fig. 1). Site 1277 basement was interpreted to be oceanic crust, i.e., it was "thin crust" similar to that described earlier, and it was close to a magnetic anomaly interpreted as M1. The hole penetrated about 95 m into a basement ridge beneath thin sediment cover. The upper ~57 m of basement consist of a sedimentary and igneous succession of alternating basalt flows; coarse breccia units containing a wide variety of basalt, gabbro, and serpentinite clasts; variably deformed gabbros; and minor volcaniclastic and ferruginous sediments (Fig. 3A and B; inside back cover). The bottom ~38 m appear to represent true basement consisting of tectonized, altered ultramafic rock including harzburgite, dunite, and serpentinite mylonite, all cut pervasively by several stages of veining and mineral precipitation (Fig. 3C and D; inside back cover). The rocks are interpreted to be mantle that was metamorphosed, deformed, and exposed by tectonic extension, probably in slow-spreading ocean crust.

Although basement was not sampled at Site 1276 in the Newfoundland transition zone, the recovery of serpentinites at Site 1277 and the similar basement velocity structure at Sites 1276 and 1277 suggest that basement in the transition zone could be either serpentinized peridotite like that drilled off Iberia or serpentinite-rich ocean crust generated by very slow seafloor spreading. Shore-based geochemical studies of the Site 1276 sills may help to constrain the composition of the underlying basement. If the magmatic event associated with post-rift intrusion of the sills significantly impregnated the transitional crust, the resulting reduced crustal density could help explain the shallow basement depth in the Newfoundland Basin compared to the conjugate Iberia margin.

PALEOCEANOGRAPHIC OBJECTIVES

Excellent core recovery in the sedimentary section at Site 1276 (Fig. 2; inside back cover) allowed detailed analysis of the deep-water sedimentary and paleoceanographic environment of the widening Newfoundland-Iberia seaway during Albian to early Oligocene time. A prominent feature in sediments of all these ages is the dominance of gravity-flow deposits that delivered fine- to very coarse-grained sediments to the basin from the adjacent Grand Banks. High accumulation rates promoted an expanded sedimentary record with minimal stratigraphic gaps, and the downslope deposits provided samples of shallower water deposits interbedded with deep-basin facies.

A sharp transition from deposition on a poorly oxygenated to a well-oxygenated abyssal seafloor occurred in Turonian time at the lithologic unit 5/4 boundary (Fig. 2, inside back cover). A marked unconformity between lithologic units 2 and 1 appears to correlate with establishment of strong abyssal circulation in the basin, equivalent to the unconformity marked by Horizon A^U farther south in the western North Atlantic basin.

During the Late Cretaceous and early Tertiary, the Newfoundland-Iberia rift was the oceanographic gateway between the main North Atlantic and developing ocean basins in the Labrador Sea (Late Cretaceous) and the Norwegian-Greenland Sea (Paleocene), with eventual deep-water connection to the Arctic Ocean (?Oligocene). Two features of the predicted sedimentary record above the U reflection were of particular interest.

First, the main basin of the adjacent North Atlantic was accumulating black shales of the Hatteras Formation in Barremian to Cenomanian time, followed by deposition of reddish shales of the Plantagenet Formation under oxygenated seafloor conditions in the Late Cretaceous (Jansa et al., 1979). The Newfoundland Basin Cretaceous sedimentary record at Site 1276 provided an opportunity to examine whether this record of reduced and then increased ventilation of the deep basin extended northward into the developing ocean basins, as well as the timing of that record. Five (possibly six) Ocean Anoxic Events (OAEs) were recognized in an expanded Albian-Cenomanian/Turonian sedimentary record at Site 1276, together with the oceanographic change to a ventilated deep basin in Turonian time. Site 1276 also provided important information on paleobiogeography in this zone of mixing between Tethyan and boreal flora and fauna.

The second feature of particular interest was the upper Eocene to lower Oligocene sedimentary record. We postulated that cores recovered across a prominent, seismically defined unconformity in the Newfoundland Basin (apparently equivalent to Horizon A^U in the main North Atlantic basin; Fig. 1) would contain important information on the first development of strong abyssal circulation in the North Atlantic. The source of the bottom water for this developing circulation was interpreted to be the sub-Arctic seas, with timing estimated as latest Eocene to early Oligocene (e.g., Miller and Tucholke, 1983). However, these predictions were based largely on the occurrences of hiatuses in boreholes farther south in the North Atlantic. The missing sedimentary record in the critical intervals there made verification difficult. Coring at Site 1276 appears to have recovered earliest Oligocene to upper Eocene sediments just above the unconformity, and lower middle Eocene sediments just below. Shorebased biostratigraphic studies will test and refine this interpretation.

In addition to the sedimentary record noted above, cores recovered at Site 1276 contained one of the few nearly complete upper Maastrichtian to lower Danian abyssal sedimentary sections across the Cretaceous-Tertiary (K-T) boundary, as well as a section across the Paleocene-Eocene Thermal Maximum (PETM). The specific PETM boundary clay layer appears to be missing in our cores, but a complete succession of the calcareous nannofossil events occurring immediately above the boundary will provide important information on biotic recovery after this event.

The full Preliminary Report for ODP Leg 210 is available at http://www-odp.tamu.edu/publications/prelim/210_prel/210toc.html.

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A Quick-Start Guide to the Integrated Ocean Drilling Program

Thomas Janecek [1], Vice-President of Science Operations, IODP-MI

INTRODUCTION

This miniguide to the new Integrated Ocean Drilling Program (IODP) provides answers to frequently asked questions. What is IODP? What are IODP's scientific objectives? What ships, platforms, and technologies are used in IODP, and who is responsible for them? How is IODP funded? What are the IODP scientific advisory and management structures? What is the current expedition schedule? How do you apply to participate on an expedition? How do you submit a proposal for an expedition? How do you access samples and data?

WHAT IS IODP?

The IODP began in October 2003 and is an international research program for the exploration of the history and structure of the Earth as recorded in seafloor sediments and rocks. IODP builds upon the earlier successes of the Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) that revolutionized our view of Earth history and global processes through ocean basin exploration, multidisciplinary research and technological development. These goals follow the themes identified in the IODP Initial Science Plan (ISP), "Earth, Oceans and Life: Scientific Investigations of the Earth System Using Multiple Drilling Platforms and New Technologies" (http://www.iodp.org/pdf/IODP_Init_Sci_Plan.pdf):

- The deep biosphere and the subseafloor ocean;
- Environmental change, processes and effects, and
- Solid earth cycles and geodynamics.

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WHAT VESSELS AND PLATFORMS ARE USED AND WHO OPERATES THEM?

IODP is a multiplatform operation involving a riserless drilling vessel, a riser drilling vessel, and mission specific platforms. Three Implementing Organizations (IOs) in Japan, the USA, and Europe will serve as "science operators" of the various ships and platforms.

Riser Vessel

Japan's JAMSTEC Center for Deep Earth Exploration (CDEX) is responsible for the overall management of the riser drilling vessel *Chikyu* (http://www.jamstec.go.jp/jamstec-e/odinfo/cdex_top.html).

- **CDEX** contracts the vessel operations; provides services to support science activities including on-board staffing, data management for core samples and logging; implements engineering site surveys; and conducts engineering developments.
- **The Center for Advanced Marine Core Research** (CMCR), operated by Kochi University and CDEX, provides analytical equipment for core processing, curates IODP cores (including microbiological samples), and manages core sample and data distribution (http://www.kochi-u.ac.jp/marine-core/CMCR_TOP_E.html).

Riserless Vessel

The JOI Alliance, the U.S. implementing organization (USIO), is responsible for the science operations of the riserless vessel (http://www.oceandrilling.org). For Phase 1 of the USIO operations (FY04/FY05), the riserless vessel will be the JOIDES *Resolution*, the same vessel used in the Ocean Drilling Program. The JOI Alliance consists of:

- **Joint Oceanographic Institutions, Inc. (JOI)**: has principal responsibility for overseeing programmatic, contractual, and fiscal management activities of the USIO (http://www.joiscience.org).

- **Texas A&M University, College of Geosciences**: subcontracts riserless drill ship operations, conducts platform-related tool development, and provides expedition staffing, logistics, program-specific engineering development, outfitting of shipboard laboratories, shipboard and shorebased curation, and distribution of core samples and data (http://www.iodp.tamu.edu).

- **Lamont-Doherty Earth Observatory of Columbia University**: provides downhole logging capabilities and support, as well as log data processing, distribution, and database services (http://www.iodp.ldeo.columbia.edu).

Mission Specific Platforms

The ECORD (European Consortium for Ocean Research Drilling), representing scientific institutions in thirteen nations, has formed the ECORD Science Operator (ESO) organization to undertake Mission Specific Platform (MSP) operations for the IODP (http://www.ecord.org/eso/eso.html). The ESO consists of:

- The **British Geological Survey (BGS)**: acts as consortium coordinator and is responsible for overall ESO management under a contract from the ECORD Managing Agency (EMA) as designated by the ECORD Council (http://www.ecord.org/eso/bgs.html).

- The **University of Bremen**: contracted by BGS to oversee curation duties and core repository facilities as well as data management tasks (http://www.ecord.org/eso/bremen.html). GeoForschungsZentrum (GFZ) Potsdam supports the ESO by contributing the Drilling Information System (DIS) for offshore data acquisition.

- The **European Petrophysical Consortium**: contracted by BGS to carry out all logging and petrophysical activities (http://www.ecord.org/eso/epc.html). This consortium is comprised of the University of Leicester, U.K. (coordinator), the Université de Montpellier 2, France, the Rheinisch-Westfälischen Hochschule (RWTH), Aachen, Germany, and Vrije Universiteit, Amsterdam, The Netherlands.

HOW IS IODP FUNDED?

IODP is funded by four entities acting as international partners (Fig. 1):

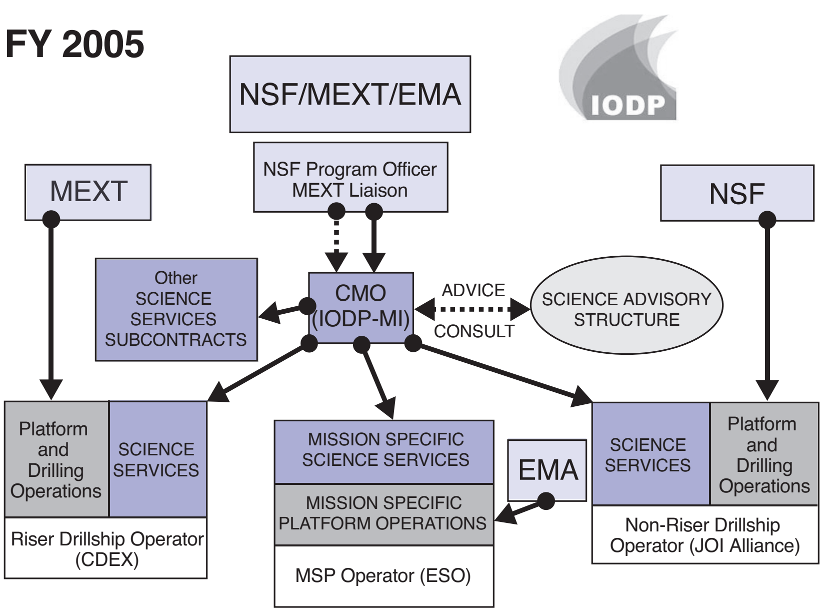

Figure 1. *Funding entities and the flow of funds are denoted by organizations in light gray boxes and black arrows, respectively. NSF = U.S. National Science Foundation; MEXT = Japan's Ministry of Education, Culture, Sports, Science and Technology; EMA = European Consortium for Ocean Research Drilling Managing Agency. The flow of advice between the Lead Agencies, the Central Management Organization (CMO), and the Science Advisory Structure (SAS) is denoted by dashed black arrows. Note that Platform Operating Costs (POCs) are funded directly by the entity supplying the particular platform capability, and that Science Operating Costs (SOCs) are commingled funds that flow through IODP Management International, Inc. (IODP-MI), which functions as the CMO.*

- The U.S. National Science Foundation (NSF; http://www.nsf.gov) and Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT; http://www.mext.go.jp/english) are the Lead Agencies.

- The ECORD Managing Agency (EMA; http://www.ecord.org/ema.html) is a Contributing Member.

- The People's Republic of China Ministry of Science and Technology (MOST; http://www.most.gov.cn/English/index.htm) is an Associate Member.

The Ocean Drilling Program office at NSF (part of the Marine Geosciences section of the Division of Ocean Sciences, within the Directorate for Geosciences) is responsible for administering commingled funds directed towards the science operating costs (SOCs) of all IODP operations (Fig. 1). These commingled funds come from the international partners as part of their membership fees used for the conduct of IODP science. Platform operating costs (POCs) are the responsibility of the agency supplying the platform capability.

HOW IS IODP MANAGED?

Management

Overall IODP program management is provided by a Central Management Office (CMO), known as IODP Management International, Inc. (IODP-MI), serving under contract to the NSF (Fig. 2). IODP-MI receives advice from the international IODP Science Advisory Structure (SAS), and, in consultation with thevessel/platform operators, or IOs, translates the scientific priorities of the international scientific ocean drilling community into program plans. IODP-MI submits an annual IODP Program Plan for review and approval first to the Executive Committee of the SAS, called the Science Planning and Policy Oversight Committee (SPPOC), then to the IODP-MI Board of Governors (BoG), and finally to the Lead Agency which gives final budget approval (Fig. 2).

IODP-MI has offices in Washington, D.C., and Sapporo, Japan, and is responsible for program-wide science planning, oversight of engineering development, publications, education and outreach, site survey data management, and core sample repositories. Most of these functions will be subcontracted to the IOs and third parties as appropriate with advice from the SAS and under the supervision of IODP-MI. IODP-MI also will arrange to provide continuous performance evaluation and assessment of all elements of IODP.

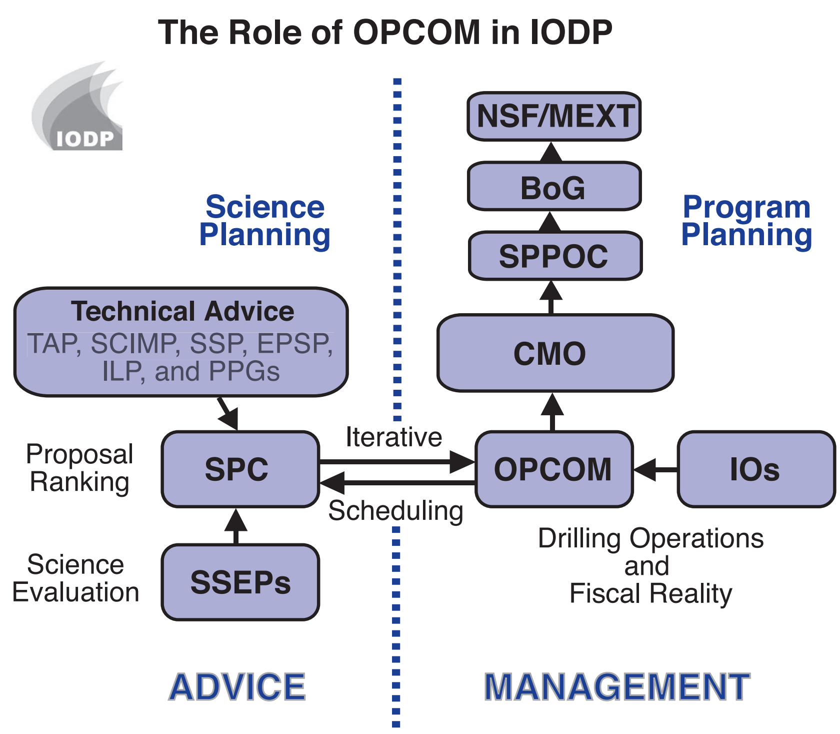

Figure 2. *The flow of scientific advice from the science and technical communities to the IODP management structure occurs via advisory panels and committees. Scientific planning for the IODP is provided by a Science Advisory Structure (SAS), which is led by the Science Planning Committee (SPC). IODP Management International is the Central Management Organization (CMO) that will translate the scientific priorities of ocean drilling community into program plans to carry out the scientific operations of IODP. It will do so based on advice from the international IODP SAS, and in consultation with vessel operators referred to as Implementing Organizations, or IOs. NSF = U.S. National Science Foundation; MEXT = Japan's Ministry of Education, Culture, Sports, Science and Technology; BoG = Board of Governors, SPPOC = Science Planning and Policy Oversight Committee; OPCOM = Operations Committee; SSEPs = Science Steering and Evaluation Panels.*

SCIENCE/ PLANNING Special Reports

IODP

Science Advisory Structure

Scientific planning for the IODP is provided by a Science Advisory Structure (SAS) that involves many scientists and engineers on standing committees and panels, and is led by the Science Planning Committee (SPC; Fig. 3). The SPC focuses on the long-term science planning activities necessary to achieve the objectives of IODP as expressed in the ISP. In this capacity, SPC prioritizes, or ranks, scientific and technological objectives to optimize the scientific returns from multi-platform drilling, sampling, and related experiments. These rankings are based in part on input and advice from the other SAS panels.

All IODP science is motivated by community input in the form of unsolicited proposals that are nurtured and prioritized by the IODP SAS. SPC receives scientific advice on drilling proposals submitted by the international community from two Science Steering and Evaluation Panels (SSEPs): the Dynamics of Earth's Environment SSEP and the Dynamics of Earth's Interior SSEP. The nurturing, development, and evaluation of proposals with proponents are the prime responsibilities of the SSEPs. They also provide the SPC with evaluations of high-priority drilling proposals, and advice on longer-term thematic development.

WHAT IS THE CURRENT SCHEDULE?

The schedules for the first five cruises of the riserless vessel (the JOIDES *Resolution*) in 2004-2005 and the first Mission Specific Platform expedition in 2004 are shown in Table 1. Routine cruises of the riser vessel *Chikyu* will begin in 2007 after sea trials and test cruises. Updates of the overall schedule can be found at the website of the IODP-MI (Sapporo) Science Advisory Structure (SAS) Office (http://www.isas-office.jp/scheduled.html). Detailed information on the operational schedules for each platform can be found as follows:

- Riserless vessel schedule: http://iodp.tamu.edu/expeditions/schedule.html
- Mission Specific Platform schedule: http://www.ecord.org/eso/msp.html

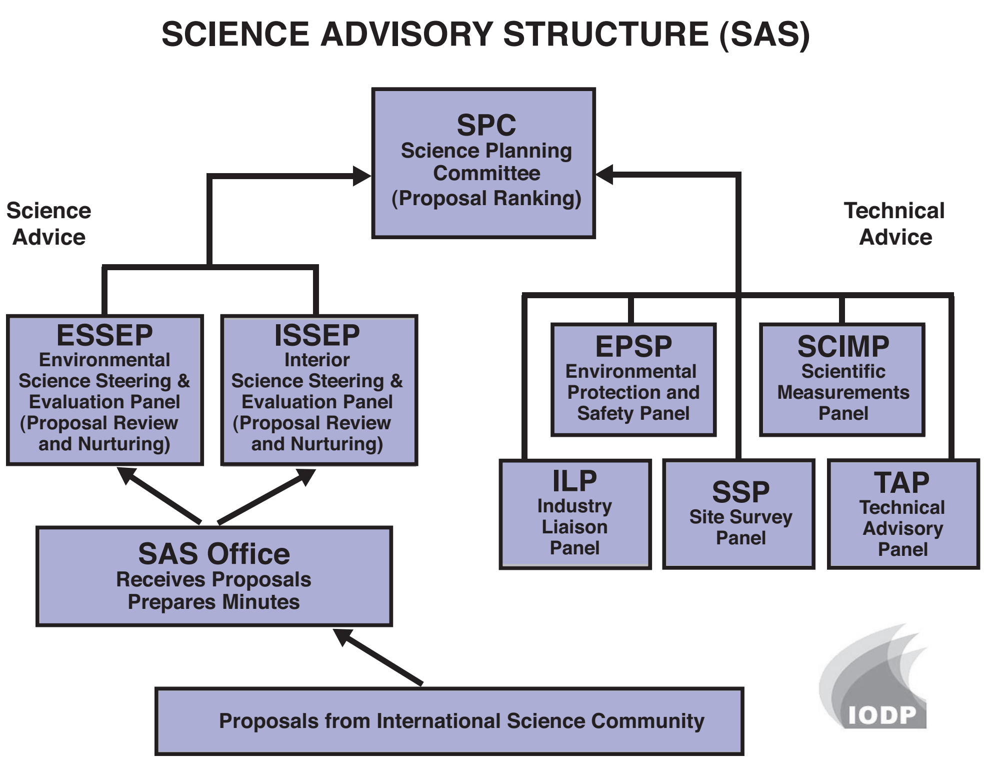

Figure 3. *Scientific planning for the IODP occurs in a network of panels and standing committees that make up the Science Advisory Structure (SAS). The Science Planning Committee (SPC) leads the SAS. The IODP-MI office in Sapporo is responsible for receiving proposals, and disseminating mandates, meeting summaries/ minutes and meeting agendas to the ocean drilling community (http://www.isas-office.jp/index.html).*

- Riser Vessel schedule: http://www.jamstec.go.jp/jamstec-e/odinfo/sdsreport.html

HOW DO YOU APPLY TO SAIL?

IODP expeditions on the riserless vessel and a mission-specific platform begin in late June, 2004. Applications for participation are currently being accepted for some of the future riserless vessel expeditions. Application forms and instructions are available at the websites of each national office as follows:

- U.S. scientists may apply to the U.S. Science Support Program (USSSP) at http://www.usssp-iodp.org/science_support/sailing_information/default.html

- Japanese scientists may apply to the Japan Drilling Earth Science Consortium (J-DESC) at http://www.aesto.or.jp/jdesc/

- Scientists in ECORD countries may apply to the ECORD Science Support Advisory Committee (ESSAC) at http://www.geo.vu.nl/users/essac

- Chinese scientists may apply to the Ministry of Science and Technology at http://www.most.gov.cn/English.index.htm.

HOW DO YOU SUBMIT PROPOSALS FOR FUTURE EXPEDITIONS?

The success of IODP rests with the quality of the science proposed and carried out by the community at large. Submission of proposals gives individual scientists, and groups of scientists, opportunities to respond to IODP's scientific priorities as expressed in the ISP, and to recommend appropriate targets for drilling. Proposals need to be well developed before they are considered by SPC for scheduling because scheduling a drilling activity is a major investment of time and resources.

The proposal process consists of two primary steps (Fig. 4):

- Submission of a "Preliminary Proposal" that will be evaluated and nurtured, if appropriate, through panels within the SAS, and

- Subsequent submission of a "Full Proposal" that is developed with the advice of appropriate panels.

Proposals for IODP scientific ocean drilling, as well as addenda to previously submitted proposals, should be submitted to the IODP-MI Sapporo Office by one of the two yearly deadlines: 1 April for the Spring SSEPs meetings, and 1 October for the Fall SSEPs meetings. Full details of Proposal Guidelines and submission/review process are available online at http://www.isas-office.jp/proposal.html.

HOW DO YOU ACCESS SAMPLES AND DATA?

The IODP oversees several core repositories around the world that store DSDP and ODP cores and will contain IODP cores. Samples

DATES	EXPEDITION	PROPOSAL
Riserless Vessel		
27 June - 21 August '04	Juan de Fuca Hydrogeology	545 - Full 3
21 August - 22 September '04	Costa Rica Hydrogeology/Transit	
22 September -14 November '04	North Atlantic Climate 1	572 - Full 3
14 November '04 - 5 January '05	Oceanic Core Complex 1	512 - Full 3
5 January - 27 February '05	Oceanic Core Complex 2	512 - Full 3
27 February - 22 April '05	North Atlantic Climate 2	572 - Full 3/ 543 - Full 2
Mission Specific Platform		
7 August - 19 September '04	Arctic Coring Expedition (ACEX)	533 - Full3

Table 1. *Schedule for Phase 1 of the riserless vessel operations (JOIDES* Resolution*) and the first Mission Specific Platform operation to the Lomonosov Ridge in the Arctic Ocean.*

are distributed according to ODP and IODP policies.

The following resources have more information about sample access:

- Online Sample Request Form: http://iodp.tamu.edu/curation/samples.html
- Online access to core images: http://iodp.tamu.edu/database/coreimages.html.
- Repository contact information: http://iodp.tamu.edu/curation/repositories.html.

The following data access resources are available to facilitate scientific research:

- Core data and log data: http://iodp.tamu.edu/database.
- Downhole log data: http://www.ldeo.columbia.edu/DATA/index.html.

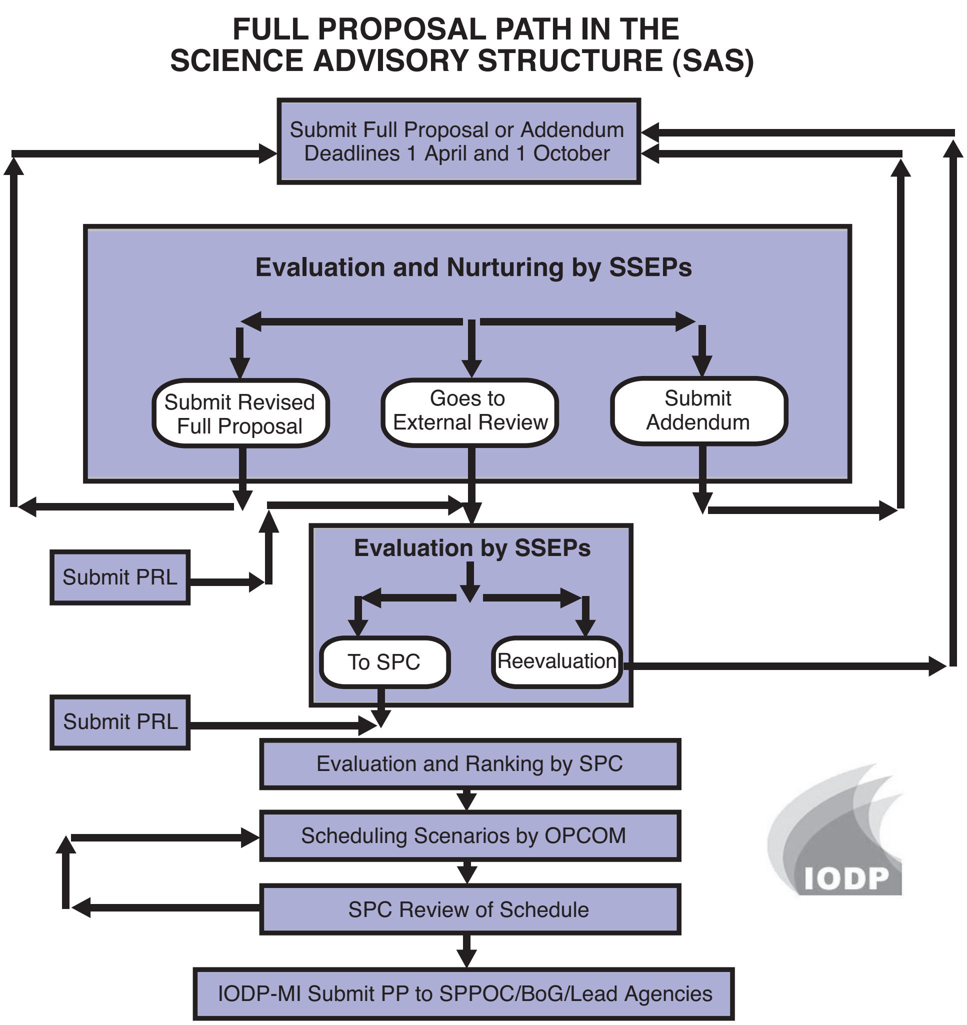

Figure 4. *An example of the path through the IODP panel structure that a full proposal path follows after submission by an individual scientist or a group of scientists. SSEPs = Science Steering and Evaluation Panels. PRL = Proposal Response Letter, SPC = Science Planning Committee, OPCOM = Operations Committee, IODP-MI = IODP Management International, Inc., PP = Program Plan, SPPOC = Science Planning and Policy Oversight Committee; BOG = Board of Governors.*

The Arctic Coring Expedition: A Preview of the First IODP Mission Specific Platform Deployment

Andrew Kingdon [1] and Colin Brett [2] (on behalf of the ECORD Science Operator)

INTRODUCTION

Fourteen nations have formed the European Consortium for Ocean Research Drilling, or ECORD, as a key component of the new Integrated Ocean Drilling Program (IODP) to undertake scientific coring operations using mission specific platforms (Table 1). Vessels of opportunity will perform specific operations that cannot be carried out by the IODP's two drilling ships, the Japanese deep-riser vessel *Chikyu*, and the US riserless vessel JOIDES *Resolution* and its successor. Examples of research areas where mission specific platforms will likely be deployed include ice-covered polar regions, continental shelf areas, and coral reef environments.

The first mission specific platform operation will take place from August 7 to September 16, 2004. The Arctic Coring EXpedition (ACEX) will investigate Arctic climate history by drilling along the Lomonosov Ridge. ACEX will be conducted on behalf of ECORD for the IODP by the ECORD Science Operator (ESO). The ESO is one of three Implementing Organizations in IODP; the others are the JOI Alliance of the U.S. and the JAMSTEC Center for Deep Earth Exploration (CDEX) of Japan.

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[2] British Geological Survey, Murchison House, West Mains Road, Edinburgh EH9 3LA, U.K.

BACKGROUND AND SCIENTIFIC OBJECTIVES

The gravest potential challenge facing the coastal populations of Europe and North America in the 21st century is the threat of rising sea level as global warming melts the Arctic ice sheet. Many questions exist regarding the nature and history of Arctic ice. Why, when and how did the ice first form? What changed to allow the ice to form and what might have to change to cause it to disappear? How do Arctic Ocean waters affect the Earth's ocean currents and global climate?

It is known that Earth's climate gradually cooled for nearly 50 m.y. With the onset of the Pleistocene ice ages, sea ice and ice sheets developed rapidly across the Northern hemisphere in pulses of growth. At times the ice sheets extended as far south as modern London, U.K., and Long Island, New York.

Greenland ice cores acquired in the last decade have provided climate information to the later stages of the Pleistocene ice age. Isotope records from deep sea sediment cores recovered by the Ocean Drilling Program (ODP) at higher-latitude boreholes provide the only detailed global climate information before the late Pleistocene, and show that changes in the Arctic have been instrumental in affecting Earth's climate. However, the

MEMBER NATION	RESEARCH COUNCIL NAME	ACRONYM
Canada	Natural Sciences and Engineering Research Council	NSERC
Denmark	Statens Naturvidenskabelige Forskningsråd	SNF
Finland	Suomen Akatemia	AF
France	Centre national de la recherche scientifique	CNRS
Germany	Deutsche Forschungsgemeinschaft	SFG
Iceland	Rannsoknarrads Islands	RANNIS
Italy	Istituto Nazionale di Oceanografia e di Geofisica Sperimentale	OGS
The Netherlands	Nederlandse Organisatie voor Wetenschappelijk Onderzoek	NOW
Norway	Norges forskningsråd	NFR
Portugal	Gabinete de Relações Internacionais da Ciência e do Ensino Superior	GRICES
Spain	Ministerio de Ciencia y Tecnología	MCYT
Sweden	Vetenskapsrådet	VR
Switzerland	Schweizer Nationalfonds	SNF
United Kingdom	Natural Environment Research Council	NERC

Table 1. *The European Consortium for Ocean Research Drilling (ECORD) is comprised of fourteen member nations and their research institutions. Scientists in Austria, Belgium, Greece, Ireland, Turkey, and Russia have expressed interest in joining the consortium.*

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oceanic core dataset contains a major gap. No paleoceanographic cores of more than a few m in length have ever been recovered from the Arctic Ocean, where pristine sediments should contain a continuous climate record.

The challenges to a successful Arctic scientific drilling expedition are obvious. Expeditions would be in remote, ice-covered areas far from logistical support. Seafloor depths up to 4 km in the Arctic Ocean can preclude drilling.

One seafloor feature accessible by drilling is the crest of the Lomonosov Ridge, a flat-topped mountain chain that crosses the Arctic Ocean from Siberia to Greenland close to the North Pole (Fig. 1). Seismic data collected during three expeditions in the1990s and in 2001 show a ridge summit covered with approximately 450 m of layered sediments. These sediments are believed to represent paleoceanographic records for much of the last 50 m.y. If this hypothesis is correct, multiple boreholes along the ridge would allow coring of a complete transect from the global temperature high of the Eocene "greenhouse climate", through the gradual cooling of the earth and the "icehouse" age, to the present day.

ACEX aims to drill into the Lomonosov Ridge at 87°40'N in water depths of about 1000 m.

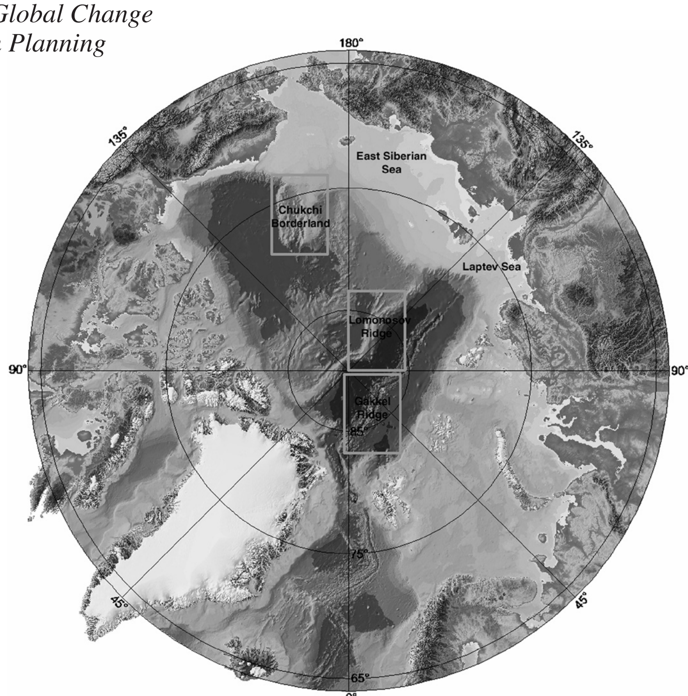

Figure 1. *The Lomonosov Ridge (center box) and other Arctic Ocean drilling targets superimposed on an International Bathymetric Chart of the Oceans map. Originally published in color in the JOIDES* Journal, *Vol. 27, No. 1 (Spring 2001) as Fig. 1 of "The High Arctic Drilling Challenge: Excerpts from the Final Report of the Arctic's Role in Global Change Program Planning Group".*

The area, within 250 km of the North Pole, is covered year round in ice over 1 m thick that moves at a speed of several km per day, and daytime temperatures rarely exceed 0°C.

The primary objective of ACEX is to recover a continuous section of Cenozoic sediments from the Lomonosov Ridge crest to reconstruct the entire climate history of this period. An unconformity visible in seismic survey data will be cored, if possible, to recover a few m of underlying rocks to help understand the tectonic history of the Arctic Ocean.

ARCTIC CORING EXPEDITION OPERATIONS AND LOGISTICS

A conventional drilling vessel would be unable to withstand the pressures of the ice, so the Swedish-registered icebreaker M/V *Vidar Viking* (Fig. 2) is being specially adapted to carry a rig capable of drilling into the seafloor nearly 2 km below sea level. A support fleet of icebreakers will ensure the safe operation of the coring vessel by escorting the *Vidar Viking* to the coring sites and then protecting it so that the vessel can maintain station, using dynamic positioning, during coring operations. The high-powered Russian-registered Arctic class icebreaker *Sovetskiy Soyuz* (Fig. 3), provided by the Murmansk Shipping Company, will lead the fleet from the pack ice margin to the proposed coring locations by as direct a route as possible. Once on location, the *Sovetskiy Soyuz* will operate upstream of the coring vessel in the moving ice, carving a channel of clear water and broken ice. The very maneuverable Arctic class icebreaker *Oden*, (Fig. 4) will be in close proximity to the coring vessel breaking up any remaining large pieces of ice or pushing them away. The *Vidar Viking* will deploy a retractable skirt through the newly constructed moonpool to protect the drill string from any lumps of ice pushed under the vessel by the ice breaking operations.

The drill rig and equipment will be mobilized on the *Vidar Viking* in late July in Aberdeen, U.K. On August 7, 2004, the *Oden* and *Vidar Viking* will depart from Tromsø in northern Norway and steam toward the ice edge north of Scandinavia. Here they will rendezvous with the *Sovetskiy Soyuz* and continue north through the ice to the drill sites. Coring operations are planned for approximately 20 days.

The *Vidar Viking* is too small for a conventional scientific party as hosted by the drilling vessel used during the ODP. The small science party will be divided between *Vidar Viking* and *Oden*. Coring operations, core handling and curation, whole-section core logging with the Multi-Sensor Track, and downhole logging potentially using innovative memory tools will be conducted on the *Vidar Viking*. Core shoe samples will be transferred regularly to the *Oden*, where micropaleontologists and stratigraphic correlators will attempt to construct the stratigraphic framework of the succession. Additional core sampling and analyses will be undertaken by a shorebased science party at the University of Bremen in November 2004.

WHY NOW?

New institutions such as ECORD allow European scientists to take a more active role in the IODP than was possible in the ODP. Three new organizations are key to ECORD's mission specific platform operations capability. The ECORD Managing Agency (EMA), based at CNRS-INSU (Institut National des Sciences de l'Univers) in Paris, manages ECORD's involvement in IODP. The ECORD Science Support and Advisory Committee (ESSAC), currently coordinated from the Free University of Amsterdam, oversees scientific participation and contributions.

The ECORD Science Operator (ESO), coordinated by the British Geological Survey, is comprised of European marine geoscience institutions with experience in conducting technically complex operations. The BGS brings experience in undertaking and managing scientific drilling operations and data acquisition using mission specific platforms around the world. The University of Bremen has curation expertise as managers of an ODP core storage repository, and will combine shorebased sampling expertise with managing shipboard science and curation. The European Petrophysical Consortium (Universities of Leicester, Montpellier, Aachen and Amsterdam) will use experience gained from ODP downhole logging operations to undertake petrophysics and logging services with new memory tools as they become available. GeoForschungsZentrum Potsdam (International Continental Scientific Drilling Program section) has been included to assist with offshore data handling and interface with the Swedish Polar Research Secretariat. The Secretariat has unique skills in undertaking Arctic operations and will organise much of the logistics and ship/ice management activities, and provide the *Oden*.

Figure 2. *A drilling derrick and moon pool will be added to the Norwegian-built M/V* Vidar Viking *to convert it into a drillship capable of coring along the Lomonosov Ridge in the Arctic Ocean during ACEX. The* Vidar Viking *is owned by Viking Supply Ships AS. (Photo courtesy of Viking Supply Ships AS.)*

Figure 3. *The Russian-built Arctic class icebreaker* Sovetskiy Soyuz*, operated by the Murmansk Shipping Company, will perform the major icebreaking duties around the ACEX drill sites. (Photo courtesy of Murmansk Shipping Company.)*

Figure 4. *ACEX operations in August-September 2004 will be directed from the* Oden*, one of seven Arctic class icebreakers operated by the Swedish Maritime Administration. (Photo courtesy of Swedish Polar Research Secretariat.)*

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JOIDES

Memorandum of Agreement to Establish JOIDES, 10 May 1964, and Milestones in JOIDES History

Document and Comments provided by Keir Becker, JOIDES Office

[Editor's Note: The first two sections of this article contain the language of the original document. The third "Milestones" section was compiled by K. Becker for this article.]

Physical scientists of the Institute of Marine Science of the University of Miami, the Lamont Geological Observatory of Columbia University, the Scripps Institution of Oceanography of the University of California, and the Woods Hole Oceanographic Institution (hereinafter referred to collectively as THE INSTITUTIONS) believe that basic oceanographic research has a pressing need to investigate the ocean floors through the laboratory examination of samples obtained from considerable depths below the bottom. The Directors of the THE INSTITUTIONS unanimously agree that this direction of research has a high probability of being rewarding. They also recognize that it is desirable to set up a cooperative joint effort to obtain financial support for, to plan for, and to carry out such a program.

The purposes of this agreement are to:

(1) Provide the terms of reference by which THE INSTITUTIONS will be guided in this joint endeavor.

(2) Establish the methods of executive direction of the overall program and its several parts.

(3) Provide for the member institutions to contribute to the planning for and the carrying out of the program through the establishment of committees.

(4) Establish the procedures of financial disbursement and fiscal responsibility for the program.

(5) Insure that the earth samples are distributed equitably among THE INSTITUTIONS and through the United States scientific community at large.

The project will be termed the JOINT OCEANOGRAPHIC INSTITUTIONS DEEP EARTH SAMPLING PROGRAM (JOIDES). To provide for the executive direction of the Program, the Directors shall constitute themselves into an Executive Committee. The Executive Committee will have the authority to approve or disapprove the actions or recommendations of the other committees, to initiate actions, to bring in other appropriate research organizations who it is hoped will be willing to join the Program as participants, and to speak for THE INSTITUTIONS insofar as JOIDES is concerned. The Executive Committee shall reach all of its decisions by the unanimous vote of its members. If a member of the Executive Committee is absent from a duly called meeting of the Committee he shall designate an alternate with full authority to act for him in his absence.

The Chairmanship of the Executive Committee shall rotate among the four directors each serving for one year and not repeating a term until each of the others has been chairman for one year. Meetings of the Executive Committee will be called by the Chairman or by any other two members. Notification of the meetings will be at least 30 days in advance unless waived by mutual consent.

To advise the Executive Committee and all other committees as are herein or may later be provided for, there will be a Business Advisory Committee to which a member from each member institution shall be appointed. The B.A.C. shall concern itself with contractual, legal, and fiscal accountability matters.

Such other committees as the Executive Committee shall deem necessary will be constituted. These committees shall be known collectively as Functional Committees, and in general will have a member from each Institution appointed by the Director of that Institution. The scope of authority of the Functional Committees shall be as determined by the

Executive Committee. Committees may be disestablished by the Executive Committee.

The vote in all committees shall be on the basis of member institutions, each being entitled to one vote regardless of the number of members from that institution serving thereon. Recommendations and decisions of all committees, except the Executive Committee, shall be on the basis of an absolute majority.

[The] Program will be divided into operational phases, and the Executive Committee will, for each phase, designate one of the member institutions to act as the "Operating Institution".

The "Operating Institution" is the selected participating institution which agrees to enter into the required contractual agreements with a sponsoring agency, to receive, to disburse, and to account for the funds, and to carry out the designated phase of the Program in a manner which is response to the needs, desires, and recommendations of THE INSTITUTIONS.

The Director of an "Operating Institution" agrees to be bound by the general guidance provided by the Executive and other committees, but he shall be deemed to have complete freedom to exercise his own judgment in matters concerned with his contractual responsibilities or with the good name and reputation of his institution.

The Executive Committee will set forth its decisions and actions by Articles of Implementation.

Signed by:

Maurice Ewing, Lamont Geological Observatory
F. G. Walton Smith, Institute of Marine Sciences
Roger Revelle, Scripps Institution of Oceanography
Paul M. Fye, Woods Hole Oceanographic Institution

May 10, 1964

JOIDES ARTICLES OF IMPLEMENTATION NO. 1

In order to implement the JOINT OCEANOGRAPHIC INSTITUTIONS DEEP EARTH SAMPLING program, the following plan is established by the JOIDES Executive Committee.

1. A Planning Committee is hereby established and directed to prepare for the Executive Committee a proposal for submission to the National Science Foundation (or such other agency as may be appropriate) seeking support for a Deep Ocean Drilling Program using an existing ship (which is converted for the purpose) and to be responsible for long-range planning which will include the development of subsequent plans and proposals for additional phases of the JOIDES program. The Institute of Marine Sciences representative will chair this committee for a period of two years from the date of initial funding.

2. When funding is available in support of this proposal, the Lamont Geological Observatory is designated the "Operating Institution" for this phase and the Lamont Geological Observatory representative will chair the Business Advisory Committee for a period of 2 years from the date of initial funding.

MILESTONES IN JOIDES HISTORY

The first JOIDES project in 1965 was to the Blake Plateau in the western North Atlantic. LDGO was the Operating Institution and Caldrill I was the drilling platform. SIO was selected as Operating Institution for the second JOIDES project that became the Deep Sea Drilling Project from 1968 to 1983. The Glomar *Challenger* was the drilling platform.

Additional institutions joined JOIDES as follows:

1968 University of Washington
1973 USSR (Shirshov Institute of Oceanology)

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1974 Germany (Bundesanstalt für Geowissenschaften und Rohstoffe)
1975 Hawaii Institute of Geophysics
Oregon State University
University of Rhode Island
Texas A&M University
United Kingdom (National Environment Research Council)
France (Centre National pour l'Exploitation des Oceans)
Japan (Ocean Research Institute)

1975/1976 - first Memorandum of Understanding between NSF and non-US members

1975 - first JOIDES Office founded at LDGO

1975 - first issue of JOIDES Journal

1976 - Joint Oceanographic Institutions, Inc. (JOI) was founded and assumed oversight of contract/project administration.

Thus, 1975-1976 marked a transition for JOIDES where it evolved from the prime organization responsible for all aspects of the program to its identity as the JOIDES Advisory Structure. The latter role continued through 2003, when the JOIDES Advisory Structure formally disbanded as the Ocean Drilling Program ended and the Integrated Ocean Drilling Program began.

In this issue from pages 20-24:

Margins of the Newfoundland-Iberia Rift: ODP Leg 210 Explores the Newfoundland Basin

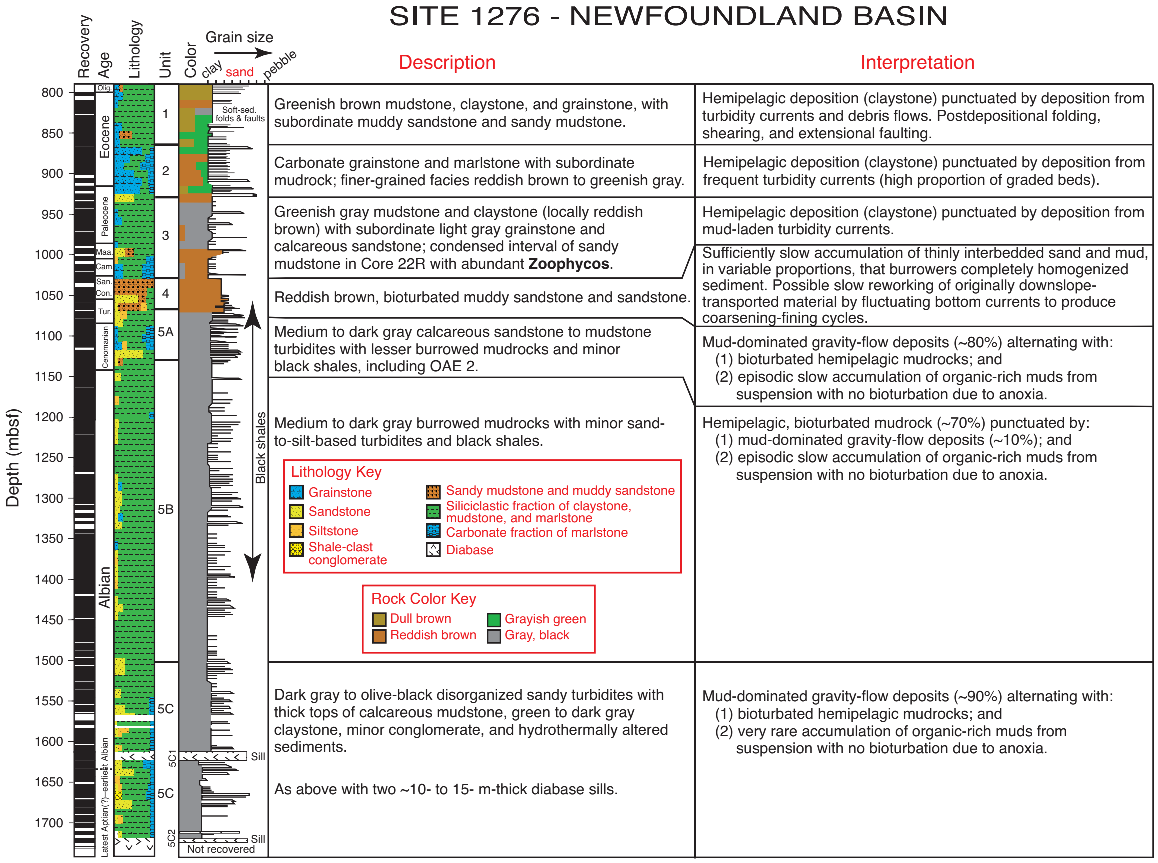

Figure 2. *Summary of core recovery and lithology at Site 1276 in the Newfoundland Basin; details are given in the text. Colors and patterns in the Lithology column show relative proportions of components. The width of the Color column approximates a 'weathering profile' that indicates relative induration of cored sediments and rocks. Note the abundant beds of coarse sediment deposited from mass flows and turbidity currents throughout the section, as indicated in the Grain Size column.*

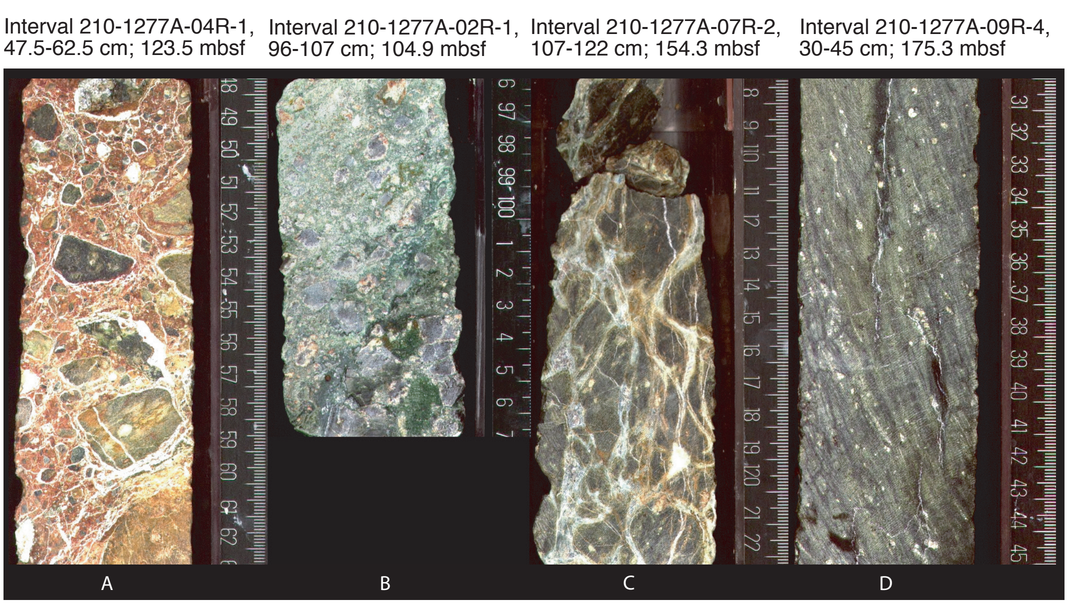

Figure 3. *Examples of basement rocks cored at Site 1277, Newfoundland Basin. Scales in cm.* **A.** *Mass-flow deposit consisting of subangular to rounded clasts of serpentinized peridotite (with spinel foliation) and rare gabbros in a clay-rich calcareous matrix. This deposit lies about 19 meters below (***B***), an altered gabbro containing plagioclase and pyroxene porphyroblasts in a strongly altered, weakly foliated, chlorite-rich matrix interpreted to be a sliver of crust displaced by mass movement at the contemporary seafloor. Only serpentinized peridotites (***C*** and ***D***) were recovered in the lower part of the hole, and interpreted to represent* in situ *basement that was unaffected by mass wasting.* **C.** *Homogeneous, foliated, porphyroclastic serpentinized peridotite dissected by a polyphase network of calcite and talc veins.* **D.** *Massive, foliated, serpentinized peridotite (harzburgite). The strong foliation is interpreted to be mylonitic (crystal-plastic recrystallization of olivine with porphyroblasts of pyroxene).*

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JOIDES Journal

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